1 · *Introduction*

Campuloclinium macrocephalum (or pom-pom weed) is a South American asteraceous herb that was probably introduced into South Africa in the 1950s as a garden ornamental. It was first recorded as a **naturalised weed** (see the glossary for this and other terms; terms in the glossary are indicated in bold on the first usage in the text) in the 1960s and was still present at low levels well into the 1990s. But over the past 20 years it has spread throughout the biodiverse grassland biome and beyond (see cover image). Every summer the fields between Pretoria and Johannesburg turn pink from the inflorescences of pom-pom weed. The plant creates near-monocultures, reducing biodiversity and the land available for subsistence grazing. Since 2008 there have been concerted efforts to clear populations and limit further spread. While this has, in places, reduced the abundance of some populations, there are no documented examples of even fairly small populations of 1–10 ha having been **extirpated**, and, given the rise in sightings, it is clear that the species has continued to spread in extent (Wilson *et al.* 2013).

The history of **plant invasions** abounds with such examples – the proverbial train-crash in slow motion. Over the last century pine invasions have covered many areas of New Zealand and South Africa, and similar invasions are now developing in South America (Richardson, van Wilgen, & Nunez 2008; Simberloff *et al.* 2010). Leafy spurge and salt cedars continue to spread across North America. The damaging effects of invasions by temperate acacias will likely be replicated in the tropics with a different cohort of invaders (Richardson, Le Roux, & Wilson 2015). The marine alga *Caulerpa taxifolia* was first detected in the Mediterranean in the 1980s, but no action was taken. It is now considered one of the world's worst invaders, known as the 'killer algae'. But in stark contrast to the situation in the Mediterranean, it took only 17 days from the first report of *C. taxifolia* in California until control measures were applied (Anderson 2005). The invasion has subsequently been declared eradicated (Simberloff 2009). In many cases relatively simple (though intensive) actions will limit future widespread consequences.

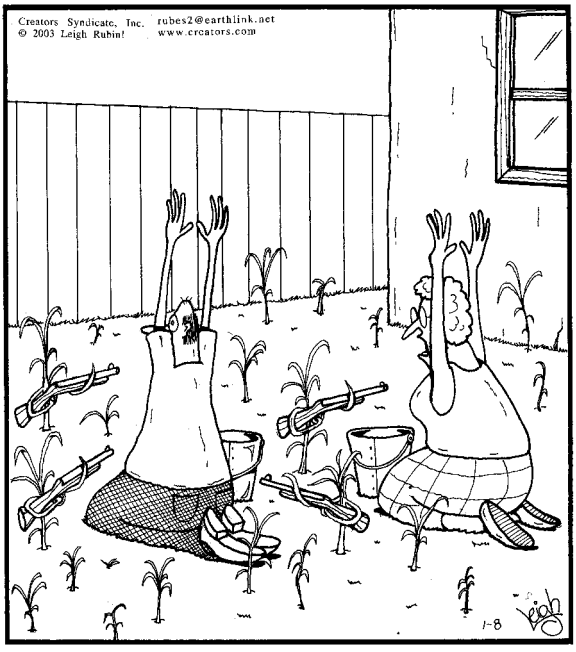

Figure 1.1. Invasive plant management has been reactive or preventative pre-border rather than proactive post-border. Reproduced with permission from Leigh Rubin and Creators Syndicate, Inc.

Plant invasions often start slowly. Sometimes a few individuals are introduced and so it takes time to build up numbers. Sometimes there are specific limiting factors, so population growth is initially slow (referred to as a lag phase). Often, there is a significant opportunity to mount an effective response. But ironically, the fact that there is time to respond can mean that nothing happens until **eradication** and **containment** are no longer feasible **management goals**, as plant invasions are often difficult and in some cases impossible to eradicate once established. The management of plant invasions is typically either reactive (an invasion is already well established, and the impacts unequivocal before action is taken) or preventative (applying measures that prevent an alien plant from entering a country or ecosystem). There has been much less effort to control invasive and potentially invasive plants after they have established but before

they get out of hand (what we term here as **incursion response**), not least because it is a challenge to secure the necessary funding and resources to respond to an incursion before there are large and palpable negative impacts.

From a management and policy perspective there has been a growth in interest in proactive management of plant invasions. More countries are developing **biosecurity** and **plant health** programmes that include detailed strategies on how to manage and reduce the impacts of invasive plants. Global agreements, for example the Convention on Biological Diversity and the International Plant Protection Convention, provide provisions and guidelines on how to address invasive plants, in many cases prior to arriving at a country's borders.

While proactive management is increasingly a focus of invasive plant programmes, it is still difficult to predict which invasions will happen where and when. We simply don't know. But what we do have is space-for-time substitutions. Incursions in one country or area can provide us with insights into what might happen elsewhere. For example, it is believed that the most robust predictor of whether a plant will become invasive is whether it is invasive in another region with a similar climate. For policy makers and land managers, responding to alien plants proactively is still, to a large extent, a matter of attempting to determine the highest-risk species, and then addressing these priority species based upon existing capacity and resources. Given that a number of potentially invasive plants might concurrently be undergoing transitions in status from casual to established, and from established to invasive, which plants should be targeted for coordinated management? This is a question that falls under the discipline of post-border weed risk management, which has been formalised as a protocol in order to foster further development of decision support models for **prioritising** species for management at different jurisdictional levels.

The ability to respond proactively has several challenges. A particular plant species (e.g. pom-pom weed) might never have been recorded as invasive anywhere else in the world and so there is no precedent for predicting impact. In such cases there will likely be low levels of awareness of the species among managers, and little information on how to respond. In other cases it might take decades before population-level processes lead to a widespread invasion; for the net impacts of an invasion to be substantially and demonstrably negative; and for societal views to change regarding the threat posed by a species (van Wilgen &

Richardson 2014). While this creates an opportunity for proactive management, potential deleterious impacts are often discounted or ignored as the costs are temporally and spatially far removed from the site of introduction. Finally, given that plants might be found across several administrative regions, it is not always clear who should champion proactive management efforts. One solution is to conduct a **risk analysis**. Potential problems are anticipated (risk identification), the likelihood and consequences of an invasion are predicted (**risk assessment**), and explicit management and regulatory measures are recommended (**risk management**). However, many authorities and jurisdictions do not have the capacity to conduct a risk analysis, which limits their ability to apply proactive management measures. Fortunately, there is a growing paradigm shift. Regulators, managers, and scientists are beginning to appreciate and act on invasive plant problems before they get out of hand – in many cases before they enter a country or ecosystem, by following the age-old adage, 'an ounce of prevention is worth a pound of cure'.

This book is about the theory and practice of responding to **alien plants** before they become widespread invaders. Would it have been possible to predict that pom-pom weed was going to invade the way it did in South Africa (Chapter 2)? Could it have been detected earlier through better **surveillance** (Chapter 3)? What should have been the national management goal (Chapter 4)? How could progress towards this goal have been measured (Chapter 5)? How could legislation and **regulation** best be used to facilitate pom-pom weed management (Chapter 6)? What **strategy** should have been taken, and what sort of **action plan** was needed (Chapter 7)? And finally, and perhaps most importantly, what organisational structures were needed for this to happen (Chapter 8)?

The general model of the invasion process has, in various forms, been well documented. For the purposes of this book we consider four stages of invasion (**pre-introduction**, **incursion**, **expansion**, and **dominance**), each linked to a specific **management goal** (**prevention**, eradication, containment, and **asset protection/impact reduction**). These specific management goals are often couched only in terms of single species (a species-based approach), but should also consider managing priority areas invaded by one or more species (an area-based approach), or managing the **pathways** that are responsible for the spread of alien species (a pathway-based approach) (Fig. 1.2).

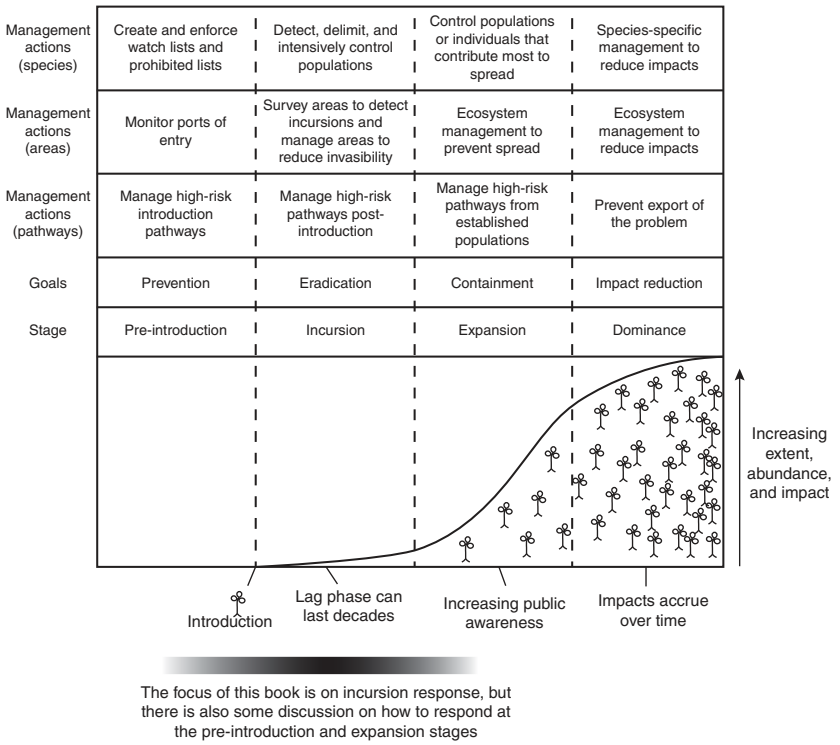

Figure 1.2. A conceptual framework for the management of biological invasions. There is a plethora of similar schemes that one could adopt, but we recommend that any scheme should be careful in separating the invasion stages from the overall management goal and the proposed actions. This framework is adapted from that used as the basis of South Africa's National Strategy for Biological Invasions (Box 7.1).

The focus of this book is therefore primarily on the incursion stage. Importantly, populations that are casual, naturalised, or invasive might all be incursions, but widespread invasions are not. However, whether a population is casual, naturalised, or invasive will affect the most appropriate incursion response (Table 1.1).

1.1 A Brief History of Incursion Response

There are some excellent examples of incursion response programmes that have reacted quickly and efficiently to new invasions well before

Table 1.1. *Recommended response to different categories of alien plants. The categories are as defined by Richardson* et al. *(2000b).*

Category	Definition	Response
Casual	Alien plants that might flourish and even reproduce occasionally in an area, but which do not form self-replacing populations, and which rely on repeated introductions for their persistence.	Monitor (look for evidence of naturalisation) Only consider further action if resources are available
Naturalised	Alien plants that reproduce consistently and sustain populations over many life cycles without direct intervention by humans (or in spite of human intervention); they often recruit offspring freely, usually close to adult plants, and do not necessarily invade natural, semi-natural, or human-made ecosystems.	Monitor (look for evidence of spread) Conduct risk analysis if invasive elsewhere and climate is suitable* Consider management feasibility and start implementation
Invasive	Naturalised plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants (approximate scales: >100 m in <50 years for taxa spreading by seeds and other propagules; >6 m in 3 years for taxa spreading by roots, rhizomes, stolons, or creeping stems), and thus have the potential to spread over a considerable area.	Conduct risk analysis Consider management feasibility and start implementation

* Climatic suitability (and other factors) should be considered over the entire jurisdiction potentially affected. Conditions might be marginal where the introduced plant is detected, but much more suitable elsewhere. Non-suitable local conditions should increase the feasibility of management, if an intervention is considered warranted.

there were large negative impacts. There are over 700 documented eradications of vertebrate species from islands (http://diise.islandconservation.org, accessed 13 May 2014), and an increasing number of successful campaigns against plants (though not as systematically documented). One country that arguably has been leading efforts at incursion responses against plants is New Zealand (Box 1.1).

Box 1.1 *Incursion Response in New Zealand (Philip E. Hulme)*

In New Zealand, over half of the entire flora is composed of naturalised alien plants, and this level of invasion has considerable economic and ecological consequences (Hulme 2014). For example, invasive plants threaten one-third of all of New Zealand's nationally threatened plant species and estimates suggest that, without action, invasive plants would degrade the conservation estate, corresponding to a loss of native biodiversity equivalent to NZD 1.3 billion. The costs to the productive sector are easier to quantify and, not surprisingly, much higher, as is the case for the pastoral sector, where the aggregate annual cost of invasive plants has been estimated to be around NZD 1.4 billion. Many of the most problematic plant species in New Zealand became established in the nineteenth century, soon after European settlement, and are now sufficiently widespread that eradication is no longer viewed as an option. Nevertheless, for species that are less widespread, the National Interest Pest Response programme established in 2006 aims to eradicate selected established invasive plants from New Zealand. Species were selected for national response because of their potential to have a significant impact on economic, environmental, social, and cultural values. The final selection of ten alien plant species (Box 1.1 Table 1) was the result of representatives from the Ministry of Primary Industries, Department of Conservation, and local government bodies undertaking a one-off prioritisation exercise that considered the technical, practical, cost–benefit, strategic, and acceptability aspects of each species. In most cases, the response entails intervention to eradicate the species from New Zealand, but in two cases this also includes containment to either the North or South Islands of New Zealand.

The strategy underpinning the National Interest Pest Response programme is to manage existing known sites where species are found, but also respond promptly to any newly discovered populations or new incursions. Eradication programmes involve continued management though the application of physical, chemical, or, in the case of *Hydrilla verticilata*, biological control (using grass carp) that aims to remove the target species until zero density is achieved. This is followed by surveillance at each site for several years, dependent on the likely size of the seed bank or risk of regeneration from rhizome fragments. The goals for both hornwort and Johnson grass have been achieved, and in both cases the programme has shifted to one of surveillance. Other species, such as white bryony and Cape tulip, have

Table 1. *Alien plants listed under New Zealand's National Interest Pest Response programme and the response goal*

Common name	Scientific name	Family	Goal
Salvinia	*Salvinia molesta*	Salviniaceae	Eradication
Water hyacinth	*Eichhornia crassipes*	Pontederiaceae	Eradication
Johnson grass	*Sorghum halepense*	Poaceae	Eradication
Cape tulip	*Moraea flaccida*	Iridaceae	Eradication
Pyp grass	*Ehrharta villosa*	Poaceae	Eradication
Phragmites	*Phragmites australis*	Poaceae	Eradication
Hydrilla	*Hydrilla verticillata*	Hydrocharitaceae	Eradication
White bryony	*Bryonia cretica* subsp. *dioica*	Cucurbitaceae	Eradication
Hornwort	*Ceratophyllum demersum*	Ceratophyllaceae	Eradication and exclusion from the South Island
Manchurian wild rice	*Zizania latifolia*	Poaceae	Eradication of isolated populations and containment of large populations on the North Island

been more challenging; seed longevity and dispersal of these species have hampered eradication. In the case of Manchurian wild rice, several sites targeted for eradication occur within production forests, and require ongoing, close liaison with the owners to ensure the pests are not spread as a result of forest management activities. Water hyacinth and salvinia have had the additional challenge that members of the public have been deliberately spreading these species. However, any new sites are contained to prevent the weeds spreading further and are treated with herbicide. Subsequently, the sites are inaccessible to the public until the complete eradication can be confirmed. It is hoped that for many species the goal will be achieved by 2021.

However, incursion response is not restricted to species listed in the National Interest Pest Response programme. New Zealand maintains a register of 'unwanted organisms' which are understood to be capable of causing harm to any natural and physical resources or human health. Although government has no obligation to act against an unwanted organism simply because it has that status, in certain cases an incursion of an unwanted organism results in an eradication campaign. Once an organism has been detected, an incursion response is initiated to stop

or restrict the spread of the organism, identify it, and define its distribution ('delimitation'), followed by an assessment of management options – including control or eradication. The following three examples highlight both the kinds of plant species recently targeted for eradication and the different approaches to managing the problem.

(1) Sea anemone passionflower (*Passiflora actinia*) is a potential threat to New Zealand's environment, with its ability to smother and shade the vegetation it grows on. It has been present at a former horticultural nursery since 1993, the only known population of this species in New Zealand. Initial treatment of the passionflower vines occurred in mid-2012. Over a two-year period, negotiations with the property owners resulted in an agreed cost share arrangement to eradicate the species and replace the shade house roof upon which many of the vines occurred. Eradication was declared in May 2014 and the surveillance operation continued until November that year.
(2) Blackgrass (*Alopecurus myosuroides*) is a serious weed that affects winter crops in Europe, resulting in yield loss, and could have an economic impact on New Zealand agriculture if it became established. Unfortunately, an estimated 2100 blackgrass seeds were spilt from a contaminated consignment of red fescue seed along a 40 km route in the South Island in 2013. An industry–government partnership was established to address this incursion, including media releases on national television. The operation included ten rounds of surveillance, three rounds of mowing, and targeted applications of a selective herbicide to high-risk sites along the entire 40 km route. It is proposed operations and surveillance will continue for three years but may be reviewed earlier if the risk is sufficiently reduced. The liable company admitted fault and has been active and supportive in the response process, fully funding the operational activity and providing the expertise to carry out the herbicide application. A check system for transport operators has been implemented to help ensure every load is secured appropriately before transport to prevent further spills.
(3) Sea spurge (*Euphorbia paralias*) is a European dune shrub that was introduced to Australia in ballast water and now forms dense stands in foredune and backdune habitats, threatening native biodiversity. The species is now widespread across the south coast, from Perth to Tasmania, and its ability to spread on ocean currents means

Ministry for Primary Industries
Manatū Ahu Matua

FACT SHEET ON SEA SPURGE

SEA SPURGE

A SERIOUS NEW THREAT TO NEW ZEALAND'S BEACHES

BACKGROUND

The beach weed sea spurge, *Euphorbia paralias*, has been found at a beach near Aotea Harbour in the Waikato. It may also be at other beaches. This invasive weed would seriously impact on our coastal environments if it became established.

Sea spurge infestations have caused major environmental problems at many Australian beaches by displacing native plants and changing natural patterns of sand movement.

It is likely to have arrived on ocean currents from Australia.

WHAT WE ARE DOING

The Ministry for Primary Industries, Department of Conservation and Waikato Regional Council have started control measures at the beach where sea spurge was found, and are also checking other beaches near Aotea Harbour.

HOW YOU CAN HELP

We need to find out if sea spurge is growing at other beaches, so let us know if you find any of the plants by calling the exotic pest line – 0800 80 99 66.

Please do not disturb the plants, as this could spread the seeds. Take a photo and note the location as accurately as possible – GPS coordinates are ideal. If you don't have a camera with you, take a sample of the plant without disturbing the seeds, and store in a sealed plastic bag in the fridge. Sea spurge has toxic sap, so be careful it doesn't get on your skin. The exotic pest line will tell you what to do with the plant sample.

WHAT TO LOOK OUT FOR

Sea spurge is a hardy European shrub that thrives in sand dunes. It has multiple stems that are often reddish at the base, and its spiky, tightly-packed blue/green leaves are 4-20mm long and 1-16mm wide. Green flowers bloom at the stem tips from September to May and the flower stems die off each year. The milky sap that oozes from broken stems is toxic to people and animals. The plants grow to about 1m tall in dense clusters.

Sea spurge is most likely to grow on sand dunes or around beach debris. Sea currents are likely to carry the seeds from Australia to northern beaches on the North and South Islands, as well as Southland and Stewart Island.

Sea spurge looks similar to the rare native shore spurge, *Euphorbia glauca*, and New Zealand linen flax, *Linum monogynum*. However, native shore spurge has much larger leaves that are 30-80mm long, while the stems of New Zealand linen flax are not reddish at the base and do not ooze milky sap when broken. The New Zealand Plant Conservation Network website has photos of all these plants.

Waikato Regional Council

MPI exotic pest and disease hotline
0800 80 99 66

Department of Conservation
Te Papa Atawbai

May 2012

New Zealand Government

Growing and Protecting New Zealand

Figure 1. A publicity fact sheet produced by the New Zealand government to improve passive detection and communicate management activities.

there is a risk it will reach New Zealand, where it could become a serious coastal environmental weed. Sea spurge was first detected in New Zealand in February 2012 and over the following two years an eradication programme was successfully completed. The