PROCEEDINGS

California Weed Risk Assessment Workshop

October 30-31, 2006
Davis, California

These proceedings comprise notes from presentations and facilitated discussions. For more information on the workshop, contact info@cal-ipc.org.

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Executive Summary and Recommended Actions

Weed risk assessment (WRA) is a critical undertaking for addressing the introduction and spread of invasive plants. Programs that avoid introduction and spread are much more cost-effective than programs to manage invasive plant populations that have already established, and should be made a top priority.

Many entities are working on WRA. These efforts range in scale from international to local. Some are tied to regulatory mandates, while others are voluntary. They vary in complexity, scope, and purpose.

This workshop brought together a small team of experts from Australia and the US to advance dialog on the science, techniques and policy of WRA. The goal was to identify key research needs, strategies and methods, and also to guide WRA development in California.

Several key opportunities emerged from the presentations and discussion at the workshop. One is the continued review of the US Q-37 regulations for plants for planting. An upcoming electronic discussion through USDA will allow a broader group of stakeholders to be involved more directly than ever before in federal screening policy. Also, a study soon to be released by the University of Florida testing the Australian WRA provides further review of the system's performance, and demonstrates new ways to evaluate such systems.

Workshop attendees discussed the needs facing the field currently, and how to address them. Below are listed six priority areas recommended for attention:

1. ***Botanical Gardens*** - Encourage botanical gardens to record and communicate information on plants that show signs of invasiveness.
2. ***Database*** - Create a database to share data and citations used in existing WRAs (with notations on data quality) to assist in future WRAs.
3. ***WRA Systems, refinement*** - Improve WRA methodologies to increase resolution of assessment for plants that fall into a middle-ground "needs further evaluation" category, while also minimizing "false positives" in which a safe plant is assessed as an invasive risk.
4. ***WRA Systems, testing*** - Test the various WRA systems with comparable data sets to refine the systems, to best determine the utility of each, and to demonstrate their effectiveness to decision makers, industry, and the public.
5. ***Education*** - Educate the public about weeds in order to support the basic need for WRA programs.
6. ***Research*** - Target research on the ecology of invasive plants towards the goal of developing simpler predictive models.

WRA is a rapidly evolving discipline and needs continued interaction between science and policy. As organizations around the world progress on WRA, there are significant efficiencies to be gained in sharing WRA systems and databases.

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Introduction to California WRA Workshop

Doug Johnson, California Invasive Plant Council

The purposes of this workshop are to:

- Advance international dialog on the science, techniques and policy of WRA
- Identify key research needs, strategies and methods for California and the U.S.
- Increase capacity for WRA in California
- Improve U.S. WRA efforts at the state level

From a California-centric perspective, we want to learn from others doing this work as we embark on our first pre-introduction efforts in the state. From a national perspective, we want to make sure that regional efforts are coordinated, and that we are working in harmony with federal efforts. And from an international perspective, it's an opportunity to continue dialog on WRA in advance of the second international WRA workshop next September in Perth.

We have some of the world's top experts here. John Virtue and Richard Groves from Australia are co-editors of the 2001 volume *Weed Risk Assessment*. Belinda Riddle works for Biosecurity Australia implementing their WRA system. Curt Daehler from the University of Hawai'i has done extensive work modifying the Australian system and using it on species in the Pacific. Alison Fox from the University of Florida works with others there to test the usefulness of the Australian system in their state. We also have Barney Caton from the USDA to talk about the US screening system, and Alan Whittemore from the National Arboretum to discuss the role of botanical gardens in WRA. Dorthea Zadig from the California Dept. of Food and Agriculture is centrally involved in efforts by the North American Plant Protection Organization to address WRA. Joe DiTomaso of the University of California, Davis, and John Randall of The Nature Conservancy, have been involved in WRA efforts here in California.

"Overview: The Critical Need for WRA"

John Randall, The Nature Conservancy

The seminal event was the meeting in Australia in 1999, the first international workshop on WRA. Out of it came the collection of papers in the book *Weed Risk Assessment*, edited by R.H. Groves, F.D. Panetta & J.G. Virtue, 2001. The second international workshop will be next fall, so this serves as a good warm-up for that.

The International Plant Protection Convention (IPPC) states that phytosanitary measures must be "technically justified," i.e. justified on the basis of conclusions reached by using an appropriate pest risk analysis or, where applicable, another comparable examination and evaluation of available scientific information. Otherwise measures can be deemed a barrier to trade.

Terminology is a little tricky. We're here to talk primarily about Risk Assessment, with is an assessment of the likelihood and consequence of an adverse event such as introduction of an invasive plant. Risk Management is the evaluation and recommendation of mitigation measures. Risk Analysis is the aggregate of these two, plus the communication about this process to the public and decision makers.

WRA consists of both pre-introduction (or pre-border, or screening) WRA and post-introduction (or post-border) WRA. Pre-introduction WRA asks whether a plant could become a weed if it were introduced, and how bad might it be. Post-introduction WRA asks how bad an established weed is. In general, pre-introduction WRA is done at the national level, while post-border WRA also happens at a more local level.

Systems vary by nation. For instance, the US system has a division between agricultural and natural resource analysis whereas Australia has more of a unified program.

This meeting focuses primarily on pre-introduction WRA. We also focus mostly on import screening, but export screening is also important.

One resource I'll mention, since The Nature Conservancy has been intimately involved in it, is the US list created by NatureServe based on their Invasive Species Assessment Protocol. Over 450 completed assessments are available at www.natureserve.org/explorer.

Q&A:

Athan: How does the precautionary principle fit in?

Randall: This is partly a political question of what people will accept. What will be more of a problem, false positives (where safe plants are misclassified as potentially invasive) or false negatives (where some invasive plants are misclassified as safe)?

Caton: Burden of proof in the US is to prove that it's bad. False positives are most problematic.

Q: Are states bound by international laws?

Caton: States can't prevent something from being introduced if it's already present and they aren't doing anything about it.

Q: What about export?

Caton: USDA has done export assessments for agricultural commodities

Q: How much science is there to back up USDA's assessments?

Caton: Everything on noxious weed list had an assessment. The question is more which ones are chosen to be assessed.

Science as the Foundation for WRA

"Weed Risk Analysis: Current Status and Future Developments"

John Virtue, South Australia Dept. of Water Land & Biodiversity Conservation

The presentation will cover (1) terms and definitions in WRA, (2) overview of 1st International Workshop on Weed Risk Assessment, February 1999, and (3) current and future developments and challenges in WRA

Weed risk assessment (WRA) is the application of models based on technical criteria to determine the relative weed threats posed by various plant species. Weeds are naturalized plant species that cause negative economic, environmental and/or social effects and hence warrant control. Risk is determined as a combination of the likelihood and consequences of an event. In WRA the event is introduction of a particular plant species; likelihood relates to the plant's 'invasiveness' (i.e. an index measure of likely rate of spread); and consequences relates to the species' 'impacts' (i.e. its negative effects) and 'potential distribution' (i.e. geographic areas at risk of invasion). Applying the Australian/New Zealand risk management standard (AS/NZS 4360:2004) to weeds, WRA is a step within the overarching process of what we term "weed risk management" or WRM. Note that there are differences in the definitions of risk terms between those applied to international plant quarantine (IPPC 1996) and those being commonly applied in risk management (AS/NZS 4360:2004). For us, WRM is equivalent to what the IPPC calls Risk Analysis. Note that pre-introduction and post-introduction WRA will also be termed "predictive" and "prioritizing" WRA.

WRA systems are based on a series of technical questions, grouped into key criteria (e.g. invasiveness, impacts, potential distribution). The questions can be answered through yes/no or multiple choice, or can be scored. A final score or ranking allows comparison. There are various structures, including scoring systems, decision trees and process-based models.

The 1st International Weed Risk Assessment Workshop was convened in Adelaide, Australia, in February 1999. We met for a three-day workshop with 65 delegates from 8 countries. The workshop established a network of WRA experts, a community which is represented at this current workshop.

The meeting examined two key uses of WRA – the prediction of potential weediness, applied for example at the quarantine border, and the prioritization of weeds for management, applied for example in planning a state's noxious weeds management program. Workshop discussion notes are available at www.hear.org/iwraw/index.html and the formal proceedings of the meeting were published as the book *Weed Risk Assessment* (Groves *et al*. 2001). By 1999 there had been key advances in predictive plant traits for invasiveness (e.g., Rejmanek 2001), particularly relating to reproduction. Weed history remained the key predictor of potential weediness (e.g., Reichard and Hamilton 1997), but propagule pressure was also important in the likelihood of naturalization (e.g., Mulvaney 2001). Climate-based models of weed distribution were being applied in WRA (Kriticos and Randall 2001). The Workshop introduced the "Weed Risk Assessment System" (Pheloung 2001), hereafter the "Pheloung System," to a wider international audience and showed its application for a permitted list approach to plant species imports (Walton 2001). There was also a strong focus on the use of WRA to prioritize weeds for control programs, with national and ecosystem approaches presented (e.g., Virtue *et al*. 2001, Randall *et al*. 2001).

The 1st IWRA Workshop catalyzed a significant expansion in the development and use of WRA systems, particularly in Australia. Besides enabling a consistent and transparent process, WRA has focused peoples' thinking on the vast number of weed threats in existence and the need for a coordinated, strategic and preventative approach. Australia, New Zealand and South Africa have been the strongest proponents of WRA, but the USA also has a history of WRA (e.g., Hiebert 1997) and there has been much recent activity in developing predictive WRA systems and understanding weed invasions (see these proceedings). Future issues raised at the Workshop for the development and implementation of predictive and prioritizing WRA were presented in Panetta *et al*. (2001) and progress against these issues have been made.

The Workshop raised important issues in the field. Among them were:

- Need for core WRA criteria
- Need for a universal database for WRA
- Advancing predictions of invasiveness
- Predicting high impact weeds
- Post-entry evaluation of weed risk
- Taking account of global change
- Dealing with uncertainties
- Benefit/cost analysis vs. WRA
- Generic vs. specific approaches
- Taking account of the base-rate of weediness in plant populations

The 1st IWRA Workshop called for core, internationally-agreed-upon criteria for WRA to enable common approaches and data sharing. For predictive WRA there has since been further testing of two key systems, the MS Excel-based Australian Pheloung System (Pheloung 2001) and the decision tree for woody invaders in North America (Reichard and Hamilton 1997). The Pheloung System has been shown to be adaptable to New Zealand (Pheloung *et al*. 1999), Hawaii (Daehler and Carino 2000) and Central Europe (Krivanek and Pysek 2006) and is also being examined in other parts of the USA, Japan and Scotland. The performance of the Pheloung System has averaged at around 90% sensitivity (% of true weeds predicted) and 62% specificity (% of true non-weeds predicted). This poorer performance for non-weeds is exacerbated by the base-rate effect, whereby the low prevalence of weed incidence in the general plant population (around 10% in Australia) can mean a high incidence of false-positives (i.e. true non-weeds predicted to be weeds). Another problem of the Pheloung System has been the significant proportion of species assessed as 'further evaluate', for which there is no agreed methodology on how to resolve this.

Experimental post-entry evaluation of weed risk needs to consider not just what plant attributes to measure and what methods to use, but how this can be achieved under suitable quarantine conditions. Alternatively (and as a considerably cheaper option than experimentation), Daehler *et al*. (2004) developed a 2nd-stage decision tree that substantially reduced the final number of 'further evaluates' in Hawaii and has shown considerable promise in other regions (see these proceedings, Krivanek and Pysek 2006). A key advantage of the decision tree approach of Reichard and Hamilton (1997) is the relatively few criteria needed to make a decision. There is work to see if the number of questions in the Pheloung System can be reduced. Williams shortened it to 14 questions for FAO (2005). Caley and Kuhnert (2006) applied a classification tree analysis to the original training dataset and concluded they could use just 4 key questions: (1) evidence of naturalisation beyond native range, (2) documented repeated introduction outside natural range, (3) level of domestication, and (4) ability for unintentional human dispersal. A classification tree analysis by Weber (in prep.) for a long-term Biosecurity Australia dataset has again highlighted a short list of key questions: (1) unintentional human dispersal, (2) existence of congeneric weeds, (3) history of being a weed elsewhere, (4) tolerates or benefits from mutilation, cultivation or fire, and (5) reproduction by vegetative propagation. Fox has also been investigating reducing the number of questions.

Given the experience with predictive WRA in many world regions it is apparent that a common international model of core criteria could be developed. For future development of predictive WRA, some questions are:

- Is the Pheloung System the basis for an international border WRA system?
- Can the number of questions in the Pheloung System be shortened?
- Is the scoring approach optimized?
- Should a decision tree be considered instead?
- Should there be separate likelihood and consequence scores?
- Should the system give a probability of weediness rather than a score?
- Is the decision tree approach of Daehler *et al*. (2004) broadly applicable to 'further evaluate' species?

For prioritizing WRA there have been many systems at national, state and land use/ecosystem scales developed for a wide range of uses (see Appendix A in anon. 2006). Concern about a proliferation of such systems in Australia led to the development of a national protocol for post-border weed risk management (anon. 2006). Whilst not prescribing a new WRA system, the protocol seeks to have a common approach, language and criteria in prioritizing weeds. It addresses both weed risk and feasibility of control as the two components needing consideration in determining weed species priorities for strategic management. A simplified version of the protocol has also been prepared for developing countries (FAO 2006).

In 1999 the Workshop delegates sought a universal database of WRAs and weed information, but this has not yet eventuated. Answering the core criterion of "weediness elsewhere" has been substantially aided by the online publication of *A Global Compendium of Weeds* (Randall 2002) at www.hear.org/gcw. The environmental weed risk information on the USA's NatureServe (www.natureserve.org/explorer/) is a good example of how WRAs can be shared online. In addition, there are the Global Invasive Species Database (www.issg.org/database/welcome/), and Ecoport (www.ecoport.org). The question remains—should there be an international website of border and/or post-border WRAs, and a centralized database of potential distributions of weed species?

On the topic of predicting high impact weeds, this is still a key area for research, especially for deciding whether to respond to 'sleeper weeds'. There have been 4 research projects in Australia: on sub-tropical weeds (Hastwell), on herbaceous plants of sub-tropical woodlands (McIntyre), on aquatic plants (Vivonne Smith), and on legumes in temperate natural ecosystems (Emms). Emms' work suggests that high impact species have greater seedling establishment rates in undisturbed natural ecosystems.

Dealing with uncertainties is an ongoing challenge in WRA. Burgman (2005) lists nine sources of uncertainty in risk analysis, relating to incomplete knowledge (e.g., errors in scientific measurements, inaccuracies in models, subjective judgments when faced with limited data) and to language and communication (e.g., vague definitions, generality in data sources). The post-border WRM protocol (anon. 2006) is meant to address some of these for prioritizing WRA. For predictive WRA, models which present weed risk in terms of a probability with confidence intervals are useful (e.g. Caley *et al.* 2006). Robertson *et al.* (2003) had an uncertainty score to accompany their weed risk prioritization score. Global change is a major source of uncertainty which needs to be taken account of in WRA, including the effects of dramatic changes in CO_2 levels, climate, nitrogen and trade (Mooney *et al.* 2006).

The continued development and application of WRA as a discipline needs to involve close collaboration between weed science and policy. Input from economists in terms of benefit:cost analysis (BCA) and ecological valuation is also important, as are interactions with other fields of risk management to apply their techniques to weeds. BCA gives a framework to resolve conflicts of interest (e.g. for a species introduction, the cost of it as a weed versus its use as a commercial crop). Craig Walton in Queensland, Australia has a prioritizing WRA that assesses benefits and costs of a species in which economic, environmental, and social factors are weighted 40:40:20.

Summing up, WRA is a rapidly evolving discipline and needs continued interaction between science and policy. WRA fits into the wider context of WRM (Australian definition), both of which should aim to enable rapid, logical, transparent and consultative decision-making. Jurisdictions should invest in WRA in proportion to the context and resources available (just as is done for actual weed management). There are significant efficiencies to be gained in sharing WRA systems and databases.

Q&A:

Gluesenkamp: Other fields have balanced Type I and Type II error. Is it more important to catch all weeds, or to allow economic benefits from imports that aren't weeds?

Virtue: Again, this is a policy decision that depends on the context.

Schoenig: It sounds like the best predictor of weediness is that it's already a weed somewhere else. Does this mean that over the long term, weeds have to go everywhere to be recognized by other regions?

Virtue: Hopefully not. The WRA screens can catch potential invaders based on their biological characteristics, even if they have not been invasive elsewhere. But "weediness elsewhere" remains the logical first question.

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"Impact Assessment and WRA: An Example from SE Australia"

Richard Groves, CSIRO Plant Industry

Bridal Creeper (*Asparagus asparagoides*) was popular as an ornamental for bridal bouquets, but then fell out of favor. Now, decades later, it takes over Australian bush in New South Wales. It threatens remaining habitat of the rare plant *Pimelea spicata*, which occurs in suburban fragments surrounding Sydney, especially vulnerable isolated habitats. A biocontrol has been introduced (rust, *Puccinia myrsiphylli*, specific to bridal creeper). The large tuber mat of bridal creeper means rust must work for several years. The hope is that it will result in species recovery. Data so far is inconclusive, because drought is another major factor, but glasshouse studies suggest the *Pimelea* should recover as the *Asparagus* dies back.

The direct impacts of a major weed like this are simply competitive exclusion. There are also indirect impacts on ecosystem properties, and other trophic levels. Weed impacts on native plant diversity are rarely quantified and only a few examples are available – even for Weeds of National Significance in Australia. The indirect impacts of weeds on biodiversity are greatly in need of research attention.

Q&A:

Johnson: Are there any calculations of dollar values of threat of weeds?

Groves: CRC hired economists to calculate figures, but not sure of their accuracy, mostly focused on agriculture. Jack Singer, University of New England, has a scotch broom cost:benefit analysis

Bossard: How much of reduction in creeper was due to drought rather than rust?

Groves: Have estimates of effect of rust with and without drought.

Klinger: Higher trophic levels sometimes benefit, for example the wildlife on Santa Cruz Island when fennel was removed.

Comment: Need to examine positive effects to wildlife as well to make a complete cost:benefit analysis. Being comprehensive helps convince partners that you're playing fair and respecting all angles.

Schoenig: Genetic diversity is important to conserve, and it seems like there are few if any studies on fragmentation of genetic richness of rare plants being reduced by weeds. Reduction in genetic diversity could leave plants less able to respond to and survive global warming.

Groves: Someone in Canberra is looking at this related to eucalypts.

Gluesenkamp: There's the native *Spartina foliosa* in danger of going extinct due to hybridization with exotic *S. alterniflora* in San Francisco Bay.

Kelch: *Xanthium* is now homogeneous, used to be more diverse.

"What Attributes Make Some Plants More Invasive and Some Habitats More Susceptible to Invasion?"

Marcel Rejmánek, University of California, Davis

Key questions for this subject are: (1) what makes some species more invasive than others? (2) what determines the rate of invasions in a particular plant community? and (3) what is the impact of plant invaders?

The first thing we do is extrapolate based on previously documented invasions, using resources such as Randall's *Global Compendium* and Weber's *Invasive Plant Species of the World*. However, E. Rapoport (1992) estimated that at least 10% of the earth's 260,000 vascular plant species are potential invaders. Given how many have currently been identified, we still have about 85 % of them (22,000) that have yet to be recognized as such. Williams, Nicol, and Newfield (2001) reported that 20% of alien weedy species collected in New Zealand for the first time in the second half of the twentieth century had never been previously reported as invasive outside New Zealand. So we can't just go on reports of weediness elsewhere, or we will miss all the new invaders.

This is where attributes of invasive species come in. I have worked on the genus *Pinus*, which has been very useful. Invasive pine species are reported as spreading from at least two continents, while non-invasive pine species: cultivated on at least three continents, but never reported as naturalized. What's the difference?

Analysis led us to three factors: juvenile period, seed mass, and interval between large seed crops. Invasiveness is aided by shorter juvenile periods, smaller seeds (more dispersal, more seeds), and shorter intervals between large seed crops. (Interestingly, we also saw a perfect example of the continuum between K species and r species.) Deriving a Z function from these three factors provides us with a predictive formula for *Pinus* species (Rejmánek & Richardson 1996).

Through principal component analysis, we determined which factors were most influential (Grotkopp, Rejmánek & Rost, 2002). The Z function can be used on other woody species to determine weediness. For instance, invasive tree-of-heaven (*Ailanthus altissima*) and *Tecoma stans* have $Z>0$, while non-invasive horse chestnut (*Aesculus hippocastanum*) and bunya-bunya (*Araucaria bidwillii*) have $Z<0$. Then you have instances where a plant with $Z<0$, such as Italian stone pine (*Pinus* *pinea*) becomes invasive when a seed disperser like the Gray squirrel (*Sciurus carolinensis*) is introduced.

We have condensed these studies to come up with a simple set of tentative rules for determining which woody species will become invasive (Gurevich, Scheiner, Fox 2002). For species with Z<0, they will only be potentially invasive where seeds are dispersed by water or where there is a vertebrate disperser present. For species with Z>0, they are likely to be invasive when they have dry fruits, and seed mass exceeds 2mg; when they have smaller seeds but are found near water; or when they have fleshy fruits and vertebrate dispersers are present.

Studying alien *Crotalaria* species in Taiwan, we determined that residence time matters, and fecundity matters (Wu *et al*. 2005; see also Cadotte *et al*. 2006). Shade tolerance can also be a competitive advantage for an invasive species, such as Chinese tallow (*Triadica sebifera*). For aquatic weeds, vegetative reproduction is the most important attribute.

Opuntia species provided another useful study. Why are such a high proportion of species in the Opuntioideae invasive relative to the proportion for the closely related Cactoideae? Some key differences appear to be: vigorous vegetative reproduction, relatively fast growth rate, relatively high allocation of resources to sexual reproduction, common polyploidy, common hybridization, and a large phenotypic plasticity. Interestingly, it appears that invasiveness could be a mirror of rareness. In this case, there is a much higher proportion of species in the Cactoideae that are rare than in the Opuntioideae.

We are currently working on measuring the survival and growth rate of invasive vs. non/less-invasive angiosperm woody congeners.

Now looking at what makes a habitat more vulnerable to invasion. One can see a distinct latitudinal gradient of naturalized plant species richness along the Pacific coast of Americas (Rejmánek *et al*. 2005a). California is quite high.

We look at many factors, for instance: species diversity of residents, actual amount of available resources, propagule input of exotic taxa, and disturbance. One can also see that some families are more heavily represented in particular ecosystems than are other families. In closed canopy tropical forests, for instance, the Miconieae, Myrtoideae, and Fuschia are overrepresented, so the very identity of a species can be considered a factor.

Propagule input can be resisted by both abiotic and biotic factors. Abiotic factors can actually shut off propagule survival entirely, while biotic factors tend to only reduce pressure. Thus, high propagule pressure can overcome biotic resistance (D'Antonio *et al*. 2001). We have seen that the invasiveness of Eucalyptus species in South Africa relates positively to the number of plantations established (Rejmánek *et al*. 2005b). Also see Krivánek *et al* (2006) on planting history and propagule pressure as predictors of invasion by woody species in a temperate region. Propagule pressure relative to density of plantings, as measured by "seed rain index," was found to correlate strongly with the number of new seedlings in fynbos habitats, especially wet ones.

Lastly, on impacts, we must be careful about not overstating what we know. Certainly, in some cases, such as that of the brown tree snake in Guam, the impacts are apparent and severe. However, in others, it is easy to misstate matters. European beach grass (*Ammophila arenaria*) is blamed for altering the structure of dunes along the California coast. It would be easy to blame it for the demise of a dune wildflower, *Erysimum menziesii*, but in fact this is not the case. Several studies that do document impacts are Lugo (2004) on the outcome of alien tree invasions in Puerto Rico, and Brown *et al*. (2006) on the effects of an invasive tree on community structure and diversity in a tropical forest in Puerto Rico.

We should especially pay attention to keystone invaders, such as feral pigs here in California, since they open the door for other invasions.

Q&A:

Kelch: *Myrtales* shows up as highly invasive, but it's also horticulturally very popular, which contributes to propagule pressure.

Rejmanek: Yes, this makes it hard to separate propagule pressure from biological characteristics.

Holloran: Why is extinction the gold standard for impacts, rather than abundance, etc.? We seem to suffer from criticism that "weeds haven't caused any extinctions."

Rejmanek: It's true, we need better data on effects on populations. If we use the wrong arguments, our credibility is harmed.

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“’Sleeper weeds’: An Evolving Concept”

Richard Groves, CSIRO Plant Industry

When I first began speaking on this topic in 1999, I defined sleeper weeds as those invasive plants that have naturalized but whose rate of population increase is still low. This assumes that at some point in the future they enter a much more rapid phase of population growth. It has always been apparent that this is the most cost-effective time to address an incipient weed population.

More recently, I made an attempt to define sleeper weeds a bit more quantitatively as “a sub-group of invasive plant species for which population sizes are known to have increased significantly more than 50 years after they became naturalized.” In addition, the factors that may ‘awaken’ sleeper weeds are poorly understood, but the predictability of a species ‘awakening’ is greater, however, if that species is known to be invasive in another region and if its invasion history is both well-recorded and well-understood ecologically.

Caley *et al*. (in prep.) have analyzed data sets from Kloot (1986) for naturalized species in South Australia. They show that the first reports of naturalization vary by the type of plant—annual, herbaceous perennial, and woody species—with the length of time from introduction growing longer for each.

So today, perhaps I would offer yet another, newer definition modified to account for this variation: “the lag phase between naturalization and increase in weediness for sleeper weeds will depend on life cycle: c. 10-15 years (?) for an annual, c. 50 years (?) for an herbaceous perennial and c. 50-100+ years (?) for a woody perennial.” But even these time frames may be too short—witness the Brandenburg flora (Kowarik 1995).

As a case study, consider *Fallopia japonica* in Britain. Child & Wade (1999) show two lag phases—the first, between introduction and reported naturalization (c. 30 years), and the second, between reported naturalization and rapid expansion as an invasive plant (c. 50 years). Two other examples are *Hieracium pilosella* in New Zealand and *Senecio squalidus* in Britain.

In terms of remaining problems, we need greater understanding of:

- genetics (e.g. *Onopordum* spp. in southeastern Australia (& France?) and *Senecio* spp. in Britain)
- environmental suitability (e.g. *Mimosa pigra* within Northern Territory, Australia)
- anthropogenic disturbance (e.g. *Dipsacus laciniatus* along US highways? (Crooks & Soule 1996))
- with-in species variability (e.g. *Lythrum salicaria* in Usversus elsewhere)
- biological attributes of species pairs—one ‘sleeping’ and the other already invasive (examples from southeastern Australia)
- mathematical models to determine (prospectively) the point at which a population size begins to increase exponentially, especially when there are limited data

The question of “weediness elsewhere” used in WRA may be inadequate for evolving genotypes (e.g. *Senecio squalidus* in Britain and other such ‘new’ hybrids) and for some sleeper weeds (e.g. *Bromus inermis* in SE Australia - and New Zealand?).

In summary, the concept of ‘sleeper weeds’ is intuitively attractive but in need of further definition and criticism. There are a few well-documented instances that seem to meet the present (but still evolving) definition. A number of problems remain to be overcome before the concept can gain wide recognition. The usefulness of the concept for WRA (cf. funding agencies) remains unclear.

Q&A:

Fox: Arundo has not been invasive in Florida to date, but it's being proposed for massive biofuels planting. Might it be a sleeper there? It might be helpful if those in California could describe its habitat requirements accurately enough so that Floridians can determine if it's just not found suitable habitat there yet.

Randall: What about the issue of soil type and soil biota? We don't find arundo here in some watersheds north of here in California where one would expect it, and I suspect soils might be the answer.

Kelch: Taxonomy of soil biota very limited.

Discussion: What Research is Needed to Support WRA?

Moderator: Rick Roush, University of California, Integrated Pest Management Program

Johnson: We've heard about impacts, characteristics (plant and habitat), and lag phase. Do any areas stand out as having particularly pressing research needs?

Gluesenkamp: Scale is important—what needs study at the federal level will be different than what we need at the local land management level.

Roush: As a rough approximation, weeds get much less research funding than biocontrols, which in turn gets much less than GMOs. Does this really reflect the true risks?

Klinger: Research needs (and approaches for that matter) for WRA's will vary depending on whether you are working at a national, regional, state, or local scales. For instance, the variables for predictive models vary depending on your the scale you're focusing on.

Deehler: GMO and biocontrol tests require experimental protocols, but introduction of other plants don't. There's no demand for it.

Groves: The development of an herbicide is similar to GMOs in terms of data collected.

Caton: The potential for public outcry and the occasional failure of old biocontrols drove development of protocols.

DiTomaso: It would be useful to have experimental protocol for testing plants.

Athan: Probabilistic risk assessment is more expensive than current deterministic analysis, and it would be useful to know if using probabilistic methods is worth the effort. The potential benefit of a probabilistic system comes for reducing the number of plants in the middle, the "evaluate further" category. That's where we need experiments.

Randall: Needs at state and federal level are different. In California, post-introduction WRA may be most important, since there's a strong need to prioritize management efforts. At the federal level, there's the opportunity for improvement to the pre-introduction protocol.

Kempton: Screening info is definitely helpful for working with the nursery industry. Nurseries can avoid plants that won't make it through, and move onto another cultivar. Much better than being told to stop planting something after they've spent a lot of money developing a cultivar.

Zadig: It's difficult to remove any plant that is already in the trade.

Roush: Could US move to a white list approach?

Zadig: Clean list approach is unlikely with US nursery partners. New horticultural introductions are to large extent not monitored at this point, and it's a long way from there to a clean list.

DiTomaso: Is there testing that can be done immediately when a new weed is found, that will help assess risk?

Kempton: In our work with the nurseries, we're finding the need to know more about how cultivars of known invasives will behave.

Roush: Yes, need to be careful—new cultivars can allow genetic diversity or sexual reproduction where not present before, allowing spread.

Fox: The onus should be on the cultivar developer to prove it's safe.

Randall: In large regions (like US), it may not be necessary to include habitat suitability, because there are so many habitat types that one can assume there is something suitable. On a local scale, though, habitat type becomes more important. For pre-introduction screening, the federal level is the key. It seems crucial to have a database of ecological information gained through WRAs.

Gluesenkamp: We have the tools—the problem is that we don't have the incentives in place to put the tools to work.

Holloran: Requiring industry to do assessments is a social science question. In New Zealand plants are brought in illegally and mislabeled because companies refuse to pay for it. Compliance is better when they feel their economic interests are addressed.

Klinger: California could benefit greatly from a database of information that already exists for these species. It would be a waste to go through reinventing that wheel.

Virtue: I was concerned about the data availability of some of the factors in Marcel's talk, such as intervals between large seed crops, and wonder if those can be documented more so that we have data to use.

Fox: There is a balance between the total number of questions in a system, and whether you have leeway to not answer some questions. The fewer questions you have total, the less likely you are to have the option of leaving some unanswered. Better to have many questions but allow a "don't know" answer. You can narrow it down more when looking at limited taxonomic group.

Caton: The set of questions is getting more standardized.

Daehler: Plants are weeds for different reasons, so it's good to have a wide range of questions.

Techniques for WRA: Successes, Challenges, and Knowledge Gap

"The Mechanics of WRA in Australia"

Belinda Riddle, Biosecurity Australia

Following a review of quarantine in 1996, the Australian Quarantine and Inspection Service (AQIS) replaced the "Prohibited (black) List" with a "Permitted (white) List" approach. Following the adoption of the "Permitted List", a method was required to determine the potential weediness of "new" plant species proposed for importation. AQIS (now Biosecurity Australia) adopted the Weed Risk Assessment (WRA) system to assess the weed potential of a plant proposed for importation. The changes to plant importation policies necessary to implement this system have received widespread approval. Biosecurity Australia continues to re-evaluate and review the use of the system.

Biosecurity Australia's weed risk assessment has three tiers. The first tier determines whether a plant is already present and traded or naturalised in Australia, under official control or on a list of permitted plant imports. Plants that are not already present or permitted proceed to the second tier. The second tier is the WRA, based on the Pheloung model (Pheloung, 1995; Walton *et al*, 1998) and consists of a questionnaire which evaluates the weed risk of plants using 49 questions about the plants' biology, climatic preferences, reproductive and dispersal methods, and known weed history. The questionnaire is designed to identify weeds of the environment and agricultural systems. Scores range from -14 (most safe) to +29 (most weedy). The outcome of the WRA for a plant proposed for importation is *Accepted*, *Rejected* or prohibited pending *Further Evaluation*.

The questionnaire was calibrated using species already present in Australia. With this calibration the WRA system accepted no serious weeds, only 16% of the minor weeds, and *Rejected* 7% of the non-weeds. Twenty-nine percent of the species required *Further Evaluation* (Pheloung, 1996).

The third tier is required when the WRA returns a *Further Evaluate* outcome for a species assessment. This usually occurs when insufficient information is available to achieve an *Accept* or *Reject* outcome. It is intended that the third tier will allow for glasshouse trials to gather additional information not present in the literature that may affect the WRA outcome.

The cost of the weed risk assessment (second tier) is currently borne by the Government, not the importer. The costs of gathering information under the third tier setup for a species would, however, be borne by the importer.

Q&A:

Johnson: Is there a database from the Australian assessments for 2800 species, with answers to all 49 questions?

Riddle: It's in an Access database, in some cases, complemented with Word documents that contain information and justification for responses to WRA questions. Biosecurity Australia is happy to answer any queries regarding assessments. The system is designed for intentional introductions rather than contaminants.

Roush: What if something is misidentified? Are specimens examined?

Riddle: Yes, it's important to identify a plant to make sure it's labeled properly.

Johnson: Can you briefly describe the structure of the list of 49 questions?

Riddle: It takes one to two days for assessment but total assessment time averages a couple of months (to gather information, etc.). Generally, for each question, a plant gets +1 for a weedy attribute, -1 for non-weedy. Does give some allowance for species that are highly domesticated, and a matrix to account for climate and weediness elsewhere. An aquatic plant automatically starts out at +5 to account for type of plant.

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"The Mechanics of (Federal) Weed Risk Assessments in the United States"

Barney Caton, Center for Plant Health Science and Technology, USDA-APHIS-PPQ

[Note: for information on the organizational structure of USDA-APHIS-PPQ, please refer to the organizational chart at www.aphis.usda.gov/ppq/orgcharts/. Within Plant Health Programs, PERAL risk assessments typically go to PIM (Phytosanitary Issues Management) for decision-making and implementation. Plants for Planting issues are managed by CIAO (Commodity Import Analysis and Operations). Information about CPHST is available at http://cphst.aphis.usda.gov/.]

My objectives are to explain the four different kinds of weed risk assessments (WRAs) done by PERAL (Plant Epidemiology and Risk Analyst Laboratory), the risk analysis group at USDA-APHIS, focusing upon WRAs for species that may be listed as Federal Noxious Weeds. The first three types of WRAs done in PERAL are (1) screening commodities that may be imported for consumption for potential weediness, (2) New Pest Advisory Group (NPAG) evaluations of the weediness potential of recently discovered or established species, and (3) upcoming evaluations of taxa for possible designation as "Not Allowed Pending Pest Risk Assessment" (NAPPRA).

The commodity weediness screening determines if a full WRA is needed for a species. This is only required if it meets the International Plant Protection Convention (IPPC) definition of a 'quarantine pest', which is a pest that (a) can cause economic damage, and (b) is not widely present, or is present but not widely and is under official control, i.e. being contained or eradicated. The NAPPRA evaluation is based on the same definition. The NPAG evaluation is similar but also includes relevant ecological information, and the goal is to make a policy recommendation, such as, "not likely to be invasive/weedy," or "do a full WRA to consider listing the species as a Federal Noxious Weed."

Full WRAs are done to determine whether or not species are candidates for listing as Federal Noxious Weeds. The methodology used is meant to be accurate, repeatable, qualitative, and transparent. The current Federal WRA guidelines, version 5.3, may be found at http://www.aphis.usda.gov/ppq/weeds. The ratings given in different categories are Low, Moderate, and High, and in each case both the rationale for and the certainty in that rating are also given. Each step is documented as completely as possible. The two stages of the WRA process completed in PERAL are initiation and assessment. Initiation consists of documenting the reason for the assessment and establishing the identity or identities of the species considered. The assessment stage consists of the following four steps: (a) verify the species is a quarantine pest,(b) evaluate the consequences of introduction (i.e., damage potential), (c) evaluate the likelihood of introduction, and (d) determine the overall risk potential. The following four factors are evaluated for the consequences of introduction: habitat suitability, reproductive and spread potential, economic impact, and environmental impact. Factors evaluated under the likelihood of introduction include the species prevalence at origin, if it is a potential contaminant, if it is likely to survive treatment and shipment, the difficulty of detection, the likely propagule pressure (e.g., number of shipments), seasonality issues, its potential distribution in the United States, and the intended use.

A full WRA is completed for all species being considered for listing. For candidate species—those with ratings of at least Moderately-High risk—the process of listing is completed by creating and publishing a proposed rule, evaluating and responding to public comments on the WRA and the rule, and then revising (if necessary) and publishing the final rule. For each step here we showed the outcomes from a recently completed WRA on the species *Senecio inaequidens* and *S. madagascariensis*, which were listed as Federal Noxious Weeds in a final rule published on June 14, 2006.

Lastly, species are prioritized for WRAs based on needs expressed by PPQ, primarily because of the importance of the species/situation being considered. For example, *Caulerpa* spp. were prioritized highly because they posed a great threat. Species ranked highly in our prioritization model, developed by Chris Parker, will also rise in priority.

Q&A:

Virtue: Is every weed that's a state noxious weed automatically on the national list?

Caton: No, USDA only has jurisdiction for plants that match the quarantine pest definition at the Federal level.

Kelch: Has process been applied to long-term pests to test predictive value, similar to Australia?

Caton: We only do assessments when requested, so there may be too few completed Federal WRAs for that type of comparison, especially WRAs in which the overall risk rating was Moderate or lower. Most candidates for listing are already fairly well known as pests.

"WRA Efforts in Hawai'I"

Curt Daehler, University of Hawai'i, Manoa

Most invasive pests plants iIn Hawai‘i's natural areas were deliberately introduced for forestry, horticulture, fiber or food. More than 8,000 plant species have been introduced to the Hawaiian Islands and new species are being imported each year with little consideration for their potential invasiveness. To address this problem, efforts to develop a Hawai‘i weed risk assessment (H-WRA) system were initiated in 1998.

The H-WRA is a modified version of the Australian WRA. Some questions were modified to address local conditions and concerns, and a second screening was added to reduce the number of outcomes in the "evaluate further" category (Daehler *et al*. 2004). The system was tested by evaluating plant species found on planting lists for Hawai‘i, and comparing H-WRA predictions with assessments of actual plant behavior made by field experts who were asked to classify plants as major weeds, minor weeds, and non-weeds. The H-WRA correctly identified 95% of major pests; it also correctly identified 85% of non-pests.

A number of industry groups have subscribed to voluntary screening of plant introductions using H-WRA. The state of Hawai‘i has hired a plant screener on a temporary basis to assist with assessing proposed introductions. Over 600 species have been assessed. Assessments are focusing on species suggested by the horticulture industry and by invasive plant councils.

To evaluate risks among species already introduced to Hawai‘i, the Hawai‘i Exotic Plant Evaluation Protocol (HEPEP) was developed by combining H-WRA with information on how widely the species has been planted, how long it has been planted, whether it has naturalized, and whether it currently has significant economic, ecological or quality of life impacts. The HEPEP evaluation provides clear and verifiable information on the impacts of introduced plants, allowing us to objectively designate plants as invasive. The HEPEP information can also feed into the State Noxious Weed listing process, potentially resulting in legal restrictions on growing the invasive plants.

To use the WRA system well, it is important to delve into your information sources. Since ‘weediness elsewhere’ is such a big deal in the scoring, you need to make sure that your sources are really telling you that it is a weed elsewhere. For instance, some books on "weeds" list native plants, adventives, plants that do not have proper aesthic value, etc. In our system, we only consider a plant a weed if it is non-native and has clear impacts (economic, ecological, and/or quality of life). Because there are different definitions of "weeds", we need to conduct quality control on the information sources our WRA are based on.

When using Holm's *Geographical Atlas of World Weeds* (1977), we consider "serious" and "principal" weeds, but not "common" weeds. We only use Randall's Compendium for identifying references, not as evidence that a plant is a weed elsewhere. Even though we as weed scientists might accept false positives, industry will not, and it will hurt the acceptance of the WRA system.

References

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"WRA Efforts in Florida"

Alison Fox, University of Florida

In presenting our efforts on WRA in Florida, I'll describe what we have done differently and highlight issues for further discussion.

We chose to test the Australian WRA in Florida. We had completed a "Status Assessment" that was supported by industry, and testing a predictive system was the logical next step supported by industry and agencies. We received funding from the Florida Dept Agriculture, the Florida Dept. of Environmental Protection, and USDA-APHIS. After reviewing the systems in use, we decided that the Australian WRA was likely the best option.

We set as our targets to: correctly reject > 80% of invaders; correctly accept > 60% of non-invaders; and only have to evaluate further < 15 % of all species.

In our test, we reviewed a set of species (124 species in < 1 year), excluding species used in model development, and countingd a naturalized species as a non-invader if it has been in Florida > 50 years. We adapted four site-specific questions for Florida, and included the Hawaiian secondary screen. We included an equal mix of weeds of natural areas and agriculture.

We did some things differently from other tests of WRA systems. For one, the geographic scope of data sources—we experimented using evidence of "weediness elsewhere" from adjacent states, as well as from the entire US. Second, we tried to balance the data set by having plants from the same Families, life-forms, and life-history equally represented. We looked to see if we could effectively use a reduced set of questions, such as Caley & Kuhnert (2006). And we use a "blind" assessor, a zoologist familiar with invasiveness but not with plants, to answer questions based on data. This kept out the bias inherent in someone who knows the plants well. We scrutinized definitions to see what difference it would make whether we demanded that there be direct evidence for a factor (say, dispersed by water) or merely very suggestive evidence (e.g., propagules are buoyant). And finally, we required there to be independent criteria for pre-categorizing natural area invaders on a continuum of non-invaders to invaders.

There were some things we did not do. Our data set did not reflect the true (low) prevalence of invaders (the base-rate). We did not include aquatic plants.

Here are our results. The secondary screen helped—we were left with only 10% in the "evaluate further" category. The system worked for both natural area and agricultural weeds. The geographic scope of data sources was not significant. The scores were not biased by phylogeny. We were able to answer an average of 33 of the 49 questions.

There were 12 question that we were able to answer for < 33% of the species. Scores were unaffected when we deleted these questions. We found that using the Caley & Kuhnert model we rejected 93% species, while only 50% were truly invasive. We also found that, statistically speaking, we did as well answering just the "invader elsewhere" question as we did the full 49 questions.

The system properly rejected 98% of the invasive plants in the test set, but it also rejected 57% of the non-invasive plants (false positives). The system accepted one invasive plant (false negative), and 43% of the non-invasive plants.

To further explore the issue with the high number of false positives, we went back to the classification of the invaders/non-invaders and broke the plants into 3 categories—minor invaders, major invaders, and non-invaders—where a naturalized plant was considered a minor invader. With this re-categorization, the WRA system correctly accepted 100% of non-invasive plants. We determined that our original status assessments had set a high bar for invasiveness based on ecological impact, and so many minor invaders had been initially categorized as non-invasive.

Comparing with other regions that have tested the Australian system, our results fit within an overall success rate of 96-100% of invaders rejected, 80-100% non-invaders accepted, and 70% of minor invaders rejected (except in Czech Republic case).

To summarize, our results were not significantly affected/biased by:

- Natural areas vs. agricultural weeds
- Geographic scope of source data
- Families, life-form, or life-history
- Removing rarely answered questions
- Making greater assumptions about what information is needed to answer questions – which simplifies completing the WRA

Out rest shows that targets for effectiveness can be met such that the Australian WRA could be used in Florida.

To highlight some recommendations from our work: There is a need for clearer scientific reporting to support answering the questions in the WRA. We need more rigor in defining questions and information that is acceptable for answers (for instance, distinguishing when "absence of evidence" results in "no" versus "unknown"). We also need to be clear in our reporting of WRA tests as to whether percentage results are based on the complete species dataset or if they exclude "evaluate further" species.

And we need to be clear how we are using our percentages to gauge performance. There are two ways to use the percentages: (1) what percent of the invasive species were rejected, and the non-invasive species accepted; and (2) what percentage of plants rejected are actually invasive, and what percentage of plants accepted are actually non-invasive.

Logical next steps are to:

- Come to agreement about suitable definitions for unbiased and consistent application of a national WRA test
- Come to agreement on what factors should be used to clearly define non-invader and invader categories
- Develop a national species dataset which can (1) equally represent families, etc, (2) reflect prevalence of invaders, and (3) lend itself to analysis with both two and three categories to allow comparison with previous tests.
- Have several groups assess different sets of species with overlap

"WRA Efforts in California"

Joe DiTomaso, University of California, Davis

Cal-IPC's "weed list" has long been used by land managers/owners, environmental consultants, Weed Management Area's, researchers, and legislators for understanding which plants are invasive in California's wildlands. The original list was developed in the early 1990s and update in 1999. In 2006, Cal-IPC came out with a greatly updated *California Invasive Plant Inventory*.

There was impetus to develop a new process for listing weeds. The existing list had become quasi-regulatory, finding its way into management plans, environmental compliance documents, etc. There were questions about the decision-making process for listing and categorizing invasive plants (basically the opinions of an expert committee) and the organization wanted a more structured approach that would be transparent and science-based. The Cal-IPC Board recognized the need for more clear and defensible justification for placing species on the list and ranking them within the list (i.e. a common set of criteria). We also wanted to develop a common system for use in neighboring states so that there would not be compatibility issues.

Together with representatives from Arizona and Nevada, Cal-IPC developed a new criteria system. It was decided that the criteria would not be used to evaluate economic impacts, consider management challenges and costs, evaluate predominantly agricultural weeds, or pre-screen species not yet introduced to a given state or region.

The system evaluates a plant based on 13 criteria in three areas:

- Ecological Impact (actual or potential effects on ecosystem processes, plant communities, higher tropic levels, and genetic integrity of native plants)
- Invasive Potential (potential to establish, spread, and develop self-sustaining populations in wildlands)
- Ecological Amplitude and Distribution (number and percentages of different ecological types invaded)

(The system also rated the level of documentation reliability.) The scores from each criteria question lead to a section score, and the section scores lead to the overall rating of High, Moderate, or Limited. Plants with High or Moderate ratings, and relatively low distribution were given an additional Alert rating to signify a plant that could spread rapidly.

Our process consists of identifying and prioritizing species to be evaluated, compiling documentation on the species (published and observational), assigning an outside reviewer familiar with the species and providing them with appropriate documentation, reviewing their work at a central committee meeting, and compile the final list based on the assessment.

The state's Dept. of Food and Agriculture rates plants with agricultural impacts, while the Cal-IPC *Inventory* focuses on weeds of natural areas. CDFA lists 141 species, while Cal-IPC lists 199. The lists overlap, listing 60 of the same species.

Q&A:

Groves: When will list be revised?

DiTomaso: We will accumulate data every year, and the review committee will meet annually.

Virtue: How has the list been used?

Johnson: Though we don't usually hear when it's been cited, we know that it has been used in consultants' reports, county plans, agency strategies, etc. In our nursery partnership it forms the scientific basis for supporting which plants are damaging.

DiTomaso: I would like to note that we often had trouble finding any information on abiotic impacts, and this was the highest ranked question, since these impacts make a weed a true landscape transformer. This is an area where we need research.

Discussion: How Can We Improve WRA?

Moderator: Alison Fox, University of Florida

Fox: Four areas that came up today. First, model selection – several have been presented today and there are others we haven't heard about today. How do we decide what model to use? Do they need to be tested head-to-head?

Athan: Let's include the possible development of new models

Fox: Second, nuts and bolts - you've picked a system, tested it, and decided it was appropriate, now how do you use it operationally?

Kempton: And what are the major data gaps.

Schoenig: We should have a database of plant attribute info generated by WRA. This would require quality control

Rejmanek: "Ecological floras" are becoming popular to publish.

Caton: USDA is working on a GPDD (Global Pest & Disease Database)

Fox: Lastly, there's the question of whether invasion is based on likelihood of establishment and spread or based on impacts? How important are impacts in part of predictive process?

Caton: Why is "6" the magic number in Pheloung system?

Groves: Statistical discussion led to this. The scale can be calibrated to accommodate your preferred type of error¾you can make your own decision of cutoff level.

Steinmaus: Why can't you go back to questions that contributed to "wrong" answer to figure out if system can be tweaked?

Daehler: This has been tried, but o pattern to "wrong" answers, weeds identified by WRA as invader when they weren't.

Rejmanek: What would happen if we run native species through WRA? This might provide a benchmark.

Riddle: Natives should rank high because they tolerate the soil and climate and are naturalized.

Schoenig: It seems like there is a strong focus on the single question of whether a plant "causes harmful impacts elsewhere." Doesn't this relegate us to only catching weeds after they've escaped elsewhere?

Riddle: The WRA does assess all sorts of characteristics that indicate weedy potential even if the plant has not become a weed anywhere. That's just a logical first question that serves as a shortcut.

Gluesenkamp: Seems logical to use a hierarchy of questions with simple questions first.

Athan: The use of CART, as in Caley's work, is useful for identifying which questions get you farthest. With a bigger data set, this could be further refined. Questions that don't help much get "pruned" from the bottom of the decision "tree".

DiTomaso: Having a climate match doesn't mean a plant will be naturalized. For instance, Melaleuca hasn't escaped in San Diego.

Johnson: Where is this all going globally? It seems like there are different systems¾Australian, USDA… Are we converging to common system? Do we need to?

Randall: It seems like the systems being tested and used are the Pheloung system. Rejmanek has discriminant matrices, and Reichard have decision trees, but these seem less universally useful.

Fox: Perhaps we don't need one-size-fits-all? Different systems might be useful in different circumstances. It seems we may have an inherent conflict between on the one hand the desire of researchers to tinker with the tools and get into a lot of detail and on the other hand the practicality of a simple, transparent system sooner rather than later.

Virtue: There are overlaps in systems, they are based on the same types of information largely. We do have capability to converge to a system. Decision trees haven't worked as well.

Johnson: How does the USDA system differ from the Australian system?

Caton: One primary difference is that we assess the likelihood of introduction (intentional or accidental), while other systems assume that somebody wants to import something.

Groves: The challenge is to bring system to developing countries where weed problems could be immense but they aren't doing anything about it.

Riddle: With the USDA system, some invaders would still be getting through. The system doesn't screen all imports like Australia's does.

Holloran: Look at pathways for potential invaders, i.e. pasture. Risk assessments are invariably value laden and subjective, and there is a lot of sociological literature on RA from other fields.

Virtue: We can improve on definitions and guidelines.

Riddle: I understand Rod Randall's "Global Compendium" is currently being updated.

Schoenig: GISP has a database component, and seems like a logical player for housing a database of assessment data. However, populating a database is much more expensive than creating one. Would it be possible to take some nasty weeds, eg. gorse, and figure out all the potential habitats globally and just recommend it be black listed from those areas?

Gluesenkamp: simple distribution data can be very useful for assessment.

Rejmanek: Is there a correlation between the rate of spread and impact? Sometimes.

Randall: It seems that mostly our modeling is based on likelihood of establishment, and there are very few studies that actually attempt to predict impact for plants. Work of Lonsdale on fish is one.

Rejmanek: Parker and Simberloff maybe. Relationship of cover to frequency. Probably would have to be habitat specific.

DiTomaso: We see a real lack of data on abiotic impacts. It seems like factors such as nitrogen fixing, salt accumulating, high silica content = litter accumulating, etc. should be central.

Fox: There's no correlation between impacts and WRA in Pheloung system because it doesn't predict impacts.

Athan: Actually it does, but the questions are not separated out.

Daehler: The problem is that testing numerical score vs. impact rating may not have a correlation, but you will see something when plotting impact vs Accept/Reject.

Rejmanek: It's very difficult to get impacts on diversity of native flora, and when you do it's not always what you would think. Few cases of impact are simple and transparent.

Fox: Is there a difference when a species functionally substitutes for a native species, i.e. substitutive role vs. transformer. We need to think about functional roles of invasive species.

DiTomaso: In comparisons of minor and major invasives, those categories are ambiguous. How about non-invasive, naturalized, moderate, major – see how these 4 groups tease out from system. Tease out a way to look back at questions now that you know what you're looking for.

Fox: Define how you call each category. Could keep subdividing middle categories but the question is what are your expectations for middle groups. Extremes are easy to see. Everyone has to agree to test with categories and define the decision making process.

Caton: As devil's advocate, it seems like lots of tests have been done and system seems to work. Why do we need to change or fine-tune? Is there pressure to reduce the number of false positives? External or internal pressure?

Virtue: Public attitude in Australia is to keep things out that could be weeds. They support us erring on the side of caution. Benefits of a new garden plant aren't worth the cost of controlling weeds. But there is some pressure from the pasture side.

Randall: We in the US may be called on to categorize more clearly and finely because our two societies are willing to accept different levels of false positives. US isn't going to accept false positives. More litigious here.

Holloran: Yes, this is where the values come in.

Athan: Another driver is the number of plants relegated to "needs further evaluation." What do we do to reduce that?

Fox: Secondary screens, like Hawaii's, are helping.

"Implementation of WRA Policy in Australia"

Belinda Riddle, Biosecurity Australia

Australian quarantine consists of Australian Quarantine and Inspection Service (AQIS) for international border control, and Biosecurity Australia (BA) for science-based quarantine assessments, WRA and import risk analysis, policy advice, technical advice and support, and international standards.

Before 1997 Australia had a black (prohibited) list, which incorporated only 66 individual species and 19 genera—therefore new weed species were still entering Australia. In 1996, this was reviewed in the Nairn report (Nairn 1996). The review committee recommended using a permitted list. This recommendation was formally adopted in 1998.

A permitted list was developed by surveying what was currently imported. The original list was developed with a large proportion of genus-level listings. The Pheloung WRA system was formally adopted in 1998 following public consultation, and the system was implemented for about $US 750,000 (including management, software and legislation of the permitted list). Currently, weeds cost Australian agriculture more than $US 3 billion annually (in weed control and loss of production).

As part of the implementation, a manual was written to describe the WRA system, a website was created, and a publicity campaign was undertaken to notify stakeholders.

The sources of weeds are many, including bulk consignments, accompanied baggage, and international mail. In the 2005/06 financial year, 7,267 seed consignments were seized, with the US being the top source.

The AQIS Import Conditions Database (ICON), found at www.aqis.gov.au/icon/ informs clients and staff of import requirements. Assessments are paid for by the National Government under its community service obligations.

The current listings on the permitted seeds list are by species, genus, or by genus with specific exclusions. Biosecurity Australia has recently undertaken a review of the permitted seeds list (Schedule 5 of the *Quarantine Proclamation 1998*). The aim of the review is to replace the current 2,913 genus-level listings with species, from within those genera, which are present in Australia and not under official control. This will ensure that species not present in Australia undergo a WRA prior to importation

In the first stage of the review, we looked at 4,000 species claimed not to be present in Australia and known as weeds overseas (based on a list compiled by the Australian Weeds CRC). After consultation with over 550 stakeholders, 3,335 species were removed from the Permitted Seeds List in May, 2005.

In stage 2, we are aiming for a list of species from within currently permitted genera to replace the genus-level listings. We asked State/Territories to identify species under "official control." Biosecurity Australia assembled a list of 23,000 species listed as being present in Australia. After consulting with 650 stakeholders, over 9,000 additional species were added as being present. Biosecurity Australia has provided documentation for the amendment of Schedule 5 to AQIS Plant Programs, and AQIS is currently amending Schedule 5. When the amendment is completed, ICON will be updated, stakeholders will be notified, as will the World Trade Organization.

In conclusion, Australia underwent a major change in policy, a change which greatly decreases the risk of weedy species entering and becoming established in Australia. The change required careful implementation, extensive stakeholder engagement, and operational support.

Q&A:

Holloran: What triggered the Nairn review in 1997? Was there a window of opportunity for policy reform based on some events that caught people's attention?

Groves: A lot of incursion of pests, plant, pathogens, insects, etc.

DiTomaso: What's the annual cost of the program?

Riddle: We have four people employed on assessments, plus the border program.

Holloran: What are the costs for doing the two stages of permitted list refinement?

Riddle: about $US 600,000

Kelch: How did you get the permitted species list?

Riddle: We took if off species in the trade, circulated it to stakeholders including botanical gardens and nurseries to find out what they had.

Kelch: What happens with cultivars?

Riddle: We generally only go to the species level. On rare occasions, such as when specific varieties have different stable attributes, they may be assessed.

Groves: There's a Plant Finder published every two years listing where plants are for sale. It's useful for gardeners—and also for finding what weeds are being brought in.

Q: How many imports are plants vs. seed?

A: Mostly seed. All live material has to be grown in quarantine for three months to check for pests.

Johnson: Does anyone have a sense of the scale of plants in Australia versus plants in the US?

Whittemore: No. There is very little known about what plants are in the US. Bailey's 1949 was the last time anyone even tried counting. Herbaria chiefly catalog native plants.

References

AQIS Import CONditions (ICON) http://databasewww.aqis.gov.au/icon/

Biosecurity Australia website (includes a link to WRA system manual) - www.biosecurityaustralia.gov.au

Nairn, M.E., Allen, P.G., Inglis, A.R. and Tanner, C. 1996. Australian Quarantine: a shared responsibility. Department of Primary Industries and Energy, Canberra.

"Developing WRA Screening Protocols through the North American Plant Protection Organization (NAPPO)"

Dorthea Zadig, California Dept. of Food and Agriculture

NAPPO is a regional plant protection organization of the International Plant Protection Council (IPPC), which is based on a treaty deposited at the Food & Agriculture Organization of the United Nations. The purpose of the IPPC is to provide a forum for harmonizing international phytosanitary standards. It includes involvement from government, NGOs and industry. Canada, Mexico, and the US are the cooperating nations in NAPPO.

In 2005 the NAPPO established an Invasive Species Panel to, among other things, develop the role of NAPPO in addressing invasive species issues in coordination with the North American Commission for Environmental Cooperation and other relevant international treaties and conventions. In response to its 2005/06 assignment from the NAPPO Executive Committee to identify any gaps in the risk assessment process for potential invasiveness of plants imported into North American (with participation of the Pest Risk Analysis and Plants for Planting Panels), the panel quickly identified the need to provide clear policy guidance at the regional level on the application of a screening tool to identify pest plants prior to first importation of new plant species. To best address this need the Panel, this coming year, will be developing guidelines for a screening tool (not the tool itself) for member countries, and others, to use when developing screening protocols.

In August, a draft proposal white paper was completed. A public discussion paper is scheduled for release in March or April, 2007. Other NAPPOS panels will provide consultation over the summer, and draft guidelines will be prepared for October 2007 at the annual meeting. If all goes well, a regional standard will be adopted in 2008.

NAPPO has generated some fact sheets for weedy plants—see www.nappo.org.

Randall: How is NAPPO coordinating with US Invasive Species Council?

Zadig: Richard Orr, chair of our panel, is staff at US ISC. The panel membership is evolving. There's a full NAPPO meeting the 3rd weed of October each year—in 2007 it's in Newfoundland. California is the only state sustaining member, though other states are beginning to participate. This year three or four states attended. There's lot of academic involvement in addition to government and industry.

Johnson: How do the national agriculture departments fit in?

Zadig: They are all very involved. When guidelines come out, they will already have bought into the process.

"Revising the Quarantine 37 Regulations"

Barney Caton, Center for Plant Health Science and Technology, USDA-APHIS-PPQ

My objectives are to explain what the Quarantine 37 regulations are, some pest risk problems associated with them given the current situation, the alternative solutions considered, the proposed measures, how they will function (broadly), and what steps have and are being taken to enact those measures. For more detail, please see the Dec. 2005 white paper, "Addressing the Risks Associated with the Importation of Plants for Planting" available at www.aphis.usda.gov/ppq/Q37/whitepaper.pdf.

The Quarantine 37 ("Q-37") regulations (CFR7§319:37) are Federal regulations governing the import of plants for planting. When the regulations were crafted, plants for planting usually came in from only a few (European) countries in small lots that had to be grown and increased, and sometimes bred, before distribution in large quantities. Now, large numbers of live plants come in from countries all over the world, usually for direct sale to end users. Moreover, all taxa not on the list of Federal Noxious Weeds can enter after inspection if a valid permit exists for them. Compared to commodities imported strictly for consumption (Quarantine 56, "Q-56"), plants for planting represent greater risk for pest introduction because of several factors:

- they will be cultivated/propagated, often in environments suitable for pest establishment,
- much greater numbers of taxa are imported,
- the risk duration is much greater, and
- pest risk assessments are not required before entry as they are for Q-56 materials.

To reduce these risks, more effectively use resources, and fix some other problems in the Q-37 regulations with as little economic hardship as possible, Plant Protection and Quarantine proposed the following:

- combining regulations in a single section
- better collecting and utilizing data on imported plants for planting
- reevaluating prohibited taxa, and
- adopting measures to reduce pest introductions.

Those measures include a new designation for some prohibited taxa; implementing clean stock programs in exporting countries, and creating a review group to assess taxa with significant import histories.

The new designation is 'Not Allowed Pending Pest Risk Assessment,' or NAPPRA. It can be applied to taxa that either are pests or are hosts of pests. For both uses, the chief criterion is that the pest meets the definition of a "quarantine pest" under the International Plant Protection Convention. CPHST will do these evaluations. The first primary goal after the new regulations are in place is to designate as many taxa as possible as NAPPRA. Thereafter, if requested, a NAPPRA taxon can be subjected to a full weed risk assessment (WRA), after which it can be designated as either prohibited (i.e., if assessed as having Moderately-High or High risk) or "Assessed and Enterable" upon inspection and with a permit. Taxa with significant import histories are not eligible for NAPPRA, but will eventually also be subjected to full WRAs, with the same possible outcomes.

Several rounds of notices of proposed rulemakings have received public comment, and some final rules have been drafted. The next important step is an upcoming public e-discussion on methods for predicting the invasiveness of weeds. Other activities are ongoing, including the development of the initial list of NAPPRA species, and completion of rulemaking.

To be alerted of this public e-discussion, sign up for the stakeholder directory by going to http://www.aphis.usda.gov/ppq/ and clicking on "Join the PPQ Stakeholder Registry" at the bottom left. Under the Topics of Interest, select Plant imports – Plants.

Q&A:

Q: Will list of assessed species be available publicly?

A: Yes.

Randall: Clean Stock program in past focused on pests/pathogens on plants. Will it now include intentional seed introduction?

Caton: Can't imagine they would put one in place and ignore the other but not sure how much it's figured into it.

Q: What links are there with Canada and Mexico? Where are "offshore" things grown?

Caton: Polly Lehtonen is working on the Q-37 revisions and is also part of the NAPPO committee. A lot of plants for planting are grown in Mexico and Latin America.

Johnson: This will require more risk assessments. Is there the capacity to do those?

Caton: Getting things into NAPPRA designation is fairly simple. Full WRAs will take more resources. We have been on a trend of increasing the number of analysts in the lab. A good number of species—the "low-hanging fruit"—probably can be easily assessed and put on the prohibited list fairly quickly (once the regulations take effect).

Q: Are there specific plants to start with? Those Australia has rejected, for instance.

Caton: I don't know how the NAPPRA list will happen, but we will look at what's been done already.

Kelch: In Australia, petitioners provide some information, but in the US done all in house?

Caton: We typically tell importers that their assessment will go faster if they give us information to start with. But we of course evaluate their information. Includes journal articles from country of origin translated into English. We won't take anything at face value. But including their info makes them feel included in process.

Any further questions about Q-37 revisions may be directed to Polly Lehtonen at Polly.P.Lehtonen@aphis.usda.gov.

"The Role of Botanic Gardens in WRA"

Alan Whittemore, National Arboretum

Compared to government agencies, botanical gardens and arboreta are a loose group of organizations that vary in size and purpose. Some have research programs, significant plant collections, horticultural trials, etc. Much of the data on factors like cold tolerance for ornamental plants comes from tests at botanic gardens. We supply info and germplasm to the nursery industry for cultivars.

There are no specific protocols because there is no standardization. There's limited funding, and most resources go to public display, so gardens are not particularly interested in tracking potential invasiveness of cultivars for horticulture because of the associated time and cost.

There is often only a limited connection between scientific and horticultural staff at gardens. Horticultural staff are usually limited, and they rely heavily on volunteers. Thus, much that is planted is not well documented. When plants are thrown out as suspicious of being invasive, that's not recorded. Unfortunately, this means they can be brought in again by someone else who is unaware of the past experience with the plant.

Most taxonomic work now is on native plants. There is a need for taxonomy of cultivated material. Often we don't really know where things came from.

Many gardens are actually well situated for testing invasiveness. The National Arboretum, for instance, is half cultivated and half wildlands. We can watch for things escaping, and document it in herbarium.

Poor record keeping inhibits our study of invasive history. *Lonicera maackii* was introduced in 1896. It was first recorded as aggressive in Chicago woodlands in 1924, but not published until decades later. There are few records in herbaria. This case indicates that for some species the "long lag period" may be an artifact of a lack of records, when a plant is not listed correctly in local floras or keys because is not identified correctly. We need better data to track things before they become a problem.

We need to identify potential problems early in the process. If a nurseryman invests a lot of money in developing a cultivar, and just as he's recouping his money, it's found to be invasive, there will be problems. We need to have this information before nurserymen have wasted their money (and thus before they have an incentive to hang onto the cultivar). This would cut down on a portion of the problem. Then the challenge will be the dissemination of knowledge to nurseryman. It's too hard for your average nurseryman to find information in the literature. It's also hard to tell if something is truly invasive in wildlands or just a roadside/waste area weed. And it's all complicated when things are sold under incorrect names.

Gardens can help promote non-invasive germplasm to industry, and may be able to assist in developing sterile cultivars. We may also be able to help with WRA by providing data on biological characteristics like seed quantity, etc.

Roush: What policies do gardens have to contain things that become invasive? Collectors and visitors take seeds, etc.

Whittemore: It's very difficult to track everyone.

Groves: Adjacent woodlands will potentially show locally invasive plants, as well as those from the garden.

Whittemore: Yes, we are intimately in touch with the local restoration groups.

Randall: The Codes of Conduct provide guidance for public gardens. Seems like we need an incentive for folks at gardens to publish their findings. They may also be in a good position to study which pests here hammer particular foreign plants, and warn their colleagues there that this particular pest could be a big problem if it got there.

Discussion: Current Opportunities in State and National WRA Policy

Moderator: John Randall, The Nature Conservancy

Randall: So what about bringing data from Australian WRA here?

Caton: Everyone is looking at the same information, and we share pretty freely. We're all eventually assigning numerical values, so there's room for some quantitative comparisons. USDA considered the white list approach. Based on the white paper, the reason for not implementing that was the potentially great economic interruption.

Riddle. There are mail screening processes for anthrax—can it pick up seeds? How will the operational side work with Q37?

Caton: US probably has vastly more mail coming in than Australia, so I don't know if it's realistic to screen it all. USDA tries to get border patrol information. We have the AIMS (Ag Info Mgmt System) search engine to check for noxious weeds on the web. USDA can close down domestic producers/sellers but can't regulate international producers selling online.

Zadig: International mail can be inspected. Priority or express mail is sealed against inspection but can be searched by dogs, which provides probable cause. Searching domestic mail requires a search warrant, cannot be x-rayed.

Randall: In Australia, most import is by seed, but it sounds like that's not true in US? Many pots of live plants brought in.

Caton: Plants have to be brought in in approved growing media. Not soil—that's a red flag.

Randall: What are the timing and details of NAPPO and Q37?

Zadig: The web discussion will be open for three months and will provide an excellent opportunity to get involved with this. There's good overlap in people involved in NAPPO and Q37.

Randall: Will the discussion be on technical issues?

Zadig: Next will be a call for comments on proposed NAPPO rule. That will include a technical document as support.

Riddle: A word of advice—it's important to keep the public involved. Get information out about the damage from weeds. Make everyone aware of costs. Get opinions from stakeholders. Accepting a higher number of false negatives in order to get system started may be better than not having it. Involve the agricultural community as well to help with the momentum.

Holloran: There's a literature on how changes in policy happens, both gradual and sudden. The switch to a white list in Australia was a punctuated event. Such change requires a policy window to open, and you need to be ready to jump on the opportunity when it opens.

Randall: Remind us all of the Cal-HIP partnership as an example or a voluntary program.

Kempton: Cal-HIP brings together industry partners with environmental groups and agencies. We're currently only dealing with plants we know are problems in California. Want to take participation with nursery industry one step further to development of screening tools for both importers and domestic propagators to determine if something will be risky before they develop the cultivar. Whatever we can achieve here will reduce the need for always having to rely on enforcement, mail inspection, etc.

Randall: There are other hybrid approaches that have both voluntary and regulatory aspects. For instance, oil companies developing their own protocols for spills with government oversight.

Holloran. There are many examples, and lots of literature available.

Zadig: There's an international organization of standards. It incorporates hazard analysis.

Whittemore: Gardens might be able to get good data to help decisions. Unlikely they'll be involved on the regulatory side. That's more the trade association, the American Public Gardens Association.

Kelch: Botanic gardens could develop alternatives to invasive species.

Riddle: Need to influence consumer demand. Make non-invasive fashionable.

Caton: States should track how much of an impact this type of voluntary effort has. Florida's outreach to nurseries doesn't seem to have worked. The WWF report from Australia said it didn't work.

Riddle: It's starting to work in Australia, as awareness grows.

Virtue: For instance, at a major garden show in Adelaide, vendors are no longer selling species listed on our invasive garden plants brochure.

Tara - US doesn't have counterpart to third tier of Australian system, species that aren't high enough risk for WRA to justify rejecting them.

Caton: US has no options beyond exclude or allow in. No "evaluate further" option. USDA's difficulty getting things on the noxious list is not ambiguous species. CPHST can and does specifically request more information if necessary, and has some leeway in how quickly WRAs are completed. State-level action might have a role in influencing federal action.

Fox: Does Cal-IPC get called on to endorse things in middle? FL-EPPC has been asked to confirm that particular plants aren't invasive, but prefers to give their list rather than an endorsement.

Johnson: That's what we do, too. Just provide information, no endorsements.

Kempton: One goal of our Cal-HIP nursery partnership project is to put together a network of experts who can address questions.

Whittemore: Industry selection of non-invasive materials is a problem because it's mixed up with native vs. non-native questions. Transporting natives can cause problems with genetics of local populations when stock ordered from far away. There's little research on this. Then there are other people who will exaggerate the invasiveness of any nonnative.

Randall: The Center for Plant Conservation has a contract with the BLM to study genetic impacts of moving natives around.

Roush: If a white list won't work, aren't you just left with a long black list, which also takes a lot of work? Will you be getting more staff?

Caton: It's possible, but I don't know. Most APHIS funding is from user-fees for assessments. The budget is less dependent on Congress compared to other agencies. Allocation within the agency is more the issue.

Johnson: Are those user fees tied to commodity (Q-56 vs Q-37)? It sounds like Q-37 is a higher risk pathway but gets less money.

Caton: Our lab has been growing, and we may get more people.

Randall: How much personally or institutionally are each of us willing to accept in terms of false positives vs. false negatives? Think from operational standpoint, what can we do in US operationally and as a society.

Developing WRA for California

"Climatic Models of Plant Invasion"

Scott Steinmaus, California Polytechnic University, San Luis Obispo

As an illustration of how climate modeling can be used, our county Weed Management Area was working to figure out whether it should be concerned about gorse (Ulex europaeus) moving into the county. It's a significant invader in coastal counties to the north. We decided to see what we could learn from modeling with CLIMEX, a routine that matches climatic preferences and constraints of a species with meteorological data for a location of interest. Climate is the most basal of requirements, explicit or implicit in all predictive invasive models.

We adapted NOAA meteorological data and formatted it for CLIMEX. The potential for growth at a location is based on temperature and moisture preferences. CLIMEX calculates a "growth index" to determine a species abundance, based on:

TI=temperature index=f(max/min T, degree days)

MI=moisture index=f(soil moisture, rainfall, ET)

DI=diapause index=f(dormancy, vernalization)

LI=light index=f(photoperiod)

When combined with a stress index, the growth index yields an ecoclimatic index.

We determined the native range of *Ulex europeaus* from the Flora Europea. When we mapped the expected range in California, we were able to determine that it would not be likely to establish in our county. We also successfully identified a few unexpected sites where gorse ended up being found.

We did similar models for Cape ivy and pampas grass, and compared the results to the known distribution in California.

DYMEX is a routine from the same outfit. It allows one to model the plant at different life stages. One can also incorporate "events" such as an herbicide treatment. We modeled Arundo donax, and the results show us when in the course of the year it's most effective to treat.

There are many climatic models.

CART: Classification And Regression Trees use species presence/absence and environmental correlates to infer regional determinants. These determinants are then mapped using GIS. Charley Knight (Cal Poly) and David Ackerly (UCB) model native plant response to climate change

ANUCLIM(BIOCLIM): also a climate matching model but uses MBR to define an environmental envelope of a species (Nix 1986)

HABITAT: also defines a species environmental envelope but uses CART to identify the significant environmental variables. The envelopes tend to be more restrictive than those of ANUCLIM so do not over-estimate susceptible areas

CLIMATE ENVELOPE: also uses MBR using herbaria/museum collections to match climate pattern

CLIMATE: focuses on species climatic preferences to assess weed risk (Pheloung 1996)

DOMAIN: used by conservation ecologists to identify areas with a similar climate as that where invasive species occurs

GARP: (genetic algorithm for rule-set prediction) this ecological niche modeling (ENM) approach uses resampling (like bootstrapping) to generate a training data set and a test data set. Then, it generates rules using significant niche parameters using the training set, then applies these rules to the test set. Rules are allowed to change, truncate, exchange pieces (i.e. crossing over as in DNA evolution) until the rule sets with the highest "fitness" (best predictive power) are retained (Oberhauser and Peterson 2003).

Some considerations for future approaches:

Parametric approach: what we've been doing. The frequentists' tools: mean, variance, significant explanatory variables, F-test, probability.

Monte Carlo simulation: creating your own null set by resampling after rerandomizing treatment labels not relying on F or t or Chi square. Other examples are bootstrapping and jackknifing

Bayesian Analysis: Once considered "unscientific" because of the lack of "objectivity" when specifying the prior. This approach allows you to incorporate previous information. It flips everything around by asking what is P(Ha|data) not P(data|Ho). The Bayesians' tools: likelihood, conditional probabilites, prior probabilities. With modern computing power, this is the direction we will head.

Discussion: Guiding Development of WRA in California

Moderator: Doug Johnson, California Invasive Plant Council

Johnson: As an NGO, we don't have regulatory power. But we can also be proactive in developing information resources to support better decision making. To date we've established a good inventory of weeds in the state. We don't have good distribution information. In our upcoming project, we plan to do several things: (1) survey counties for distribution of 30 weeds to begin coarse mapping, (2) use CLIMEX to model habitat suitability for these weeds to see where range expansion might occur, and (3) take a first cut at a simple predictive WRA to inform our early detection activities and partnership with the nursery industry. We need your feedback. Are we focused on the right goals and tasks? Is this how you would approach range predictions? And what advice do you have for simple pre-border screening?

Holloran: How much money do you have?

Johnson: $70,000 over 2 years. Basically one person year.

Daehler: These plants are legal and can move around. Would it be better to use models to apply for these as noxious weed?

Schoenig: In California we can't put a plant that is sold on our noxious list.

Johnson: We can look at horticultural plants on a less formal basis that a noxious rating to simply say that they shouldn't be moved into the state. Climate matching can indicate where to look for plants.

Klinger: That money won't get too much. Use some time to go into the literature. The big challenge is having enough data to calibrate and validate a model. Use literature to serve for either calibration or validation. Make sure models are working first. Test with easy species.

Johnson: Perhaps we choose plants that have literature and datasets available?

Klinger: If a plant is too widely distributed, the model will tell you to look everywhere. Maybe consider using plants that are less widely distributed.

Randall: Choose species that represent a mixture. Include a couple with little info on locations. See how coarse the results are with the more typical situation of weeds we think are bad but don't have info on.

DiTomaso: Focus on horticultural species is important.

Johnson: How well are the existing models working, for instance the predictions for gorse, pampas grass and Cape ivy you showed, Scott?

Steinmaus: More info means more confidence. Gorse model is pretty good, Cape ivy only OK.

Athan: Not all WMAs line up with counties, and some counties are split by biogeography. Data at finer resolution than county would be better.

Johnson: I agree, splitting by ecoregion would be best. May be a challenge getting any response in some counties. Our first round will aim for coarse data to get people involved.

Randall: It would be good to survey graduate programs about what new research is going on, because there are efforts on particular plants, and those might be good ones to choose.

Virtue: In South Australia, we used the simple CLIMATE program and overlaid it with soil tolerance, then land use. That really helps narrow your predicted distribution to a more reliable estimate.

Rejmanek: Has anyone compared native distribution and adventive distribution? Native may be misleading. May be just surviving in some places. May be more relevant to look at other introduced areas as a better comparison.

Virtue: Based on Australian experience, the more info the better, but yes, distribution from areas invaded is vital, giving more info on tolerance since other biotic factors are at play in home range.

Gluesenkamp: Important to know what we will we use the final report for. We might focus on economic impacts of agricultural and environmental weeds. More than just where species will expand.

Groves: Can alert people to potential of weed spreading there. Model prediction doesn't necessarily mean they'll be weedy there, but it's a first step.

Kelch: CDFA could provide most info from species with limited ranges.

DiTomaso: Part of the goal could be to fine tune the weed alert list to communicate to local WMAs.

Holloran: Focus on those species with very limited distribution, like Joe's Red Alerts. Several possible results: the info would be useful for CDFA, or in the short term to improve the Cal-IPC Inventory, and in the long term to get ready when policy window opens. Also it could help look at the false positives question.

Bakke: Federal agencies are having trouble demonstrating effectiveness, especially in showing that they've reduced risk. We have a risk map for insects and forests. A weed risk map for CA would be useful for USFS to show need for additional work and so we know what to go after. It would be a strong fundraising tool for agencies.

Kempton: What about screening protocol?

Virtue: Australia developed a simple system, which is currently being tested by botanic gardens. It relies on observations of plants in a garden setting. Helps show what might become invasive. See website for Botanic garden in Melbourne for updates (www.rbg.vic.gov.au/gardening_info/weed_strategy).

Johnson: Is there a network between weed organizations from Mediterranean climate?

Groves: Yes, meets every couple of years. Last one in 2005 in France. Not formal.

Schoenig: At last year's meeting, there was an attempt to put together a network to share data, but it didn't happen.

Gluesenkamp: Cal-IPC has talked about looking at climate scenarios, could apply for funding for that.

Groves: This has been done to death. It can be useful or misused.

Athan: There's a paper in Biodiversity and Distributions.

Johnson: Do climate change scenarios affect WRAs much?

Virtue: Yes, would change distribution. There are some good contacts in Australia who look at this (e.g. Darren Kriticos at Ensis, email Darren.Kriticos@ensisjv.com).

Steinmaus: Charley Knight at UC Santa Barbara has looked at this for native species using CART.

Athan: One has to be careful of the reliability of climate change scenarios, no?

Klinger: Other variables may be better predictors than climate.

Caton: What do you want after the funding is gone? You need a clear goal. Using climate change scenario may be unrealistic in this limited time frame.

Final Discussion: Review Key Next Steps in WRA Science, Techniques, and Policy

Moderator: John Virtue, South Australia Dept. of Water Land & Biodiversity Conservation

Attendees brainstormed key items at the local, state, national, and international levels, then ranked these. The top items were then discussed as a group in order to decide on a plan of action for these items. These discussion items are presented first, followed by the full lists.

1. Getting botanical gardens to communicate information on escapes.

Kelch: Ask them to fill out a short survey annually. First, get their buy in. Then more extensive implementation might be possible.

Daehler: Anonymity might be good so people don't feel guilty.

Virtue:Who would run it?

Kelch: I will volunteer to pilot this for California.

2. Database of WRA info with detailed quality control, to improve efforts to share info on assessments.

Riddle: Not sure Australia would be able to release information from the full assessments due to potential privacy concerns. In addition to this, to accurately post detailed assessments, including the necessary referencing rights, would be resource intensive—resources that the Australian government may not have.

Fox: But this may be more of a generic database of questions and data.

Athan: Attach it to literature rather than an assessment. GISP is not set up to do that—it's organized by species, but it has no separate fields for characteristics.

Virtue: Is GISP the most likely system for something like this?

Johnson: Or what about the Global Pests and Disease database Barney mentioned?

Caton: It's in development, and I'm not sure of the final plan. Remember, it's more than weeds.

Virtue: Maybe outside what we can do, but perhaps could be recommended through NAPPO?

Johnson: Setting up a dbase is not hard. The big task to gather information. Who would assume ownership is a question.

Fox: Requires coordination among countries that have this information.

Randall: Cal-IPC and Natureserve have put our assessments online.

3. Improved methodology and resolution of "further evaluate" category (includes reducing false positives)

Kelch: Sounds like an academic needs a grant to examine the techniques and process.

Virtue: There is some linking between this and other items on using Marcel's methodology, etc. to improve models. What needs to happen to make this happen? Funding is always an issue, driven by perceived need for the work. Then who would give the support for it?

Caton: Already starting to happen, through NAPPO process.

Fox: Or is this more looking at the statistical methods?

4. Educating people about weeds at local level.

We tabled discussion. Just do it.

5. Develop data on ecology to develop simpler predictive models.

Randall: Explicitly using published data. Not necessarily subtracting questions. Just try to improve methodology.

Virtue: There's the research, funding grant approach. It's here under our international list, so it will need coordination.

Kelch: Good dissertation project.

Johnson: Make sure it has applied utility. Include a policy person.

6. Rigorous tests of WRA tools with comparable data sets.

Fox: Need to have criteria for data sets. Should be a collaborative project between people who've used these tools, including internationally, focusing on predictive weed risk assessment. Can link to making screening methods for developing countries. Key is to have tests with data sets to reduce variability in interpretation. Needs funding.

Holloran: This sounds like a good candidate for support from the National Center for Ecological Analysis and Synthesis (NCEAS), UC Santa Barbara. They like to bring together teams of experts to hammer something new out.

Riddle: I'm reconsidering. Having weed lists put into a database would be useful. For example, Australia could confirm that a plant in Florida is considered a weed rather than relying on possible misinformation from publications. Sharing international noxious weed lists, perhaps with a few ecological traits that make plants a risk, and confirming that a species is a weed would be very useful. The Global Compendium is compiled by an Australian and uses information from other weed datasets—this could form the basis for a weed database.

Brainstorm lists, with number of votes received by each item:

Local:

Educate people about weeds (5)

Collect more accurate and comprehensive distribution data for invasives, including community type (3)

Accessible data for screening and prioritization including impacts (1)

Assembly of local stakeholders into groups e.g. Weed Management Areas (1)

Give county Agricultural Commissioners "teeth" to enforce WRA recommendations (0)

Educate people at a local level not to take/transport/plant potentially invasive garden plants (0)

State:

Provide incentives to publish/communicate observations on escapes/naturalizations/spread from botanic gardens (7)

Centralized collection/database of current and historic distributions and life history characters of species (3)

WRA for early detection/rapid response to prioritize species for eradication (3)

Higher prioritization of pest plants relative to other pests, with the impact of getting more WRAs done (3)

Test a WRA system that incorporates insights from Rejmanek's Z function and matrix into the Pheloung System (2)

Coordinate with American Public Gardens Association to produce regional brochures of horticultural weeds with alternatives species, coordinating with nurseries to grow alternatives (0)

Make sure reousrce agencies and ag agencies are both working on weed issue (0)

National:

Improved methodology and resolution of "further evaluate" category in WRA and reduce false positives (5)

Cultivate flora of US to species level (3)

Database/listserve of funding sourcs, RFPs, etc. (1)

Coordinated/consistent weed inventory in order to prioritize regional spending/effort to focus effectiveness (0)

Specific protocol for 3rd tier/moderate risk weeds (0)

International:

Database of WRA info with detailed quality control (6)

Rigorous tests of WRA tools with comparable datasets (4)

Develop data on ecology to produce simpler predictive models (4)

Collaboration on a refined Pheloung/Daehler WRA predictive border system, for standardization and data sharing in border WRA (3)

Cooperation/coordination with border operations (1)

Appropriate screening methods for developing countries (1)

Write detailed case studies of white list implementation attempts, e.g.NZ, Australian (0)

Climatic suitability maps on global scale (0)

Second revised edition (electronic?) Compendium of Weeds, with increased use internationally (0)