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WEEDS IN NEW ZEALAND PROTECTED NATURAL AREAS: A REVIEW FOR THE DEPARTMENT OF CONSERVATION

by

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PREFACE

Weeds of any kind are undesirable on conservation land but certain weeds threaten the survival of some native plants and communities. To protect conservation values the Department of Conservation (DOC) allots a substantial part of its budget to weed control. There are many weeds present in New Zealand's protected natural areas, weed control is expensive and resources are limited. This review aims to guide weed management and research into the most effective areas.

The review has three complementary parts. Part 1 describes the current knowledge on impact and ecology of problem weeds of protected natural areas. It forms a directory of information drawing together published and unpublished information and also exposing gaps in our knowledge. The effects of weeds in different vegetation classes is described and then a regional analysis of weed problems is presented.

Part 2 outlines DOC's present approach to weed management and research, and assesses the state of weed knowledge as presented in Part 1. Because it is neither practical nor economically possible to control all weeds in all situations, priorities for weed management and research are given.

Part 3 provides a guide to further sources of information such as formally published papers, internal reports or unrecorded field-based knowledge.

While the three parts are complementary, it is anticipated that most users will have more recourse to just one part rather than all three parts of the review. Therefore, each part is presented complete with its own contents page, references, tables and appendices.

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LIST OF ABBREVIATIONS

DNPA	District Noxious Plants Authority
DNPO	District Noxious Plants Officer
DOC	Department of Conservation
DSIR	Department of Scientific and Industrial Research
FRI	Forest Research Institute
MAF	Ministry of Agriculture and Fisheries
MOF	Ministry of Forestry
PNA	Protected Natural Area

PART 1

THE HARMFUL EFFECTS OF WEEDS IN NEW ZEALAND PROTECTED NATURAL AREAS

SUMMARY OF PART 1

This first part of the three-part review describes the ecology, and impact on conservation values, of problem weeds of protected natural areas in New Zealand in an attempt to facilitate weed management.

Weeds may alter the balance of species in ecosystems, cause the disappearance of certain species or may alter the vulnerability of communities to fire and other damage. Undisturbed tall forest is largely impenetrable to weeds, but a few particularly important weeds smother the forest floor while others climb into the canopy. Short forest, scrub, and shrubland are vulnerable to invasion by weeds with a very wide range of growth forms, including creeping herbs, large grasses, climbers, tall shrubs, and short trees. Tussockland and openland are invaded mainly by woody weeds, plus a few herbs. Sand dunes are vulnerable to invasion by weeds of all growth forms, as are wetlands. Weeds of open water are mentioned in this review but these weeds require a separate review.

A few rare and endangered plants are directly threatened by weeds. Weeds may also affect native invertebrates, reptiles and birds but little information is available on this. Weeds can alter landscapes although this may not be considered detrimental by everyone. Other effects of weeds on human use and comfort, in protected natural areas particularly, are sometimes relevant to managers of these areas.

For the purposes of this review New Zealand was divided into five regions, and outlying islands were treated separately. The main weed problems in each are described. The climate and large human population of Northern New Zealand favour weed establishment and this region seems to have the greatest variety of weed problems in New Zealand. By contrast, Western South Island generally has strongly leached soils and a sparse human population and as a consequence the total number of weeds is relatively low.

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1.1 INTRODUCTION

New Zealand has a wide range of habitats that have been widened further by disturbance caused by humans, and an equable climate. Fire and grazing in particular have favoured the invasion and spread of weeds, coupled with the absence of the diseases and predators which would limit them in their original habitats overseas. Weeds of any kind are undesirable in protected natural areas and certain weeds threaten the survival of some native plants and communities. To protect these, the Department of Conservation (DOC) allocates a substantial part of its budget to expensive weed control.

The following account describes the ecology and impacts of weeds in an attempt to facilitate weed management in protected natural areas. It draws together published and unpublished information and verbal reports from many helpers. As a directory of information it exposes gaps in our knowledge. It must be regarded as a first approximation in many areas, and it is hoped it will stimulate sorely needed work on weeds in protected natural areas (see Part 2 for priorities for future research).

In all three parts of the review particular attention is given to 65 species (or groups, e.g. rushes) that are termed problem weeds in protected natural areas because they permanently alter the structure, successional processes, and organisms present in native communities (Timmins and Williams 1987). The list of problem weeds (Tables 1.1-1.5) was compiled originally from a survey of Department of Lands and Survey rangers (Timmins 1984) but it has been expanded since then from other published and unpublished information (Timmins and Williams 1987, Williams and Timmins in press) and has been through many revisions. The last revision was circulated to all regional botanists in DSIR, selected university botanists, and DOC regional staff. It was also discussed by a small working group at the Flora Festival at Lincoln in November 1988. Information on weeds of remote areas such as Northland was difficult to obtain, so the list contains bias. All weeds mentioned to us are included in Appendix 1.1. Tables 1.1-1.5 and Appendix 1.1 are purposely aimed towards terrestrial weeds. Some aquatic weeds are included to acknowledge the problem but a separate review of aquatic plants would be valuable.

Wilson and Sykes (1988) noted that study of the interaction of native and exotic species is lacking in New Vlok (1988) showed that worldwide there is a relative absence of theoretical papers describing such interactions. Some of the very meagre information available on the effects of weeds on New Zealand ecosystems and on a range of vegetation types, from tall forest to openland, and on other flora and fauna values is indicated in the present work, in which the regional distribution of weeds, and the communities in which they are significant problems, is tabulated. Some other weeds of severe or potentially severe local significance are not listed in the tables but are mentioned in the text. Many weeds are likely to extend their range both into New Zealand from the Pacific, and further south within New Zealand, if the predicted climate changes occur (e.g. McGlone 1988).

Where applicable, common names are used in the text and tables, and the equivalent formal names for the weeds are given in Appendix 1.1. Names of weeds follow Healy and Edgar (1980), Webb *et al.* (1988), or occasionally Elser (1987b) if no specific name is used in the previous two texts. The names of native flora follow modern usage as summarised in Connor and Edgar (1987).

1.2 EFFECTS OF WEEDS

1.2.1 Weeds and Ecosystem Structure and Function

Understanding weed biology and its effect on ecosystem structure and function can help us understand the impact of weeds (Macdonald and Jarman 1984). Weed growth form and flowering affects the flow of energy (the carbon cycle) and nutrients, geochemical processes and the hydrological cycle. Weeds may also affect rates of disturbance, for example by increasing the frequency of fires.

1.2.1.1 Plant Biomass and Carbon Cycle

Weeds may accumulate considerably more biomass than native plants e.g. pine trees growing in tussockland. This may cause shading and the return of large amounts of litter to the ground surface. Gorse for example, returns nearly 9000 kg/ha of litter to the soil surface every year (Egunjobi 1971). In climates where litter decomposes rapidly there is a rapid return to native forest (Druce 1957). Where temperature or moisture limits decomposition, litter accumulates, slowing the rate of establishment of native broad-leaved species (Lee *et al.* 1986). In this respect gorse differs from native manuka (*Leptospermum scoparium*), and also exotic broom which do not accumulate litter to such depths.

Willow-leaved hakea has similar disruptive effects in the scrub and short forest of central and northern New Zealand. Its crown becomes very dense with branches and thousands of woody capsules. When a hakea tree dies, this material falls to the ground in heaps, crushing native seedlings. While a similar process occurs when native kanuka (*Kunzea ericoides*) or manuka die, the effect with hakea is more dramatic because of its greater density of branches and capsules.

Old man's beard can alter the forest structure by causing the collapse of large native trees. Indirect effects include creating light gaps in the forest and providing a large increase in the food resources available to fungi and invertebrates. On a much smaller scale, mouse-ear hawkweed invading short tussockland causes a considerable reduction in total biomass and nett production (Makepeace 1985).

Shoreline willows can increase the carbon inputs to freshwater beyond those occurring in native riparian communities. Standing crops of oxygen weeds in lakes and slow-flowing rivers far exceed those of the native communities they have replaced (Howard-Williams and Davies 1988).

1.2.1.2 Nutrient Cycling

The changed quantities and distribution of biomass referred to above lead to altered nutrient cycling. Pine trees in snow tussock land (*Chionochloa* spp.) take up and hold a larger pool of nutrients the snow tussocks they displace. Invasive legumes increase the nitrogen stored

in the system by their ability to fix atmospheric nitrogen. In doing so they facilitate the entry of other weeds, ranging from grasses such as bromes, to shrubs such as elder.

1.2.1.3 Hydrological Cycle
Weeds may influence the hydrological cycle by altering the amount of interception of precipitation and by altering rates of evapotranspiration, infiltration, and run-off.

Adventive weeds and shrubs, especially willows, affect river flow patterns by protecting banks, and stabilising islands within the riverbed. The latter forces rivers to flow over wider areas. Herbaceous plants, in particular, frequently block small water courses and drains, causing both drought and flooding.

1.2.1.4 Fire Regime
Plants which carry a large amount of dead material are naturally flammable and pose a fire hazard. Several weeds in this category, including pampas grass and gorse, and the numerous herbs, especially grasses, occupy those strips between woody vegetation and fenced boundaries of reserves. When reserves are established, the large amounts of dead litter from browntop that often accumulates in ungrazed montane vegetation, pose a fire hazard.

The long-term indirect effects of fire are especially important where fire-adapted weeds are present. For example, in the advent of fire or the opening up of the canopy, native species, such as manuka seeded from adjacent scrub, are rarely able to compete with weeds such as gorse and broom which have long-lived seeds and can thus regenerate from buried seed on site. In this way, manuka scrub and its attendant flora, for example orchids, has been eliminated from large areas, particularly in drier zones such as Banks Peninsula and Nelson. Once these persistant legumes are present then early-successional native communities are inhibited even if the vegetation does eventually regenerate to forest.

1.2.2 Vegetation Classes
The above effects are summarised below with respect to several major structural classes of vegetation cover, and to the biota.

1.2.2.1 Tall Forest
Large tracts of intact tall forest (i.e. taller than 10 m) seem resistant to weed invasion.

Small patches and stands damaged by such factors as logging and wind throw are susceptible to two weeds in particular. Old man's beard is capable of smothering tall trees, including podocarps, dramatically altering forest structure. Once the canopy has been damaged this weed may then prevent or slow forest regeneration. Wandering Jew grows in very low light levels, forming an herbaceous carpet that seriously hampers seedling regeneration (Kelly and Skipworth 1984).

Severely damaged forest has a wider range of weed problems (see 1.2.2.2).

1.2.2.2 Short Forest

This class includes all shorter forest as well as severely damaged tall forest with large canopy gaps.

Both old man's beard and wandering Jew have a major impact here, together with many other weeds in a range of growth forms. Several vines e.g. asparagus species and banana passionfruit, and several shrubs or trees, e.g. Darwin's barberry, hawthorn, two species of privet, and sycamore are able to establish, especially in canopy gaps and openings. In these positions the weeds are occupying spaces that would otherwise be filled by native species. In some cases, e.g. hawthorn, these shrubs and low trees are unable to regenerate from seed once the canopy thickens (Williams and Buxton 1986) but others, e.g. privet and perhaps barberry, may be able to regenerate beneath the closed canopy of some short forest types (Esler 1988c). As with most weeds, the precise interaction between the native and weed flora has seldom been studied. Several weeds found in New Zealand however, have been studied elsewhere, such as Japanese honeysuckle and ivy and their effects on North American forest (Thomas 1980) and sycamore on deciduous forests in Britain (Linhart and Whelan 1980).

1.2.2.3 Scrub and Forest Margin

Scrub and forest margins offer shelter and partial shade and are more susceptible than forest to weed invasion. Wandering Jew and old man's beard are often present. In addition there are the climbers mentioned previously, many shrubs and low trees,e.g. broom, elder, Himalaya honeysuckle, and large or persistent perennial herbs, e.g. wild ginger.

It is known that some of these weeds are replaced by native species. Several climbers and other species, however, have not been present long enough across a wide range of sites, to enable us yet to make long-term predictions on whether natives will eventually replace them. In the meantime, they are severely inhibiting lateral expansion of forest margins and regeneration of scrub or forest especially in northern regions of New Zealand.

1.2.2.4 Shrubland and Pakihi

All communities with a conspicuous component of shrubs, but mixed with other growth forms such as grasses or rushes, are included under this category. Some are potentially forest. Others are likely to remain as shorter vegetation indefinitely because of stress factors such as high water table or low soil nutrients. These latter communities are particularly vulnerable to invasion by large herbs and taller growth forms. In most cases these invasions result in permanent loss of community structure with a total disruption of all ecosystem processes, e.g. when heather invades inaka (*Dracophyllum longifolium*) shrublands, and when semi-arid manuka shrublands are invaded by pine or broom. Loss of some native species is likely to be permanent in some of these situations.

1.2.2.5 Tall Tussockland

Northern hemisphere conifers such as European larch, Douglas fir, and lodgepole pine are a major threat to tall tussocklands. They could replace them completely and over extensive areas.

The recovery of many tall tussocklands at their lower altitude limits is being prevented by a dense inter-tussock sward of exotic species, of which is the most common species. Cocksfoot is locally common. The resurgence of these exotic grasses often results from changes in grazing pressure caused by changes in land use.

1.2.2.6 Short Tussockland and Herbfield
These vegetation types are subject to all the weed invasion problems of the preceding vegetation categories, i.e. woody plants invading herbaceous communities. In addition, herbaceous weeds are important invaders. The most threatening are two species of hawkweed because they can almost replace the native flora. Lotus may oust native species, particularly in damp sites, while browntop is common over large areas. Many other weeds, particularly grasses such as brome grass and tall oat grass, are present in short tussockland but not enough is known about their interactions yet to rank them.

Coastal herbfields and other low vegetation are vulnerable to invasion by a range of weeds.

The impact of weeds in this vegetation class, and also on tall tussockland, is especially variable and hard to generalise because these areas are used for farming. Practices such as over-sowing and grazing, coupled with rising rabbit populations, modify the communities directly and also increase the potential for weed invasion.

1.2.2.7 This term refers mainly to areas of native bracken which are extensive in some parts of the country. Most bracken has developed from reverting farmland or been induced by repeated burning. It regenerates to forest in time although the process is slower in drier, colder areas. Weed problems arise in when exotic woody species establish before native woody species. Gorse and broom are particularly effective in this process because they can establish immediately after fire, from buried seed (see 1.2.1.4). Other species, such as hawthorn and sycamore, invade bracken in wetter areas. As in shrubland, weeds in bracken alter successional processes.

1.2.2.8 Sand Dune
Native sand dune vegetation was originally dominated by the endemic pingao (*Desmoschoenus spiralis*) in some parts of the country and by silvery sand grass (*Spinifex sericeus*) in others. Marram grass was introduced to stabilise mobile sand dunes. It out-competes and smothers native communities and, by stabilising the sand, it allows woody or semi-woody weeds, such as gorse and tree lupin, to establish. These in turn alter the nutrient and hydrological cycles and allow the establishment of other weeds such as brome grass, elder, and pine trees.

Other weeds are able to establish without the assistance of grass e.g. kikuyu grass, which forms a complete mat over the sand. Boxthorn, and to a lesser extent bone-seed and pampas grass, are also able to establish in raw sand, although it must be relatively stable. The first two species are also common on coastal cliffs where they displace native plants. All compete in dunes with native shrubs such as sand coprosma *(Coprosma acerosa),* and small herbs.

1.2.2.9 Wetland
This category includes areas with high water tables that could naturally support herbaceous or shrubby vegetation, and includes both salt and fresh water systems of oligotrophic and mesotrophic status.

The major weed of saltwater wetlands is spartina. This completely smothers native vegetation. It also invades non-vegetated substrates, increases silt accumulation and causes loss of wading bird habitat. Further back from the high water mark the main weed is probably tall fescue and several other adventive grasses or herbs, e.g. salt barley grass and buck's-horn plantain. These two herbs are excluded from the list of problem weeds until studies indicate that they are having a major impact on natural ecosystems and biota.

In freshwater systems from the Hauraki Gulf to southern New Zealand the most conspicuous weeds are crack willow and grey willow which completely suppress indigenous vegetation. They also alter water courses. Adventive rushes are also widespread weeds of wetlands but no distinction was made between the many species for this review. Weedy rushes possibly out-compete native species in some situations.

Blackberry, gorse, and Japanese honeysuckle occupy the margins of some wetlands and swamp forest where they prevent the establishment of native species, at least in the short term. Lotus has invaded and modified many wetlands and their immediate margins.

Several adventive grasses readily invade wetlands where presumably they compete with native species. Only browntop is listed, however, to signal a possibly much broader problem that has not yet been investigated. Large herbs such as species of willow weed are prominent in Northland.

1.2.2.10 Openland
This term includes all areas with very low vegetation cover, ranging from sea level to the alpine zone, and including soil parent materials as diverse as river sand and volcanic ash and highly specialised sites such as salt pans and thermal areas. Sand dunes could also fall within this category but they have been discussed separately (1.2.2.8).

Most areas of openland, other than those in extreme habitats, are readily invaded by weeds because of the many opportunities for seed establishment, and the lack of pioneering woody species in the New Zealand flora. Many species mentioned in the previous vegetation classes invade openland. The most weed-prone sites in eastern South Island, for example, are unstable braided riverbeds covered with broom (Williams 1981), gorse, Russell lupin, tree lupin, and willows, as well as a host of other adventive species. In the lower reaches of most of these riverbeds, weeds do not appear to be replacing native plants, because the latter are no longer present. As the weeds invade inland towards less modified valley heads, e.g. Russell lupins in the Basin, the native flora of small grasses and herbs becomes increasingly threatened.

The most extensive openlands in the North Island are on the volcanic plateau and they result from a combination of the volcanic substrate which encourages fire-disposed vegetation, a fire regime resulting from natural fires, e.g. lightning strikes, Polynesian fires and volcanic ash showers over the last c.900 years. The most important weeds on these substrates are pines,

tree lupin, broom, and pampas grass. A more diverse assemblage is present in Northland, with species such as dally pine and Cape honey flower, although neither of these is listed in Table 1.1. Here, again, the native vegetation is completely suppressed by the weeds.

1.2.2.11 Open Water
There are serious weed problems in open water, particularly in still waters where, for example, lagarosiphon completely suppresses native aquatic vegetation (Howard-Williams and Davies 1988). However, because water weeds are a distinct and specialised topic, they are not dealt with in this review but two are listed in Tables 1.1-1.5 as a reminder that aquatic weeds must be considered.

1.2.3 Effects on Threatened Plants

This section discusses the impact of weeds on threatened plants. The eastern South Island shrub *Teucridium parvifolium,* the climber *Calystegia marginata,* and a climbing rata *Metrosideros carminea* of kauri forest are all examples of threatened plants in scrub or forest margins that are threatened by the wide range of weeds that invade these sites. They may also be affected by sprays directed at weeds such as blackberry, as happened in Marlborough and North Canterbury where native brooms (*Notospartium*) were inadvertently sprayed with herbicide meant for exotic broom.

Several native species of scrub and shrublands are directly threatened by weeds, many on coastal sites on the drier, eastern side of New Zealand. For example, *Olearia pachyphylla,* threatened by gorse invasion in parts of its range near Gisborne, and *Pomaderris phylicifloia* var. *polifolia* in the depleted gumlands of the far north (Given 1981). The Marlborough rock daisy *(Pachystegia insignis*) and *Helichrysum dimorphum* may be out-competed by shrub weeds on rocky bluffs, and the scrambling herb *Ewartia sinclairii* may have been reduced in extent by competition with cocksfoot and clover (Given 1981).

The population of *Ranunculus crithmifolius* at Castle Hill appears to be the only species directly threatened by weeds and, in this case, by a range of small herbaceous species such as oxeye daisy.

Several sand dune species are threatened by weeds. Pingao has been mentioned. There is Maori spurge (*Euphorbia glauca*) and sand pimilea (*Pimilea arenaria*) throughout New Zealand, *Acaena pallida* near Dunedin, *Gunnera hamiltoni* on Stewart Island and near Invercargill, and *Embergeria grandifolia* on Chatham Island are also threatened. *Fuchsia procumbens,* even in reserves, may be encroached by kikuyu grass and buffalo grass (Given 1981). The only known colony of *Sebaea ovata,* south-east of Wanganui, is threatened by pampas grass, Yorkshire fog, hawkbit and boxthorn.

1.2.4 Effects on Fauna

Weed problems are usually discussed in terms of their impacts on vegetation or humans. Few studies have attempted to understand the impact of weeds on native fauna in New Zealand. For example, gorse has been described as an excellent nurse crop in some parts of the country partly because it allows faster regeneration to native forest compared to some native species (Hackwell 1980). This description ignores long-term disruption on the native biota brought about by such woody legumes.

Adventive plants may have both negative and positive impacts on native fauna (see Williams 1984 for examples of the latter). The following comments, based largely on accumulated observations rather than research, indicate the range of impacts.

1.2.4.1 Invertebrates

Although plantations are not strictly comparable with wild situations, species diversity of invertebrates is generally lower in West Coast pine plantations compared with the original podocarp/beech forest (Dugdale1974). Where plant communities replace others major changes in the invertebrate fauna can be expected (Watt 1979). For example, many invertebrates are adapted to particular plant species or plant communities; others to particular food sources such as nectar. However, changes in invertebrates as a result of changes in vegetation go largely unnoticed.

1.2.4.2 Reptiles

Douglas fir and several pine species are becoming established on scree (openland) that forms the habitat of the endemic Otago scree skink (*Leiolopisma otagense* f. *"waimatense"*) (Whitaker 1985). There is great potential for this kind of destruction of habitat in eastern South Island. Lizard numbers would also be expected to decline when plants with nectar sources, and their attendant insects, were replaced by those without nectar, e.g. manuka scrub replaced by pine. Some lizards, and insects too, are able to use a wide range of adventive vegetation if it provides all-important cover.

1.2.4.3 Birds

A few studies have assessed the effects on native birds of replacing native forest with exotic forest, e.g. Clout and Gaze (1984). They found fewer native bird species in plantations than in native forests because of the absence of fruit, nectar, and opportunities for hole nesters. However, in their comparative study of exotic and indigenous forests in Northland, Colbourne and Kleinpaste (1983) found that North Island brown kiwi (*Apteryx australis mantelli*) can be at quite high densities in exotic pine forests.

Conifers and sycamore cannot replace intact native forest but they can invade low vegetation that would otherwise have regenerated to native forest. When this happens potential native bird habitat is set back, at least for the life span of the weeds.

Apart from loss of habitat and food sources some weeds have a deleterious effect on nesting opportunities. Woody weeds and Russell lupin in riverbeds deny wading birds such as wrybill plover (*Anarhynchus frontalis*) their usual nesting and feeding sites. These plants also harbour mammalian predators that use the weeds as cover when approaching nesting birds to destroy their eggs and young (Stead 1932, Hughey 1985).

While weeds can also be advantageous to native birds in a variety of ways, there may be disruption to the whole ecosystem when such relationships occur. In South Africa, for example, seed-dispersing birds which transfer their feeding to weed species do not feed on the native plants, resulting in reduced regeneration of the native species (Knight 1986, Macdonald and Richardson 1986). No examples of this are known in New Zealand but the possibility is an intriguing one.

1.2.5 Weeds and Humans

Weeds affect humans in a number of ways. Some of Esler's (1988b) categories of weed features are directly applicable to the management of protected natural areas.

1.2.5.1 Landscape

The Conservation Act 1987 requires DOC to conserve natural landscapes for reasons enunciated by Kelly and Park (1986):

> "Will our landscape retain its essential New Zealand character and diversity -the pohutukawa-clad shores, the thickets of bean-stick manuka, the pigeon in stream-side kowhai, or the kea crying above mountain snow tussock - a character which is of profound (but unmeasurable) economic benefit in rejuvenating all New Zealanders during their annual holidays. Or will New Zealand end up looking like any other temperate-latitude country, of diminished interest to us, and less to overseas visitors?"
>
> "Our generation has the responsibility to answer, for the last of the apparently idle land is disappearing before our eyes, and with it is lost that sense of identity which springs from everyday familiarity with the fauna and flora of our land."

Many people do have a sense of loss when the familiar changes too rapidly, such as when pine trees cross the tawny tussocklands, especially when they obstruct cherished views. Our (New Zealander's) obligation to conserve New Zealand as a distinctive landscape is now being recognised by a wider section of the community than just natural history writers, e.g. Ledgard (1988).

By contrast some weeds of protected natural areas are greatly admired by tourists and some New Zealand for the colours they bring to an otherwise sombre landscape. An example is Russell lupin in the tussock country and riverbeds of the South Island.

While many of these weeds may be controlled on a local scale, broad-scale control is a lost cause. Mouse-ear hawkweed, viper's bugloss and other herbs have transformed the short tussocklands of Canterbury and Marlborough, while broom has spread extensively in the last decade and further 'yellowing' of the hills in spring is assured. Whether or not some shrub weeds facilitate the regeneration of indigenous forest, they will all alter the landscapes where they occur, perhaps for an indefinite time.

1.2.5.2 Practical Considerations

Weeds affect human use and comfort in protected natural areas in a variety of ways (Esler 1988c). Spiny species such as gorse and sweet brier obstruct tracks. David Fountain and Clive Cornford of Department of Botany and Zoology at Massey University are currently undertaking a major study on the relationship of airborne pollens to the incidence of allergy and asthma in New Zealand. It is already known that some species affect human health in degrees ranging from irritation to extreme toxicity, e.g. privet and hemlock. The Noxious Plants Act 1978 and the demands of recreational users of PNAs require these nuisance weeds to be managed in PNAs.

1.3 REGIONAL ANALYSIS OF WEED PROBLEMS

The previous sections have dealt with problem weeds in a general sense and specific weeds and localities were given only as examples. This section discusses weed problems on a regional basis with reference to the vegetation classes of section 1.2.2. For the purposes of this review, mainland New Zealand was divided into five regions based primarily on climate differences and land use. The availability, or lack, of information means that some regions encompass a range of quite different problems, for example both Northland and metropolitan Auckland are included in Northern New Zealand. Thus the regions are conceptual only and not sharply defined:

1 Northern New Zealand: the Auckland-Northland peninsula north of the Waikato River.
2 Central New Zealand: the rest of the North Island and the Nelson-Marlborough Sounds area of the South Island.
3 Eastern South Island: east of the main divide from southern Marlborough to north Otago.
4 Western South Island: west of the main divide.
5 Southern South Island: central Otago and eastern Southland including Stewart Island.

A section 'Outlying Islands' has also been included for the Chatham Islands, the southern outlying islands and the Kermadec Islands.

The regional distribution of problem weeds is in Tables 1.1-1.5. The same list of 65 problem weeds of PNAs, as defined in the introduction (1.1), is used in each table. The weeds are as significant problem weeds for the region (*) or merely as present in the region (+).The latter are those that are not a significant problem weed in the particular region although many species would be considered as serious weeds on a local scale. The tables do not indicate the total distribution of an individual weed as given in Webb *et al.* (1988); the * sign does not imply that the weed is a significant weed throughout the entire region; and some weeds of severe or potentially severe local significance are not listed in the tables but are either mentioned in the text or listed in Appendix 1.1.

For many parts of the country this analysis is only a first approximation which we hope will stimulate sorely needed weed surveys on an ecological district basis.

1.3.1 Northern New Zealand

Auckland city's high rate of invasion by new weeds has been documented by Esler (1978a,b) and Esler and Astridge (1987). Most of these weeds have been termed by Esler (1987b) as class 1 aliens, i.e. species which are common. The rest he defined as class 2 aliens, i.e. species which occur in lower numbers and/or with a fairly limited distribution. Many of the weeds have invaded protected natural areas.

1.3.1.1 Tall Forest

Wandering Jew is a weed of forest floors in northern New Zealand.

1.3.1.2 Short Forest, Forest Margin, and Scrub
The climbers Japanese honeysuckle, climbing asparagus, and smilax are common in the southern part of the region. Climbing dock and moth plant are common in the Auckland area and were considered for listing. Several vigorous herbaceous species occupy forest margins, particularly pampas grass, kikuyu grass, and species of wild ginger. Wandering Jew is widespread and selaginella carpets forest floors, especially in damp places.

Several of these species, and others, invade forest understorey if there is sufficient light e.g. climbing asparagus, smilax, and elaeagnus. Two species of privet are the most widespread woody weeds of short forest and scrub, while willow-leaved hakea invades scrub on poor soils.

Many of the above weeds are not considered a problem further north in this region although they may represent a potential threat, e.g. evergreen buckthorn, boxthorn, climbing asparagus, and smilax, while others are only minor or local problems, e.g. the privets, woolly nightshade, and selaginella.

Weeds such as gorse and silver wattle are present but, although they have long-term effects (see 1.2.1.4), vegetation succession is rapid and they are soon overtaken by native species.

1.3.1.3 Shrubland and Pakihi
Shrublands in general have similar weeds to those in the previous category (Table 1.1) but with the addition of at least dally pine and sweet pea shrub, the last species being especially abundant in Northland. Here too, silver wattle is less of a problem than black wattle, golden wattle, and prickly wattle, while radiata pine and maritime pine are the main invasive pines. An important local problem is the invasion by maritime pine of shrubland and treelands on Rangitoto Island.

The main threats to the gumland (pakihi) vegetation are species of hakea, while other threats include oxylobium and some of the wattles. Most species listed in the broad category of shrubland and (Tables 1.1-1.5) are weeds of the shrubland however, and cannot tolerate the poor soils of pakihi.

1.3.1.4 Sand Dune
Kikuyu grass, tree lupin and the two species of pampas grass are particularly important on inner dunes. Once the dunes are stabilised, many weeds of shrublands become important. The role of weeds on the Auckland dunes has been described by Esler (1974, 1975).

1.3.1.5 Wetland
Spartina and American spartina are present in many localities. Mist flower occurs in, and adjacent to, waterways (which are strictly open water). There seems to be little understanding of the effects of the many species of rushes, sedges, willow weeds, grasses, lotus, and other weeds which are abundant in the Auckland area (Esler 1987a, b, 1988a, b) and elsewhere. Willows are abundant only in the southern part of the region, Waikato.

1.3.2 Central New Zealand

This region has a very wide range of weed problems, because of the wide range of habitats available, from wetter western districts to the drier eastern districts. Apart from the weeds discussed below there are many potential problem weeds in the central North Island (Appendix 1.1).

1.3.2.1 Tall Forest

Old man's beard is important throughout disturbed lowland tall forest and has been well documented (West in prep a, b). Wandering Jew is a widespread problem in small patches of forest.

1.3.2.2 Short Forest

The two weeds mentioned above are the worst in short forest, especially old man's beard. Barberry and Darwin's barberry are problem weeds of the western and southern parts of the region, while sycamore is widespread. Chinese privet is abundant in the northern part and in scattered places further south. Cathedral bells was also considered for inclusion in the main list.

1.3.2.3 Forest Margin, Scrub, Shrubland, Pakihi, and Fernland

All the weeds of short forest are present, together with many others. There are several climbers, e.g. banana passionfruit, German ivy, and Japanese honeysuckle. Several of the woody weeds, such as broom, gorse, and hawthorn, are widespread while others are more local. For example, buddleia, wattles, and heather are mainly weeds of the volcanic areas. Pines are also a major problem in the central North Island because of the large proportion of open habitat. Prickly hakea and willow-leaved hakea are problems on the granite soils of Tasman and Golden Bays. Pampas grass and purple pampas grass are major weeds in many parts of the region.

Species not listed in Table 1.2 but which are local problems in lowland or coastal areas and have the potential to become more widespread include the several scramblers or climbers, Cape ivy, climbing dock, and cathedral bells.

1.3.2.4 Tall Tussockland and Short Tussockland

These communities are largely confined to the central volcanic plateau and axial ranges of the North Island. (Note that eastern Nelson mountains are included in the Eastern South Island region.) Several species of pine, particularly lodgepole pine, are the worst weeds. Heather is less widespread in these communities throughout the region but it is nonetheless a significant weed problem on the volcanic plateau.

Hawkweeds are present in some areas, particularly in frost-flat vegetation. Gorse and tree lupin are present in some tussockland below timberline. Nassella tussock may become a major problem in parts of the region, particularly in the Marlborough Sounds.

1.3.2.5 Sand Dune

Most sand dunes in central New Zealand have been severely modified by weeds. Some are widespread, e.g. marram grass and tree lupin, while others are more local, boxthorn, bone-seed, radiata pine, and pampas grass.

1.3.2.6 Wetland
Species of willow are the main conspicuous weeds and they are often draped with old man's beard. All wetlands have been modified by a range of herbaceous species such as lotus, rushes, browntop, and creeping bent. The distributions of tall fescue and pampas grass have probably not yet peaked; they could occupy non-vegetated sand flats and suppress smaller native species in places such as Lake Wairarapa. Spartina is present in some areas, particularly in Nelson, Marlborough and in Manawatu (Partridge 1987).

1.3.2.7 Openland
The largest areas of openland are possibly the bare areas of volcanic material on the volcanic plateau, and there are also large areas of open riverbeds, and of slips in papa country. The weeds of such places are an amalgam of those present in other vegetation classes (Table 1.2). Several pine species and pampas grass are the most conspicuous and widespread weeds with other shrubs being more local, e.g. buddleia on riverbeds in the Ureweras.

1.3.3 Eastern South Island
This region includes the greater area of the communities characteristic of inter-montane basins such as tussocklands, but also includes small areas of lowland forest, scrub, and wetland.

1.3.3.1 Tall Forest and Short Forest
The only problem weed of tall forest is old man's beard in the centre and north of eastern South Island. The important weeds of short forest are old man's beard and sycamore. Darwin's barberry and ivy are common in small forest stands.

1.3.3.2 Forest Margin, Scrub, and Shrubland
Scrub of this region has the same assemblage of weeds as short forest, as well as gorse, broom, and hawthorn. The drier shrublands of the intermontane basins are invaded mainly by sweet brier, broom, and to a lesser extent gorse. The most open shrublands are susceptible to invasion by all the conifers. The reference to bowthorn in Table 1.3 refers to the coastal scrub community, e.g. on Motunau Island.

1.3.3.3 Tall Tussockland and Short Tussockland
The major weeds of these communities are conifer species, and in some areas, the shrubs broom, gorse, Spanish heath, and sweet brier. Herbaceous weeds are prominent in short tussockland. Mouse-ear hawkweed and king devil are widespread and several grasses are important (Table 1.3). Nassella tussock may become a problem to some protected areas. If so, its control could use a large proportion of DOC's resources.

1.3.3.4 Sand Dune
With very few exceptions, sand dunes in this region have been taken over completely by weeds, particularly marram grass, tree lupin, boxthorn, and pines. The one outstanding natural dune system is Kaitorete Spit, but even this is threatened by weeds, particularly Marram grass and tree lupin.

1.3.3.5 Wetland
The few unmodified lowland wetlands that remain are invaded by willows, blackberry, and many adventive grasses. Some intermontane wetlands are less modified, but lotus, browntop, other grasses, and rushes are present in most.

1.3.3.6 Openland
A very wide range of habitats is represented in this vegetation class in eastern South Island. Braided riverbeds are a major feature but they have been almost completely taken over by weeds, especially willow and the legume Russell lupin. Only some upper catchment areas remain relatively weed-free. Openland at higher altitudes above timberline is invaded by several conifer species.

1.3.4 Western South Island
This region is uniformly wet but has a wide range of temperature regimes. The soils are generally strongly leached and, as a consequence of the low fertility, the total number of weeds is rather low. The sparse human population is probably also a factor.

1.3.4.1 Tall Forest
Old man's beard threatens the forests in the northern part of the area, particularly those in the Buller catchment, and wandering Jew is also present in northern parts.

1.3.4.2 Short Forest, Forest Margin, and Scrub
Old man's beard and wandering Jew are the major weeds. Small tree weeds, which are so prevalent over the rest of the country, are not a problem here because native forest regeneration on the West Coast is so rapid.

1.3.4.3 Shrubland and Pakihi
Gorse and blackberry are present on the margins of many shrublands and pakihi, but they seldom extend out into relatively undisturbed areas. Many adventive herbs are found in pakihi but they are not considered problem weeds as they are mostly confined to disturbed areas and do not appear to displace native species to any extent.

1.3.4.4 Tall Tussockland and Short Tussockland
High altitude tussocklands are not threatened by pines as they are in drier areas, but some low altitude tussockland is threatened by gorse.

1.3.4.5 Fernland
No extensive bracken fernlands occur on the West Coast apart from those in the heads of some of the valleys, e.g. near Murchison. Localised invasions by broom, and to a lesser extent by hawthorn, are not sufficient of a problem to be listed in Table 1.4.

1.3.4.6 Sand Dune
Except for a few areas of relatively unmodified dunes in the south, gorse, marram grass, and tree lupin are usually present.

1.3.4.7 Wetland
Blackberry and willows are the main weeds of wetlands, with lotus, grasses, and rushes present in many of them.

1.3.4.8 Openland
Riverbeds are readily invaded, particularly by leguminous shrubs. Road cuttings and moist, bare areas are invaded and/or sown with lotus which temporarily slows regeneration of native species.

1.3.5 Southern South Island

This region includes both extremely dry areas similar to eastern South Island, and extremely wet areas.

1.3.5.1 Tall Forest and Short Forest
There are no problem weeds of tall forest. The only problem weeds of short forest are Darwin's barberry, sycamore and, to a lesser extent, hawthorn. Barberry is also establishing beneath short forest on Stewart Island.

1.3.5.2 Forest Margin, Scrub, and Shrubland
Several woody weeds are abundant in these communities (Table 1.5). Elder is particularly important in Southland, while barberry is more abundant in Otago. Sweet brier and hawthorn are becoming increasingly prominent in some of the gorges adjacent to main highways.

1.3.5.3 Tall Tussockland and Short Tussockland
The weeds of these communities are similar to those in eastern South Island, with conifers being the major threat. Hawkweeds are perhaps less important than further north.

Two other very distinctive plants of parts of central Otago, wild thyme and purple fuzzweed, are not problem weeds in the existing PNA network but they threaten potential protected natural areas. Spanish heath appears to be spreading in parts of Southland and may become a more serious weed.

1.3.5.4 Fernland
Bracken is extensive in parts of Otago and western Southland and in the absence of any native woody species it is being invaded by elder, hawthorn, and to a lesser extent sweet brier.

1.3.5.5 Sand Dune
Significant areas of relatively unmodified sand dunes are found in southern New Zealand particularly in Fiordland. They are threatened by marram grass and other weeds (Table 1.5).

1.3.5.6 Wetland
Spartina is widespread in Southland, while willows and herbaceous weeds are abundant in fresh water habitats (Table 1.5).

1.3.5.7 Openland
These habitats have the same leguminous weeds as openland habitats in eastern South Island with the addition of Russell lupin (Table 1.5).

1.3.6 Outlying Islands

1.3.6.1 Chatham Islands
The Chatham Islands have remarkably few problem weeds, probably because most of the soils are low fertility peats. Marram grass is a threat to sand dune vegetation and gorse has shown a recent increase in its spread. The stands of strawberry myrtle near Whare Kauri should be monitored. Herbaceous species such as browntop, Kentucky bluegrass, and tall fescue are widespread but their impact on the native vegetation appears to be minor at this stage.

1.3.6.2 Southern Outlying Islands
It is especially important that the outlying islands with unmodified floras, e.g. Snares and Antipodes, continue to be kept free of weeds.

Most southern islands are not threatened by exotic species but problem weeds occur on Campbell and to a lesser extent Enderby Island which have had greater disturbance (Meurk 1989). The following weeds are widespread or important in some habitats: Kentucky bluegrass, foxtail, creeping bent, and browntop. They will probably be suppressed by native vegetation although foxtail may invade salt marsh. The most persistent species, and those with the greatest potential to spread, are Yorkshire fog, tall oat grass, and lotus. Cocksfoot may also be a potential problem. Further spread of these species and others should be prevented (Meurk 1989).

Olearia lyalli, thought to have been introduced to Northern Auckland Islands from the Snares, should be prevented from spreading further south than Ross Harbour and to other islands (Meurk 1989).

1.3.6.3 Kermadec Islands
The only truly subtropical part of New Zealand, the Kermadec Islands, has many weed problems and the species involved do not occur elsewhere in New Zealand. Most of the weeds were introduced accidentally with the establishment of the Meteorological Station in 1937 and the subsequent development of the farmlet. The later retirement of the grassland area, and devastation of the forest understorey by goats has further encouraged weed spread. The weeds have been listed (Sykes 1977) and a plan for the control of the most serious ones outlined (e.g. Devine 1977).

Aroid lily has taken over large areas of Raoul Island forest floor and also spread to Meyer Islets. Growing in both low and high light conditions, it swamps ground cover and prevents regeneration. Eradication does not seem possible.

The legume Brazilian buttercup colonises light patches in forest and out-competes native understorey plants. Although the thorny climber, Mysore thorn, forms impenetrable thickets and can smother tall trees, it is virtually confined to Denham Bay and through control its distribution is diminishing. Purple passionfruit can also smother canopy trees.

Guava and Cattley guava are fast growing short trees which, while they don't invade forest, can out-compete native species where they become established. Other problem weeds, particularly of open areas, include African olive, shore hibiscus, Mauritius hemp, Madeira vine, fennel, and buffalo grass.

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TABLE 1.1. Distribution of selected weeds[#] in Northern New Zealand either as significant problem weeds (*), or merely present (+), in protected natural areas.

Problem weed species	Tall forest	Short forest	Scrub & Forest margin	Shrub-land or pakihi	Tall tussock land	Short tussock land	Fern land	Sand dune	Wet land	Open land	Open water
asparagus, climbing		*	*								
banana passionfruit		+	+								
barberry		+	+								
barberry, Darwin's		+	+								
blackberry			*	*							
bone-seed				*				*		*	
boxthorn			*	*				*		*	
broom			+	+						+	
browntop											
buddleia			+	+						+	
cocksfoot											
Douglas fir											
elaeagnus			*	*							
elder											
evergreen buckthorn			*	*							
gorse			+	+							
hakea, downy				*							
hakea, prickly				*							
hakea, willow-leaved			*	*							
hawkweed (king devil)											
hawkweed, mouse-ear											
hawthorn			+								
heather											
honeysuckle, Himalaya			+	+							
honeysuckle, Japanese			*	*							
hydrilla											
ivy		+	+								
ivy, German			+								
kikuyu grass			*	*				*	*		
lagarosiphon											+
larch, European											
lotus									*	+	
lupin, Russell											
lupin, tree								*		*	
marram grass								+			
mist flower			*						*		
Mysore thorn			*	*							
nassella tussock										+	
old man's beard	+	+	+	*							
pampas grass			*	*				*		*	
pampas grass, purple			*	*				*		*	
periwinkle			+								
pine, Corsican			+	+							
pine, kodgepole											
pine, maritime				*		*					
pine, radiata			*	*		+					
privet, Chinese		*	*								
privet, tree		*	*								
robinia			+	+							
rush									*		
selaginella		*	*								
smilax			*	*							
Spanish heath			+	+							
spartina									*		
stinking iris			+	+		+					
sweet brier				+		+				+	
sycamore			+	+							
veld grass											
wandering Jew	*	*	*								
wattle, silver		*	*	*							
wild ginger (kahili)			*	*							
wild ginger (yellow)			*	*							
willow, grey									*		
willow, crack									*		
woolly nightshade			*	*							

[#]The 65 species (or groups) selected have been termed problem weeds in protected natural areas because they permanently alter the structure, successional processes, and organisms present in native communities. The same list is used for Tables 1.1-1.5.

TABLE 1.2. Distribution of selected weeds[#] in Central New Zealand either as significant problem weeds (*), or merely present (+), in protected natural areas.

Problem weed species	Tall forest	Short forest	Scrub & Forest margin	Shrub-land or pakihi	Tall tussock land	Short tussock land	Fern land	Sand dune	Wet land	Open land	Open water
asparagus, climbing											
banana passionfruit		*	*								
barberry		*	*	*							
barberry, Darwin's		*	*	*							
blackberry			*	*					*		
bone-seed				*				*		*	
boxthorn			*	*				*			
broom			*	*	*	*					
browntop									*		
buddleia			*	*						*	
cocksfoot									*	+	
Douglas fir			+	+	+	+					
elaeagnus											
elder			*	*							
evergreen buckthorn				+				+			
gorse			*	*	*	*	*	*		*	
hakea, downy											
hakea, prickly			*	*							
hakea, willow-leaved			*	*							
hawkweed (king devil)											
hawkweed, mouse-ear						*					
hawthorn		*	*	*							
heather				*	*	*					
honeysuckle, Himalaya			*							*	
honeysuckle, Japanese									+		
hydrilla											*
ivy		+	+								
ivy, German		*	*								
kikuyu grass								+			
lagarosiphon											*
larch, European											
lotus									*	*	
lupin, Russell										+	
lupin, tree						*		*			
marram grass								*		*	
mist flower			+								
Mysore thorn											
nassella tussock						+				+	
old man's beard	*	*	*	*					*		
pampas grass			*	*				*	+	*	
pampas grass, purple			*	*				*	+	*	
periwinkle		+	+								
pine, Corsican											
pine, lodgepole					*	*				*	
pine, maritime				*							
pine, radiata				*				*		*	
privet, Chinese		*	*		*						
privet, tree		+	+								
robinia			*	*							
rush									*		
selaginella		+	+								
smilax			*	*							
Spanish heath			*	*							
spartina									*		
stinking iris			+	+							
sweet brier				+		+				+	
sycamore		*									
veld grass										*	
wandering Jew	*	*	*								
wattle, silver										*	
wild ginger (kahili)			+	+							
wild ginger (yellow)											
willow, grey									*		
willow, crack									*		
woolly nightshade			+	+							

[#] The 65 species (or groups) selected have been termed problem weeds in protected natural areas because they permanently alter the structure, successional processes, and organisms present in native communities. The same list is used for Tables 1.1-1.5.

TABLE 1.3. Distribution of selected weeds[#] in Eastern South Island either as significant problem weeds (*), or merely present (+), in protected natural areas.

Problem weed species	Tall forest	Short forest	Scrub & Forest margin	Shrub-land or pakihi	Tall tussock land	Short tussock land	Fern land	Sand dune	Wet land	Open land	Open water
asparagus, climbing											
banana passionfruit		+	*								
barberry		+	+								
barberry, Darwin's		+	+								
blackberry			*	*					*		
bone-seed								+			
boxthorn			*	*				*		*	
broom		*	*	*	*	*			*	*	
browntop					*	*			*		
buddleia					+	+				+	
cocksfoot					*	*			*		
Douglas fir		+	+		+	+					
elaeagnus											
elder			*	*							
evergreen buckthorn				+							
gorse			*	*	*	*	*	*		*	
hakea, downy											
hakea, prickly											
hakea, willow-leaved											
hawkweed (king devil)						*				*	
hawkweed, mouse-ear						*				*	
hawthorn			*	*		*	*				
heather											
honeysuckle, Himalaya			*							*	
honeysuckle, Japanese											
hydrilla											
ivy		+	+								
ivy, German			+								
kikuyu grass											
lagarosiphon											+
larch, European			*	*		*					
lotus									+		
lupin, Russell										*	
lupin, tree								*		*	
marram grass								*		*	
mist flower											
Mysore thorn											
nassella tussock					*	*	*			*	
old man's beard	*	*	*								
pampas grass											
pampas grass, purple											
periwinkle		*	*								
pine, Corsican				*	*	*				*	
pine, lodgepole				*	*	*				*	
pine, maritime											
pine, radiata				*	*	*		*		*	
privet, Chinese											
privet, tree											
robinia			+	+							
rush									+		
selaginella		+	+								
smilax											
Spanish heath		+	+		+						
spartina								*			
stinking iris											
sweet brier				*		*			*		
sycamore		*	*	*							
veld grass											
wandering Jew	+	+	+								
wattle, silver							+		+		
wild ginger (kakili)		+	+								
wild ginger (yellow)											
willow, grey									*	*	
willow, crack									*	*	
woolly nightshade											

[#] The 65 species (or groups) selected have been termed problem weeds in protected natural areas because they permanently alter the structure, successional processes, and organisms present in native communities. The same list is used for Tables 1.1-1.5.

TABLE 1.4. Distribution of selected weeds[#] in Western South Island either as significant problem weeds (*), or merely present (+), in protected natural areas.

Problem weed species	Tall forest	Short forest	Scrub & Forest margin	Shrub-land or pakihi	Tall tussock land	Short tussock land	Fern land	Sand dune	Wet land	Open land	Open water
asparagus, climbing											
banana passionfruit		+	+								
barberry		+	+								
barberry, Darwin's		+	+								
blackberry			*	*			*		*		
bone-seed											
boxthorn								+			
broom										*	
browntop					*	*			*		
buddleia			+	+							
cocksfoot					*	*					
Douglas fir											
elaeagnus											
elder											
evergreen buckthorn											
gorse			*	*	*	*	*	*		*	
hakea, downy											
hakea, prickly											
hakea, willow-leaved											
hawkweed (king devil)											
hawkweed, mouse-ear						+					
hawthorn			+	+							
heather				+							
honeysuckle, Himalaya			+	+							
honeysuckle, Japanese											
hydrilla											
ivy											
ivy, German			+								
kikuyu grass											
lagarosiphon											
larch, European											
lotus									*	*	
lupin, Russell											
lupin, tree								*		*	
marram grass								*			
mist flower											
Mysore thorn											
nassella tussock											
old man's beard	*	*	*								
pampas grass											
pampas grass, purple											
periwinkle		+	+								
pine, Corsican											
pine, lodgepole											
pine, maritime											
pine, radiata											
privet, Chinese											
privet, tree											
robinia			+	+							
rush									*		
selaginella		+	+								
smilax											
Spanish heath			+	+		+					
spartina											
stinking iris											
sweet brier											
sycamore			+								
veld grass											
wandering Jew	*	*	*								
wattle, silver											
wild ginger (kahili)											
wild ginger (yellow)											
willow, grey									*		
willow, crack									*		
woolly nightshade											

[#]The 65 species (or groups) selected have been termed problem weeds in protected natural areas because they permanently alter the structure, successional processes, and organisms present in native communities. The same list is used for Tables 1.1-1.5.

TABLE 1.5. Distribution of selected weeds[#] in Northern New Zealand either as significant problem weeds (*), or merely present (+), in protected natural areas.

Problem weed species	Tall forest	Short forest	Scrub & Forest margin	Shrub-land or pakihi	Tall tussock land	Short tussock land	Fern land	Sand dune	Wet land	Open land	Open water
asparagus, climbing											
banana passionfruit			+	+							
barberry		+	+								
barberry, Darwin's		*	*	*							
blackberry											
bone-seed											
boxthorn								+		+	
broom			*	*	*	*	*		*	*	
browntop					*	*			*		
buddleia			+								
cocksfoot					*	*			*		
Douglas fir					*	*	*				
elaeagnus											
elder			*	*			*				
evergreen buckthorn											
gorse			*	*	*	*	*	*		*	
hakea, downy											
hakea, prickly											
hakea, willow-leaved											
hawkweed (king devil)						*				*	
hawkweed, mouse-ear						*				*	
hawthorn		*	*	*		*	*				
heather				+		+					
honeysuckle, Himalaya			+	+							
honeysuckle, Japanese											
hydrilla											
ivy			*								
ivy, German			*								
kikuyu grass											
lagarosiphon											
larch, European			*	*		*					
lotus						*				*	
lupin, Russell						*				*	
lupin, tree								*		*	
marram grass								*		*	
mist flower											
Mysore thorn											
nassella tussock						*	+			*	
old man's beard	+	+	+								
pampas grass											
pampas grass, purple											
periwinkle		+	+								
pine, Corsican				*	*	*					
pine, lodgepole				*	*	*					
pine, maritime											
pine, radiata				*	*	*		*			
privet, Chinese											
privet, tree											
robinia			+	+							
rush									*		
selaginella			+								
smilax											
Spanish heath			*	*		*					
spartina									*		
stinking iris											
sweet brier				*		*	+			*	
sycamore		*	*	*							
veld grass											
wandering Jew											
wattle, silver											
wild ginger (kakili)											
wild ginger (yellow)											
willow, grey									*		
willow, crack									*		
woolly nightshade											

[#]The 65 species (or groups) selected have been termed problem weeds in protected natural areas because they permanently alter the structure, successional processes, and organisms present in native communities. The same list is used for Tables 1.1-1.5.

APPENDIX 1.1
Common and formal names of weeds occurring in New Zealand protected natural areas referred to in the text or tables, listed in Williams and Timmins (in press), or mentioned by various correspondents to the authors as potentially serious weeds in some localities.

Common name	Formal name
African olive	*Olea africana*
annual poa	*Poa annua*
apple of Sodom	*Solanum linnaeanum*
aroid lily	*Alocasia macrorrhiza*
arum lily	*Zantedeschia aethiopica*
asparagus	*Asparagus asparagoides, A. scandens*
asparagus, climbing	*Asparagus scandens*
banana passionfruit	*Passiflora mollissima*
barberry	*Berberis glaucocarpa*
barberry, Darwin's	*Berberis darwinii*
blackberry	*Rubus fruticosus* agg. (and others)
blue gum	*Eucalyptus globulus*
bone-seed	*Chrysanthemoides monilifera*
boxthorn	*Lycium ferocissimum*
Brazilian buttercup	*Senna septemtrionalis*
Brome grass	*Bromus* spp.
broom	*Cytisus scoparius*
Browntop	*Agrostis capillaris*
buck's-horn plantain	*Plantago coronopus*
buddleia	*Buddleja davidii*
buffalo grass	*Stenotaphrum secundatum*
burdock	*Arctium spp.*
Canadian pond weed	*Elodea canadensis*
Cape honey flower	*Melianthus major*
Cape ivy	*Senecio angulatus*
cathedral bells	*Cobaea scandens*
catsear	*Hypochoeris radicata*
cherry laurel	*Prunus laurocerasus*
cherry, wild	*Prunus avium*
chickweed, mouse-ear	*Cerastium fontanum* ssp. *triviale*
Chilean flame creeper	*Tropaeolum speciosum*
climbing asparagus	*Asparagus scandens*
climbing dock	*Rumex sagittatus*
clover	*Trifolium* spp.
cocksfoot	*Dactylis glomerata*
cotoneaster	*Cotoneaster* spp.
creeping bent	*Agrostis stolonifera*

dally pine	*Psoralea pinnata*
Douglas fir	*Pseudostuga menziesii*
egeria	*Egeria densa*
elaeagnus	*Elaeagnus x reflexa*
elder	*Sambucus nigra*
elm	*Ulmus x hollandica*
evergreen buckthorn	*Rhamnus alaternus*
fennel	*Foeniculum vulgare*
foxglove	*Digitalis purpurea*
foxtail	*Alopecurus pratensis*
German ivy	*Senecio mikanioides*
ginger, wild	*Hedychium spp.*
gorse	*Ulex europaeus*
guava	*Psidium guajava*
guava, Cattley	*Psidium cattleianum*
hakea, downy	*Hakea gibbosa*
hakea, prickly	*Hakea sericea*
hakea, willow-leaved	*Hakea salicifolia*
hawkbit	*Leontodon taraxacoides*
hawkweed	*Hieracium spp.*
hawkweed (king devil)	*Hieracium praealtum*
hawkweed, mouse-ear	*Hieracium pilosella*
hawthorn	*Crataegus monogyna*
heather	*Calluna vulgaris*
hemlock	*Conium maculatum*
Himalaya honeysuckle	*Leycesteria formosa*
holly	*Ilex aquifolium*
hydrilla	*Hydrilla verticillata*
inkweed	*Phytolacca octandra*
Italian arum	*Arum italicum*
Ivy	*Hedera helix*
Japanese bamboo	*Arundinaria japonica*
Japanese honeysuckle	*Lonicera japonica*
Jerusalem cherry	*Solanum diflorum*
jointed rush	*Juncus articulatus*
Kentucky bluegrass	*Poa pratensis*
kikuyu grass	*Pennisetum clandestinum*
king devil	*Hieracium praealtum*
lagarosiphon	*Lagarosiphon major*
larch, European	*Larix decidua*

larch, Japanese	*Larex kaempferi*
Lawson cypress	*Chamaecyparis lawsoniana*
lotus	*Lotus pedunculatus*
lupin, Russell	*Lupinus polyphyllus*
lupin, Russell	*Lupinus polyphyllus x arborea*
lupin, tree	*Lupinus arboreus*
macrocarpa	*Cupressus macrocarpa*
Madeira vine	*Anredera cordifolia*
marram grass	*Ammophila arenaria*
Mauritius hemp	*Furcraea foetida*
Mexican devil	*Ageratina adenophora*
mile-a-minute	*Dipogon lignosus*
mist flower	*Ageratina riparia*
montbretia	*Crocosmia x crocosmiiflora*
Montpellier broom	*Teline monspessulana*
moth plant	*Araujia sericifera*
Mysore thorn	*Caesalpinia decapetala*
nassella tussock	*Stipa trichotoma*
nodding thistle	*Carduus nutans*
oak	*Quercus robur*
old man's beard	*Clematis vitalba*
oxeye daisy	*Leucanthemum vulgare*
oxygen weed	*Elodea canademis, Lagarosiphon major*
oxylobium	*Oxylobium lanceolatum*
pampas grass	*Cortaderia selloana*
pampas grass, purple	*Cortaderia jubata*
periwinkle	*Vinca major*
pine	*Pinus* spp.
pine, Corsican	*Pinus nigra*
pine, lodgepole	*Pinus contorta*
pine, maritime	*Pinus pinaster*
pine, radiata	*Pinus radiata*
pohuehue, large-leaved	*Muehlenbeckia australis*
privet	*Ligustrum ovalifolium*
privet, Chinese	*Ligustrum sinense*
privet, common	*Ligustrum vulgare*
privet, tree	*Ligustrum lucidum*
purple fuzzweed	*Vittadinia gracilis*
purple passionfruit	*Passiflora edulis*
ragwort	*Senecio jacobaea*
robinia	*Robinia pseudacacia*
rush	*Juncus* spp.

salt barley grass	*Hordeum marinum*
selaginella	*Selaginella*
shore hibiscus	*Hibiscus*
smilax	*Asparagus asparagoides*
Spanish heath	*Erica lusitanica*
spartina	*Spartina anglica*
spartina, American	*Spartina alterniflora*
stinking iris	*Iris foetidissima*
strawberry myrtle	*Ugni molinae*
sweet briar	*Rosa rubiginosa*
sweet pea shrub	*Polygala myrtifolia*
sweet vernal	*Anthoxanthum odoratum*
sycamore	*Acer pseudoplatanus*
tall fescue	*Festuca arundinacea*
tall oat grass	*Arrhenatherum elatius*
thorn apple	*Datura stramonium*
thyme, wild	*Thymus vulgaris*
tree lucerne	*Chamaecytisus palmensis*
veld grass	*Ehrharta erecta*
viper's bugloss	*Echium vulgare*
wandering Jew	*Tradescantia fluminensis*
watsonia	*Watsonia bulbillifera*
wattle, black	*Racospema mearnsii*
wattle, brush	*Paraserianthes lophantha*
wattle, golden	*Racosperma longifolium*
wattle, green	*Racosperma decurrens*
wattle, prickly	*Racosperma verticillatum*
wattle, silver	*Racosperma dealbatum*
wild ginger (kakili)	*Heydychium flavescens*
wild ginger (yellow)	*Hedychium gardnerianum*
wild thyme	*Thymus vulgaris*
willow	*Salix* spp.
willow, crack	*Salix fragilis*
willow, grey	*Salix cinerea*
willow weed	*Polygonum* spp.
woolly mullein	*Verbascum thapsus*
woolly nightshade	*Solanum mauritianum*
Yorkshire fog	*Holcus lanatus*

PART 2

WEED MANAGEMENT AND RESEARCH IN NEW ZEALAND PROTECTED NATURAL AREAS

SUMMARY OF PART 2

This second part of the three-part review outlines the Department of Conservation's present approach to weed management and discusses priorities for management and research. Research priorities are based on an assessment of current knowledge of weed ecology, as presented in Part 1, and in the bibliography and sources of information section (Part 3) of this review.

Department of Conservation (DOC) weed control activity is guided by legislation for protected areas and the Noxious Plants Act 1978. As a result DOC is engaged in a wide range of weed control activities. They include major programmes to eliminate ecologically damaging species from a whole region, control weeds in important protected natural areas, control weeds for non-ecological reasons such as track clearance, and control noxious weeds. These different pressures for weed control create different priorities for action.

Despite the diversity of weed management required by legislation and other pressures, most DOC conservancies do not have formal written control plans. Weed control is often directed towards perceived top priority species, but the rationale is rarely stated.

Weed control activity generally receives fewer resources than are required to complete comprehensive programmes and thus management is often in response to immediately perceived problems. Mechanisms for sharing information on weed ecology and control between the widely dispersed DOC staff need to be developed.

Available control methods are summarised for each problem weed. For many weeds the best control is achieved by combining more than one method, e.g. mechanical and chemical controls. For only about half the problem weeds is there a known control technique, even on a local scale. Overseas experience can be applied to the control of some weeds, especially herbaceous weeds, but the control of woody weeds seems to be as much a problem overseas as it is in New Other less commonly used control methods, e.g. grazing, could be considered in the future. Several weeds appear to have potential for biological control but so far priorities for biological control programmes in New Zealand have tended to be set according to the economic importance of weeds rather than their conservation significance.

Weed control should be directed to where it will achieve the greatest conservation benefit for the money spent. It is suggested that weed control will be most effective if the following strategies are pursued:

1) slow the rate of introduction;
2) reduce the susceptibility of protected natural areas to invasions;
3) detect new invasions;
4) establish management priorities in terms of species, places, and circumstances;
5) plan, execute, and monitor control;
6) educate, train, and co-ordinate with other agencies;
7) conduct research.

In terms of species, the priority for action should be those species which have a limited distribution but have the potential to destroy conservation values. A selected number of these will require nationally co-ordinated control programmes. In terms of places, the priorities should be the protected natural areas of highest conservation value - nature reserves, representatives of nationally or regionally threatened communities, or the best representative of a particular community in an ecological district. We suggest that DOC needs to move some of its emphasis in weed control from being species-focused to place-focused. Weed control should be seen as an integral part of good protected areas' management and should be funded as such.

This approach would lead to the establishment of a few reserves in each ecological district which were free of problem weeds. Priority for attention could be given to nationally threatened communities.

A wide range of research on weeds is required. The first priority is to improve the level of knowledge about weeds in those ecological districts where it is limited. To aid collection of appropriate information, two data sheets tailored to DOC's needs have been devised. A national database of all weeds in protected natural areas should be developed to collate and disseminate biological and management information on weeds.

Weed research relevant to protected natural areas should be guided by the principles that the worst weeds are likely to be those that: are known to be harmful in other countries, have a major disruptive effect on the vegetation structure, have a capacity to spread rapidly, are persistent through time, and are difficult to eradicate. Weeds with these characteristics which grow in areas of high conservation value should be studied first. Research should be directed at revealing the 'weak point' of problem weeds. Some regional priorities are presented.

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APPENDICES

2.1 INTRODUCTION

The large number of weeds present in New Zealand protected natural areas (see Part 1) requires DOC to be involved in much expensive weed control. It is not economically possible to control all weeds in all situations. Priorities for management and research of weeds are needed to make best use of staff and resources. This part of the review outlines present approach to weed management and discusses priorities for management and research. It builds on to Part 1, which presents the current knowledge on impact and ecology of weeds in New Zealand. It also draws on Part 3 which provides a guide to further sources of information.

Common names for weeds are used in the text and tables; equivalent formal names for weeds are given in Appendix 2.1. Nomenclature follows Healy and Edgar (1980), Webb *et al.* (1988), or occasionally Esler (1987) if no specific name is used in the previous two texts.

2.2 DEPARTMENT OF CONSERVATION WEED CONTROL ACTIVITY

2.2.1 Legislation

The philosophy of weed control, and much of its impetus, comes from the protected areas legislation, e.g. Reserves Act 1977, National Parks Act 1980, Conservation Act 1987. These require that conservation values be protected from damage by plant pests. For example, the National Parks Act 1980, section 4.2, states that parks are to be managed so that they:

a) shall be preserved as far as possible in their natural state;
b) except where the Authority otherwise determines, the native plants and animals of the parks shall as far as possible be preserved and the introduced plants and animals shall as far as possible be exterminated:"

The other protected natural areas statutes have similar provisions.

These acts are rather demanding, perhaps too demanding given the number and extent of problem weeds present in protected natural areas, let alone less detrimental introduced plants. Problem weeds of protected natural areas are those which permanently alter the structure, successional processes, and organisms present in native communities (see 1.1). Under the auspices of the protected areas legislation, weeds are also controlled for recreation or aesthetic reasons.

In addition, at present at least, DOC is obliged to conform to the requirements of the Noxious Plants Act 1978 in which a noxious plant is defined as one which causes, or may cause, serious economic loss to any person or harm to the environment. This Act requires all land occupiers, including DOC, to draw up written programmes of control, in accordance with the district noxious plants programme, for any noxious plant infestations on their land. These arrangements are currently being reviewed in conjunction with the Resource Management Bill and the demise of the Noxious Plants Council quango. There are likely to be both

nationally funded and co-ordinated noxious plant programmes and regionally administered control programmes with which DOC will have to comply (MAF 1987).

2.2.2 Present Activity

As a result of the above legislation, and other pressures, DOC engages in a wide range of weed control activity. Table 2.1 presents the weed control budget, by each DOC region for the 1988-89 year, as an example of DOC's weed activity and expenditure in any one year. In that year Regional Managers requested a total of $2.9 million but initially only $1 million was allocated. Subsequently, a further $0.9 million became available from supplementary estimates for funding noxious-plant control on unallocated Crown land and unoccupied Maori land. Work accomplished, as well as work proposed but not achieved, in the 1988-89 year is given in Table 2.1. Table 2.2, presenting weed control proposals for the 1989-90 year, is included as an additional example of activity. Note that data were collected prior to 1 July 1989 and thus are based on the 8 DOC regions that applied at that time (Fig. 1, p. 69). Since then DOC has been re-organised and is administered as 15 conservancies (Fig. 2, p. 69). The data in the tables refer to the old regions, and that in the text refers to the new conservancies which came into being on 1.7.89.

2.2.3 Weed Control Strategies

DOC conservancies have refined their weed control strategies to varying degrees (Table 2.3). Most conservancies (then regions and districts) did not have a formal, written weed control plan as at the beginning of 1989. This probably reflected lack of staff resources, or the diversion of staff into other DOC establishment activities, rather than lack of recognition of the need for a plan. Most 1989-90 business plans stated the intention to write a plan in the coming year.

Table 2.3 lists the major aspects of weed control strategies employed by the different conservancies, whether explicitly stated or simply implicit in their activities. In the past, weed control activity was dissipated among a myriad of projects, which reflected the diverse requirements of the legislation. Today, weed control activity is often directed towards a group of species perceived as having top priority, but the rationale is still rarely expressed as a strategy. More usually business plans used general statements such as:

> "prevent or limit damage to conservation estate from plant pests";
> "respond to control of noxious plant problems considered to be of the greatest threat to the environment";
> "control of species with ecological impact".
> "damage", "greatest threat", or "impact" had no criteria given for their assessment.

2.2.4 Effectiveness

The most effective weed control programmes have been those where a co-ordinated plan of attack on a species or reserve has been adopted and concerted effort maintained until the goal has been reached, be that elimination or control. The lodgepole pine programme at Tongariro National Park is an example. This programme has involved departmental staff and

volunteers, departmental money and Noxious Plants Council special grants, helicopter survey and mechanical control. The effort has been sustained so progress has been made. Similarly, the old man's beard programme in the Rangitikei area involves chemical control by departmental staff, mechanical control by school children, a nationwide publicity campaign, a wide ranging education programme including information kits, talks, television clips, field trips, and research into control methods.

By contrast, lack of planning, changes of staff, or fluctuating resources have often led to less than effective control programmes. For example, weed control efforts on Raoul Island have suffered from a lack of consistent effort so that often one good year's work is not capitalised on the following year. The method of control of broom at Tongariro National Park has varied over the years as staff have changed, bringing with them different experiences and convictions, and as funding levels have been varied. This has reduced the overall effectiveness of the broom control programme.

As mentioned earlier, DOC must comply with the Noxious Plants Act 1978. On occasions the demands of the noxious plants legislation, or of an adjacent land owner, has not lead to the best use of the limited money available for weed control for conservation purposes. Indeed, most of the 65 species identified in Part 1 (listed in Tables 1.1 -1.5) as significant problem weeds in protected natural areas are not declared noxious plants. Nevertheless DOC has prepared control measures for these plants (listed in Table 2.4). On the other hand, an often cited conflict is that of spraying gorse, because it is noxious, but which given time and certain situations will be replaced by native species.

Even within the protected areas legislation there can be different priorities. For example, clearing weeds from tracks, camp sites, and other high use facilities, may be important for maintaining recreation values, but is a lower priority weed activity in terms of ecological values. In the 1988-89 year, weed control tasks for recreation purposes were often actioned at the expense of ecologically significant work because the former were achievable within a limited budget.

In addition to legislative requirements, the department must also be sensitive to public and political pressure. The pressure may be to control a highly visible weed, e.g. lake weed in Rotorua lakes, particularly if the Rotorua Yacht Club was to be successful in its application to have the pre-selection trials for the Olympic Games on Lake Rotorua. Conversely, the pressure may be against control of an "attractive" species, e.g. Russell lupin, or against the use of a particular control method, e.g. helicopter-spraying old man's beard near an urban area, or biological control of heather. Political pressure can sometimes change established priorities for weed control in a district. Diversion of money into other activities has reduced the effectiveness of weed control for the protection of ecological values.

In complying with these conflicting pressures, not surprisingly one of the most oft-cited problems in weed control is lack of resources. In 1988-89 Lakes and Takitimu Districts (now Otago Conservancy) received no money specifically for weed control prior to supplementary estimates. In Bay of Plenty Conservancy (previously Eastern Region), there was insufficient money to deal adequately with the huge and continuing problem of lake weed. Only the lake weed that was visible on the surface of the lake was removed, and more money was needed

to remove the rest of the weed. As a cost-benefit analysis on old man's beard control in the Rangitikei has shown, insufficient funding at crucial times can increase the total cost of control (Wanganui Region 1989/90 Business Plan). Similarly, the cheapest long-term option for control of heather in Tongariro National Park may well be biological control (DOC 1988) but this sort of control can only be initiated with a large injection of cash over a relatively few years ($86,000 to $239,500 over 3 to 4 years; Richard Hill, DSIR, pers. comm., Hill 1988). In addition, there are the costs of managing and monitoring the control organisms.

It is not only lack of money that hampers weed control activities. Lack of suitable staff to conduct the control work was identified as a problem in Bay of Plenty and Canterbury Conservancies suggested that departmental staff usually do a more thorough job than contract staff. Bay of Plenty, Canterbury, and West Coast Conservancies all mentioned that lack of staff and money in general, means limited staff movement around the DOC estate. This means reduced chances of early detection of new weed problems or, indeed, limited information on which to plan an effective weed control programme.

Some problems relate to the opposing needs of adjacent land owners or other agencies. Plantations of pine species mean that nearby tussockland or open communities on DOC estate will have a continuing problem of wilding pines because the source of the problem cannot reasonably be expected to be removed. The creation of Lake Dunstan will provide a new habitat for lagarosiphon and an additional weed problem for Otago Conservancy. DOC has a legal obligation, at present at least, to inspect and control noxious weeds on its boundaries even if those weeds are not of ecological significance. In the Rotorua sector of the Bay of Plenty Conservancy, dealing with statutory responsibilities under the Noxious Plants Act 1978 took all the allocated weed control money in 1988189 leaving none for conservation management. Not only can DOC be in a legal bind, it is often poor public relations for DOC to be seen to be inactive on a weed problem, even if inaction makes good ecological or economic sense.

In a few cases lack of knowledge has prevented effective weed control, e.g. heather control at Tongariro National Park, control on Mana Island. In neither case is an effective control method known.

2.3 AVAILABLE METHODS OF WEED CONTROL

2.3.1 Mechanical and Other Methods of Control

Table 2.4 summarises some measures available for control of weeds in PNAs, using a format extended from Esler (1988). In the last 5 years there has been an increasing number of papers and reports dealing with "environmental weeds", and weeds of forestry land such as pampas grass, reported in *Proceedings of the New Zealand Weed and Pest Control Society,* and the journal of the Noxious Weeds Inspectors Institute Inc., *Protect.* Nowhere, however, are there regular reports of the efficacy of various techniques on weeds of protected land. Thus, the entries in Table 2.4 are partly speculative, except for weeds that have been controlled for some time, e.g. broom.

"Hand methods" involve pulling, digging, cutting, i.e. without the aid of machines, whereas "mechanical" methods involve use of machinery, usually an operator holding a petrol-driven or scrub cutter, or sitting on some wheeled vehicle. Biological control is discussed in the following section (2.3.2).

"Local" indicates that a method is effective, but only within a restricted area. The method would be effective over a much wider area if resources were unlimited, e.g. all lodgepole pines in the central North Island could be cut and stump-treated, for a price. "Local" has been used liberally to cover situations where the use of sprays would usually be entirely appropriate, e.g. isolated weeds on riverbeds, to those where their use is more difficult, e.g. weeds near camping grounds, or native vegetation.

"Limited" means either that the method is partially effective, e.g. pines that are merely cut will sometimes resprout, the available sprays achieve only a partial kill, or the effort required is so great as to have only very limited application, e.g. hand removal of grass. Some species are totally resistant to hand or mechanical methods because they have underground parts or other features that make it virtually impossible to remove them, e.g. hawkweed.

Many weeds are known to be susceptible to "chemical" control, while others, such as wild ginger, have had no concerted trials conducted using chemical control, at least as far as the labels of propriety compounds suggest (Esler 1988). It is beyond the scope of this review to recommend particular chemicals, but Part 3 suggests other sources of information.

Many weeds can be controlled by a "combination" of hand or mechanical control with chemical control. This applies particularly to trees and vines where the stumps are cut and the regrowth sprayed.

Other less commonly used control methods could be considered in the future. For example, some weeds can be controlled or even killed by heavy grazing, e.g. pampas grass controlled by beef cattle in pine plantations (West and Dean in press), pines and broom controlled by sheep in tussockland (e.g. Crozier and Ledgard in press), blackberry and gorse controlled by goats (e.g. Radcliffe in press), or aquatic weeds controlled by various introduced fish (e.g. McCarter in press). Some DOC managers have experience in grazing for weed control though there have been few monitored trials to assess the impacts of this grazing on natural values.

Fire and ground raking are other possibilities. Experience in site preparation for forestry is available among staff members at Forest Research Institute, Rotorua; some of this may have application in weed control in PNAs. In Australia, for example, bone-seed scrub is burnt specifically to stimulate the germination of buried seed which is then killed by chemicals (Weiss 1986). The process is most effective if the ground is disturbed to bring buried seeds to the surface. These methods may have particular application in restoration projects or in the removal of small "islands" of seed over a shorter period than would otherwise be the case. Here, as in all weed control programmes, the post-treatment vegetation dynamics must be considered.

Some weeds can be controlled by natural regeneration if the native plants do eventually overtop the weeds. This method is very site-specific and cannot be applied to a weed species as a whole. However, it is often an important part of PNA management, e.g. in the control of gorse or wandering Jew (Kelly and Skipworth 1984).

The control of herbaceous weeds in low stature native vegetation has rarely been attempted. The hand-weeding of an area of montane herbfield with *Ranunculus chrithmifolius* at Castle Hill scientific reserve in Canterbury, and of the only North Island population of *Leptinella nana* near Wellington, are examples of exceptions. Some of the vast international literature on the susceptibility of herbaceous plants to various chemicals may have application in New Zealand, particularly in weed control programmes on very specific sites. However, some of the worst herbaceous weeds, e.g. mouse-ear hawkweed (Scott 1984) are relatively resistant to herbicides.

From the limited information sighted, it appears that where weeds present in New Zealand occur in reserves overseas, the same problems and partial solutions occur. Thus, some solutions to our weed problems could be borrowed (e.g. Boyd 1985). This is encouraging because Table 2.4 indicates that for only about half the weeds in New Zealand protected natural areas is there a known control technique.

2.3.2 Biological Control

Entomology Division, DSIR, is the main organisation in New Zealand conducting research on potential biological control organisms, and managing the release of organisms in full scale field trials. Other DSIR divisions, such as Plant Diseases and Plant Physiology, and other institutions, are likely to be more active in this research in the future (e.g. Johnston in press, Kay in press). The work is partly funded by the District Noxious Plants Authorities (DNPAs) who thus have a large say in which species are investigated. The following section is based partly on notes provided by P. Syrett (pers. comm.).

Biological control has rarely been initiated to control weeds threatening natural values. The initiative has usually come from weed threat to productive values such as those of farmland. Where the same weeds also threaten natural values, protected natural areas benefit. Biological control rarely eliminates target species but can slow their spread and reduce their cover. For example, where native and introduced woody species with overlapping ecological tolerances grow together, e.g. gorse and manuka, biological control of gorse may allow manuka to dominate.

Several of the 12 weed species currently under investigation for biological control threaten protected natural areas. Several organisms are being field-tested for gorse (Hill 1986, Hill and Sandry 1986). Broom is under investigation (Scheele and Syrett 1987, Syrett 1987, Syrett and 1987). Blackberry and sweet brier were investigated but host-specific organisms were not found. Grasslands Division, DSIR, are investigating rusts for control of hawkweed (Scott 1984).

A few other species which threaten conservation values are listed by district noxious plant officers as having moderate priority for control: privet, barberry, hawthorn, wild ginger, and pampas. Some of these warrant investigation if money is available, e.g. barberry, while others

are totally unsuitable for biological control, e.g. pampas grass, because of their close relationship with economic or native plants.

Theoretically there is potential for biological control of weeds primarily of concern in protected natural areas. Heather has been briefly examined (Hill 1988). Preliminary work has begun on old man's beard (Syrett 1984). Overseas work suggests that buddleia, banana passionfruit, hakea species, mist flower, wandering Jew, and woolly nightshade could be candidates for biological control (Julien 1982, Neser *et al.* in press).

The expense of such programmes, and lack of funding, are barriers to biological control of weeds threatening conservation values. This means that programmes will probably be viable only when they can be run jointly with other agencies.

2.4 RECOMMENDED STRATEGIES FOR WEED CONTROL

Weed control should be directed to where it will achieve the greatest conservation benefit for the money spent. Effective weed control involves reserve management and reserve design as well as direct spending on weed control. With input from Macdonald (in press) the following guidelines were formulated at a workshop at the 1988 New Ecological Society conference (Timmins in press):

1) slow the rate of introduction;
2) reduce the susceptibility of protected natural areas to invasions;
3) detect new invasions;
4) establish management priorities in terms of species, places, and circumstances;
5) plan, execute, and monitor control;
6) educate, train, and co-ordinate with other agencies;
7) conduct research.

2.4.1 Slow the Rate of Introduction

Slowing the rate of introduction of weed propagules must be the first step in any weed control strategy. It is counter-productive to attempt control in protected areas of weeds that are still being deliberately imported, e.g kikuyu grass by farmers; or spread, e.g. Russell lupins in the Eglinton Valley; or sold, e.g. cathedral bells by nurseries. Accidental spread can be minimised by restricting roading to and through reserves, controlling visitor movements, and controlling spread of weed propagules, e.g. in road gravel or garden rubbish.

2.4.2 Reduce Susceptibility to Invasions

The number of potential sites which weed species can invade can be reduced by restricting disturbances (Crawley 1986) such as visitor activity (Macdonald *et al.* in press), roading and grazing. Reserve design also has a part to play; protected areas which are small, narrow remnants, with clearings, on fertile soils, and close to towns are the most to weed invasion (Williams and Timmins in press). Where possible, reserves should be designed to minimise these features (Timmins and Williams in press).

2.4.3 Detect New Invasions

Knowledge of the behaviour of weeds in other parts of New Zealand and in other countries, can be used to anticipate which species will become problems. All new invasions in an area should be watched, and recorded preferably on maps, so that control can be initiated as soon as a potential problem is detected. Early detection and action improves the chances of eliminating a potential problem weed. The costs of monitoring, recording, and checking are outweighed by the reduced costs of direct weed control.

2.4.4 Establish Management Priorities

Regional weed management plans must focus on establishing priorities for action in terms of both species and places.

In terms of weed species, features such as ease of establishment, rate of spread, impact on the invaded community, and difficulty of control, can be used to distinguish three types of weeds:

a) those which have a limited distribution but the potential to destroy conservation values, e.g. the recently established cathedral bells;

b) those which are already widespread and doing considerable damage in protected areas, e.g. old man's beard around Wellington;

c) those which are present in reserves but which do not cause catastrophic change, or will disappear with time, e.g. California thistle.

Priority should be given to control of group (a) weeds. Many of these will be among the 65 listed in Tables 1.1-1.5 and Table 2.4, and some will need a nationally co-ordinated programme of action to control them, e.g. cathedral bells. Others are probably not yet recognised as problems.

This approach is in accordance with principles espoused by MAF (1987, 1989) in discussing noxious plants administration. They recommended that the highest priority should be to continue to prevent the importation of weeds not present, or present only in small numbers in New Zealand, i.e. point 1 above (2.4.1). They suggested the second highest priority of central government should be to eradicate weeds which are of very limited distribution, but which have the potential to cause serious harm to any part of the environment if they are not controlled, i.e. group (a) above. This is a prevention rather than cure approach to weed control.

In terms of places, the features of importance are reserve status, reserve values, and feasibility of eradication. DOC needs to shift its emphasis in weed control more towards protecting important protected areas and ecosystems rather than focusing on the control of particular weed species. The following is a suggested priority order of areas:

a) nature reserves;
b) the best examples of nationally threatened communities;

c) the best examples of regionally threatened communities;
d) the best representative of a particular community in an ecological district.

DOC should work towards establishing a selected number of representative unmodified reserves in each ecological district that are free of problem weeds. Priority for attention could be given to nationally threatened communities such as sand dunes and wetlands. This sort of approach treats weed control as an integral part of reserve management rather than as a discrete activity. It also recognises that protected areas without problem weeds have a higher value than those with weeds.

In terms of circumstances it is the feasibility of control which is most significant, including accessibility, level of infestation in the reserve and surrounding area, available control methods, and conflicts of interest. Following the same logic used for species priorities, control should begin with the most feasible situations and later move to the more difficult. Priority should be given to infestations which are small, on stream berms or other transport routes, or at the heads of otherwise 'clean' catchments. This approach deals with smaller problems before they become big problems. Auld *et al.* (1978) have shown that the rate of spread from a number of isolated small infestations is higher than that from a single large one. Modelling studies suggest that overall effectiveness of control measures is greatly improved by destroying even 30% of satellite infestations (Moody and Mack 1988). However, there is usually a critical level of control activity which must be achieved to make any significant impact on the weed population (Auld *et al.* 1978), rather similar to the experience of attempting goat control on Raoul Island (Parkes 1984).

It may only be possible to eradicate a problem weed from selected reserves, or even selected portions of reserves. In Hawaii, for example, the priority sites for weed control in Hawaii Volcanoes National Park are within special ecological areas (Shaw 1988). By confining the problem to realistic proportions, real progress can be made in ecologically important areas.

2.4.5 Plan, Execute, and Monitor Control

Having established the several priorities for control in terms of species, places, and circumstances, a realistic plan for each protected area must be prepared which details what action is required, when, how often, and over what period of years, and the cost of the whole programme. The best control methods, based on current research, should be selected. Some priorities will vary with different sites. For example, oxeye daisy normally has limited impact in a reserve. However, in the Castle Hill nature reserve, where a population of *Ranunculus crithmifolius* is protected, oxeye daisy could be potentially devastating and has a high priority for control.

The plan would provide for monitoring, including mapping, and if necessary further control work. Much weed control money, both for reserves and elsewhere, has been wasted in the past for want of follow-up work, or because of lack of resources to complete the programme.

2.4.6 Educate and Co-ordinate

Both the general public and other agencies must be educated in the need for weed control in reserve management (Auld *et al.* 1978). At the very least they should be educated to avoid spreading weeds through actions such as dumping garden in reserves.

In addition, the public's energies can be harnessed to actively control weeds in and around protected areas, as in the public campaign for control of old man's beard in Wanganui Conservancy and the volunteer programme for eradication of lodgepole pine in Tongariro National Park. Departmental staff, too, need training in: weed control methods including equipment use, type of chemicals to be used, application rates, timing of application, and safety.

It is desirable to co-ordinate weed control efforts with other agencies and within different sections of the department. The new legislation may promote better inter-agency coordination (MAF 1987).

2.4.7 Conduct Research

All the above steps should be supported by continued research into the interactions of native and problem plant species, likely successional pathways, and long-term effects of different management options. The present research priorities are given in Section 2.5.

2.4.8 Administration Strategy

Weed control should be viewed as an integral part of protected natural area management. In some circumstances it may be in the best interests of conservation not to proceed with a particular control programme, especially if it is an overly ambitious one which takes money away from more realistic programmes. On other occasions it will be an essential part of managing a particular reserve. Except for a few selected weed species which will need nationally co-ordinated programmes of control, it is probably inappropriate to separate out funding for weed control from other reserve management funding. Thus, funding for control of grass at Spit should come from Southland Conservancy's estate protection funds for management of that reserve; perhaps biological control of heather at Tongariro National Park from national funds; and funding for willow control to give anglers access to Lake Taupo should come from recreation funds. Therefore, it is recommended that emphasis in weed control should switch from being species-focussed to place-focussed.

2.5 INFORMATION, MONITORING, AND RESEARCH PRIORITIES

A wide range of research on weeds is required. Surveys and plant community studies help to define the problem status of and potential management strategies for weeds in particular circumstances. We also need further investigation of weed control methods. Apart from the actual distribution of species, much weed research needs to be directed towards clarifying the problem of weed invasions in protected natural areas. DOC needs to balance its efforts across the full spectrum of weed research.

2.5.1 Information

Management of weeds in New Zealand protected natural areas is hampered by large gaps in our knowledge and by the wide dispersal of pertinent information in the literature, among various agencies, and within DOC staff (see Part 3).

Some weed control queries could be most simply answered by a detailed search of the literature. Similarly, an evaluation of the experience of staff in DOC, Forest Research Institute, District Noxious Plants Authorities, and other individuals may obviate the need for further field research on some problems. Part 3 of this review indicates the weed species which are candidates for these two types of analysis.

Much information held by DOC staff is unavailable to others because it is not systematically recorded or deposited. To accommodate all the above difficulties DOC would be well served by compiling a comprehensive database on weeds in PNAs.

To aid collection of appropriate information and to bring together existing information we have developed two data sheets tailored to DOC's needs (Appendix 2.2).

The **Taxon Sheet** details the main biological features of a weed, as would be found in scientific reviews such as the biological flora series in either *Journal of Ecology* or *Journal of Australian Institute of Agricultural Research.*

The **Impacts and Management Sheet** focuses on the effects of the weed and approaches required to lessen these effects. It is similar to recent summaries of weeds in natural areas, e.g. Macdonald and Jarman (1984). These two sheets have been filled in for **3** examples, a grass, a climber and a tree (Appendix 2.2). The data obtained from these sheets will provide a database. This should be computerised so it can be searched by DOC staff throughout New Zealand and continually updated.

This database could be extended with a third sheet on Weed Control Measures. A standard format for recording weed control measures, perhaps taking into consideration some of the details presently recorded in similar schemes run by some district noxious plants authorities, would be very useful. In this way each attempt at weed control would become an experiment, albeit often with limited rigour, from which others can profit. Such information would be most useful for new weeds or novel methods. More formal trials, similar to those already tried on wandering Jew by Kelly and Skipworth (1984) could also be done.

The conclusions for individual control operations or trials could be added as a fourth sheet to the database suggested above and thus become available to all DOC staff.

2.5.2 Weed Monitoring, Community and Autecological Research

Historically, weed researchers interested in wild plants generally have been employed in organisations separate from those responsible for weeds in PNAs. As a result very little conservation-related weed research has been conducted or co-ordinated.

Apart from the continual updating of the information base from the literature and day to day experience of managers as discussed in section 2.5.1, the requirements for research on weeds ranges from systematic field surveys to intensive autecological studies and control measures.

The first priority is to improve the level of weed knowledge in ecological districts where it is limited; parts 1 and 3 of this review highlight the wide disparity in knowledge available about weeds in different parts of New Zealand.

Many plants are considered weeds because of a complexity of anthropocentric reasons, not necessarily related to their impact on the native biota. Thus, the second general priority is to investigate the biological nature of adventive plant/native biota interactions and to understand the ecology of the weeds themselves. With luck these studies will reveal the weed's weak points and indicate areas of research that may assist directly with their management.

In most areas of New Zealand the highest priority for future weed research should go to autecological and community studies involving low or shrubby vegetation. The exceptions include study of climbers such as old man's beard, wandering Jew and banana passionfruit.

We know very little about the ecology of most of our weed species, e.g. wild ginger, asparagus species, hakea species, and buddleia. Autecological studies of these species, wherever they were conducted, would reveal useful information on their interaction with native biota. This information would be directly applicable to management strategies.

For other species, particularly agricultural plants, there is a vast literature on their biology but almost nothing is known about their impact on the natural environment which may thus be underestimated, e.g. browntop in tussocklands and tall fescue or jointed rush in wetlands. Monitoring is a priority for these species, and for those at the limits of their range, e.g. banana passionfruit on the West Coast, as well as for species that we have not listed but which may become problem weeds, e.g. dally pine, cathedral bells.

A third general area where we lack knowledge is in management tactics. For a few species we know a lot about their biology and gross impacts but not how to manage them, e.g. gorse, broom and pampas grass. Research may be directed specifically at eradication techniques, e.g. for wandering Jew, or more generally at the effects of grazing on mouse-ear hawkweed.

Some people have suggested that DOC research should be directed at the development of entirely new chemicals for control of particular weeds. It is most unlikely that DOC could afford such research. Nor should DOC embark on biological projects on its own. Rather it

should contribute to projects which are directly relevant to PNA needs but which would not otherwise be conducted without DOC's support, e.g. old man's beard control. DOC should not subsidise projects which primarily benefit the agricultural industry, e.g. control of nodding thistle.

Because weed problems are usually highly site-specific, research priorities are best discussed on a regional basis using the regions defined in Part 1 (1.3). As we hope this review will be a guide that will be used for several years, priorities are presented in general terms and precise projects have not been ranked here.

2.5.2.1 Northern New Zealand

Autecological studies in the far north should concentrate initially on the weeds of gumlands and shrublands, especially on the hakeas and oxylobium. Further south in the Auckland area the highest priority is weeds of low forest and shrublands, particularly those species about which little is known either here or overseas, e.g. privet, wild ginger, climbing asparagus, and smilax. Research on these species will allow management to be directed most effectively.

2.5.2.2 Central New Zealand

Effective control techniques for old man's beard has a high priority for research, despite the work done in several recent studies (Popay 1986, West in prep a,b). This is because old man's beard is so widespread, and so damaging to conservation values, across much of central New Zealand.

Another high priority for research is into ways of limiting invasion of several weed species into the tussockland and openland of central North Island. The invasions of species of pine, heather, and pampas have been studied to some extent, but there appears to be very little information on buddleia. Two of the hakeas, prickly and willow-leaved, which threaten northern gumlands, also occur in central New Zealand but over smaller areas.

The third important topic is weed invasions of the rapidly dwindling areas of lowland wetlands, including turf communities. A fourth research priority is on effective methods of control of weeds on sand dunes.

2.5.2.3 Eastern South Island

The priority for research here concerns herbaceous and woody weeds invading tussockland and shrubland. In particular, managers need to know the appropriate measures to control their spread, which may include the use of fire and grazing management. Some work has been done on the autecology of some of the weeds involved, e.g. by FRI, and Grasslands and Botany Divisions, DSIR, while for other species, e.g. browntop, a massive overseas literature is available. But for the most part management is proceeding without the backing of appropriate research.

A second priority is to study the weeds of braided rivers, especially at their present inland (western) limits, and to determine the most cost-effective methods for their control where this is justified. The species involved are also important weeds of openlands, and in some cases sand dunes. There is a particular need to develop specific management techniques to reduce the invasion of grass on Kaitorete Spit which is so important as an unmodified

sand dune system.

A third priority is weeds of scrub and low forest, with the largest and most long-lived species being the most important, i.e. sycamore. (This species is also important in central New Zealand.) It is a typical example of a weed which has the capacity to disrupt forest succession but we know little about its role in this process.

2.5.2.4 Western South Island

Marram grass, tree lupin, and gorse on sand dunes, particularly in the far south of the region, are the weeds most requiring research. Research is needed on both the biology and the control of these species, particularly grass.

2.5.2.5 Southern South Island

As with eastern South Island the main priority for research is weed invasion of tussockland. Because this region and parts of Western South Island have the largest remaining areas of unmodified sand dunes in New Zealand, research about keeping these communities free of weeds, particularly grass, is also a high priority.

2.5.2.6 Outlying Islands

The main priority is to continue monitoring the existing weeds. On Kermadec Islands careful recording of weed distributions and control work, planning, and thus appropriate follow-up work are also priorities. Any research on the interaction of native and exotic herbaceous species would be particularly relevant to these island situations.

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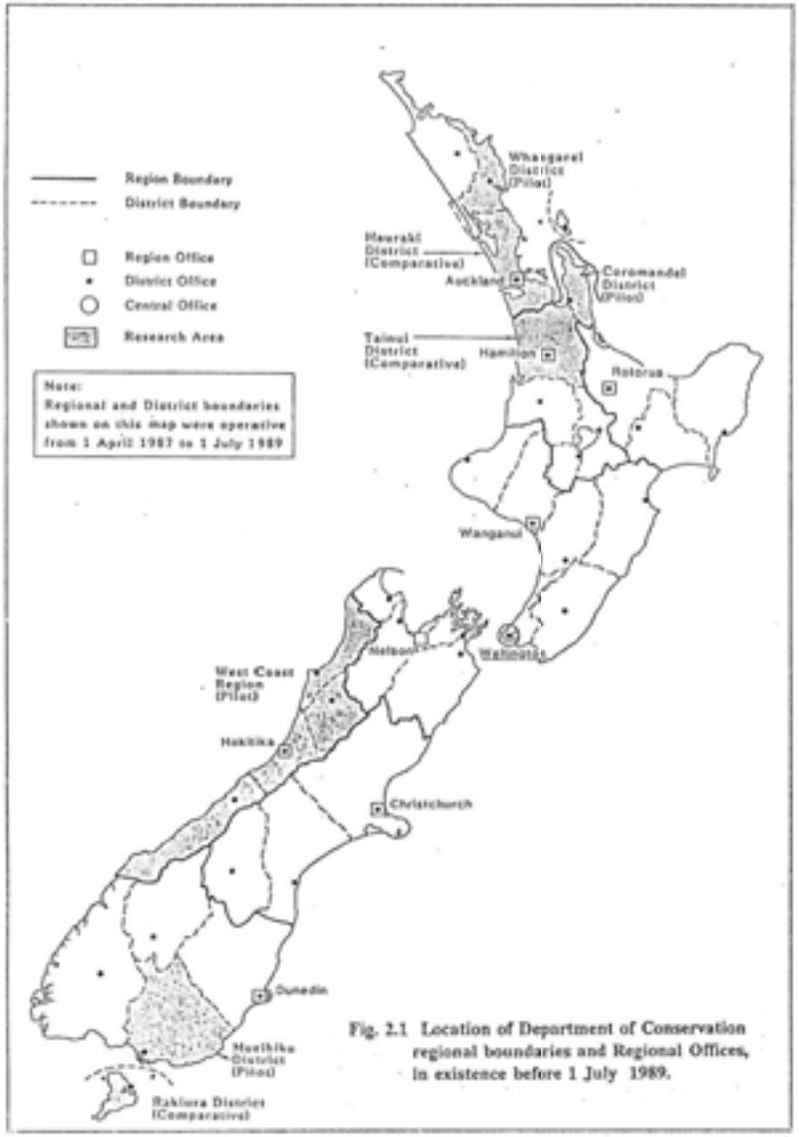

Fig. 2.1 Location of Department of Conservation regional boundaries and Regional Offices, in existence before 1 July 1989.

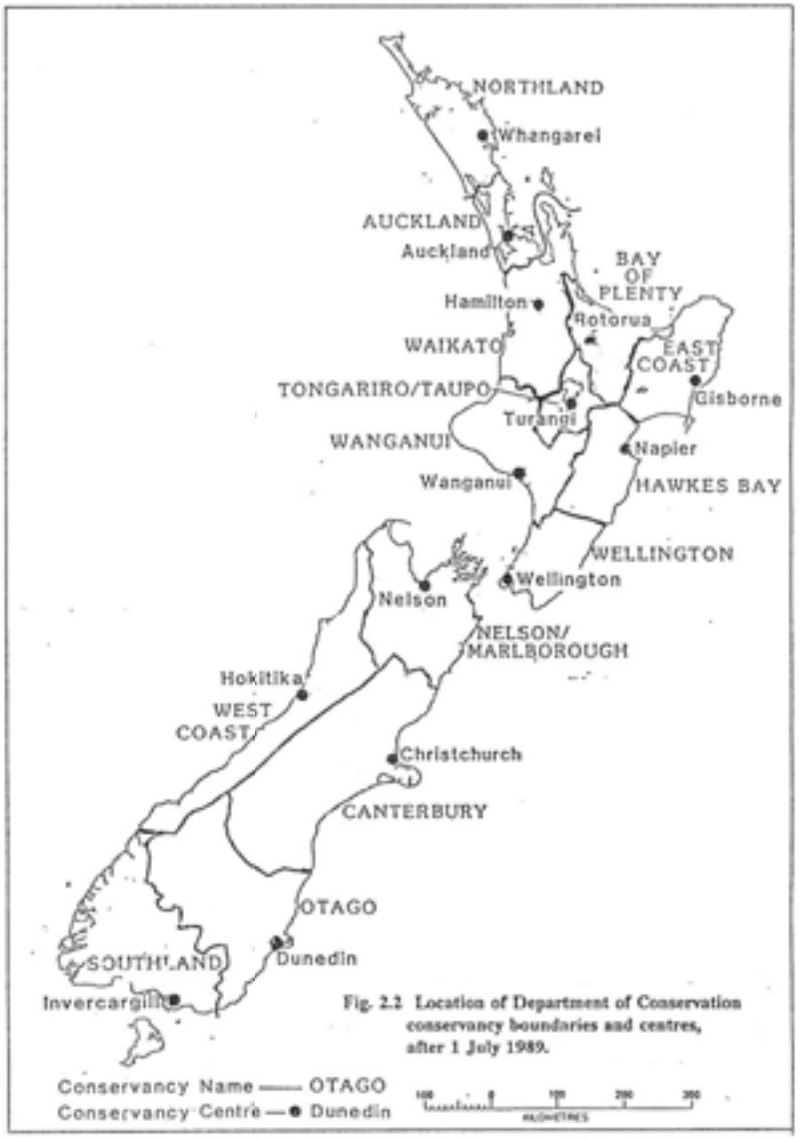

Fig. 2.2 Location of Department of Conservation conservancy boundaries and centres, after 1 July 1989.

TABLE 2.1. Weed control budget and work programme of the Department of Conservation for the financial year ending 31 March 1989.

DOC Region +	Request ($000)	Allocat. ($000)	Sup.Est.# ($000)	(a) Work accomplished (b) Work proposed but not achieved
Northern	45	25	0	(a) Road/track verges, picnic areas (b) Gorse localised and recently colonised areas Pampas where recent colonist Spartina
Waikato	425	160	35	(a) Lodgepole pine - Tongariro National Park, Rangitaiki, Lake Taupo** Broom Marram, buddleia, cottoneaster Willow - low priority (b) Gorse, lupin - containment to protect Tongaririo NP and conservation parks* Spartina - low priority Willow -low priority Spartina -low priority
Eastern	285	170	158	(a) Lagarosiphon and egeria -Rotorua lakes** Buddleia, gorse, broom, blackberry - roadside and camping areas Nassella tussock –localised Spartina - estuaries (b) Wilding pines, buddleia, heather, pampas -Urewera NP* Buddleia -Lake Rotoma Old man's beard –Tarawera Landing, Okareka River
Wanganui	635	195	235	(a) Old man's beard** (b)Lodgepole pine – northern Ruahines, Kawekas* Spartina – Manawatu estuary* Hydrilla – localised, Lake Tutira Blackberry, gorse, buddleia, broom, pines, barberry, Japanese honeysuckle, Himalaya honeysuckle, - Wanganui NP

TABLE 2.1 continued

DOC Region +	Request ($000)	Allocat. ($000)	Sup.Est.# ($000)	(a) Work accomplished (b) Work proposed but not achieved
				(b) Raupo - encroachment Pukepuke Lagoon Willow -low priority
Nelson	225	75	135	(a) Nassella tussock (b) Old man's beard Wilding pines -island reserves, Molesworth, Tasman NP "Brushweeds" [sic] - island reserves Sweet brier -localised Spartina -low priority
Canterbury	330	65	140	(a) No information on accomplishments (b) Wilding conifers* Nassella tussock Marram grass Russell lupin Wattle, blue gum - localised Broom, gorse, hawkweed, nodding thistle, old man's beard, tree lupin, spartina, browntop, sweet vernal, large-leaved pohuehue
West Coast	245	120	65	(a) Old man's beard Buller, Karamea Rivers* Gorse, broom, blackberry in recently colonised areas Marram grass - Cascade River Spartina – Karamea
Southern	720	170	224	(a) Lodgepole pine, other pines, gorse and broom** Old man's beard Spartina -low priority Gorse, broom, blackberry -small reserves Tree lupin** Marram grass** Elder

TABLE 2.1 continued

DOC Region +	Request ($000)	Allocat. ($000)	Sup.Est.# ($000)	(a) Work accomplished (b) Work proposed but not achieved
				(b) Lagarosiphon – Lake Wanaka Russell lupin, foxglove, marram grass, willow - Fiordland NP Blue gum
Central		20		

+	-Information collected prior to 1 July 1989 so is based on DOC regions (Fig. 2.1), not on present Conservancy areas (Fig. 2.2)
Allocat.	-Allocation
# Sup. Est.	-Supplementary estimates - funding for noxious plant control on unallocated lands of the Crown and unoccupied Maori land
*	-$ 50,000 to $150,000 requested
**	-$1,250,000-plus requested
NP	-National Park

TABLE 2.2. Weed control proposals of the Department of Conservation for the financial years 1 April 1989 - 30 June 1989 and 1 July 1989 - 30 June 1990.

DOC Region [+]	Net allocation # June 89	June 90	Proposed weed activity (1 April 1989 – 30 June 1990)
Northern	35,842	148,366	Gorse,wild ginger, and apple of Sodom invading DOC lands Pampas, Mexican devil on offshore islands Evergreen buckthorn on Rangitoto and Motutapu Islands Japanese honeysuckle on Tiritiri Island Privet and woolly nightshade on North Head Weed control in camping grounds, picnic areas, and adjacent to high use tracks and walkways
Waikato	59,400	300,900	Lodgepole pine at Tongariro National Park Broom Class B noxious plants
Eastern	40,000	116,000	Lake weeds Class B noxious plants Protection of identified high priority conservation areas; control of old man's beard, spartina, lodgepole pine, nassella tussock
Wanganui	149,105	646,680	Old man's beard in all districts Boxthorn on Mana Island Lodgepole pine in NE Ruahines and Kawekas Spartina in Manawatu Estuary Marram grass on Manawatu Coast Blackberry in Wanganui River Pampas grass and boxthorn in Harakeke Conservation Area
Nelson	29,452	163,269	Nassella tussock in Omakau Bay Old man's beard in scenic reserves Pines on Molesworth Spartina in Kenepuru and Queen Charlotte Sounds Climbing dock at Farewell Spit Cotoneaster in Cobb Valley
Cantebury	72,000	136,500	Old man's beard on Banks Peninsula Marram grass at Kaitorete Spit and Banks Peninsula

TABLE 2.2 continued

DOC Region [+]	Net allocation # June 89	June 90	Proposed weed activity (1 April 1989 – 30 June 1990)
West Coast	21,000	85,000	Old man's beard in Buller River Marram grass in Cascade Valley Willow at Paringa Spartina in Karamea Noxious weeds in Paparoa National Park
Southern	77,701	391,178	Lagarosiphon in Lakes Wanaka and Dunstan, Clutha River Wilding pines at Wakatipu, Blue Mountains, northern Southland Tree lupin on Rakiura Gorse and broom in riverbeds in Takitimu District Lodgepole pine in Eyre Mountains, Nardoo, Black Rock Spartina in estuaries Annual poa and chickweed on Snares Islands Exotic trees at Mason Bay *Olearia lyalli* on Auckland Islands

\+ - Information collected prior to 1 July 1989 so is based on DOC regions (Fig. 2.1), not on present Conservancy areas (Fig. 2.2)

\# - Net allocation sought in 1989/90 business plans, divided into 2 bids for 3-month period 1 April to 30 June 1989, and 12-month period 1 July 1989 to 30 June 1990

TABLE 2.3. Weed control strategies developed by Regional Offices (pre-1989) of the Department of Conservation.

DOC Region[+]	Strategy
Northern	Comply with statutory requirements Protect important natural ecosystems Control weeds in highly visible areas
Waikato	Concentrate on major plant in top priority protected natural area, i.e. lodgepole pine in Tongariro National Park Co-ordinate all agencies involved Use volunteer labour Prevent spread; eliminate plants before seeding Begin control in low density areas Prevent spread by waterways
Eastern	Comply with DNPO requirements Containment, but not eradication, of lakeweed
Wanganui	Concentrate on major plant, i.e. old man's beard Integrated control plan involving control programme, volunteers, monitoring, publicity Public education campaign to mobilise volunteer labour Do it properly first time
Nelson	Control of species spreading into threatened communities
Canterbury	Comply with statutory requirements Put as much effort into noxious plants as into classified plants Eradicate outlier infestations Eradicate species which have proved to be a major problem in other parts of the country Eradicate species overcoming native communities Prevent sources of exotic plant spread, e.g. shingle, structures, horses Educate people to report problem plants in remote places Time control methods for maximum effectiveness Use natural succession to control weeds when appropriate
West Coast	Continue with existing weed control programmes Eradicate new weed infestations
Southern	Control of weeds on high priority areas of DOC estate, i.e. those of ecological importance, e.g. Fiordland National Park, Snares, Codfish Island

+ Information collected prior to 1 July 1989 so is based on DOC regions (Fig. 2.1), not on present Conservancy areas (Fig. 2.2)

TABLE 2.4. Summary of some control measures available for selected+ weeds in New Zealand protected natural areas.

Weed species	Hand[1]	Mech.[2]	Chem.[3]	Comb.[4]
asparagus, climbing		lim[5]	lim	
banana passionfruit	lim		lim	
barberry	lim	lim	lim	loc[6]
barberry, Darwin's	lim	lim	lim	loc
blackberry	lim	lim	loc	loc
bone-seed	lim	lim	loc	loc
boxthorn	lim	lim	lim	loc
broom	lim	lim	loc	
browntop			loc	
buddleia	lim	lim	lim	loc
cocksfoot			loc	
Douglas fir	lim	lim	lim	loc
elaeagnus		lim	loc	
elder	lim	lim	loc	
evergreen buckthorn	lim			
gorse	lim	lim	loc	loc
hakea, downy	lim	lim		loc
hakea, prickly	lim	lim		loc
hakea, willow-leaved	lim	lim		loc
hawkweed (king devil)				
hawkweed, mouse-ear			lim	
hawthorn	lim	lim	lim	loc
heather	lim		lim	
honeysuckle, Himalaya	lim	lim	lim	
honeysuckle, Japanese		lim	loc	
hydrilla				
ivy	lim		lim	
ivy, German	lim		lim	
kikuyu grass			lim	
lagarosiphon				
larch, European	lim	lim		loc
lotus			loc	
lupin, Russell	lim	lim	loc	
lupin, tree	lim	lim	loc	
marram grass	lim		lim	
mist flower				
Mysore thorn		lim	lim	
nassella tussock	lim		loc	
old man's beard			loc	loc

TABLE 2.4 continued

Weed species	Hand[1]	Mech.[2]	Chem.[3]	Comb.[4]
pampas grass		lim	loc	
pampas grass, purple		lim	loc	
periwinkle			loc	
pine, Corsican	lim	lim		loc
pine, lodgepole	lim	lim		loc
pine, maritime	lim	lim		loc
pine, radiata	lim	lim		loc
privet, Chinese	lim	lim	lim	loc
privet, tree	lim	lim	lim	loc
robinia	lim	lim	loc	loc
rush			loc	
selaginella				
smilax		lim		
Spanish heath	lim	lim	loc	loc
spartina			loc	
stinking iris	lim			
sweet brier	lim	lim	loc	loc
sycamore	lim	lim	lim	loc
veld grass	lim	lim	loc	
wandering Jew	lim		lim	
wattle, silver	lim	lim	loc	loc
wild ginger (kakili)	lim	lim	lim	
wild ginger (yellow)	lim	lim	lim	
willow, grey		lim	loc	loc
willow, crack		lim	loc	loc
woolly nightshade	lim	lim	lim	loc

\+ The 65 species (or groups) selected have been termed problem weeds in protected natural areas because they permanently alter the structure, successional processes, and organisms present in native communities.
The same list is used in Tables 1.1-1.5.

[1]Hand = pulling or other forms of hand removal

[2]Mech. = mechanical devices such as

[3]Chem. = chemical sprays or other forms of chemical application

[4]Comb. = combination of two methods, usually cutting and spraying
Other forms of control, i.e. grazing and biological control, are applicable in very few cases (see 2.3.1, 2.3.2)

[5]lim. = effective only to a limited extent either because of the effort required, or plant is resistant

[6]loc.= effective on a local scale

Species with no entries indicate no information, or are not fully covered by this report

APPENDIX 2.1
Common and formal names of weeds occurring in New Zealand protected natural areas referred to in the text or tables, listed in Williams and Timmins (in press), or mentioned by various correspondents to the authors as potentially serious weeds in some localities.

Common name	Formal name
African olive	*Olea africana*
annual poa	*Poa annua*
apple of Sodom	*Solanum linnaeanum*
aroid lily	*Alocasia macrorrhiza*
arum lily	*Zantedeschia aethiopica*
asparagus	*Asparagus asparagoides, A. scandens*
asparagus, climbing	*Asparagus scandens*
banana passionfruit	*Passiflora mollissima*
barberry	*Berberis glaucocarpa*
barberry, Darwin's	*Berberis darwinii*
blackberry	*Rubus fruticosus* agg. (and others)
blue gum	*Eucalyptus globulus*
bone-seed	*Chrysanthemoides monilifera*
boxthorn	*Lycium ferocissimum*
Brazilian buttercup	*Senna septemtrionalis*
Brome grass	*Bromus* spp.
broom	*Cytisus scoparius*
Browntop	*Agrostis capillaris*
buck's-horn plantain	*Plantago coronopus*
buddleia	*Buddleja davidii*
buffalo grass	*Stenotaphrum secundatum*
burdock	*Arctium spp.*
Canadian pond weed	*Elodea canadensis*
Cape honey flower	*Melianthus major*
Cape ivy	*Senecio angulatus*
cathedral bells	*Cobaea scandens*
catsear	*Hypochoeris radicata*
cherry laurel	*Prunus laurocerasus*
cherry, wild	*Prunus avium*
chickweed, mouse-ear	*Cerastium fontanum* ssp. *triviale*
Chilean flame creeper	*Tropaeolum speciosum*
climbing asparagus	*Asparagus scandens*
climbing dock	*Rumex sagittatus*
clover	*Trifolium* spp.
cocksfoot	*Dactylis glomerata*
cotoneaster	*Cotoneaster* spp.
creeping bent	*Agrostis stolonifera*

dally pine	*Psoralea pinnata*
Douglas fir	*Pseudostuga menziesii*
egeria	*Egeria densa*
elaeagnus	*Elaeagnus x reflexa*
elder	*Sambucus nigra*
elm	*Ulmus x hollandica*
evergreen buckthorn	*Rhamnus alaternus*
fennel	*Foeniculum vulgare*
foxglove	*Digitalis purpurea*
foxtail	*Alopecurus pratensis*
German ivy	*Senecio mikanioides*
ginger, wild	*Hedychium spp.*
gorse	*Ulex europaeus*
guava	*Psidium guajava*
guava, Cattley	*Psidium cattleianum*
hakea, downy	*Hakea gibbosa*
hakea, prickly	*Hakea sericea*
hakea, willow-leaved	*Hakea salicifolia*
hawkbit	*Leontodon taraxacoides*
hawkweed	*Hieracium spp.*
hawkweed (king devil)	*Hieracium praealtum*
hawkweed, mouse-ear	*Hieracium pilosella*
hawthorn	*Crataegus monogyna*
heather	*Calluna vulgaris*
hemlock	*Conium maculatum*
Himalaya honeysuckle	*Leycesteria formosa*
holly	*Ilex aquifolium*
hydrilla	*Hydrilla verticillata*
inkweed	*Phytolacca octandra*
Italian arum	*Arum italicum*
Ivy	*Hedera helix*
Japanese bamboo	*Arundinaria japonica*
Japanese honeysuckle	*Lonicera japonica*
Jerusalem cherry	*Solanum diflorum*
jointed rush	*Juncus articulatus*
Kentucky bluegrass	*Poa pratensis*
kikuyu grass	*Pennisetum clandestinum*
king devil	*Hieracium praealtum*
lagarosiphon	*Lagarosiphon major*
larch, European	*Larix decidua*

larch, Japanese	*Larex kaempferi*
Lawson cypress	*Chamaecyparis lawsoniana*
lotus	*Lotus pedunculatus*
lupin, Russell	*Lupinus polyphyllus*
lupin, Russell	*Lupinus polyphyllus x arborea*
lupin, tree	*Lupinus arboreus*
macrocarpa	*Cupressus macrocarpa*
Madeira vine	*Anredera cordifolia*
marram grass	*Ammophila arenaria*
Mauritius hemp	*Furcraea foetida*
Mexican devil	*Ageratina adenophora*
mile-a-minute	*Dipogon lignosus*
mist flower	*Ageratina riparia*
montbretia	*Crocosmia x crocosmiiflora*
Montpellier broom	*Teline monspessulana*
moth plant	*Araujia sericifera*
Mysore thorn	*Caesalpinia decapetala*
nassella tussock	*Stipa trichotoma*
nodding thistle	*Carduus nutans*
oak	*Quercus robur*
old man's beard	*Clematis vitalba*
oxeye daisy	*Leucanthemum vulgare*
oxygen weed	*Elodea canademis, Lagarosiphon major*
oxylobium	*Oxylobium lanceolatum*
pampas grass	*Cortaderia selloana*
pampas grass, purple	*Cortaderia jubata*
periwinkle	*Vinca major*
pine	*Pinus* spp.
pine, Corsican	*Pinus nigra*
pine, lodgepole	*Pinus contorta*
pine, maritime	*Pinus pinaster*
pine, radiata	*Pinus radiata*
pohuehue, large-leaved	*Muehlenbeckia australis*
privet	*Ligustrum ovalifolium*
privet, Chinese	*Ligustrum sinense*
privet, common	*Ligustrum vulgare*
privet, tree	*Ligustrum lucidum*
purple fuzzweed	*Vittadinia gracilis*
purple passionfruit	*Passiflora edulis*
ragwort	*Senecio jacobaea*
robinia	*Robinia pseudacacia*
rush	*Juncus* spp.

salt barley grass	*Hordeum marinum*
selaginella	*Selaginella*
shore hibiscus	*Hibiscus*
smilax	*Asparagus asparagoides*
Spanish heath	*Erica lusitanica*
spartina	*Spartina anglica*
spartina, American	*Spartina alterniflora*
stinking iris	*Iris foetidissima*
strawberry myrtle	*Ugni molinae*
sweet briar	*Rosa rubiginosa*
sweet pea shrub	*Polygala myrtifolia*
sweet vernal	*Anthoxanthum odoratum*
sycamore	*Acer pseudoplatanus*
tall fescue	*Festuca arundinacea*
tall oat grass	*Arrhenatherum elatius*
thorn apple	*Datura stramonium*
thyme, wild	*Thymus vulgaris*
tree lucerne	*Chamaecytisus palmensis*
veld grass	*Ehrharta erecta*
viper's bugloss	*Echium vulgare*
wandering Jew	*Tradescantia fluminensis*
watsonia	*Watsonia bulbillifera*
wattle, black	*Racospema mearnsii*
wattle, brush	*Paraserianthes lophantha*
wattle, golden	*Racosperma longifolium*
wattle, green	*Racosperma decurrens*
wattle, prickly	*Racosperma verticillatum*
wattle, silver	*Racosperma dealbatum*
wild ginger (kakili)	*Heydychium flavescens*
wild ginger (yellow)	*Hedychium gardnerianum*
wild thyme	*Thymus vulgaris*
willow	*Salix* spp.
willow, crack	*Salix fragilis*
willow, grey	*Salix cinerea*
willow weed	*Polygonum* spp.
woolly mullein	*Verbascum thapsus*
woolly nightshade	*Solanum mauritianum*
Yorkshire fog	*Holcus lanatus*

APPENDIX 2.2

Formats for the **Taxon Sheet** (p. 84), and **Impacts and Management Sheet** (p. 88), for weeds in New Zealand protected natural areas. Samples filled in to demonstrate their use are provided for three examples - a grass (pp. 85, 89), a climber (pp. 86, 89), and a tree (pp. 87, 91).

Weeds of New Zealand Protected Natural Areas -
Taxon Sheet

1. **Common Name:** **Family:**

   Formal Name: **Synonym:**

2. **Distribution**: present infestation (l low, m medium, h high) / potential infestation (l, m, h):

3. **Habitat**: coastal / lowland / montane / subalpine / alpine

4. **Substrate, fertility:**

5. **Communities:** tall forest / low forest / scrub and forest margin / shrubland / tall tussockland / short tussockland / herbfield / fernland / sand dune / cliff, bluff / riverbed / wetland / other
   Comments:

6. **Growth and reproduction**: herb, grass / woody herb / shrub / small tree / large tree / climber / other
   Comments:

   Breeding system:
   Life cycle:
   Deciduous, evergreen:
   Age to reproduction:
   Life span:
   Seed production (yes / no)
   Seed dispersal: explosive / gravity /wind /water / man / vertebrates / invertebrates / other
   Vegetative reproduction:
   Seed viability and germination:
   Seed bank:

7. **Response to environment**: seedling requirements and tolerances:
   Growth rates:

   Response to
   drought:
   shade:
   frost:
   physical damage:
   fire:
   grazing:
   other:

8. **General facilitation:**

9. **Predators and parasites**:
   New Zealand:

   Elsewhere:

10. **Date of last revision:**

Weeds of New Zealand Protected Natural Areas -
Taxon Sheet

1. **Common Name:** *marram grass* **Family:** *Gramineae*

Formal Name: *Ammophila arenaria (L.) Link* **Synonym:** *none in use in NZ*

2. **Distribution**: present infestation (l low, m medium, h high) / potential infestation (l, m, h):
Coastal throughout NZ; high infestations throughout except for Sotuh Westland and parts of Southland where infestations are low. Also inland Central Otago (l/-) and Volcanic Plateau.

3. **Habitat**: coastal / lowland / montane / subalpine / alpine

4. **Substrate, fertility:** *sand dunes; unstable; free draining; low nutrients; low organic matter*

5. **Communities:** tall forest / low forest / scrub and forest margin / shrubland / tall tussockland / short tussockland / herbfield / fernland / sand dune / cliff, bluff / riverbed / wetland / other

6. **Growth and reproduction**: herb, grass / woody herb / shrub / small tree / large tree / climber / other
Comments: *buds formed in the surface and on deeper rhizomes. These extend laterally then vertically. Growth patterns enable it to survive when buried by mobile sand. Once population has established, and on stable dunes, the shoot production involves on replacement of dead tillers.*
Breeding system: *strongly protandrous, wind pollinated*
Life cycle: *rarely established from seed, perennial grass, clonal spread important*
Deciduous, evergreen: *grows throughout the year*
Age to reproduction: *sexual at least two years; asexual expansion once plant established*
Life span: *veg. reproduction means gennets may be hundreds of years old*
Seed production (yes / no):
Seed dispersal: explosive / gravity /wind /water / man / vertebrates / invertebrates / other
Vegetative reproduction: *most important aspect of growth- see above*
Seed viability and germination: *variable, but up to 90% after 40 days. Highest after winter chilling, in fluctuating temperatures and with high light*
Seed bank: *some seed dormancy but it is not strong, most seeds germinate in the autumn*

7. Response to environment: seedling requirements and tolerances:
Growth rates: *seedlings rarely establish, but adult growth rate rapid*

Response to
drought: *strongly drought tolerant*
shade: *intolerant*
frost: *tolerant*
physical damage: *recovers from crushing and breaking*
fire: *recovers from fire, by underground rhizomes*
grazing: *seedlings highly palatable, but adults much less so*
other:

8. **General facilitation:** *has spread by man, and further spread has been increased by breakdown of native vegetation cover by fire and grazing*

9. **Predators and parasites**:
New Zealand: *rabbits, hares, other animals eat young plants. Introduced birds feed on the seed*

Elsewhere: *many parasites, especially fungi, are known to occur on it overseas. No plants diseases known.*

10. **Date of last revision:** *March 1989*

Weeds of New Zealand Protected Natural Areas -
Taxon Sheet

1. **Common Name:** *old man's beard* **Family:** *Ranunculaceae*

   Formal Name: *Clematis vitalba L.* **Synonym:** *none*

2. **Distribution**: present infestation (l low, m medium, h high) / potential infestation (l, m, h):
   Northern l/l, Waikato l?m, Easter NI m/m, Wanganui h/h, Nelson-Marlborough h/h

3. **Habitat**: coastal / lowland / montane / subalpine / alpine

4. **Substrate, fertility:** *moderate to high fertility, medium to good drainage*

5. **Communities:** tall forest / low forest / scrub and forest margin / shrubland / tall tussockland / short tussockland / herbfield / fernland / sand dune / cliff, bluff / riverbed / wetland / other

6. **Growth and reproduction**: herb, grass / woody herb / shrub / small tree / large tree / climber / other
   Comments: *very fast growing, can flower at an early stage if exposed to full sun. Generally produces many thin vines per plant. Grows to a great height.*

   Breeding system: *hermaphrodite, wind pollinated*
   Life cycle: *perennial, flowers Dec-May, fruit Mar-Oct*
   Deciduous, evergreen: *deciduous*
   Age to reproduction: *sexual 1-3 years; asexual less than one year*
   Life span: *individual/plants probably grow for more than 30 years*
   Seed production (yes / no): *massive seed production*
   Seed dispersal: explosive / gravity /wind /water / man / vertebrates / invertebrates / other
   Vegetative reproduction: *rooting from stem fragments and attached stems*
   Seed viability and germination: *viability high initially, but drops rapidly; germinates in spring with adequate light*
   Seed bank: *some seed retained for up to five years in the soil*

7. **Response to environment**: seedling requirements and tolerances:
Growth rates: *young plants and new shoots can grow up to 2 m per year*

Response to
drought: *recovers from wilting in pots – otherwise unknown*
shade: *light demanding for growth and sexual reproduction*
frost: *tolerant, partly because deciduous*
physical damage: *recovers rapidly by resprouting from stems*
fire: *unknown*
grazing: *grazed, but resprouts rapidly*
other:

8. **General facilitation:** *grows wherever land is not intensively managed or grazed, especially along river margins*

9. **Predators and parasites**:
   New Zealand: *a few generalists; Lepidoptera, diptera, rust fungi*

   Elsewhere: *Xylocleptes bispinus, a stem borer, occurs in Britain*

10. **Date of last revision:** *March 1989*

Weeds of New Zealand Protected Natural Areas –

Taxon Sheet

1. **Common Name:** *sycamore* **Family:** *Aceraceae*

   Formal Name: *Acer pseudoplatanus* **Synonym:** *none*

2. **Distribution**: present infestation (l low, m medium, h high) / potential infestation (l, m, h):
   Northern l/l, Waikato l/m, Eastern l/l, Wanganui m/m/, Nelson-Marlborough m/h, West Coast l/l, Cantebury m/h, Southern l/m

3. **Habitat**: coastal / lowland / montane / subalpine / alpine

4. **Substrate, fertility:** *occurs in a wide range of soils, but best in moderate fertility, moderately deep, freely drained soils*

5. **Communities:** tall forest / low forest / scrub and forest margin / shrubland / tall tussockland / short tussockland / herbfield / fernland / sand dune / cliff, bluff / riverbed / wetland / other

6. **Growth and reproduction**: herb, grass / woody herb / shrub / small tree / large tree / climber / other
   Comments: *up to 25m tall; among the fastest growing of all European trees*

   Breeding system: *monoecious, flowers produce nectar*
   Life cycle: *perennial, mesophanerophyte with bud covering*
   Deciduous, evergreen: *deciduous*
   Age to reproduction: sex*ual about 10 years; asexual*
   Life span: *may live to 400 years; but none that old in NZ*
   Seed production (yes / no): *annually, in buches up to 40, totalling >10,000/tree*
   Seed dispersal: explosive / gravity /wind /water / man / vertebrates / invertebrates / other
   Vegetative reproduction: *resprouts readily and occasionally forms suckers*
   Seed viability and germination: *no information in NZ; in Britain germination % high under normal sowing conditions; germinates in spring in NZ*
   Seed bank: *no information in NZ; probably very little lasts more than 1-2 years; "Seedling bank" is important in regeneration after disturbance*

7. **Response to environment**: seedling requirements and tolerances:
   Growth rates: *rapid, but slow in shaded conditions*

   Response to
   drought: *only moderately tolerant*
   shade: *highly tolerant*
   frost: *fairly resistant, especially as is deciduous*
   physical damage: *can resprout as seedlings and from stumps*
   fire: *no information*
   grazing: *deer, cattle graze its foliage*
   other:

8. **General facilitation:** *spread by man initially, then by wind into a wide range of open habitats where protected from animal grazing*

9. **Predators and parasites**:
   New Zealand: *apart from grazing, no information*

   Elsewhere: *no information*

10. **Date of last revision:** *March 1989*

Weeds of New Zealand Protected Natural Areas -
Impacts and Management Sheet

1. Common name: **Formal Name:**

2. Illustration:

3. Impact on biota and ecosystem: small (s), medium (m), large (I), very large (v):

Plant - plant relationships:

Plant - animal relationships:

Ecosystem (e.g. effects on biomass, nutrient cycling, fire frequency):

Other:

4. Management:

Physical control:

Chemical control:

Combination:

Other:

Biological control:

New Zealand

Elsewhere:

5. Legislation:

6. References:

7. Other sources of information and current projects:

8. Date of last revision:

Weeds of New Zealand Protected Natural Areas -
Impacts and Management Sheet

1. Common name: *marram grass* **Formal Name:** *Ammophila arenaria (L.)*

2. Illustration: *Hubbard, C.E. 1968: "Grasses. A guide to their structure, identification, uses and distribution in the British Isles." Penguin Books. 462p.*

3. Impact on biota and ecosystem: small (s), medium (m), large (l), very large (v):

Plant - plant relationships: *invades and competes with native sand plants, particularly Desmoschoenus spiralis, especially in the South Island; dense tall cover also precludes smaller native species such as Convolvulus soldanella.*

Plant - animal relationships: *effects on native invertbrates etc. unknown*

Ecosystem (e.g. effects on biomass, nutrient cycling, fire frequency):
Increases substrate instability, rapid accumulation of above and below ground biomass, and then organic matter build-up in topsoil

Other: *major effect on whole landscapes by stabilising dune systems; this allows establishment of other species, especially adventive legumes and pines.*

4. Management:

Physical control: *digging and pulling of rhizomes is the only practical method of removal or control*

Chemical control: *no useful data available; very resistant to most chemicals*

Combination:

Other:

Biological control:

New Zealand: *no possibility because of economic importance of marram grass in controlling sand dune stability*

Elsewhere: *no information*

5. Legislation:

6. References: *Huiskes, A.H.L. 1979: Biological flora of the British Isles – Ammophila arenaria. Journal of Ecology 67: 363-382.*

7. Other sources of information and current projects: *sand dune surveys being prepared by Botany Division, DSIR (T.R. Partridge). Also relevant, Sykes, M.T. 1986: The native sand dune vegetation of Southern New Zealand. PhD thesis, University of Otago.*

8. Date of last revision: *March 1989*

Weeds of New Zealand Protected Natural Areas -
Impacts and Management Sheet

1. Common name: *old man's beard* **Formal Name:** *Clematis vitalba L.*

2. Illustration: *Upritchard, E.A. 1985: A guide to the identification of New Zealand common weeds in colour. NZ Weed & Pest Control Society Inc.*

3. Impact on biota and ecosystem: small (s), medium (m), large (l), very large (v):

Plant - plant relationships: *scrambles and climbs over other vegetation including tall podocarp trees, denying them light. Branches break off with weight of vine. Prevent regeneration in forest gaps etc. by blocking light to the ground and preventing establishment of new plants.*

Plant - animal relationships: *by killing native woody plants, it destroys food sources for native species including birds, lizards and insects. Have not been studied in detail. Has been implicated in stock poisoning but this has not been proven.*

Ecosystem (e.g. effects on biomass, nutrient cycling, fire frequency): *reduces forest live biomass by killing trees, but increases dead material. Effect of nutrient regime unknown*

Other: *Catchment authoritiews concerned about its effect on willow trees lining river verges that provide river control.*

4. Management:

Physical control: *small seedlings can be pulled; large stems have to be cut; roots grubbed out and placed off the ground.*

Chemical control: *variety of sprays effective; spray aerially if in trees, from ground if in lower vegetation.*

Combination: *cut stumps at 1m in winter and spray regrowth in spring.*

Other:

Biological control:

New Zealand: *no investigations underway*

Elsewhere: *not practised*

5. Legislation: *declared a Class B target-noxious plant in those DNPA's where infestations are considered eradicable.*

6. References: *Van Gardingen, J.R. 1986: The physiological ecology of Clematis vitalba. MSc Thesis, University of Cantebury.*

Buxton, J.M. 1985: The potential for biological control of Clematis vitalba L. Unpublished MSc Thesis, Imperial College, Ascot.

7. Other sources of information and current projects: *Department of Lands & Survey 1984: Distribution and control of the introduced weed, old man's beard (Clematis vitalba). Dept Lands & Survey Information Series 11.*

West, C.J. in prep: An ecological investigation of Clematis vitalba (old man's beard) in New Zealand. Botany Division, DSIR, Unpublished Report, Wellington.

West, C.J. in prep: Literature review of the biology of Clematis vitalba (old man's beard). Botany Division, DSIR, Unpublished Report, Wellington.

8. Date of last revision: *March 1989*

Weeds of New Zealand Protected Natural Areas - Impacts and Management Sheet

1. Common name: *sycamore* **Formal Name:** *Acer pseudoplatanus*

2. Illustration:

3. Impact on biota and ecosystem: small (s), medium (m), large (l), very large (v):

Plant - plant relationships: *establishes in competition with native woody species in oen situations. Occupies subcanopy position position in disturbed forest, reducing vigour of native species. Long-term role in forest dynamics is not known.*

Plant - animal relationships: *not known whether native insects use the nectar, otherwise nothing known.*

Ecosystem (e.g. effects on biomass, nutrient cycling, fire frequency): *much more rapid increase in biomass of stands than where native species occupy most sites.*

Other:

4. Management:

Physical control: *can be cut at or near ground level, but likely to resprout*

Chemical control: *can be killed with sprays, but not normally practised because of expense and surrounding vegetation*

Combination: *cut stumps and apply herbicides is the best method, but seedlings must also be removed for full control*

Other:

Biological control:

New Zealand: *none*

Elsewhere: *none as important as a timber and ornamental tree*

5. Legislation: *not declared a noxious plant anywhere in NZ*

6. References: *Bussell, W.T. 1968: The growth of some New Zealand trees. NZ Journal of Botany 6: 63-75; NZ Journal of Botany 6: 76-85.*

Jones, E.W. 1944: Biological Flora of the British Isles: Acer L. Journal of Ecology 32: 215-252.

7. Other sources of information and current projects:

8. Date of last revision: *March 1989*

PART 3

SOURCES OF INFORMATION AND PARTIAL BIBLIOGRAPHY FOR WEEDS IN NEW ZEALAND PROTECTED NATURAL AREAS

SUMMARY OF PART 3

Information on weeds relevant to Department of Conservation (DOC) is spread across a wide range of institutions such as Ministry of Agriculture and Fisheries (MAF), Department of Scientific and Industrial Research (DSIR), Forest Research Institute (FRI), universities, and DOC itself. No single organisation has a database on all the weeds of interest to DOC. The quantity and quality of information available on individual weeds is highly variable. For some there is virtually no information at all, while others have been studied intensively. The latter group are mostly those weeds that are of importance to agriculture.

A summary table shows the likely sources of information for 65 problem weeds. A partial bibliography for 32 weeds is presented and it indicates the level and sources of information available.

CONTENTS

3.1 INTRODUCTION

In the process of preparing Parts 1 and 2 of the review many references were collected. In this Part **3** of the review the sources of information on weeds are discussed. The varying amount of information available for different weeds is indicated in the partial bibliography and in Table 3.1. Because of time constraints, the bibliography covers two thirds only of the 65 problem weeds listed in Parts 1 and 2. We concentrated on those species which were unlikely to be intensively studied by other agencies in New Zealand. No attempt was made to review or compile information which is obviously held by other agencies, e.g. information on conifers is held by Forest Research Institute (FRI) and information on water weeds is held by Ministry of Agriculture and Fisheries (MAF).

The bibliography was compiled by:

1. correspondence and discussions with numerous colleagues involved in scientific research on weed management, including overseas contacts;

2. a manual search of all the New Zealand scientific journals, management journals such as *Protect,* theses available from universities, and lists of current projects;

3. a search through all the Biological Flora, or related series, in New Zealand and overseas scientific and management journals;

4. a manual search of the Commonwealth Agricultural Bureau publication, *Weed Abstracts,* back to 1965.

These searches will not have revealed all the information available. The vast experience of the DNPO's (District Noxious Plants Officers), DOC staff, retired experts, and no doubt others, plus field trials of chemical companies were largely untapped. Short of touring New Zealand and talking to all these folk it is difficult to see how this information could be tapped.

Computer searches for each species were not conducted because of the expense and because, for species which are also cultivated, this could have been rather fruitless. For example, all the references for ivy in *Weed Abstracts* pertained to keeping (other) weeds out of cultivated ivy.

In Table 3.1 the category "probably" ("p") has been used where it is suspected that the species will have been investigated, perhaps for commercial reasons such as fruit production, e.g. elder. Species which are important economic plants, such as lodgepole pine, will also have been studied intensively and are in the "probably" category.

The published material, both overseas and in New Zealand, is divided into 3 categories: biology of the species, conservation, and management. The latter may not have been written for conservation purposes but is still useful, e.g. weed control methods. In fact, most entries under management, especially in New Zealand are concerned with chemical control.

3.2 INSTITUTIONS HOLDING WEED INFORMATION

Within New Zealand, the main sources of both published and unpublished information on weeds are government departments and universities.

3.2.1 Ministry of Agriculture and Fisheries

MAF has statutory responsibility for noxious weeds and plant quarantine regulations, although this whole area of administration is presently (October 1989) being reviewed. The administration activities are backed by an information base housed at Auckland and Palmerston North. Scientific research into a wide range of agricultural weeds, including water plants, is conducted at Ruakura, Palmerston North, Lincoln and to a lesser extent, Mosgiel. Most research is directed towards autecology and management of weeds, especially by chemical means, and although some of these weeds are of interest to PNA managers, mostly they are not, e.g. nodding thistle.

The great deal of knowledge and experience that is held by the is, theoretically at least, fed back into the MAF network.

3.2.2 Forest Research Institute

FRI of Ministry of Forestry has conducted extensive research on shrub weeds, including pampas grass on forestry land and the ecology of exotic conifers in the high country. This work is conducted from Rotorua, Ilam and Rangiora and much of it is useful to PNA managers. More recently, FRI have begun specific weed projects for DOC.

3.2.3 Department of Scientific and Industrial Research

Three DSIR divisions conduct research of direct relevance to PNA management. Entomology Division, which is based at Auckland and Lincoln, is New Zealand's main organisation concerned with biological control (see 2.3.2). Grasslands Division is the main source of information on hawkweeds and grass species such as browntop which also behave as weeds.

Botany Division has recently (1988) published *Flora of New Zealand,* volume IV which contains descriptions of the naturalised dicotyledons, gymnosperms, and ferns. When volume V dealing with grasses is completed, all the groups of naturalised plants will have been described. Taxonomic work is conducted largely at Lincoln, where the largest herbarium in New Zealand is located. Ecological work is conducted at Lincoln, and at the regional stations of Auckland, Rotorua, Havelock North, Lower Hutt, Nelson, and Dunedin. The *Biological Survey of Reserves Series,* prepared principally by Botany Division and published by DOC, is a significant repository of information on weeds. Botany Division also holds a large number of unpublished reports on New Zealand vegetation, many of which contain information on weeds.

3.2.4 Department of Conservation

DOC inherited staff from several organisations concerned with daily management of weeds and, to a much lesser extent, research on weeds. The total information held by DOC is therefore very large. Although the information is mostly in the collective memories of the staff and on file, the entries in Table 3.1 indicate that useful information is obtainable from DOC

for 19 problem weeds. In most cases the species are those for which other organisations also have information. e.g. broom, but for a few, DOC is the main source of information, e.g. Mysore thorn.

3.2.5 Universities

Several theses and projects on weeds, or on wider ecological topics but including weeds, have been conducted recently in universities, e.g. Sykes (1986, see 3.4).

3.2.6 Museums

Museums are not listed in Table 3.1 but they have herbaria and botanists, both sources of weed information.

3.3 QUANTITY OF INFORMATION AVAILABLE FOR EACH SPECIES

Table 3.1 indicates the amount of information available for each problem weed species.

For some species there appears to be virtually no information at all, other than a formal description. These are predominantly plants of little or no interest to agriculturalists in New Zealand, although they may be considered as weeds overseas. Most are from South America, Asia, or Africa, e.g. smilax, wild ginger, and mist flower. In the case of woolly nightshade, possibly important references are available in other than Australasian sources.

Some species are rarely referred to in the published literature and have received very little study in New Zealand. Where there is information held, by MAF for example, this usually pertains to the control or management of the weed. However, because many of these weeds are temperate species, some information ("S") on them probably ("p") exists somewhere. This situation is indicated in Table 3.1 by “pS”.

For some species there is much information on their biology relevant to their productive potential, but very little directed specifically at their management within PNAs. This group includes all the commercial and widespread trees, e.g. pines, grasses such as browntop and kikuyu grass, species planted for erosion control, e.g. willows and grass, and herbaceous grassland weeds such as hawkweeds. This biological information has not been summarised here but some of it could help to define the nature of a weed problem in PNAs. There are also some species which have been studied overseas, sometimes for biological purposes, e.g. prickly hakea and bone-seed, but which have not been studied in New Zealand.

A select few species have been extensively studied overseas and in New Zealand, including their impact on New Zealand PNAs. In several cases the studies have suggested management approaches, e.g. for gorse, broom, old man's beard, and spartina. Many weeds in this category are also weeds of agriculture.

The above discussion has concentrated on weeds as species requiring study in their own right. An equally important way of approaching weeds is to examine closely their interaction with the native biota. For example, defining the timing and nature of secondary succession

through shrub weeds such as gorse, e.g. Druce (1957, see 1.2), and Lee *et al.* (1986, see 3.4), and broom, e.g. Williams (1981, see 3.4). Other examples are theoretical studies examining species interactions in plant communities, e.g. Sykes (1986, see 3.4, marram grass) and Wilson and Sykes (1988, see 1.5). Some intensive autecological studies have also examined interactions with native species, e.g. Chapman (1984, see 3.4) for heather and West (in prep a, b, see 3.4) for old man's beard. This topic has been discussed more fully in 2.5.2. For most species, however, there have been few studies on the nature of the interactions of weeds and native species. This is one of the main reasons why it is so difficult to define problem weeds and why there is disagreement as to which are the most serious weeds in PNAs.

3.4 A PARTIAL BIBLIOGRAPHY FOR PROBLEM WEEDS

Table 3.1 indicates how complete or otherwise this bibliography is likely to be for individual weeds. For some species, e.g. privet species, and those for which no references were located, e.g. asparagus species, the number of entries is a fair indication of the amount of information available. For others, particularly species where there is likely to be a large overseas literature, or where information is likely to be held by government agencies, e.g. pines, gorse, hawkweed, browntop, only a selection of references, reviews, or theses have been included and are those most likely to offer a lead into the literature.

BARBERRY (2 species)

Meeklah, F.A.; Mitchell, R.B. 1985: Control of barberry by 'spot-gun' application method. *Proceedings of the 38th New Zealand Weed and Pest Control Conference: 78-80.*

BLACKBERRY

Park, O.L.; Lane, P.M.S. 1984: Blackberry control with glyphosate. *Proceedings of the 37th New Zealand Weed and Pest Control Conference: 200-202.*

Yortt, M.L.; Atkinson, G.C. 1980: Blackberry control with glyphosate. *Proceedings of the 33rd New Zealand Weed and Pest Control Conference: 177-180.*

BONE-SEED

Anderson, T. 1984: Bitou bush *(Chrysanthemoides monilifera* ssp. Rotundata) control in Wide Bay district, Queensland. *Proceedings of the Seventh Australian Weeds Conference 1:* 200-202.

Lane, D.; Shaw, K. 1978: The role of fire in bone seed *(Chrysanthemoides monilifera* (L.) Norl.) control in bushland. *Proceedings of the First Conference of the Council of Australian Weed Sciences Societies: 333-335.*

Weiss, P.W. 1981: Seed dynamics of bone seed and coastal wattle in relation to their potential invasiveness. *Proceedings of the Sixth Australian Weed Conference* 1: 25-28.

Weiss, P.W. 1984: Seed characteristics and regeneration of some species in invaded coastal communities. *Australian Journal of Ecology* 9: 99-106.

Weiss, P.W. 1986: The biology of Australian weeds. 14. *Chrysanthemoides monilifera* (L). *monilifera* (L.) T. Norl. *Journal of the Australian Institute of Agricultural Science* 52: 127-134.

BOXTHORN

Parsons, W.T. 1973: Noxious weeds of Victoria. Inaka Press, Melbourne.

BROOM

Balneaves, J.M. 1982: A multiple spray regime for broom control in forestry operations. *Proceedings of the 35th New Zealand Weed and Pest Control Conference:* 157-161.

Scheele, S.M.; Syrett, P. 1987: The broom twigminer, *Leucoptera spartifoliella* (Lepidoptera: Lyonetiidae), in New Zealand. *New Zealand Entomologist* 10: 133-137.

Syrett, P. 1987: The biological control of broom (*Cytisus scoparius*) in New Zealand - an environmental impact assessment. Entomology Division Report, DSIR, Christchurch

Syrett, P.; O'Donnell, D.J. 1987: A seed-feeding beetle for biological control of broom. *Proceedings of the 40th New Zealand Weed and Pest Control Conference:* 19-22.

Williams, P.A. 1981: Aspects of the ecology of broom (*Cytisus scoparius*) in Canterbury, New Zealand. *New Zealand Journal of Botany* 19: 31-43.

Williams, P.A. 1983: Secondary vegetation succession on the Port Hills, Banks Peninsula, Canterbury, New Zealand. *New Zealand Journal of Botany* 21: 237-247.

BROWNTOP

Rapson, G.L. 1985: Vegetative strategy in *Agrostis capillaris* L. PhD thesis, University of Otago.

Rapson, G.L.; Wilson, J.B. 1988: Non-adaptation in *Agrostis capillaris* L. (Poaceae). *Functional Ecology* 2: 479-490.

ELDER

Williams, P.A. 1983: Secondary vegetation succession on the Port Hills, Banks Peninsula, Canterbury, New Zealand. *New Zealand Journal of Botany* 21: 237-347.

GORSE

Hartley, M.J.; Popay, A.I. 1982: Gorse control by stump treatment. *Proceedings of the 35th New Zealand Weed and Pest Control Conference:* 149-151.

Hill, R. 1986: Biological control of gorse: implications for the natural environment and for primary production. Entomology Division Report, DSIR, Christchurch.

Hill, R.L.; Sandrey, R.A. 1986: The costs and benefits of gorse. *Proceedings of the 39th New Zealand Weed and Pest Control Conference:* 70-73.

Ivens, G.W. *1978:* Some aspects of seed ecology of gorse (*Ulex europeus*). *Proceedings of the 31st New Zealand Weed and Pest Control Conference: 53-57.*

Lee, W.G.; Allen, R.B.; Johnson, P.N. 1986: Succession and dynamics of gorse (*Ulex europaeus L.)* communities in the Dunedin Ecological District, South Island, New Zealand. *New Zealand Journal of Botany 24:* 279-292.

Popay, A.I.; Rolston, M.P.; Edmonds, D.K. 1985: "Non-hormone" herbicides for gorse control. *Proceedings of the 38th New Zealand Weed and Pest Control Conference:* 94-97.

Preest, D. 1980: Seasonal variation in seedling gorse susceptibility to four herbicides. *Proceedings of the 33rd New Zealand Weed and Pest Control Conference:* 165-169.

HAKEA (several species)

Allo, A.V. 1959: Weeds associated with land development. *Proceedings of the 12th New Zealand Weed and Pest Control Conference:* 18-20.

Beever, R. 1988: Gumland scrub. *Auckland Botanical Society Journal 43:* 1-16.

Esler, A.E. 1962: Botanical features of Abel Tasman National Park. *Transactions of the Royal Society of New Zealand 1(25):* 297-311.

Esler, A.E.; Rumball, P.J. 1975: vegetation at Kaikohe, Northland, New Zealand. *New Zealand Journal of Botany 13:* 425-436.

Fugler, S.R. 1983: The control of silky hakea in South Africa. *Bothalia 14:* 977-980.

Guillarmod, A.F.M.G.J. 1983: Recovery of Eastern Cape heathland after fire. *Bothalia 14:* 977-980.

Lee, H.M. 1984: The biology of *Hakea ulicina* R. Br. and H. *repullans* (Proteaceae). *Australian Journal of Botany 32: 679-699.*

HAWKWEEDS (several species)

Makepeace, W. 1985: Growth, reproduction, and production biology of mouse-ear and king devil hawkweed in eastern South Island. *New Zealand Journal of Botany* 23: 65-78.

Makepeace, W. 1985: Some establishment characteristics of mouse-ear and king devil hawkweeds. *New Zealand Journal of Botany* 23: 91-100.

Makepeace, W.; Dobson, AT.; Scott, D. 1985: Interference phenomena due to mouse-ear and king devil hawkweed. *New Zealand Journal of Botany* 23: 79-80.

Scott, D. 1984: Hawkweeds in run country. *Grasslands and Mountain Lands Institute Review* 42: 33-48.

HAWTHORN

Burgason, B. 1978: Prescribed burning for management of hawthorn and alder. *New York Fish and Game* 23: 160-169.

Williams, P.A.; Buxton, R. 1986: Hawthorn (*Crataegus monogyna*) populations in mid-Canterbury. *New Zealand Journal of Ecology 9:* 11-17.

HEATHER

Chapman, H.M. 1984: The ecology of heather, *Calluna vulgaris,* in New Zealand, with particular reference to Tongariro National Park. PhD thesis, University of Otago.

JAPANESE HONEYSUCKLE

Carter, G.A.; Teramura, AH.; Forseth, I.N. 1989: Photosynthesis in an open field for exotic versus native vines of the south eastern United States. *Canadian Journal of Botany 67:* 443-446.

Gunnings, B.A. 1964: Controlling honeysuckle in hedges. *New Zealand Journal of Agriculture* 108: 330.

Leatherman, A.D. 1955: Ecological life history of *Lonicera japonica* Thunb. PhD thesis, University of Tennessee.

Thomas, L.K. Jr 1980: The impact of three exotic plant species on a Potomac Island. *National Park Service Scientific Monograph Series* 13. US Department of the Interior, Washington, DC.

LAGAROSIPHON

Howard-Williams, C.; Davies, J. 1988: The invasion of Lake Taupo by the submerged water weed *Lagarosiphon major* and its impact on the native flora. *New Zealand Journal of Ecology* 11: 13-19.

LOTUS

Jones, D.A.; Turkington, R. 1986: Biological flora of the British Isles –*Lotus corniculatus* L. *Journal of Ecology 74:* 1185-1212.

LUPIN, TREE

Davidson, E.D.; Barbour, M.G. 1977: Germination, establishment, and demography of coastal bush lupin (*Lupinus arboreus)* at Bodegahead, California. *Ecology* 58: 592-600.

Pitelka, L.F. 1977: Energy allocation in annual and perennial lupins *(Lupinus:* Leguminosae). *Ecology* 58: 1055-1065.

MARRAM GRASS

Esler, A.E. 1974: Vegetation of the sand country bordering the Waitakere Range, the southern beaches. *Proceedings of the New Zealand Ecological Society 21:* 72-77.

Hurskes, A.H.L. 1979: Biological flora of the British Isles - *Ammophila arenaria. Journal of Ecology 67:* 363-382.

Sykes, M.T. 1986: The native sand dune vegetation of southern New Zealand. PhD thesis, University of Otago.

MIST FLOWER

Rai, J.P.N.; Tripathi, R.S. 1984: Alleopathic effects of *Eupatorium riparium* on population regulation of two species of Galinsoga and soil microbes. *Plant and Soil* 80: 105-117.

Yadav, A.S. Tripathi, R.S. 1982: A study on the seed population dynamics of three weedy species of *Eupatorium. Weed Research 22:* 69-76.

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TABLE 3.1. Summary of information available, and its likely location, for selected weeds[1] in New Zealand protected natural areas.

	PUBLISHED						UNPUBLISHED				
	Overseas			New Zealand			Univ.	Government Departments			
	Bio	Con	Man	Bio	Con	Man		MAF	FRI	SIR	DOC
asparagus, climbing											
banana passionfruit											
barberry	pS				S			PN			
barberry, Darwin's	pS				S			PN		Dn	
blackberry	M	pS	pS	S	M	S		PN		Ch	
bone-seed	M	M	M					PN			
boxthorn	S	S	S				Ch	PN			We
broom	S	S	S	S	S	S		PN	Ro	Ch	TP
browntop	M	M		M			Dn		Ch	Ch	
buddleia									Ro		G
cocksfoot	M	M		M					Ch	Ch	
Douglas fir	pM	pS	pS		S	S			Ch	Dn	
elaeagnus											
elder	pS	pS		S						Dn	
evergeen buckthorn	pS										
gorse	M	S	S	M	M	M		PN	Ro	Ch	
hakea, downy	M	S	S								
hakea, prickly	M	M	M	S						Ne	
hakea, willow-leaved	M	pS	pS	S						Ne	
hawkweed (king devil)	M	M	pS	M	M	S	Ch	PN		Ch	

hawkweed, mouse-ear	M	M	pS	M	M	S	Ch	PN		Ch	
hawthorn	S		S	S	S		PN				
heather	M	M	M	S			Dn				TP
honeysuckle, Himalaya									Ro		
honeysuckle, Japanese	S	S	S			S					
hydrilla								Ru			G
ivy	pS										
ivy, German											
kikuyu grass	M	M	pS					PN		Ka	Ak
lagarosiphon					S	S		Ru			
larch, European	M	S		S	S				Ch		
lotus	M	M	M	M	S	S		PN	Ch		
lupin, Russell	pS								Ch	Ch	FP
lupin, tree	M								Ch	Ch	
marram grass	M	S	S	S			Dn			Ch	Ch
mist flower	S										
mysore thorn						S					Ak
nasella tussock	M		S	S		M		PN		Ch	
old man's beard	S			S	S	S		PN		We	Wa
pampas grass	S	S	S	S	S	S			Ro		
pampas grass, purple	S	S	S	S	S	S			Ro		
perwinkle	pS										
pine, Corsican	M	pS	pS	pS	S	S			Ch		
pine, lodgepole	M	pS	pS	M	S	S	Wa		Ch		TP

pine, maritime	M	pS	pS	pS			Ch		Ch		
pine, radiata	M	pS	S	M	S	S			Ch		
privet, Chinese	S				S		Ak	PN			Ak
privet, tree	S				S		Ak	PN			Ak
robinia											
rush	M	M			M			PN		Ch	
selaginella	M										
smilax											
Spanish heath	S			S			Dn	PN		Ne	
spartina	M	M	M	M	M	M	Dn	PN		Ch	Wa
stinking iris	pS										Ak
sweet brier	pM			S	S	S	Dn	PN		Dn	
sycamore	M	S	S	S				PN		Ch	
veld grass				S	S						Wa
wandering Jew	pS	pS		S	S	S	PN				
wattle, silver	M	M	M						Ro		
wild ginger (kakili)				S	S			PN			
wild ginger (yellow)				S				PN			
willow, grey	M	pM						PN		Ch	
willow, crack	pM	pM						PN		Ch	
woolly nightshade	S	pS	pS		S			PN		Ch	

NOTES

[1]The 65 species (or groups) selected are the problem weeds in protected natural areas; they permanently alter the structure, successional processes, and organisms present in native communities.

a. Column headings:

These are divided into published accounts and unpublished information held in NZ. The latter includes information on file and present and past unpublished projects.

Bio, the biology of a species; Con, control of a species - mostly by chemical methods; Man, management of a species for conservation.

MAF, Ministry of Agriculture and Fisheries; FRI, Forest Research Institute; SIR, Department of Scientific and Industrial Research; DOC, Department of Conservation; Univ., Universities.

b. Columns: S, some information; M, much information; p, probably - an estimate.

Ak, Auckland, Ch, Christchurch; Dn, Dunedin; FP, Fiordland National Park; G, Gisborne; Ka, Kaikohe; Ne, Nelson; PN, Palmerston North; Ro, Rotorua; Ru, Ruakura; TP, Tongariro National Park; Wa, Wanganui; We, Wellington.

Water weeds are not fully covered by this review.

c. Formal names are given in Appendices 1.1 and 2.1.