Control of invasive plants on the Poor Knights Islands, New Zealand

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Abstract In 1995 the New Zealand Department of Conservation initiated a weed control programme on the Poor Knights Islands, 16km offshore from Tutukaka, Northland, New Zealand. The intention is to eradicate all infestations of five environmentally invasive plant species (weeds) to the point where windborne re-invasion from seed sources on the mainland is the only threat. The invasive plants targeted, *Ageratina adenophora, A. riparia, Araujia sericifera, Cortaderia selloana* and *C. jubata,* are the only invasive plants present. All known weed sites are visited twice a year and all weeds found destroyed. Visits are timed to coincide with peak germination periods and pre-to-early flowering to prevent further seed set. Aerial surveys are completed during early flowering to locate any plants on cliff faces or in the canopy of trees. Areas of the island prone to reinvasion are thoroughly ground searched every year in spring, while the weed-free areas are searched every second year. *Ageratina adenophora* numbers have been reduced from several thousands to fewer than fifty. *Araujia sericifera* has continued to have high germination of seedlings, but is now in decline, probably because the seedbank is being depleted. *Araujia sericifera* has been the most difficult species to locate. A spreadsheet was developed that provides useful field data for control purposes and the raw statistical information for management and monitoring purposes. With refinement and manipulation this database could be beneficial for scientific research including species fecundity, seedling recruitment trends/time, seedbank viability under various geophysical site conditions, and rates of re-invasion from outside sources.

Keywords Mexican devil, *Ageratina adenophora*; mistflower *Ageratina riparia*; pampas grasses, *Cortaderia selloana, Cortaderia jubata;* mothplant, *Araujia sericifera*.

INTRODUCTION

Scope of this paper

This paper describes and discusses observations and actions at one location, with one group of target plants and the results of one management technique designed to fit the site conditions and plant behaviour in that site. It is a report on what was planned, how it was done and what has happened as a result. Analysis and comparison is left for others to consider.

Poor Knights Islands Management Area

Location and geography

The Poor Knights Islands (PKI) are situated 16km off the coast of Northland, New Zealand. The group comprises 272 hectares of land and consists of two main islands, Tawhiti Rahi and Aorangi, and seven smaller islets. The islands themselves are a Nature Reserve and are administered by the New Zealand Department of Conservation (DOC). They are surrounded by an 800m-wide Marine Reserve which is internationally recognised for recreational diving. The general public are not allowed access to the islands and all landings are by permit only.

The islands were created by ancient volcanic activity and have been geographically separate from the mainland for longer than any other islands around New Zealand's immediate coast. Thus the Poor Knights biota has one of the highest rates of local endemism in New Zealand (Nieuwland 1999).

History of human contact

Maori, the Polynesian settlers of New Zealand, had significant settlements on both the main islands until a massacre occurred around 1820. The islands were then declared sacred and settlement ceased. Prior to the massacre, Captain Cook, an 18th century English explorer, gifted pigs *(Sus scrofa)* to Maori on Aorangi island, and when the Maori left these animals reached high numbers (Fraser 1925). A successful feral pig eradication project was completed in the 1930s (Challies 1976). No other mammals have been recorded.

Invasive naturalised plants targeted

There are numerous alien plant species on the islands but only five have been identified as likely to have adverse impacts on the islands if left uncontrolled. These are Mexican devil (*Ageratina adenophora*), mistflower (*A. riparia*), two pampas grasses (*Cortaderia selloana* and *C. jubata*) and mothplant (*Araujia sericifera*). These weeds invade open disturbed sites, forming dense swards that outcompete the native regeneration. They gradually expand their range from the margins of their infestations by encroachment and displacement as the surrounding native species die out. Mistflower is shade-tolerant, so it can penetrate the forest interior and smother native seedlings. Mothplant seedlings are also shade-tolerant and remain in a phase of low foliar growth, until conditions such as increases in light and moisture levels enable a burst of growth up into the canopy.

All five species were introduced to New Zealand as garden ornamentals around 1900. By the 1930s they had natu-

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ralised and started spreading. A trypetid gall fly (*Procecidochares utilis*) was released in 1958 as a biological control agent for Mexican devil (Hoy 1960) but it does not provide successful control. To control mistflower the white smut fungus *Entoloma ageratinae* was released in 1998 (Frollick 1999) and it appears to be very successful. These control agents have not been observed on the Poor Knights although they are present on the Hen and Chickens Islands which are a similar distance from the mainland. The control agents are certainly capable of reaching the islands so their absence is probably due to the Poor Knights now having a lower weed density and therefore less chance for the control agents to establish.

Determination of when the invasive weeds arrived on the islands is difficult. Pampas grass, Mexican devil and mistflower have been widespread in Northland (Fig. 1) since the 1950s. Mothplant appeared in Northland around the 1980s. Pampas grass was first recorded on the Poor Knights Islands in 1974 (Veitch 1974) and Mexican devil in 1986 (Daugherty and Powlesland 1986). Mistflower was first recorded in 1991 (Wright 1991) and mothplant in 1993 (Parrish 1993). Density or distribution was not recorded at these early stages. Seedbank longevity of these species under New Zealand conditions is unknown.

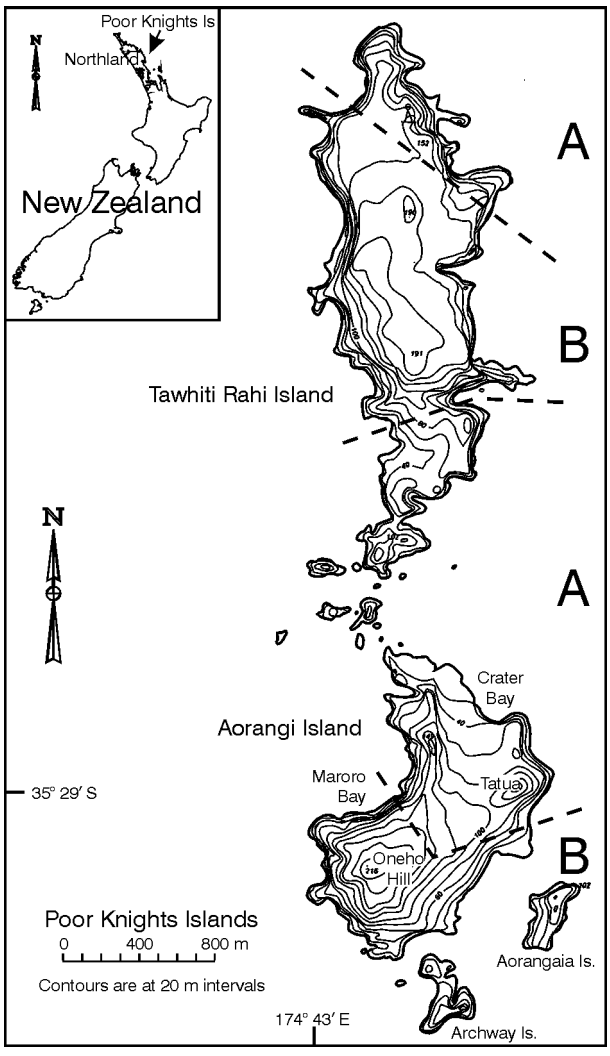

Fig. 1 The Poor Knights Islands showing their relationship to the coast of Northland and the places named in the text. The weed areas are marked as: "A" weed-free prone to invasion – contains known sites; "B" weed-free not prone to invasion – no known sites.

METHODS

Early control efforts

Control of pampas (not identified to species level at this time) commenced in 1991 and focused on three obvious infestations on the coastline. Control of the other three invasive species commenced in 1994. This work was done using volunteers and involved one trip a year to each island. No formal search techniques or data recording protocols were in place and the information gathered from sites was lacking detail or extremely variable. Sites were marked with various techniques. Random searching patterns at this point also resulted in many sites not being found. By 1995, 36 sites had been located.

Weed Eradication Strategy Poor Knights Islands (WESPKI)

A formal Weed Eradication Strategy for the Poor Knights Islands (referred to as WESPKI) was developed in 1996 (Bowden and Bowden 1996). The purpose of the strategy was to give control direction for the following five years and to standardise procedures for all weeding teams and data collection. The sensitive nature of the cultural and ecological values of the islands were also recognised. There was little information available at this time regarding the individual weeds and their attributes in this type of environment. Suitable techniques for intensive survey, relocation of sites and eradication were not available. The strategy was developed around errors uncovered during early control efforts, relating to seasonal timing of visitation and an appropriate site management regime.

This strategy has been altered each year since 1996 to recognise newly-developed best practices. Further reviews will continue to redirect it for the next five years. When it was developed, WESPKI was referred to as an "almanac for island visitation." Factors such as site hygiene and minimising impacts of visitation were incorporated because they impact directly on the efficacy of the weed work and success of the programme. Key aspects of WESPKI are listed below:

Management regimes and island visitation

The islands have been divided into three management zones: actual weed sites; weed free zones prone to invasion; weed free zones not prone to invasion. These were determined with consideration to the proximity to existing weed sites and the type of vegetation cover present. Where unmodified pohutukawa *(Metrosideros excelsa)* forest is found there is a striking absence of invasives. All existing weed sites occur in areas of disturbance associated with exposed coastal faces, shrubland and broadleaf forest. The

weed free areas not prone to re-invasion coincide with the major seabird breeding areas.

A weed site is defined as any continuous infestation of weeds usually defined by proximity to a mature plant for mothplant or by the size of the light patch in which the weeds are present. Weed sites range from 1m x 1m plots with an individual plant to areas 20m x 30m. These are searched twice a year in early spring and early summer to coincide with the earliest flowering to occur.

Weed-free zones prone to invasion consist of the northern and southern tips of Tawhiti Rahi and Crater Bay, Tatua and Maroro Bay on Aorangi, and incorporate all those areas surrounding existing sites. These are intensively searched annually in early Spring.

Weed-free zones not prone to invasion include the seven islets, the tableland on Tawhiti Rahi and Oneho Hill on Aorangi. These are searched every second year in spring.

Every spring four people spend two days transit/setting/breaking camps, four days searching and visiting sites and weed-prone areas on Aorangi and three days searching and visiting sites and weed-prone areas on Tawhiti Rahi. On each alternate year half of the weed-free areas not prone to invasion are searched. In summer sites are re-checked by four people spending one day transit/setting/breaking camp, three days on Aorangi and one day on Tawhiti Rahi.

Aerial surveys

An aerial search is conducted annually in early summer for flowering mothplant and pampas grass and, every second spring for flowering mistflower and Mexican devil. In the case of mothplant it is virtually impossible to locate mature vines from the ground in dense vegetation once the plant has reached the canopy. Some coastal faces are not accessible by foot and the only way to search them is by aerial observation.

Database and information recording

The information recorded provides detail for re-location of weed sites and for analysis of the success of the weed programme.

For new sites details are taken describing the location and size of the site and satellite infestations. Details for relocation from other sites or from the track system are recorded. For both new and re-visited sites details of weeds removed include: date; species; numbers of adult/immature; control actions taken; and team leader. Adult plants are those which have completed a cycle from germinating to setting and dropping seed.

Search techniques

Sweep searching is conducted during spring visits to locate new infestations. Except for mothplant the species are all just commencing flowering at this stage. The sweeping technique involves all team members. They space themselves 10-20m apart, dependent on terrain and visibility, and move in line abreast between reference points. When weeds sites are encountered all weeders come together to record and intensively ground search the site. They then spread back out and continue sweeping. Intensive ground searching of sites by people on their hands and knees will pick up the majority of seedlings which could set seed by the next visitation. During the summer visits only known sites are visited. This avoids accidental movement of seed and disturbance of breeding seabirds.

Search timing

In northern New Zealand Mexican devil and mistflower can set seed from mid-spring to late summer although peak seed set is around late spring. The first treatment is therefore timed for early spring prior to seed setting in late September/October. During spring/early summer the time taken from germination to maturity is much faster than over autumn/winter and January has proven to be the best time to revisit sites to catch plants that have germinated since the spring trip, prior to their setting seed in late summer (February/March).

Site marking protocols

All weed sites are marked with a purple plastic triangle with the site number written on it. This is placed in the centre of the site with a piece of pink flagging tape to identify its location. Around the boundary of the site more pink flagging tape is installed also with the site number and reference to its position on the site (e.g. northern limit of site 124). The labels are replaced regularly to avoid perishing completely. The site location is recorded on GPS (Global Positioning Systems).

Weed removal

All flowers and seedheads are removed from the plants and placed in secure bags for removal from the island.

All plants are hand pulled, soil is shaken from the roots and the plant is placed so that the roots are clear of the ground. The roots of larger mothplants are grubbed out to ensure that they do not re-grow.

In the first two years of this operation adult mothplant stems were cut and painted with a herbicide mix of metsulfuron methylester (600g/kg) at 2g/2*l* of water.

RESULTS

Field trips in 1996 required 96 person/days per year: 40 person/days searching and 56 person/days weeding sites. It now takes 56 person/days per year: 40 person/days completing surveillance for new infestations and 16 person/days searching and controlling the existing sites.

On the Poor Knights Islands 142 weed sites have been recorded since 1995. During the visit of 9 February 2001,

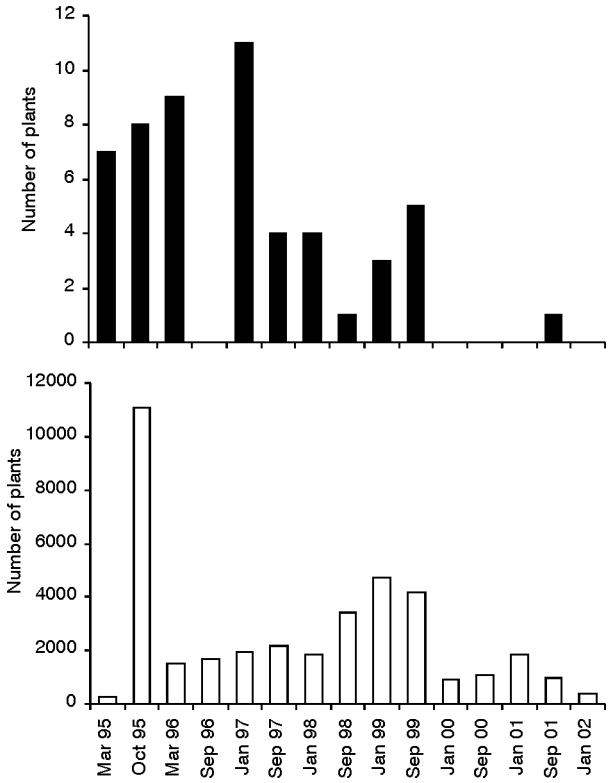

Fig. 2 The numbers of mothplants (*Araujia sericifera*) destroyed on Aorangi Island. The upper graph is adult plants and the lower graph is immature plants.

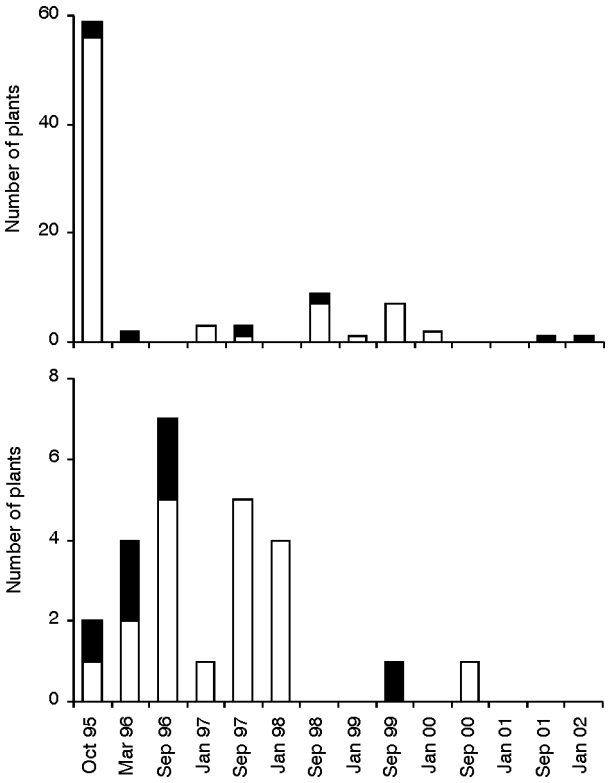

Fig. 4 The numbers of pampas plants (*Cortaderia selloana* and *C. jubata* combined) destroyed on Aorangi Island (upper graph) and Tawhiti Rahi Island (lower graph). The black bars are adult plants and white bars immature plants.

112 of these were weed free. A comparison of the detail recorded in our field trip reports over successive years, shows that the number of clean sites continues to increase and the number of new sites has rapidly decreased.

The numbers of weeds controlled on successive visits are presented in Fig. 2-5. There are seasonal fluctuations between spring/summer visits but there is a clear declining trend. The actual 'effort' in terms of applying attention to thoroughness has remained constant during searching within sites for weeds and during surveillance for new infestations. As there are now fewer weeds to remove the hours required to complete trip visits have reduced.

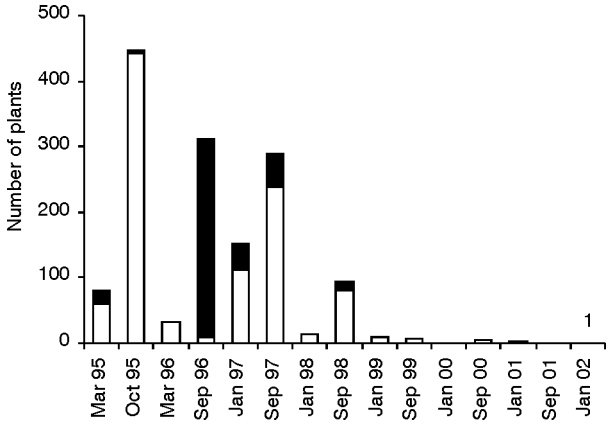

Fig. 3 The numbers of mistflower (*Ageratina riparia*) plants destroyed on Aorangi Island. The black bars are adult plants and white bars immature plants. Note that one immature plant was destroyed in Jan. 2002.

The total number of mothplants (Fig. 2) has fluctuated as new sites were found after aerial survey commenced in January 1997. However, since this time the trend line has started a steady decline, although this appears to be slower than other species and could be a reflection of greater seed longevity in the soil.

Mistflower (Fig. 3) showed an interesting reversal in adult to juvenile plants numbers around 1996/1997. This came about because two mistflower sites were missed and were full of adults the following year. This stresses the importance of visiting sites at least twice a year to beat the setting of seed. After this, juvenile numbers increased and then a steady decline occurred as the seed bank started depleting.

Pampas grass control commenced on Aorangi earlier than on Tawhiti Rahi (Fig. 4). There has been a dramatic decline in numbers of pampas after the large infestations were dealt with. Pampas probably has a shorter seed viability than the other weeds.

The reduction of mature Mexican devil has been similar on both islands (Fig. 5) but immature plants continue to occur on Aorangi. There have been significant benefits

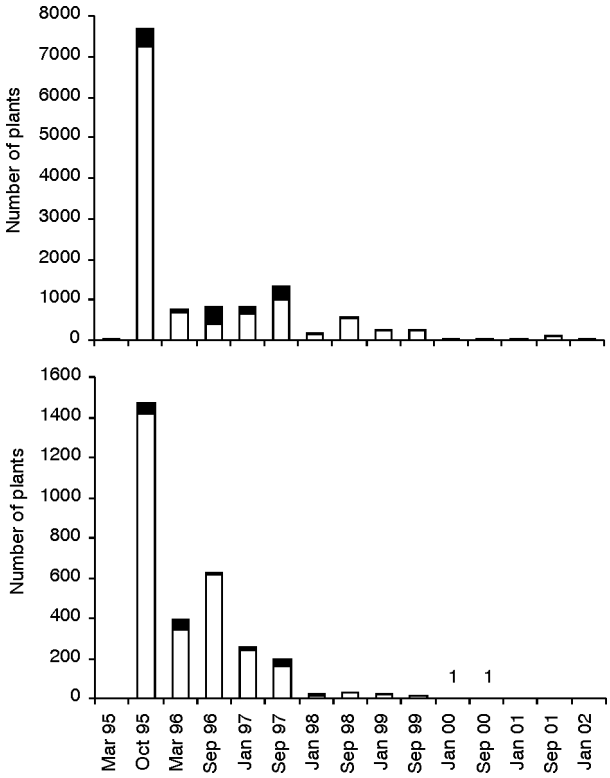

Fig. 5 The numbers of Mexican devil (*Ageratina adenophora*) plants destroyed on Aorangi Island (upper graph) and Tawhiti Rahi Island (lower graph). The black bars are adult plants and white bars immature plants. Note that one immature plant was destroyed on Tawhiti Rahi in Jan. 2000 and one in Sep. 2000.

from commencing control on Tawhiti Rahi before the weed was well established.

Tawhiti Rahi had no weeds during the visit of 9 January 2001 and consistently had only one or two plants found during each of the last four visits. There have been no new sites found for more than two years. The fortunate factor that has resulted in success is the simple fact that weeds had only just started to establish and never reached significant populations. It is my assumption that these sites may have established later from seed dispersing from Aorangi.

Mist flower on Aorangi had declined to zero plants but then two new sites containing one plant each in the first year of flowering (one of which had set seed) were located. Mexican devil, which was the most widely dispersed and prevalent weed, is now down to around 20 plants, all juveniles, found during each search.

DISCUSSION

Although control was not commenced until well after the invasive species had arrived on the islands, we started control before massive encroachment had occurred. In any eradication programme involving these five species this should be a fundamental criterion in evaluating whether or not to proceed with eradication or focus on sustained control. Once populations have become well-established, the ability to achieve coverage over all sites at the critical management times makes it difficult to beat the rapid cycle from germination to seeding.

A team of four people was found to be a good number to manage. More people become difficult to keep in formation and resulted in delays waiting for others to catch up. Fewer people meant sweep searches were narrower and took longer to complete. For greater efficiency the team can split in two to deal with very small sites less than nine metres square.

Existing literature on the topic of weed control consists either of site-specific data, general autoecological/biological information about species, or models on plant behaviour such as dispersal. The behavioural traits of species vary dramatically in different geophysical and climatic contexts. For example, *Ageratina adenophora* is also invasive in Australia and Hawaii, yet in all three locations it occupies very different habitats and has different behavioural characteristics, such as seed density and infestation/proliferation density, compared with its growth in New Zealand. The techniques described here would probably be excessive in Hawaii and inadequate in Australia.

Seed viability

We do not know the maximum time over which seeds can remain viable for any of the species being controlled in this environment. Individual site trends on the Poor Knights suggest that significant seed bank depletion for pampas grass, mistflower and Mexican devil occurs between two and four years. Mothplant seeds seem to persist for longer as seedling numbers only started to decline after five years. Mothplant does not show a decline as clearly because a number of adults have been located in the last two years. It is expected that they may persist for ten years. We initially planned to declare individual sites weed-free and to "archive" the site (i.e. no longer specifically search the site twice a year) after two years without any seedlings. It has been considered too early to take this step and we are considering a four year period of seedling absence instead.

Risks and impacts associated with intensively searching the islands

Our presence on the islands could be contributing to the weed problem. This was especially so during the early stages of control when the seedbank in the soil and the number of mature plants with setting seed was still high.

It is easy to prevent visitors bringing weeds onto the islands by following standard hygiene procedures prior to visitation, but it is very difficult to control the spread of seeds on staff footwear and clothing after weeding one site and moving onto another. It has been observed that many of the new sites encountered in the past two years have been on tracks or regularly-used pathways. The man-

agement regimes described in WESPKI are an attempt to reduce the amount of unnecessary travel and therefore the risk of spreading seed. Protocols of dusting seed off team members before leaving a site are followed but are not infallible.

Re-invasion from the mainland

Weeds have arrived on the islands in the past therefore re-introduction remains a threat. The main means of dispersal for these species is by wind and they may have got there by their own means. It is also possible that they arrived with earlier research parties, as they did not follow stringent island hygiene standards.

We do not know whether new sites are the result of new invasion or from existing seed in the soil being given optimum conditions to germinate. We do not know the extent of the seed shadow from the mainland, but the probability of seed dispersing 16 km and landing on an island in a location with suitable germination factors is low. All new Mexican devil, mistflower and mothplant sites have been in close proximity to existing sites, suggesting they have originated from the old sites. New pampas sites have occurred in remote areas away from old infestations. The pampas seed shadow may be more frequent than the other three weeds and the physical design of dispersal methods for the various seeds supports this theory.

The weed control programme and WESPKI model has been replicated on the Chicken Islands since 1997 and is showing promising results there. Hen Island has been included since 1998. However, we cannot logistically or financially complete control trips to all the islands over the critical pre-flowering period, and the Hen and Chickens programme is regarded as an intensive control programme. The intention is to contain and reduce infestations and allow natural regeneration to aid the process by means of displacement. We anticipate successful control will be achieved on these islands over a longer timeframe. It will be several years before we can confirm this, as some sites are yet to receive initial treatment. On the Hen and Chickens we have complete records of all sites, commencing with their first control visit, so the data will include earlier weed trends which are missing from the Poor Knights database.

Over five years our strategy has been refined with the knowledge gained from each visit. It is a case of successful techniques evolving and being developed by trialing ideas for management. On the Poor Knights Islands we have created a recipe that is successful at eradicating the five invasive weeds present and involves a balance between the timing of field trips, techniques for control and reducing interference and impacts of our visits. Attention to detail by those doing the work is paramount as to miss one plant prior to seeding has a significant bearing on the duration of the programme and whether the final result will be control or eradication.

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