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Conference Paper · September 2010

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A review of the marram grass eradication programme (1999–2009), Stewart Island, New Zealand

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Summary This paper examines issues that have arisen during a large scale weed eradication project. Since 1998, marram grass has been systematically controlled in Stewart Island. Key issues that have emerged over course of the programme include (i) the goals of the programme; (ii) the imperative for a multidisciplinary approach; (iii) the efficacy of different treatment methods and the need to develop new methods and strategies; (iv) the integration of operations and impact monitoring; (v) the need to develop medium to long-term strategies; and (vi) the need to foster relationships with stakeholders. This is not a comprehensive list, rather those matters that should influence the design of similar operations.

Keywords Marram grass, monitoring, restoration, strategic management, weed eradication.

INTRODUCTION

The majority of New Zealand's active dune systems have been invaded and stabilised by invasive exotic species, particularly marram grass (*Ammophila arenaria* (L.) Link) (Hilton *et al*. 2000). Marram grass was deliberately introduced from Australia to stabilise dunes. It has naturalised and then dispersed throughout central and southern New Zealand. It may also be invasive in northern New Zealand. A cluster of dune systems in the south of New Zealand retain high natural values – specifically dune systems in Fiordland and on Stewart Island (Rakiura) (Johnson 1992). All, however, are threatened by marram grass. Even the most remote systems in southern New Zealand are vulnerable to marram grass, which can establish from marine-dispersed fragments of rhizome (Konlechner and Hilton 2009). These southern dune systems require active management if their remaining biodiversity is to be preserved.

The Stewart Island Marram Eradication Programme (MEP) was initiated in 1998 and is probably the largest marram-related operation by area. Several key issues have emerged over the decade of the Programme including: (i) the goals of the MEP and dune restoration; (ii) the imperative for a multidisciplinary approach; (iii) the efficacy of different treatment methods and the need to develop new methods and strategies; (iv) the integration of operations and impact monitoring; (v) the need to develop medium to long-term strategies based on good information; and (vi) the need to foster relationships with stakeholders. It is timely to reflect on these issues and the development of practice after a decade of intensive marram eradication on Stewart Island, given the imperative to address new challenges and the increasing interest in dune restoration. We also briefly document the history of operations.

HISTORY OF MARRAM GRASS OPERATIONS ON STEWART ISLAND

Marram was planted at Kilbride in Mason Bay in the 1930s and then spread north, by marine-dispersed rhizome. It established in the foredune north of Martins Creek in the early 1950s, and then spread to the hinterland of the dune system by wind-blown seed. Some sections of the dunes were also planted by farmers in the 1960s (possibly earlier). Marram grass was also well established in Doughboy Bay by the early 1950s. By 1998 marram had occupied most available habitat in Doughboy Bay (30 ha) and was established across 68% of the 676 ha of active dunes in Mason Bay. The rate of spread was rapid – Hilton *et al*. (2005) estimated that areas of dense marram (>50% cover) increased from 1.4 ha in 1958 to 74.9 ha in 1998. Marram grass would have successfully invaded most of the dune system between 2023 and 2043 (Jul 1998). It was not surprising that leading botanists of the time dismissed the option of eradicating marram.

The history of marram eradication on Stewart Island can be divided into two phases. Small-scale operations targeted isolated populations of marram on the northwest beaches of Stewart Island up to and following the formation of the Department of Conservation (DOC) in 1987. Knapsacks were used to spray small areas of marram that had established from marine-dispersed rhizome. The second phase commenced in February 1999 when the Department undertook an aerial operation over the southern barrier in Doughboy Bay.

Approximately 7 ha of the southern barrier were sprayed with haloxyfop-R, a systemic, grass-selective herbicide, using a Robinson-22 helicopter. Complete necrosis of leaf material was observed 4 months later.

However, numerous shoots established from surviving rhizome by late spring. The helicopter was used to spray re-growth in February 2000, after which DOC employed a pump unit mounted on an ARGO amphibious vehicle. Subsequent re-growth, primarily from *in situ* seeds, has been sprayed using the Argo or with knapsacks, or pulled during grid search in the period 2004–2010. Operations are ongoing due to (i) the persistence of a marram seed bank and (ii) growth from marine-stranded rhizome in 2005 and 2008. Marram was washed into the sea during storm events and rhizome deposited around the entire 2.1 km margin of Doughboy Bay by wave action, above the line of spring high tides. On both occasions stranded rhizome produced vigorous growth within 12 months.

This sequence of spray methods – helicopter, Argo, knapsack/grid search – has also been employed on the northern and central barriers in Doughboy Bay and at Mason Bay. Marram is still present in the dunes of Doughboy Bay, albeit in low densities (<1 plant 100 m^{-2} in June 2009).

Marram eradication in Mason Bay has advanced relatively rapidly since operations commenced in 2001. Marram growing in back-dune environments succumbs more rapidly than that growing in the foredune environment, probably because the root and rhizome mass is less massive. In addition, the seedbank associated with coppice dunes appears relatively small or non-existent. Most seed is probably blown downwind by the prevailing onshore winds following flowering and does not germinate in a favourable location. All of the back dune work in the central dunes of Mason Bay has been completed with the Argo or with knapsacks. A Jet Ranger helicopter has been used to spray large sections of the northern dunes in 2004/05, 2005/06, 2006/07 and 2008/09. The resulting necrosis was patchy compared with the Argo and helicopter operations have been discontinued for the time being. Eradication of marram in the hinterland of the northern and central dunes is ongoing because of sparse regeneration from wind-blown seed associated with foredune flowering.

It was recognised in 2006 that the mechanical methods used to apply spray – helicopters and the Argo – were not suited to the location and treatment of widely scattered plants. A grid search, which used lines of searchers equipped with hand-held GPS units, was trialled in November 2006. The breadcrumb trails on the GPS screen were used to maintain direction and spacing and ensure total coverage of the search area. Every marram plant encountered was way-pointed, pulled or (subsequently) sprayed. In November 2006 the four-person volunteer team searched 70 ha over 4 days. In total, 5817 plants were surveyed, of which 4712 were pulled. Effective execution of this simple method is critical to the success of the MEP on Stewart Island. Marram grass will be eradicated from Doughboy Bay over the next few years, but only if operations are conducted annually, systematically and with precise spatial control. Eliminating the first 99% of marram from Doughboy Bay was, in hindsight, relatively easy – compared with the task of finding and destroying the last 100 seedlings.

DISCUSSION

In the following sections we examine issues that have arisen during the 10 year history of the MEP. It is not a comprehensive list, rather those matters that should influence the design of similar operations. Some are specific to the problem of marram grass in dunes of high conservation value, while others might be more widely applicable. We should note that the Stewart Island MEP evolved, from a site-specific operation to an island-wide programme. Little was known about the biology of marram grass in southern New Zealand or the response of dunes and the dune system to an extensive and intensive herbicide-based programme. DOC has progressed cautiously, as information and understanding has allowed.

Marram eradication or dune restoration? The Stewart Island MEP was initially focused on marram grass. From the outset of the Doughboy Bay work, however, consideration was given to the impact of marram on barrier development and dune flora. The flora and landscapes of the three dune barriers at the time the MEP commenced was, in large part, an artifact of marram grass, with stable foredunes and high species diversity. Ten years after the commencement of the MEP in Doughboy Bay the form of the barriers is little changed, partly because of the slow decay of marram rhizome (Hilton *et al.* 2009). In contrast, however, the surface of the barriers is mobile due to ongoing sedimentation and the flora is now dominated by dune-specific species – species usually associated with unmodified active dune systems.

The goal of the MEP is to restore and safeguard the geomorphic processes that underpin the natural character of the pre-marram dune-barrier system. These processes are driven by high energy wave and wind events, and result in the circulation of large quantities of sediment. Transgressive dune forms, blowouts and parabolic dunes are common. The most exposed sections of the barriers are continually contested – pioneering plants may establish but seldom persist for long. Barrier erosion, progradation and accretion is cyclic, in response to storm events. An erosion scarp

at the rear of the northern and southern barriers was probably cut in the early 1950s or late 1940s. Such events could recur at any time, substantially altering or even removing the current 'restored' landscape. *D. spiralis* was systematically planted in Doughboy Bay from 2003. Hence, the current dunes now have two important qualities – a seed bank of *D. spiralis* and the (near) absence of marram grass. Post-storm barrier progradation and accretion would (henceforth) occur in the presence of indigenous plants, not marram grass. At this site, restoration is achieved by eliminating marram grass, but also by re-establishing the seed bank of key native species and conserving the dynamic potential of the barrier.

The Dune Restoration Advisory Group (DRAG) Since 2008 the Stewart Island MEP has gained technical support and strategic direction from an advisory group (DRAG), comprising technical support staff, managers, field staff and staff of the University of Otago (the authors). The Stewart Island DRAG meets prior to each spray or treatment season (late-September), to review the results of monitoring and to set priorities for the next season. The DRAG reconvenes in April of each year to review and discuss the previous season's operations.

The DRAG provides a forum to address operational issues, solve problems and to ensure monitoring and operations are integrated. Failure to integrate operational and monitoring objectives can be wasteful. The Mason Bay project, for example, commenced with extensive aerial spraying – over an area that could not be sustained in subsequent seasons. Operational areas are now carefully evaluated and prioritised and monitoring is focused on priority sites.

The DRAG has also provided a forum for considering broader ecological and conservation goals. The emphasis has changed from marram eradication to 'dune restoration'. DRAG recognised the need to expand the scope of work to include other exotic species, particularly *Lupinus arboreus*, which threaten natural patterns of sedimentation, habitat development and native species diversity.

Treatment methods The methods employed during the MEP, including methods of spray application, operations monitoring, and monitoring the effects and effectiveness of the programme, have evolved as our understanding of the biology of marram has developed. At the outset there was little understanding of the significance of re-invasion by wind-blown seed (Mason Bay) or *in situ* germination of marram seed (Doughboy Bay). There was an expectation that helicopter and Argo operations would suffice. It was difficult to predict how the programme would progress because little was known about the biology of marram grass in southern New Zealand, or which technologies or combination of technologies would be needed in the second year of the programme. In hindsight, too much reliance was placed on aerial applications, which have been less effective than the Argo. Applying enough herbicide to the underside of the leaves using a helicopter can be difficult. The preference is to employ small, low-flying machines, over discrete management areas.

The area to be treated in the first season of operations should be carefully considered. There is a (natural) temptation to treat an area that is too large in the first season, so that it is difficult or impossible to achieve effective follow-up operations in the following season. The first operation at Doughboy Bay resulted in complete die-back, but about 30% of the treatment area contained re-growth by the following spring. This growth was concentrated on the face of the foredune, but was elsewhere patchy and widely dispersed. The only option was to re-spray with the helicopter, which means much of the herbicide applied fell on bare sand or marram killed the previous year. Helicopters have the capacity to spray many hectares in a matter of hours, depending on the size of the machine, rate of application and degree of overlap. The issue then becomes the capacity to re-spray surviving plants in the second year of operations. Survivors may be widely dispersed over difficult terrain and vehicle access may be problematic. We recommend that programmes work through the sequence of technologies in the initial treatment area before new areas are treated, although caution needs to be balanced against the need to limit further invasion.

The importance and role of monitoring The intensity, effectiveness and effects of the Stewart Island MEP have been assessed annually by members of the Dune Research Group at the University of Otago since 1998. The cost of monitoring equates to about 5% of the total budget for the Programme. All marram spray operations on Stewart Island, including helicopter, Argo and grid search operations, have utilised GPS since 2004 to record the target species, location and duration of each operation. The monitoring strategy was designed to address particular questions. These include the impact of haloxyfop-R on marram grass and non-target species in different environments; the expected decline in species diversity with marram decline; the impact of marram decline on overall barrier morphology; and patterns of sedimentation (in relation to the inundation of downwind habitats as a result of sand transport following marram decline).

Monitoring involves networks of permanent quadrats at Doughboy Bay and Mason Bay, grid search for surviving marram, and regular mapping of landforms and plant cover using a total station survey instrument. ARC-GIS was used to integrate and report operations and the results of monitoring. All operations are now carefully evaluated. This has allowed the response of the target species to be quantified in relation to the extent and intensity of operations. Areas that have been overlooked during a spray season can be mapped and targeted late in the spray season or prioritised for the following season. These technologies also provide a means to locate and report the location of surviving populations or individuals of the target species. This process is critical to the total eradication of a species at the stage when surviving individuals are scattered over a wide area.

The need to adopt a long-term perspective The Doughboy Bay project has progressed more slowly than anticipated – complete eradication may not be achieved before 2015. It could take longer, depending on the longevity of buried marram grass seed. The presence of a viable marram grass seed bank, two rhizome stranding events (2005 and 2008), inclement weather and certain operational decisions have all delayed the completion of the project. This is hardly surprising, given the Doughboy operation was the first such operation.

The Doughboy Bay experience demonstrates the need for conservation managers to adopt a long-term management perspective. Marram eradication will be achieved when all marram plants are destroyed and the marram seed bank is exhausted. Thereafter, DOC will need to undertake ongoing surveillance, involving annual visits to the site and systematic searches for marram, including marine-dispersed rhizome from the mainland. In this regard the MEP will be on-going, albeit the cost of these operations will be low compared to the present.

Stakeholder involvement Large-scale weed control operations will attract public scrutiny. Some opposition to the MEP on Stewart Island arose when the Programme was publicised in 2007. Mason Bay was farmed until 1987, when DOC was formed and the pastoral lease was relinquished. The last farmer and several senior members of the Stewart Island community oppose the marram programme and have actively campaigned for marram to be retained. Some of these people helped spread marram grass in the 1960s. In essence, they wish to see the active dunes of Mason Bay stabilised. Their concerns have been addressed, in part, through dialogue (including DOC-sponsored familiarisation visits to Mason Bay), and by including new research and monitoring objectives. Similar reaction can be anticipated elsewhere, since there is generally a low level of understanding of the natural character of active dunes, particularly their mobility and dynamism.

CONCLUSION

The marram eradication programme on Stewart Island has evolved from small scale, ad hoc operations, driven by the enthusiasm of individual rangers, to a systematic dune restoration programme. The programme has successfully addressed a range of issues since 1999, in part because of the long-term commitment of DOC and staff from the University of Otago, but also because of the development of effective management tools, such as the Dune Restoration Advisory Group. New strategies and methods will be needed to address other invasive species, including tree lupin, but there are clearly positive lessons to be learned from the current approach to dune restoration on Stewart Island.

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