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Pest risk assessment and invasion pathways: invasive weeds†

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Abstract

For pathogens and insect pests, risk assessments are carried out to determine to what extent they are likely to enter *accidentally*, as passengers on an imported commodity. By contrast, risk assessments of potential weeds are typically conducted on plants that people actually *want* to introduce, either as ornamentals, or for agriculture. Here, the focus is on determining whether a species, unknown elsewhere as a weed, could become invasive in the country of proposed introduction. A proper assessment of risk here, therefore, requires us to understand what triggers a species to become invasive. Such understanding still eludes us, and indeed is at the frontier of ecology, yet weed risk assessment systems are already being implemented or adopted all over the world. I present concepts from the epidemiological literature, that are relevant to the assessment of such systems.

Keywords: base-rate effect; prevalence; epidemiology.

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Introduction

The United States National Academy of Sciences (1983) has published a general four-stage formulation of risk assessment: (i) hazard identification (what is the harm caused by the hazardous agent?); (ii) dose-response assessment (how does the amount of harm caused change with the amount of the hazardous agent?); (iii) exposure assessment (where is the hazardous agent likely to spread, and in what amounts, upon release?); and (iv) risk characterisation, which synthesises the first three stages to provide an overall assessment of risk. The specific process of pest risk assessment is still in its infancy, however. Much of what is termed "risk assessment" in pest ecology is, in fact, merely part of stage (i) above. The other stages also need to be considered, i.e. the relationship between the abundance of the pest or weed and the harm it causes (stage (ii)), where the weed is likely to be most abundant (stage (iii)), as well as the risk characterisation stage (iv). Most weed risk assessments fall far short of providing this kind of synthesis. In addition, invasion ecologists have only recently begun to grapple with the test and prediction problems that other disciplines, such as medical test evaluation (Kraemer, 1992) and earthquake prediction (Matthews, 1997; Smith et al., 1999), have had to face in the past. I have outlined here some concepts from these other disciplines that are relevant to pest screening systems.

Weed entry pathways are mostly intentional

For weeds the most important modes of intercontinental movement and entry are intentional. A large proportion (67%) of naturalised plant species in Australia were introduced for ornamental or agricultural purposes (Groves et al., 1997). As a result, the focus for weed risk assessment has been on the potential for proposed "useful" plant introductions to become weeds. The key risk assessment question for weeds is: "could this plant, intended for introduction, become weedy?"

In contrast, strong correlations exist between the number of established plant pathogens, molluscs, and insects and the volume of trade entering the United States (Levine & D'Antonio, 2003). The implication here is that the pathway of entry is as accidental contaminants in trade commodities. The key risk assessment question here is: "what species could enter as a contaminant in this commodity?"

Successful weed invasions should be hard to predict

A weakness of current weed risk assessment systems is that they tend to focus on on the attributes of the species (which are governed by genotype). In fact, the outcome of an introduction is only partly dependent on this factor. Harmful invasions actually result from an interaction of genotype with two other key factors – environment and chance (the latter being strongly influenced by what is termed propagule pressure, effectively the number of introduced organisms, sites of introduction, and introduction events). Indeed, a prominent ecologist has argued that "attempts to predict [the outcome of an introduction] are futile" (Crawley, 1996). Despite this, some studies, set up to test the efficacy of weed risk assessment systems, have applied the systems to the characteristics of previously introduced successful weed species to test retrospectively the predictive power. They have found impressively high accuracy rates in their identification of known weed species, based solely or largely on plant characters (e.g. Perrins et al., 1992; Reichard & Hamilton, 1997; Pheloung et al., 1999; Daehler et al., 2004; Gordon et al., 2008).

Effectiveness of pest screening systems

Clearly there is a disconnect between the apparent difficulty of predicting invasion and the impressively high accuracy rates reported above. A possible explanation for this disparity is that evaluations regarding the effectiveness of various pest screening systems for assessing the weed potential of species at the point of entry have been insufficiently rigorous. In fact, evaluating the effectiveness of any type of screening system is fraught with difficulties. A growing body of medical research suggests that more than a quarter of the medical screening currently being performed is unnecessary, and also yields results that are inaccurate and misleading (Nash, 1985). The medical literature is also rich in directives about how to assess the effectiveness of medical screening systems (see Kraemer, 1992). Using insights from medical epidemiology and ecology, Lonsdale and Smith (2001) highlighted the following methodological flaws that may occur in evaluations of pest screening systems:

(a) the initial sample test population to be run through the screening process is not appropriately taken. A typical methodology is to actually devise the screening system using a population of species, then carry out the evaluation of the system using different subsamples of the same population, which is often composed of unnatural proportions of extreme pests and non-pests (see "Effect of prevalence and uncertainty on predictions" below). Even if found to be accurate, it is unsafe to generalise results from such an evaluation to the wider population. The results are likely only to be valid for the original sample population. More appropriate sampling would, for example, involve identifying a large group of incoming exotic species. These would then be diagnosed (identified as weeds or not), then sub-sampled

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to get a random sample of positive and negative diagnoses as a weed. The accuracy of the identification can then be tested (using different operators to those who diagnosed them as weeds or not) using the screening system (which would in itself have been designed using a completely different population of species);

(b) the same people may run the test and carry out the diagnoses, or the tests are run on species that are already widely known to be weeds (contravening the requirement in medicine for blind evaluation). This becomes particularly critical where the screening procedure involves value judgements (e.g. “weed or not”?);

(c) species may be dropped from the evaluation because insufficient information is available to complete the test (the problem of “drop-outs”, in medical terms);

(d) characters are measured or estimated on introduced, not native, populations of the organism. Invasive plants in the introduced range usually look very different from their appearance in the native range where they are subject to the depredations of pests and pathogens. In operation, a weed risk assessment system would actually be required to detect weediness based on behaviour in the native range. Questions about plant vigour or seed production would have a very different answer if asked prior to introduction, in the native range; and

(e) phylogeny (the effect of taxonomic relatedness, whereby related species are used as independent datapoints, but actually share properties through a common evolutionary history – see Kelly et al., 1996) and lag phase effects (we may diagnose a species as a non-weed today, yet some species may take hundreds of years after they are introduced to become invasive – see Kowarik, 1995) are not taken into account.

Effect of prevalence and uncertainty on predictions

Smith et al. (1999) highlighted the phenomenon of the **base-rate effect**, or, as it is known to epidemiologists, **prevalence**, and its bearing on the evaluation of pest screening systems. The base-rate is the natural prevalence of a phenomenon in the population under study. In this context, it would be defined as the proportion of species introduced to a region that becomes weedy in a given time period. It is generally believed that the proportion of organisms entering a region that will actually become pests is rather low (e.g. Williamson & Fitter, 1996). This means that, even in a situation where the accuracy of information used for identifying possible weed species is high, the predictive value of this information will be low (e.g. Smith et al., 1999). This is because the error rate will combine with the large number of species destined not to become weedy to swamp the correct predictions with false positives. Thus, prevalence alone could account for much of the discrepancy between Crawley (1996), on the one hand, and the proponents of accurate screening systems, on the other – all are simultaneously correct! In this situation, do we bother to predict the outcome of an introduction or not? Decision theory can help to structure this choice (Smith et al., 1999).The answer also depends on an assessment of the costs of letting in a pest relative to the costs of losing a potentially useful organism. The best known weed risk assessment system is that described by Pheloung et al., 1999. This uses 49 attributes to assess the potential for a species to become a weed and has an impressive accuracy (but see Caley & Kuhnert, 2006 which shows that the number of questions can be reduced dramatically with little impact on accuracy). However, Caley et al. (2006) confirmed that the accuracy of the prediction was very sensitive to the base-rate probability of weediness of plants proposed for importation. Caley et al. (2006) also found that uncertainty in this base-rate probability manifests itself in uncertainty surrounding predicted probabilities of weediness. I believe a more critical appraisal of weed risk assessment systems is necessary.

Conclusions

Impressive claims of accuracy for weed risk assessment systems seem to conflict with the current understanding of how introduced species interact with the environment. Ecologists need to address this tension. Insights from epidemiology will help ecologists to design, appraise and improve risk assessment tools by taking better account of the great uncertainty in present estimates of the prevalence of invasions.

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