Chapter 14
Small, Dynamic and Recently Settled: Responding to the Impacts of Plant Invasions in the New Zealand (Aotearoa) Archipelago

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Abstract New Zealand was one of the last land masses to be populated by humans, and its isolation has contributed to the large number of endemic species that the country is known for. With increased global movement of people and goods this historic advantage no longer exists. In the last several decades numerous legislative, policy and operational tools have been used to protect New Zealand's special areas and biota from invasive alien species. With the benefit of 25 years of dedicated protection efforts by the Department of Conservation, best practice alien plant control techniques have been developed, building on lessons from animal pest eradications, trophic relationships, and on-the ground pragmatism and experience. Increasingly, an essential tool to achieving greater success will be working with other agencies, businesses and communities to harness resources. Three case studies illustrate the approaches and lessons learnt from alien plant management in New Zealand in the last 25 years: Raoul Island in the far north of New Zealand, Hen and Chicken Islands to the east of North Auckland Peninsula, and Fiordland National Park in south-western South Island.

Keywords Eradication • Fiordland National Park • Hen and Chicken Islands • Raoul Island • Seed bank • Seed dormancy • Zero-density

14.1 Introduction: New Zealand No Longer Isolated

New Zealand (named Aotearoa by indigenous Māori people) lies approximately 1,600 km east of Australia in the southern Pacific Ocean, between latitudes 29°S (the Kermadec Islands) and 52°S (Campbell Island). It is an archipelago of approximately 700 islands more than 1 ha in size upon the mostly submerged continent

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Zealandia (Campbell and Hutching 2007), and extends approximately 15,000 km in length. The New Zealand biota evolved in geographical isolation, and the unique flora and fauna that is characteristic of New Zealand is particularly vulnerable to the impacts of alien species generally (Diamond 1990).

Historically, New Zealand had no land mammals, other than three species of bat, one now presumed extinct. Instead, the fauna was laden with endemic birds (many of them flightless), lizards and invertebrates, set against an equally high endemic flora of conifer/broad-leaved forests, tussock grasslands, and subalpine communities (Williams and West 2000). Many endemic plant species, including approximately half of New Zealand's threatened plant species, are found in historically rare ecosystems that occupy just a fraction of the land surface (Williams et al. 2007).

The first introduced plant species resulting from human habitation came with Māori settlement approximately 800–1,000 years ago, mostly as food sources. However, the number of plant species introduced by Māori was substantially less than the number of plants introduced by European settlers in the early nineteenth century. Both groups brought food plants, but Europeans also replicated their homelands with ornamental garden flowers and shrubs. Introductions from Europe flourished, whereas plants introduced by the Polynesians largely died out (some surviving only on Raoul Island in the far north of New Zealand), primarily because the climate is more similar to Europe than Polynesia. Today, New Zealand has 2,418 species of native plants, and over 80 % of these are endemic (NZPCN 2012). In contrast, there are 25,049 species of introduced plants (Diez et al. 2009) and 2,536 of these have naturalised (NZPCN 2012). The Department of Conservation (DOC) recognises 328 environmental invasive alien plants (IAPs; Howell 2008).

This chapter focuses on IAP management on public conservation land; that is, land managed or administered by the Government's Department of Conservation. Public conservation land makes up about 8.5 million ha of land, about one-third of New Zealand. Intensive management of IAPs is carried out only within about 500,000 ha in areas of high value ecosystems and species (DOC 2012), in recognition that alien plant invasions can eliminate some native species (Williams and Timmins 1990).

14.2 Legislation and Policy Tools

14.2.1 Legislation to Support Protected Area Management

Legislation has been used for several decades to help prevent new IAPs entering the country or a region, and for limiting the spread of a new introduced species. The Biosecurity Act 1993, and the Hazardous Substances and New Organisms Act 1996, provide legislative and regulatory tools to prevent the unwanted importation of new pests into and throughout New Zealand.

The Conservation Act 1987 established the Department of Conservation and is the umbrella legislation for the protection of public conservation lands, and natural and historic resources. The Act also restricts the transfer and release of live aquatic life into any freshwater environment. Three further Acts: The National Parks Act 1980, the Reserves Act 1977 and the Marine Reserves Act 1971 are administered by DOC and establish the purpose, principles, and powers for managing national parks, reserves and marine reserves, respectively. This legislation prohibits alien species from being introduced without authorisation.

14.2.2 Policy Platforms for Invasive Alien Plant Management

In 1995, DOC developed a strategic plan and supporting tools to identify, prioritise and manage IAPs. This framework (Owen 1998) contains five objectives, namely to: (i) minimise the risk of introductions of new plant taxa that are potentially invasive, (ii) minimise the numbers, or contain the distribution of significant new IAPs where feasible ('Weed-led' programmes), (iii) protect land, freshwater and marine sites that are important to New Zealand's natural heritage from the impacts of IAPs ('Site-led' programmes), (iv) sustain and improve skills, control techniques, information and relationships to support DOC's management of IAPs, and (v) maintain and improve the quality of DOC's invasive alien plant management systems.

The New Zealand Biodiversity Strategy (Department of Conservation and Ministry for the Environment 2000) was developed in response to the Convention on Biological Diversity held in Rio de Janeiro in 1993, and with the recognition that New Zealand's indigenous biodiversity was declining. Later, a national Biosecurity Strategy (The Biosecurity Council 2003) was developed to meet the increased challenges associated with excluding, eradicating and managing risks to New Zealand's economy, environment, and the health of its citizens. The Biosecurity Strategy included institutional arrangements, Māori capacity, improved science, border protection, incursion response and pest management.

14.2.3 Managing for Outcomes

DOC undertakes work according to an 'Outcomes Model', comprising five intermediate outcomes that state the high level results that DOC aims to achieve, and the steps to be taken to achieve those results. Invasive plant management contributes primarily to the first Outcome, namely, protecting biodiversity: "The diversity of our natural heritage is maintained and restored". Supporting the outcomes model are the scientific tools that enable improved prioritisation of where and how work is done, and measures to assess the outcomes of that conservation work (see Lee et al. 2005).

DOC's 2012 annual report was, for the first time, informed by the data collected and analysed for 14 biodiversity indicators measured throughout New Zealand. Invasive alien plants occurred in 33 % of the locations sampled (fewer than previously recorded from the same plots), but the distribution and frequency appears similar to the situation in about 2000. Invasive plants are most commonly recorded in grassland areas and near human habitation, with most IAPs being non-woody and shade intolerant (MacLeod et al. 2012). The data also supported DOC's IAP management priorities, for example, the current focus on forest margins close to grasslands and habitation.

14.3 Impacts on Protected Areas in New Zealand

14.3.1 Grasslands

Before human habitation, grasslands dominated by native tussocks grew in alpine or dry climates with limited soil fertility and high light. After extensive burning by both Māori and European settlers the quantity of the grasslands increased (McGlone 2004). Northern hemisphere conifers, particularly *Pinus contorta* (lodgepole pine), were sown above the natural treeline and have since spread considerably (Brockerhoff et al. 2004; Craine et al. 2006), affecting native grasslands at all altitudes within range of any plantations. The high altitude plantations were sown by the New Zealand government in the (erroneous) belief that they would combat the high levels of erosion caused by overgrazing by stock, and wild introduced animals such as deer (primarily red deer, *Cervus elaphus*) and rabbits (common rabbit, *Oryctolagus cuniculus*; Bellingham and Lee 2006). Wilding conifers alter not only landscape values but also the ecosystem services such as the water supply provided by grasslands (Mark and Dickinson 2008).

Hieracium and *Pilosella* species, particularly *Pilosella officinarum* (mouse-ear hawkweed), *P. piloselloides* subsp. *praealta* (king devil hawkweed), *H. caespitosum* (field hawkweed) and *Hieracium lepidulum* (tussock hawkweed) have invaded short tussock montane and alpine grasslands in recent decades (Duncan et al. 1997). The extent of their cover is now hundreds of thousands of hectares, resulting in displaced native species and possible higher nutrient deposition than from tussock vegetation (Wiser and Allen 2000).

14.3.2 Forests and Shrublands

New Zealand's forests covered 80 % of the land before human settlement, but today less than 25 % of the original forest remains. There are two main types of indigenous forest in New Zealand, the southern beech forests and the conifer/broad-leaved forests, and each type is invaded by a different suite of IAPs.

Nothofagus spp. (beech) forests provide a range of ecosystem services, including the production of honeydew from native scale insects (*Ultracoelostoma* spp.), which in turn provide a rich food source for birds. These forests have been found to be susceptible to colonisation by *H. lepidulum*, with species-rich sites more likely to be invaded (Wiser et al. 1998; Wiser and Allen 2000). A different suite of IAPs invade conifer/broad-leaved forests. These species often originate as alien ornamental garden plants, and the smothering combination of woody vines (*Clematis vitalba*, old man's beard; *Asparagus scandens*, climbing asparagus; *Hedera helix*, ivy) and herbaceous groundcovers (*Tradescantia fluminensis*, wandering Jew; *Plectranthus ciliatus*, plectranthus; *Vinca major*, periwinkle) can have major impacts. Shrublands are similarly vulnerable to the spread of garden plants, with frequent invasion of *Cotoneaster glaucophyllus* (cotoneaster), *Lonicera japonica* (Japanese honeysuckle) and *Chrysanthemoides monilifera* (boneseed), as well as many others that combine to out-compete native plant communities.

14.3.3 Wetlands and Estuaries

The effects of IAPs are equally apparent in wetlands. Only 10 % of the original extent of New Zealand wetlands remain (Peters and Clarkson 2010). Wetland IAPs can be particularly difficult to manage because of the restrictions placed on the use of herbicides near and on waterways, combined with the volume and mass of the types of alien plants often present, such as *Salix* spp. (willows), *Glyceria maxima* (floating sweetgrass) and *Osmunda regalis* (royal fern), with *Spartina* spp. (cordgrass) particularly impacting estuaries. *Spartina* spp. have been controlled in all estuaries in the South Island that had been invaded either from deliberate planting (for land reclamation) or long-distance spread by sea. This work has been very successful and eradication from the South Island is now being considered. However, finding *Spartina* spp. plants in South Island estuaries is difficult as they typically occur amongst grasses in drains and wet pasture. To improve the likelihood of finding these last individuals, DOC is about to train a '*Spartina* detection dog' (K Vincent pers. comm.).

14.3.4 Sand Dunes

Invasive alien plants such as *Ammophila arenaria* (marram), *Lupinus arboreus* (tree lupin), *Stenotaphrum secundatum* (buffalo grass) and *Carpobrotus aequilaterus* (iceplant) dominate many sand dunes. These weed species invade dunes but, with the exception of *A. arenaria*, are not as effective at binding the sand as the native species *Spinifex sericeus* (silvery sand grass) and *Ficinia spiralis* (pingao). The relatively open nature of the cover of the native sand binding species readily enables invasion by alien species. In about 2012 the alien plant *Euphorbia paralias* (sea spurge) has naturalised at one known site on the west coast of the North Island in the Waikato region. As forewarned by Hilton (2001, 2003) this species has dispersed from Australia where it has rapidly invaded sand dunes along southern and eastern coastlines. The relevant agencies have responded with a control programme, including public communications and alerts, with the goal of eradication at this known site.

14.3.5 Lakes and Rivers

Few water bodies are free of introduced plants, although the abundance and impact of the IAPs varies between water bodies. Freshwater bodies on Stewart Island and the New Zealand sub-Antarctic Islands are not known to contain any IAPs.

The predominant introduced alien plants in lakes and low-gradient rivers are *Elodea canadensis* (Canadian pondweed), *Egeria densa* (egeria), *Lagarosiphon major* (Lagarosiphon), *Hydrilla verticillata* (Hydrilla) and *Ceratophyllum demersum* (hornwort). These species are spread by vegetative fragments, which is an important consideration when attempting to reduce their spread through public education. As many lakes on the South Island's West Coast, including Fiordland, have not yet been invaded by many aquatic IAPs, precautionary sanitation measures between water bodies are essential to prevent alien plant spread into unaffected lakes.

Perhaps the most widely known invasive alien species that has impacted New Zealand's freshwater resources and values is *Didymosphenia geminata* (didymo). This diatomaceous alga, descriptively named 'rock snot' and capable of producing substantive algal blooms, was discovered in the South Island in 2004 and has spread widely throughout the Island (Ministry for Primary Industries 2012). An intensive publicity campaign ('Check, Clean, and Dry' between waterways) has helped restrict its spread in the South Island, and so far it is not known to have spread to the North Island or Stewart Island.

14.3.6 Marine Coastlines

A number of marine alga species have been introduced to New Zealand via international shipping, usually in ballast water. Most are not invasive but *Undaria pinnatifida* (wakame), first recorded as naturalised in 1987 in Wellington Harbour, strongly modifies rocky sub-tidal and intertidal communities (Russell et al. 2008). This species has spread rapidly, primarily via coastal shipping and subsequently by natural dispersal from all foci. Eradication has been successful in one location to date (a fouled vessel that ran aground in the Chatham Islands, Wotton et al. 2004), and is currently underway in Dusky Sound, Fiordland.

14.4 Case Studies

We present two case studies of IAP control on New Zealand islands, and a third case study from the mainland. These regions are undergoing extensive IAP management because of their intrinsic natural values, including endemic species and landscape features, and the likelihood that sustained intervention would succeed in maintaining or improving the conservation values. Further, the islands selected are mostly free of mammalian pests, resulting in the IAPs being the primary inhibiting factor to achieving ecological integrity.

14.4.1 Case Study 1: Raoul Island: Rangitahua

Raoul Island is the largest island in the Kermadec Group and constitutes the northernmost region of New Zealand, lying about 1,000 km north-east of Auckland city; it is the only subtropical environment in New Zealand. The island, 2,943 ha in extent and rising to 516 m a.s.l., is the rugged, emergent summit of a large, active volcano.

Raoul Island is forested, with beach strand and rocky headland plant communities and a central, volcanically active crater. The dominant species are the hardwood *Metrosideros kermadecensis* (Kermadec pohutukawa) and *Rhopalostylis baueriana* (Kermadec nikau palm) with associated, primarily endemic, subcanopy trees and shrubs (e.g. *Myrsine kermadecensis*, Kermadec mapou; *Coprosma acutifolia*; *Homalanthus polyandrus,* Kermadec poplar; *Cyathea kermadecensis,* Kermadec tree fern and *C. milnei,* Milne's tree fern) (Sykes et al. 2000).

A high degree of natural disturbance is normal for Raoul Island, and the vegetation has evolved in response. Until the early twentieth century, Raoul Island was home to immense numbers of burrowing wedge-tailed shearwaters (*Puffinus pacificus*) as well as thousands of sooty terns (*Onychoprion fuscatus*) and many other seabirds of tropical and subtropical distribution (Gaskin 2011; Veitch et al. 2011b). Cyclones are frequent and the island occasionally experiences more than one during the cyclone season (December to March). Extensive patches of forest are blown down and coastal vegetation is defoliated by salt-spray. In addition, volcanic eruptions have been intermittent, the most recent being in 2006 (West 2011). Forest within the blast zone is felled or defoliated and may be buried in ejecta (pers. obs.). Even though the native vegetation is adapted to recover from these disturbances, many of the IAPs on the island also benefit.

Multiple human-derived disturbances originated with Polynesian voyagers about 960 AD (Anderson 1980), who introduced Pacific rats/kiore (*Rattus exulans*) and plants (e.g. *Aleurites moluccana*, candlenut; *Colocasia esculenta*, taro and *Cordyline fruticosa*, ti pore). This continued with European explorers and whalers in the late 1700s to early 1800s who introduced goats (*Capra hircus*), pigs (*Sus scrofa*) and possibly cats (*Felis catus*) (West 2002). The island was then settled intermittently by Europeans from 1836 to 1914 and the number of introduced plant species quickly exceeded the native plant species, many of which are endemic (Sykes et al. 2000). In 1934, Raoul Island was gazetted as a Flora and Fauna Reserve and subsequently transferred to nature reserve status under the Reserves Act 1977. A meteorological station was staffed from 1937 to about 1992 when occupation passed to DOC, as the primary work on the island was IAP eradication (West 2002). An eradication programme was started in 1972 by the Department of Lands and Survey.

Like most outlying islands of New Zealand, Raoul Island is a priority for the restoration of ecosystems and threatened species. The target for restoration is that Raoul Island once again becomes a seabird-dominated island, specifically, to "restore the Raoul Island ecosystem to a high level of ecological integrity by assisting its recovery from multiple disturbances" (unpublished Draft Kermadec Islands Restoration Plan 2009–2019). Following the successful eradication of all introduced mammals (Broome 2009), preventative biosecurity measures and IAP eradication are the key focus for management.

14.4.1.1 Raoul Island Restoration: The Story So Far

Raoul Island is free of all introduced mammals, with goats being eradicated in 1984 (Sykes and West 1996), and rats and cats eradicated in 2002 and 2004, respectively (Broome 2009). As a consequence seabirds are now returning to breed on Raoul Island and, each year, are recorded in greater numbers. Also, red-crowned parakeets (*Cyanoramphus novaezelandiae cyanurus*) and spotless crakes (*Porzana tabuensis*) have re-colonised from the nearby Meyer Islets and are plentiful (Gaskin 2011; Veitch et al. 2011b).

The response of the vegetation to mammal eradication has been similarly striking. After goats were eradicated canopy cover increased, resulting in a decline of light-demanding IAPs like *Alocasia brisbanensis*. Many preferentially browsed native species recovered, some from near extinction, e.g. *Veronica breviracemosa* (Kermadec koromiko; West and Havell 2011), and *Homalanthus polyandrus*, which is now widely distributed and relatively common. There was no noticeable increase of IAP species, which is attributed to the lower light levels within the forest and the effectiveness of the IAP eradication programme. Also the IAPs targeted for eradication appear to have been unpalatable as they were not recorded in the diet of goats on Raoul Island (Parkes 1984).

Eradication of rats enabled greater recruitment of many native plant species, as it did for a number of IAPs. Indeed, many IAPs that did not fruit in the presence of rats began to fruit and recruit seedlings for the first time, e.g. *Hibiscus tiliaceus* (fou), *Catharanthus roseus* (rosy periwinkle) and *Bryophyllum pinnatum* (airplant; West and Havell 2011). However, this outcome was anticipated and *Vitis vinifera* (grape), the species most likely to spread, was targeted for eradication before the rat eradication was undertaken (West 2011). Understanding species interactions such as this has contributed to an efficient IAP eradication programme.

14.4.1.2 Invasive Alien Plant Species: Eradication Successes and Remaining Challenges

The eradication programme for the range of IAPs on Raoul Island was described by West (1996) and progress in achieving eradication was subsequently reported (West 2002). With the eradication of rats in 2002 shown to be a significant factor in recovery of native sea and land birds on Raoul Island, eradication of IAPs is now essential for complete ecosystem restoration (West 1996, 2002). To date 11 IAPs have been eradicated (Table 14.1). For some of the historic species (listed in Table 14.1), some adult specimens are retained (the original planted individuals or, in the case of *Aleurites moluccana*, their adult offspring), but the progeny are eradicated or controlled to zero-density. *Aleurites moluccana* and *Araucaria heterophylla* (Norfolk pine) seed freely and seedlings are common but easily located and removed, and time to maturity is several years. Mature *A. heterophylla* specimens are now confined to a small grove within a historic site on the northern terraces. *Aleurites moluccana* has no dispersers and the large seeds fall beneath the parent plants which are relatively localised at easily managed and confined sites. *Araucaria heterophylla*, on the other hand is wind-dispersed from tall, historic individuals but the seed shadow distance is known and predictable. *Ficus cairica* (fig), although it fruits prolifically now that rats have been eradicated, has no pollinator present so there is no viable seed production and control is limited to removing vegetative spread. *Phoenix dactylifera* (date) is dioecious with one gender assumed to be present and no fruit has ever been observed on the mature palms despite the absence of rats (West 2011). The few plants removed since 1995 are likely to have grown from discarded date stones as they were located by the roadside.

Determining when a plant species has been eradicated is difficult for two reasons. First, plants can be very difficult to detect and, in a forested environment such as on Raoul Island where the transformer IAPs are vines, trees and shrubs, the IAPs blend in well with the native species. *Olea europaea* subsp. *cuspidata* (African olive) is an example of such a species, and therefore how attenuated the eradication time can be. In the last nine years only seven individuals have been

Table 14.1 Species listed in the Raoul Island alien plant database, indicating when eradication began, the last time a species was recorded (and removed) and whether they might have been eradicated

Species	Common name	Family	Eradication began	Last record	Eradicated?
**Aleurites moluccana*	candlenut	Euphorbiaceae	1993	2013	No
Anredera cordifolia	Madeira vine	Basellaceae	1995	2013	No
**Araucaria heterophylla*	Norfolk pine	Araucariaceae	1974	2013	No
Bryophyllum pinnatum	airplant	Crassulaceae	1998	2013	No
Caesalpinia decapetala	Mysore thorn	Fabaceae	1974	2013	No
Cortaderia selloana	pampas grass	Poaceae	1984	1993	Yes
**Ficus cairica*	fig	Moraceae	1996	2012	No
Ficus macrophylla	Moreton Bay fig	Moraceae	1996	1999	Yes
Foeniculum vulgare	fennel	Apiaceae	1969	1999	Yes
Furcraea foetida	Mauritius hemp	Asparagaceae	1974	2002	Yes
Gomphocarpus fruticosus	swan plant	Asclepiadaceae	1979	2002	Yes
Macadamia tetraphylla	macadamia	Proteaceae	1996	2003	Yes
Olea europaea subsp. *cuspidata*	African olive	Oleaceae	1973	2011	No
Passiflora edulis	black passion fruit	Passifloraceae	1980	2013	No
**Phoenix dactylifera*	date palm	Arecaceae	1995	1999	Yes
Phyllostachys aurea	bamboo	Poaceae	1996	2001	Yes
Populus nigra	poplar	Salicaceae	1995	2003	Yes
Prunus persica	peach	Rosaceae	1994	2013	No
Psidium cattleianum	purple guava	Myrtaceae	1973	2013	No
Psidium guajava	yellow guava	Myrtaceae	1972	2013	No
Ricinus communis	castor oil plant	Euphorbiaceae	1990	2012	No
Selaginella kraussiana	selaginella	Selaginellaceae	1998	2013	No
Senecio jacobaea	ragwort	Asteraceae	1980	1980	Yes
Senna septemtrionalis	Brazilian buttercup	Fabaceae	1978	2013	No
Tropaeolum majus	nasturtium	Tropaeolaceae	1999	2013	No
Urochloa mutica	para grass	Poaceae	1996	2009	No
Vicia sativa	vetch	Fabaceae	1996	2013	No
Vitex lucens	puriri	Verbenaceae	1997	1997	Yes
Vitis vinifera	grape	Vitaceae	1995	2012	No

* indicates species that have some mature plants retained because of their historic significance but all progeny are removed

found (just one mature plant), whereas 700 mature trees were removed from one location in a single year in an earlier phase of the eradication programme (West 1996). Second, the longevity of the seed bank for all species is unknown and can only be inferred from data from other members of the same families or genera, acknowledging that there is substantial inter- and intra-specific variability in recorded longevity (Thompson et al. 1997). In evaluating progress toward environmental weed eradication in New Zealand, Howell (2012) suggests that infestations should be checked annually for at least 3 years after the last plant has been removed and that this time frame should be significantly longer for species with long-lived seed banks. Data from Raoul Island indicate that 3 years is insufficient for some species as suckers may develop after that time from large individuals, e.g. *Vitis vinifera*, or individuals may persist in a seedling bank, e.g. *A. heterophylla* seedlings found more than 6 years after parent trees were felled (D Havell pers. comm.).

All seven species that were tentatively described as eradicated in 2002 (West 2002) are confirmed to be eradicated (Table 14.1) as no individuals have been detected for at least 10 years. In addition, a further four species (*Furcraea foetida*, Mauritius hemp; *Gomphocarpus fruticosus*, swan plant; *Phoenix dactylifera* and *Phyllostachys aurea*, walking stick bamboo) are also now confirmed as eradicated.

For seven of the targeted species still present on Raoul Island the challenges for eradication are based primarily on their biology, but also on the difficulty of accessing the terrain (West 2002). For *Senna septemtrionalis* (Brazilian buttercup) and *Caesalpinia decapetala* (Mysore thorn) the persistent seed bank (possibly decades, Thompson et al. 1997) is the largest problem, though the highly disturbed environment on Raoul Island is potentially an advantage, in that soil movement can bring seed to the surface and increased light at ground level induces germination. A large population of *S. septemtrionalis* was detected during aerial surveillance (May 2009), with approximately 1,500 mature individuals, 4,500 adolescents and tens of thousands of seedlings. The spread was however limited by dense stands of *Imperata cheesemanii* (imperata), an endemic grass (C Ardell pers. comm.). The detection of this infestation further proves the value of aerial surveillance whenever it can be achieved.

The challenges to eradicating *Anredera cordifolia* (Madeira vine) are the herbicide-resistant tubers and the terrain (the main population is situated at the top of 50 m bluffs above the sea). In 2003 more than 3.5 tonnes of tubers were removed and since then some sites have remained free of plants after multiple surveys. However, new populations are occasionally discovered downhill of known sites. A total of almost 17 tonnes of tubers has been removed since 1999, with a total of over 5,000 h of effort. It was hypothesised that this infestation arose via sea dispersal of tubers from the original plant dumped in Bell's Ravine (West 1996). Therefore, a goal of this programme is to avoid tubers falling into the sea to minimise the risk of distant infestations establishing, as experiments have shown that some *A. cordifolia* tubers will float for at least 30 days in fresh water (Vivian-Smith et al. 2007).

It is often possible to anticipate a species' behaviour based on biological traits, however, *Prunus persica* (peach) proved an exception. This species generally requires considerable winter chilling for strong foliage growth and fruit crops (Lyle 2006) and it is likely that chilling would be required to break seed dormancy (Martínez-Gómez and Dicenta 2001). However, the climate on Raoul Island is humid and warm temperate, substantially different from the optimal conditions described for cultivation. Therefore, it was anticipated that seeds would rot and

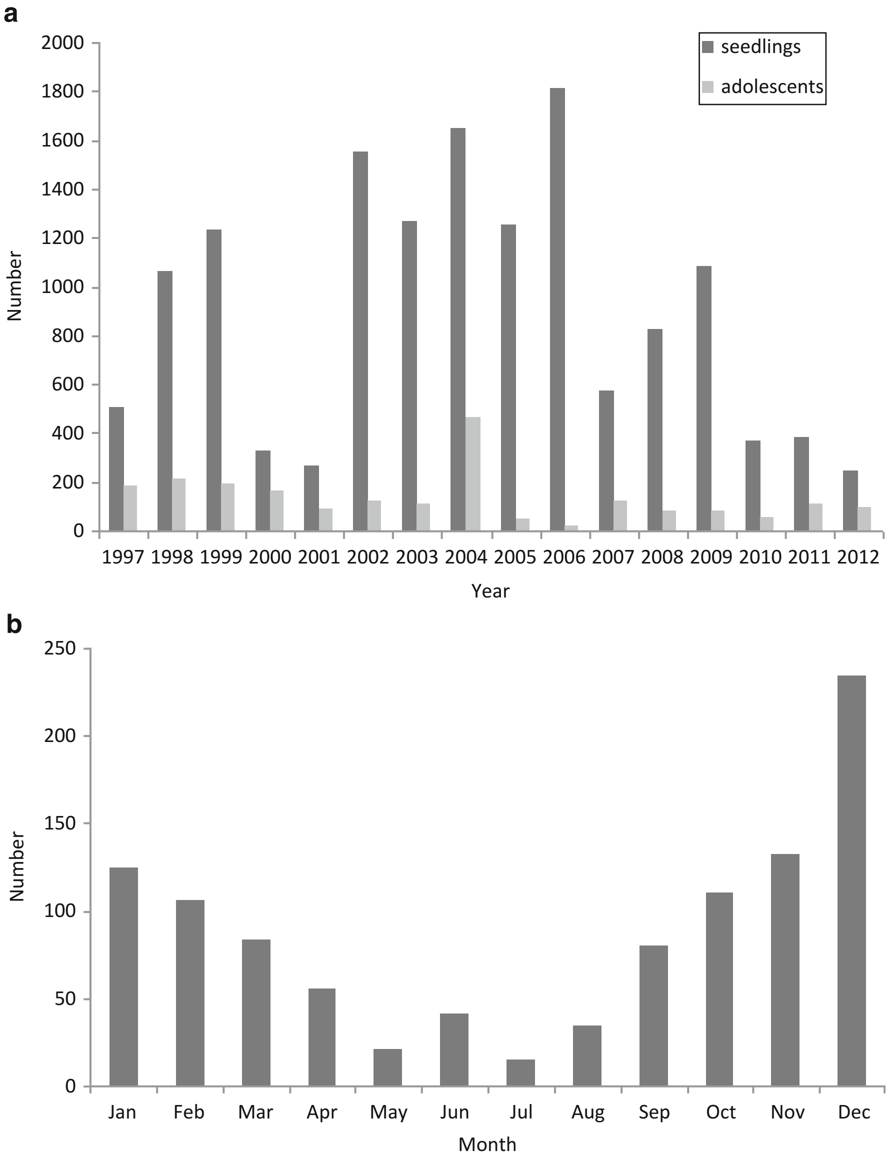

Fig. 14.1 (**a**) *Prunus persica* seedlings and adolescents removed from Raoul Island (**b**) The average number of *P. persica* seedlings on Raoul Island removed each month (1997–2008)

viability rapidly reduce. Despite this, *P. persica* naturalised away from planted individuals, most likely to have been inadvertently spread by staff on the island. Because of the amount of naturalisation and the tendency for felled, poisoned trees to resprout, *P. persica* was added to the eradication programme in 1994.

Approximately 300 mature trees were felled in the first 4 years (since 1994) and about 30 have been detected since. The longevity of seeds was unexpected, and seedlings are still germinating more than 12 years after the adult trees were removed (Fig. 14.1a).

It would appear that *P. persica* on Raoul Island has physiological seed dormancy (sensu Finch-Savage and Leubner-Metzger 2006) and that the difference between winter and summer temperatures is sufficient to break seed dormancy for a proportion of the seed bank each year. Some seedlings are recorded during winter months, although the majority are found in spring and summer (Fig. 14.1b). Spraying gibberellic acid on the ground in the infested sites could potentially break the seed dormancy and extinguish the seed bank more quickly. However, although there are many laboratory tests that demonstrate the effectiveness of gibberellic acid at breaking seed dormancy (e.g. Evans et al. 1996), it appears that this technique has not been used in the field.

The reason that *P. persica* behaved differently than expected is most likely because, with the possible exception of *Vicia sativa* (vetch) and *Foeniculum vulgare* (fennel), it is the only species targeted for eradication (see Table 14.1) that produces physiologically dormant seeds. All others, if they seed on Raoul Island, would appear to have non-dormant seed that may or may not form a seed bank.

The highly disturbed environment on Raoul Island presents challenges as well as the potential advantages described above. After the 2006 eruption, in which a staff member was killed, staff were not permitted to enter the crater (for safety reasons) for more than two years. This meant that several target species were able to reproduce in the crater and add new seeds to the seed bank (e.g. *Passiflora edulis*, black passion fruit; *Psidium cattleianum*, purple guava and *Senna septemtrionalis*). Cyclones that cause widespread but patchy treefall and intense rainfall events that create slips make access more difficult and result in time being spent on clearing tracks and roadways and slow the rate of progress when grid-searching in weed plots. The frequency of these events is very variable but can reduce weeding time significantly in some years.

14.4.2 Case Study 2: The Hen (Taranga) and Chicken (Marotere) Islands

Taranga and the Marotere Islands were originally settled by the indigenous Ngātiwai people but were named the Hen and Chicken Islands by Captain James Cook, who sighted the island group in 1769. The group lies approximately 12 km east of the Bream Head Scenic Reserve on the east coast of Northland, at latitude 35°S. The islands vary in size, from 2–3 to 489 ha, with a range of native vegetation across the lands, emerging from eroded volcanic remnants. The islands were designated as a scenic reserve in 1925, prior to becoming a nature reserve in

1977. Before protection of these islands was implemented, various, but not extensive, human activities ensued, including the gathering of seabirds and *Phormium* spp. (New Zealand flax) and the brief introduction of cattle to Mauimua (Towns and Parrish 2003). Mauipae (Coppermine Island) underwent several attempts at mining despite its protected status (Moore 1984).

There has been a long history of scientific interest in the islands, from the late nineteenth century when noted botanists Kirk and Cheeseman visited, followed by Cockayne and numerous others (Atkinson 1973), resulting in a wide range of records for flora and fauna. Many plant and animal species exist on these islands that are rare or absent on the mainland. Special fauna include the endemic ancient reptile the tuatara (*Sphenodon punctatus)*, various lizards (*Oligosoma townsi, Oligosoma ornatum)* and birds such as saddleback (*Philesturnus carunculatus)* and kākā (*Nestor meridionalis*). Numerous endemic plants are found on these islands, many of which are rare, declining, or at risk. These range from annual and perennial herbs such as *Euphorbia glauca* (shore spurge), *Lepidium oleraceum* (Cook's scurvy grass) and *Rorippa divaricata* (New Zealand water cress), to coastal shrubs like *Senecio scaberulus* (fireweed) and trees including *Meryta sinclairii* (puka) and *Streblus banksii* (turepo).

Hen Island (Taranga) is the largest of the group (489 ha), with a steep coastline giving way to undulating valleys. Vegetation varies from *Kunzea ericioides* (känuka) shrubland and *Beilschmiedia tarairi* (taraire) and *B. tawa* (tawa) forest, with 235 native and 43 adventive species recorded in 1978 (Wright 1978). The three main Chicken Islands are Lady Alice (Mauimua, 151 ha), Middle Chicken (Whatupuke, 99 ha), and Coppermine (Mauipae, 77 ha). In 1984, 245 indigenous vascular plants and 73 introduced species were recorded (Cameron 1984). Since kiore were eradicated during the 1990s, the health of the native plant communities, particularly the fruiting species, is expected to improve (Towns and Parrish 2003).

14.4.2.1 A Partnership at Work

The Department of Conservation and the Ngātiwai Trust Board jointly manage these islands, guided by a 10-year restoration plan (Towns and Parrish 2003). This plan addresses all biodiversity aspects of the three largest islands. Significantly, Mauitaha and Araara Islands are managed as kiore refuges. Kiore were introduced by Māori approximately 800 years ago, and are regarded as a taonga, or treasure. Despite this, DOC and Ngātiwai worked together to successfully eradicate the kiore from Hen Island in 2011. Now, all but the two islands containing kiore are free of mammalian pests resulting in improved conservation outcomes for both the birds and the invertebrates.

14.4.2.2 Implementing the Management Plan

The islands have been ranked as a priority ecosystem under the DOC's Outcomes Model. In practice, this integrates the site-led weed programme into a holistic 'prescription' that aims to mitigate all threats to the islands as well as using best practice species management techniques.

One of the goals of the 2003 restoration plan is to eradicate or control plant and animal pests that have the potential to compromise other restoration goals (Towns and Parrish 2003). To support this goal a Weed Strategy and Operational Plan was developed to identify the priority IAPs and their management objectives, as well as the operational methodology for the islands (M. Valdes pers. comm.) The IAPs include several escaped ornamental garden plants, as well as plants derived of seed from wind and bird dispersal from the mainland.

Three classes of IAPs (Classes 1, 2 and 3) were determined based on the invasiveness of the plant and their likely competition with desirable plants (Table 14.2).

Class 1: IAPs that have the potential to spread quickly and result in the highest impact on the surrounding ecosystems. The objective of these for Hen Island is sustained control by 2018, i.e. limiting each species to its present distribution and, where possible, reducing the abundance of the species (M. Valdes pers. comm.). For the Chicken Islands, eradication is the objective.

Class 2: IAPs in Class 2 represent the next level of invasiveness and impact after Class 1 IAPs. The objective for these is eradication from all of the islands.

Class 3: IAPs that have been judged to have less of an environmental impact, although their spread may be rapid. The objective of Class 3 IAPs is also eradication from all of the islands.

The known IAP sites are displayed on a map and GPS unit, so the sites can be easily found and thoroughly searched. This is especially important as the terrain is difficult to work on, with some cliff sites accessed by abseiling (Fig. 14.2). Management is by hand, in order to limit collateral damage to desirable plants and landscapes. Seed heads are bagged and removed from the island (M. Valdes pers. comm.).

14.4.2.3 Assessing Progress to Date

In the 20 years since IAP management was strategically considered and resourced, progress has been achieved in the management objectives. This success has been analysed using the Total Count method (Holloran 2006). Individuals are counted when they are removed/killed and recorded in one of three size classes: seedlings, adolescents and matures. Progress towards eradication is

Table 14.2 The Hen and Chicken Islands: Priority invasive alien plants are classified according to their environmental impact and management objective. Class 1 are the most environmentally damaging

Class 1	Class 2	Class 3
Hen: Sustained control	Hen: Eradication	Hen: Eradication
Chicken: Eradication	Chicken: Eradication	Chicken: Eradication
Ageratina adenophora	*Lycium ferocissimum*	*Cirsium* spp.
Ageratina riparia	*Asparagus asparagoides*	*Phytolacca octandra*
Araujia hortorum	*Senecio elegans*	*Senecio cineraria*
Cortaderia jubata	*Physalis peruviana*	*Senecio bipinnatisectus*
Cortaderia selloana	*Pennisetum clandestinum*	*Cannabis* sp.
	Paraserianthes lophantha	
	Erigeron karvinskianus	
	Myosotis sylvatica	
	Gladiolus spp.	
	Senecio jacobaea	
	Hakea sericea	

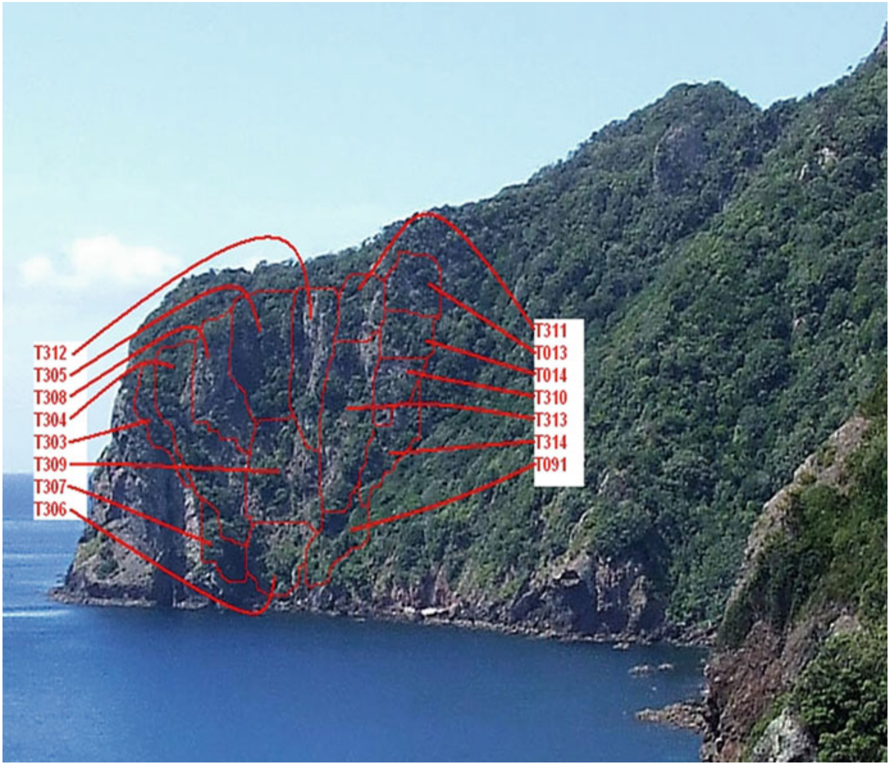

Fig. 14.2 Sites invaded primarily by *Ageratina adenophora*, accessed from the 'Don't be silly' track on Taranga. Each site measures between 15 and 150 m^2 (Photo Toby Shanley, Department of Conservation)

shown as a reduced number in each size-class or a reduced number of adults or juveniles over time.

On Hen Island, which has the most challenging terrain of the islands, there have been intensive search efforts in recent years, with a focus on large, active, or difficult IAP sites (Shanley 2010). *Araujia hortorum* (moth plant), with its tuberous roots, and shade tolerant seedlings wind-blown seed poses a particular challenge. There are nine existing sites, eight of which are located on the windward western side of the island. The ninth site on the eastern side is reportedly clear of the plants. Since the early 2000s, the number counted has steadily decreased, but the numbers of adults did increase as a result of intensive searching and control on a particularly steep site.

The results of *Ageratina adenophora* (Mexican devil) control have been less consistent, with a large number of adult plants removed in 2009–2010. Records show that 17 new or rediscovered plant sites required control. These sites appear to have been neglected due to their inaccessibility, and point to the need to have appropriately trained and competent staff on the island (Shanley 2010). The combination of the high seed production of the Asteraceae, and the rapid growth of *A. adenophora* seedlings, means that this short-lived, historical lack of control at certain sites is likely to have increased the work required over time to achieve sustained control on the island. Similarly, *Ageratina riparia* (mist flower) is presently known at two sites on Hen Island. However, one site has needed repetitive work due to inadequate previous management.

Currently there are approximately 100 sites with records of *Cortaderia* spp. (pampas), although some sites are found to be clean when examined, and there are increasing numbers of archived sites. To counter the ability of *Cortaderia* spp. to colonise cliffs, detection and surveillance of new plants is achieved by using a boat to patrol the coast.

The objective for the class 1 IAPs is sustained control, and this appears to be succeeding for four of the five species. Both *Araujia hortorum* and *A. riparia* plant numbers show general trends and numbers of *Cortaderia* spp. tally at dozens, with some sites now reported as clear of this species. However, *A. adenophora* numbers have increased markedly in the last few years (Unpublished data, DOC 2012).

There are some likely near-eradications for two species from class 2 (*Physalis peruviana*, Cape gooseberry and *Hakea sericea*, prickly hakea), and one eradication of a class 3 species, *Cannabis* (marijuana). For *P. peruviana*, all known sites were found clean in 2012. No *H. sericea* has been recorded on Hen Island since 2009, and no *Cannabis* plants have been found since 1997 (unpublished data, DOC 2012). These three IAPs all produce abundant amounts of seed, but the factor that is likely to have helped these potential eradications succeed is the very limited distribution that the plants seem to have had. Both *Cannabis* and *H. sericea* had been recorded at single sites, and *P. peruviana* was recorded at only three sites (unpublished data, DOC 2012). Further, hygiene on the island preventing seed spread has been vital, as have the strict biosecurity procedures that are part of any excursion to the islands.

The Chicken islands have had less consistent weeding efforts but overall have more invasive plant sites than Hen Island. However, similar progress appears to be occurring, with some sites on these islands also found to be clean of previously recorded IAPs, including *Araujia hortorum, Pennisetum clandestinum* (kikuyu grass) and *Gladiolus* spp. (gladiolus) on Lady Alice and *A. riparia* on Coppermine (Shanley 2010).

14.4.3 Case Study 3: Fiordland National Park

Fiordland National Park (FNP), gazetted in 1952, is New Zealand's largest national park (1,260,740 ha) and is part of the Te Wahi Pounamu South-West New Zealand World Heritage Area designated in 1990 (Fig. 14.3). The Park is mountainous and the myriad U-shaped valleys reveal past glaciation from the Pleistocene era. Forests dominate the slopes to treeline (800–1,000 m a.s.l.), with shrubland, tussock grassland and permanent snow above. Inland valleys have tussock grass flats. Very little of the original vegetation has been cleared although it is subject to high rates of disturbance through tectonic activity and heavy precipitation (rain and snow). Fiordland National Park lies in the belt of Southern Hemisphere westerly winds known as the 'Roaring 40s', so the combination of strong, moist, onshore winds and steep topography leads to the high rainfall. There are just three roads in FNP (Fig. 14.3). Access to the park is by road, water (sea, lakes and rivers) and air (helicopters and light aircraft).

14.4.3.1 Documentation of Alien Plant Invasion

The major impact on biodiversity in FNP is due to the establishment of alien mammal species, and IAPs, though the invasion of IAPs has been slower. Red deer (*Cervus elaphus*), stoats (*Mustela erminea*) and rodents (*Rattus* spp. and *Mus musculus*) occur throughout the park. Australian brush-tail possums (*Trichosurus vulpecula*) have become abundant in the drier and warmer eastern and northern parts of the park. Stoats are the main driver behind the reduced populations of many seed-dispersing native bird species (Dilks et al. 2003). Pigs and chamois (*Rupicarpa rupicarpa*) are more confined in their distribution (DOC 2002) and goats have been eradicated (M. Willans pers. comm.).

Captain James Cook spent 6 weeks in Dusky Sound in 1773, and during that time created a vegetable garden (Thomson 1922), but by 1791 no traces of the vegetables could be found (McNab 1907). The first record of naturalised plants (sensu Richardson et al. 2000) comes from Poole (1951) who, from February to May 1949, recorded ten herbaceous species within the area bordered by George Sound and Caswell Sound. In 1962, Bryony Macmillan recorded four naturalised plant species at Deep Cove, Doubtful Sound (Given 1973). At Puysegur Point, the site of a lighthouse that was permanently staffed from 1879 until 1980, G.I. Collett recorded 37 naturalised plant

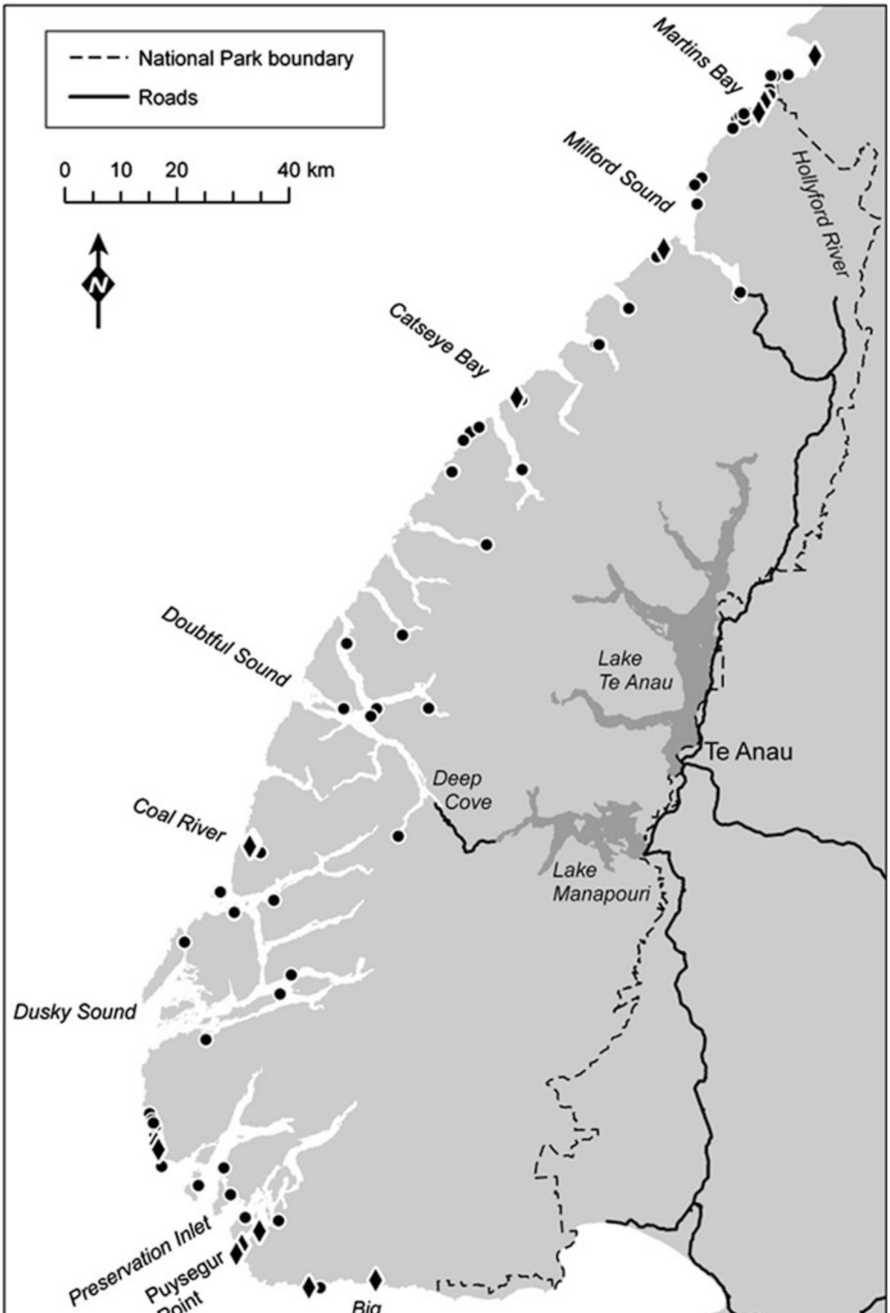

Fig. 14.3 Locations that *Ammophila arenaria* (*diamonds*) and *Ulex europaeus* (*dots*) have been recorded from in coastal Fiordland National Park

species in 1963 (Given 1973, Johnson 1982). In 1972, four naturalised plant species were recorded in Dusky Sound and Wet Jacket Arm (Given 1973).

The most comprehensive assessment of the distribution and abundance of naturalised plants was undertaken between 1969 and 1979 by Johnson (1982). Naturalised plants from 51 locations throughout FNP, from Martins Bay in the north to the Wairaurahiri River mouth in the south (as well as coastal areas to the north of the Park) were recorded. The number of species recorded at each site ranged from 1 to 71, and 136 species were recorded in total (Johnson 1982). Between 1996 and 2000, CJW resurveyed all 27 of the coastal sites surveyed by Johnson (1982). In addition all other areas where people may have come ashore, or where naturalised plants might be able to establish between Milford and Puysegur Point, were surveyed, totalling 99 sites. Johnson (1982) recorded a total of 100 naturalised species at the 27 coastal sites, whereas CJW recorded 93 species.

14.4.3.2 Alien Plant Management

Very few of the naturalised plants recorded in FNP are transformer species, but those that were identified are being actively managed. The top priority IAPs that are being controlled to zero-density include *A. arenaria*, *Crocosmia*×*crocosmiiflora* (montbretia), *Cytisus scoparius* (broom), *Rubus fruticosus* (blackberry), *Salix fragilis* (crack willow) and *Ulex europaeus* (gorse). Active surveillance occasionally detects other transformer species, which have required on-going eradication efforts, for example, *Calluna vulgaris* (common heather), and *Buddleia davidii* (buddleia, A Hay pers. comm.). The incursions of these two species represent long-distance transport by people, most likely tourists.

When Peter Johnson surveyed Fiordland coastal dunes in the mid-1970s, he recorded *A. arenaria* from eight locations from Martins Bay in the north (immediately south of Milford Sound) to Big River in the south (Johnson 1982). At that time this species was not being controlled but, at his suggestion, eradication was initiated. Approximately 20 years later *A. arenaria* was no longer present at Neck Cove but had established at Catseye Bay where it had not been recorded by Johnson (1982). Since then, *A. arenaria* has been found establishing at Neck Cove on two separate occasions, but has been controlled during annual surveillance (A Hay pers. comm.; Fig. 14.3). Some of the infestations of *A. arenaria* expanded substantially before eradication commenced and many of the locations can only be accessed readily by helicopter but this IAP is now at zero-density.

Crocosmia×*crocosmiiflora* is associated with human settlements and has not dispersed widely. It has probably been present since the lighthouse at Puysegur Point was built in the 1870s (Hall-Jones 1990). It is currently at zero density and active surveillance continues.

Cytisus scoparius has never been abundant in FNP, but small populations have been detected and controlled at several sites, possibly introduced with road gravel. Johnson (1982) recorded *C. scoparius* in nine locations and these are the places that are actively managed today. This species is at zero-density and subject to active searches of known locations as well as broader surveillance.

Rubus fruticosus agg. was recorded from four locations in coastal Fiordland: and also at Deep Cove in Doubtful Sound. The infestation at Deep Cove is likely to have arisen during the construction of the Manapouri power scheme and possibly after the road over the Wilmott Pass was built in the mid-1960s (Peat 1995) since it was not recorded in 1962 (Given 1973). The other locations are likely to date from the late 1800s. Some of the infestation sites are large and control is on-going.

Eradication of *Salix fragilis* has been achieved in coastal Fiordland. This species was known only from Cromarty, the site of a town that sprang up in 1892 to support a gold rush in Preservation Inlet (Hall-Jones 1990). However, in eastern Fiordland National Park, *S. fragilis* is being controlled to zero-density. Active surveillance is required because this species is well-established immediately adjacent to the east of the National Park in a stream flowing through private land that flows into the Eglinton River and thence into Lake Te Anau. It is also along the Waiau River from the outlet of Lake Manapouri at Pearl Harbour because two major rivers lined with *S. fragilis* enter from the east and lake-level manipulations as part of the hydro power generation scheme result in back eddies of water that contain stem fragments. Aside from this location on Lake Manapouri, *S. fragilis* has been controlled to zero-density elsewhere on the lake edge, a programme that was begun by National Park staff in the 1970s (Johnson 1982). Surveillance of the previously invaded areas as well as areas downstream within the National Park is undertaken regularly and any regeneration of this species, which only reproduces vegetatively in New Zealand, is controlled.

Ulex europaeus has established in a multitude of spots along the Fiordland coast (Fig. 14.3) but given that it is easy to detect when flowering and is a very well-known but not well liked plant by many, most people who encounter it in Fiordland pull it out or report the location to National Park staff so they can control the plants as soon as possible (Johnson 1982). Fishermen observing the bright yellow flowers from sea often report infestations to Park staff (pers. obs.). Johnson (1982) recorded 15 locations of *U. europaeus* within the National Park whereas CJW recorded 22 locations in her survey and was aware of additional sites. However, all known sites have been controlled to zero-density and any newly reported sites are added to the inventory of sites for annual helicopter-based surveillance and control. Every effort is made to kill *U. europaeus* before it has seeded for the first time as the seed is known to be viable for at least 40 years under normal seed bank conditions (Hill et al. 2001).

There are three other species that are controlled whenever they are detected within Fiordland National Park: *Berberis darwinii* (Darwin's barberry), *Hypericum androsaemum* (tutsan), and *Leycesteria formosa* (Himalayan honeysuckle). All three species are bird dispersed and have populations too large to control effectively outside the National Park, often on private land or public land not managed by DOC.

Berberis darwinii grew densely on the foreshore of Lake Manapouri in the township of Manapouri and for a number of years was controlled by a community "Weedbusters" group. Now this infestation is being managed by Southland District Council but it has given rise to new populations immediately adjacent to the

National Park that are not being controlled. Around Lake Te Anau all known incursions of *B. darwinii* are controlled. These are derived from a large population on private land east of the lake. This species was not recorded naturalised anywhere by Johnson (1982) and has invaded the eastern edge of Fiordland National Park from hedgerows and plants in private gardens within the last decade.

Hypericum androsaemum has entered the National Park as a garden escape through bird dispersal from Milford Sound village. The fruit-eating New Zealand pigeon (*Hemiphaga novaeseelandiae*) is a strong flier, well capable of flying the distances involved to spread the seed from Milford Sound to Anita Bay and Bligh Sound where it has been found (Powlesland et al. 2011). *Hypericum androsaemum* is widespread, though not abundant. However, given the rugged terrain of Fiordland and the ability of *H. androsaemum* to persist under a forest canopy (Johnson 1982), this species is controlled wherever it is found but is not actively searched for because birds can disperse it anywhere within forest over a vast area, making it very difficult to find.

Also invading from the east is *Leycesteria formosa*: it is relatively common on the eastern side of Lake Te Anau on private land and within the National Park is controlled whenever it is encountered.

14.4.3.3 Coping with the Current

All of the *Ulex europaeus* in FNP originates from the West Coast of the South Island, where it is abundant. The seeds do not float but the wood does (Johnson 1982) and when rivers on the West Coast are in flood entire plants can be uprooted and discharged to the sea where they are swept along by the Southland Current. If there are strong onshore winds along the Fiordland coast, surface water drift will transport the *U. europaeus* and other flood debris onto the rocky coast above the normal strand line or push debris into the fiords where, again, it will strand on downwind shores or in river deltas. The natural vegetation in these locations is typically low shrubland, often windshorn, which is ideal habitat for *U. europaeus*.

Ammophila arenaria is also dispersed to Fiordland from the West Coast on the Southland Current and was recorded by Johnson (1982) at Big Bay and Cascade Bay, both increasingly further north of FNP. It was apparently planted at Cascade Bay and is abundant on some beaches further north. Konlechner and Hilton (2009) have demonstrated that rhizome fragments of *A. arenaria* can be dispersed more than 600 km and remain viable in seawater for up to 70 days. This is ample time, given the rate of movement of the Southland Current and any associated wind-assisted surface movement (Stanton 1976) for *A. arenaria* to be dispersed to FNP from points north.

In order to reduce the rate of reinvasion of *A. arenaria*, Southland DOC staff (who manage FNP) requested West Coast DOC staff to eradicate *A. arenaria* from Cascade Bay since they were doing the same at Big Bay, north of the National Park. West Coast staff agreed and Cascade Bay is now free of *A. arenaria*. The ideal situation for Fiordland National Park regarding *U. europaeus* is that all rivers on the West Coast, south of latitude 42°S would have this species cleared from the maximum flood zone. This could be achieved via the West Coast Regional Council whose responsibility is to consider IAP management and then consult with the public about it.

Given the constant pressure of propagules (higher for *U. europaeus*, lower for *A. arenaria*) dispersing from the West Coast it is important that the surveillance and control programme for both species continues on an annual basis. After the eradication of *A. arenaria* commenced in the 1980s there was a significant lapse of commitment and populations at most locations expanded so that, in some cases, significant knock-down work was required to achieve zero-density. The effort to maintain zero-density status, however, is slight in comparison. Meanwhile, longer term strategies, as outlined above, can be implemented.

In addition to surveillance for these two known invaders from the West Coast we know that dispersal of *Euphorbia paralias* from Australia to FNP sand dunes is highly likely (see Sect. 14.3.4). This species will need to be included in the *A. arenaria* surveillance programme.

14.4.3.4 Contributors to Success

Sites or regions within FNP with the greatest and most prolonged human contact have more IAPs (Timmins and Williams 1991). Success has depended, firstly, upon having clear goals in relation to FNP as an iconic natural landscape and in recognition that the ecosystems and species within the park are of high value. Second, a collaborative approach with the communities and agencies who live and work alongside and in FNP, has allowed for early control of some species (e.g. fishermen reporting *Ulex europaeus*; Fiordland Marine Guardians prioritising biosecurity and supporting the eradication of *Undaria pinnatifida* from Dusky Sound: or minimised reinvasion (e.g. Manapouri Weedbusters controlling *Berberis darwinii*; West Coast DOC staff controlling *Ammophila arenaria* up-current). However, possums are still spreading uncontrolled within the park. The potential impact they could have in modifying the habitat to the advantage of IAPs, or if they are likely to disperse seeds that so far have not been dispersed by native and alien fauna within the park, is unknown. Part of the reason for the low invasion rates of IAPs in FNP is the intact forest cover, lack of roads and tracks, and the small number of huts. Possums will have an impact on this at canopy level whereas deer have been minimal promoters of IAPs in forest communities (CJW pers. obs.).

14.5 Invasive Alien Plant Management in New Zealand: Adapting to a Different World

The ecology of alien plants and on-the-ground experience has reinforced to weed managers that achieving successful control and eradication of IAPs is not easy or achievable in the short-term. In the past 25 years DOC has improved management techniques and knowledge, chastened by the length of time that has been required to eradicate some IAPs.

Despite New Zealand, like Australia, having one of the best border biosecurity systems in the world and very strong legislation internally, IAPs continue to arrive from overseas, e.g. *Euphorbia paralias*, or establish from cultivated plants (Esler 1988; Williams and Cameron 2006). The scale of the problem means that a strategic approach is essential, as is a stringent surveillance and monitoring regime that can be used to react to new introductions. Techniques need to be adaptable to the specific situation.

Eradicating IAPs or controlling them to zero-density is difficult and can be expensive, and most work shows that eradication is usually only effective when the population is very small (occupying <1 ha, Howell 2012). Innovative approaches are going to be needed if the control is to be successful, particularly with species that have rapid growth rates to maturity, persistent seed banks, bird dispersed seeds, and are hard to locate. In the case of Raoul Island, for example, it is particularly difficult to estimate the time it might take to achieve eradication of any species. A compromise in ecological integrity may need to be accepted, for example, where some IAPs are not eradicated in order to achieve the restoration of a seabird-driven ecosystem. Genetic markers could in future also be used to identify sources of invasion to then more effectively manage these sources or their pathways, as is done with some mammal control programmes (Russell et al. 2005).

From some of the mammal eradication work on islands (Veitch et al. 2011a), and changes in land use on the mainland, insight into how IAPs respond to the removal of invasive alien browsers and seed predators or dispersers is being improved. As invasive alien mammal eradication becomes a reality, the understanding of the biology and responses of IAPs to altered trophic relationships needs to be improved.

In tandem with the broader scale approach, the 'managing for outcomes' framework that DOC has developed (see Sect. 14.2.3) relies on 'prescriptions' that describe the management actions required to ensure ecosystem integrity and/or species persistence. Many of the actions require the control of IAPs to specific levels, and monitoring to understand the effectiveness of these actions, and whether the outcomes are being achieved. This presents further opportunities to understand trophic interactions and adapt management practices to achieve the desired outcomes.

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