Control to eradication of *Tradescantia fluminensis* on Stephens Island (Takapourewa): the importance of systematic and persistent effort

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DOC RESEARCH AND DEVELOPMENT SERIES 346

New Zealand Government

Department of Conservation
Te Papa Atawhai

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.

This report is available from the departmental website in pdf form. Titles are listed in our catalogue on the website, refer www.doc.govt.nz under *Publications*, then *Science & technical*.

ISSN 1177–9306 (web PDF)
ISBN 978–0–478–15041–4 (web PDF)

This report was prepared for publication by the Publishing Team; editing and layout by Lynette Clelland. Publication was approved by the Deputy Director-General, Science and Capability, Department of Conservation, Wellington, New Zealand.

Published by Publishing Team, Department of Conservation, PO Box 10420, The Terrace, Wellington 6143, New Zealand.

In the interest of forest conservation, we support paperless electronic publishing.

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Abstract

This case study describes control to eradication of tradescantia (*Tradescantia fluminensis*, wandering jew) on Stephens Island (Takapourewa), Cook Strait. Control commenced in 1990 and most tradescantia was removed by May 1992, leaving only small isolated patches. Island caretakers attempted to control tradescantia along with their other tasks for the next 10 years. Tradescantia abundance increased over this period. Not until 2003 was the eradication goal made clear and a dedicated weed team assigned to implement it. Eradication of tradescantia from Stephens Island now appears imminent but remains elusive, with two small plant fragments having been found in the last 5 years. We discuss factors important to achieving eradication and suggest that systematic and persistent effort by highly motivated and dedicated people is critical to eradication success.

Keywords: eradication, *Tradescantia fluminensis*, wandering jew, systematic and persistent effort, highly motivated people

Brown & Brown 2015: Control to eradication of *Tradescantia fluminensis* on Stephens Island (Takapourewa): the importance of systematic and persistent effort. *DOC Research and Development Series 346*. Department of Conservation, Wellington. 11 p.

1. Introduction

The Department of Conservation (DOC) took over management of Stephens Island (Takapourewa) (Fig. 1), hereafter Stephens Island, from the Marine Division of the Ministry of Transport in 1989. Stephens Island is a nationally important wildlife sanctuary located in Cook Strait, between the North and South Islands, that is renowned for its population of tuatara *Sphenodon punctatus* and large numbers of burrowing seabirds (fairy prions *Pachyptila turtur*, sooty and fluttering shearwaters *Puffinus griseus and P. gavia*, diving petrels *Pelecanoides urinatrix* and little blue penguins *Eudyptula minor*). It is also home to the rare Cook Strait striped gecko *Toropuku stephensi*, endemic frog *Leiopelma hamiltoni* and an endemic weevil *Anagotus stephensi*. A number of other bird species formerly present on the island were driven to local extinction following the establishment of a lighthouse in 1894, when cats (*Felis cattus*) were introduced and large areas of forest removed. Stephens Island wren *Xenicus lyalli*, South Island kokako *Callaeas c. cinerea* and South Island piopio *Turnagra c. capensis* all occurred on Stephens and are now nationally extinct.

Figure 1. Stephens Island (Takapourewa) showing steep cliffs present around all sides of the island. *Photo: Bill Cash.*

Tradescantia (*Tradescantia fluminensis* or wandering Jew) (Fig. 2) is an introduced ornamental plant, originally from South America. It was first recorded in New Zealand in 1916 (Healy & Edgar 1980) and is now widespread nationally in frost-free areas. Tradescantia is a shade-tolerant, ground-smothering perennial creeping herb that prevents seedling growth (Standish et al. 2001). It grows vegetatively from fragments as small as 1 cm long or less (Kelly & Skipworth 1984), but does not produce seed in New Zealand, and transportation by people is an important means of dispersal (Esler 1988).

Tradescantia flourished in the relatively high light and soil fertility conditions on Stephens Island. Its spread was likely assisted by its ability to grow vegetatively combined with the high level of soil disturbance resulting from tuatara and seabird burrowing activities (Brown & Rees 1995), with steep slopes assisting its downhill spread. Its ecological impacts included 'preventing or greatly reducing establishment of seedling tree and other understory species, and greatly impairing access to burrows of tuatara and fairy prion' (Brown & Rees 1995).

Figure 2. *Tradescantia fluminensis* (wandering Jew). *Photo: Susan Timmins.*

In 1966, tradescantia was known to be well established in two of the small bush remnants on the island—particularly in Keeper's Bush and, to a lesser extent, in Ruston Bush (Pip Aplin pers. comm. 2013); although, in the absence of an island-wide survey, it may have also been present elsewhere. Botanist Geoff Walls noted that the area covered by tradescantia had increased threefold between 1975 and 1988 (Walls et al. 1988). He recorded 'large patches up to 150 m^2 and 1.8 m tall immediately adjacent to old gardens. … Smaller patches 1.10 m^2 are scattered throughout the forest right to the edge of the cliffs. There are also several large patches in Ruston Bush … There are very few places in these forest areas where the light is so sparse as to preclude this weed.'

A survey of tradescantia distribution carried out by Victoria University in 1990 estimated that it covered 60% (1.8 ha) of the ground surface in Keepers Bush and 105 m^2 in Ruston Bush (Fig. 3) (Allen et al. 1990). The authors also noted that it had spread onto the northwestern cliffs.

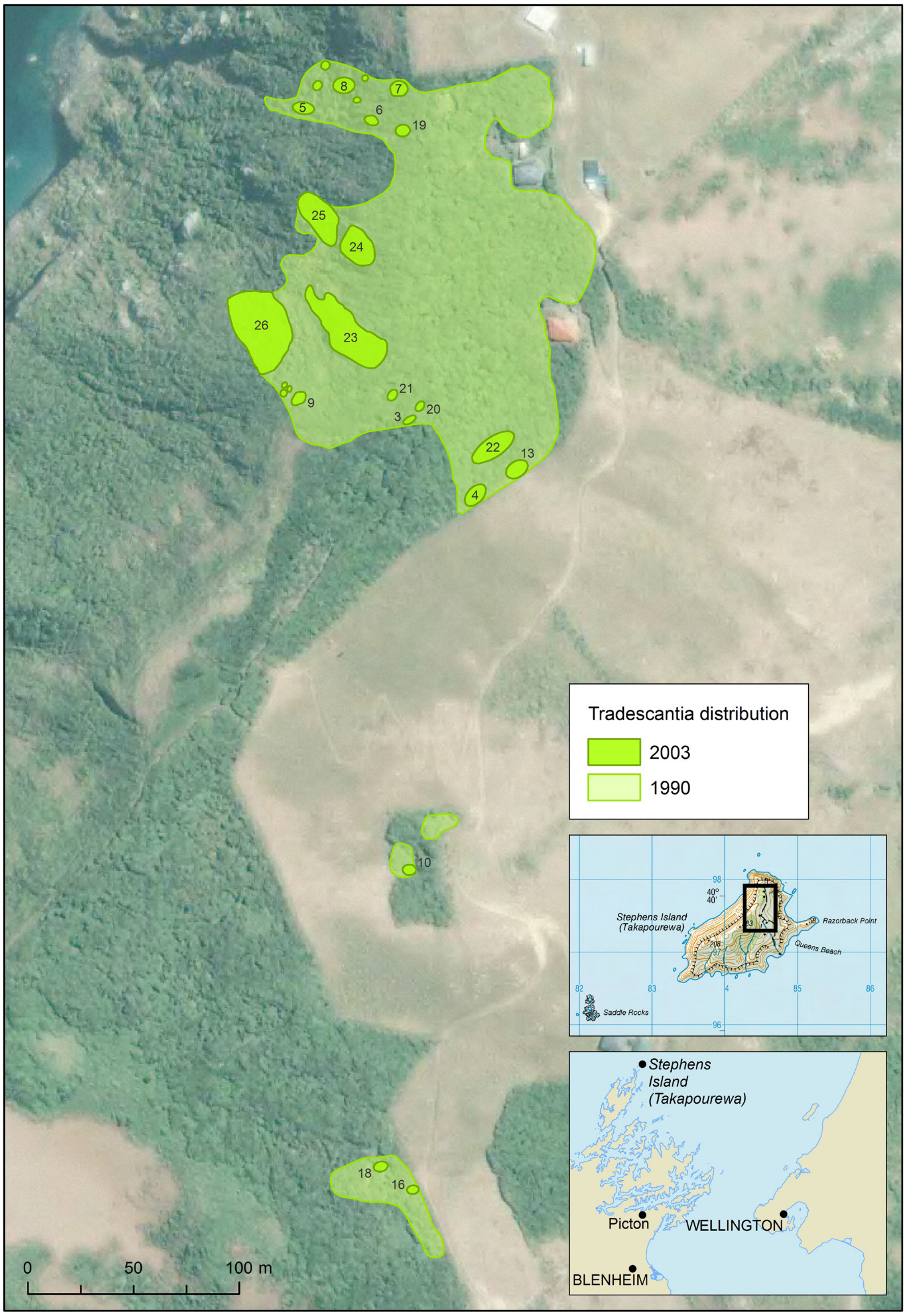

Figure 3. Tradescantia distribution on Stephens Island in 1990 and 2003.

In the heavily infested areas in Keepers Bush the biomass of tradescantia averaged 3.9 kg/m² dry weight. While they doubted that eradication could be achieved, they did call for intensive management to control its spread. The Stephens Island Management Plan written in 1990 advocated elimination of tradescantia from the northwestern cliffs and Ruston Bush and its control in Keepers Bush (Anon 1990).

We describe the history of the control and eradication programme from 1990 to 2014 and assess it against the various social, ecological and operational factors identified as important to achieving eradication in the pest management literature (Bomford & O'Brien 1995, Myers et al. 2000, Parkes 2006, Pluess et al. 2012a & b, Pacific Invasives Initiative 2013, Tobin et al. 2013).

2. Methods used to control and eradicate tradescantia

2.1 Knock-down control (1990–1992)

Figure 4. Dense ground covers of *Tradescantia fluminensis* (similar to this area at Karangahake Gorge, near Paeroa) were present on Stephens Island. *Photo: Kate McAlpine.*

In 1988, botanists visiting Stephen's Island identified control of tradescantia as a high priority (Walls et al. 1988) (Fig. 4). Small-scale trials of the effectiveness of hand-clearing and various herbicides were conducted, and these were followed by large-scale hand removal and herbicide control trials in 1990 (Brown & Rees 1995). Tradescantia was surveyed and then controlled using Triclopyr (Grazon). Triclopyr mixed at 5–6 ml per litre of water with the penetrant Pulse added at 1.33 ml per litre of water was deemed to be the most effective control tool trialled (Brown & Rees 1995). Triclopyr was applied from a backpack sprayer by Dave Rees between August 1990 and July 1991. Dave Rees then carried-out follow-up spraying in March and April 1992, including the application of Glyphosate (Roundup) to remove rank grass to improve access and expose tradescantia foliage for spraying with Triclopyr (Brown & Rees 1995).

2.2 Sporadic control (1993–2003)

Follow-up control between 1993 and 2003 was carried out by the seven resident caretakers and, occasionally, by volunteer groups. The duration of each caretaker's stay on the island varied from 6 months to just over 3 years. Resident caretakers were expected to show new caretakers known sites. Tradescantia remnants were widespread and no attempt was made to formally map them until 1999. However, when they were mapped, only 19 sites of remnant growth were located. These were marked and numbered, and subsequently controlled. Other sites, particularly on the steep cliffs, went undiscovered and uncontrolled from 1993 until 2003, (Brown 2003).

2.3 Eradication (2003 onward)

Following intensive survey (Fig. 3) and control by Derek Brown in July 2003, a dedicated weed team carried out twice-yearly control visits from October 2003 to August 2006. Yearly visits have been carried out subsequently. All 26 known sites were visited and tradescantia was treated with Triclopyr when present and when appropriate its absence noted. Wider searches were repeatedly carried out over other portions of the island, but no further sites were located. From 2007 onwards, a few small tradescantia fragments were removed by hand. For person effort and results see Table 1. Survey and site searching was carried out by people walking slowly approximately 2 m apart in a grid pattern. The same ground was covered multiple times in a single visit.

Tradescantia treatment, monitoring and survey efforts on Stephens Island were constrained by steep and sometimes unstable terrain, thick vegetation and unfavourable weather, seabird breeding and hot/dry conditions. Lines were cut through thick vegetation and ropes used in

Table 1. Tradescantia control effort and results from 2003 to 2013.

YEAR	PERSON EFFORT	SPRAY SOLUTION	FRAGMENTS FOUND	NUMBER OF SITES		
				ACTIVE*	SURVEILLANCE	HISTORIC
2003	37 days	153 litres	N/A	17	8	1
2004	18 days	128 litres	N/A	13	10	3
2005	20 days	20.5 litres	N/A	11	9	6
2006	20 days	0.1 litre	9	3	15	8
2007	11 days	N/A	9	4	11	11
2008	11 days	N/A	3	1 (23)	10	15
2009	8 days	N/A	0	0	5	21
2010	6 days	N/A	3	3 (8, 23, 26)	2	21
2011	18 days	N/A	0	0	3	23
2012	16 days	N/A	1	1 (26)	2	23
2013	8 days	N/A	0	0	3	23
2014	6 days	N/A	1	1 (8)	1	24

Note: person effort was determined by multiplying the weed team visit person days each year by 0.75 (to account for down time travelling and wet weather). Active = population size is greater than 0; surveillance = population size is 0 for 3 years; historic = population size is 0 for more than 3 years,

*The numbers in the brackets are sites were tradescantia was detected.

steep terrain to gain access. Unfavourable weather limited spray application during some visits. Spraying on the western cliffs was only feasible in southerly to easterly conditions or in very light winds from the northwest. Visits during the seabird breeding period (October to February) were limited to avoid undue damage to burrows or nest contents. The cliffs can also be very hot and dry in the height of summer. Control work was therefore carried out in the period from early March to early October.

We have used a total count site approach (Holloran 2006) to report monitoring results and as a means of quantifying progress towards eradication. Monitoring records of tradescantia presence/absence and control effort (Table 1) at each known site were collected from 1999 onward, with 1998 recorded in retrospect. All tradescantia sites were marked with white pegs and the positions of all pegs were recorded with a Garmin GPS. Patches of tradescantia re-growth were mapped in relation to the pegs (i.e. distance and compass bearing from the pegs), as this provided greater relocation precision than the use of GPS waypoints.

3. Results of control, trials and eradication attempt

3.1 Knock-down control

The intensive control carried out between August 1990 and July 1991 was estimated to have removed tradescantia from 95% of the area (2.3 ha) where it had formerly been present (Brown & Rees 1995). The spraying between March and April 1992 resulted in only small isolated 'hidden' patches of tradescantia remaining (DB pers. obs.). The control effort between 1990 and 1992 was very successful at delimiting the distribution of tradescantia on Stephens Island and then removing most of it (Fig. 3).

3.2 Sporadic control

Control between 1993 and 2002 was sporadic. Not all of the known sites were inspected or treated in a given year. Successive caretakers either didn't know the location of all the active sites or were deterred by steep cliffs. This situation began to change in 1999 when formal mapping of known remnants began, although the mapping was incomplete and survey beyond these sites was limited. Nineteen sites were marked and mapped in 1999. In April 2002, tradescantia was detected beyond the treated boundaries of these known sites and a large new area was detected on the western cliffs (Knight 2002). A further six sites were found in July–October 2003, bringing the total number of sites requiring active control to 26. Tradescantia distribution and abundance increased between 1993 and 2003 because control was not systematic and persistent.

3.3 Eradication

When eradication commenced in July–October 2003, tradescantia was present on approximately 0.3 ha or 13% of the original 1990 pre-control coverage of 2.3 ha (DB pers. obs.; Fig. 3). We estimate that the biomass was less than 1% of that in 1990 (DB pers. obs.). All 26 known sites in 2003 were within the areas delimited in 1990.

Herbicide use declined dramatically between 2003 and 2006 due to the significant reduction in abundance of tradescantia. By 2006, only 0.1 litre of spray solution was used. After 2006, case-by-case decisions were made to either spray fragments or remove them by hand. These decisions were dependent on the amount of leaves on the plants and the nature of the substrate in which they grew. Observations of regrowth following clearance suggest that tradescantia fragments can remain buried in loose substrate and only resume leaf growth when exposed to the light through soil movement. Tradescantia remained undetected for 4 years at site 8, in loose substrate on the western cliffs of the island.

The number of known sites increased from 19 in 1999 to 26 in 2003 and remained at 26 for the duration of the programme. The number of active sites decreased markedly from 17 to 4 between 2003 and 2006. The latest find of a single tradescantia fragment was in 2014 from a site that had been clear for 3 years previously (i.e. active surveillance).

Figure 5 provides a clear visual representation of the change in status of tradescantia control sites on Stephens Island between 1998 and 2014. Sites are scored as follows:
Active—population size is greater than 0,
Surveillance—population size is 0 for 3 years,
Historic—population size is 0 for more than 3 years,
Unreported—site not visited that year.

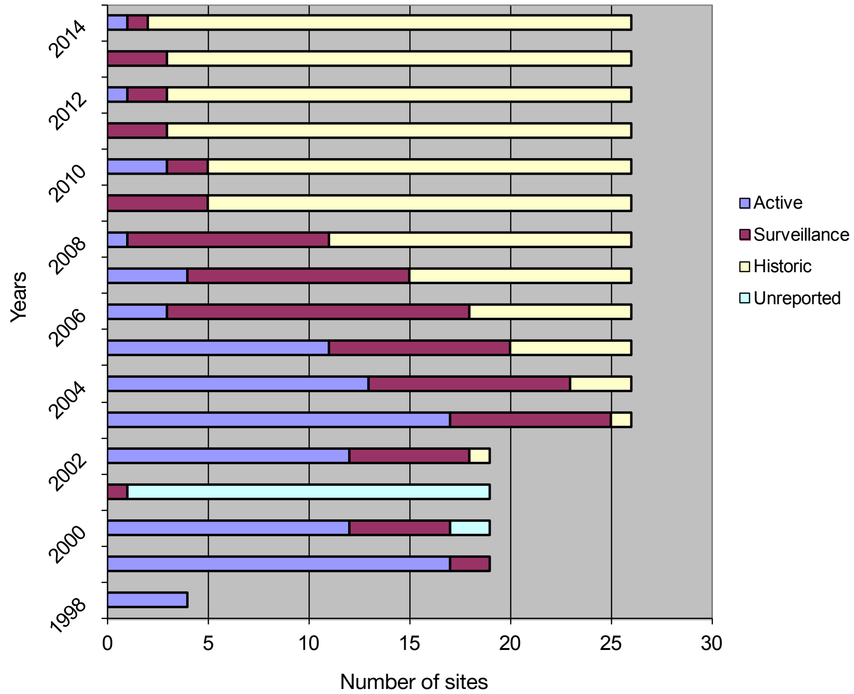

Figure 5. Change in the status of tradescantia control sites on Stephens Island between 1998 and 2014.

3.4 Estimated cost of eradication to date

We estimate a total cost for the programme to date of approximately $100,000. From 1990 to 2002 the programme cost approximately $16,500, made up predominantly of staff time. Knock-down costs between 1990 and 1992 were estimated at $6,500 with a further $10,000 for sporadic control between 1993 and 2002. A further $83,500 was estimated to have been spent on transport, food, equipment and staff time between 2003 and 2014.

3.5 Detection probability

Amongst the site checks there were 34 site visits when tradescantia might or might not have been detected when it was definitely present (as it was found during a subsequent check). Tradescantia was detected in 21 of these checks (62%, 95% confidence intervals 44% to 78%). This suggests that it takes at least 5, but up to 9, visits to a site with nothing found to be 99% confident that tradescantia is no longer present.

4. Discussion

Factors important to achieving eradication have been identified in the literature. Several of these support the likelihood of tradescantia being eradicated from Stephens Island. The risk of immigration/re-invasion (Bomford & O'Brien 1995) is minuscule given that Stephens is an island with controlled access and biosecurity measures in place. The extent of the weed incursion (Rejmanek & Pitcairn 2002; Panetta & Lawes 2005; Pluess et al. 2012a & b; Tobin et al. 2013) was also relatively small (2.3 ha) and it is an obvious advantage that tradescantia does not produce viable seed (Cacho et al. 2006). Tradescantia is relatively conspicuous, an important factor identified by Myers et al. (2000) and Simberloff (2003). However, the difficult terrain (Cunningham et al. 2004) and difficulty in detecting small fragments (Panetta & Timmins 2004) amongst loose soil and leaf litter are likely to be the main reasons why eradication has yet to be achieved.

For tradescantia on Stephens Island, the low environmental impacts, significant ecological benefits and relatively low financial cost of eradication versus control in perpetuity suggest a favourable cost-benefit ratio (Bomford & O'Brian 1995; Pacific Invasives Initiative 2013) for eradication efforts, although no formal analysis has been carried out. Panetta et al. (2011) point out the need for more estimates of eradication costs in the literature and here we estimate the cost to date at approximately $100,000 (see section 3.4). Time and money could undoubtedly have been saved if the programme had had a clear eradication goal (Cromarty et al. 2002) and sufficient resources (Myers et al. 2000) to achieve it from the start, although cost savings are difficult to quantify.

Triclopyr was identified as an effective control tool in 1990 (a key factor identified by Bomford & O'Brien 1995). Bomford & O'Brien (1995) and Tobin et al. (2013) both point out the need for tools that can detect pests at low density. For tradescantia, detection through human search effort has proved effective, as individual plants inevitably become more conspicuous as they grow larger over time. Sites have been checked through repeated surveys (active surveillance) (Mack & Lonsdale 2002) and multiple searchers (as per Braithwaite 2000) since 2003. No tradescantia beyond known sites has been detected despite wide-scale searches since 2003. Only when systematic mapping and survey was initiated from 2003 onwards have all tradescantia plants on Stephens Island been placed at risk (Bomford & O'Brien 1995).

Another factor identified in the literature is the need for a favourable socio-political environment (Bomford & O'Brian 1995; Pacific Invasives Initiative 2013) including institutional support (Gardener et al. 2010). Stephens Island is administered by DOC under the 1977 Reserves Act in partnership with Ngati Koata (Anon 1994) and both parties are very supportive. The legal mandate is in place as the Act is explicit that 'exotic flora and fauna shall as far as possible be exterminated' and there are no other political or community barriers.

Ultimately, the provision of financial and human resources has been the key institutional support enabling eradication of the weed. Prior to 2003, weed control costs were from a single 'Stephens Island' budget and had to compete with other work on the island. The allocation of additional biodiversity funding by the government of the day and the priority given Stephens Island by DOC's weed planning system (Owen 1998) enabled the goal of eradication to be agreed and a dedicated weed control team to commence work in 2003.

Cromarty et al. (2002) and Morrison et al. (2011) point out the need for effective project management. While the knock down between 1990 and 1992 was very successful, the programme was failing between 1993 and 2003 due to lack of project management. From 2003, planning and implementation was led by DB and each visit was reported on by DB. The programme was reviewed in 2008 as part of the DOC weed management system (Owen 1998), resulting in ongoing support for eradication.

Howell (2012) found that the DOC administrative area was the strongest determinant of eradication progress when he analysed 111 DOC weed eradication programmes, although he was unable to tease out the relative importance of staff skills and attitude (i.e. being thorough) from an ability to pick and back winners or good project management or some combination of these.

As discussed above, many factors are important to achieving eradication, but individual human attributes are seldom discussed. We suggest that highly motivated and dedicated people (Brown & Sherley 2002) are needed if systematic and persistent effort is to be achieved over extended timeframes in difficult terrain. We also suggest that one personality type identified by Belbin (2010), the Completer-Finisher, is particularly important to eradication success. The Completer-Finisher is concerned with detail, has well-developed self control and strength of character, is hard working, conscientious and a good organiser who aims for success and is reluctant to leave the job unfinished.

The Stephens Island tradescantia eradication programme was fortunate to have two Completer-Finishers involved—Dave Rees who achieved the initial knock-down of tradescantia (despite the dense vegetation and steep terrain) but whose term of employment ended soon after, and Derek Brown who has lead the eradication team since 2003. Staff continuity within an eradication project is important, and it can be seen here that the greatest progress was made in reducing tradescantia when the Completer-Finishers were employed on a regular basis.

However, tradescantia eradication from Stephens Island has not been declared yet. Determining the optimal amount of search effort required before declaring that eradication has been achieved is problematic (Dominiak et al. 2011, Regan et al. 2006, Ramsey et al. 2008, Ramsey et al. 2011). Our approach, based on the relationship between finds and misses where tradescantia was known to be present, suggests that up to nine further annual visits without finds are required to have 99% confidence that no tradescantia remains. The time between visits could be extended, allowing any remaining tradescantia to become more visible, but annual tradescantia survey is carried out in association with other weed work, so annual visits remain practical. No tradescantia was found during the latest search in May 2015 and the current plan is to continue to carry out annual visits.

In this paper we have described the history of control to eradication of tradescantia on Stephens Island with the aim of informing eradication attempts elsewhere. While many factors contribute to achieving eradication, we suggest systematic and persistent effort is critical. Such effort requires highly motivated and dedicated people (especially in difficult terrain) over extended timeframes. As far as we are aware, if the eradication of tradescantia from Stephen's Island is successful, it will be a world first at this scale.

5. Acknowledgements

We would particularly like to acknowledge the efforts of Dave Rees, Phil Clerke, Gus Laird, Johnny Joseph and the many 'volunteers and conscripts' who took on the arduous task of searching for and controlling tradescantia in challenging conditions. Susan Timmins, Carol West and Keith Broome provided valuable comments on earlier drafts. Graeme Elliot assisted with determining the detection probability and Geraldine Moore assisted with Figure 1.

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