Tawharanui Open Sanctuary – detection and removal of pest incursions

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Abstract Tawharanui Regional Park north of Auckland, New Zealand, is being developed as an Open Sanctuary integrating conservation, recreation, and farming operations. Through a council and community partnership, 550 ha of the Tawharanui peninsula was isolated with a 2.7 km coast to coast pest proof fence, completed in 2004. Multi-species mammalian pest eradication was undertaken in spring 2004. Seven of the ten pest mammal species present were eradicated but three species persist. Since the eradications, many native species have recovered, and several others have been reintroduced as contributions to regional and national biodiversity conservation. Public access remains unrestricted with 160,000 visitors per year. Potential pest incursion pathways include coastal ends of the fence, arrival via park activity and visitors by land or from the coast. To date, individuals of all but one of the eradicated species have been detected within the sanctuary, including an *in situ* breeding population of *Rattus rattus* in 2008. All incursions have subsequently been removed. Five years' operational experience gives a greater understanding of the incursion profile of the site and the required management responses. We remain confident that such incursions can be detected and removed without compromising existing biodiversity values and future restoration potential of the site. Although the incursion risk profile of Tawharanui Open Sanctuary is greater than most sites, lessons learnt about the detection and removal of pest incursions and surveillance management are applicable to most insular situations.

Keywords: Invasion potential, invasive mammals, pest proof fences, brushtail possum, cat, weasel, stoat, Norway rat, ship rat

INTRODUCTION

The distinction between the eradication and control of unwanted organisms is becoming increasingly blurred as technical advances increase our ability to manage riskier sites with greater reinvasion potential. In some cases, this increased operational risk may violate some of the criteria or definitions commonly used for pest management. For example, eradication is the permanent removal of a target pest species from a managed area. Several authors (e.g., Parkes 1993) describe conditions that must be met to achieve eradication as: 1) all animals can be put at risk by the eradication technique(s); 2) the animals must be put at a risk at a rate exceeding their rate of increase at all densities; and 3) immigration must be zero. This last criterion is violated by undertaking eradications in locations where there is some immigration risk. Programmes with residual immigration risk can be justified when these risks can be managed cost-effectively, suitable habitats for the native species to benefit do not exist elsewhere, as test cases for more complex operations, and to address the aspirations of communities of interest and community groups.

In theory, the incomplete removal of target species is not eradication, it is a failure (Parkes 1993). In practice, the criteria for success are less clear when there is complete removal followed by subsequent reinvasion. Here the operational failure may be one, or a combination of, lapses in biosecurity, ineffective buffering between the managed site and pest populations, or poor surveillance management. Yet the eventual outcome resembles an eradication failure. In most cases, eradication is not necessarily the desired outcome *per se*; rather it is the release from pressures exerted by unwanted organisms upon their host ecosystems.

If pest management is undertaken where the risk of reinvasion is high, eradication may only be a temporary achievement. At such locations, eradication is an ideal but the reality may be best described as maintenance at zero density. The distinction between a series of eradication operations and ongoing detection and removal of invaders is not great. The primary consideration should be confidence that the original population was eliminated and that perceived incursions are not in fact survivors.

Clear terminology is important when practitioners and stakeholders may have divergent views of the same outcome. Stakeholders, who may include political decision makers, funding agencies and affected communities, often take an absolute view of pest removal. When pest incursions are encountered these absolute views may become feelings that either the operation has failed, or that expected outcomes were communicated falsely from the outset. This in turn can translate to erosion of support for current or future operations. Such situations reflect the first of Bomford and O'Brien's (1995) desirable criteria for eradication success: that the social and economic conditions must be conducive to meeting the critical rules. Whatever terminology is used it must be aspirational and attention applied to any attendant qualifications and communication of ongoing operational risk.

The consequences of occasional pest incursions depend on the vulnerability of the species or ecosystems under threat. Ecological resilience can increase as the restoration process progresses when pests are removed, but ecological vulnerability can also increase as new threatened taxa are reintroduced. These changes increase the imperative to act against new pest incursions, while the suite of tools required to respond effectively may need to be changed or improved.

In this paper I discuss the development of incursion response theory and describe how this was applied in a fenced sanctuary that receives periodic incursions of pest mammals.

REINVASION POTENTIAL

For the purposes of this paper, an incursion is the arrival of a species without establishment, whereas an invasion is arrival followed by establishment of a breeding population (Russell *et al.* 2008).

Every site has an incursion profile, which reflects the probability of reinvasion. The incursion probability (*IP*) for a site can be expressed by the formula

$$IP = d + a - q + p + e$$

Where d = distance from nearest or most probable source population; a = assistance (e.g., sea currents, freight and transportation); q = quarantine measures implemented at either source or recipient site to detect or remove invaders;

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p = pest species characteristics (e.g., swimming or climbing capability, breeding biology); and e = environmental factors (e.g., climate, season, population pressure, mate and food availability). The relationship between, and relative weighting of, each factor is unknown. Only d and p are constants; a, q and e are variables, with the last being mostly beyond the direct influence of management.

Incursion profiles form a continuum. Open mainland reserves with sustained pest control are infinitely re-invasible at their edges and thus have IP=1. Islands that are closed by virtue of their management, legal status, remoteness, or environment can have IP near zero. However, since incursions can reach all sites, including remote islands, no site has IP=0. Between the extremes of the continuum cluster a suite of fenced peninsulas, ring fenced mainland reserves and inshore islands. Some of these may have incursion probabilities nearer to that of oceanic islands than open mainland reserves. Where these sites sit on the continuum can be heavily influenced by human activity. These anthropogenic factors also mean that IP is not constant through time, but is affected by complacency, improved knowledge, management regime change, and social pressures.

The probability of pest mammal incursion is not the sole determinant of the security of a managed site, it merely describes the risk. The biological consequences of any incursion event are determined by the managers' ability to intervene, and their confidence that new incursions can be detected.

Timeliness of detection is important in two regards. First, there is a biological imperative to detect and remove an incursion before there is unacceptable biodiversity loss, and before the incursion becomes an invasion. This is consistent with the third of Bomford & O'Brien's (1995) desirable criteria for eradications: animals surviving the eradication campaign should be detected and dealt with before an increased population becomes obvious.

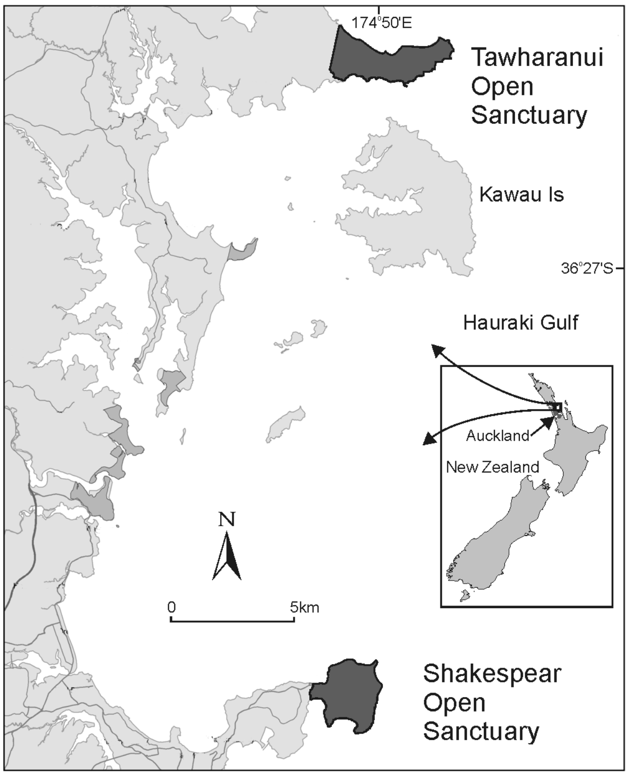

Fig. 1 Tawharanui and Shakespear Open Sanctuaries are on the east coast north of Auckland City.

The second imperative is financial. The scale of any incursion is the greatest determinant of the cost of managing such an event. Scale must be considered both spatially (area covered) and temporally (time taken to return to 'normal' management). Scale and subsequent resources and techniques to address the issue can become constrained as scale increases. Some options (e.g., aerial toxin application) may be untenable on biological (non target impacts), financial, or socio-political grounds (i.e. objections to methodology or constraints on other activities). Any cost of managing pest incursions carries an opportunity cost of other desired conservation management activity.

Detection confidence can be expressed by the formula $DC = d + r + t + p + h$

Where d= number and density of detection devices; r = reliability of devices and operators; t = time interval (exposure); p = pest species characteristics; h =habitat condition (e.g., prey and cover availability affecting pest animal ranging). The relationship between, and relative weighting of, each factor is unknown. However, the first three factors are in the manager's hands to influence.

Animals may be detected away from the point of incursion, so conclusions should not be hastily drawn regarding potential defensive weaknesses. The ranges of incursive or displaced animals can be far in excess of normal behaviour (Russell *et al*. 2005) in response to social isolation, and the animals' need to determine the presence of competitors, predators, prey and breeding opportunities.

CASE STUDY: INCURSIONS AT TAWHARANUI OPEN SANCTUARY

Tawharanui Open Sanctuary is a management layer at Tawharanui Regional Park 50km northeast of Auckland, New Zealand (Fig. 1). The park is administered by the Auckland Council in partnership with a community group: Tawharanui Open Sanctuary Society. The open sanctuary philosophy integrates the varied land uses of recreation, conservation and farming. Public access is unimpeded with approximately 160,000 visitors per year including a 260 person capacity camping ground. A 2.7km Xcluder coast to coast pest proof fence isolates 550ha of the peninsula as a barrier to the passage of mammalian pests, which enables the isolated area to be managed as a 'virtual island' (Day and MacGibbon 2007).

Mammalian pests were eradicated in spring 2004 using two aerial applications of brodifacoum (Pestoff 20R) toxic baits supported by trapping, hunting, poisoning at bait stations, and detection dogs. Ten species of pest mammals were targeted for eradication including brushtail possum (*Trichosurus vulpecula*), cat (*Felis catus*), ferret (*Mustela furo*), stoat (*M. erminea*), weasel (*M. nivalis*), ship rat (*Rattus rattus*), Norway rat (*R. norvegicus*), house mouse (*Mus musculus*), European rabbit (*Oryctolagus cuniculus cuniculus*), and European hedgehog (*Erinaceus europaeus occidentalis*). Seven of the ten species were eradicated but house mice, rabbits, and hedgehogs persisted.

In the five years following the eradications, previously absent fauna have recolonised, breeding success of resident threatened native species of flora and fauna has improved, five absent species of birds and two species of reptiles have been reintroduced, and species of fauna have been

Table 1 Animal pest incursions at Tawharanui Open Sanctuary 2005-2010

Species	n incidents	n individuals
Brushtail possum	3*	9
Cat	>50*	4*
Weasel	4	4
Stoat	2	2
Norway rat	6	10
Ship rat	6*	47*
Rat spp. (unspecified)	4	7

*minimum

translocated from this site to establish new populations.

These conservation outcomes were achieved despite incursions by all eradicated species except for ferrets (Table 1). Had rabbits and mice been eradicated, there would also have been incursions of these species around coastal ends of the pest proof fence. Footprints of both species have been detected in sand and there was also evidence of movement through Rhodamine B biomarker studies (Goldwater 2008).

There was no single proven vector or pathway for all of the animal pest incursions. Potential pathways included entry around the coastal ends of the fence, breaches of the pest fence, entry via the single automated vehicle gateway (which has no quarantine containment 'cell'), stowaways via visitors' vehicles and camping equipment, stowaways via park managers' vehicles or materials, and coastal landings either by animals swimming along coast or from boats moored offshore or hauled up on beaches.

Entry around coastal ends of the fence is the most likely source of incursions because at low tide up to 60m of beaches may be exposed beyond each fence terminus. The fence was not extended into the intertidal zone because of: 1) engineering challenges associated with storm swells and long shore sediment drift; 2) consequent maintenance costs of structure if implemented; 3) likely difficulty of obtaining planning consent due to conflict with coastal policy for coastal and foreshore structures; and 4) impeding coastal access being in conflict with primary role of the site for public recreation. Potential incursions were discouraged through a spiral 'koru' structure at each fence terminus. These structures were experimentally tested to increase interception, containment and deflection of animal pests (T. Day unpubl. data) and are used in conjunction with a trap and poison bait based animal pest management buffer designed to reduce pest mammal density. Both tools were used to reduce pest animal encounters with the ends of the fence.

Until 2008, we were confident that we could detect and remove any incursions, which had involved one or few individuals rather than populations or invasions with *in situ* breeding. The question of whether detected animals were survivors of the eradication or new incursions was addressed through the time to first capture or the time elapsed between events. Such data generally confirmed that most detected animals were new incursions. Some incursions involved multiple individuals and some individuals invaded multiple times. For many of these incursions, including those for all mustelids, the first sign of an incursion was a dead animal in traps used in the fixed surveillance network.

Once detected, each incursion triggers a management response. With incursions by a few individuals, localised response can be invoked with tools and on a scale relevant to each target species. In circumstances where toxic baiting is employed, carcasses may not be recovered to show that an animal has been killed. This absence of proof of removal can be challenging. We assume that the absence of new sign for a minimum of one month is evidence of successful interception. We do not assume that first or any capture is the last or only invader and maintain heightened surveillance for a minimum of one month after last sign detected. Throughout these responses, routine surveillance continues throughout the entire sanctuary.

In December 2007, three areas of rat activity at separate locations were detected using tracking tunnels during routine monthly surveillance. Localised response activity at the three sites resulted in captures of *Rattus rattus* at two of them. Another month of control/surveillance revealed no further sign at two sites, but the third provided further captures including juvenile rats. This evidence of *in situ* breeding resulted in a shift in response activity from localised incursion to invasion and a corresponding escalation of management activity.

Four phases of invasion response were implemented at Tawharanui: 1) detection and delimitation; 2) containment to prevent further spread; 3) eradication of animals contained in area; 4) withdrawal and review. These phases are hierarchical but can overlap. The tools and methods deployed can concurrently or sequentially serve to deliver phases 1 through 4 entirely or in part.

The process of incursion management is as important as the method employed, especially the rationale forming the basis of each management action. Attempts should always be made to follow the principles of a formal adaptive management process of model testing and refinement.

Responses to the 2007-2008 ship rat invasion at Tawharanui Open Sanctuary followed the process described above, and escalated sequentially according to information derived from the detection and delimitation phase. This was augmented by further delimitation information produced during the containment phase. Efforts focussed on the unknowns of the situation because effective management must be guided by quality information. Within reason, we could ignore the known population as long as it was contained, which allowed resources to be concentrated on implementing the incursion response.

The final area delimited in the 2007-2008 incursion was approximately 240ha, or about half the sanctuary, and was reached in four escalations. The final area was probably related to dispersal behaviour of the rats, coupled with the time it took to detect dispersing individuals. Demarcation lines need to be conservative if any statement is made as to where animals are not being supported by evidence from searching. At no time was our attention entirely focussed on the "known invasion" zone; the fixed surveillance network continued to operate with increased intensity and attention.

In order to determine the extent of invasion, all ship rat carcasses recovered (n=36) underwent genetic analysis to test levels of relatedness between individuals to determine the number of 'founding invaders'. It is assumed that due to the use of poison as well as traps that many carcasses were not recovered and could not contribute to this analysis. A pairwise relatedness estimate was used to assess the prevalence of novel or shared alleles. There were limitations to the genetic analyses because we lacked baseline information and relatedness could be imported through parents, siblings or cousins already present just outside the fence. Nonetheless, the values obtained indicated a combination of multiple founders and *in situ* breeding (D. Gleeson pers. comm.). The invading ship rat population was eradicated and the site status of zero density rats was reclaimed.

DISCUSSION

The managers' challenge is when to stand down the incursion response, i.e. how to determine 'stopping rules'. Station checks with nil positive sign provide absence of evidence rather than evidence of absence. Each check consumes resources and carries an opportunity cost for resources that may be deployed elsewhere. If effort expended on incursion response is plotted against time, the objective is to produce a steep downward trajectory. Alongside this, there should also be confidence that reduced effort will not induce unforeseen negative effects that require renewed effort not just to intercept the incursion, but also to prevent further losses of biodiversity. Thus decisions to withdraw must be inherently conservative.

Surveillance networks must detect incursions before breeding populations of pests establish, or before rare and vulnerable native species can be negatively impacted. This means that surveillance devices must be well maintained in order to avoid 'false negative' detection through malfunction, overgrowth with vegetation, or being 'swamped' with non-target activity. Similarly they need to be easily found by new staff (K. Broome pers. comm.). Such networks must also be supported by the capability to increase response efforts at short notice. Decisions are required about whether to maintain a fixed network, to keep contingency response inventory in storage, or to have some combination of both. The ongoing maintenance costs of a fixed network must be balanced against deployment costs and subsequent lost time of the stored contingency option. The network chosen needs to be easily converted from routine surveillance, to delimitation, and incursion response. The network will then need to be converted to post incursion monitoring and back to routine surveillance. These changes need to be achieved by varying the intensity and scale of checking without the need for substantial new equipment or infrastructure. The tools themselves should be adaptable to different phases, i.e. tracking tunnels for delimitation reconfigured as snap traps or bait stations for control (K. Broome pers. comm.). This adaptability addresses the resources required for deployment while overcoming potential neophobic responses from target animals.

Pest management buffering, biosecurity, surveillance, incursion response and escalation are very resource intensive. However, these are crucial to protecting the initial investment of the eradication and restoration programme and subsequent improvement in condition. If the resources do not allow for these management actions, the viability of the project becomes compromised, and the social and economic conditions are not conducive to meeting the critical rules for an eradication (Bomford and O'Brien 1995).

The 'stopping rules' must also address the possibility that the pest free state prior to incursion may not be recoverable, and that further investment of resources will not increase likelihood of achieving this. Such decisions are difficult to make as they signal the end of the dream for many stakeholders.

The Tawharanui Open Sanctuary project has demonstrated the realities of managing the aspirations of a community partnership. Significant biodiversity gains have been achieved despite considerable management challenges. An adaptive management approach has improved our management of the sanctuary and information gaps have been identified and in some cases addressed. The operational success has been sufficient to give us the confidence to undertake a similar open sanctuary at Shakespear Regional Park, Whangaparaoa Peninsula, New Zealand (Fig. 1). Here 500 ha will again be fenced to exclude mammalian pests and a suite of species similar to those at Tawharanui will be eradicated. At Shakespear, there are likely to be greater operational challenges due the proximity of 30,000 households and annual park visitation by 550,000 people.

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