Assessing the risk to indigenous New Zealand biota from new exotic plant taxa and genetic material

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ABSTRACT

This report describes the potential risks to New Zealand natural areas and indigenous biota from the importation of new plant taxa and additional material of taxa already here. A broad comparison of weed impacts throughout the world with those in New Zealand suggests the impact of new taxa or material is likely to be similar to impacts observed here. The ecosystems most likely to be invaded and the opportunities for novel impacts are described. In the absence of border controls, at least one to two percent of all introductions will become a significant environmental or agricultural weed. Plants arrive in New Zealand via many pathways including different forms of postage, baggage, and with air travellers. The relative importance of these carriers, and their geographical origins, appear to be changing. These trends have implications for detecting potential weeds, especially amongst undeclared imports. Recent experience of screening prospective plant imports suggests the potential weediness of legal imports can be reduced. But this takes no account of illegal imports of which very little is known. The importation of additional material of taxa already here cannot be convincingly demonstrated to pose a high risk other than simply by increasing propagule pressure. Clear exceptions are where it removes a bottleneck in the life cycle of a taxon, such as the introduction of male plants where none were present before. A review of the instances of 'genetic pollution' of native species from introduced taxa shows this is a minimal threat. The threat to conservation values in the medium term of new plant imports is considered to be less than that posed by the large pool of taxa cultivated in New Zealand.

Keywords: invasive weeds, exotic taxa, plant imports, ecological risk, New Zealand

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1. Introduction

The Department of Conservation (DOC) has responsibility for protecting the New Zealand native biota from the impacts of introduced plant species over large areas of land. Currently, this includes controlling approximately 160 alien plant species (Owen 1997), assessing the risk from a further 1900 (Healy & Edgar 1990, Webb et al. 1988), and being aware of potential invaders from amongst the nearly 18,000 alien species recorded in cultivation that are not yet growing in the wild (Landcare Research databases). This potential avalanche of new environmental weeds has accumulated in New Zealand because previous border control policies did not take into account impacts of introduced species on indigenous biota. Since June 1997, DOC has been responsible for providing policy advice to the Minister of Biosecurity and now the Minister of Food, Fibre, Biosecurity and Border Control, on the risks posed by potential weed species and new genomes of exotic taxa already here. The potential impacts of this latter material, which includes new varieties or subspecies, may be less than that involving new species, but the subject merits examination because it is an important aspect of importing new material of taxa already known to be weeds.

The Department of Conservation requested Landcare Research prepare a scoping report to investigate the risk of these two (new species and new genomes) closely related potential threats. Issues surrounding the importation of new weeds are intensifying for a number of reasons. Our national economy is becoming increasingly unrestricted, associated with an increase in travel and trade. For example, the number of tourists arriving here has increased by 230% since 1985 and these are coming especially from Asia, a 680% increase since 1985 (Statistics New Zealand 1998). Diversification of the agricultural sector has resulted in more intensive land use and a search for new plant taxa to grow as crops or forage, especially as older crops go out of favour (Halloy 1999). Increasing urbanisation, which in itself increases the susceptibility of conservation land to weed invasions (Timmins & Williams 1991), also brings an increase in recreational gardening and a relentless search for new and novel plants from around the world. These are becoming increasingly available through specialist plant societies, commercial catalogues, and other sources including the Internet. As a consequence, there has been pressure to bring a diverse range of new plant material into New Zealand.

The information needed for an assessment of weed entry and impacts in New Zealand is extremely disparate and dispersed, and severely hampered by society's failure to collect and preserve in an accessible form, a record of which plant taxa were introduced when and by whom. These limitations constrain what we can predict about future pathways and threats. Only very recently has the situation begun to improve and data for this report has come from many sources, including the Ministry of Agriculture and Forestry (MAF), Customs Department, Department of Conservation (DOC), Landcare Research, territorial authorities, nurseries, private individuals and colleagues, referenced and unpublished literature, and the Internet.

This report examines the plant groups of concern because of the risks they pose to New Zealand natural areas and indigenous biota, **what** impacts they would have were they to arrive and establish, **who** might want to bring them in, **where** they might come from and by what means, **whether** the damaging invasive taxa would be detected, and finally, what is **the risk** (probability × impact) to native biota from these taxa. The issues are covered only in a general way, with representative examples. Complete species lists in particularly invasive genera for example, are held on Landcare Research databases at Lincoln. Only terrestrial weeds are covered by this report; aquatic weeds are being reviewed by National Institute of Water and Atmospheric Research (NIWA).

2. Methods

2.1 OVERVIEW

This report discusses plant taxa new to New Zealand (sections 3.1–3.3), and additional genetic material of taxa already here (sections 3.4–3.5).

As the potential number of taxa that could be introduced to New Zealand is almost limitless, i.e. the global flora, we used the past as a guide to the future by focusing on taxa or groups of plants that have become environmental weeds in the 150 years of European settlement. We used existing classifications of plant life forms (Williams 1997) and summaries of their recorded impacts (Cronk & Fuller 1995; Owen 1997; Williams 1997), to identify likely future impacts in New Zealand. These included novel types of impacts not yet occurring in New Zealand that could arise if new taxa were introduced and which might be more damaging than increases in the existing kinds of impacts. The current array of prospective imports (Landcare Research databases) of weeds was examined. The pathways by which new taxa arrive in New Zealand (Ministry of Agriculture and Forestry, Department of Statistics data) and the probability of these new taxa being intercepted and evaluated for potential weediness is assessed by examining the results of recently screened prospective imports (Landcare Research databases). The risks described are assessed and compared with the risk of invasions from taxa already in New Zealand but not yet invasive, as determined from the rate at which new environmental weeds develop (Owen 1997).

2.2 PRINCIPLE SOURCES OF NUMERICAL DATA

Many of the data used in this report were derived from data bases held by Landcare Research. These have been developed partly in response to the need to screen prospective plant imports for MAF since 1996. Approximately 1500 species were assessed in this way. While this screening is not strictly part of the methods of this report, an understanding of the process is necessary to interpret our findings. The following is a brief description of the preliminary assessment pathway (not necessarily always in this strict order) that has operated within Landcare Research:

1. **Check Genus; Family names**.

2. **Check Prohibited Species database** (~600 spp.). *Reject if prohibited.* This database is compiled by MAF and includes most plants known to be weeds in New Zealand.

3. **Check species name and synonyms** (*AllNZspp database; Index Kewensis,* etc.). These data bases help determine an absolute identification.

4. **Check weed history** *(AllWeeds database)* **and species characteristics and horticultural history** (*Floras, Royal Horticultural Society Dictionary,* etc.). These databases determine whether, and where, the taxon is known to be a weed elsewhere in the world, and its general characteristics.

5. **Check for recorded presence in New Zealand** *(AllNZspp database).* This determines whether the taxon is among the 20,000 or so species growing in the wild or in cultivation in New Zealand.

A response is then sent to MAF with a recommendation to accept the species, reject it, carry out a more complete evaluation, or seek more information.

With a small number of exceptions (e.g. *Pinus radiata*; some *Lupinus* species), species are automatically rejected if they have an 'Entry Prohibited' import status or are actively controlled by DOC or a Regional Council. Other species that are widely distributed here, or fully naturalised, would normally be accepted. A new species, one that is doubtfully here or not thought to be widely distributed, would be rejected if it had a number of adverse characters a significant off-shore weed history or belonged to a family or genus with a disproportionate number of invasive species. 'Widely distributed' is usually considered to be naturalised, available through a major seed supplier (e.g. King Seeds), several small nurseries, or occurring in multiple specialist collections or Alpine Garden Society seed lists. On rare occasions, even should a species be quite widely distributed here rejection would be recommended if it appeared particularly noxious and had not naturalised. Whether other naturalised species in New Zealand appear on controlled lists is an important consideration. Climate match in a broad sense was also taken into account, bearing in mind that a number of subtropical or even tropical species (especially climbers and grasses) have naturalised or become invasive here.

In doubtful cases, more information is requested from the importer (via MAF) or a recommendation is made to evaluate the species further. Thus evaluation usually involves the New Zealand WRA model (Pheloung et al. 1999) if sufficient data is available. This model will generally give a clear 'reject' recommendation if there is evidence of a species naturalising outside its home range, becoming weedy, or having congeneric weeds.

These criteria will probably alter as the importation of new plant taxa becomes increasingly under procedures set out in the Hazardous Substances and New Organisms (HSNO) Act (1996) and subsequent regulations. Decisions on imports will be made by Environmental Risk Management Authority (ERMA) and will need to comply with Import Health Standards prepared under the Biosecurity Act (BSA) (1993).

MAF supplied data on the seizures of seeds and nursery stock (propagating material other than seeds) made by MAF officers at entry points for the period January–March 1997. Aquatic material would be included in these data, although this report deals only with terrestrial plants. The assumption is made that seizures during this period are representative of recent times. A seizure comprises an item or group of items, either declared or undeclared, and in this case of plant material, which does not comply with one or more MAF quarantine regulations, and must be further assessed before a decision is made to allow entry.

For comparison with the number of seizures, data were obtained from Statistics New Zealand on the number of visitors to New Zealand during 1997.

3. Plant taxa new to New Zealand

3.1 IDENTIFYING POTENTIAL THREATS

3.1.1 Characterisation of potential threats

Weeds impact in an individualistic manner, depending partly on the biota present in the ecosystems they are invading. There are thousands of potential new taxa world-wide that could establish in New Zealand, including several thousand known potential new weeds (Nicol 1997). It is therefore impossible to examine potential pest taxa on an individual species basis. The alternative approach is to classify potential pests at coarser scales, based on taxonomy and life form types, and use these to develop generalisations regarding impacts.

The impact of invasive species has become recognised in the last two decades as an event of global significance (Drake & Mooney 1988), and has resulted in a number of high quality reviews (e.g. Cronk & Fuller 1995, including 450 references). These indicate that broad generalisations can be made about community and ecosystem processes changed by weed invasions. New Zealand has a unique biota and a particular set of environmental problems related to this biota and its ancient and recent history. For example, timber-lines are lower here than in continental parts of the world and this exposes our alpine biota to invasion from northern conifers. The result, is the generic effect of small plants being smothered by larger ones—a world-wide phenomena. Assuming, therefore, that the kinds of impacts of weeds not yet in New Zealand will fall within the broad range of categories as impacts currently recognised elsewhere in the world, then the general nature of these potential impacts can be described. A comparison of these potential impacts based on international reviews of the global weed flora with the impacts of weeds presently in New Zealand will reveal whether there are novel impacts not yet experienced in New Zealand.

Weed impacts are determined primarily by the plant's life form, growth rate, and regeneration characteristics which enable a species to persist at a site. The potential impacts of weeds on New Zealand can be deduced by comparing the major life forms of environmental weeds of the world with the life forms of New Zealand environmental weeds (Table 1). Using a very coarse classification, all the major life forms among weeds of the world appear well represented in New Zealand, and these are distributed across terrestrial vegetation types (Table 2). Full descriptions of these types are given in Williams (1997). These comparisons do not compare absolute impact, but they indicate the kinds of impact environmental weeds have on the rest of the world compared with New Zealand. Herbs other than grasses are equally important in both the world as a whole and New Zealand in particular, whereas shrubs and trees are currently less important in New Zealand than they are elsewhere. One reason for this disparity is the veritable tidal wave of trees and shrubs that have been introduced into the tropics (Hughes 1995). However, many trees and shrubs have been introduced into New Zealand within the last 50 years, an insufficient time for them to have exhibited their weed potential (Landcare Research

TABLE 1. LIFE FORMS OF ENVIRONMENTAL WEEDS AS A PERCENTAGE OF THE TOTAL WORLD* SPECIES COMPARED WITH NEW ZEALAND† PLANT SPECIES.

	WORLD*	NEW ZEALAND†	NZ cf. WORLD
NO. OF SPECIES	190 (%)	160 (%)	
Ferns	0.5	2.6	>
Dicot. herbs	18.7	20.4	=
Grasses and rushes	14.5	19.1	>
Woody vines	9.8	16.4	>
Shrubs	26.9	19.1	<
Trees	29.5	22.4	<
	100	100	

* Based on species listed in Cronk & Fuller (1995).

† Based on Owen (1997).

TABLE 2. THE NUMBER OF WEED SPECIES OF EACH LIFE FORM INVADING THE MAIN VEGETATION TYPES OF CONSERVATION LAND† IN NEW ZEALAND.

LIFE FORM	VEGETATION TYPE							
	FOREST INTACT	FOREST MODIFIED	SCRUB SHRUBLAND	TALL TUSSOCK	SHORT TUSSOCK	FERN LAND	HERB FIELD	BARE LAND
Herbs	5	21	24	4	19	11	15	27
Ferns	*	2	3	0	3	2	0	3
Grasses	0	2	6	2	13	1	9	15
Rushes	0	0	*	*	*	0	1	3
Vines	3	21	24	1	5	8	*	4
Shrubs	0	0	11	24	4	19	8	5
Trees	0	25	33	3	19	9	4	18
Sum	8	71	101	34	63	50	37	75
Rank	8	3	1	7	4	4	6	2

* Types in which there are weed life forms not yet particularly invasive but which may become so in the future.

† Based on Owen (1997).

unpublished data). Grasses, rushes, ferns, and particularly vines, are proportionately more important in New Zealand than the rest of the world generally. On average these have much shorter life cycles than woody trees and shrubs, and have had a greater potential to spread.

Weed impacts are likely to be similar among closely related groups of genera and species, and the range of genera and species present in New Zealand could indicate potential impact. Two examples illustrate the range of the world's weed diversity currently present in New Zealand, and hence the potential impacts of these weeds. First, Landcare Research holds some 50 weed lists from around the world, including all the major international lists such as Holm et al. (1977) with thousands of entries, as well as many smaller lists (Nicol 1997). All lists have species that are currently naturalised in New Zealand, the percentage ranging from 94% (Tasmania), to 5% (Brazilian cocoa plantations). Second, of the 40 angiosperm genera contributing the worst woody weeds in the world (Rejmánek & Richardson 1996), 29 have at least one taxa naturalised in New Zealand. The remaining 11 genera are represented in New Zealand, but have not become adventive, or else belong to strictly tropical genera that are rather unlikely to become invasive in New Zealand. This may also be true of the few major taxonomic/life form groups represented in the adventive flora of New Zealand that are not yet found amongst the environmental weeds, such as cacti and palms (these would be considered subdivisions of the categories of herbs, shrubs, or trees). Overall, the New Zealand natural environment has already been exposed to an enormous diversity of the world's present weed flora and presumably the life forms they represent, although few have been here long enough for their full potential to be assessed.

The general impacts of weeds, with examples from around the world, are summarised from published papers and reports in Table 3. Many of the species examples shown are also present in New Zealand, and where they are not, a similar taxon is indicated where applicable.

The impacts of weeds as classified and summarised by several authors follow. *Changes to vegetation structure* occurs primarily where one life form dominates a community where it was previously absent or physiognomically inconspicuous, e.g. tall tufted herbs where there were previously herbs of lesser stature. This involves a *change in the vegetation composition*, but such changes can also occur where a native life form is replaced by a weed of similar life form. Such changes usually result in *suppression of regeneration* patterns of native species or they may *facilitate the invasion of other weed* species, e.g. by fixing nitrogen and raising nutrient levels, or by collapsing canopies and allowing entry of light demanding weeds. These changes can lead to *changes to plant biodiversity*, usually resulting in reduction in the number of native species. *Changes to animal biodiversity* can also occur for a host of reasons ranging from destruction of habitat or nesting areas to changes in food availability. Many of these changes may in themselves be the result of *changes to animal behaviour* such as the provision of cover or food for predators of native species. Migration patterns of native species may be altered with as yet unknown consequences.

Some of the more dramatic impacts result from changes to ecosystem processes and function. Weeds can *change the hydrological regime* resulting in either

TABLE 3. REPRESENTATIVE WEEDS AND THEIR IMPACTS, DRAWN FROM THE WORLD LITERATURE*, WITH THEIR PRESENCE IN NEW ZEALAND, OR THOSE WITH SIMILAR IMPACTS, NOTED.

WEED SPECIES IN LITERATURE	N.Z. EXAMPLE	CHANGES VEGETATION STRUCTURE	CHANGES VEGETATION COMPOSITION	SUPPRESSES REGENERATION	FACILITATES OTHER WEEDS	DECREASES PLANT BIODIVERSITY	DECREASES ANIMAL BIODIVERSITY	CHANGES ANIMAL BEHAVIOUR	CHANGES HYDROLOGICAL REGIME	CHANGES FIRE REGIME	CHANGES NUTRIENT REGIME	CHANGES EROSION/DEPOSITION
Ageratina adenophorum	Present		x			x						
Mesembryanthemum crystallinum	None										x	
Myrica faya	*Cytisus* spp.	x	x	x	x	x					x	
Rhododendron ponticum	Present	x	x	x		x						
Andropogon virginicus	*Pennisetum clandestinum*	x	x	x		x				x		x
Hakea spp.	Present		x	x		x			x	x		
Ligustrum robustum	*Ligustrum lucidum*	x	x			x						
Acacia saligna	*Acacia* spp.	x	x	x		x			x	x	x	x
Sesbania punicea	None	x	x	x	x	x	x	x	x		x	x
Lantana camara	Present	x	x	x		x	x	x				
Passiflora molllissima	Present	x	x	x		x	x					
Rubus spp.	Present	x	x	x	x			x				

* Cronk & Fuller (1995).

flooding or down-stream water shortages. The *fire regime* may be altered, usually increasing fire frequency or intensity through the accumulation of greater flammable biomass. The most frequent *change to the nutrient regime* occurs when nitrogen fixing species invade ecosystems where nitrogen fixation was previously more slow. Changes in fire or nutrient regimes often lead to increases in other weeds as well. By accumulating biomass, stabilising areas which were formerly unstable, or the reverse, weeds can also lead to *changes in erosion or deposition* of hillslope debris and alluvium.

The presence of all these effects in New Zealand can be illustrated by taking a single species for each of the major vegetation types in New Zealand (Table 4). New taxa entering New Zealand are unlikely to present novel impacts that are different from the existing impacts at a broad functional level, but there may be particularly dramatic impacts in particular places.

Weed effects occur via individual combinations of plant attributes and those of the invaded environment and its biota, and new weeds will follow this pattern. Possibilities for novel combinations within New Zealand include particularly shade-tolerant shrubs or trees capable of invading the under storey of relatively intact broad-leaved forest in a way similar to ginger (*Hedychium* spp.). Adventive ferns may also become more abundant in forest and shrub vegetation, partly because they are cryptic and there is a high chance of underestimating

TABLE 4. EXAMPLES OF PROBABLE IMPACTS OF INVASIVE WEEDS PRESENTLY IN NEW ZEALAND, ON A RANGE OF VEGETATION TYPES.

VEGETATION TYPE	REPRESENTATIVE SPECIES	CHANGES VEGETATION STRUCTURE	CHANGES VEGETATION COMPOSITION	SUPPRESSES NATIVE SP. REGENERATION	FACILITATES OTHER WEEDS	CHANGES PLANT BIODIVERSITY	CHANGES ANIMAL BIODIVERSITY	CHANGES ANIMAL/BIRD BEHAVIOUR	CHANGES HYDROLOGICAL REGIME	CHANGES FIRE REGIME	CHANGES NUTRIENT REGIME	CHANGES EROSION/DEPOSITION
Intact forest	*Clematis vitalba*	x	x	x								
Disturbed forest	*Hedychium* spp.	x	x	x		x	x?	x?	x		x	x
Shrubland	*Calluna vulgaris*	x	x	x?		x	x			x	x	
Tall tussockland	*Pinus contorta*	x	x	x		x	x	x	x	x	x	x
Short tussockland	*Hieracium* spp.	x	x			x	x		x	x	x	x
Fernland	*Lonicera japonica*	x	x			x		x?		x?		
Herbfield	*Lotus pedunculata*	x	x	x	x	x					x	x
Bare	*Pennisetum clandistenum*	x	x	x	x	x	x?	x?	x	x	x	x
River banks	*Lupinus polyphyllus*	x	x	x	x	x	x	x	x	x	x	x
Fresh wetland	*Argeratina riparia*	?	x	?		x	x?	x?	x			x
Saline wetland	*Spartina* ssp.	x	x			x	x	x	x		x	x

? Indicates less certainty of effect.

their impacts. Because the new taxa must in some cases occupy habitats already occupied by adventive species, successful taxa would need be extremely vigorous. For example, a species able to invade dense ginger (*Hedychium* spp.) or agapanthus (*Agapanthus* spp.) would potentially be a super-weed. A further opportunity for novel weed characteristics would be attributes that contribute to a species' biological success and resistance to management such as tolerance of flooding, e.g. temperate species with characteristics of the highly invasive tropical weeds *Sesbania punicea* (coffee weed) and mimosa (*Mimosa pigra)*.

The identification of those vulnerable communities susceptible to invasion by weeds, where there is presumably the greatest chance of future impacts, provides a basis for assessing the risk from new weeds. Assuming the number of weed species presently invading a community is an indication of the total impact of invasive weeds on that community, then scrub and shrub lands are currently being affected most strongly, with bare land (less than 10% plant cover) and modified forest in close second and third place (Table 2). Intact forest, tussock lands, and herbfield, are invaded by the least number of species. On the basis of the current level of weed invasion, a new species is therefore most likely to invade relatively short or modified woody communities, or open communities, and least likely to invade closed forest, tussock land or herbfield. Once again, however, the individual nature of weed impacts must be kept in mind, and a single species capable of impacting particularly heavily on *any* community, be it forest fragments or alpine tussock land, could have a disproportionate impact on New Zealand biota.

Climate change may increase the probability of more subtropical species establishing in New Zealand as this zone extends southwards, but there is little evidence these would have different impacts from those already present.

The vegetation classification used here is too coarse to place any overall 'conservation value' on individual types. One measure of their significance is the number of threatened plant taxa they contain. A list of threatened plant taxa in various habitats (Wilson & Given 1989; Cameron et al. 1995) shows that a disproportionate number are found in low woody vegetation, such as coastal and inland scrub. This community type has the largest number of invasive weeds (Table 2). Impacts on threatened taxa are therefore likely to be greatest where new weed taxa invade low stature communities.

Vascular plant species dominate the weed literature, but some 14 species of mosses are recognised as adventive to New Zealand. Most species appear confined to disturbed sites but others may have the capacity to invade relatively intact native ecosystems where they can smother native moss species (pers. comm. A. Fife). There are no adventive lichens (Galloway 1985). These risks are not further examined here.

3.1.2 Probability of becoming a threat

An important part of the risk assessment of a new plant taxon is an estimate of the probability of it becoming invasive. This can be expressed as the chance of a species progressing from one stage of the invasion sequence to the next. For British angiosperms and Pinaceae it appears this probability is 1:10 for each defined stage (Williamson & Fitter 1997). This relationship has become known as the 'tens rule': it predicts that of every 1000 plant species imported into a country, 100 will escape into the wild, 10 of these will become naturalised, and one naturalised species will become an economic (in the broadest sense) pest. However, there are problems in applying any rule predicting a constant proportion in each transition. Firstly, it depends on the concept of a weed and the number of conceptual steps from introduction to weediness, all of which may differ from place to place (Perrin et al. 1992; Williamson 1993; Pheloung et al. 1999). Secondly the ratio varies with the group of plants being considered. For example, of 463 grasses and legumes introduced (equals imported, cf. Williamson 1993) into northern Australia, 12.9% became weeds, which is an order of magnitude greater than that predicted by the 'tens rule' (Lonsdale 1994). Thirdly, any rule can apply only where all the taxa under consideration have had sufficient time to reproduce and express their invasive capacity in the new land (Kowarik 1995).

We are confronted with all these issues when attempting to apply the 'tens rule' to New Zealand. Firstly, the number of conceptual steps differs between Great Britain and New Zealand (Williamson 1993) because of the greater propensity in New Zealand to classify adventive species as weeds (Pheloung et al. 1999). Secondly, there are still many plant species which have not been widely recognised as weeds and controlled as such on public conservation lands but which may be positioned at the early 'lag stage' (Owen 1997; Rejmánek in press). Furthermore, taxa are still being first recorded in the wild in New Zealand after having been available in nurseries for over 100 years (Landcare Research unpublished data). There are thousands of species introduced in recent decades that are still only cultivated and have neither escaped into the wild nor passed through the 'break out' phase (Cousens & Mortimer 1995). Three kinds of interrelated factors may initiate the 'break out' stage: intrinsic factors related to life history traits; the availability of 'safe sites'; and climatic change (Kowarik 1995). Finally, there is evidence in New Zealand as in the work of Lonsdale (1994), that the ratio for some weedy families is much higher than that predicted by the 'tens rule'. For example, there are about 115 species of Fabaceae (legumes) growing wild in New Zealand and 16 species listed in Owen (1997). This is more than that predicted by the 'tens rule', without considering the weeds of agriculture. The habitat preferences of these 16 species contribute to the greater number of weeds in some communities (section 3.1.1) which reinforces the point that weed predictions are most accurate when focused on individual biomes (Tucker & Richardson 1995).

Despite the limitations of **any** predetermined ratio (Rejmánek in press), they are potentially useful in indicating the probability of a new plant species being invasive in New Zealand. There are about 20,000 species in cultivation and of these, 2000 have become established in the wild. Of these 2000, approximately 100 are known to significantly affect only the environment (Owen 1997), and it would seem likely there are about another 100 weeds of both agriculture and the environment. This figure, of 20 per every 1000 introductions, is ten times that predicted by 'tens rule' of Williamson (1993). It therefore appears conservatively, that in the absence of border controls, for every 100 new taxa introduced into New Zealand, **at least one (and probably nearer two)**, will become a significant environmental and/or agricultural weed. This ratio will be referred to as the 'NZ rule' hereafter. And as explained, for some combinations of plant families and habitats the probability will be even higher and we can expect it to increase with time from the pool of species already here.

3.2 PLANT INTRODUCTIONS

3.2.1 Reasons for plant introductions

The importation of animals into New Zealand has been researched and documented, but this is not so for plants (Esler 1988), and there is no surety that future efforts to import new plant species will be for the same reasons as those in the past. During the history of New Zealand settlement, the reasons for the introduction of plants has changed. Prior to the 1970s there were many accidental introductions (Esler 1988) but we know little about this pathway in recent times. Early importation was primarily for food and shelter, and since the 1950s there have been searches for new fruits, erosion prevention species and, most recently for alternative medicines and personal products. Throughout, there has been a constant influx of new species for private gardens and public amenity plantings. Describing the profile of persons and organisations currently importing plants, and the reasons behind particular proposals, this would assist in identifying the kinds of plants likely to be imported in the immediate future, irrespective of the country of origin.

The only available information we have on this topic is our own recollections of some 300 plant taxa screened for MAF by Landcare Research at Lincoln as described in section 2 (above). The point in the risk assessment process for seeds and nursery stock where this screening occurred in the recent past is shown in Appendix 1. Under provisions of the HSNO Act this will shortly change (Appendix 2).

Ninety percent of what was screened was for private collectors or commercial nurseries, and 8% for primary production groups or agencies concerned with forestry or herbs for medicinal or culinary reasons. Only 2% of the applications were from botanical gardens. However, these 300 or so will be biassed towards those individuals who seek to import material legitimately. Material intercepted at the border is not identified and is destroyed (pers. comm. MAF Quarantine, to P.A. Williams). [The issue of illegal imports is discussed in section 3.3.2.]

The nature of plant imports possibly influences the rate at which new plant taxa are likely to spread around New Zealand and establish loci from which they may potentially escape into the natural environment. It appears the vast majority of plant imports are proposed for horticulture, primarily for urban gardens. Those new introductions that were commercially successful through garden centres and the like, would become widespread in private gardens within the climate zones to which they were suited within a relatively short time, perhaps <10 years. The largest concentration of commercial nurseries is in the northern North Island, especially near Auckland, and it is in this region that we would first expect to see the impact of new species, as occurred in the past (Esler 1988).

Some commercial agricultural and forestry species may also become widespread relatively quickly (<20 years), particularly if they were imported to develop stocks to sell to individual enterprises such as private woodlots. Growers of new crops also have a need to build up critical mass to be commercially viable, and this could result in whole fields of new species (witness the increase in lavender, albeit not a new species, to satisfy new markets). In contrast, some commercial herbs for medicinal/health purposes may have more restricted distributions in the short term as the importer attempts to capture the benefits of the new products.

In summary, new plant species are proposed for a range of land-use systems, and they are likely to be grown in a range of habitats from semi-tropical forest edges in Northland to dry land in Otago and throughout the country in urban gardens. Because most are proposed for horticulture, it is expected the majority would be likely to spread first, into semi-natural environments near urban areas, particularly in northern New Zealand.

3.2.2 Importation pathways

New Zealand border controls pre-1990 were inadequate to minimise the risk to the natural environment, as opposed to the agricultural environment. Indeed, any plant species that were not carrying diseases and were not a known major agricultural weed could be imported, and at least 20,000 plant species were (*AllNZspp database*, Landcare Research).

Importation regulations have been tightened since the BSA Act (1993), and there is now a much greater chance of detecting unwanted plants, provided these pass through the full quarantine procedures (Appendix 1 and 2). This section examines the origins and pathways of plant taxa currently entering New Zealand (Fig. 1) based on data described in section 2.2.

The data on seizures at the border (Table 5) show the region or country of origin of the seizure (note: this may not coincide with the native range of the

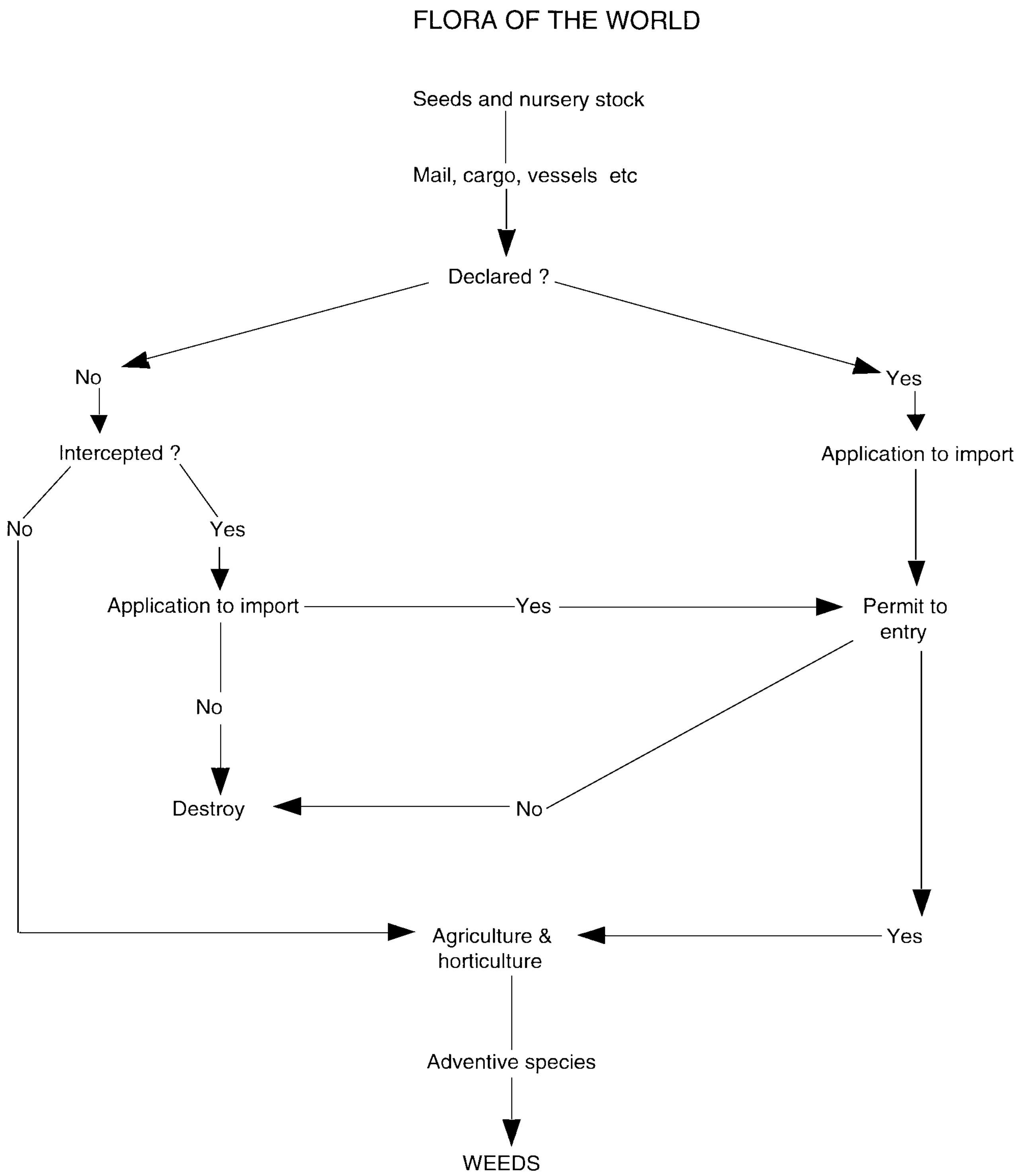

Figure 1. Pathways of entry into New Zealand of new plant species that become weeds.

material) and the method of transport to the border: accompanied baggage, air cargo, sea cargo, mail, vessels, or personal effects. Note that 'mail' includes only packages. Letter mail is probably a major route of undeclared material but has only recently begun to be inspected, and is indeed proving to contain large numbers of items (pers. comm. B. Whimp, MAF Quarantine Service). Seeds are recorded by weight, and nursery stock by the number of 'units'. A single seizure for example, may be a small packet containing 20 different assorted seeds, a sack of illegal grain, an apple cutting, or a number of potted shrubs. The data are not classified into plant species at this point; this can occur at a later date in the process if the prospective importer wishes to continue with a formal importation process. However, many do not. Seeds or other plant material of drug species are not included in the data although they may be present, e.g. as contaminants. For simplicity, we examine the number of seizures of seeds and nursery stock.

Nearly 70% of seed seizures arrive by air baggage and 25% by mail, whereas 84% of nursery stock arrives by air baggage (Table 5). There are over four times as many seed seizures as there are nursery stock. Seed origins are fairly evenly spread between Australia, S.E. Asia, and Europe, with slightly less from North America, and the Middle East–N.W. Asia. Relatively small amounts come from the Pacific Islands, Africa, or South America. Nursery stocks show a slightly different pattern, with Australia and Europe still contributing c. 40% of the total, but with Pacific Islands in third place. Note that the limits of these zones are not

TABLE 5. THE NUMBER OF SEIZURES OF SEEDS AND NURSERY STOCK MADE AT THE BORDER BY THE MINISTRY OF AGRICULTURE AND FORESTRY FOR THE PERIOD JANUARY–MARCH 1997, THEIR MEANS OF ARRIVAL, THE ORIGIN OF THE CARRIER, AND THE PERCENTAGE UNDECLARED.

ORIGIN	AIRCRAFT BAGGAGE	SEA CARGO	AIR CARGO	PARCEL MAIL	VESSELS	PERS. EFFECTS	ORIGIN %	UNDECLARED %
Seeds								
Europe	95	3		243	1	11	18.6	46.3
North America	131	7		119	3	9	14.2	18.8
Middle-East & Asia	252	7	2	45	2	7	16.6	34.7
South East Asia	361	5		8	1	5	20.1	37.1
Pacific Is.	97			3	3	1	5.5	30.6
Australia	344	2	3	41	5	12	21.5	36.1
Central & S. America	16		1	2		2	1.1	45.7
Africa	8	2	1	23		10	2.3	38.5
Sum	1304	26	7	484	15	57	100.0	
% of total seeds	68.9	1.4	0.4	25.6	0.8	3.0		
Nursery stock								
Europe	50	2	3	21	2	4	18.0	40.2
North America	31	1	2	13		1	10.5	12.5
Middle East & Asia	57			4		3	14.0	56.6
South East Asia	55			1	1	1	12.6	25.9
Pacific Is.	83			2	1	1	19.0	46.0
Australia	97	1	3	3	1		23.0	21.9
Central & S. America	4			2			1.3	33.3
Africa	6		1				1.5	42.9
Sum	383	3	9	46	5	10	100.0	
% of total nursery stock	84.0	0.7	2.0	10.1	1.1	2.2		

closely defined in this report because they are used by agencies and found in published data and accounts, in different ways, so that a universal classification is not possible here.

The proportion of undeclared seizures is very similar for both seeds and nursery stock (c. 34%). The proportion is highest for Europe (46%), where most seed arrives by mail, and lowest for North America (18%) where it is equally divided between mail and baggage. Undeclared seizures are also high for Africa and South America, but based on only a small sample. The highest percentage of undeclared nursery stocks originate from the Middle East–N.W. Asia (56%) and the lowest is from North America. The relatively high proportion from the Pacific Islands possibly reflects attempts to introduce food plants*.

Seizures from baggage were modified to reflect the actual number of passenger arrivals, as a closer approximation to the actual number of declared and undeclared seizures coming across the boarder (Table 6). For seed seizures, these can be divided into three groups: Australia, S.E. Asia > Middle East–N.W Asia > North America, Europe, Pacific Is. > Africa and probably South America where we have no data for arrivals. Nursery stock shows a different picture, with Australia, Pacific Is. > Europe and all of Asia > North America > Africa.

Efforts to identify plant taxa that had been introduced illegally in recent years and that might become weeds, were unsuccessful. This was partly due to the absence of a publicly available list of proposed new imports with which to compare the apparently new(?) taxa being sold or distributed or otherwise in people's possession. The reasons for this are various and beyond the scope of this report.

In summary, the pathways for plant material entering New Zealand are complex, they differ for seeds and nursery stock, and the overall importance of letter mail is unknown, but is probably significant. Nevertheless, we can probably generalise that the greatest risk of undeclared material expressed as numbers of items is from Asia and Australia via baggage and from Europe via packages and letters.

3.2.3 Biogeographical origins of existing weeds

Political boundaries used to define visitors and origins of mail do not correspond exactly to the biogeographical boundaries used to describe the evolution and origin of plant species. Moreover, either these boundaries were not always capable of being clearly defined for some species, or the taxa are widespread, as in the tropics. Table 7 shows in a simplified manner the main centres of the distribution of the 140 or so conservation land weeds (Owen 1997) which could be readily prescribed and grouped. The origins of these weeds are distributed unevenly across the centres of biogeographical origin. Eurasia, which here includes mainland Asia, has historically been the main source of environmental weeds, followed by central and South America, and South Africa. South East Asia and the Pacific, including Australia, have historically been a rather minor source. Life forms are not distributed evenly between these regions. There are no vines from North America, whereas 32% of

* It is not possible to use a consistent geographical classification for all tables and comparisons because all data are not derived from the same sources.

taxa from Southern Africa are vines. These data integrate the history of plant introductions into New Zealand since 1870, and it would be useful to know if there have been any detectable changes through time which might indicate trends for the future. The history of the movement of plants around the world is a vast topic, but the changing patterns shown in Table 8 probably reflect the overall history of the human occupation of the southern hemisphere and its impact on the New Zealand flora. In particular, the historical importance of

TABLE 6. THE NUMBER OF PERSON ARRIVALS INTO NEW ZEALAND, THE NUMBER OF SEIZURES OF SEEDS AND NURSERY STOCK FROM BAGGAGE, AND THE TOTAL 'PRESSURE' OF THIS MATERIAL FROM SEVERAL REGIONS.

	NZ DEPARTURES[1] (000s)	OVERSEAS VISITORS[2] (000s)	TOTAL ARRIVALS[3] (000s)	SEIZURES PER ANNUM[4]		SEIZURES PER 1000 ARRIVALS		TOTAL ARRIVING[5]
				DECLARED	UNDECLARED	DECLARED	UNDECLARED	
Seeds								
Europe	97.1	276.7	373.8	244	136	0.7	0.4	380
North America	97.5	173.5	271	428	96	1.6	0.4	524
Middle East & Asia	70.5	322.3	392.8	552	456	1.4	1.2	1008
South East Asia	82.5	134.5	217	900	544	4.1	2.5	1444
Pacific Is.	129	70	199	240	148	1.2	0.7	388
Australia	598.6	433	1031.6	836	540	0.8	0.5	1376
Africa	5.9	13.7	19.6	28	4	1.4	0.2	32
Central & S. America[6]				44	20			
Others[6]	50.1	72.6	122.7					
Total	1131.2	1496.3	2627.5	3272	1944	1.2	0.7	5216
Nursery stock								
Europe	97.1	276.7	373.8	132	68	0.4	0.2	200
North America	97.5	173.5	271	108	16	0.4	0.1	124
Middle East & Asia	70.5	322.3	392.8	104	124	0.3	0.3	228
S.E. Asia	82.5	134.5	217	164	56	0.8	0.3	220
Pacific Is.	129	70	199	184	148	0.9	0.7	332
Australia	598.6	433	1031.6	304	84	0.3	0.1	388
Africa	5.9	13.7	19.6	12	12	0.6	0.6	24
Central & S. America[6]				12	4			
Others[6]	50.1	72.6	122.7					
Total	1131.2	1496.3	2627.5	1020	512	0.4	0.2	1532

1 Based on Statistics New Zealand data, for New Zealand resident short-term departures by country of main destination in 1997. Assumption is residents return from much the same region.

2 Based on Statistics New Zealand data, for overseas visitor arrivals by country of last permanent residents in 1997.

3 Sum of 1 and 2.

4 Based on annualised data from Ministry of Agriculture and Forestry for the period January–March 1998.

5 An index of the total risk of the region, based on seizures per 1000 arrivals, times number of arrivals.

6 In these cases, there is no match between Statistics Department data and Ministry of Agriculture and Forestry data.

Note: these data are not an indication of the number of species arriving, because a single seizure may contain more than one species and many will no doubt be the same species.

weeds from Eurasia, and also South Africa, is consistent with the historical migration route to New Zealand over several generations via Southern Africa and Australia, and the decreasing importance of agriculture, particularly since the 1940s (Esler 1988). Whether the conservation land weeds, as a proportion of all naturalised species, differ significantly between biogeographic regions, and whether the risk is therefore greater for some regions, is an important question. Databases being established by Landcare Research will eventually enable us to examine this question.

3.2.4 Relationships between imports and biogeography

Most plant species were not imported directly in the past from their biogeographical region of natural distribution. They generally arrived via secondary exportation from botanic gardens such as Kew, as illustrated by the spread of lantana (*Lantana* spp.) and the vast majority of plant species from the Himalayas, through the colonial period. Neither is there a close link in time between the importation of a species and the establishment date in the wild. There is usually a considerable delay between a new species establishing in cultivation, escape into the wild, and then becoming recognised as a weed. Many taxa will not even become established in the wild, and collected, in the same decade they were originally imported. For example, we have estimated that it takes some 200 fleshy fruited woody plants in New Zealand, about 50

TABLE 7. THE PERCENTAGE COMPOSITION OF THE MAIN LIFE FORMS OF 140 WEEDS OF PUBLIC CONSERVATION LAND FROM SEVERAL GEOGRAPHICAL CENTRES OF ORIGIN.

	EURASIA	SOUTH AFRICA	E. ASIA & PACIFIC	NORTH AMERICA	CENTRAL & S. AMERICA
Herbs, grasses, ferns	41	37	15	14	41
Trees, shrubs	47	32	69	86	33
Vines	12	32	15	0	26
%	100	100	100	100	100
Number of species	75	19	13	7	27

TABLE 8. THE MAIN CENTRE OF THE DISTRIBUTION (%) OF WEEDS OF CONSERVATION LAND[1] GROUPED INTO FOUR TRIDECADES OF FIRST RECORD IN THE WILD IN NEW ZEALAND[2]

MAIN CENTRE OF RANGE	TRIDECADE OF FIRST RECORD			
	1870–1900	1901–1930	1931–1960	1961–1990
Europe and Eurasia	58	48	31	30
North America	6	12	4	5
East Asia	0	8	13	16
Pacific and Australia	12	8	4	13
South Africa	15	8	9	18
Central & South America	9	16	32	18
%	100	100	100	100
Number of species	34	25	45	38

1 Based on Owen (1997)

2 Based on Webb et al. (1988)

years, once the species is available in nursery catalogues, to be first recorded in the wild (Landcare Research unpublished data), and an unknown period for them to become recognised as weeds. To overcome this time lag, the data for species establishing in the wild are combined for fairly long time periods (Table 8) by expressing the proportion from each region arriving post-1930 as a ratio of those arriving pre-1930. This reveals a dramatic trend, with East Asia 3.6 > Central–South America 2.0 > South Africa 1.1 > Pacific and Australia 1.1 > Europe, Eurasia 0.63 > North America 0.50. Weeds of conservation land are therefore coming increasingly from South East Asia and Central and South America. The question arises whether these patterns of species becoming weeds relate directly to seizures at the border from all sources in recent times, and hence the value of these seizures for predicting the origins of future weeds?

In fact, the data for seizures arriving by all means, including both seeds and nursery material, and modified for number of arrivals, show South East Asia > Australia > Middle East and West Asia > Europe, North America, Pacific > Africa, South America. This order does not closely correspond to the recent origin of weeds (Table 8). The placement of Latin America, in particular, is vastly underestimated by being ranked last in terms of absolute numbers of seizures, compared with its importance as a source of weeds. Furthermore, if we assume that letter mail is arriving in similar proportions to packages, then Europe as a source of undeclared arrivals in particular will be underestimated. Overall, there is little direct relationship between the origins of seizures and traffic volumes in the very recent past, and those weeds that have become established in the last few decades. The outstanding exception is East Asia, or South East Asia, depending on how we define it. Here, the total number of seizures is high, the seizure rate per visitor is high, and there is a trend for this region to contribute a growing proportion of the conservation land weeds.

Overall, these rather tentative patterns substantiate Esler's statement that weeds arrived in New Zealand via the busiest lines of commerce. However, these trends are being eroded by the universal spread of information and the ready availability of seed catalogues from all over the world including via the Internet where, for example, five seeds of banana passion vine (*Passiflora mollissima*) are available for US$2.60 from CarolSeeds@aol.com. It may still be true that most new species arrive indirectly from their region of origin, represented particularly as seed in the mail as both packages and letters coming via Europe from commercial seed suppliers. This continues the long history of botanical gardens and their commercial associates importing plants from all over the world and then re-exporting them, often to become weeds (Cronk & Fuller 1995). Against this pattern, there is probably an increasing proportion of new species arriving directly from their countries of natural origin, particularly from the warmer parts of the world. *Cestrum parqui,* for example, was brought directly from Chile by a private individual (Esler 1988). In the case of Eastern Asia and the Pacific, including Australia, these species are more likely to be woody plants, whereas those from South Africa and South America are more likely to be vines (Table 7).

3.3 RISKS POSED BY NEW PLANT IMPORTS

3.3.1 Recently proposed imports screened for weediness

Prediction of weed potential has always been difficult (Crawley 1987), but progress is emerging via several approaches (reviewed by Mack 1996) and screening tools are now available, such as the WRA developed in Australia and New Zealand (Pheloung et al. 1999). Integral components of weediness prediction are the taxonomic relationships and weediness of a taxons relatives, and the taxons history of weediness elsewhere in the world. This section examines these relationships for the existing weeds of conservation land in New Zealand within the context of any process put in place to assess weed risk. The relationship between illegal imports and conservation land is discussed in section 3.3.2.

Taxonomic relationships

A comparison of weeds on the AllWeeds database with the 140 terrestrial weeds of the public conservation land (Owen 1997), shows that 85% have been reported as weeds in other countries, indicating the power of weediness elsewhere to describe weediness in New Zealand. The limitations of this predictor are discussed elsewhere, but first, how useful has it been in the brief period when prospective imports have been screened?

An examination of the 1500 species screened by Landcare since 1996 shows that some 220 species have been recorded as weeds elsewhere in the world. An unknown but presumably high proportion would probably be capable of becoming weeds in New Zealand, given the general vulnerability of New Zealand to a wide range of plants (Esler 1988). Taken as a whole, the original 'tens rule' suggests that only about 1.5 of the 1500 species should become weeds here, so prospective plant imports forwarded by MAF to Landcare for an assessment are some 100 times more likely to be weeds than a random selection of the plants of the world. Of the 220 weed species, 44 species were not in New Zealand and were recommended by Landcare as rejected imports for various reasons including New Zealand weed potential*.

The taxonomic relationships of these plant imports may also be important. The 14 families of plants, dicotyledons, monocotyledons, and Pinaceae, reported to be the most important plant families as far as environmental weeds are concerned, are shown in Table 9, derived from Cronk & Fuller (1995). They are ranked in order of the number of species amongst the 1500 screened prospective imports into New Zealand. There is some relationship between the taxonomic richness of these weedy families on a world scale, i.e. Compositae > Fabaceae > Gramineae > Euphorbiaceae, and the relative proportions of screened proposed imports into New Zealand. The major exceptions are Cruciferae, which are greatly under represented, and Labiatae which are greatly over represented.

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* However, an unknown number of benign taxa may have been screened and permitted entry by MAF already, while some potentially invasive grasses were formally assessed for MAF by research organisations other than Landcare Research. These data were not examined here, but it raises the possibility that the overall weed potential of **all imports** may differ in their weed potential than that discussed here.

The species proposed to be imported that are not already in New Zealand, and which are known to be weeds, follow the same general trend among the 14 weedy families, i.e. Compositae > Fabaceae > Gramineae (Table 10). Labiatae is again an exception, but here the taxa are mostly annuals (*Salvia* spp.) with little weed potential, because none of the naturalised species are invasive here.

These families include 50% of the present terrestrial conservation land weeds (Owen 1997) (Table 10). The majority of weeds presently on the DOC database are therefore weeds elsewhere, and half of them belong to just 14 families.

There are ten other families amongst the proposed imports and some have several species, e.g. Oleaceae (5), Iridaceae (4), and Liliaceae (4), while some of the worst weeds belong to families poorly represented numerically amongst conservation land weeds, e.g. *Tradescantia fluminesis* (Commelinaceae 1) and *Clematis vitalba* (Ranunculaceae 2).

Most (75%) of the species on the main DOC database (Owen 1997) that are not weeds elsewhere in the world tend to belong to families other than the 14 weedy families, and many are from tropical families represented by very few weedy species in New Zealand (e.g. Cobaeaceae, Tropaeolaceae, Zingiberaceae). Furthermore, several other families are represented amongst the nascent weeds of limited distribution not yet included on the DOC database of 160 weeds, e.g. Moraceae, Aizoaceae, Palmae. Of particular note is the family Labiatae which has several species known to be bad weeds (Owen 1997). The origins and taxonomic relationships of weeds and potential weeds is, therefore, likely to present us with surprises.

To emphasise this point, an increasing proportion of species that have become weeds in recent decades have become recognised as such for the first time in New Zealand (Table 11). Most species first collected in the wild before 1940 have a history of weediness elsewhere, whereas those with no history of weediness have increased to 20% for the period since then. These trends are a reflection of the invadibility of New Zealand on the one hand, and the increasing awareness of environmental weeds amongst New Zealand managers of conservation land (Pheloung et al. 1999).

The risk that proposed new taxa will have neither weedy relations nor a history of weediness elsewhere, but will prove to be invasive in New Zealand if permitted entry, is therefore increasing.

Life mode relations

A further indication of the potential impact of new weeds can be gauged from their life forms, shown in Table 12. There are no annual herbs amongst the current conservation weeds, but these compare with 7.2% amongst the proposed imports. Biennial and perennial herbs are the largest single category (49.3%) amongst the proposed imports, more than twice the proportion but among the present conservation weeds. Cacti constitute a small proportion of the imports, albeit a growing proportion, but none are yet weeds in New Zealand. There are few vines amongst the imports (0.6%) but the proportion of shrubs is only slightly less, at 15.1%, than their current contribution to environmental weeds. Dicotyledonous trees are less than a tenth of the imports (8.2%), but they make up almost a quarter of the weeds. Monocotyledonous trees in the form of palms make up 8.8% of the imports but they are absent from the weeds. Overall, there is a poor match between the life forms of the conservation weeds and those screened as imports. If the past is a guide to the future, then on average, prospective imports are much less weedy than the current conservation land weeds because of a low proportion of weedy life forms.

In part, the less weedy nature of the new legal imports is due to a screening process that has rejected grasses and most of the vines proposed for importation (Table 12).

Life form spectra vary between major centres of origin of proposed plant imports. For example, species from East Asia and the Pacific (including Australia in this table) are more likely to be woody weeds, whereas those from Southern Africa and South America are more likely to be vines (Table 7). On average, therefore, plant taxa from these regions are more likely to be weeds of conservation land. [Note the previous rider concerning geographical classifications.]

3.3.2 Illegal and accidental plant imports

The amount of material detected at the border (Table 5) shows that many people try to import seeds and other plant parts illegally. The volume and origins of this material have been discussed in section 3.1.3, but a few points can be made about its potential weediness and the resulting risks. First, in the absence of any evidence to the contrary, it is assumed is that material imported illegally is at least as weedy as the material submitted for formal risk assessment, in this case, as evidenced by the material handled by Landcare Research. A cautious approach would suggest it is likely to be more weedy. Obtaining a correct identification is a further complication, even for legitimate material, especially because so many of the plants handled by the nursery trade are cultivars (Gaddum 1997) of uncertain parentage and hence of unknown weed potential.

A possible profile of this illegal material can be gained from a combination of both the accepted and rejected material shown in Tables 9–11. Taxonomically, this is dominated by the world's weedy families and it includes species from some highly invasive genera, both internationally and in New Zealand (*Bidens, Lupinus, Sporobolus*). On average, a large proportion of the material would be herbaceous (Table 12), but there would be many more grasses and vines amongst the illegitimate imports. The risk of this material becoming invasive will also vary with pathway of entry, as discussed in section 3.2.3, but there is no information on how this relates to illegitimate material. Overall, however it appears there are likely to be many invasive species imported illegally, e.g. *Stipa tenuissima* (a grass) and *Macfadyena unguis-cati* (a vine) (Landcare Research data).

Anecdotal evidence from Landcare Research and suggests some species are introduced illegally by being incorrectly named, or purposely misnamed as a species already here, but we have no quantitative data to judge the importance of this pathway as distinct from illegal introductions generally.

Accidental introduction as a contaminant has historically been an important pathway, particularly for agricultural weeds (Esler 1988). Data on species detected as seed contaminants is held by the National Seed Testing Laboratory,

TABLE 9. THE MOST IMPORTANT WEEDY PLANT FAMILIES OF THE WORLD* AND THEIR REPRESENTATION AMONG 1500 RECENTLY SCREENED PROSPECTIVE IMPORTS INTO NEW ZEALAND.

MAIN WEEDY FAMILIES OF THE WORLD*	WORLD SPECIES	ALL PROSPECTIVE IMPORTS INCLUDING SPECIES ALREADY PRESENT IN NEW ZEALAND		
		ALL SPECIES	WEEDY SPECIES	LARGEST GENERA AMONG WEEDY SPECIES
Compositae	21000	214	45	*Artemisia* (4) *Eupatorium* (3) *Aster* (3) *Bidens* (3) *Emilia* (3)
Labiatae	5600	106	16	*Salvia* (5) *Stachys* (3)
Fabacaceae	16400	102	18	*Lupinus* (8)
Cruciferae	3000	68	–	
Euphorbiaceae	8000	59	6	*Jatropha* (3)
Scrophulariaceae	4500	29	1	*Rhinanthus*
Gramineae	9000	25	14	*Pennisetum* (2) *Bromus* (2) *Zizania* (2)
Rosaceae	3000	17	2	*Potentilla* (2)
Convolvulaceae	1700	16	6	*Ipomoea* (4)
Polygonaceae	1200	11	7	*Rumex* (6)
Solanaceae	2600	10	5	*Datura* (2)
Cyperaceae	3600	5	1	*Kyllinga*
Malvaceae	1600	5	1	*Callirhoe*
Pinaceae	100	–	–	
Others		847	100	

* Based on Cronk & Fuller (1995).

TABLE 10. THE MOST IMPORTANT WEEDY FAMILIES OF THE WORLD, THEIR REPRESENTATION AMONG 348 PROSPECTIVE IMPORTS INTO NEW ZEALAND, AND WITHIN 160 WEEDS OF PUBLIC CONSERVATION LAND.

MAIN WEEDY FAMILIES OF THE WORLD	PROSPECTIVE IMPORTS OF SPECIES NOT KNOWN TO BE IN NEW ZEALAND				CONSERVATION WEEDS*	
	SPECIES ACCEPTED	LARGEST GENERA	SPECIES REJECTED	LARGEST GENERA	SPECIES	LARGEST GENERA
Compositae	29	*Syncarpa* (5) *Emilia* (3)	11	*Bidens* (2)	9	*Ageratina* (2), *Senecio* (3)
Labiatae	25	*Salvia* (11) *Agastache* (7)	–		–	
Fabacaceae	14	*Lupins* (7)	7	*Lupinus* (2)	16	*Racosperma* (3), *Lupinus* (2)
Cruciferae	–		–		–	
Euphorbiaceae	10	*Euphorbia* (9)	1	*Jatropha*	–	
Scrophulariaceae	9	*Keckiella* (4)	–		1	*Mimulus*
Gramineae	–		2	*Sporobolus*, *Panicum*	18	*Cortaderia* (2), *Ehrharta* (2)
Rosaceae	6	*Potentilla* (4)	–		9	*Cotoneaster* (2)
Convolvulaceae	1	*Evolvulus*	1	*Ipomoea*	2	*Convolvulus*, *Ipomoea*
Polygonaceae	1	*Fagopyrum*	–		3	*Reynoutria* (2)
Solanaceae	2	*Withania*, *Nicotiana*	1	*Chamaesaracha*	6	*Solanum* (4), *Cestrum* (2)
Cyperaceae	–		–		5	*Juncus* (5)
Malvaceae	1	*Alcea*			–	
Pinaceae	–		–		4	*Pinus* (4)
Others	213		21		68	

* From Owen (1997).

TABLE 11. THE YEAR OF FIRST COLLECTION FROM THE WILD, OF WEEDS ON CONSERVATION LAND THAT ARE NOT KNOWN AS WEEDS IN OTHER COUNTRIES, COMPARED WITH ALL THOSE WEEDS ON CONSERVATION LAND.

DECADE BEFORE YEAR INDICATED	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990
Conservation weeds*	23	19	18	9	12	9	8	21	12	15	11	10	14
Conservation weeds not weedy in other countries†		1	1					1	3	4	2	3	4

* Weeds on public conservation land in New Zealand, partly from Owen (1997).

† Data from Landcare Research ALLWeeds database.

TABLE 12. LIFE FORMS (INCLUDING TAXONOMIC CLASSIFICATION) OF WEEDS ON CONSERVATION LAND COMPARED WITH THOSE NEW SPECIES RECOMMENDED AS EITHER PERMITTED OR REJECTED ENTRY INTO NEW ZEALAND IN RECENT YEARS.

	CONSERVATION WEEDS	NEW SPECIES		IMPORTS cf. CONS. WEEDS*
		ACCEPTED	REJECTED	
Number of species	160	304	44	
Annual herbs	0	7.2	9	>>
Bi annual/perennial herbs	20.4	49.3	59.3	>>
Grasses and rushes	19.1	0	4.5	<<
Cacti (herbs and shrubs)	0	5.6	0	>
Ferns	2.6	0	0	<
Dicot. Shrubs	19.1	15.1	13.7	<
Dicot. Trees	22.4	8.2	4.5	<<
Monocot. trees and shrubs	0	8.8	0	>>
Vines	16.4	0.6	9	<<
Uncertain form	0	4.9	0	n.a.
%	100	100	100	

* > = greater; >> = much greater.

but these data were not available for analysis. The risk from such introductions establishing and spreading must be very low compared with horticultural species which are assisted to overcome all the barriers to introduction (Mack 1995).

3.3.3 Probabilities of imports becoming invasive

An attempt can be made to quantify the chances of new imports becoming weeds, despite the innumerable unknowns, and to compare them with the rate at which weeds are developing from amongst the c. 20,000 adventive species present in New Zealand.

The 348 species new to New Zealand used to compile the family summaries in Table 10 were those requested as imports and subsequently screened between August 1995 and February 1998, a period of 2.5 years. A total of 304 species were accepted which equates to 122 per year. In the absence of any weediness screening and the application of the 'NZ rule', this would mean 1.2 weeds (both agricultural and environmental) per year. But the 304 species have been screened, and the potential weediness of screened imports will hopefully have been reduced. Furthermore, from the perspective of the conservation land this risk will be unequally distributed amongst the 304 species because the risk will differ for each life form. For this exercise, the assumptions are (a) that very few annual herbs or palms have the potential to become conservation weeds as neither are currently represented and the screening procedure has entirely removed this slight risk, and (b) that the application of the screening procedure to those species with life forms well-represented amongst weeds of conservation may have reduced the risk by 75%. Applying the factor of 0.025% (the 'NZ rule' of 1% reduced by 75%) reduces the values sum to 0.54 species (herbs other than annuals 0.37, vines 0.005, shrubs 0.11, dicotyledenous trees 0.06) over 2.5 years, which equates to 0.2 species per year.

Over the period 1880–1990, 160 species have become widely recognised as conservation land weeds, and a further 70 odd species show signs of eventually becoming weeds (Owen 1997). These data sum to 1.4 species per year and to 2.1 species per year respectively for the 160 or 230 species. This risk is many times higher than the risk from screened imports based on the assumptions used here.

Risk assessment is concerned with managing uncertainty and can be broken into three distinct types (Orr et al. 1993). The first of these is concerned with the methodology of the assessment process. This includes the probability of intercepting material, the pathways of an application or a seizure through MAF and weed risk assessment procedures, and the final recommendation from MAF. However, the number of identifications being carried out by MAF and Landcare Research has declined in recent years as potential importers have been subject to charges for this process. The number of seizures at the border has not declined proportionately over the same time (pers. comm. MAF official). The main flaw in the process therefore appears to be that we are simply not identifying what people are attempting to bring in. In the worst case scenario,

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* This paper is the best we know of dealing with this topic.

people might also be avoiding the entire screening process and attempting to import material undetected. It is not possible to quantify this risk.

The second type of uncertainty—human error during the screening process—cannot be assessed at this stage.

The third component is the uncertainty associated with the organisms themselves, the biological unknowns. These have been discussed elsewhere, but it must be reiterated that it is not possible for any risk assessment process to determine precisely whether, when, or how, a particular plant will establish (Orr et al. 1993). Data presented here suggest, however, that this risk has been reduced, in so far as it effects potential weeds of conservation land. Our capacity to reduce this risk is nevertheless decreasing with time as prospective imports come increasingly from geographical regions outside those that have traditionally contributed to our weeds (Nicol 1997).

All three types of uncertainty are independent of each other and will continue to exist regardless of improvements in the others. The present screening process has been in existence for only a few years. The greatest potential area of improvement is to identify a greater proportion of actual and potential plant imports to the taxonomic level of species or variety.

The implementation of the HSNO legislation will see these uncertainties carefully assessed and, in the process, the criteria for acceptance of a new species may be significantly altered (Appendix 2). Approval for importation of any new species must be sought, and importation will normally only be permitted if there are good reasons for importation and the organism does not pose any threat to the New Zealand environment. Under this regime the criteria for acceptance may be more stringent than in the recent past and, as an example, the *Salvia* species mentioned earlier (section 3.3.1) may possibly fail to meet the acceptance criteria.

A salutary lesson from the current exercise is that among the most difficult species to deal with are those that have not been widely distributed in the past, or are new to horticulture and are not well known, particularly if the genus is not in New Zealand. Often the only information that has been available is life form, area of origin, and broad genus or family characters. Conventional flora provide little information that helps in assessment. Under the new legislation it would seem such species are unlikely to be approved for importation unless the importer can provide a great deal more information than has normally been the case in the past.

It should also be noted that the risk assessment process cannot determine the acceptable level of risk. The community may change its collective opinion of the level of risk to conservation values it is prepared to accept, in the bid to increase production of tradeable goods.

4. Additional material of taxa already in New Zealand

4.1 THE SIGNIFICANCE OF TRADE PROTOCOLS

World trade protocols dictate that exporting countries are not required to meet higher environmental standards than are imposed on domestic producers in the importing countries. Therefore, to justify quarantine regulations on environmental grounds where weed species are already established in a country, the species must be under official control in the importing country. The level of control must also be recognised at a national level. As a result of this modus operandi, it is legal to import material of many taxa that are already recognised as having some weed potential in New Zealand. This raises the issue of what additional risk, if any, is posed by the continued introduction of such plant taxa, including the introduction of new genetic material.

The issue is further clouded under the HSNO Act because the interpretation of the taxonomic unit of species is unclear and species may not always be used in the strictly scientific sense when determining if an organism is 'new'. It is also unclear how hybrids and cultivars will be handled, particularly in cases where parentage is unknown. The boundaries of species, and additional material of taxa already in New Zealand, may be used less distinctly than we have done here.

4.2 RISKS FROM ADDITIONAL MATERIAL OF TAXA IN NEW ZEALAND

4.2.1 The element of chance

Additional material of a plant species brought into a country may be able to influence the factors controlling the life history traits of a taxon and hence its invasive potential. The most obvious is an increase in propagule pressure; the number of propagules of the same species available for dispersal to a defined area over a defined time period. In theory, the greater the pressure, the greater should be the chance of a species establishing in a new area. The most parsimonious effect the increased pressure can have is to create another locus which reduces the chance of a species dying out through a site specific stochastic event (Mack 1995) and increases the chances a species will find conditions suitable to achieve a 'break out'. This effect would have maximum impact at the early stages of a species invasion. For example, if there is only one known population, the establishment of a second population doubles the chance that a species will survive and spread. In the experience of every gardener, and from the long term studies of plants (and animals) invading new islands, there is ample evidence that repeated introductions are often needed for a species to become established. An example of the influence of additional introductions on the spread of weeds has been documented for downy brome (*Bromus tectorum*) into western North America (Mack 1981). However, beyond this simple 'game of chance', there is little evidence to show that for established species, the arrival of more propagules of the same genetic composition will significantly increase the rate of spread (Williamson 1996; and pers. comm. to P.A.W. 1998).

In summary, there appears to be little difference in theory between plant material originating in another area of New Zealand and that originating outside the country, so those wishing to restrict imports of species already here must show that the material is different in some way.

4.2.2 Increased genetic diversity

The increase in genetic diversity associated with new introductions is possibly a more important issue than simply enhancing propagules pressure. As Mack (1996) has succinctly expressed it:

> 'a misnomer has long been used in describing plant invasions—i.e. that *species* invade new ranges. In a strict sense, it is usually small populations drawn from only part of the species' home range or elsewhere that give rise to naturalisation and subsequent invasion. These founders often display little of the genetic variation in the species as a whole (Barrett & Richardson 1986), and consequently their fate in a new habitat may bear little relation to the outcome for genetically different members of the species'.

While plants cope in a host of ways with this limited variability, there is clearly an advantage in colonising populations containing much genetic variation (Barrett & Richardson 1986)*, and examples are given by Kowarik (1995) and Williamson (1996).

While there have been very few studies that identify the level of genetic variation required to achieve invasive success, and presumably also a break out, they do point to a genetic difference of 10 genes or less as being sufficient (Williamson 1996).

The manner in which this increased genetic variation is manifest in the phenotype is of critical importance to its detection, and to the management of the taxon.

There are only a few case studies where the genetic variation of invasive weeds has been identified at the subspecific level. For example, where the subspecies have originated from different areas, each pre-adapted to a part of the geographic range of the host country, the total infestation can be greater than would be likely with only one subspecies (Panetta & Randall 1994). In some cases the variability will not be visible, for example, some provenances of several *Pinus* species are better able to colonise high mountain areas than others, yet they may have no distinguishing features.

The corollary of this argument is that the importation of novel genetic material of a species that one already in New Zealand will increase the chances of that species becoming invasive. However, the level of genetic variation that could possibly have this effect would seldom be recognisable at border control.

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* This paper is the best we know of dealing with this topic.

Reproductive bottlenecks

One subset of genetic variation that clearly stands out as providing identifiable and explicable reasons for a taxon's increased invasiveness relates to the first of Kowarik's (1995) limiting factors, namely, where genetic material is imported that breaks a bottleneck somewhere in the reproductive system of the taxon. An excellent example is provided by the many species of *Populus* (poplars) and *Salix* (willows) represented in New Zealand (van Kraayenoord et al. 1995) by only unisexual or non-breeding hybrids which limits their capacity to spread (Webb et al. 1988, Kremer et al. 1995) (Note: Full lists of these taxa are held on data bases at Landcare Research, Lincoln). However, they show a great ability to form fertile hybrids that aid their dispersal and that incidentally, give rise to complex patterns of nomenclature. Most of these taxa have not spread to their maximum possible range but there is still a great threat to many wetlands from taxa already in the country. Many of these *Salix* and *Populus* taxa are more widely distributed throughout their potential ranges in both their native ranges and where both sexes have been introduced (Thompson and Reeves 1994). Clear evidence that the introduction of new genetic material, particularly in the form of female plants, would increase the reproductive capacity of both willows and poplars has lead the Australians to recommend that no female plants be introduced (Kremer et al. 1995). Thus recommendation is appropriate for New Zealand (Thompson and Reeves 1994).

Hybridisation

Apart from interacting with other populations of the same taxon, new genetic material of taxa already here may hybridise more readily with other adventive or native taxa. It is now possible, via molecular biology, to study the ecological and/or evolutionary origins of invasive weeds and any evolutionary consequences that arise from hybrids between weeds, or between weeds and native species (Abbot & Milne 1995). Such intensive research has been conducted on very few groups, two senecios (*Senecio squalidus*, *Senecio viscosus*) and a rhododendron (*Rhododendron ponticum*) (Abbot & Milne 1995), and a few others. For example, the evolutionary relationships between Japanese knotweed (*Reynoutria [Fallopia] japonica*) and its relatives *Reynoutria sachalinesis* and *R.baldshuanica* have been studied closely in England by Bailey et al. (1995). They concluded that the hybridisation between these species was an important factor in the weediness of the group, a case where increased genetic diversity in the form of a second species has lead to a disproportionate increase in the weediness of the genus. The first two of these species are present in New Zealand (Webb et al. 1988), but *R. sachalinensis* does not produce mature fruit. Presumably, the kinds of evolutionary processes described by Bailey et al. (1995) could be occurring here, or may occur in the future, to increase the weediness of this group.

Aside from these examples, the *Flora of New Zealand,* volumes 3 (Healy & Edgar 1980) and 4 (Webb et al. 1988) reveal many taxa where invasibility could potentially be limited by the relatively narrow range of genetic material in New Zealand. These can be conveniently grouped into several related and sometimes overlapping syndromes. They range from known weeds, such as willows discussed above, to those with merely potential for weediness. Most obvious among these are the many species which do not set fruit, or do so only sporadically, perhaps reflecting the narrow range of genetic material. Some taxa are weeds elsewhere in the world, whereas others are demonstrating weed potential for the first time in New Zealand. Apart from *Salix* (Salicaceae) and *Alnus* (*Betulaceae*), others are in several genera of the families Lamiaceae (e.g. aluminium plant (*Galeobdolon luteum*)), Lobeliaceae (e.g. white root (*Pratia purpurascens*)), Apocynaceae (e.g. periwinkle (*Vinca* spp.), oleander (*Nerium oleander*)), and Solanaceae (e.g. potato vine (*Solanum jasminioides*)). There are many species fitting this syndrome in a closely related group of families, Bignoniaceae (e.g. *Distictis buccinatoria,* wonga wonga vine (*Pandorea jasminoides*)), Basellaceae (e.g. Madeira vine (*Andredera cordifolia*)), Balsaminaceae (e.g. impatiens (*Impatiens sodenii*)). Of the two wild gingers (Zingiberaceae) in New Zealand, *Hedychium flavescens* does not set seed.

Several species, recorded only recently as adventive, belong in this group, including those known to be weeds elsewhere and sometimes widely cultivated, e.g. a pepper tree (*Schinus terebinthifolius*, Anacardiaceae), sweet chestnut (*Castanea sativa*, Fagaceae) and a rose (*Rosa roxburghii*, Rosaceae) which is known to be invasive here, but is not known to produce seeds. Most plants reach some level of abundance in cultivation before showing weedy tendencies. In contrast, a few species begin to spread even before they are known in cultivation, e.g. white bryony (*Bryonia cretica*, Cucurbitaceae), and false tamarix *(Myricaria germanica*, Tamaricaceae) recently discovered in Canterbury (Sykes & Williams 1999). The limited distribution of these species presents an opportunity to limit their national distribution. Some hybrids are present in this category too (e.g. dahlias (*Dahlia coccinea ´ D. pinnata*)).

Other hybrids of interest are those that show varying degrees of weediness and where one or other of the putative parents are absent from New Zealand, or at least from the naturalised flora. These include Russell lupin (*Lupinus polyphyllus*) (or as it is often described, *L.* × *polyphyllus*, Fabaceae) which is so named because it resembles the strict species of the same name, but where in fact genetic material of this true species may not even be in New Zealand. Others include elaeagnus (*Elaeagnus* × *reflexa*, Elaeagnaceae), *Spiraea* × *billiardii* (*S. douglasii* × *S. salicifolium*) (Rosaceae) and several pelargoniums (*Pelargonium* spp., Geraniaceae).

Some genera show a particularly strong ability to hybridise that could translate into new genetic combinations with invasive tendencies, e.g. the daisies *Aster lanceolata* and *Bellis perrenis* (Asteraceae). In some cases, this hybridisation occurs in species, where there is good morphological evidence to suggest only a portion of the species variability is present in New Zealand, e.g. *Alnus* as discussed, but also barberry (*Berberis* spp., Berberaceae) and St. John's worts (*Hypericum* spp., Clusiaceae).

The absence of the full genetic range of alien plant species probably applies to most adventive species, and would be difficult to investigate as discussed above. However, in some species where there is already indication of weed potential, morphology comparisons of New Zealand with overseas material suggests that only part of a species range is present in New Zealand, for example as one variety. This situation commonly arises because the New Zealand adventives species have been derived from a particular cultivar, e.g. Paraguayan nightshade (*Solanum rantonnei*, Solanaceae) and salvias (*Salvia* spp., Lamiaceae). Other species representing this syndrome range from those that are already well recognised as weeds, for example, spiny broom (*Calicotome spinosa*, Fabaceae), to those that are just beginning to show weed potential, for example, *Plectranthus grandis* (Lamiaceae) and canary-bird bush (*Crotalaria agatiflora*, Fabaceae). In fact, this feature probably applies to many species of the Fabaceae.

One further aspect of genetic importance in which new introductions may be involved concerns hybridisation with the native flora, and the possibility that this will pollute the native gene pool and spread the genes of adventive species more widely than had a native species not been present. However, although the two flora have been interacting for almost 200 years, and in highly disturbed landscapes for much of that time, there is little evidence of this phenomenon. This is probably due to numerous barriers to interbreeding ranging from different flowering times to pollen incompatibility. The few examples where hybridisation has occurred (Connor 1985) are mostly ruderal sites maintained in this state by natural or man-made forces, that is the native and adventive convolvulus (*Convolvulus-Ipomoea-Calystegia*) complex (Ogden 1978), and ice plants (*Carpobotus-Disphyma)* interactions (Chinnock 1972). One exception might be in the Auckland region where *Metrosideros kermadecensis* (Kermadec pohutukawa) and cultivars of *Metrosideros polymorpha* s.l. are widely planted. The former hybridises with *Metrosideros excelsa* (pohutukawa) Bercusson & Torrance (1998) and *M. polymorpha* is well known as a problematic complex because of hybridism and/or genetic polymorphism (Wagner et al. 1990). The potential for genetic pollution of the native pohutukawa populations is present and should be monitored.

There has been some record of experimental hybridisation between native and adventive species, summarised by Connor (1985), and most recently between species of cudweed (*Gnaphalium* and *Pseudognaphalium)* but, as is frequently the case, no natural hybrids between native and foreign Gnaphalieae have been collected (pers. comm. Robert McKenzie). We conclude that the threat to native flora from genetic pollution from new adventive species is slight.

In summary, despite the intuitive appeal of not allowing more material of taxa that have already shown weedy tendencies into New Zealand, there is actually little published information to demonstrate how this would increase their weediness. Nevertheless, the above examples suggest there are adventive taxa in New Zealand, ranging from those that are already bad weeds to those developing weedy tendencies, where new material may be different from that already present. Interbreeding of this material with genetic material already in New Zealand could potentially result in some of these taxa expanding here.

Similar relationships potentially exist between new genetic material and many of the c. 18,000 species present in New Zealand, but not adventive. We have not examined this potentially enormous pool of interactions. However, if merely 50 or so taxa discussed above from an adventive flora of 2000 could have an increase in weediness precipitated by additional genetic material (some 2.5%), then there may be several hundred taxa amongst cultivated taxa not yet adventive which would be more likely to spread if additional genetic material was imported.

5. Conclusions

From section 3

- New Zealand has examples of most kinds of weed impacts present throughout the world. Further impacts from new species are therefore likely to be similar to those already experienced. Nevertheless, some life modes, such as shade-tolerant shrubs and bulbs, are under represented in New Zealand, and unpredictable and unique combinations of new taxa and place are possible. [3.1.1]
- Communities most likely to be affected by new taxa are low-statured vegetation such as shrub lands and open lands, and disturbed forest. A particularly successful species with novel impacts including resistance to management could invade any community, however, and have a disproportionate impact on New Zealand biota. [3.1.1]
- A minimum of one plant in every 100 not screened for weediness and introduced into New Zealand will become a conservation land weed. A high proportion of these, and all other imports, will belong to plant families known to be particularly weedy. The probability of a species belonging to one of these families being invasive in one of the more susceptible habitats is very much higher than 1:100. [3.1.2]
- New taxa and genetic material are imported mainly for horticulture and to a lesser extent for agricultural production. All regions of New Zealand are potentially affected by invasions resulting from these enterprises, but northern New Zealand is especially vulnerable. [3.2.1]
- New taxa enter the country via diverse pathways ranging from letter mail to cargo in ships holds. About 34% of the items seized at the border because they do not comply with import regulations are undeclared. The highest probability of undeclared material entering New Zealand, expressed as numbers of items, is probably via air baggage from Asia and Australia, and packages and letters from Europe. However, because this material is not identified to generic or species level, the risk it poses cannot be accurately assessed. [3.2.2]
- The biogeographical origins of plant material entering New Zealand are changing and there is probably an increasing proportion coming directly from their country of origin rather than through intermediary countries. There is an increasing chance of material coming from East Asia and South America. [3.2.4]
- Most taxa proposed for import are weeds belong to families and genera known throughout the world as especially weedy. However, an increasing percentage of proposed imports will be new to horticulture, have no history of weediness elsewhere in the world, and have few if any weedy relatives. [3.3.1]
- The weediness of permitted imports will be substantially reduced if screened (using similar criteria used by Landcare Research) to determine whether

they should be allowed entry. The difficulty of predicting their weed potential using existing procedures will increase with time as the proportion with unknown histories increase. In the short term, say 10 years, the probability of one of these taxa becoming a weed of conservation land is substantially lower than there being a new weed from among the taxa already in New Zealand. [3.3.1, 3.3.3]

- The risk to conservation land from illegal imports is suspected as being greater than that from screened legal imports, particularly for vines and grasses. The number of applications for permits to import plant material has declined in recent years. If the assumption is made that there has been no parallel reduction in the actual number of imports then the risk from illegal imports is increasing. [3.3.2, 3.3.3]

From section 4

- Trade protocols demand that the justification of prohibiting imports of taxa already in New Zealand, and not subject to an official control program, be closely examined. [4.1]
- The importation of additional plant material 'identical' to that of taxa already in New Zealand has an undefined potential to increase the probability of some taxa becoming invasive. Attention must be directed to showing that material of species already here is actually different. [4.2.1]
- The importation of additional plant material of the same taxon but genetically dissimilar to that of taxa already in New Zealand, has a definite potential to increase the probability of some taxa becoming invasive. In some cases, this potential is well known, e.g. *Salix* spp., while in others the actual potential is unknown. [4.2.2]
- There is a low chance that new exotic taxa, or additional genetic material of exotic taxa already here, will hybridise with the native flora and 'pollute' the indigenous gene pool. [4.2.2]
- Coda: Under the HSNO Act it will be more difficult to import little-known taxa, which are the most difficult to assess for weediness, than it has been in the past. This will require the importer to provide more information than has been the case. How this will translate into taxa actually imported, and therefore the risk to conservation land, will need to be examined after the new legislation has been in operation for some time.

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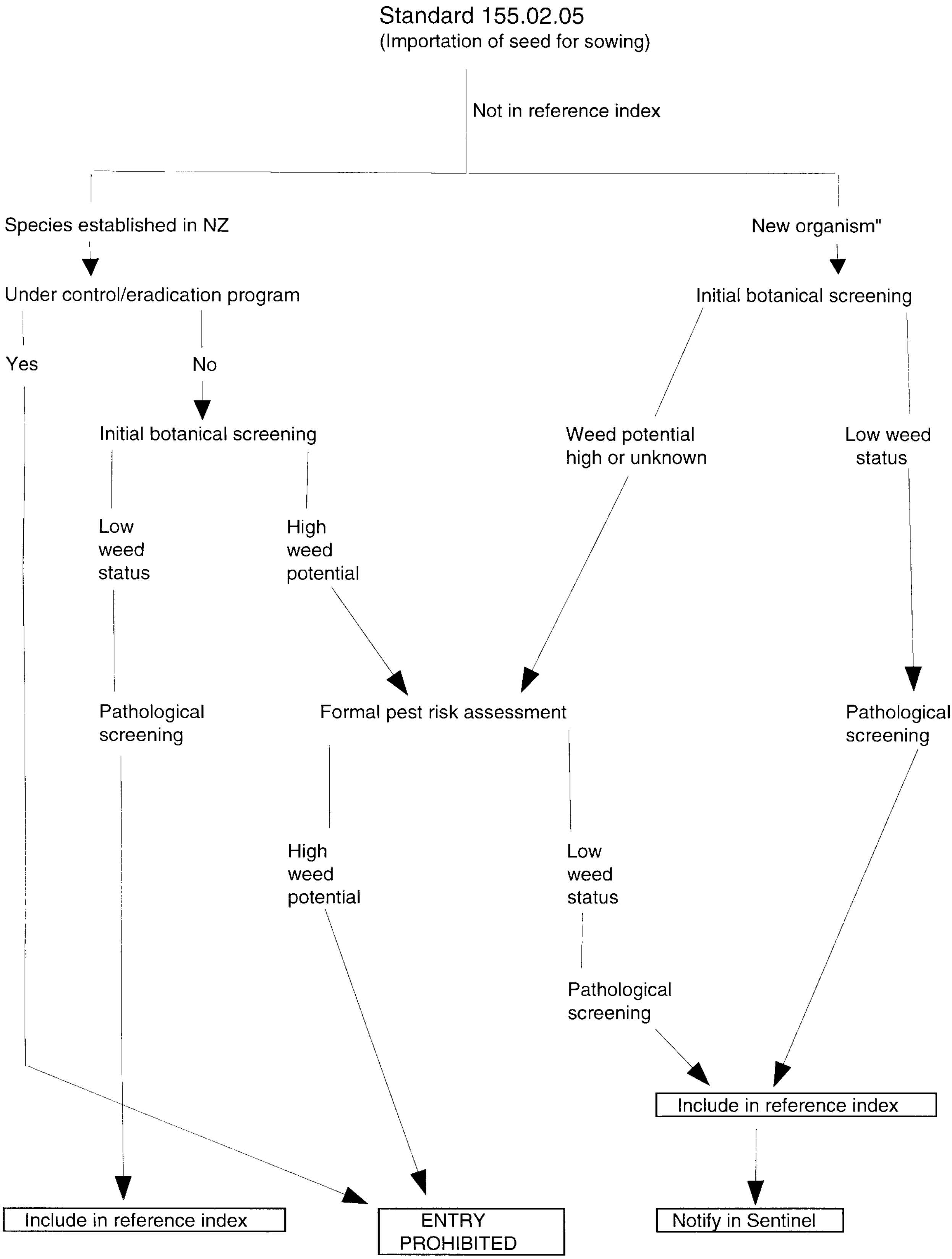
Appendix 1

Risk assessment for seeds or nursery stock



Appendix 2

Consideration of new organism applications under the HSNO and Biosecurity Acts