Biol Invasions
DOI 10.1007/s10530-009-9451-2

ORIGINAL PAPER

Predicting plant invaders in the Mediterranean through a weed risk assessment system

Núria Gassó · Corina Basnou · Montserrat Vilà

Received: 3 March 2008 / Accepted: 17 February 2009

Abstract Risk assessment schemes have been developed to identify potential invasive species, prevent their spread and reduce their damaging effects. One of the most promising tools for detecting plant invaders is the weed risk assessment (WRA) scheme developed for Australia. Our study explores whether the Australian WRA can satisfactorily predict the invasion status of alien plants in the Mediterranean Basin by screening 100 invasive and 97 casual species in Spain. Furthermore, we analysed whether the factors taken into account in the WRA are linked to invasion likelihood (i.e., invasion status) or to impacts. The outcome was that 94% of the invasive species were rejected, 50% of the casual species were rejected and 29% of them required further evaluation. The accuracy for casuals is lower than in other studies that have tested non-invasive (i.e., casuals or non-escaped) alien species. We postulate that low accuracy for casual species could result from: (1) an incorrect "a priori" expert classification of the species status, (2) a high weight of the WRA scores given to potential impacts, and (3) casual species being prone to becoming invasive when reaching a minimum residence time threshold. Therefore, the WRA could be working as a precaution early-warning system to identify casual species with potential to become invasive.

Keywords Alien plants · Casual plants · Mediterranean region · Species traits · Weed risk assessment

Introduction

Predicting the success of alien species has been a major aim of ecological research since invasions were recognized as an important conservation issue (Rejmánek and Richardson 1996; Reichard and Hamilton 1997; Smith et al. 1999; Kolar and Lodge 2001; Pyšek 2001; Caley et al. 2006). To this purpose, many studies have focused on finding which biological traits make a species invasive and the characteristics of invaded habitats (Goodwin et al. 1999; Daehler 2003; Heger and Trepl 2003; Richardson and Pyšek 2006). Since Baker (1965), the search for invader syndromes (i.e., suites of traits and abiotic factors associated to invasiveness) aims to improve our ability to predict the invasion success of alien plants in new regions (Richardson and Pyšek 2006). For example, Thuiller

N. Gassó (✉) · C. Basnou
CREAF (Centre for Ecological Research and Forestry Applications), Universitat Autònoma de Barcelona, E-08193 Bellaterra, Catalonia, Spain
e-mail: n.gasso@creaf.uab.es

M. Vilà
Estación Biológica de Doñana-Centro Superior de Investigaciones Científicas (EDB-CSIC), Avda. Américo Vespucio s/n, Sevilla E-41092, Spain

et al. (2006) have found that the spatial regional distribution of invasive alien species in South Africa is driven by life forms, reproductive traits and human uses.

The accumulated knowledge on invader traits together with the characteristics of invaded habitats, and information in whether a species is invasive in other parts of the world, especially in areas with similar environmental conditions (Westbrooks 1981; Rejmánek 2000; Union of Concerned Scientists 2001; Thuiller et al. 2005; Richardson and Thuiller 2007), has been the basis to develop risk assessment schemes that attempt to predict the success of alien species in a given region of introduction (Mcneely et al. 2001; National Invasive Species Council 2001; Wittenberg and Cock 2001; Leung et al. 2002; Keller et al. 2007a; Gordon et al. 2008). For plants, only a small proportion of introduced alien species become invasive (Di Castri 1989; Williamson 1996) and it is important to identify them to prevent their spread and impacts.

Because risk has two components: likelihood of invasion and ecological or socioeconomic impacts, risk assessment schemes attempt to identify this small fraction of species with a high likelihood of becoming invasive, and also to prevent their spread and their damaging effects (Andersen et al. 2004). So far, there is evidence that the implementation of risk assessment protocols produces net economic benefits (Keller et al. 2007b).

The scientific literature abounds in risk assessment schemes differing in the methods used and the phase of invasion process they target. Recently, taking advantage of the rapid increase in computing tools, facilities and database availability, new screening models have been developed. The most convenient to compare across regions are the quantitative tests that offer a species score. One of the most promising as a tool for detecting plant invaders is the Australian weed risk assessment (WRA, Pheloung 1995) which has also been tested for New Zealand (Pheloung et al. 1999) and implemented in other regions (Hawaii and Pacific islands: Daehler and Carino 2000; Daehler et al. 2004; Bonin Islands: Kato et al. 2006; Czeck Republic: Křivánek and Pyšek 2006; Italy: Crosti et al. 2007). A recent review has compared the WRA accuracy in different geographic regions (Gordon et al. 2008) and has found it to be high. The WRA scheme can be adopted as an initial screen for plant species proposed for introduction in a new region with the aim to reduce their economic and ecological impacts.

Our study explores whether the original Australian WRA scheme (Pheloung et al. 1999) satisfactorily predicts the invasion success of alien plants in the Mediterranean region. For this purpose, we have chosen Spain as a representative because of its climatic, geological, landscape and habitat heterogeneity and high species diversity (Medail and Quezel 1997). In many studies the WRA scheme has been used to evaluate "major invaders", "minor invaders", and "non-invaders" (species not-escaped from cultivation or casuals) (Gordon et al. 2008). In this study we compare the accuracy for invasive and casual (non-invasive) species. We follow Richardson et al. (2000a) and Pyšek et al. (2004) in defining invasion plant status. Invasive species are alien species with self-sustaining populations not requiring direct human intervention, that produce offspring at considerable distances from the parent plants, and thus, have the potential to spread over large areas. Casual species do not form self-replacing populations outside cultivation and rely on repeated introductions for their persistence. Differently from other studies, we did not include non-escaped from cultivation species because we found it difficult and not very accurate to randomly chose a list of non-escaped species while among the invasive and casual species sets there are several pathways of introduction (e.g., 21% of the 1,000 alien species listed in Sanz-Elorza et al. 2004 are unintentionally introduced). Furthermore, by testing casual species the screening protocol can be interpreted as an early screening system of potential invaders among casual species. Moreover, in our study we go a step further by analysing whether the factors taken into account in the WRA are those really involved in differentiating invasive from casual alien plants, considering status differences to be a consequence of invasion likelihood.

Specifically, our main questions are (1) Does the WRA have a high accuracy in identifying invasive species when adapted and applied to a Mediterranean region? and (2) What are the determining factors for an alien plant species to be considered invasive and do these correspond with the questions taken into account to calculate the WRA final score?

Methods

Weed risk assessment for Mediterranean regions

The scheme chosen for testing was the original Australian WRA (Pheloung 1995) (See "Appendix 1"). The WRA system consists of 49 questions which encompass biogeography, undesirable plant attributes and biology/ecology (Pheloung et al. 1999). A high score (>6) identifies a species likely to be of high risk (weed) and rejects it for import; a low score (<1) accepts the plant for import (non-weed) and intermediate scores (1–6) require further evaluation. The WRA score ranges from −14 (benign species) to 29 (maximum risk).

From the original WRA we modified the question 2.01 from "Species suited to Australian climates" to "Species suited to Mediterranean climates". This question and the 2.02 were answered without performing any climatic model, but following the criteria described in Daehler et al. (2004). We also modified the question 5.03: "Nitrogen fixing woody plant" to "Nitrogen fixing plant", to include the non-woody nitrogen fixing plants. These are an important component of Spanish alien flora, many of such species being very abundant in ruderal, disturbed habitats (Sanz-Elorza et al. 2004).

Screened species and information sources

We screened a plant data set that was comprised of information on 100 invasive and 97 casual alien plants recorded in the Atlas of Invasive Plant Species in Spain (Sanz-Elorza et al. 2004), including a broad range of life-forms (See "Appendix 2"). Species status was defined following Richardson et al. (2000a) and Pyšek et al. (2004). The chosen invasive species comprised all the most invasive species listed in the Atlas, while the casual species were selected randomly from the pool of 380 casual species recorded therein. To answer the WRA questions, the information was gathered from regional and local floras (Castroviejo et al. 1986–2000; Bolòs et al. 2005), weed atlases (Sanz-Elorza et al. 2004), and Internet databases such as: BioFlor (http://www.ufz.de/biolflor), Plants for a Future (http://www.comp.leeds.ac.uk/pfaf), Hypermedia for Plant Protection—Weeds (http://www.dijon.inra.fr/hyppa), Poisonous Plants of North Carolina (http://www.ces.ncsu.edu/depts/hort/consumer/poison), species accounts from Plantas Invasoras en Portugal (http://www.uc.pt/invasoras), USDA Plants database (http://plants.usda.gov), International Survey of Herbicide Resistant Weeds (http://www.weedscience.org), Global Compendium of Weeds (http://www.hear.org/gcw), Global Invasive Species Database (http://www.issg.org/database/welcome), Weeds in Australia (http://www.weeds.gov.au), and Ecological Traits of New Zealand Flora (http://ecotraits.landcareresearch.co.nz).

Data analysis

To evaluate the predictive ability of the WRA applied in Spain, we developed a receiver operating characteristic (ROC) curve (DeLong et al. 1988) because it has been found to be a useful tool for evaluating the performance of invasive species screening tests (Caley and Kuhnert 2006; Hughes and Madden 2003; Gordon et al. 2008). This analysis requires comparison of two groups: one for which rejection is the incorrect outcome and the other for which it is the correct. A ROC curve is formed by plotting the proportion of true positives (i.e., rejected invasives) against the proportion of false positives (i.e., rejected casuals) across the range of cutoff points on an indicator scale (i.e., the WRA score). The area under the ROC curve (a value between 0.5 and 1) represents the probability that a randomly chosen positive case (an invasive species) will have a higher test value (WRA score) than a randomly chosen negative case (a casual species) (DeLong et al. 1988). The closer the area under the ROC curve is to one, the better the screening tool's ability to differentiate between the two groups (Lasko et al. 2005).

A principal components analysis (PCA) was used to identify the main variables that characterize the pool of all tested alien species and to reduce the number of multivariate data for a posterior comparison between invasive and casual species characteristics. This linear method was chosen because the number of species was low (197) compared to the number of variables (30) and the length of the longest gradient from Detrended Correspondence Analysis was between 1 and 2 (Lepš and Šmilauer 2006). Ordination was performed using CANOCO for Windows 4.5.

We adopted the framework of the generalized linear mixed models (GLMM) (e.g., Blackburn and

Duncan 2001) to determine variation between species in invasion status (i.e., casual or invasive) and WRA score (i.e., two estimations of invasion risk) as a function of the 15 WRA variables best characterized by the first two principal components (Fig. 2). Both GLMM analyses incorporated taxonomy to overcome potential phylogenetic biases. Because species are linked by phylogeny (Harvey and Pagel 1991), using species as independent data points may inflate the degrees of freedom (Brändle et al. 2003) and increase the Type-I error. GLMM deals with phylogenetic effects by allowing the incorporation of taxonomic categories as nested random factors. In this way, the likely non-independence of response values of closely related species is controlled by assuming a common positive correlation between introduction outcomes for species within nested taxonomic groups (genera and family, in our case). Conversely a zero correlation is assumed between introduction outcomes for species in different groups (a variance components model). There are more sophisticated procedures that allow implementing the complete phylogenetic structure in the model (Sol et al. 2008), but we could not use such methods because there was no robust phylogenetic hypothesis available for the species studied. In addition, the approach we used helped to mitigate the problem of invasive species being a non-random subset of all species introduced (Blackburn and Duncan 2001).

We modeled invasion status with a Binomial distribution of errors (Crawley 2002), because the response variable was binary [i.e., casual(0)/invasive(1)]. Invasion risk (i.e., WRA score) followed a normal distribution and did not need transformation to achieve the requirements of parametric analysis, so we modeled it with a Normal distribution of errors. In both cases, the inspection of the residuals showed that error structures adjusted well to our response variables.

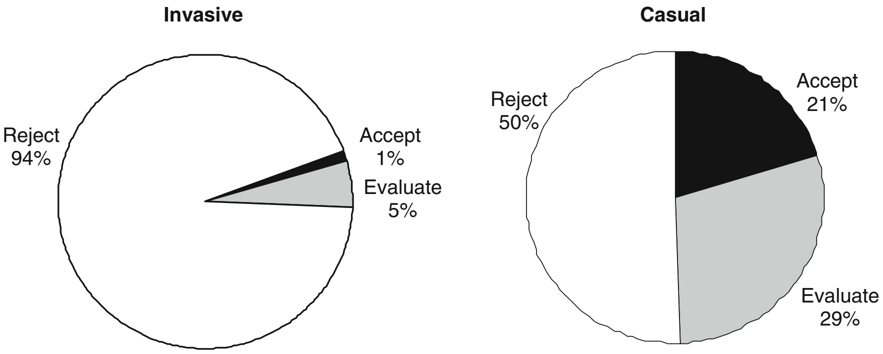
We started modeling invasion status with a full model that contained all our predictors. Using a backward selection process, we next simplified the model so as to leave only significant predictors (minimum adequate model). The model was run in the glmmPQL procedure of the MASS library on the R statistical package (Venables and Ripley 2002; R Development Core Team 2006).

Results

We were able to answer a mean of 43 questions (range 29–49 questions) out of 49, after a detailed search of at least 5 h on information for each species. Furthermore, for each species the test was answered by two different persons to avoid subjectivity or biases. While only one invasive species (*Chloris gayana*) was accepted, the system accepted 21% of casual species. Surprisingly, half of the casual species were rejected and many of them needed further evaluation (Fig. 1). The area under the ROC curve for the WRA classifying plants as invasive or casual was 0.79 (Fig. 2).

When performing the principal components analysis, the first two principal components explained 24% of the variability in the species data. Out of the 49 WRA questions, there were only 15 that were best characterized by the first two principal components, so they were the ones that better predicted the total of alien plant species variation. The PCA biplot (Fig. 3) indicates invasion-related traits, which are assembled in three different groups. The first group contains crop and gardening plants, most of them nitrogen fixing, bird dispersed, and forming dense thickets. Many species included in this cluster belong to the

Fig. 1 Results of the Australian weed risk assessment system of Pheloung et al. (1999) applied to 100 invasive and 97 casual plant species in Spain. The percentage of species rejected, accepted or suggested for further evaluation is indicated



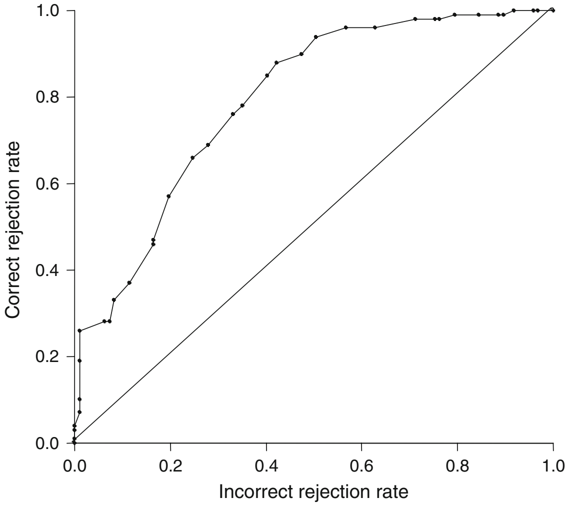


Fig. 2 Receiver operating characteristic (ROC) curve for the WRA classifying plants as invasive or casual species in Spain. The area under the ROC curve was 0.79

genus *Acacia*, *Opuntia* and *Lonicera*. The second group comprises species of Mediterranean origin and species that may create a fire hazard, such as *Gleditzia triacanthos* and *Eucalyptus globulus*, respectively. Finally, the last cluster is mainly composed of grasses (e.g., *Eleusine indica*, *Sorghum halepense*) and species belonging to Asteraceae and Amaranthaceae, and also species which are unintentionally or wind dispersed, or potentially dispersed as a contaminant.

There was a clear taxonomic bias in the set of all alien species analysed, with 33% of species belonging to just three families; Asteraceae (12%), Fabaceae (11%), and Poaceae (10%). Thus, clustering the species according to taxonomic relationships throught the GLMM analysis, we found that only five out of the 15 PCA predictors were significantly related with the invasion status of the species: existence of congeneric weeds, creating fire hazard, intentional

Fig. 3 Alien species—WRA (Australian weed risk assessment) variables ordination biplot (PCA Axes 1–2). Alien species fit > 20% and variables fit > 40%. Only the first 15 WRA variables that are best characterized by the first two principal components are displayed in the figure. See "Appendix 1" for explanation of variables

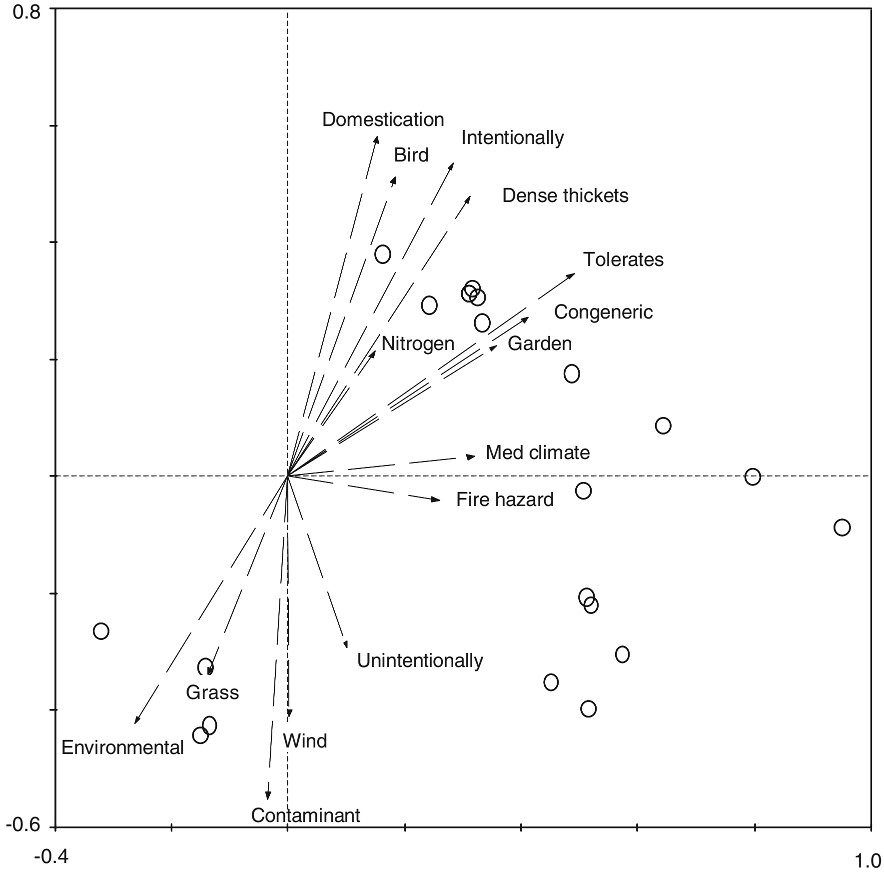


Table 1 Minimum adequate mixed model accounting for variation in invasion status (i.e., invasive or casual species)

Variable	Estimate	Standard error	DF	*t*-value	*P*
Intercept	−1.249	0.653	60	−1.912	NS
Congeneric	2.476	0.519	42	4.767	<0.0001
Fire hazard	−1.700	0.795	42	−2.137	<0.05
Intentionally	−1.312	0.558	42	−2.349	<0.05
Contaminant	1.557	0.544	42	2.861	<0.01
Bird	1.214	0.583	42	2.082	<0.05

A positive estimate value indicates a positive relationship with the invasion status. See "Appendix 1" for explanation of variables

Table 2 Minimum adequate mixed model accounting for variation in WRA final score

Variable	Estimate	Standard error	DF	*t*-value	*P*
Intercept	−8.875	1.787	48	−4.966	<0.0001
Domestication	−3.894	0.891	24	−4.368	<0.001
Med climate	2.764	0.601	24	4.595	<0.0001
Fire hazard	2.769	1.118	24	2.476	<0.05
Dense thickets	3.516	0.755	24	4.655	<0.0001
Garden	4.570	0.785	24	5.820	<0.0001
Environmental	5.154	0.721	24	7.150	<0.0001
Congeneric	6.107	0.746	24	8.185	<0.0001
Tolerates	2.651	0.730	24	3.629	<0.001
Unintentionally	3.644	0.804	24	4.530	<0.0001
Intentionally	2.140	0.907	24	2.360	<0.05
Contaminant	2.240	0.758	24	2.956	<0.01
Wind	2.040	0.846	24	2.412	<0.05
Bird	3.632	0.816	24	4.451	<0.001

A positive estimate value indicates a positive relationship with WRA score. See "Appendix 1" for explanation of variables

introduction, introduced as contaminant, and bird dispersed (Table 1). In contrast, we found that the WRA score was significantly related with more predictors: 13 out of the 15 (Table 2). These variables were mainly related to domestication, climate and area of distribution, undesirable traits, dispersal mechanisms, and persistence attributes.

Discussion

The WRA scheme developed for Australia and New Zealand (Pheloung et al. 1999) has been recognized as potentially suitable for a wide range of geographical regions (reviewed by Gordon et al. 2008). We also obtained encouraging results when screening invasive species through the WRA scheme for Spain as an example for a Mediterranean region: 94% of invasive species were rejected. This result is similar to that for other regions (see "Results" for "major invaders" in Gordon et al. 2008). The results for casual species (considered here as non-invasive) were somewhat unexpected, 50% of them being rejected. As some of the inconsistencies when comparing different studies are due to different ways of defining the alien status (Gordon et al. 2008), we opted for a clear and accepted definition of "casual species" as alien species that do not reproduce outside cultivation and rely on repeated introductions for their persistence (Richardson et al. 2000a; Pyšek et al. 2004), avoiding any possible conceptual confusion. However, this terminology does not take into account the impact caused by these species as other studies do (Pheloung et al. 1999; Kato et al. 2006). According to the results for non-invasive species in other regions (ranking from 2 to 23% of species rejected, Gordon et al. 2008), our results for casuals are less accurate. This difference could be due to the fact that we did not include species not escaped from cultivation in the pool of non-invasive. Křivánek and Pyšek (2006) using the same terminology than in our study, found that only a 6% of casual woody species were rejected. Probably, they found lower rates of rejection for casuals because they only tested for woody species and therefore their plant sample was more homogeneous than ours.

Pheloung et al. (1999) designed the WRA score to be a precautionary method, rejecting all serious and most of minor invaders. It is better to make the mistake of denying introduction to a species that would not manage to survive outside cultivation than to allow the introduction of a harmful invader, because the consequences of an introduction are often irreversible (Daehler et al. 2004). From this point of view, our result of rejecting 50% of casual species would not be a result of low accuracy but an indication of the invasive potential of these species. However, after calculating the area under the ROC curve, we found that the WRA test applied in our dataset is less accurate in separating invasive from casual species than the test applied in other regions (Gordon et al. 2008). As mentioned above, our lower accuracy could be a consequence of not including species not escaped from cultivation into the pool of non-invasive or a consequence of several other non-exclusive explanations concerning the status of casual species. First, as mentioned, the species rejected could be in fact potential invaders with small residence time or with long lag phases, therefore, needing more time to pass from casual to naturalized and later to invasive status (Caley et al. 2008; Crooks 2005). As other authors have demonstrated, minimum residence time is one of the most important factors that should be considered in evaluating invasion success (Pyšek and Jarosík 2005). We did not have information on minimum residence time for casual species, so more research would be needed on this direction, because according to this hypothesis, the WRA scheme could be working as an early-warning mechanism for potential invaders. Another reason for our findings could be an inappropriate classification of species as casual in the Atlas of Invasive Plant Species in Spain (Sanz-Elorza et al. 2004) when they could be considered invasive. For example, *Ligustrum lucidum*, classified as casual, has recently experienced a high population growth in some localities near Barcelona (Gassó, unpublished data) and could be locally classified as invasive. Finally, another explanation for the large number of casual species misclassifications could be a consequence of the high weighting that the WRA gives to some variables that are not related with invasion status but to the potential impact of the species (Table 1). In fact, risk has two components: the likelihood of invasion which is related to invasion status and impact. Other studies have shown that quantitative risk evaluation systems only based on invasion likelihood would have almost the same performance as the current WRA (Caley and Kuhnert 2006).

Characteristics related to dispersal capacity are highly related to invasion status. Dispersal as a produce contaminant and bird dispersed species are prone to becoming invasive, as previous studies have demonstrated (Rejmánek and Richardson 1996; Richardson et al. 2000b; Lloret et al. 2005). On the other hand, intentional dispersal by humans is related to casual status. Species intentionally introduced in new regions (e.g., for agricultural purposes or as ornamentals) often manage to jump into natural ecosystems and survive; becoming casual species, but their persistence depends on the constant influx of more individuals. This result is in accordance with the intention of the first question of the WRA; "Is the species highly domesticated?" If answering "yes" to this question, the final score becomes lower (i.e., the more domesticated is a species, the lower the invasion risk). This assumption considers that plants selected and bred by humans for many generations to grow in a cultivated environment have a handicap that might limit the species survival in the wild because of their reduction of competitive traits (Daehler and Carino 2000). However, when competitive traits have been selected through domestication, we considered the answer to be negative. Moreover, a species that is highly domesticated might have a higher propagule pressure, and many studies have demonstrated that propagule pressure is one of the most important factors related to invasion success (Williamson 1996; Lockwood et al. 2005). For example, Pyšek and Jarosík (2005) found frequent planting to be correlated to invasive success, because the more times the species has been introduced the higher its probability of being successfully dispersed and spread. Thus considering propagule pressure, there is a positive relationship between intentional dispersal (question 7.02) and the final WRA score. Indeed, we consider that, in certain cases, there might be a contradiction between the question regarding intentional dispersal and the one addressing domestication (question 1.01). More research is needed to elucidate the effects of domestication and propagule pressure on invasion likelihood.

We obtained a conspicuous result concerning the difference between invasion likelihood and impact: the capacity of creating a fire hazard was negatively related to invasion status. Therefore, fire risk generation does not appear to be a factor that increases the probability of spread, as there are more species with fire generation capacity among casual species than among invasive. Nevertheless, the capacity of creating a fire hazard is positively related to the WRA score, because it is an undesirable trait, especially in the Mediterranean region where fire is an important inherent disturbance and plants with this capacity could cause major impacts. Therefore, because many plants currently classified as casuals, if spread in the future, could generate significant impacts, we can highlight the importance of including impact questions in a risk assessment. However, as the additive model to integrate probability and risk could result in misunderstandings (e.g., casual species with low probability to become invasive but a high potential impact such as increase of fire hazard), we suggest that specifications on the impact and likelihood components weight on the final score should be done, or even a separate analysis to evaluate them. This measure would provide clearer interpretation and more useful information for management and decision makers.

Finally, concerning the viability of applying the WRA scheme, we would like to stress that many questions require very specific information that in many cases, especially for casual species, has not been documented yet. Those species that are widely invasive over the world have been studied considerably, thus there is generally more information about invasive species than casual species. For some characteristics, information is lacking or is very difficult to obtain for most of the taxa even if there is clear evidence of their importance in successful invasions. Examples of such traits are hybridization (Vilà et al. 2000), allelopathy (Callaway and Ridenour 2004), release of natural enemies (Colautti et al. 2004), self compatibility (Daehler 1998), and potential impacts (e.g., pest and pathogens).

In conclusion, we found that the rate of correctly identifying invaders is high, and that it could be working as an early-warning mechanism for casual species with potential to become invasive. Moreover, having detected some incongruities between invasion likelihood questions and impact questions, we suggest that a separate analysis should be done to evaluate these two risk components, in order to provide what would provide more useful information for management. Concerning invasion likelihood, more research is needed to determine if differences between casual and invasive are due to differences in biological traits, or whether it is a matter of propagule pressure and residence time. This study represents a first step towards the construction of a Mediterranean Basin WRA. However, more research is needed to evaluate the performance of the test in identifying non-invasive species.

Acknowledgments We thank I. Kühn and P. Pyšek for providing the WRA excel application; and C. Daehler and three anonymous reviewers for comments on an early version of the manuscript. This study has been partially financed by the 6th Framework Programme of the European Commission projects ALARM (Assessing large-scale environmental risks for biodiversity with tested methods. GOCE-CT-2003-506675; http://www.alarmproject.net/alarm/) and DAISIE (Delivering alien invasive species inventories for Europe. SSPI-CT-2003-511202; http://www.europe-aliens.org/) and the Spanish Ministerio de Ciencia e Innovación CONSOLIDER project MONTES (Spanish woodlands and global change: threats and opportunities. CSD2008-00040).

Appendix 1

See Table 3.

Table 3 Table of correspondences between the adapted questions from the Australian weed risk assessment system of Pheloung et al. (1999) (WRA) to our study, and abbreviations used in our analysis

Category	WRA code	WRA question	Abbreviation
Domestication/cultivation	1.01	Is the species highly domesticated?	Domestication
	1.02	Has the species become naturalized where grown?	Naturalization
	1.03	Does the species have weedy races?	Weedy races
Climate and distribution	2.01	Species suited to Mediterranean climate	Med climate
	2.02	Quality of climate match data	Quality data
	2.03	Broad climate suitability (environmental versality)	Climate suitability
	2.04	Native or naturalized in regions with extended dry periods	Native med climate
	2.05	Does the species have a history of repeated introductions outside its natural range?	Repeated intro

Table 3 continued

Category	WRA code	WRA question	Abbreviation
Weed elsewhere	3.01	Naturalized beyond native range	Nature native range
	3.02	Garden/amenity/disturbance weed	Garden
	3.03	Weed of agriculture/horticulture/forestry	Agriculture
	3.04	Environmental weed	Environmental
	3.05	Congeneric weed	Congeneric
Undesirable traits	4.01	Produces spines, thorns or burrs	Spines
	4.02	Allelopathic	Allelopathy
	4.03	Parasitic	Parasitic
	4.04	Unpalatable to grazing animals	Unpalatable
	4.05	Toxic to animals	Toxic
	4.06	Host for recognized pests and pathogens	Host pathogens
	4.07	Causes allergies or is otherwise toxic to humans	Allergies
	4.08	Creates a fire hazard in natural ecosystems	Fire hazard
	4.09	Is a shade tolerant plant at some stage of its life cycle	Shade tolerant
	4.10	Grows on infertile soils	Soil
	4.11	Climbing or smothering growth habit	Climbing
	4.12	Forms dense thickets	Dense thickets
Plant type	5.01	Aquatic	Aquatic
	5.02	Grass	Grass
	5.03	Nitrogen fixing plant	Nitrogen
	5.04	Geophyte	Geophyte
Reproduction	6.01	Evidence of substantial reproductive failure in native habitats	Reproductive failure
	6.02	Produces viable seed	Viable seed
	6.03	Hybridizes naturally	Hybridizes
	6.04	Self-compatible or apomictic	Self-compatible
	6.05	Requires specialist pollinators	Specialist pollinators
	6.06	Reproduction by vegetative propagation	Vegetative
	6.07	Minimum generative time	Min time
Dispersal mechanisms	7.01	Propagules likely to be dispersed unintentionally	Unintentionally
	7.02	Propagules dispersed intentionally by people	Intentionally
	7.03	Propagules likely to disperse as a produce contaminant	Contaminant
	7.04	Propagules adapted to wind dispersal	Wind
	7.05	Propagules buoyant	Water
	7.06	Propagules bird dispersed	Bird
	7.07	Propagules dispersed by other animals (externally)	Animals
	7.08	Propagules dispersed by other animals (internally)	Gut
Persistance attributes	8.01	Prolific seed production	Seed production
	8.02	Evidence that a persistent propagule bank is formed	Propagule bank
	8.03	Well controlled by herbicides	Herbicides
	8.04	Tolerates, or benefits from mutilation, cultivation or fire	Tolerates
	8.05	Effective natural enemies present locally	Enemies

Appendix 2

See Table 4.

Table 4 Species used to test if the Australian weed risk assessment system (WRA) of Pheloung et al. (1999) was suitable to predict (A) 100 invasive (A) and (B) 97 casual species in Spain. The final WRA score is given

Family	Species	Score	Family	Species	Score
(A) *Invasive species*					
Aceraceae	*Acer negundo*	13	Crassulaceae	*Crassula lycopodioides*	14
Agavaceae	*Agave americana*	14	Cyperaceae	*Cyperus alterniformis flabelliformis*	18
Aizoaceae	*Carpobrotus acinaciformis*	21	Elaeagnaceae	*Elaeagnus angustifolia*	21
Aizoaceae	*Carpobrotus edulis*	22	Fabaceae	*Acacia dealbata*	24
Amaranthaceae	*Achyranthes sicula*	12	Fabaceae	*Acacia longifolia*	23
Amaranthaceae	*Amaranthus albus*	10	Fabaceae	*Acacia melanoxylon*	21
Amaranthaceae	*Amaranthus blitoides*	10	Fabaceae	*Acacia saligna*	22
Amaranthaceae	*Amaranthus hybridus*	10	Fabaceae	*Gleditsia triacanthos*	10
Amaranthaceae	*Amaranthus muricatus*	12	Fabaceae	*Leucaena leucocephala*	21
Amaranthaceae	*Amaranthus powelli*	7	Fabaceae	*Parkinsonia aculeata*	15
Amaranthaceae	*Amaranthus retroflexus*	6	Fabaceae	*Robinia pseudoacacia*	15
Amaranthaceae	*Amaranthus viridis*	10	Fabaceae	*Sophora japonica*	12
Anacardiaceae	*Schinus molle*	4	Hydrocharitaceae	*Elodea canadensis*	20
Asclepiadaceae	*Araujia sericifera*	17	Iridaceae	*Chasmanthe aetiopica*	15
Asclepiadaceae	*Asclepias curassavica*	9	Iridaceae	*Tritonia crocosmiiflora*	1
Asclepiadaceae	*Gomphocarpus fruticosus*	9	Malvaceae	*Abutilon theophrasti*	15
Asteraceae	*Achillea filipendulina*	11	Myrtaceae	*Eucalyptus camaldulensis*	17
Asteraceae	*Ageratina adenophora*	13	Myrtaceae	*Eucalyptus globulus*	21
Asteraceae	*Ambrosia artemisifolia*	18	Nyctaginaceae	*Mirabilis jalapa*	7
Asteraceae	*Arctotheca calendula*	17	Onagraceae	*Oenothera biennis*	9
Asteraceae	*Artemisia verlotiorum*	7	Onagraceae	*Oenothera glazioviana*	8
Asteraceae	*Aster squamatus*	17	Oxalidaceae	*Oxalis pes-caprae*	24
Asteraceae	*Conyza bonariensis*	15	Poaceae	*Bromus willdenowii*	4
Asteraceae	*Conyza canadensis*	12	Poaceae	*Cenchrus incertus*	6
Asteraceae	*Conyza sumatrensis*	15	Poaceae	*Chloris gayana*	−3
Asteraceae	*Cotula coronopifolia*	10	Poaceae	*Cortaderia selloana*	26
Asteraceae	*Helianthus tuberosus*	7	Poaceae	*Echinochloa hispidula*	14
Asteraceae	*Senecio inaequidens*	23	Poaceae	*Echinochloa oryzicola*	17
Asteraceae	*Senecio mikanioides*	16	Poaceae	*Echinochloa oryzoides*	17
Asteraceae	*Xanthium spinosum*	19	Poaceae	*Eleusine indica*	8
Asteraceae	*Xanthium strumarium*	17	Poaceae	*Paspalum dilatatum*	18
Azollaceae	*Azolla filiculoides*	32	Poaceae	*Paspalum paspalodes*	20
Buddlejaceae	*Buddleja davidii*	19	Poaceae	*Paspalum vaginatum*	12
Cactaceae	*Austrocylindropuntia subulata*	11	Poaceae	*Pennisetum setaceum*	26
Cactaceae	*Cylindropuntia spinosior*	18	Poaceae	*Sorghum halepense*	24
Cactaceae	*Cylindropuntia imbricata*	21	Poaceae	*Spartina alterniflora*	14
Cactaceae	*Opuntia dillenii*	22	Poaceae	*Spartina patens*	10
Cactaceae	*Opuntia engelmannii*	22	Poaceae	*Stenotaphrum secundatum*	13
Cactaceae	*Opuntia ficus-indica*	22	Polygonaceae	*Fallopia baldschuanica*	15

Table 4 continued

Family	Species	Score	Family	Species	Score
Cactaceae	*Opuntia humifusa*	22	Polygonaceae	*Fallopia japonica*	15
Cactaceae	*Opuntia monacantha*	22	Pontederiaceae	*Eichhornia crassipes*	23
Cactaceae	*Opuntia phaeracantha*	22	Simaroubaceae	*Ailanthus altissima*	12
Cactaceae	*Opuntia stricta*	22	Solanaceae	*Datura innoxia*	15
Caprifoliaceae	*Lonicera japonica*	14	Solanaceae	*Datura stramonium*	19
Chenopodiaceae	*Atriplex semibaccata*	19	Solanaceae	*Nicotiana glauca*	14
Commelinaceae	*Tradescantia fluminensis*	12	Solanaceae	*Solanum bonariense*	19
Convolvulaceae	*Ipomoea indica*	14	Tropaeolaceae	*Tropaeolum majus*	14
Convolvulaceae	*Ipomoea purpurea*	21	Verbenaceae	*Lantana camara*	25
Convolvulaceae	*Ipomoea sagittata*	17	Verbenaceae	*Lippia filiformis*	15
Convolvulaceae	*Ipomoea stolonifera*	17	Zygophyllaceae	*Zygophyllum fabago*	14
(B) *Casual species*					
Agavaceae	*Yucca aloifolia*	4	Liliaceae	*Hemerocallis lilioasphodelus*	5
Aizoaceae	*Lampranthus multiradiatus*	12	Liliaceae	*Ornithogalum arabicum*	3
Amaranthaceae	*Alternanthera sessilis*	20	Liliaceae	*Tulipa clusiana*	3
Amaranthaceae	*Amaranthus caudatus*	18	Liliaceae	*Tulipa gesneriana*	−1
Amaranthaceae	*Amaranthus tricolor*	6	Malvaceae	*Gossypium arboreum*	13
Amaryllidaceae	*Narcisus* × *medioluteus*	6	Malvaceae	*Hibiscus rosa-sinensis*	−5
Apocynaceae	*Catharanthus roseus*	1	Malvaceae	*Hibiscus syriacus*	−6
Araceae	*Monstera deliciosa*	6	Moraceae	*Morus nigra*	4
Asteraceae	*Ageratum houstonianum*	7	Myrtaceae	*Callistemon citrinus*	−4
Asteraceae	*Calendula officinalis*	−6	Myrtaceae	*Eucalyptus gunnii*	11
Asteraceae	*Cynara scolymus*	0	Myrtaceae	*Eucalyptus sideroxylon*	14
Asteraceae	*Gamochaeta subfalcata*	9	Nymphaeaceae	*Nymphaea mexicana*	14
Asteraceae	*Gazania rigens*	12	Oleaceae	*Jasminum nudiflorum*	0
Asteraceae	*Senecio cineraria*	−1	Oleaceae	*Ligustrum lucidum*	4
Asteraceae	*Solidago gigantea*	10	Oleaceae	*Ligustrum ovalifolium*	9
Asteraceae	*Tagetes patula*	0	Oleaceae	*Syringa vulgaris*	−2
Balsaminaceae	*Impatiens glandulifera*	18	Onagraceae	*Oenothera laciniata*	17
Bignoniaceae	*Doxantha unguis-cati*	17	Passifloraceae	*Passiflora caerulea*	6
Bignoniaceae	*Jacaranda mimosifolia*	−1	Pinaceae	*Larix eurolepis*	−4
Cactaceae	*Cereus peruvianus*	3	Pinaceae	*Pinus canariensis*	14
Casuarinaceae	*Allocasuarina verticillata*	−3	Pinaceae	*Pinus ponderosa*	8
Casuarinaceae	*Casuarina cunninghaniana*	15	Pittosporaceae	*Pittosporum tobira*	3
Chenopodiaceae	*Beta vulgaris*	−3	Poaceae	*Arundo donax*	8
Convolvulaceae	*Convolvulus mauritanicus*	4	Poaceae	*Lolium multiflorum*	10
Crassulaceae	*Sedum sexangulare*	10	Poaceae	*Panicum capillare*	10
Cucurbitaceae	*Lagenaria siceraria*	0	Polygonaceae	*Fagopyrum esculentum*	8
Cupressaceae	*Cupressus macrocarpa*	4	Polygonaceae	*Fagopyrum tataricum*	4
Cyperaceae	*Cyperus michelianus*	20	Polygonaceae	*Rumex maritimus*	12
Fabaceae	*Acacia decurrens*	17	Polygonaceae	*Rumex patientia*	5
Fabaceae	*Acacia mearnsii*	17	Rosaceae	*Cydonia oblonga*	5
Fabaceae	*Acacia pycnantha*	24	Rosaceae	*Photinia serrulata*	−6
Fabaceae	*Acacia sophorae*	6	Rosaceae	*Prunus persica*	−4
Fabaceae	*Acacia verticilata*	13	Rosaceae	*Prunus serotina*	12

Table 4 continued

Family	Species	Score	Family	Species	Score
Fabaceae	*Bauhimia grandiflora*	6	Rosaceae	*Pyracantha angustifolia*	19
Fabaceae	*Cassia obtusifolia*	17	Rosaceae	*Rosa moschata*	8
Fabaceae	*Lathirus odoratus*	15	Rosaceae	*Spiraea cantoniensis*	1
Fabaceae	*Lathyrus sativus*	10	Rutaceae	*Citrus limon*	5
Fabaceae	*Mimosa pudica*	20	Salicaceae	*Populus simonii*	0
Fabaceae	*Phaseolus lunatus*	8	Salicaceae	*Populus* × *canescens*	7
Fabaceae	*Robinia hispida*	20	Sapindaceae	*Cardiospermum halicacabum*	15
Geraniaceae	*Pelargonium peltatum*	−4	Solanaceae	*Datura ferox*	19.5
Iridaceae	*Iris albicans*	14	Solanaceae	*Nicandra physaloides*	4
Lamiaceae	*Mentha spicata*	1.5	Solanaceae	*Nicotiana tabacum*	5
Lamiaceae	*Perilla frutescens*	5	Ulmaceae	*Ulmus pumila*	12
Lamiaceae	*Salvia microphylla*	13	Verbenaceae	*Aloysia citrodora*	7
Liliaceae	*Aloe arborescens*	20	Verbenaceae	*Lantana montevidensis*	14
Liliaceae	*Aloe vera*	18	Verbenaceae	*Verbena canadensis*	−1
Liliaceae	*Asparagus setaceus*	4	Vitaceae	*Parthenocissus inserta*	11
			Vitaceae	*Vitis berlandieri*	1

References

Andersen MC, Adams H, Hope B, Powell M (2004) Risk assessment for invasive species. Risk Anal 24(4):787–793. doi:10.1111/j.0272-4332.2004.00478.x

Baker HG (1965) Characteristics and modes of origin of weeds. In: Baker HG, Stebbins GL (eds) The genetics of colonizing species. Academic Press, New York

Blackburn TM, Duncan RP (2001) Determinants of establishment success in introduced birds. Nature 414:195–197. doi:10.1038/35102557

Bolòs O, Vigo J, Masalles RM, Ninot JM (2005) Flora manual dels Països Catalans, 3rd edn. Ketrès, Barcelona

Brändle M, Stadler J, Klotz S, Brandl R (2003) Distributional range size of weedy plant species is correlated to germination patterns. Ecology 84:136–144. doi:10.1890/0012-9658(2003)084[0136:DRSOWP]2.0.CO;2

Caley P, Kuhnert PM (2006) Application and evaluation of classification trees for screening unwanted plants. Austral Ecol 31:647–655. doi:10.1111/j.1442-9993.2006.01617.x

Caley P, Lonsdale WM, Pheloung PC (2006) Quantifying uncertainty in predictions of invasiveness. Biol Invasions 8:277–286. doi:10.1007/s10530-004-6703-z

Caley P, Groves RH, Barker R (2008) Estimating the invasion success of introduced plants. Divers Distrib 14:196–203. doi:10.1111/j.1472-4642.2007.00440.x

Callaway RM, Ridenour WM (2004) Novel weapons: invasive success and the evolution of increased competitive ability. Front Ecol Environ 2:436–443

Castroviejo S, Laínz M, López G, Montserrat P, Muñoz F, Paiva J, Villar L (eds) (1986–2000) Flora Ibérica. Real Jardín Botánico, CSIC, Madrid

Colautti RI, Ricciardi A, Grigorovich IA, MacIsaac HJ (2004) Is invasion success explained by the enemy release hypothesis? Ecol Lett 7:721–733. doi:10.1111/j.1461-0248.2004.00616.x

Crawley MJ (2002) Statistical computing: an introduction to data analysis using S-Plus. Wiley, Chichester

Crooks JA (2005) Lag times and exotic species: the ecology and management of biological invasions in slow-motion. Ecoscience 12:316–329. doi:10.2980/i1195-6860-12-3-316.1

Crosti R, Cascone C, Testa W (2007) Towards a weed risk assessment for the Italian peninsula: preliminary validation of a scheme for the central Mediterranean region in Italy. In: Rokich D, Wardell-Johnson G, Yates C, Stevens J, Dixon K, McLellan R, Moss G (eds) Proceedings, International Mediterranean Ecosystems Conference, Perth, Australia, 2–5 September 2007, pp 53–54

Daehler CC (1998) Variation in self-fertility and the reproductive advantage of self-fertility for an invading plant (*Spatina alterniflora*). Evol Ecol 12:553–568. doi:10.1023/A:1006556709662

Daehler CC (2003) Performance comparisons of co-occurring native and alien invasive plants: implications for conservation and restoration. Annu Rev Ecol Evol Syst 34:183–211. doi:10.1146/annurev.ecolsys.34.011802.132403

Daehler CC, Carino DA (2000) Predicting invasive plants: prospects for general screening system based on current regional models. Biol Invasions 2:93–102. doi:10.1023/A:1010002005024

Daehler CC, Denslow J, Ansari S, Kuo H-C (2004) A risk-assessment system for screening out invasive pest plants from Hawaii and other Pacific Islands. Conserv Biol 18:360–368. doi:10.1111/j.1523-1739.2004.00066.x

DeLong ER, DeLong DM, Clarke-Pearson DL (1988) Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics 44:837–845. doi:10.2307/2531595

Di Castri F (1989) History of biological invasions with special emphasis on the Old Word. In: Drake JA (ed) Biological invasions: a global perspective. Wiley, Chichester

Goodwin BJ, Mcallister AJ, Fahrig L (1999) Predicting invasiveness of plant species based on biological information. Conserv Biol 13:422–426. doi:10.1046/j.1523-1739.1999.013002422.x

Gordon DR, Onderdonk DA, Fox AM, Stocker RK (2008) Consistent accuracy of the Australian weed risk assessment system across varied regions. Divers Distrib 14:234–242. doi:10.1111/j.1472-4642.2007.00460.x

Harvey PH, Pagel MD (1991) The comparative method in evolutionary biology. Oxford University Press, Oxford

Heger T, Trepl L (2003) Predicting biological invasions. Biol Invasions 5:313–321. doi:10.1023/B:BINV.0000005568.44154.12

Hughes G, Madden LV (2003) Evaluating predictive models with application in regulatory policy for invasive weeds. Agric Syst 76:755–774. doi:10.1016/S0308-521X(02)00164-6

Kato H, Hata K, Yamamoto H, Yoshioka T (2006) Effectiveness of the weed risk assessment system for the Bonin Islands. In: Koike F, Clout MN, Kawamichi M, De Poorter M, Iwatsuki K (eds) Assessment and control of biological invasion risk. Shoukadoh Book Sellers, Kyoto, Japan and IUCN, Gland, Switzerland pp 65–72

Keller RP, Drake JM, Lodge DM (2007a) Fecundity as a basis for risk assessment of nonindigenous freshwater Molluscs. Conserv Biol 21:191–200. doi:10.1111/j.1523-1739.2006.00563.x

Keller RP, Lodge DM, Finnoff DC (2007b) Risk assessment for invasive species produces net bioeconomic benefits. Proc Natl Acad Sci USA 104:203–207. doi:10.1073/pnas.0605787104

Kolar CS, Lodge DM (2001) Progress in invasion biology: predicting invaders. Trends Ecol Evol 16:199–204. doi:10.1016/S0169-5347(01)02101-2

Křivánek M, Pyšek P (2006) Predicting invasions by woody species in a temperate zone: a test of three risk assessment schemes in the Czech Republic (Central Europe). Divers Distrib 12:319–327. doi:10.1111/j.1366-9516.2006.00249.x

Lasko TA, Bhagwat JG, Zou KH, Ohno-Machado L (2005) The use of receiver operating characteristic curves in biomedical informatics. J Biomed Inform 38:404–415. doi:10.1016/j.jbi.2005.02.008

Lepš J, Šmilauer P (2006) Multivariate analysis of ecological data using CANOCO. Cambridge University Press, Cambridge

Leung B, Lodge DM, Finnoff D, Shogren JF, Lewis MA, Lamberti G (2002) An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. Biol Sci 269:2407–2413. doi:10.1098/rspb.2002.2179

Lloret F, Médail F, Brundu G, Camarda I, Moragues E, Rita J, Lambdon P, Hulme PE (2005) Species attributes and invasion success by alien plants on Mediterranean islands. J Ecol 93:512–520. doi:10.1111/j.1365-2745.2005.00979.x

Lockwood JL, Cassey P, Blackburn TM (2005) The role of propagule pressure in explaining species invasions. Trends Ecol Evol 20:223–228. doi:10.1016/j.tree.2005.02.004

McNeely JA, Mooney HA, Neville LE, Schei PJ, Waage JK (eds) (2001) A global strategy on invasive alien species. IUCN, Gland

Medail F, Quezel P (1997) Hot-spots analysis for conservation of plant biodiversity in the Mediterranean basin. Ann Mo Bot Gard 84:112–127. doi:10.2307/2399957

National Invasive Species Council (2001) Management plan: meeting the invasive species challenge. Washington, DC. Available from http://www.invasivespeciesinfo.gov/docs/council/mpfinal.pdf. Accessed August 2007

Pheloung PC (1995) Determining the weed potential of new plant introductions to Australia. Agriculture Protection Board Report. West Australian Department of Agriculture, Perth

Pheloung PC, Williams PA, Halloy SR (1999) A weed risk assessment model for use as a biosecurity tool evaluating plant introductions. J Environ Manag 57:239–251. doi:10.1006/jema.1999.0297

Pyšek P (2001) Past and future of predictions in plant invasions: a field test by time. Divers Distrib 7:145–151. doi:10.1046/j.1366-9516.2001.00107.x

Pyšek P, Jarosík V (2005) Residence time determines the distribution of alien plants. In: Inderjit (ed) Invasive plants: ecological and agricultural aspects. Birkhauser Verlag, Switzerland

Pyšek P, Richardson DM, Rejmánek M, Webster GL, Williamson M, Kirschner J (2004) Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. Taxon 53:131–143. doi:10.2307/4135498

R Development Core Team (2006) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available from http://www.R-project.org

Reichard SH, Hamilton CW (1997) Predicting invasions of woody plants introduced into North America. Conserv Biol 11:193–203. doi:10.1046/j.1523-1739.1997.95473.x

Rejmánek M (2000) Invasive plants: approaches and predictions. Austral Ecol 25:497–506

Rejmánek M, Richardson DM (1996) What attributes make some plant species more invasive? Ecology 77:1655–1661. doi:10.2307/2265768

Richardson DM, Pyšek P (2006) Plant invasions: merging the concepts of species invasiveness and community invasibility. Prog Phys Geogr 30:409–431. doi:10.1191/0309133306pp490pr

Richardson DM, Thuiller W (2007) Home away from home—objective mapping of high-risk source areas for plant introductions. Divers Distrib 13:299–312

Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta FD, West CJ (2000a) Naturalization and invasion of alien plants: concepts and definitions. Divers Distrib 6:93–107. doi:10.1046/j.1472-4642.2000.00083.x

Richardson DM, Allsopp N, D'Antonio CM, Milton SJ, Rejmánek M (2000b) Plant invasions—the role of mutualisms. Biol Rev Camb Philos Soc 75:65–93. doi:10.1017/S0006323199005435

Sanz-Elorza M, Dana ED, Sobrino E (2004) Atlas de las plantas alóctonas invasoras de España. Dirección General para la Biodiversidad, Madrid

Smith CS, Lonsdale WM, Fortune J (1999) When to ignore advice: invasion predictions and decision theory. Biol Invasions 1:89–96. doi:10.1023/A:1010091918466

Sol D, Vilà M, Kühn I (2008) The comparitive analysis of historical alien introductions. Biol Invasions 10:1119–1129. doi:10.1007/s10530-007-9189-7

Thuiller W, Richardson DM, Pyšek P, Midgley GF, Hughes GO, Rouget M (2005) Niche-based modelling as a tool for predicting the risk of alien plant invasions at a global scale. Glob Chang Biol 11:2234–2250

Thuiller W, Richardson DM, Rouget M, Proches S, Wilson JRU (2006) Interactions between environment, species traits, and human uses describe patterns of plant invasions. Ecology 87:1755–1769. doi:10.1890/0012-9658(2006)87[1755:IBESTA]2.0.CO;2

Union of Concerned Scientists (2001) The science of invasive species. An information update by the Union of Concerned Scientists, http://www.ucsusa.org/ssi/invasive-species/science-of-invasive-species.html. Accessed 27 July 2006

Venables WN, Ripley BD (2002) Modern applied statistics with S, 4th edn. Springer, New York

Vilà M, Weber E, D'Antonio CM (2000) Conservation implications of invasion by plant hybridization. Biol Invasions 2:207–217. doi:10.1023/A:1010003603310

Westbrooks R (1981) Introduction of foreign noxious plants into the United States. Weeds Today 14:16–17

Williamson M (1996) Biological invasions. Chapman and Hall, London

Wittenberg R, Cock MJW (eds) (2001) Invasive Alien species: a toolkit of best prevention and management practices. CAB International, Wallingford