FORUM ARTICLE

Are predator-proof fences the answer to New Zealand's terrestrial faunal biodiversity crisis?

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Abstract: A review of pest-exclusion fences throughout New Zealand shows that the goals of fence projects are frequently not achieved and cost-benefit analyses often do not adequately quantify ongoing costs. The creation of these sanctuaries enclosed by predator-proof fences often creates small expensive zoos surrounded by degraded habitat that will never be able to sustain the animal and plant species contained within the fence. We examine what fence proponents and conservation trusts believe they are achieving and ask whether the evidence available demonstrates that fenced areas are capable of fulfilling these objectives.

Keywords: conservation; economics; pest-exclusion fences

Introduction

Mainland New Zealand is currently experiencing a decline in terrestrial faunal diversity unprecedented since the 1870s (MfE2007; Robertson et al. 2007; Cranston 2010; Hitchmough et al. 2010; Newman et al. 2010). Predation by introduced predators has been shown by numerous studies to be the fundamental cause of this decline (King 1984). Furthermore this has been exacerbated by prey-switching in stoats following large-scale possum eradication (Murphy & Bradfield 1992; Innes & Barker 1999) and disease (Newman et al. 2010). Whatever the causes of the current crisis, New Zealand Department of Conservation (DOC) data show that in the three years between 2002 and 2005, the conservation status of 40 bird species worsened (Hitchmough et al. 2007). Twenty-one bird taxa that were assessed as 'Nationally Critical' in 2005 remained in that most threatened category in 2008 and 13 had declined further (Miskelly et al. 2008). Similar trends exist in other terrestrial fauna (MfE 2007; Hitchmough et al. 2010; Newman et al. 2010).

To deal with this crisis and to give structure to their biodiversity operations, DOC in conjunction with the New Zealand Ministry for the Environment implemented a New Zealand Biodiversity Strategy in 2002. A review of this strategy in 2006 (Green & Clarkson 2006, p. 19) concluded that '77% of the acutely or chronically threatened species still lack targeted recovery work and are most likely in decline. The inability to deal with these "priority" species appears to be due to a lack of resources'.

It is well known that biodiversity management cannot be entirely reliant on government departments and in recent years a groundswell of private organisations, 'not for profits', local and regional government have sought to 'do their bit'. A notable feature in recent years is that many of these conservation organisations have established predator-'proof' fence projects throughout New Zealand. The best known of these is the Karori Sanctuary, now known as Zealandia, in the suburbs of Wellington (Campbell-Hunt 2002).

These fences were promoted by an important publication in 2001, which strongly suggested that exclusion fencing for stoats and other pests was the most cost-effective way of preserving large areas of natural habitat for conservation benefit (Clapperton & Day 2001). The analyses of conventional pest control versus exclusion fencing costs reported in that study are flawed as they do not calculate present values for the 25-year-long projects and hence do not provide a sound basis for making comparisons of cost-effectiveness. As well, a recent review of pest-exclusion fences throughout New Zealand shows that the goals of fence projects are frequently not achieved and cost–benefit analyses often do not adequately quantify ongoing costs (Brown, in Sanders et al. 2007). Furthermore several overseas authors recently questioned whether fences are indeed the panacea that will solve the global extinction crisis (Hayward & Kerley 2008; Bode & Wintle 2010); with one paper going so far as to suggest that wholesale fence creation will restrict endangered species' evolutionary potential (Hayward & Kerley 2008). We consider that in many cases the creation of sanctuaries enclosed by predator-proof fences is little more than the creation of expensive zoos surrounded by degraded habitat that will never be able to sustain the animal and plant species contained within the fence.

To enable a better informed debate on the merits of the predator-'proof' sanctuaries, we carried out a survey of some of the predator-proof-fenced sanctuaries in New Zealand to determine why the fences were established, how much they cost, who paid for them, and what it was hoped the projects would achieve. The aim of this forum article is to use the results of this survey and a general literature review to air widely held, but rarely published, opinions about predator-exclusion fences and to pose questions that we hope can be asked before further investments in predator-proof fences occur.

Methods

Little has been written in the scientific literature on predator-proof fences and, as most of the organisations funding these

projects are charitable trusts, or 'not for profits', records are rarely publicly available. Searching the Internet and popular magazines enabled us to determine that in late 2006 at least 18 predator-proof fences existed or were in the final stages of preparation (Table 1). In January 2007, we posted surveys to 15 organisations currently operating predator-proof-fenced sanctuaries throughout New Zealand. We received 12 replies and were also able to access the publicly available documents of another two projects.

The survey form asked questions about funding sources, capital costs, methods of calculating depreciation, and maintenance costs. It also asked the trusts or 'not for profits' what their perceptions of achievable outcomes were and what role they believed their projects had in biodiversity recovery in New Zealand. Respondents were asked to assess the importance of five types of benefits: (1) research; (2) ecosystems restoration; (3) education and recreation; (4) providing habitat for species (perhaps locally rare); and (5) tourism, using a score of 1 for most important and 5 for least important.

In order to compare the trusts' perceptions of achievable outcomes with actual outcomes, we independently assessed the performance of each predator-proof sanctuary against the stated goals of the New Zealand Biodiversity Strategy and the threat assessment criteria of Townsend et al. (2008). Townsend et al. (2008) takes into account: (1) total population size; (2) area of occupancy; (3) degree of fragmentation of populations; (4) rate of decline in total population; (5) decline in habitat area; and (6) predicted decline due to existing threats. Thus to make a tangible benefit to a species' threat classification, one of these criteria must be improved. We assessed this for each 'predator-proof' sanctuary, given what we knew about the species currently in the area, what translocations had been made to each area and the success of these translocations.

Results

Capital costs

We calculated there were over 109 km of 'predator-proof' fencing in New Zealand protecting 7133 ha of forest. We estimated (Table 1) that the overall capital cost to the end of 2006 of these fences exceeded (in 2006 dollar terms) NZ$24 million. As well as the initial start-up investments, consideration of annual expenditure is also essential. The annual budget for Karori for 2006, for example, comprises $1.2 million (unpublished 2006 report) for the 252-ha sanctuary.

Depreciation

Few respondents were able to answer the questions on depreciation, maintenance costs and overall total costs. The Karori Sanctuary has calculated depreciation of fixed assets on a straight-line basis so as to allocate the cost of their predator fence over its useful life, which they estimate to be 25 years. Thus the deprecation for 2005 was calculated to be $91,617 or $10,653 per annum per kilometre of fence. A similar calculation for the Maungatautari project would put depreciation for their fence at approximately $500,000 p.a. For all 18 projects depreciation of the fences is calculated to be in the region of $880,000 p.a.

Table 1. Predator-proof fences for non-captive species management in New Zealand.

Site	Ownership	Cost (NZ$m)	Length (km)	Area (ha)	Public funding?
Mainland 'islands'					
Maungatautari	Charitable Trust	14	47	3363	Central & Local
Karori	Charitable Trust	2.2	8.6	252	Central & Local
Bushy Park, Whanganui	Charitable Trust	0.05	4.7	98	Lotteries Board
Pitt Island	DOC	0.25	1.2	32	DOC
Chatham Island – Sweetwater	Charitable Trust	0.1	1.1	25	Lotteries Board and the Biodiversity Condition Fund
Macraes Flat	DOC	0.3	1.7+1.2	18+9	Biodiversity Condition Fund
Mt Bruce	DOC	0.2	1	18	DOC
Warrenheip	Private	0.6	2.4	16	Kiwi Recovery Fund
Riccarton Bush	City Council	0.2	1.1	7.7	Local
Orokonui EcoSanctuary	Charitable Trust	2.2	8.7	307	Local
Peninsula fences					
Stewart Island (Dancing Star)	Private	0.5	2.1	160	No
Rapanui Point, Taranaki	Charitable Trust	0.08	0.44 + 0.3 km coast	5	Central
Young Nicks Head	Private	0.15	0.6 + 5 km coast	35	No
Tawharanui	ARC	0.6	2.5 + 9 km coast	588	Local
Cape Kidnappers to Ocean Beach	Private	c. 2.5	9.5	2200	No
Planned fences					
Rotokare Scenic Reserve Trust	Charitable Trust/ DOC	c. 2	8.4	230	Local
Brook Waimarama Sanctuary	Charitable Trust	3.2	14	715	Local
Lake Opouahi, Hawke's Bay	Charitable Trust	0.7	3.3	40	Local

Table 2. Ratings of five objectives for fenced sanctuary projects. Value is mean of the scores given by all respondents. Figures in brackets are ranges.

Questions answered (n = 12)	Ecosystems restoration	Providing habitat	Education and recreation	Research	Tourism
Initial objectives	1.0	1.08 (1–2)	1.33 (1–3)	2.08 (1–4)	2.25 (1–4)
Benefits achieved	1.08 (1–2)	1.33 (1–2)	1.17 (1–2)	2.42 (1–4)	2.33 (1–4)

Maintenance

The trustees of the Karori Sanctuary calculated that fence maintenance cost $20,000 p.a. in 2003 dollar terms (unpublished 2003 report). In 2003 dollars, then, the Maungatautari fence maintenance may cost in the vicinity of $80–$100,000 p.a. and all sanctuary fences currently in New Zealand cost approximately $193,000 p.a. It is important to note the Karori Sanctuary does not include labour costs in any of these equations but simply materials' costs. Little consideration appears to have been given for catastrophic events. It is worth considering what a severe natural disturbance, e.g. a cyclone equivalent to Cyclone Giselle (the 'Wahine Storm') at Karori or Cyclone Bola at Maungatautari, might do to these costs. What would the impact of a less frequent, but still likely, natural disaster (such as an earthquake) at Karori be?

Perception of initial objectives

Respondents were asked to assess the importance of five objectives using a score of 1 for most important and 5 for least important. Respondents felt (Table 2) overwhelmingly that 'Ecosystems restoration' was the most important initial goal. This was closely followed by 'Providing habitat for species (perhaps locally rare)'; 'Education and recreation' and 'Research'. The least important initial objective given was 'Tourism'.

Apparent benefits achieved

Respondents felt that 'Ecosystems restoration' was the most important goal achieved but this was no longer a unanimous view. This achievement was closely followed by 'Education and recreation; 'Providing habitat for species (perhaps locally rare)'; 'Tourism'. The benefit that respondents felt they had achieved least successfully was 'Research'.

Actual biodiversity outcomes

The results show that respondents had a slight difference between their rating of initial objectives and the apparent benefits achieved. Respondents still felt that ecosystems restoration was the greatest of all apparent benefits achieved. Using the Townsend et al. (2008) criteria, we found that the area of occupancy of many vertebrate species had increased as a result of wild populations becoming established within predator-proof fences; however, no introductions made into these enclosures could be said to have as yet made any difference to any species' threat status. Two introductions (of Chatham Island taiko *Pterodroma magenta* and Chatham Island petrel *Pterodroma axillaris*) made recently to two sites on the Chatham Islands do have the potential to eventually improve these species' threat status, but as yet they have not produced viable populations (G.A. Taylor, DOC, pers. comm.). It may be argued, however, (see below) that no population requiring a fence maintained in perpetuity will ever be truly viable and self-sustaining.

Discussion

Costs

Our assessment of costs of fencing showed that for every million dollars invested on predator-proof fencing, 297 ha of habitat has been protected. To put this figure in perspective, this was approximately the same cost per hectare that forested hill country land in New Zealand cost to purchase (www.trademe.co.nz rural property accessed on 27 Sept. 2007). Note that our assessment of predator-proof-fencing costs only reflects the cost of fencing and not the cost of land purchase. It is also important to note, but is outside the scope of this study, that the cost per hectare is strongly influenced by the shape of the area being fenced and also if the fence is complete or solely isolates a peninsula. The total depreciation costs for all 18 fenced projects is approximately the annual budget of New Zealand's premier 'not for profit' conservation organisation, the Royal Forest and Bird Protection Society. By applying the rates of depreciation and maintenance shown in the annual budget for Karori for 2006 to the 47-km Maungatautari fence, the annual commitment to this fence (to protect 3400 ha of forest) is slightly more than the budget DOC Waikato uses to maintain endangered species programmes for the whole of the Waikato Conservancy estate (3.8 million ha).

Conservation benefits

When assessing the conservation contribution of each project, we recognised the Townsend et al. (2008) criterion 'a re-introduced wild population must be self-sustaining and thus populations held in captive institutions or grown in nurseries or gardens are not considered to be within the definition of sub-population, unless they are the only remaining individuals of the taxon'. Even more important, a population is deemed to be self-sustaining if it is considered probable that succeeding generations will persist without human interference (Dudley 2005). It could readily be argued that, as fences require maintenance in perpetuity, no population within a fence will ever fit the criterion of self-sustaining used by Dudley (2005).

Do fences work?

Despite the high levels of investment in fences, it is unfortunate that there are no published studies to show that fences in New Zealand either (1) increase breeding success of native birds, (2) increase survival of native birds, or (3) definitely

exclude all predators. Indeed many overseas results are equivocal on those questions and some even show a negative impact (see review in Sanders et al. 2007, p. 14). On the plus side, however, a recent study of Māhoenui giant weta (*Deinacrida mahoenui*) releases showed that the only successful mainland release was at the private Warrenheit fenced enclosure (Sherley 1994; Watts & Thornburrow 2009). We observe that predators quickly exploit new breaches in fences (e.g. fallen trees, damaged fences) and many studies examining the effectiveness of predator fences report the need for ongoing removal of predators from within fenced enclosures (i.e. Numata 1996; Reynolds & Tapper 1996). Fences also have a limited role in the preservation of vascular plants whose principal threats are changing land use or impedance of regeneration by competing non-native plants (de Lange et al. 2009). Rather than improve conditions for native plants, poorly maintained enclosures may effectively create environments where competing non-native plants thrive at the expense of natives.

Islands are often better

A huge weight of published evidence (see review in Drake et al. 2002) shows that islands suitably far from shore are better than fences at (1) restricting ongoing need for expenditure on fencing, maintenance and monitoring, (2) eliminating the probability of predator reinvasion, and (3) providing a low-cost long-lasting conservation benefit. New Zealand has fought the bulk of its recent conservation battles using the 'island ark' approach and this has been done remarkably successfully; take, for example, the black robin (*Petroica traversi*) and kākāpō (*Strigops habroptilus*) saved from extinction by placing them on isolated islands (Butchart et al. 2006). The costs of ongoing maintenance and surveillance of predator-free islands is extremely low; Little Barrier Island (Hauturu) in the Hauraki Gulf near Auckland has been shown to have annual costs of maintenance of only $29 per hectare (Cullen et al. 2005a). It would seem logical, then, that DOC would concentrate its purchasing fund on islands to increase the number of habitats and choice. However, only one island has been purchased to add to the DOC estate in several decades, Motu Kaikoura in 2004. This purchase only came about due to protracted lobbying by interest groups and the Government contributed only half the $10.5 million cost through the Nature Heritage Fund's 'Public Wildlands Programme'. The ASB Bank Trust contributed at least $2 million, Auckland Regional Council $250,000, and a further $250,000 came from the Auckland Region's city and district councils (information retrieved from http://www.kaikouraisland.co.nz/Reserve.htm). It is paradoxical, therefore, that in mid-2006 the New Zealand Government gave $5.5 million to help build a predator-proof fence at Maungatautari, while at the same time DOC was unable to secure the funds to buy a large rat-free island in Golden Bay from which it had paid the owners to eradicate the rats. We do not deny that a 'mainland island' will protect different overall biodiversity values than an oceanic island due to the wider habitat range available on the mainland, and this is especially true of montane and alpine ecosystems (Meurk & Blaschke 1990). We emphasise, however, that what is critically important here is the preservation of taxa that will become extinct without immediate intervention, not the somewhat illusory goal of the preservation of an exact copy of a prehuman functional ecosystem.

Comparative costs of fences over large-scale predator management

North Island kōkako (*Callaeas wilsoni*) is one of a suite of species that are in critical decline throughout their mainland range. Declines have been attributed to habitat loss, competition with brushtail possums (*Trichosurus vulpecula*) and predation (Innes & Flux 1999). North Island kōkako's remaining habitat is now almost entirely protected by DOC. However, the threats posed by introduced predators, such as possums and ship rats (*Rattus rattus*), are still causing decline throughout their mainland range and are the main focus of the North Island kōkako recovery plan (Innes & Flux 1999). Fairburn et al. (2004) calculated that, in 2002, effective kōkako protection using a regime of trapping and poisoning in unfenced forests was costing between $115–155 per hectare per year. Other effective fence-free mainland islands have annualised costs per hectare of between $11 and $96 (Cullen et al. 2005b; Vesey et al. 2008). We calculate that the mean cost per hectare protected of the 18 sites listed in Table 1 that use predator-proof fences is approximately $3,365 per hectare, which is one–two orders of magnitude greater than the annual cost of ongoing effective predator control using the unfenced-mainland-island approaches above. New investment in fences will be required every 25 years – their estimated life.

Another innovative New Zealand project aims to implement predator control to protect more than 20 000 ha of the upper Tasman River catchment (Dean Nelson, pers. comm. 2007) to 'increase the annual fledging success rate of wild hatched black stilt (*Himantopus novaezelandiae*) by 10% and reduce annual adult river bird mortality by a similar amount whilst enhancing populations of selected lizard and invertebrate species'. With start-up costs of $117,000 and an annual cost per hectare of $1.65 this represents far better cost per hectare for what we consider to be achievable and realistic goals than any predator-proof fence.

Single-species management and fences have a place

We recognise that fenced sanctuaries, particularly those close to or within major urban centres, can play important roles in education, provide considerable benefit to visitors to the sites, and increase public support for species conservation efforts. While we applaud the idealistic goal of ecosystem restoration to its prehuman state, its implementation in New Zealand is problematic (Norton 2009). The keystone avian herbivores, the moa (Dinorthiformes), are extinct and so are crucial components of the prehuman biota, from the giant flightless herbivorous goose (*Cnemiornis*) to the tiny flightless avian mouse (*Traversia*) (Worthy & Holdaway 2002). A perfect re-creation of a prehuman ecosystem is impossible and New Zealand conservation has to accept that the crucial issue of the next few years is to maintain what we now have. Predator-resistant (not predator-proof) fences have a role in achieving this goal. Good examples of predator-resistant fences achieving significant single species management goals for minimal cost include fences designed to protect giant land snails (*Powelliphanta*) in the north-west of the South Island (Walker 2003), and the fence used to reduce predation on takahē (*Porphyrio mantelli*) at Burwood Bush in Southland (Numata 1996). A recent paper provides a useful Australian example of how fence design can be targeted at species-specific conservation goals (Bode & Wintle 2010) rather than using a 'one design fits all' approach, which seems to be prevalent in New Zealand. We need more thinking 'outside the box' to ensure cost effective management occurs.

Lessons that history teaches

We believe that the rate of growth in predator-proof-fence building is out of proportion to its benefits. The rapid growth rate may well be fuelled by the ready availability of community grants to fund such visible, tangible projects. However, time should be allowed for existing fences to show they can make contributions to species management, and to have their worth evaluated scientifically. We plead for consistent, timely and more complete information on fence benefits, costs and pitfalls to be disseminated and published. The conservation community as a whole needs to know as quickly as possible when fence projects fail in their stated goals, so that conservation organisations and project managers may learn from any mistakes. Furthermore conservation organisations need to be politically and economically savvy: a change of government and a drop in the conservation vote could lead to a drastically altered conservation landscape. It is crucial that allowance for funding shortfalls occurs, and that contingency plans can be implemented if needed. It has to be accepted and understood that these plans will remain in place in perpetuity (Norton 2009). We urge all those thinking about predator-proof fences to ask the following questions:

(1) What species conservation goals do we really want to achieve?
(2) How much will meeting our goals cost – not just right now but over the next 25 years?
(3) Can we achieve most of our goals in a less expensive way with less infrastructure and fewer up-front costs?
(4) Is pest control over a larger area a viable alternative to a fenced sanctuary?
(5) Is the best approach for our area a single fenced site or would the money be spent better on many smaller projects?

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