

Chapter 6. Risk Assessment and Decision Making for Invasive Plant Management Planning

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INTRODUCTION

There are many exotic plant species in North America, but only a small percentage become invasive. An exotic species inventory of your area may indicate there are many exotic species present. Which species should be ignored, which should be managed to limit impact, and which should be eradicated? Plant communities vary in their susceptibility to invasion, so assessment of areas at particular risk to invasion should be included in an overall assessment. Within the management area there may be areas that are free or nearly free of exotic species which could be identified for special consideration. Areas where rare plants are located may also require special management consideration, since managers may have a low tolerance for any weeds in such areas.

Risk assessments differ depending on what is at risk. An invasive species approach to risk assessment involves identifying plant characteristics to determine exotic species that should be considered for management. A community-based assessment would look at characteristics of plant communities and human activity that suggest susceptibility to invasion. Matching plant species to potentially susceptible habitat allows a combination of the two approaches and may lead to better assessment overall (Heger and Trepl 2003). Risk assessment has its greatest impact when incorporated into initial invasive plant management planning.

SPECIES-BASED APPROACH

A species approach could be used in two ways. First, it could be used as a form of invasive plant triage where exotic plants from an inventory are categorized according to their potential to become invasive. Second, the species approach could help prioritize which species should be targeted for prevention and early detection programs.

Identifying traits of invasive plant species allows for identification of approximately 20 to 30% of the species that are potentially invasive in Hawaii (Daehler and Carino 2000; Daehler et al. 2004). The single best indication of invasiveness is whether a species has been identified as invasive elsewhere, and when applied to Hawaiian exotic species this factor alone distinguished 50% of truly invasive species (Daehler and Carino 2000; Daehler et al. 2004). By combining specific traits and prior invasive characterization, about 80% of invasive plant species were correctly identified when using an Australian screening process (Pheloung 2001) for exotic species in Hawaii (Daehler and Carino 2000; Daehler et al. 2004).

Previous chapters have covered characteristics that may aid prediction of invasiveness. In summary, characteristics that warrant caution include: constant fitness across wide range of environments, small genome size, small seed mass, vertebrate dispersal, exotic genera (no natives in genus), use of non-specific mutualisms (e.g. mycorrhizal relationship, generalist pollinators), large plant size in mesic sites, and small and numerous seeds (Rejmánek 2000). Several risk assessment tools utilize the species characteristics that you have discussed. The risk assessment tools rate exotic species according to the developers' consideration of the relative importance of any given characteristic. One system screens woody plant species (Reichard and Hamilton 1997) and was used with good success in the Hawaiian rating study discussed above. The screening tool does work well for screening potential ornamental plants and it likely would be useful to determine if ornamentals within or near the areas you manage are potentially invasive. The limitation to this tool is that it was designed for woody plants. The Australian screening system (Pheloung 2001) could be

used for woody and herbaceous plants (see <http://www.affa.gov.au/content/output.cfm?ObjectID=D2C48F86-BA1A-11A1-A2200060B0A04014>).

Another system that functions primarily for a triage approach was developed by NatureServe as a cooperative venture between the USGS, the National Park Service, The Nature Conservancy, and the NatureServe staff. The NatureServe screening system relies primarily on the effects of a plant species at the scale of the plant community to the scale of an entire ecosystem (see *An Invasive Species Assessment Protocol: Evaluating Non-Native Plants for Their Impact on Biodiversity* p. 8, at <http://www.natureserve.org/getData/plantData.jsp>), and secondarily on plant characteristics. The screening system also considers the difficulty level in managing the invasive species, and assesses what the management program impacts may be on native species. For a specific example from NatureServe, look at leafy spurge (enter “leafy spurge” in the search box): <http://www.natureserve.org/explorer/servlet/NatureServe>).

For the states of California and Nevada, the California Invasive Plant Council and USDA-ARS scientists in Reno have developed an online system for collecting data and completing forms, as well as displaying data on species where data have been collected. The system is similar in approach to the NatureServe screening system because it does weight the results towards species currently having significant impact.

Traits that predict invasiveness and past history of invasion elsewhere provide vital information for risk assessment. Other factors also contribute to our understanding of successful invaders. The number of times a species has been introduced, its residence time, and the size of an infestation all become important when determining risk to invasion. Prevention programs can limit the number of times a species is introduced.

Species are often strongly associated with transportation routes, suggesting that species may spread along roads and trails, in part through an ability to facilitate multiple introductions (Parendes et al. 2000; Maxwell and Rew 2006). Plant survey programs targeted to transportation routes can improve detection of newly invading species and allow successful removal. Multiple introductions can be minimized by using certified weed free products and cleaning equipment.

PLANT COMMUNITY-BASED APPROACH

Plant communities vary in their susceptibility to invasion, and this susceptibility is modified by human activity. Biogeography provides some insight into natural susceptibility. It has been documented that islands appear to be more susceptible to invasion than continents (Elton 1958). Climate likely affects susceptibility to invasion; for example, the five geographic areas with Mediterranean-like climates appear to contain more annual native plants as a percentage of the total number of native plants than other regions. The average percentage of annual native species worldwide is 13%, compared to nearly 30% for the Mediterranean-like regions. The higher percentage of annual plant species indicates that natural disturbance is higher or that there are niches that are not filled with perennial plants.

Research suggests that plant communities with greater biomass are less susceptible to invasion than plant communities with less biomass (**Figure 6-1**). A plant community susceptibility project led by Region 4 of the US Forest Service and The Nature Conservancy also showed lower susceptibility to invasion in areas of greater biomass by counting the number of species considered invasive in grassland plant communities versus forest plant communities. Within those forest communities, there were fewer invasive plant species that invaded plant communities with greater biomass (moving from more open forests dominated by Ponderosa pine to forests dominated by cedar and hemlock) and with shorter growing seasons.

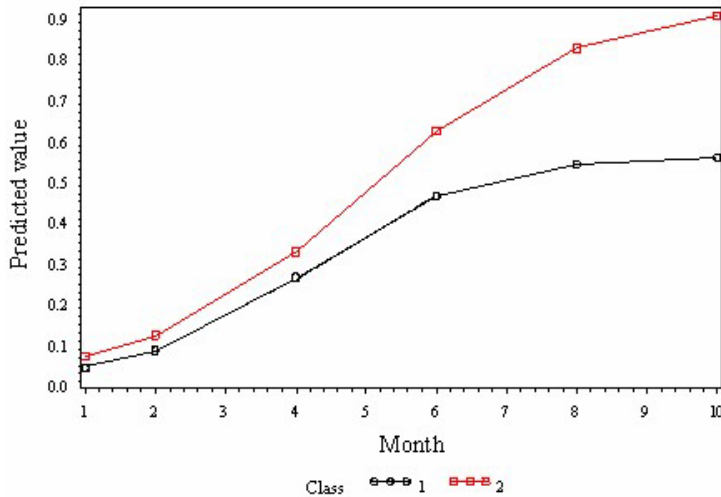


Figure 6-1. Estimated logistic models for accumulated Normalized Difference Vegetation Index ($NDVI = \frac{\text{near infrared band} - \text{red band}}{\text{near infrared band} + \text{red band}}$) from January to October. Classes are as follows: Class 1 = southwest aspect and 60 – 65% slope, class 2 = southwest aspect and 0 – 10% slope, class 3 = north aspect and 0 – 10% slope. Greater NDVI accumulation on shallow slopes indicated greater biomass accumulation. The shallow slope is where yellow starthistle occurrence is low and the steeper slope is where yellow starthistle occurrence is high.

Disturbance is important to determining which plant communities are susceptible to invasion (Rejmánek 1989; Higgins and Richardson 1998). Disturbance may remove species that are competitive but unable to survive frequent disturbance; for example, an increase in the frequency of fire due to downy brome invasion may result in the loss of sagebrush. Disturbance removes plant biomass and may leave plant communities open to invasion because resources previously captured by the plant community are

available to invading plant species. Areas experiencing disturbance likely are at greater risk to invasion, so these areas should have high priority for surveys to detect new invasions.

Combining disturbance effects and competitive effects implicit from plant community biomass production allows for determination of areas likely at risk of invasion (**Figure 6-2**). As disturbance frequency or intensity increases, the plant community becomes

Plant Community Susceptibility: Gradients for Risk to Invasion

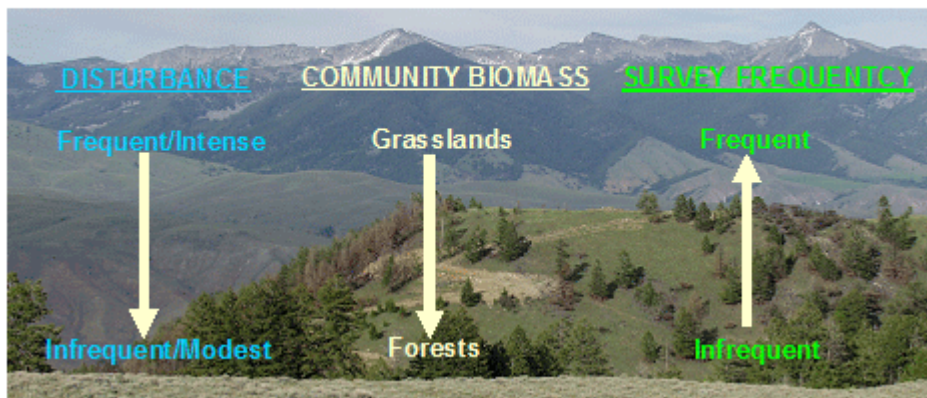


Figure 6-2. As disturbance frequency or intensity increases, the plant community becomes more susceptible to invasion. The relationship of biomass to competitive ability suggests that larger plants are more competitive and it appears this relationship holds for the plant community as well. Plant communities that produce more biomass are less likely to be invaded, suggesting that grasslands may be at higher risk than forests.

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Dispersal is critical to the process of invasion, so dispersal vectors should be identified in order to effectively manage for reduced immigration of invasive plant species. Since roads and trails are vectors for dispersal, areas with higher road density also have more invasive plant species (**Figure 6-3**). Road density can be contrasted among areas under management to determine areas at greater risk to invasion.

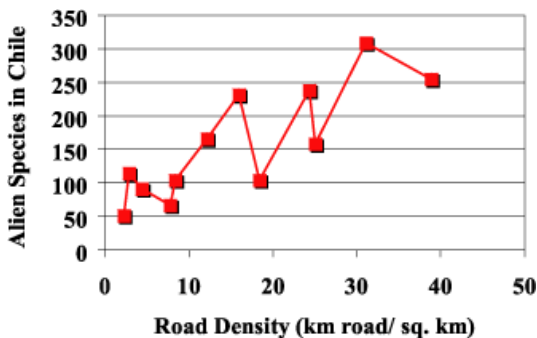


Figure 6-3. Density of roads was associated with an increased number of exotic plant species (adapted from Kalin et al. 2000).

COMBINING PLANT AND PLANT COMMUNITY CHARACTERISTICS

Matching species with invasive characteristics to plant communities susceptible to invasion should improve risk assessment. However, combining the two approaches requires considerable additional information and has been characterized as being descriptive, explaining specific cases of invasion, but not predictive (Heger and Trepl 2003). The Australian screening system does incorporate habitat matching and several of the risk assessment protocols suggest identifying the type of plant community invaded in other

regions in order to identify similar plant communities within the area you are managing.

Computer programs do exist for environmental condition matching. One such program is CLIMEX, which allows input of data about the species and habitats where it is successful, and then determines overlap of climate and habitat in the new range. A companion program, Dymex, allows incorporation of population models to provide additional insight into how to approach management of the target species. Constructing climate diagrams may also be helpful, so that you can look at the climate in the native range of a species and compare it to your climate. Climate diagrams for many locations worldwide are available at <http://www.globalbioclimatics.org>. Two examples from [globalbioclimatics.org](http://www.globalbioclimatics.org) are presented in **Figure 6-4** and show very different conditions for two locations in western North America, likely with few plant species in common.

Predicting characteristics of invasive species was thought untenable 20 years ago but there are now several risk assessment procedures being used to identify species that are potentially invasive. It is reasonable to expect that with experience, the key-lock methods suggested in Heger and Trepl (2003) will become more predictive. One key-lock approach is a weed risk assessment conducted by the USDA Forest Service and The Nature Conservancy (http://www.fs.fed.us/r1/cohesive_strategy/data/weeds.htm). The project identified habitat types that were invaded without disturbance, invaded with disturbance, or not invaded by a specific exotic species. The habitat type GIS layer was constructed from remotely sensed data. Once these relational or key-lock methods become predictive, our risk assessments will be refined and become more useful.

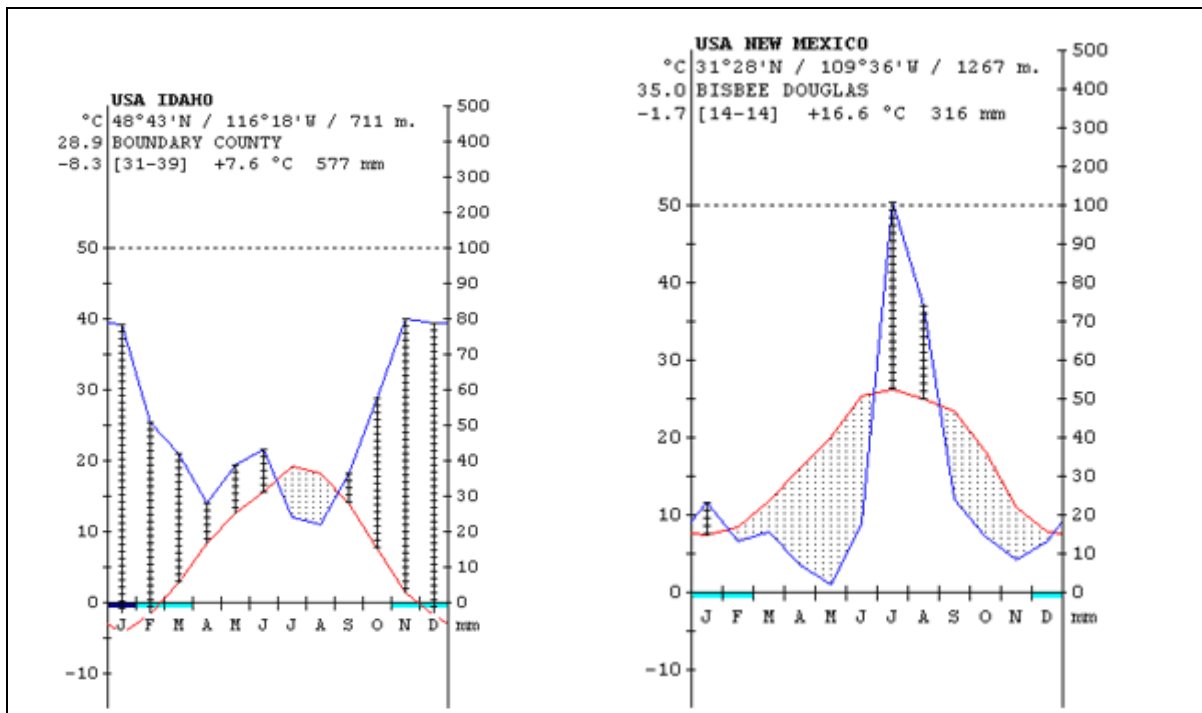


Figure 6-4. The blue line represents precipitation in millimeters, the red line is air temperature. The hatched bars represent periods when precipitation exceeds evapotranspiration and the dotted area represents periods when evapotranspiration exceed precipitation.

RISKS OF ACTION OR INACTION

In addition to assessing risk from a plant species approach or a habitat susceptibility approach, risk can be considered with respect to treatments used and with respect to taking no action. Use of chemicals to control weeds has risks, many of which are assessed during the EPA process for registering a herbicide. From a human perspective it appears that the risk from chemicals used in our environment to humans is small compared to other risk factors (Dunnette1989).

One resource for information on toxicity and tests conducted on a range of organisms is the Herbicide Handbook published by the Weed Science Society of America. EPA has the Integrated Risk Information System (IRIS: <http://www.epa.gov/iris/intro.htm>) to provide interested individuals background on EPA's assessment process. IRIS also provides assessments on some herbicides.

Additional resources are available from the Oak Ridge National Laboratory (<http://www.esd.ornl.gov/programs/ecorisk/ecorisk.html>). Herbicides can have a negative impact on soil microbial communities; for example, benfluralin decreased soil microbial carbon (Vischetti et al. 2002), yet herbicides such as glyphosate, bensulfuron-methyl, prometryne, propanil, and imazamox had either no effect or a positive effect on soil microbial communities (Saeki and Toyota 2004; Araujo et al. 2003; Vischetti et al. 2002; Crecchio et al. 2001).

Herbicides are not alone in having other effects on plant communities. Other actions can have consequences as well. Biological control of some weeds has reduced the impact of several target weed species. In some cases, rare plant species have declined after feeding by biological control agents (Louda

et al. 2003), and 15 insect species introduced for biological control have fed on 41 native plant species (Pemberton 2000). Mechanical disturbance of the soil can reduce mycorrhizal fungi (Anken et al. 2004; Jasper 1989).

Taking no action can have effects in addition to the impacts invasive species have on our native systems. Uncertainty may cause a delay in controlling new species. Often we do not have sufficient information to conduct a risk assessment and we have to make a decision with insufficient data. Small infestations, less than 10 acres, can be removed at low cost, so removal of species even with uncertainty is prudent (Rejmánek and Pitcairn 2002).

Taking no action could result in significant environmental and economic impacts. For example, in Idaho, bur chervil (*Anthriscus caucalis*) was located under hackberry trees and did not move from hackberry for many years. Now the species is becoming widely distributed and it is replacing yellow starthistle at the wetter end of the yellow starthistle range. Bur chervil has no forage value and it appears to be well adapted to the range of plant communities found within Palouse Prairie, one of the most endangered plant systems in the USA, with less than 1% of the prairie remaining.

TOOLS FOR DECISION MAKING

The time course of an invasion provides a framework to discuss decision making (**Figure 6-5**). Prior to introduction, prevention techniques should be adopted. Prevention reduces the chance of multiple introduction, which has been shown to facilitate successful establishment in the case of *Eucalyptus* in Southern Africa and exotic grass species in Venezuela (Rejmánek 2000). Regulatory efforts to exclude species coming into the United States have been largely unsuccessful, in part from inadequate funding for port-of-entry inspections and a system focused on excluding species known to be invasive rather than allowing only species likely to not become invasive, as is done in New Zealand. Prevention methods at more local scales can be effective because greater control over entry pathways is possible. Examples include: (1) In Mariposa County, CA, bonding has been required for construction projects to provide funds should weed problems arise; and (2) requiring bonding for weed-free products and clean equipment contributes to reducing multiple introductions. Utilizing risk assessments for nonindigenous species known to occur in adjacent areas can allow land managers to develop prevention techniques that address specific characteristics of the nonindigenous species.

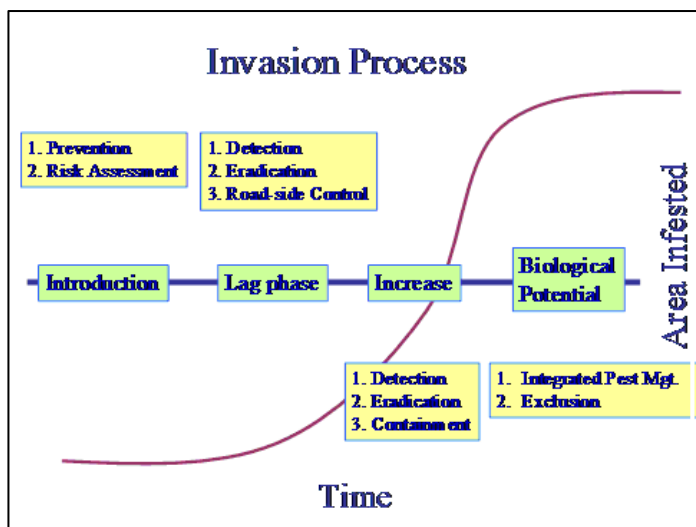


Figure 6-5. Time course of an invasion framework to use during management planning

Build a detection program to find newly invading species using plant community susceptibility as a guide. Putting together a survey plan to search for incipient infestations is a developing technique. Where are species likely to be found first? A joint project between Region 4 of the USDA Forest Service and the University of Idaho is developing a prioritization of sites where survey should occur more and less frequently. For example, survey would be more frequent along an improved roadway

through a grassland than along an unimproved roadway through a grassland (**Table 6-1**). Both of these sites would require more frequent survey than a roadway through a more mesic forested area in the cedar hemlock series. Once completed, the study should provide rankings for sites where nonindigenous species are commonly found and allow resource allocation for more frequent survey of areas with higher proportions of nonindigenous species.

Table 6-1. A subset of types of sites includes road type and adjacent plant community, which affect the proportion of nonindigenous species present on the Nez Perce National Forest and Idaho County in Idaho.

Site	Improved		Unimproved	
	Roadside	Adjacent community	Roadside	Adjacent community
	-----%-----			
Grassland	72	33	12	18
Cedar/Hemlock	9	0	11	0

Lag Phase (see Figure 6-5)

A new nonindigenous species is now present in the area you manage. What should be done? Most nonindigenous species do not become problems. If you are not familiar with the species, then utilize the risk assessment tools discussed earlier in this chapter. If the species is one to potentially be concerned about, then determine the extent of the infestation. Once you know how large an area is affected you can use the graph in Rejmánek and Pitcairn (2000) to determine the feasibility of eradication.

In general, infestations over 100 acres were difficult to eradicate for the California Department of Food and Agriculture. If the area is less than 100 acres then you certainly are in a position to consider eradication. In eradication projects we have found that at least three site visits per year are needed. The first visit is to survey the known infestation and surrounding areas to ensure the outer border has been delineated. The second visit is to control the infestation. A third visit is to determine if the control was successful and if not, whether another control action is necessary and a subsequent follow-up

survey. (If only a few plants were missed, the survey crew should control the remaining plants; **Figure 6-6**).

Eradication is only successful when seed production has been stopped and 95% control is not adequate (Zamora et al. 1989). Eradication projects typically move to survey only after the first few years. Eradication is often declared six years after the last seed was produced, but it probably requires more than six years for species with long-lived seeds.

Delaying action does have costs. Higgins (2000) determined that delaying action in control of a weedy species increased the cost of control and decreased the chance of success. Higgins looked at a number of alternatives which included delaying action to build reserves or provide funding for another priority before moving to the invasive plant species, and in each case discussed the result was the same. Delays increased costs of control and reduced the likelihood that a species could be removed.

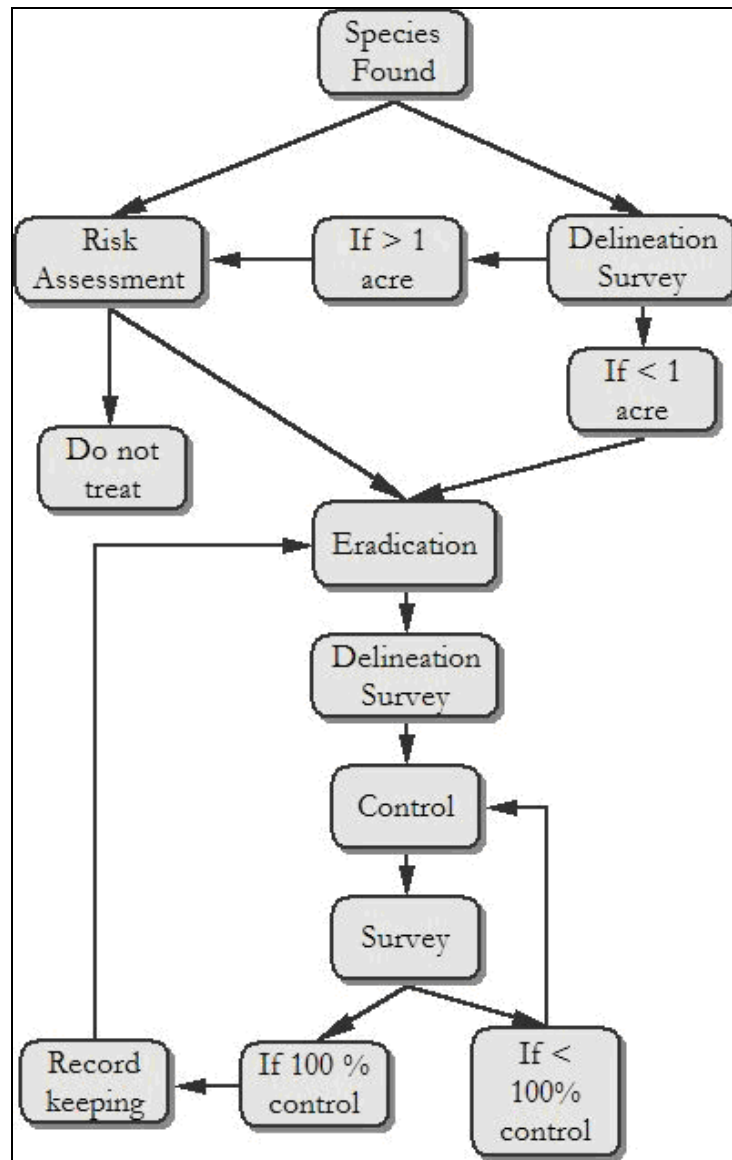


Figure 6-6. Eradication schematic

Mack (2000) argues that small founding populations are highly susceptible to failure because of stochasticity in the environment. By tending plants, often through ornamental horticulture, we allow for founding populations to survive and eventually escape. We have other less intentional ways of tending plants. Consider roadsides as a way we tend plants. Precipitation moves off roads, effectively doubling or tripling the precipitation at the road's edge. Roadsides tend to be disturbed sites with open niches that allow for a species to enter. Then adjacent to the road-

way is the natural system where seeds can disperse from the founding population. Through natural selection, a biotype may be selected that survives in the surrounding environment and begins to move outside the area where we were tending it. So while roadsides may appear to only be corridors for movement, they also can allow founding populations to survive environmental stochasticity and to survive any initial lag phase caused by constriction in the gene pool. Roadside weed management should be an integral part of a management plan.

Increasing Phase (see Figure 6-5):

Once an invasive plant species has moved through a lag phase, is producing new satellite populations, and is able to reproduce across a wider range of conditions, the chance of successfully removing the species goes down. The increasing phase is usually where land managers begin to be concerned about a species. While removal may be possible it usually requires institution of a containment area. The containment area would be an area defined as currently beyond eradication but still limited to where expansion could be prevented by monitoring and eradication of satellite populations. Some control actions may be adopted within the containment area to reduce propagule dispersal but the immediate focus is not removal.

How much time does the land manager have during the increasing phase before the species should be considered at its biological potential and as a permanent resident? The answer to that question is specific to the species. A species that readily disperses like a hawkweed would have a shorter increasing phase than an invasive tree that does not move into a reproductive phase for 6 to 8 years. Species that are capable of long-distance dispersal without human intervention are less likely to be contained than species with limited ability for long distance dispersal. New infestations of rush skeletonweed in Oregon are being found 2 to 5 miles apart but Bohemian knotweed dispersal (mostly by vegetative propagules) tends to be measured in tens of meters. Bohemian knotweed containment would have greater potential for success than rush skeletonweed. Consider proximity to roads, trails, or water to prioritize areas for management, because these features allow movement outside of the containment area

The techniques described for use during the lag phase are still relevant to the increasing phase. Areas outside the containment area could be managed to prevent founding population establishment. In the best of situations, the containment area could become smaller as infestations outside the containment areas are removed.

Biological Potential Phase (see Figure 6-5)

Species that land managers are pressured to manage typically fall into this category. The invasive plant species are now permanent residents and they continue to negatively impact plant community function and interfere with the ability of managers to meet objectives for land use. How can the impact of the invasive plant species be minimized? An integrated pest management approach, commonly used in agricultural production, can be applied. Knowing the biology of the species, a management program could be implemented that takes into consideration those plant communities on which the species has minimal impact (adaptive management). Why expend resources in plant communities where impacts will be minimal? Monitoring populations across a range of plant communities can provide critical information for land managers so that they can focus resources where they will minimize the overall impact of an invasive plant species. Decision tools for making control decisions are central to integrated pest management. Sadly, we do not have the degree of tool development present in agricultural systems and particularly the level of sophistication present for management of insects and pathogens in crop production. Within agricultural systems, decision tools are looked on by scientists more for educational value than for their utility in management (Wilkerson et al. 2002).

In grasslands infested with yellow starthistle, several decision tools exist. Successional stages signified by presence of species at abundant levels can be used (**Figure 6-7**). If even 15% cover of perennial grasses are present, the plant community will not be dominated by yellow starthistle. Perhaps an occasional herbicide application will move plant communities near the 15% cover threshold to a point over the 15% threshold to make it resilient. Timing of grazing can also decrease the impact of yellow starthistle, with cattle grazing at the pre-spine bolting stage (Thomsen et al. 1993), and goat grazing prior to opening of flowers. If mowing is possible it can be used at 5% flowering stage and still prevent seed production.

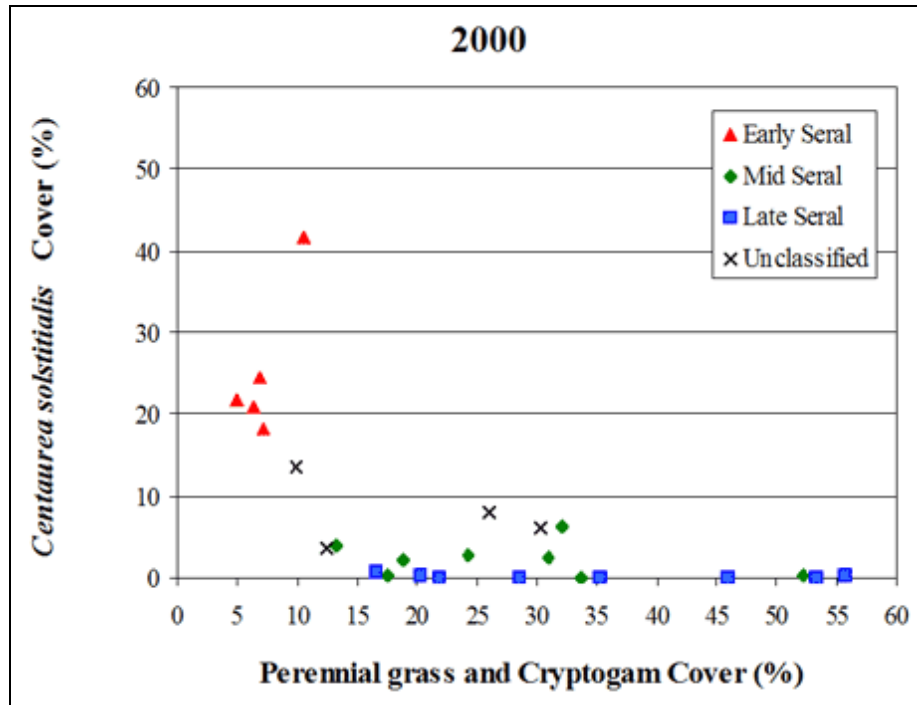


Figure 6-7. Ability of yellow starthistle to dominate plant communities depends on perennial grass cover or presence of a biological soil crust (cryptogam layer) (Robins 2001).

Management of leafy spurge can be aided by a mature collection of decision tools developed through the efforts of Team Leafy Spurge:

(<http://www.team.ars.usda.gov/v2/publications/teamleafyspurge.html>). In North Dakota, grazing of leafy spurge was most successful when both cattle and sheep were used with stocking rates at approximately 3.7 aum/ha. Grazing with either species was not as effective. Utilizing biological control with grazing has also been effective. In Wyoming, if brown flea beetle densities were 6 beetles per net sweep and black flea beetle densities were 14 beetles per sweep, then leafy spurge declined and grasses increased from 31% cover to 84% cover. The leafy spurge manuals suggest that herbicide application followed by biological control and sheep grazing are effective for long-term control of leafy spurge. While these results are not fine-tuned to providing % cover ranges where spraying should be done versus waiting for biological control or sheep to have greater impact, they do demonstrate that working with several tools together can be effective. There are numerous monitoring programs for biological control. Unfortunately those

programs are useful to assess biocontrol agent population health but not their impact on the target. One of the few examples is for yellow starthistle, developed by California Department of Food and Agriculture. They found that 84% parasitism of flower heads by a combination of *Eustenopus villosus* and *Chaetorellia succinea* and any other agent would result in decline of yellow starthistle seed banks.

Other decision tools are in development and there may be a number of them that have not been published and are therefore not accessible to a wider audience. Given the number of invasive plant species that are naturalized, there should be a significant number of decision tools available for use, and this part of the chapter should have the potential to be quite long. Lacking a large set of decision tools, the importance of adaptive management should become clear. As we manage invasive species and monitor the effects of our management we create numerous outcomes that could serve as the basis for decision tool development.

SUMMARY

Determining which species to target for management is a daunting task. Allowing a species to persist could lead to a permanent ecosystem change. Allocating resources to remove a species that won't be a problem prevents use of those resources on an important problem species. Assessing risk continues to improve and access to existing assessments allows informed decision-making that was not possible even five years ago. Prioritizing species for eradication and prevention requires an approach like that taken for New Zealand and the Hawaiian Islands. Determining how to allocate resources to management of existing species can be achieved using assessments like those presented by NatureServe. Neither approach includes a feasibility of eradication as part of the assessment process. Costs of eradication and potential success of eradication should be included to adequately assess whether a species should be eradicated or managed.

We have decision tools to aid our management for species that have not reached their biological potential. We need to develop many more decision tools for invasive plant management in range and forest settings when those species are naturalized and permanent residents of our plant communities. Some well-studied plant species have decision tools available, yet even in those situations, the decision tools rarely are synthesized to provide a comprehensive treatment of tools that are useful to land managers for decision making.

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