

Ecology and Control of Introduced Plants

JUDITH H. MYERS
DAWN BAZELY



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1 · *Introduction*

This book is about plants that have been introduced to new areas, usually new continents. It is about the attempts that have been made to characterize which introduced species will become serious weeds, about their impacts on native communities, and on how introduced weeds might be controlled. Studies of invasive plants have provided a rich literature in applied plant ecology. The invasion of plants into a new environment is an example of succession in action and an experiment on the role of species in communities. In the following chapters we bring together theory and application to focus on both what the study of introduced plants reveals about ecological processes and what ecological processes might be applied to management programs. We consider how community and population ecology can be brought to bear on the topic of invasive plants. Because many introduced plants become invasive and are considered to be weeds, we start here by defining weeds. Next, in this introductory chapter, we describe the socio-economic context surrounding introduced plants and introduce topics to be discussed in more detail in following chapters.

Weeds and the value of native species

Weeds are plants growing out of place or plants whose value has not yet been discovered. They have demanded the time, attention and resources of farmers, gardeners and proud homeowners for centuries. Despite being pulled, sprayed, cursed and competed with, in the long run the weeds always seem to come back. Weeds are plants that can grow at high population densities and can have a negative impact on other plants valued by humans. Many of the most dominant weeds in the world are those that have been introduced to new habitats, sometimes accidentally, but all too often intentionally, for what seemed to be a good idea at the time. The story of gorse in New Zealand is an example (Box 1.1). Colton and Alpert (1998) surveyed the public and found that while most were aware of what weeds are, few understood the ecological and economic

Box 1.1 · *Gorse in New Zealand, a country filled with invaders.*

Gorse, *Ulex europeaus*, currently a curse in New Zealand, was intentionally brought from England to be used for hedgerows. A farmer by the name of McLean was put in charge of spreading the gorse seeds to other landowners because he was considered to be responsible, and could be trusted to spread the seeds fairly among the farmers. Gorse hedgerows in New Zealand probably did keep sheep in their pastures, and might also have boosted the morale of homesick immigrants who remembered gorse from the British countryside. In hindsight, if McLean had realized that gorse would eventually escape from the hedgerows and come to dominate in many areas of the countryside (Hill *et al.* 2000), he as a responsible farmer would have refused to take part in the seed distribution.

Like many other plants that were transplanted to new countries without their natural enemies, gorse was able to outcompete the native vegetation. Introduced domestic herbivores such as cattle, sheep, and goats, are likely to have aided in this process. Gorse and grazing mammals had been interacting for generations in the Old World, and the spines on gorse make it unacceptable to most grazers. On the other hand, before sheep arrived in New Zealand, the vegetation had only to deal with browsing by moas (Aves: Dinorthithoformes), large, flightless birds, now extinct (Myers and Bazely 1991), and one or two smaller species of herbivorous birds. Therefore the introduced mammals are likely to have preferred the less well-defended, native plant species.

Since the European settlement of New Zealand, over 80 species of vertebrates have been introduced and have caused the extinctions of native plants and animals. However, the number of introduced mammals pales by comparison to the 1600+ species of plants that have been introduced. These have caused no known extinctions, but they have altered native ecosystems by outcompeting or smothering native species and altering successional pathways (Clout and Lowe 2000). The New Zealand Government today considers introduced species to be as much of a threat to national security as those that are normally considered in this category, such as invading armies of humans! While New Zealand has perhaps received more than its share of new plant species, this situation is not unique.

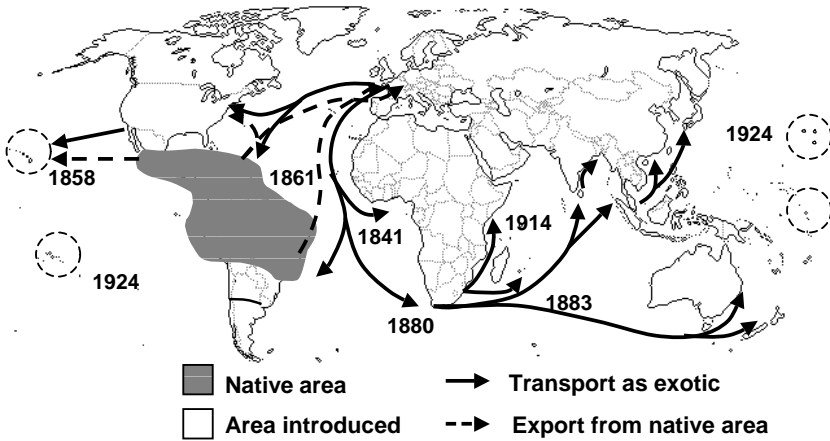


Figure 1.1. Map showing years of transport and introductions of the shrub *Lantana camara*, around the world, from its native continent of South America. Modified from Cronk and Fuller (1995).

impacts of biological invasions by plants. This is not surprising because these impacts are varied and often complicated.

Not all weeds were introduced from faraway places. Indeed, many weeds are members of the native flora in an area. Similarly, not all introduced plant species that become established have obvious negative impacts on plant communities. For example, Arroyo *et al.* (2000) estimated that of 690 non-native plant species in Chile, 430 are considered weedy, compared with 132 native weeds. While there has been increasing concern over the consequences of human-aided transport of species around the world over the last 20 years, botanists have been well aware of the presence of plant species introduced from other countries for over a century (di Castri 1989). As early as 1905 Stephen Dunn published the *Alien Flora of Britain*, which examined introduced species in that country. In Australia, Robert Brown noted 29 species of introduced plants from Europe during a botanical reconnaissance of the coast near Sydney from 1802 to 1804 (Groves 1986b). Australia received its first European settlers in 1788. A good example of a plant that has been spread around the world is *Lantana camara* (Figure 1.1). This plant was valued as an ornamental. Its ability to invade and dominate new environments was not recognized until after it had become widely spread.

The history of plant introductions has been recorded by the activities of dedicated botanists who collected, pressed, mounted and archived plants in herbaria. This work has turned out to be a goldmine for ecologists

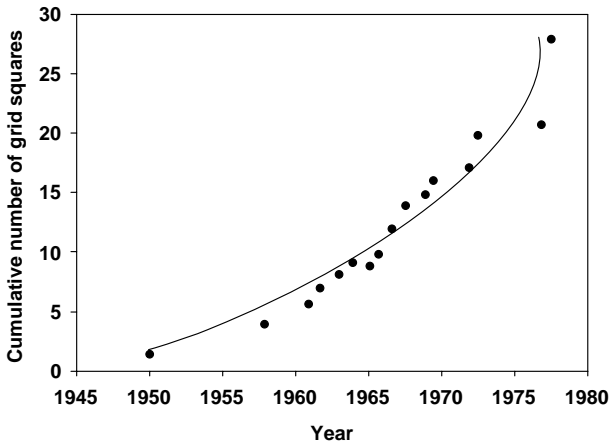


Figure 1.2. The spread of *Carduus nutans* in Australia as quantified by Medd (1987) from herbarium specimens. The spread was recorded in 0.5° longitude \times 0.5° latitude squares. After Cousens and Mortimer (1995).

seeking to understand the patterns of spread of introduced plant species (Mack 2000) (Figure 1.2). There can, however, be inaccuracies associated with these records. While really different looking plant species are obvious and rapidly identified, the arrival of new species that resemble native species may be slow to be recognized. This was apparently the case for *Anthemis austriaca* in Pullman, Washington, USA, which was originally identified as the well-known species, *Anthemis cotula* (Mack 2000). Often the exotic nature of a species is indicated by its high density. Nevertheless, herbarium records can give a picture of the history of the expansion of the ranges of plant species following their introductions to other countries and regions.

In Europe historical records provide such detailed knowledge of plant movement that introduced species can generally be classified according to whether they arrived before or after the year 1500, although this date should more correctly be 1492, the year of return of Christopher Columbus from the New World (Scherer-Lorenzen *et al.* 2000, Williamson 2002). Given this long history of the spread, movement and naturalization of plant species in foreign locations (di Castri 1989), we might question why there has been so much recent interest in this topic. There is even a question of how native species should be identified. For example, if plants occurred in an area before the ice age, and do not currently exist there but have recently been reintroduced, are

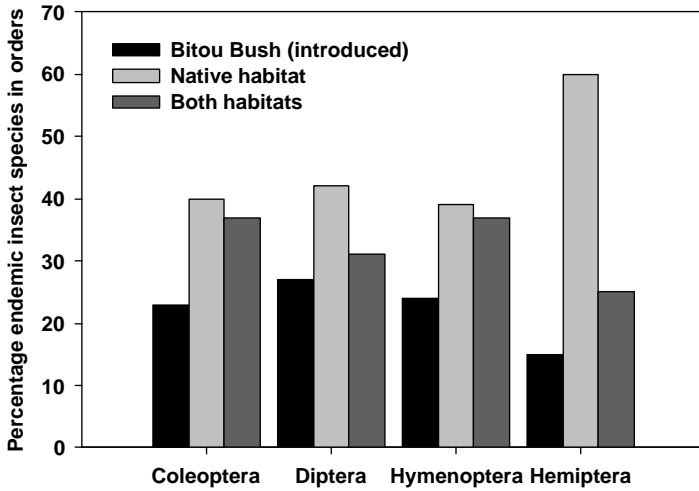


Figure 1.3. Percentage of endemic insect species found in habitats invaded by Bitou Bush, *Chrysanthemoides monilifera*, and native coastal habitats in New South Wales, Australia. Specialist insect species may be more affected in the areas invaded by the exotic species. Data from French and Eardley (1997).

they native or exotic? In defining native species the particular environmental and climatic conditions that currently influence their distribution can be important.

Native species are usually valued above introduced species by ecologists and environmentalists. However, for horticulturalists, introduced ornamentals are often given equal or higher preference. The value of exotic versus native species is discussed by Kendle and Rose (2000) who list five common arguments that are frequently used to support the protection of native over introduced species in landscape plantings. First natives may be more hardy than exotics and better adapted to the local environment. On the other hand, exotics may become invasive and outcompete natives. Additional arguments for the advantages of native plant species are that (1) they support more associated species such as insect herbivores (Figure 1.3), (2) their genetic diversity represents unique adaptations that should be protected from contamination through gene flow from exotic species, and (3) native plants define the landscape character. However, Kendle and Rose (2000) conclude that much of the research behind these arguments is either limited or equivocal. They also conclude that many of the justifications for using native plant species in landscape plantings have more to do with societal values than science. It is interesting

that many plant introductions arose from Europeans attempting to recreate a familiar landscape character after they colonized new continents (Box 1.1). One of the main objectives of this book is to consider from an ecological perspective whether native plants should be valued over introduced plants.

The socio-economic background of plant introductions

Human-aided movement of plant and animal species is an intrinsic part of our history and social development (di Castri 1989) (see Chapter 2). Many of the major crop and domestic species that sustain the human population have been introduced species (Pimentel *et al.* 2000) and have clear benefits to the human race. In addition to crops, many introduced plants are ornamentals and valuable to gardeners and horticulturalists. The horticultural industry in the United States of America is worth billions of dollars – in 1998 US consumers spent \$8.5 billion on lawn and garden supplies (McCartney 1999). A Gallup poll conducted in February 1999 revealed that many gardeners are middle-aged, highly educated homeowners with ‘impressive’ household incomes (McCartney 1999). In the USA, gardening has ranked in the top five favorite leisure-time activities in the six Harris polls conducted from 1995 to 2001, and in 1999, it ranked third (15%) behind reading (27%) and watching TV (22%) (Taylor 2001). C. D. Andrews, executive director of the Canadian Nursery Landscaping Association remarked in 2001, that gardening is the fastest growing leisure activity in North America (Porter 2001). This has created a public demand for new and exciting species (Mack and Lonsdale 2001) and international trade in plants and plant seeds.

One example of the international market in plants that we have observed is the sale of seeds of many Eastern North American prairie species at a local garden festival in Wales, UK. Another example was highlighted in a newspaper article in Vancouver extolling the creativity of a nursery owner who had imported a plant species from China to Canada that ‘appears to be unaffected by pests or disease and does not resent being sheared’. Surely these are the characteristics of a species that will be hard to stop once it moves from the gardens into parks. Continuing in this ‘shouldn’t we be concerned’ vein is an analysis of ‘native’ wild flower seeds in the Pacific Northwest carried out by Lorraine Brooks and Susan Reichard, University of Washington, Seattle. They found that seed packets from nine companies contained from three to 13 invasive plant species with seeds from one company containing nothing but introduced

and potentially invasive plant species. It seems that seed companies are confused about the definition of native species.

In addition to the issue of introduced plant species the growing popularity of gardening has other negative impacts on the environment. In the United Kingdom, widespread mechanical extraction of peat from moorland bogs, for use by gardeners, threatens a number of plant communities that have been designated as 'Sites of Special Scientific Interest' by English Nature. The negative impact of gardening's popularity was even mentioned by the Member of Parliament, Caroline Flint, in a debate in the British House of Commons on 3 November 1999 (Hansard 1999). She stated that a number of gardening companies 'have turned large parts of Hatfield moors into nothing more than a lunar landscape'. Ms Flint pointed to the need for British celebrity TV and radio gardeners to take a stand on the issue. The growing popularity of gardening in Britain has led in recent years to a fourfold increase in the use of peat. With the movement of peat comes the distribution of plant seeds to new regions.

Billions of dollars are spent controlling weeds, pests and pathogens world-wide, many of which are introduced species. Pimentel *et al.* (2000) have estimated the annual cost of controlling and managing some non-indigenous species to be \$136 630 million. Costs of control can easily be totaled in monetary values, but there are other less easily quantifiable costs. Some introduced species are less of a problem in agricultural areas, and more of a problem for natural communities. Here they may affect the provision of 'ecosystem services', by modifying water tables, reducing water flow in streams, and modifying wildlife habitat (Zavaleta 2000a). Naylor (2000) discusses the complexity of determining the costs of introduced species, since cost-benefit analyses are based on human values. It is difficult to estimate the values to place on non-use and indirect use of ecosystems (Chapter 3).

There are increasing calls for us to change our habits in terms of how we treat our environment. One example of this is the US Environmental Protection Agency's promotion of 'Beneficial Landscaping' (EPA 2002). The rationale for practicing beneficial landscaping includes, among other reasons, the possibility of reversing biodiversity loss due to 'clearing of native habitats and the introduction of invasive exotic plants'. The general principle of beneficial landscaping is that it is possible for people to meet their 'needs and sense of beauty, while maintaining or restoring healthy natural ecosystems'. These principles are outlined in Table 1.1. As discussed previously, Kendle and Rose (2000) question the rationale

Table 1.1. *Principles of beneficial landscaping that can be applied in any area experiencing human activity*

Principles of beneficial landscaping
Protect existing natural areas
Select regionally native plants
Reduce use of turf
Reduce or eliminate use of pesticides
Compost and mulch on-site
Practice soil and water conservation
Reduce use of power landscape equipment
Use planting to reduce heating/cooling needs
Avoid use of invasive exotics
Create additional wildlife habitats

From EPA (2002).

behind selecting natives and avoiding exotic plants in landscape design. Clearly the EPA principles go beyond a focus on introduced plants to incorporate a broader range of ecologically friendly changes in landscaping procedures. However, the conflict remains between the ecological view that exotic species are bad, and the view of horticulturalists that exotic plants are, if not good, at least not demonstrated to be bad.

Turning back the clock – is restoration possible?

Most introduced species are not invasive but those that are can have a spectacular impact when they come to dominate large areas. For a number of these species the initial stages of population increase and spread will appear to be slow (Figure 1.4). This early phase represents what Naylor (2000) calls a ‘time-bomb’. She also discusses the long-term benefits of early control as compared to dealing with the problem following widespread establishment. A very serious problem is that humans only seem to respond strongly to perceived crises. This leads to a need to create an atmosphere of urgency in regard to preventing the introduction of new species and to attacking those species with a clear potential for invasion (Myers *et al.* 2000).

Applied biologists and land managers are challenged by the need to conserve the diversity and integrity of natural plant communities in the face of invasive introduced species, increased disturbance and changing

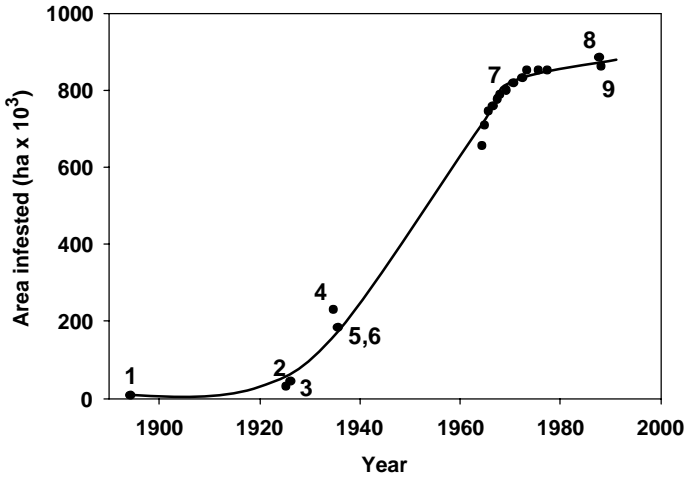


Figure 1.4. Invading plant species can demonstrate an initial lag phase followed by a log phase of population growth as demonstrated here by the cactus *Opuntia aurantiaca* in South Africa. This plant was introduced in the 1840s and established in glasshouse collections. The rapid spread between the 1930s and 1964 was due to both real population spread and increased search efforts. During this period of spread control efforts were applied including mechanical control, herbicide treatment and biological control by the cochineal insect, *Dactylopius austrinus*. The latter has reduced the density of the cactus but not its distribution. Numbers refer to different studies carried out between 1892 and 1981. After Moran and Zimmerman (1991).

environmental conditions. To meet this challenge effectively, three basic ecological interactions must be recognized: plant–environment, plant–plant, and plant–herbivore. The ability to restore a habitat to its original state is a litmus test of our ability to put ecological principles into action. Long-term quantitative assessment and well-designed experiments allow the evaluation of what works and what does not. In this book we appeal for more quantitative studies of invasive species and their control. Thus we include in an Appendix an introduction to population and biodiversity measurement techniques.

The introduction of non-native plant species to ecosystems and habitats can be considered as grand experiments. The addition of new species allows us to study the roles of species in these communities (see Chapters 3, 4 and 7 in particular). It provides us with an opportunity to assess whether ecological theory is able to predict pathways of change in species abundance and plant community composition. For the manager challenged with habitat conservation, the most important question is whether the

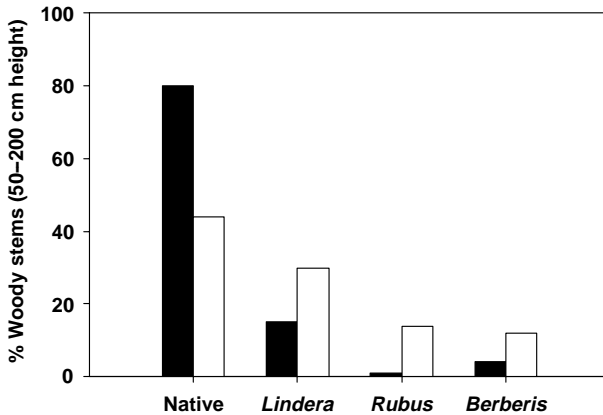


Figure 1.5. Changes in the percentage composition of woody browse species following reductions of deer populations from >54 deer km^2 prior to 1993, to 7–9 deer km^2 from 1993 to 2001 in a southern Ontario deciduous forest. Black bars are species' occurrences before deer removal and white bars are from 2001. Sample sizes were $n = 247$ stems in 1994 and $n = 403$ stems in 2001. Plant groups are palatable native trees and shrubs, and less palatable species – spicebush, *Lindera benzoin*, bramble, *Rubus idaeus*, and introduced Japanese barberry, *Berberis thunbergii*. (S. Chopra and D. R. Bazely, unpublished data.)

impacts of introduced species can ever be reversed or if, once an exotic is established, the community reaches a new 'equilibrium state'. Disturbed habitats are frequently assaulted by several factors simultaneously. Increased browsing may facilitate the invasion of a well-defended plant. However, the establishment or dominance of such a species may not be reversed by the removal or reduction of the browser population (Figure 1.5).

The irreversibility of a modified plant community after removal of a disturbance is shown in Rondeau Provincial Park, a deciduous forest in southern Ontario, Canada. In this case high densities of deer selected for increases in plant species defended against browsing and many native understory species disappeared from the forest plant community (Koh *et al.* 1996). The managers challenged with restoring the original plant community reduced the numbers of white-tailed deer, *Odocoileus virginianus*, in 1993 from over 400 to fewer than 100. However, following reduced deer densities, the unpalatable woody species continued to increase significantly. These were spicebush, *Lindera benzoin*, a highly aromatic, small, native tree; the prickly, native bramble, *Rubus idaeus*; and the thorny, non-native species, Japanese barberry, *Berberis thunbergii*, a cottage garden

escape. This result ran counter to predictions that the regeneration of native, palatable tree and shrub species would increase with reduced deer browsing. The assumption is that the defended plants benefited more from deer removal than undefended, native species. Reduced seed banks of native species could also have been associated with poor regeneration (see Chapters 4 and 5). This is not the result a manager would have hoped for.

For the land manager, restoration is complex and unpredictable (see Chapter 9). While eradication of introduced species may be considered, the reality is that once a species has reached the point where it is recognized as a problem, eradication is not likely to be achievable even with massive economic investment. There have been successful eradications of introduced animal species and examples include rats, *Rattus* spp., from islands (Myers *et al.* 2000), and nutria, *Myocaster coypus*, in the UK (Gosling and Baker 1989). Mack *et al.* (2000) cite two examples of successful plant eradications, but these two species were present in very localized areas. As research into the economics of introduced species develops, we may see more costly eradication programs. However, benefit–cost analyses of the type proposed by Naylor (2000) are rare. Thus, the more common option has tended to be to do nothing or to attempt to control the species to some acceptable level through chemical or biological methods (see Chapters 7 and 9).

Biological control as an approach to introduced weeds

If introduced weeds have a competitive advantage because they lack natural enemies, then re-establishing the natural enemy complex should be a way of leveling the playing field. It seems the obvious solution. Classical biological control is the introduction of natural enemies in an attempt to control exotic pests (Chapter 7). It is based on the premise that one, some, or all of the natural enemy complex can reduce the density of the introduced pest to the extent that native vegetation will be able to assert a competitive edge. In native habitats, even weedy species tend to have lower and often more patchy distributions than the same species in an exotic habitat. The hope is that introducing part or all of the natural enemy complex will cause the reduction of the plant density to something more similar to the native situation.

Biological weed control has been highly successful in some cases and the most spectacular of these cases are cited time after time in ecology textbooks. Two species of weeds that have been greatly suppressed through

biological control are prickly pear cactus, *Opuntia* spp., and St John's wort, *Hypericum perforatum*, both projects undertaken in the first half of the twentieth century. More recent successes include tansy ragwort, *Senecio jacobaea*, in western North America and an aquatic fern, *Salvinia molesta*, in many tropical lakes (Room 1990). Although these and other clearly successful programs represent only a fraction of those that have been attempted, biological control is the only potential solution for many invasive weeds. It is an area of increasing effort. By the early 1980s, approximately 100 species of plants had been targeted for biological control and by early 1990s this number had doubled (Julien 1992, Julien and Griffiths 1998). High proportions of these weeds are in the families Asteraceae and Cactaceae.

Just as the introduction of plants to new communities can be viewed as ecological experiments, so can the introduction of biological control agents. These programs, if appropriately monitored can be used to test hypotheses on interactions among plants and their natural enemies. In Chapter 7 we consider the problem of predicting what characteristics make a good biological control agent and why some agents reduce the population density of their food plants while others do not. Biological control is often the best hope for managers faced with reducing the impacts of introduced species, and any increase in the ability to predict what makes a successful program will be greatly valued.

Promoting ecosystem management for native species

Thus far we have considered the negative attributes of weeds. However, native weeds are part of the agricultural environment that has changed dramatically in recent times. A group of weeds that are now declining are known as 'agrestals'. These are annual weeds found in arable fields and their seeds have become adapted to disperse with crop seeds (Kornas 1988). Research during the 1950s in the Western Carpathian Mountains of Poland showed that this was the major group of weeds in cereal and flax fields. By 1985, a number of these species of weeds had disappeared from the fields (Kornas 1988). This has happened in part for two reasons – improved technology for sifting weed from crop seeds, and more sophisticated herbicides (Fox 1990). Indeed, a number of the 'old aliens' – introduced pre-1500 from southern and southeastern to central and northern Europe – are the subjects of conservation programs (e.g. *Adonis aestivalis*, *A. flammea*, and *Agrostemma githago*) (Scherer-Lorenzen *et al.* 2000). This story is an excellent example of how ecosystem-level

practices, in this case in agricultural habitats, can alter the conditions so that particular species disappear.

The importance of ecosystem-level attributes such as disturbance regimes in determining the abundance and distribution of plants is increasingly being recognized both for rare and endangered species but also for non-native species. Understanding how alterations in the landscape, land use and ecosystems affect non-native species will help the manager mitigate habitat changes that may increase the likelihood of invasion (Chapter 9).

Conclusions

In this introduction, we raise some of the topics that we consider in the chapters to follow. It is clear that human activity has led to both the accidental and intentional global redistribution of plants. Therefore social, economic, and ecological influences are intimately involved in studies of introduced species. Humans will continue to move and more plant species will go with them and create a continuing need for the management of plant communities. However, the movement of plant species is also a valuable perturbation for the study of the ecological principles that are relevant to future management schemes as well as the understanding of plant communities. We will next look in more detail at the patterns, impacts and control of introduced plant species.