

## Chapter 4. Inventory

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### BACKGROUND

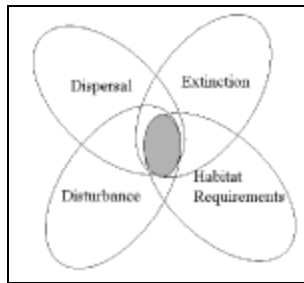
#### How Plant Communities Are Structured

**Niche-Assembly Theory.** In order to conduct an inventory, we need to begin with what we know about plant distributions and processes that may influence their distribution, then use that knowledge to develop the inventory methodology. The theories that most closely pertain to the ideas of plant distribution are those associated with how plant communities are structured. These can be grouped into two general categories. The most prevalent view is that plant communities are groups of interacting species whose presence, absence, or even relative abundance can be deduced from “assembly rules” that are based on the functional roles of each species (inherently defined ecological niches) (MacArthur, 1970; Levin, 1970; Diamond, 1975; Weiher and Keddy, 1999). According to this theory, species coexist in interactive equilibrium with the other species in the community. The stability of the community and its resistance to invasion are derived from the adaptive equilibrium of member species, each of which has evolved to be the best competitor in its own ecological niche (Pontin, 1982). The theory assumes that the species, which can co-occur within a community, are determined by interspecific (between species) competition for limited resources and other biotic interactions. This theory is particularly appealing to land managers, because it has the built-in assurance that communities can be constructed or manipulated in such a way to fill existing niches, making the community stable and resistant to invasion (Sheley et al., 1999). This theory would also suggest that disturbance that removes plants could open niches and thus be the primary mechanism allowing invasion of exotic species. In addition, disturbed areas would be a good predictor of exotic species distribution.

**Unified Neutral Theory.** The other general theory that has emerged to explain commu-

nity structure is based on the assumption that communities are open, non-equilibrium assemblages of species thrown together largely by chance, including genetic drift and random dispersal (Hubbell, 2001). Thus, this theory assumes that species come and go, and their presence or absence is dictated by random dispersal and stochastic local extinction. Hubbell (2001) called this the *Unified Neutral Theory* and contrasted it with the most prevalent theory described above, which he called the *Niche-Assembly Theory*. The Unified Neutral Theory is far less appealing to land managers because it suggests that one can have little control over the processes determining the species composition in plant communities in general. The empirical evidence, particularly from plant communities, tends to accumulate in support of the Unified Neutral Theory: species composition, abundance and relative abundance in plant communities are so variable, at the scales that we tend to measure them, that it is difficult to conclude that assembly processes are determining the community structure. That is, the Unified Neutral Theory is more of a null hypothesis and we rarely produce evidence to reject it. This doesn't mean that the ecological niche processes are not acting, it just suggests that their relative importance in determining the structure of the community may often be weak. Thus, land managers can take heart in managing vegetation based on Niche-Assembly Theory, but they must have realistic expectations and understand that it may be limited in its deterministic potential. Thus, management recommendations cannot be prescriptive; instead, an adaptive management approach including local experimentation must be incorporated in the management plan for a plant community. What this all means for a weed inventory is that one must understand that exotic species distribution is likely to have a large random component and thus sampling methods for inventory and monitoring must be appropriately structured.

So how do we apply these theories to weed inventory and monitoring? A mix of the two theories provides a perspective for managers to structure their exotic species inventory and monitoring. We suggest an approach that first tries to determine if the distribution of exotic species is suggestive of specific underlying processes (**Figure 4-1**), and then structuring the sample of the management area to take advantage of the knowledge of the processes found to be associated with weed distribution. The underlying assumption for the remainder of the discussion about inventory is that the management area is too large to search in its entirety for the weeds. Thus, it must be sampled. In addition, the sample must be structured (stratified random) for the express purpose of statistically predicting current and future patch locations, because the entire area cannot be observed.



**Figure 4-1.** Diagram of interacting processes that can determine the success of an invading exotic species. The shaded area is where conditions are adequate for invasion to be successful. At any given time or place the relative contribution of any one of these factors can vary in importance of determining the success of a new invader. Similarly, each factor has a large random component.

### WHY INVENTORY?

Under most land management scenarios, it is not possible to observe all of the plants or even plant communities in a managed area. In most cases we do not know which non-native species are present within a managed area, their frequency or their distribution pattern; how much their distribution is changing, and finally, what impact they are

having on the endemic ecosystem. It is only armed with all of this information that land managers should begin to control or manage exotic or invasive species.

The first step to managing invasive plants on a tract of land is to conduct an inventory of the species present. First we need to know both which species are present and where they are present. Secondly, we need to know which of the exotic species are invasive. Two basic approaches to weed inventory have emerged with somewhat different goals.

### Alternative Approaches to a Weed Inventory

The first goal is the survey approach that simply uses previous intuition about weed distributions to search for the weeds, and the usual intention is to manage (kill) them once they are found. In some cases, this approach becomes a survey with the intention to monitor the results of management. Thus, once a weed population (patch) or meta-population (patches) are found, the position is recorded (geo-referenced) on a map or with a Geographic Positioning System (GPS) and at the same time the spatial extent of the patch is estimated or measured. The spatial extent is sometimes calculated by actually measuring the length and width of the patch (feet or meters), but more often by estimating the area in categories at a coarse resolution (e.g. <0.1 acres, 0.1 to 0.5 acres, 0.5 to 1.0 acres, etc.). The assumption of this type of approach is that it leads to monitoring. Someone can return to the position of the patch at some future date, using the GPS location and re-estimating the spatial extent. The information from the spatial extent estimate or measurement can then be used to estimate the rate of population increase.

#### *Advantages of the survey approach:*

1. Capitalizes on integrated knowledge of the person conducting the survey.
2. May be a time-efficient, and thus cost-efficient way to manage small infestations (patches).

3. Maybe best approach if the total management area is small and can easily be 100% observed.
4. A rapid method to estimate changes in spatial extent of the metapopulation (patches) if it is growing very fast (i.e. >5-10 m radius/year).

***Disadvantages of the survey approach:***

1. Highly variable results because of variation in people conducting the survey and making estimates of spatial extent.
2. Little shared knowledge is gained about the factors that may help predict the distribution of a given weed species.
3. No use of prior knowledge to stratify sampling to conduct the survey/inventory.
4. No means of estimating accuracy or completeness of the inventory. Variability in results and inaccuracy increase with the size of the area to survey/inventory.
5. The monitoring that follows from the survey is not likely to detect spatial extent change within a short period of time (2-3 years), particularly when a relatively coarse spatial resolution and/or categories are used. Even if finer spatial resolutions (length and breadth measurements) are used, detecting changes would still be more likely to take 5-10 years for most weeds based on their typical rate of spread.

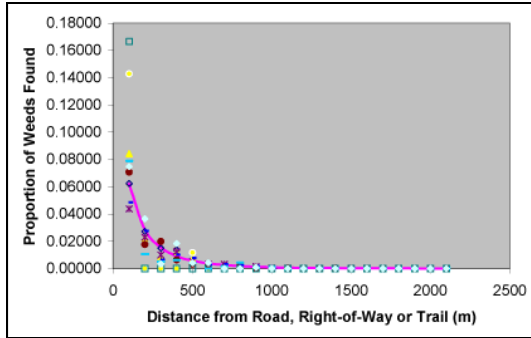
Surveys are generally directly linked to management and often do not include a monitoring phase prior to management. Thus, there is the implicit assumption that any weed found need to be managed. The management of some exotic plant populations may be more destructive to the environment than the presence of that exotic. There may be some environments where the exotics are not invasive or significantly interfering with ecosystem function and thus, their impact does not warrant potentially environmentally harmful management.

A different approach to weed inventory overcomes the disadvantages of the survey approach described above. The goal of this approach is to utilize an inventory to discover factors that may help explain the exotic species distribution, and if significant correlations are observed with environmental variables it would be possible to create probability maps of where an exotic species was more likely to be found. Plus, using this knowledge of exotic species distribution, metapopulations located with the inventory can be monitored and the impacts of the species experimentally examined for the different variables, which subsequently leads to prioritization for management. This inventory approach uses *prior knowledge*, *first principles* and *preliminary data* to design the inventory.

Prior knowledge may include a list of the exotic species identified in the management area and region, previously observed metapopulations in the area, and scientific literature on the biology and distribution of the exotic species that may be present in the management area.

First principles relate to the ecological processes that interact to determine where any particular exotic species is located. For example, a first principle of plant dispersal is that there will be more propagules near the source and the propagules will decline along a diffusion gradient with increased distance from the source (**Figure 4-2**).

Since most species are introduced via human activity, source areas can be assumed to be associated with areas of human activity. Thus, in forests, grasslands or ranchlands, roads, power lines and other areas of human-mediated disturbance will serve as source areas and one may expect weed occurrence to decline with increased distance from these sources into areas of no or low human activity. Another first principle example is



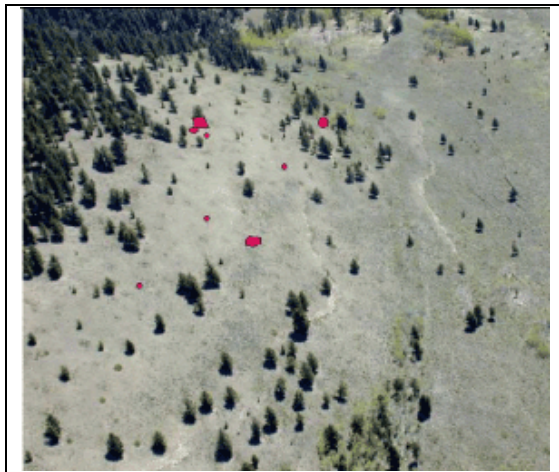
**Figure 4-2.** The proportion of weeds, by species (different symbols), found along continuous transects oriented perpendicular to human activity (roads and trails) in the Northern Range of Yellowstone National Park (Rew et al., 2002).

based on species-specific habitat requirements. Annual colonizing species usually require recently disturbed soils with a lack of competitors. Many colonizing species require higher light intensities than native species and thus cannot tolerate extensive shade from the canopy of a forest, so they will only invade meadows and grasslands. Other species may be moisture limited and thus are more likely to be found in riparian plant communities.

Preliminary data is another piece of information that can sharply increase the accuracy and completeness of the weed inventory. Preliminary data should be used to verify first principles determining weed distribution. For example, use the first season of an inventory or the first part of a season, to verify that first principles or specific driving factors are defining the distribution of weed species (see Figure 4-2 for example).

Identifying some first principles will allow stratification of sampling that increases the probability of finding all of the locations for any given species in the inventory area. Stratified random sampling can further allow one to predict with an estimated confidence interval where any given species will be located. In addition, stratified random sampling allows one to more completely

identify the possible range of habitats where any given species is likely to occur. The value of learning the range of habitats is useful in stratifying sample populations for monitoring. Some species will be much more invasive in some habitats than others and this knowledge will again be helpful in prioritizing management. In addition, this sampling method will allow us to build correlation models to predict the occurrence of each weed species so that areas not infested but with high likelihood of invasion can be monitored for new colonies.



**Figure 4-3.** Red areas are yellow toadflax weed patches in an approximately 500-acre area. The total area infested by the weeds is less than 0.1 acres. This is a typical problem for weed inventory, low frequency of weed occurrence. Thus, we need to predict where the weeds will be or provide an estimate of the probability of weed occurrence over the landscape.

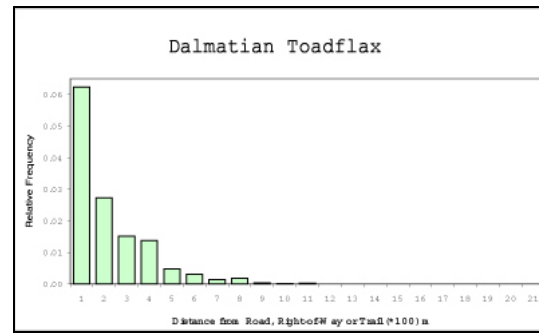
## STEPS IN CONDUCTING A WEED INVENTORY

### Step 1: Pre-sample to Identify Inventory Sample Stratification

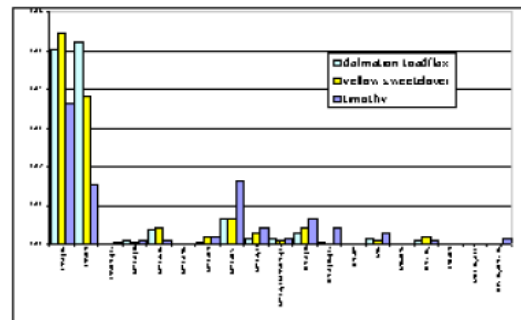
The pre-sample is typically based on two assumptions: (1) weed occurrence will decrease with distance from human activity,

and (2) weeds will be more frequent in some plant communities (e.g. grass-, forb-, and shrub-dominated communities rather than forested communities). The pre-sample is established to verify these assumptions. Therefore, one should establish transects perpendicular to roads or other human disturbed areas that are logical sources for weeds and sample continuously for a 1- to 2-km distance (straight line transect using a compass) away from the road (or other forms of human activity). Each time the sampler observes a weed species within 5 m (10-m-wide transect) of the line it is recorded along with its geographic position (using the GPS) and environmental data (e.g. habitat, dominant vegetation, aspect). In addition, each time a new habitat type is entered, the sampler will record the habitat type and other variables and record the position. It is best to establish the transects in a GIS prior to going to the field to avoid sampling bias.

In the example shown in **Figure 4-4**, there was a clear relationship between distance from roads and trails and the number of exotic plant sightings. So we concluded that the source of exotics (roads and trails) and dispersal from that source was useful information and could be used to stratify future sampling for the inventory. In addition, we found that most of the exotic plants observed were in a few vegetation habitat types (primarily the shrub-, forb- and grass-dominated types rather than the forest habitat types (**Figure 4-5**). Thus, we could further structure our sampling to increase the chance of finding a high proportion of the exotic species metapopulations (group of populations or patches). One aspect in the analysis of the preliminary data that should be noted is the correction of species occurrence relative to distance from human activity. It is often possible that transects are established and later found to intersect or come close to areas of human activity. Thus, any areas of human activity, not already mapped, should be mapped and distance to weed observations should be corrected.



**Figure 4-4.** Distribution of a representative species, Dalmatian toadflax, relative to roads and trails along continuously sampled 2 km long transects on the Northern Range of Yellowstone National Park (Rew et al., 2002).



**Figure 4-5.** The frequency of a representative set of weed species in vegetation habitat types on the Northern Range of Yellowstone National Park (Rew et al., 2002).

## Step 2: Sample for Inventory

Next, stratify your sample based on relationships detected in resample. (See Chapter 5, Yellowstone Inventory Case Study, for an example of how an inventory was conducted.)

If the common relationship between weed frequency and distance from human activity is found or any other relationship between some factor and weed frequency is found, there are two considerations. One consideration emphasizes locating the most weed occurrences; the other focuses on getting an

accurate estimate of the overall frequency of any given weed species.

If the objective is to get an approximately complete map of the weeds then one would want to concentrate sampling in the areas predicted to have the greatest frequency according to the correlated factor(s) (e.g. within 0.5 km of roads, right-of-ways and trails and in the grass and forb meadows if they were found to be good correlates of the weeds).

If the objective is to have equal confidence in finding weeds even where they are known to be at low frequency, one would need to increase sampling in the low frequency areas relative to the high frequency areas as determined by preliminary data.

We have tried to outline logic for conducting an initial assessment of the exotic species that may reside in a management area. We have provided special definitions to the terms “survey” and “inventory” to differentiate between approaches for the initial assessment. The important elements to remember about the logic for a survey or an inventory is what one intends to do with the information about where the exotic species reside within the area that one manages. Thus, if the area that you manage is large and cannot possibly be entirely observed, then the inventory approach that we describe offers a number of advantages over the survey approach. However, if you think that you can observe the entire area and map all of the weeds with confidence, then the survey approach can be just as effective as an inventory method.

## REFERENCES

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