A weed risk assessment system for new conservation weeds in New Zealand

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ABSTRACT

New species of weeds are appearing on conservation land in New Zealand at a rapid rate. It is not feasible to control them all, and a system is required that will enable conservation managers to rank new weeds in order of priority for control. Existing ranking systems have many good features but no one system seems suited for prioritising species at the earliest invasion stages. A new score system was therefore developed, initially for fleshy-fruited vines and woody plants invading lowland woody vegetation in the Nelson/Marlborough region of New Zealand. Questions within the system are related to: weed history elsewhere; weediness of a species' relatives; potential interactions with native vegetation; history of the species in the area under consideration; and the technical considerations and social implications of attempting control. Scoring is weighted towards the most recent weed arrivals, because these will tend to be the easiest to control. The system is calibrated from the 22 species of primarily bird-dispersed climbers and woody weeds in the Nelson/Marlborough region, so that it is in approximate agreement with the authors' own assessment based on experience of weeds in the region. The score system can be applied to any region of New Zealand with broadly similar invading species and environments. It can be adapted for other plant life forms and vegetation types and other regions.

Keywords: New Zealand, weed risk assessment, ranking, conservation weeds.

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1. Introduction

At least 2000 exotic plant species have become naturalised in New Zealand, resulting in an equal proportion of exotic to native species in the wild flora (Wilton & Breitwieser 2000). A naturalised species is one that forms a minimum of one self-sustaining population in the wild ‘away’ from, or not merely ‘in the vicinity of’ the original plantings. Any naturalised plant may be considered a weed if it conflicts with human values. There appears to be no slackening of the rate at which exotic plants are naturalising—it has been a steady 12 species per year since records first began about 150 years ago (Lee et al. 1999). Approximately 240 naturalised plant species have already become ‘conservation weeds’—and as most naturalised plants are still expanding their populations, this number of conservation weeds is increasing by about 2 per year (Owen 1997). A ‘conservation weed’ is, as we define it, any naturalised species at any stage of its expansion in the wild, which is perceived by persons working in the area of nature conservation in New Zealand to be impacting in any way on nature conservation objectives (Williams et al. 2002). The ‘discovery’ of new conservation weeds is now enhanced by increased effort to detect and control naturalised plant species through measures such as surveillance plans within the Department of Conservation (DOC) (Braithwaite 2000). However, if DOC attempted to control every new weed species that appeared on the land it manages, it would waste resources on species that might never become significant conservation weeds. A major constraint in taking action against new weeds is the uncertainty in the trajectories over time and space of these invasions, and just what damage they might cause to natural systems. Irrespective of this, it is widely recognised that controlling weeds at the earliest stages of their invasion is generally the most cost effective strategy (Mack 1996). This has led to the concept of a ‘species-led’ control strategy (Williams 1997) that has been incorporated into DOC planning as ‘weed-led’ control (Owen 1998). The imperative then becomes: which of the new weeds appearing on conservation land should we control?

There are several weed risk assessment systems that attempt to discriminate weeds (as defined above) from non-weeds amongst the naturalised floras of different countries, and to rank weeds by their potential impact or need for control. Most progress has been made internationally when dealing with a single biome, or ecological community (usually defined by vegetation type) because species attributes that facilitate invasions are habitat-specific (see section 2). The Department of Conservation felt that a more refined risk assessment system could be developed by dealing with specific life forms or functional groups of plants, taking into account recent literature on weed invasions. This report describes a weed risk assessment system developed by Landcare Research for the ranking of naturalised species for weed-led control. The system is designed for specific terrestrial plant life forms that are at the earliest stages of their spread, and within a specified biome of a defined area—fleshy-fruited vines and woody plants in the lowland zone of Nelson/Marlborough. This system is distinct from the new conservation weed risk assessment system designed for the border, termed the CWR system (Williams et al. 2002).

2. Overview and aims

Apart from the relatively few weed risk assessment systems that aim to predict weediness of species not yet in a country (reviewed in Williams et al. 2002), there are several systems that rank existing weeds. Some of these were presented at a recent symposium on weed risk assessment (Groves et al. 2001). Some are designed for specific biomes, such as the fynbos (shrublands) in South Africa (Tucker & Richardson 1995) and wetlands in New Zealand (Champion & Clayton 2001). Others are prioritising schemes for weeds of national importance (Virtue et al. 2001), while others are designed to operate at a range of scales (Hierbert 1997; Randall 2000; Timmins & Owen 2001). The systems consider a range of socio-economic effects (Wainger & King 2001), including visual effects (Hierbert 1997), and effects on ecosystem structure and function (Randall 2000; Timmins & Owen 2001). Only rarely have the determinants of the invasion of a specified biome been investigated and subsequently formed the basis for a scoring system for that biome, which is clearly the most useful way of predicting invasions (Tucker & Richardson 1995). Table 1 summarises the main weed risk assessment models from the literature.

For most ecosystems, however, there is a rudimentary understanding only of the determinants of invasion success and the ecosystem impacts of particular species, even for widespread species. Consequently, there is no ready way to quantify the impact of one species as opposed to another, or to quantify the impacts of individual species at defined levels of infestation (Panetta & James 1999; Parker et al. 1999). There is little hope, therefore, of applying standard analyses such as cost benefit analysis, to weed risk management decisions (Panetta & James 1999). These authors considered 'the most meaningful trigger for the management of serious weeds in natural systems may be determined primarily by the cost and efficacy of control measures'. These must be considered relative to the stage of weed invasion (Hiebert 1997), and such information is critical in identifying potential weed-led programmes (Owen 1998).

In the absence of any direct measure of impact, a wide range of assessment criteria have been used in attempts to characterise weediness and prioritise species for control. These assessment criteria can be divided into three groups based on bio-physical criteria, socio-economic effects (including environmental damage), and the costs and risks of control or failure to control (Wainger & King 2001). Most systems rely on scoring detailed biological attributes that are only *assumed* to equate to invasiveness. Some very general rules relating species' attributes to invasiveness are emerging (Rejmanek 2000). However, these relate to only a few groups of plants (summarised in Williams et al. 2002) in specific habitats, with particular disturbance regimes, including those determined by human activities.

For example, we do not know the relative importance of dispersal modes in various systems in New Zealand. We might expect birds to be an important dispersal mechanism in habitats favoured by them, and for weeds with seeds that are attractive to birds. Fleshy-fruited woody weed species *are* abundant in lowland wooded vegetation (Timmins & Williams 1987), but there is no evidence that dispersal mode is the main reason for their abundance. In contrast,

TABLE 1. A SUMMARY OF THE MAIN WEED-RISK ASSESSMENT MODELS FROM THE LITERATURE, THEIR APPROACHES, AND STRONG AND WEAK POINTS, TO ASSESS THE RISK OF CONSERVATION WEEDS AT RELATIVELY EARLY INVASION STAGES.

AUTHOR(S)	APPROACH	STRONG POINTS	WEAK POINTS
Esler et al. 1993	Sums scores for ability to succeed with a score for weediness	Clear, transparent, comprehensive	Designed for well-established noxious plants. Mixes a number of weed features
Hierbert 1997	Weighs relative impact against ease of control and cost of delay	Clear, transparent, comprehensive, and takes management into account	Assumes causal relationship between biology and impact, and that much information is available. Weed history is an integral part of the system
Pheloung et al. 1999	Relies primarily on weed history, modified by biological and ecological factors	Clear, transparent, comprehensive	Too reliant on weed history
Randall 2000	Scores for invasiveness/ impacts/ potential distribution/invasion stage	Straightforward, transparent, considers invasion stage, urges users to consider weeds within a biome	Assumes detailed biological attributes are related to weediness/ impacts. Mixes land use classes
Timmins & Owen 2001	Explicit weed-led approach cf. site-led. Considers value of area potentially impacted	Clearly defined options, simple criteria, takes practicality of control into account	Assumes detailed biological attributes are related to weediness and that ecosystem impacts understood
Tucker & Richardson 1995	A set of rules derived from a conceptualisation of the invasion process in fynbos vegetation	Transparent, based on specific invasion processes, flexible	Limited to one biome (although could be adapted to others), and requires good understanding of causal factors
Virtue et al. 2001	Matches current and potential distribution. Adds this to score of invasiveness and impacts	Transparent, pan-sectorial weightings, considers potential spread	Only for well-established weeds. Assumes impacts are understood. Practicality of control given only minor importance
Wainger & King 2001	Relates likelihood of damage/defined functions of landscape/and the scale of threat to appropriate response	Enables justification of decisions in economic terms	Very complex. Costs and benefits must be known, so aimed at existing invasions

wind dispersal *may* be more important than bird dispersal for the invasion of open habitats unsuitable for frugivorous birds, and a scoring system for that habitat type might give bird dispersal a lower score. Even so, many naturalised species have abundant wind-blown seeds, but only a few are considered to be conservation weeds. Thus, attributes such as dispersal mode may be most useful if used indirectly in determining management options, such as search frequency, rather than in attempting to predict invasion rates per se.

Many weed assessment systems are not context- or ecosystem-specific. For example, Esler et al. (1993) ranked all the noxious plants in New Zealand based on scores relating to their biological success and index of weediness. However, this rank order of the species should not be expected to be equally applicable across all New Zealand environments. We should expect differences between, for example, Northland forests and Canterbury tussock grasslands.

Risk assessment systems developed for the border, i.e. with the aim of preventing the entry of potential new weeds, usually consider the weediness of a species' relatives (Reichard & Hamilton 1997; Pheloung et al. 1999) as a surrogate estimate of the species' potential weediness. This factor is seldom considered as a risk component of systems designed for detecting weeds from a group of naturalised species (Tucker & Richardson 1995). There is potential, however, to incorporate information on the weediness of a species' relatives in internal risk assessments when dealing with species at their earliest invasion stages.

The weed risk assessment systems we examined mostly assumed that any species then identified as potential weeds were also considered to be weeds by the wider community. The existence of values (crop plant, popular ornamental, for example) attached to the species other than its weed status, as they affect the feasibility of eradication, are seldom explicitly stated (e.g. Timmins & Owen (2001) and Randall (2000)). Consequently, scoring systems are often couched in terms that suggest that the species can be managed in isolation from the wider community. The system of Hiebert (1997), for example, equates ease of control of outside sources of weeds simply with their abundance, without considering the values attributable to these sources. Owen (1998) considers that for a species to qualify for a weed-led control programme, the probability of re-invasions from outside populations should be nil or very low, or that these outside populations can be controlled. While these considerations are important, a species should not be disqualified from a weed-led control programme simply because it cannot be controlled everywhere, including on productive land. The management option of engaging in a weed-led control programme with the aim of minimising the risk of damage within a defined area of the conservation estate would still seem a possibility. This option will become increasingly necessary as more species currently confined to commercial horticulture naturalise on conservation land (e.g. *Actinidia* spp.).

Most weed ranking systems consider the present and potential geographical extent of a species under consideration, but again, this usually relates to the species' distribution as a weed (e.g. number and size of infestations, Randall 2000), and not to its distribution in cultivation. Neither do ranking systems generally take into account the time a species has been resident within an area, which is an important factor in assessing invasion stage (Rejmanek 2000), and how this might vary in importance depending on the life history of the species. Timmins & Owen (2001) consider time to reproduction (termed the maturation rate) and now this obviously relates to the speed at which a species can potentially extend its range. These factors of present range and expansion rate need to be considered within the context of the kinds of environments a species has, by pure chance, been attempting to colonise to date, compared with the more favourable habitats it might encounter as it spreads (Mack 1985).

The existing weed risk assessment systems differ in the information required to operate them, and also in their internal rules structure. The simplest systems give numerical ratings to a set of criteria that may or may not be divided into sections, and are then summed. The criteria ratings may have equal (Esler et al. 1993) or unequal value (Hiebert 1997; Randall 2000). The individual scores may or may not be modified by the answers to other criteria (Pheloung et al 1999), and the subtotals from one section may be modified by other subtotals (Owen 1998; Randall 2000). Because species' attributes are often not independent of each other, attributes of a species may sometimes contribute to more than one part of the scoring system; e.g. as a species pest ranking *and* the ease with which it can be controlled (Hiebert 1997). There may or may not be default scores where questions are not answered, and points may be deducted if answers to certain questions are negative (Pheloung et al. 1999). Other systems operate via hierarchical decision trees (Reichard & Hamilton 1997). In a completely different approach, Tucker & Richardson (1995) used an 'expert system' where a series of questions filtered out or sorted species into *high* or *low* risk before progressing to the next question.

Any weed risk assessment system that examines species at the early stages of their invasion will generally have very limited information available apon which to base management decisions. Even so, the amount of information will be considerably greater than that available for use in border control models (Pheloung et al. 1999; Williams et al. 2002). This is because species already naturalised in New Zealand are already reproducing in the wild which provides information on their likely impact. If a system is designed around what information is available, or can be readily obtained within one year, then it is likely to be useful. It is also important that the sources of information are reliable (Randall 2000) and preferably documented, even if the information is only estimates and opinions. For transparency and consistency, a weed risk assessment system should be single purpose and designed for specified land-use classes (e.g. farmland, conservation land). The information required about a plant species to assess its risk to conservation values and land can be categorised as: its weed history overseas and that of its relatives; estimates of its impact and interactions with New Zealand native vegetation; the manner in which its biological characteristics and invasion stage influence management options; how these, in turn, are constrained by societal attitudes to the species; and the technology available to control the species.

In all probability, any risk assessment system of this nature should confirm, more or less, the existing ranking of weeds within an area, if this has been undertaken by 'experts' (Hiebert 1997; Pheloung et al. 1999), rather than produce a reordering of priority species for management. In other words, the outcomes from any new system must be generally in accordance with present knowledge and understanding, if the system is to gain acceptance and be applied. This approach then acquires all knowledge of the weeds of an area and formalises it within a system that is systematic, repeatable, and applicable to new species as they emerge.

3. Methods

We critically examined existing weed risk assessment systems and designed a new system that utilised good aspects and rejected less satisfactory aspects of the various existing systems, as well as incorporating advances in our understanding of the ecology of weed invasions. The aim was to make the system as comprehensive as possible, but to be limited strictly to likely available information. We based our review on three premises: that weed management effort should be a function of the magnitude of the risk the weed poses to conservation values; that the greatest benefit is likely to be achieved by controlling weed populations at the earliest stages of their invasion; and that the physical and financial ability of the manager to reduce the risk must also be considered. Because technology and available weed control resources can change, control techniques were not considered to be part of the primary risk assessment.

A necessary requirement for developing and 'calibrating' a system like this is a 'study area' which contains a group of species for which we have some understanding of their present and potential status as conservation weeds. In developing the system we used invasive fleshy-fruited woody climbers, trees, and shrubs that are beginning to invade lowland forest and scrub within the Nelson/Marlborough area[1]. We first developed a series of scored questions and then adjusted the weightings via a spreadsheet to conform to our understanding of these weed species in this environment. In applying the system to other biomes, such as grasslands of the inland South Island, the system structure would be maintained, but the weightings and rankings of the scores would change, based on the particular set of species and environmental conditions.

4. Results

4.1 OUTLINE OF THE NEW CONSERVATION WEED RISK (NCWR) ASSESSMENT SYSTEM

This system is distinct from that designed to detect potential weeds at the border, the conservation weed risk assessment (CWR) system of Williams et al. (2002). The present system is designed to rank the risks posed by new conservation weeds and is termed the NCWR assessment system. It uses a combination of scores from a series of questions, all of which must be answered. The final management recommendation is adjusted to reflect what resources are available at the time to control weeds.

The first group of questions determines the weed history of the species and its relatives. The second group attempts to quantify the weed species' interactions

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1 Unless given in the text, Scientific names are in Table 3.

with native vegetation and conservation values. The third relates to the invasion stage of the weed both in New Zealand as a whole, and in the area under consideration, quantified as the chance of spreading. The fourth set of questions relates closely to the 'biological success' rating of Esler et al. (1993). These features influence the ability of the species to establish before it is detected, and to persist. The penultimate group of questions assess the likelihood of our being able to control the species by quantifying the abundance of the species in the horticulture/urban landscape and assessing the public perception of the species and the difficulty of gaining acceptance for control measures. The last question assesses whether technology and resources are available to kill the weed.

4.2 EXPLANATION OF THE NCWR ASSESSMENT SCORE SHEET

This section explains the rationale underlying the structure of the score sheet and the factors that must be taken into consideration when using it. The information in brackets corresponds to the sections of the NCWR assessment score sheet that are presented in Section 4.3 where there are also specific instructions for filling it in.

4.2.1 Weed history

The history of a particular species in other countries is used in the evaluation of a species only if there is little information on its New Zealand naturalisation and history. Once a species has become naturalised, it is more useful to examine its behaviour here. The outcomes of this module may increase our concerns about a particular species, based on its behaviour elsewhere, although this will apply only where the species has a history of introduction elsewhere. It should be noted that many conservation weeds in New Zealand are the first representatives of their genera to become weeds of any sort anywhere in the world (Williams et al. 2000), so there may be no history of weediness amongst very close relatives.

This module [Section 1] is based on the CWR assessment model for the New Zealand border (Williams et al. 2002), where worked examples are given, and is not further elaborated here. The score sheet is shown in Appendix 1 but it has yet to be calibrated against a list of candidate species.

4.2.2 Weed impacts

Species vary widely in their ability to spread and increase in volume, as reflected in the biomass at maturity that can be generated from a single propagule (seed) or ramet (piece of stem or root). An estimate of the biomass and extent of a species, particularly compared with the native vegetation with which it grows, is used here as a rudimentary estimate of impact. The score is based on the proposal of Parker et al. (1999) that: I (overall impact) = R (range) × A (abundance) × E (impact per capita). These data are not available for most species, but are likely to range over tens of orders of magnitude; e.g. from a single *Poa annua* plant 10 cm tall by 25 cm^2 (0.002 m^3), to *Selaginella*, 1 m^2

and 10 cm deep (0.10 m^3), through a typical perennial herb, 1 m^2 and 1 m tall (1 m^3), to trees 10 m tall and with crowns 10 m diameter (1000 m^3). 'E' is likely to be related to the log of the volume of a single individual plant: 1, 10, 100, 1000, 10 000, which are expressed here as scores ranging from 1 to 5 [A 2.1]. This scoring will be most accurate where the general dimensions of a plant can be measured, but may be of less use for creeping perennial herbs (e.g. *Tradescantia* spp.) or vines that spread over the vegetation canopy. For example, putative single plants of *Lonicera japonica* covering several hectares are likely to have crown volumes in excess of 100 000 m^2 (Williams et al. 2001).

Biomass as a surrogate measure of impact is modified by the species' physical interaction with native vegetation and its role in vegetation succession. Information is generally available on whether the species co-occurs with native species, or whether it replaces native species, either at canopy or a lower regenerative layer. The long-term effects of weeds in these relative positions are unknown, but experience suggests that a conservation weed that replaces the vegetation canopy will, in the short term, displace more species, including invertebrates, than one that occupies a sub-canopy position [A 2.2–2.3].

Similarly, impact is related to a weed's persistence at a particular site, whether it survives for a single generation, or for successive generations [A 2.3]. If a weed species has been present in an area for some time, then an idea of its persistence, which is a function of its longevity, regenerative capacity at the site, and resistance to management, may have been gained. Regenerative capacity and resistance to management are ecosystem specific: gorse and broom, for example, regenerate and persist in riverbeds but not in successional forests that are free of major canopy disturbance, although they remain in the seed bank [A 2.4].

Because any particular conservation weed assessment system is likely to be reliable for only a narrow range of community types, communities potentially invaded need to be defined [B 2.5]. The most basic vegetation/community classification that should be applied is forest, scrub and grasslands, open-lands, and wetlands. Present and potential impact of a weed on a region is related to the number of community types the species has invaded or could invade. The risk to conservation values is derived (in part) from the sum of the values of the communities threatened. These are encapsulated in the concept of the *distinctiveness* of a particular environment compared with the relative amount of that environment in the conservation estate (Stephens et al. 2002) [B 2.5]. However, because it cannot be assumed that a species at its earliest invasion stage will remain confined to its present habitats, scores based on the present distribution are not incorporated into the species' NCWR assessment score, but are used only as an additional guide to prioritising.

4.2.3 Chance of spreading

Knowledge of the time of introduction and reasons for a species' introduction into New Zealand is the starting point for estimates of its rate and stage of spread, and for understanding its present distribution pattern. The history of the species' introduction and very early naturalisation in New Zealand can often be ascertained (e.g. Cameron 2000a, b), but this will not always be the case (e.g. Sykes & Williams 1999). Few species have been here long enough to indicate their ultimate distribution. The range expansion of a species is often the trigger for its being classified as a conservation weed. It thus seems reasonable to assume that species naturalised only recently and now recognised as conservation weeds, are likely to spread faster than species that have been here longer, and have a similar distribution. The period since a species' first introduction into New Zealand and when it was first recorded in the wild varies widely, even amongst fleshy-fruited species. The former date is not always readily obtainable (R.B. Allen pers. comm.), whereas the naturalisation period is indicated by the first record in New Zealand Floras, Vols. 1–5 (e.g. Webb et al. 1988) and subsequent listings (e.g. Webb et al. 1995), and serves as a datum [C 3.1].

The stage of the infestation is critical in determining the practicality of controlling a species. While it is possible to have questions that seek an interpretation of the invasion stage and its timing, as per fig. 4 in Owen (1998), it has seldom, in fact, been possible to predict the trajectory of a species. Most species that are 'discovered' as new weeds within an area have been there for some time, albeit at low numbers. Unless a plant species is on a list of unwanted organisms for a specific area, most newly recognised weed species are well established and spreading (e.g. Cameron 2000a, b) before they are recognised as weeds. The simplest approach to infestation stage, and the one taken here, is to ask how well the species is established [C 3.2]. This also relates most closely to the possibility of controlling a species. Note that this does not ask how fast a species is spreading, because a species that is spreading rapidly will, in most cases, be well established with many loci (Mack 1985).

Scores for dispersal and persistence have been used to estimate species invasiveness, but with relatively little empirical success (summarised in Williams et al. 2002). These endogenous attributes of particular species do, nevertheless, have management implications (see Table 1, Williams 1997). In the NCWR system they are used to indicate the effort required to control a species. Foremost among these is the question of whether the species can be detected in the wild. Those that are conspicuous *before* they set seed/ reproduce are likely to be more readily detected and, ultimately, controlled than less conspicuous species [D 3.4].

Most species do produce viable seed, and new weeds should be presumed to do so unless there is strong evidence they do not [D 3.5]. The seed dispersal mode can be determined from the fruit and seed characteristics [D 3.6]. In the case of fleshy-fruited species, the dispersers can be identified by observation. Species with fruits consumed by the more numerous small birds, or dispersed by wind, will probably be more frequently dispersed than those reliant on large birds for dispersal, or those with large seeds and passive dispersal. The presence of soil seed banks or vegetative organs that aid in persistence at the site can be ascertained, i.e. specialised plant parts or the ability to re-sprout from the roots or the base of damaged stems [D 3.8]. Species with short regeneration times [D 3.7], more frequent dispersal and greater persistence, and especially species which exhibit a combination of these features, will require greater control effort.

The abundance of juveniles [D 3.9] as indicators of spread and the ability to recover from control efforts are indicative of the control effort required.

4.2.4 Public attitudes

Whether a particular conservation weed is also currently a commercial crop species [E 4.3], or widely cultivated or sold through nurseries, can be ascertained. While this question has a direct bearing on propagule rain into some conservation areas, and therefore might well be placed in section D, societal attitudes are attributes over which a conservation manager may have some control. Moreover, public awareness of environmental weeds is growing (Reichard & White 2001). Information about public attitudes will indicate the possibility of restricting a species' propagation and sale, and the effort required to educate and persuade people to take responsibility for their planting [E 4.1], or to comply with legislation restricting a species. Those species that are more widely planted and sold [E 4.1–4.2] will be more difficult to eradicate without a public campaign, and it will generally be impossible to eradicate commercial species such as kiwi fruit. Even so, commercial species may still be the subject of weed-led campaigns aimed at maintaining populations in the wild to some minimum defined level, by means such as removing all excess fruit from cultivated vines to prevent bird dispersal and actively searching for wildling individuals before they seed. Note that the actual 'damage threshold' to conservation values will probably not be applicable (Panetta & James 1999). Some species have undesirable or unpleasant characteristics, such as inducing hay fever, which the public in general recognises, and it will be easier to obtain public support in eradicating these species [E 4.4].

4.2.5 Control techniques

Probably all terrestrial species of plants in New Zealand could potentially be controlled by an appropriate herbicide or control technique, given sufficient resources, so that lack of technology in itself will generally not be an issue [5.1]. If no information on the efficacy of control measures is available, then trials (including costs) could be conducted before management decisions are made, even if they are 'trials aimed at attempting to manage'. Failing this, costs should be estimated from a similar species where the treatment is likely to be the same. This could be multiplied by the projected rate of increase in area over a defined time period, perhaps 2, 5, and 10 years, to give an estimate of future costs (see Stephens et al. 2002).

Collateral damage to conservation values occurs to some extent in most weed control programmes, and only where this is likely to be severe should it deter early weed-led programmes from proceeding.

4.3 THE NEW CONSERVATION WEED RISK (NCWR) ASSESSMENT SCORE INSTRUCTIONS

The following notes are to be used when completing the score sheet shown in Table 2. Assessors entering the scores are recommended to first read section 4.2.

Except where otherwise mentioned, Y = 1, N = 0

Section 1. Weed history (if applicable)

This section is computed only if the species is not fully naturalised in New Zealand.

Section 2. Impacts (sum 2.1–2.4)

A. Interactions

2.1 Estimate the volume of an individual plant.

2.2 This applies to the canopy of the vegetation, i.e. the layer that intercepts direct sunlight. 'Pre-empts' means it arrives first and excludes native species. Otherwise it must grow taller via self-supporting stems or climb over and smother other plants, as do vines. Species that occupy only sub-canopy positions as shrub or herb layers score 0, because in the long term their effects may be less than those of plants that grow into the canopy.

2.3 This is a judgement about the growth rate of the weed, and rather than use terms like 'slow' or 'fast', comparisons are made with the native species it grows with or excludes.

2.4 Persistence may be either through the growth of the original individuals or through regeneration via sexual or vegetative reproduction. The sites where the species persists the longest should be considered here, but only in the biome being considered. For example, gorse persists for a shorter time—at least as adult plants—in moist forest environments than in riverbeds.

B. Communities potentially invaded

2.5 The number of community types the species invades or is likely to invade and their representativeness. The outcome for the question is not included in the final score but is used as background information.

Section 3. Chance of spreading (sum 3.1–3.9)

C. History and distribution

3.1 Here 10 is used only as a constant, and the score is derived from the decade in which a species was first recorded in the wild minus the decade in which it was first recorded as a conservation weed. The first can be obtained from New Zealand floras, and the latter from DOC databases, or from the recollections of certain individuals. Example: 1945 (year of first wild record) is 6 decades ago, 1980 (recognised as a conservation weed) is 2 decades ago, therefore 10–(6–2) = 6.

3.2 The species must have just (< 5 years) been recorded as a weed in the wild, irrespective of whether it is growing in cultivation or not.

3.3 The absolute 'size' of small as opposed to 'large' infestations will be ecosystem specific, as will the density (individuals per area).

D. Dispersal and persistence

3.4 Most species will receive a score here, but a few, e.g. wild ginger or pines, are highly distinctive.

3.5 Seed should be assumed to be viable unless there is evidence to the contrary.

3.6 This distinguishes species with relatively large fruit (> 12 mm diameter on their shortest axis), or which cannot be eaten in part and must be dispersed by large birds, from those that are able to be swallowed whole and dispersed by the more numerous species of small birds. Very small dry seeds without specialised attachments are likely to be wind dispersed, e.g. heather (*Calluna vulgaris*).

3.7 Regeneration time is from seed to first seed of the next generation. Species that reproduce only by vegetative means are classed as < 3 years. Short regeneration times mean more frequent site inspections.

3.8 Species that reproduce by vegetative means, as well as those with a seed bank, are classed as persistent.

3.9 This means, in practice, that juveniles can be located by an observer within 15 minutes of their arriving at an area where they would be expected, given the dispersal mode and site characteristics of the adults. New plants of those reproducing vegetatively would be included.

Section 4. Public attitudes (E1–E4)

E. Cultivation and perceptions

4.1 'Mass plantings' means either commercial crops or civic plantings, etc. 'Frequently cultivated' means the species would occur on more than c. 1/1000 urban properties, and 'uncommon' means less than 1/1000. Data apply to the DOC conservancy undertaking the assessment.

4.2 Use the latest edition of *Gaddums Plant Finder*. Data apply to New Zealand as a whole, because these are mainly wholesale outlets.

4.3 Does the plant produce food or fibre on a commercial scale?

4.4 Does the plant have any features that are quite well recognised, although not necessarily widely so, that could be used to prejudice public feeling about it (e.g. causes dermatitis)?

Total NCWR score = Combined risk [Impacts score × chance of spreading score] + public attitudes

Section 5. Control techniques available

5.1 This is a decision and not a score.

4.4 A WORKING EXAMPLE OF THE NCWR ASSESSMENT SYSTEM

The NCWR assessment system proposed here was applied to the whole of the Nelson/Marlborough conservancy where there are about 20 species of bird-dispersed woody vines, trees, and shrubs undergoing range expansion. NCWR assessment scores for two examples are shown in Table 2 and scores for all species are summarised in Table 3. All 20 species are well established so that only NCWR sections dealing with their interactions with local conditions [Sections 2–4] are completed, and not their weed histories elsewhere [Section 1].

Impact scores in Table 3 range from a low of 4 (gooseberry) to a high of 9 (lilly pilly and strawberry dogwood). Overall, the highest scores are attributed to medium-sized trees followed by vines. The *chance of spreading* scores range from 10 (gooseberry and woolly nightshade) up to 23 (evergreen buckthorn). When the scores for *impact* and *chance of spreading* are multiplied together to give the *overall risk* score, the results cover a 4-fold range, from 40 (gooseberry) to 161 (Cascara sagrada). Banana passion vine, which is widespread in the region, and therefore can be the subject only of 'site-led' control, was included for comparison. Despite the heavy weighting given to species of low abundance (Q.3.3) banana passion vine still achieved a rather

TABLE 2. INDIVIDUAL NCWR ASSESSMENT SCORES FOR 2 SPECIES IN THE EARLY STAGES OF INVASION.

The example scores are for Chinese privet (*Ligustrum sinense*) and climbing spindleberry (*Celastrus orbiculatus*) in the Nelson/Marlborough region. Note that these two species are well established and therefore Section 1 pertaining to weed history is blank. The computed species scores are in Table 3.

SECTION 1. WEED HISTORY (IF APPLICABLE; SEPARATE SCORE SHEET IN APPENDIX 1)		POINTS	SPECIES SCORE(S) EXAMPLES	
			PRIVET	CLIMBING SPINDLEBERRY
Section 2. Impacts		sum 2.1 to 2.4	5	7
A. Interactions				
2.1	Volume of individual plant m^3: < 1, 10, 100, 1000, 10 000	1 to 5	3	3
2.2	Totally pre-empts sites, or covers native species to form canopy	1 or 0	0	1
2.3	Growth appears faster than associated native species	1 or 0	0	0
2.4	Species persists: < 5 yrs, 5–20 yrs, > 20 yrs	1 to 3	2	3
B. Communities potentially invaded (not included in total score)				
2.5	Sum of (n.) community types invaded, with high (3), medium (2) or low (1) distinctiveness in the Ecological Region(s)	(Max. various, but not used in final score)	(6)	(7)
Section 3. Chance of spreading		sum 3.1 to 3.9	13	21
C. History and distribution				
3.1	10–(Naturalisation decade–DOC weed status decade)	10 to 0	4	8
3.2	Weed potential only recently recognised	2 or 0	0	1
3.3	Number/size of infestations: one small (8), several small/single large (4), numerous small (2), numerous large (0)	4 to 1	0	4
D. Dispersal and persistence				
3.4	Species cryptic and cannot be detected before it reproduces	1 or 0	1	0
3.5	Produces viable seed	2 or 0	2	2
3.6	Seed dispersed primarily by: small birds or wind (2), large birds or passive/accidental dispersal (1)	2 or 1	2	2
3.7	Minimum regeneration time < 3 years (2) , > 3 years (1)	2 or 1	1	1
3.8	Persistent vegetative organs above or below ground, or seed bank (> 1 year)	2 or 0	2	2
3.9	Juveniles common within 100 m of parents	1 or 0	1	1
Section 4. Public attitudes		sum 4.1 to 4.4		
E. Cultivation and perceptions				
4.1	Present as: mass plantings (3), frequent smaller plantings (2), infrequent small plantings (1), not planted (0)	3 to 0	2	1
4.2	No. nurseries selling species: > 3, < 3, 0	3 to 0	0	1
4.3	Is it a crop plant?	1 or 0	0	0
4.4	Does it have unpleasant features?	1 or 0	1	0
Section 5. Control techniques available (not included in total score)				
5.1	Yes or no, but a decision not a score	Yes or No	Yes	Yes

high score. This outcome is undesirable, but not unexpected, in view of the extreme weediness of this species. Such widespread species are readily identified, and to avoid such species confusing the rankings of less widespread species, they should be omitted from the outset in any ranking of new conservation weeds.

The 'public attitudes' scores range from 1 to 5 (Table 4). This range represents plants that can be controlled with little public oppsition or, indeed, with some public support through to those that are politically difficult to control—an important crop plant or favoured garden ornamental for example. When the 'public attitude' scores are compared with 'combined risk' scores, it becomes apparent that in the Nelson/Marlborough region, climbing spindleberry and evergreen buckthorn are the highest priority for control, followed by cascara sagrada and lilly pilly. If the scores for 'communities potentially invaded' (Table 2) were taken into consideration, the rankings of these top-scoring species would remain unchanged.

TABLE 3. EXAMPLES OF NCWR ASSESSMENT SCORES FROM WOODY CLIMBERS, TREES, OR SHRUBS THAT ARE BIRD DISPERSED AND UNDERGOING RANGE EXPANSION, IN THE NELSON/MARLBOROUGH AREA.
Banana passion vine, while not a recent invader, is included to demonstrate the relatively low priority such species would have. Note that weed history scores are not relevant because the species are established.

SPECIES		SCORES				
		IMPACT	SPREAD	COMBINED RISK	PUBLIC ATTITUDES	TOTAL
Banana passion vine	*Passiflora mollissima/mixta*	7	16	112	3	115
Bone seed	*Chrysanthemoides monilifera*	6	11	66	1	67
Cascara sagradra	*Frangula purshiana*	7	23	161	2	163
Chinese privet	*Ligustrum sinense*	5	12	60	2	62
Climbing asparagus	*Asparagus scandens*	6	19	114	1	115
Climbing spindleberry	*Celastrus orbiculatus*	7	21	147	1	148
Cotoneaster	*Cotoneaster microphyllus*	5	17	85	1	86
Darwin's barberry	*Berberis darwinii*	7	15	105	2	107
Elaeagnus	*Elaeagnus × reflexa*	7	17	119	1	120
Evergreen buckthorn	*Rhamnus alaternus*	7	23	161	1	162
Gooseberry	*Ribes uva-crispa*	4	10	40	4	44
Italian jasmine	*Jasminum humile*	6	16	96	2	98
Jasmine	*Jasminum polyanthum*	8	12	96	3	99
Kiwi fruit	*Actinidia deliciosa*	7	21	147	5	152
Lilly pilly	*Acmena smithii*	9	19	171	3	174
Madeira vine	*Anredera cordifolia*	8	15	120	1	121
Rowan	*Sorbus acuparia*	8	13	104	4	108
Smilax	*Asparagus asparagoides*	5	18	90	1	91
Spindleberry	*Euonymus europaeus*	5	15	75	4	79
Strawberry dogwood	*Dendrobenthamia capitata*	9	16	144	4	148
Woolly nightshade	*Solanum mauritianum*	7	10	70	2	72

TABLE 4. SPECIES FROM TABLE 3 GROUPED INTO FIVE CLASSES OF PUBLIC ATTITUDE SCORES (ROWS) AND RANKED FROM HIGHEST TO LOWEST COMBINED RISK SCORES FROM TABLE 3 (COLUMNS).
The higher the public attitudes score, the greater the propagule pressure from plantings, and the greater the effort required to educate people to take responsibility for their plantings. Species towards the top left of the table are the best prospects for control; those towards the bottom right are the worst. The species positions are applicable only for the Nelson/Marlborough area.

Combined risk score		Public attitude score 1	2	3	4	5
	> 150	Climbing spindleberry Evergreen buckthorn	Casgara sagrada	Lilly pilly		
	126–150				Strawberry dogwood	Kiwifruit
	101–125	Climbing asparagus, Elaeagnus, Madeira vine	Darwin's barberry			
	76–100	Cotoneaster, Smilax	Woolly nightshade	Italian jasmine, Jasmine	Spindleberry	
	51–75	Bone seed	Chinese privet			
	0–50				Gooseberry	

5. Conclusions

There are several weed risk assessment systems in existence. Combined, they have many good approaches for predicting the potential weediness of plant species. Their main failing for application to new conservation weeds is that most require too much information, or do not place sufficient emphasis on species that are recently invasive, and therefore offer the best chance of being controlled (Mack 1996). Most assessment systems also apply to several biomes, despite the inter-relationship of species attributes and specific biome characteristics being important determinants of invasion success. The NCWR assessment system outlined in this report, when applied to a group of species invading mostly woody vegetation in the Nelson/Marlborough region, places species in an order that largely agrees with our own understanding of their priority for control. It should be tested in other conservancies, and if it appears to have utility, it could be adapted to other conservation life forms and native vegetation types.

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Appendix 1

SECTION 1 OF THE NCWR ASSESSMENT SYSTEM PERTAINING TO WEED HISTORY OF THE SPECIES AND ITS RELATIVES

This has been slightly modified from the CWR assessment model for the New Zealand border (Williams et al. 2002) and consists of only the first part of that model. In addition, it includes a question pertaining to the species of concern within New Zealand because it may be growing elsewhere in the country. Because the number of overseas weed lists on which woody species appear and to which their perceived weediness in New Zealand are related (Williams et al. 2000), this factor is included in the score. Higher weightings are given to a species if the taxonomic group is already naturalised in New Zealand, because this indicates that at least one member of the grouping has demonstrated an ability to cross the environmental thresholds associated with the New Zealand environment. Higher weightings could be given to genera than families, on the basis of closer behavioural similarity, but many genera contain few species and the reliability of the data will yield a lower probability. Unlike Sections 2–4 of the NCWR assessment system, this score sheet has not been calibrated for a range of potential conservation weeds.

History		**Score**	**Class:** yes/no, or % group to which the species belongs (score)					
Family naturalises	N.Z.		> 10% (5)	10–5% (4)	4–2% (3)	2–1% (2)	< 1% (1)	0 (0)
	Elsewhere		Yes (1)	No (0)				
Genus naturalises	N.Z.		> 10% (2)	< 10% (1)				
	Elsewhere		Yes (1)	No (0)				
Family weedy	N.Z.		> 50% (4)	50–10% (3)	9–1% (2)	< 1% (1)	0 (0)	
	Elsewhere		Yes (1)	No (0)				
Genus weedy	N.Z.		> 10% (2)	< 10% (1)	0 (0)			
	Elsewhere		Yes (1)	No (0)				
Species being assessed weedy	Other N.Z. region		Yes (1)	No (0)	Multiply by number of weed lists if woody			
	Elsewhere		Yes (1)	No (0)	Multiply by number of weed lists if woody			
Total								