Rapid commencement of ecosystem recovery following aerial baiting on sub-Antarctic Macquarie Island

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Supporting Information

Additional Supporting Information may be found in the online version of this article.

Appendix S1. Methods Details.

Appendix S2. Results Detail.

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Rapid commencement of ecosystem recovery following aerial baiting on sub-Antarctic Macquarie Island

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Key words: *eradication,introduced rabbits, island restoration, Poa foliosa, tussock grassland.*

Summary

Introduced rabbits have severely impacted the terrestrial ecosystem of sub-Antarctic Macquarie Island. Here we describe first observations of rapid recovery of an important plant species following the commencement of a vertebrate pest eradication plan. The tussock grass *Poa foliosa*, a major component of the Macquarie Island landscape, has been severely impacted by rabbit grazing with large-scale reductions in cover across the island observed at times over the last 50 years. Preliminary aerial baiting for rabbits and rodents commenced in winter 2010, and within 6 months, we observed substantial regrowth of tussock grass. The rapid re-emergence of this grass over such a short time period following localised removal of rabbits has positive implications for the island's recovery and provides insight for restoration monitoring.

Introduction

Invasive species, particularly invasive mammals, can have devastating effects on island biodiversity, (Courchamp *et al.* 2003). Technological advances and conservation initiatives have seen an expansion in island eradications over the last few decades. Typically, ecosystem recovery has been deemed successful once the target species has been removed. However, there can be complexities associated with this approach. For example, it can take a long time for the landscape to restore (Jones 2010) or there can be associated, unexpected, flow-on effects (Bergstrom *et al.* 2009). Here we present field observations of the rapid response of vegetation following the initial implementation of a vertebrate mammal eradication effort on an oceanic island. Recently, secondary poisoning of seabirds associated with this aerial baiting (Springer 2010) drew considerable scrutiny. However, at the same time, the positive vegetation responses reported here highlight and reinforce the immediate benefits of such operations.

Rabbits were deliberately introduced to Macquarie Island in the 1870s. Since this time the rabbit population has fluctuated in size because of various control methods (see Copson & Whinam 2001; Bergstrom *et al.* 2009). With these fluctuations, there have been concomitant changes in vegetation (Costin & Moore 1960; Copson & Whinam 1998; Scott & Kirkpatrick 2008; Bergstrom *et al.* 2009).

Most recently, an explosion of the rabbit population (Terauds 2009) has resulted in the destruction through grazing of almost half the *Poa foliosa* dominated tussock grasslands through grazing (Scott & Kirkpatrick 2008).

Poa foliosa is a large tussock grass that is a key component of the island ecosystem. Ungrazed, it forms dense tussocks, with extensive roots that stabilise steep slopes. These tussocks also provide habitat for surface nesting seabirds (Fig. 1b), protection from predation for burrow nesting seabirds and are an important habitat for invertebrates. Thus, its removal not only leads to increased frequency of landslips (Costin & Moore 1960; Scott & Kirkpatrick 2008) but has broad ecosystem impacts. The smaller grass *Agrostis magellanica* also occurs on coastal slopes but is not as structurally important. It is widespread and abundant across the island, and in contrast to *P. foliosa,* benefits from rabbit grazing (Copson & Whinam 1998).

As part of an integrated pest management program, a rabbit and rodent eradication program was initiated in 2007 (Tasmania Parks and Wildlife Service 2007) and aerial baiting (using cereal pellets containing the anticoagulant brodifacoum) began in the winter of 2010, but was halted shortly after because of poor weather conditions (Springer 2010). Most of the baiting occurred on the southern coastal slopes where *P. foliosa* has been heavily grazed, and this accounted for around 10% of the island (total island area = 12 700 ha).

Field Observations

In December 2010–January 2011, we visited Macquarie Island to undertake comprehensive, spatially explicit vegetation surveys. During these surveys, we traversed 95% of the island on foot, covering upland plateau areas, coastal terraces and accessible coastal slopes. Our transects took the form of travelling a minimum distance (750 m) through a network of 1 km grid squares that covered the entire island.

Our survey coincided with recent confirmation that the initial baiting (June 2010) of the southern slopes had been successful, with ground searches revealing the localised removal of rabbits (Springer 2010). Prior to the baiting, this area had been heavily grazed resulting in the loss of tall tussock grasslands (Scott & Kirkpatrick 2008).

During our vegetation surveys, we observed vegetation recovery on these coastal slopes. *Poa foliosa* growth was observed. Through re-sprouting and culms tillering, from what appeared to be dead tussock pedestals, a substantial coverage of new, live *P. foliosa* had emerged (Fig. 1c). The patterning and size of the *P. foliosa* shoots were a clear indication that the pedestals were not completely

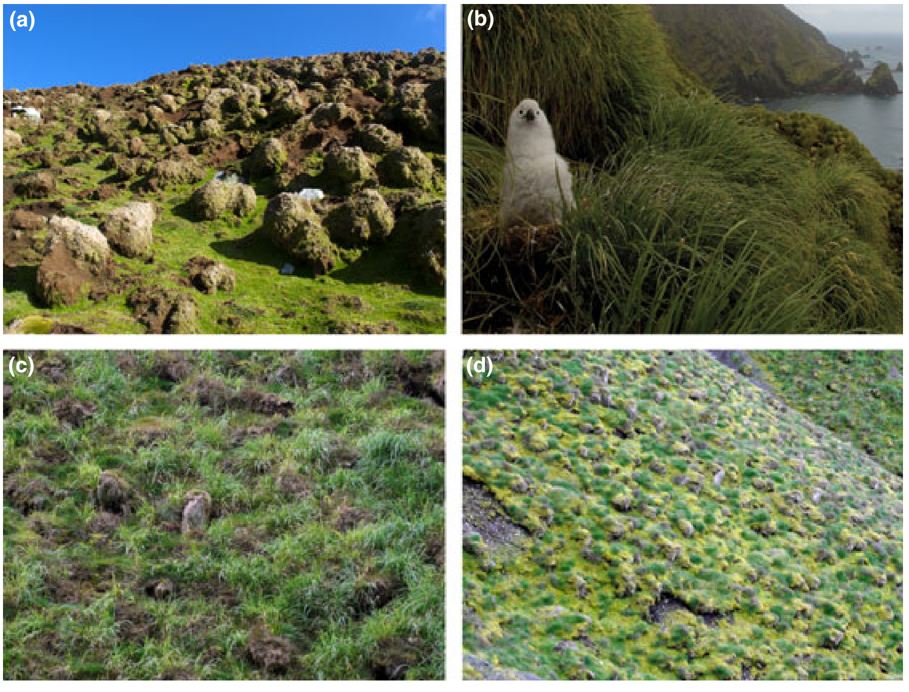

Figure 1. (a) Severe rabbit grazing has removed all of the above ground tissue of the keystone species (*Poa foliosa*), leaving only tussock pedestals. Non-native grass (*Poa annua*), interstitial herbs and bryophytes grow amongst the grazed tussocks. This area was not able to be baited in winter 2010 and at the time of this study, rabbits were abundant at the site. (b) *Poa foliosa* provides nesting habitat for seabirds, including Black Browed Albatross (c) Six months following rabbit removal, *P. foliosa* has re-emerged on coastal slopes through re-sprouting of the apical meristem and/or rhizomatous tillering. Previously grazed tussock pedestals are visible. (d) A severely grazed slope, now with rabbits removed, supports small tussocks of *Agrostis magellanica* and bryophytes. The dead pedestals of *P. foliosa* are visible, but there were no signs of re-growth at the site.

dead and that vegetation recovery was not attributable to newly emerged seedlings.

At other sites, we observed little sign of *P. foliosa* re-growth, instead there was widespread expansion of the smaller grass *A. magellanica* amongst turves of bryophytes (Fig. 1d). Because of the intensity of rabbit grazing, this site had previously undergone a regime shift from tall tussock grassland to short grassland (dominated by *A. magellanica*). Despite the removal of rabbits through baiting, there appeared little capacity for re-growth of *P. foliosa* at such sites. However, the rabbit removal had resulted in substantial expansion in size and height of *A. magellanica* (Fig. 1d).

All our observations of *P. foliosa* re-growth are attributable to asexual, or vegetative, expansion as plants were too large to have emerged from seed. The observed *A. magellanica* expansion was also vegetative and attributable to small surviving individuals being released from grazing pressure.

Discussion

Our observations of rapid vegetation emergence in heavily denuded areas, over a large scale, are the first of their kind following the current localised removal of rabbits because of baiting on Macquarie Island. Long-term studies have focused on changes in vegetation over long periods of time and have successfully quantified the role of rabbits, and how fluctuations in rabbits drive ecosystem change. These studies have determined the successional stages involved in recovery (Copson & Whinam 1998, 2001; Scott & Kirkpatrick 2008; Bergstrom *et al.* 2009) and how different plant species are affected by grazing (Costin & Moore 1960; Copson & Whinam 1998). Our observations describe the earliest successional stages following the removal of rabbits from a large area and demonstrate that immediate vegetation response is variable and dependent on previous grazing pressure. By reporting these observations, we provide new insights that should prove useful for interpretation of future long-term monitoring. These insights also have broader implications for the management of oceanic islands dominated by grassland ecosystems.

It is not surprising that removing introduced rabbits from an island with no native vertebrate herbivores results in vegetation regrowth. Indeed, there are numerous small fenced plots (5 × 5 m) on the island that provide evidence that exclusion of rabbits promotes vegetation (Copson & Whinam 1998). However, the rapid vegetation emergence described is an important indicator of the success of a management action, and as such timely reporting is essential. The re-emergence of these grasses by no means equates to total ecosystem recovery; however, the benefits of vegetation recovery in heavily denuded areas (see Fig. 1a) have immediate ecosystem benefits. Anticipated benefits include the following: increased slope stability (thus, reducing landslip occurrence), habitat restoration for nesting seabirds and invertebrates, increased cover for burrowing seabirds, repaired geomorphological processes (i.e. peat formation) and hydrological processes (i.e. fog interception).

Our preliminary observations suggest that monitoring programs associated with island eradications may benefit through adaptive measures that can respond immediately or concurrently with management actions. This is especially important as our observations indicate ecosystem recovery may be cryptic and variable. Often the focus is on long-term monitoring of seabirds and general 'greening' of the island. The secondary poisoning of seabirds owing to the preliminary baiting received media and governmental attention in this high-profile eradication program. Despite this, the island ecosystem has commenced recovery in other forms.

At the time of publication, the entire island has been successfully baited, and hunting of remnant rabbits has commenced. If successful, this will be the largest eradication of rabbits, rats and mice ever undertaken, boding well for broader vegetation recovery and ultimately the island ecosystem. Introduced vertebrates can transform islands ecosystems, and restoration can be slow following removal, particularly when recovery is only measured by seabird diversity or abundance. Here we show that under the right circumstances, ecosystem repair can commence rapidly.

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A framework for managing and monitoring bush regeneration programs: a case study from Lake Macquarie, NSW

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Key words: *data management*, *ecological restoration*, *management plans*, *natural resource management*, *rehabilitation*.

Summary

It is widely recognised that effective bush regeneration and ecological restoration programmes must be well planned and require effective management and monitoring. While general guidelines for monitoring are available, few examples of effective site monitoring and reporting exist in practice. The note describes a framework developed for managing and monitoring a bush regeneration programme for coastal NSW and evaluates it against a set of principles for monitoring ecological restoration programmes. The example illustrates how tools could be developed to improve management and monitoring practice.

Introduction

Monitoring is recognised as an important component in vegetation management and restoration programmes (NSW Department of Environment and Conservation 2005; Lovett *et al.* 2007). Monitoring ecological change, testing assumptions and record keeping are identified as issues to be considered in the preparation of natural resources management plans and bush regeneration (Fallding 2000; NSW Department of Environment and Conservation 2005).

It is well known that better documentation is likely to lead to appropriate actions and must be sufficient to monitor progress and change, assess effectiveness of approaches, and justify past and future expenditure (NSW Department of Infrastructure, Planning and Natural Resources 2003; Croft *et al.* 2005; Lindenmayer and Likens 2010). Essential criteria for successful natural resources monitoring, evaluation and reporting programmes (Lovett & Price 2007; NSW Natural Resources Commission 2007) are as follows:

- Defined purpose and clear objectives.
- Strong drivers including stakeholder demand for information and public support.
- Good governance structure integrated with strategic project planning.
- Effective monitoring design to detect changes at relevant spatial and temporal scales.
- Monitoring measures reflecting anticipated project outputs and outcomes.
- Consistent and reliable measurement and presentation of monitoring data.
- Adequate funding.

Notwithstanding the guidance that is available, there are few examples of systematic monitoring, data management and evaluation for bush regeneration projects. To help fill this gap, this note describes a management and monitoring framework developed by Lake Macquarie City Council for a bush regeneration programme and evaluates it against the Lovett and Price (2007) principles listed previously.

Description and Methods

As part of a 5-year bush regeneration programme on a 4 ha Council-owned bushland site at Dudley south of Newcastle NSW, a framework was prepared to monitor and record bush regeneration works. The framework was designed to be useful for a range of regeneration projects and comprises a package of standard documents to record and organise project data over time and to facilitate the preparation of monitoring reports and summary information.

Baseline data collection facilitated by the framework includes vegetation quadrat data, native vegetation mapping and weed distribution/cover data. The framework recommends dividing a site into practical management