ESTABLISHING THE REPLICATION AND DISTRIBUTION GOALS FOR ECOLOGICAL COMMUNITIES IN THE NORTHERN APPALACHIANS

Objective

The objective of this section was to determine the number of occurrences of each community that needed to be represented in the reserve system and how those occurrences should be distributed across the ecoregion. Conservation of multiple examples (i.e., replication) of each ecological community, stratified across the community's geographic range, is necessary to capture the variability of the community (Noss and Cooperrider 1994). Equally important, replication of viable community occurrences provides redundancy to ensure persistence of the target in the face of environmental stochasticity. Stabilizing the long-term persistence of a community through a reserve system is a tradeoff between minimizing the probability of extinction in each individual reserve (the viability assessment of an occurrence) and distributing risk the over a larger number of protected reserves (replication of the occurrences across gradients) (Quinn and Hastings 1987). As such, it is analogous to failure time of mechanical systems with redundant subunits (e.g., back up engines on an airplane, Waring 1985) and discussed as increasing the subunit reliability or redundancy. This section is concerned with the redundancy and replication of occurrences and assumes that each occurrence has already met the viability criteria concerning its size, current condition and landscape context.

Primary Factors Considered in Establishing Numeric Replication Goals

There is little empirical or theoretical scientific research that addresses replication goals specifically for ecological communities, thus, concepts were adopted from species viability theory (Shaffer 1981) and system reliability theory (Polovco 1968). The four factors considered were:

1. The theoretical baseline number of replicates established for the community across its entire range
2. The scale and spatial pattern of the community in the ecoregion;
3. The proportion of the community's total distribution contained within the ecoregion;
4. The resolution of the vegetation classification used in the ecoregion

My first step was to consider the number of replicate examples needed to conserve a community across its entire known distribution (e.g., the restricted communities). Subsequently, specific goals for the community in the Northern Appalachian ecoregion were then derived by taking into account the occurrence scale and the proportion of each community's distribution that was found within each ecoregion. Lastly, further adjustments were made based on the resolution of the classification with respect to the type.

Determining the baseline number of replicates: The field of population viability analysis (Shaffer 1981) offers some insights for communities. For example, replication goals could be established for a community based upon PVA goals for certain species that are restricted to that community. However, because it is likely that not all examples of a community will harbor a particular species, a conservative approach would be to adjust upwards any replication goals based upon such an analysis. Research on population viability analysis, however, has focused on the level of an individual population. Some studies, however, have considered the importance of multiple populations (Soule and Simberloff 1986, Quinn and Hastings 1987, Harrison and Quinn 1989, Morris et al. 1999). In developing a biodiversity conservation plan for Florida, Cox et al. (1994) recommended that 10 viable populations be conserved for each of their target species. They utilized the model of Quinn and Hastings (1987) to develop a relationship between the number of replicate populations protected and the probability of each population's persistence. They assumed that each population had a 30% probability of persistence and therefore the protection of 10 populations would give a greater than 90% probability of at least one population persisting for 100 years. This same approach can be applied to communities. However, in the case of species, the persistence of at least one population could allow for the preservation of the species, given captive breeding and re-introduction efforts. It is less clear that the persistence of only one occurrence of a community could as easily lead to the preservation of the type. This also suggests that goals for communities be adjusted upwards, from those indicated by the PVA model, to ensure that several examples persist. [Implicit, to some extent, in the 50/500 guideline is a ten-fold increase as one moves from short-term to long-term persistence which may be spatially analogous to moving from local (short-term) to regional (long-term) scale. However the guideline was not intended for determining how many replicate metapopulations need to be conserved (Soule 1980)].

Scale and pattern: By definition, the reserve system must contain viable examples of communities at all scales from matrix-forming to small patch (defined in chapter 2). I assumed that the inherent probability of persistence increases with the size class of the community type. Thus, relatively more examples of patch communities are necessary to buffer against the high probability of attrition over time due to stochastic processes. Additionally, patch communities are smaller in extent, and multiple examples are needed to add up to substantial area and viable population sizes for specialist component species. Given these considerations, goals for representing small patch types in conservation sites should be relatively higher, followed by large patch types, and then matrix-forming types (see chapter 2 for definitions).

Global range and distribution pattern: Theoretically, the number of examples of each type of community preserved within conservation sites in an ecoregion should reflect the percentage of each community's global distribution contained within that ecoregion. For example, consider two communities, A and B, for which a total global objective was set at 100 examples each. If the distribution of community A was restricted to the Northern Appalachian ecoregion then all 100 examples would have to be represented in the Northern Appalachian reserve system. By contrast, if community B occurred across 4 ecoregions than each ecoregion need only conserve 25 examples for the overall goal to be met. Scaling in this way puts appropriate weight and emphasis on endemic communities while insuring that widespread types receive representation but not over-representation with respect to endemic communities. The four distribution categories I used, Restricted, Limited, Widespread, and Peripheral, (defined in chapter 2) were based on an estimate of the community’s relative endemism. Below I reason further that different examples of these communities should be stratified across the ecoregion more rigorously to better represent the variation within the community. Conversely, the goals for widespread communities, which will ultimately be conserved by a group of ecoregions, may be lower within any given ecoregion and may be stratified less rigorously.

Peripheral communities, those communities that occurred near the boundaries of the ecoregion but were more typical of other ecoregions, were dealt with on a case-by-case basis as no single guideline appeared to be appropriate for all, or even most, cases. Some occurrences of communities at the edge of their distribution may be of significant value due to their ecological variability, but the value of peripherals (Lesica and Allendorf 1995) is related primarily to peripheral populations of species. Because the geographic range of a community is likely different than the ranges of most of its constituent species, a peripheral community occurrence may not contain many peripheral populations. Peripheral occurrences of communities, however, may still play a valuable role in persistence of the community under predicted changes in global climate (Hunter 1988).

Classification resolution: I used the *association* as the basic unit for describing and counting community examples. In several cases, however, I was unable to accurately describe the associations within an alliance because of a paucity of data or due to confusion in the descriptive information. In these instances I worked from the alliance level and estimated the expected number of associations by examining the distribution of the alliance across biophysical gradients in the ecoregion. Subsequently, I multiplied the goal by the expected number of associations. Thus, I used the general principle that the coarser the level of classification resolution of the community target the more examples and spatial stratification will be needed to ensure that the target's variability is captured. The numeric goals listed below assume that the community targets are at the association level of the NVC or an equivalent level of resolution. If the targets were of a coarser grain, then the replication goal in the portfolios of sites was set relatively higher.

The Distribution and Stratification of Community Examples Across the Ecoregion

To maximize the coarse-filter value of communities, buffer against degradation in one portion of its range, and allow for possible geographic shifts over time, it is important to conserve examples of each community across the full range of conditions within which they occur (Hunter 1991, Noss and Cooperider 1994, Soule and Sanjayan 1998). The full range of conditions, in turn, may be characterized as geographical and biophysical gradients in the ecoregion and summarized as biophysical subregions. With this intent, I developed the hierarchically-nested subregions based on an analysis of ecological land units (ELUs). ELUs were assumed to reflect explicit relationships with the communities (see chapter 2). Thus, to ensure the representation of communities across gradients, I set stratification goals for each community across ecoregional *subregions* that exhibited a variety of contrasting biophysical characteristics.

As with the numeric goals, I assumed that the degree to which a community needed to be represented across the biophysical subregions of the ecoregion was primarily a function of how restricted the community was to the ecoregion, as well as of its distribution and variability within the ecoregion. Restricted or endemic communities required a more thorough and finer-scale stratification of the ecoregion as their entire range of conditions is represented within the ecoregion. Conversely, widespread communities required less intensive stratification within the ecoregion, as they are already partially and naturally stratified among other ecoregions. Using the nested hierarchy, I set the stratification levels at four subregions for restricted communities, two subregions for limited communities and one (or no stratification) for widespread communities. For example, consider two communities, A and B, both of which occur throughout the entire ecoregion. Community A is an endemic community while B is widespread. In my model, community A receives a stratification goal of four subregions. This translates into some examples needing to be conserved in the Adirondack / Tughill subregion, The White and Green Mountain subregion, The Northern Boreal subregion, and the Southern Boreal subregion. Community B receives a stratification goal of one, meaning that the examples may be conserved anywhere in the ecoregion as it already naturally stratified across other ecoregions and thus does not require as much stratification within this ecoregion.

To illustrate the utility of the nested hierarchy of subregion further consider community C, which is endemic to the ecoregion, and occurs only within the mountainous regions (this translates to the community actually being restricted to the Northern Appalachian Mountain subregion). Because it is a restricted community it receives a stratification goal of four, but in this case the goal translates into some examples needing to be represented in the Tughill Plateau, some in the Adirondacks, some in the Green Mountains and some in the White Mountains. These are finer subregions then were used for restricted community A, which occurred throughout the entire ecoregion.

Intentionally, I did not force the stratification scheme down to the level of individual subsections. This was because there is an ecological trade-off between the stratification of occurrences across subsections, which captures variation and distributes risk, and the clustering of occurrences to insure communication (e.g., migration, dispersal) between occurrences that is important to the viability of many communities (Forman 1995). This tradeoff becomes increasingly important at smaller geographic scales. Thus the 4/2/1 scheme insures a broad level of stratification across the ecoregion but allows for clustering within a subregion. Initially, I anticipated needing some criteria as to which of the viable occurrences were the best to conserve within a subregion. Operationally, however, there was rarely enough known viable occurrences within a given subregion to meet the minimum numeric goals. This fact rendered the finer level distribution choices a rather theoretical point. In summary, I imposed enough stratification of the occurrences across the ecoregion to insure that general geographic and ecologic variation was represented, but left flexibility in the final solution with regard to specific locations within a subregion.

Establishing the Initial Conservation Goals for Patch Communities

There are numerous ways to combine and weight the factors of geographic scale and spatial pattern, global range and distribution, and classification resolution. I developed initial conservation goals for communities by synthesizing the numeric and stratification goals for communities of differing patterns and distribution (Table 4.6). My reference point for developing the recommendations was a theoretical small-patch community, endemic to the ecoregion, and distributed throughout the ecoregion (some of the fen types meet this description). Building upon the above discussion, I initially considered a baseline goal of 10 occurrences for this type of community at the association level of the NVC. Subsequently, I doubled the goal to 20 based on data and occurrence descriptions that suggested less than half of the occurrences contained all or any of the associated rare or uncommon species (unpublished data in Natural Heritage BCD descriptions). Additionally, I reasoned that small patch communities have the highest likelihood of attrition due to their small size and thus the assumption of a 30% probability of persistence for each occurrence may be too high. As the community was restricted to the ecoregion, then, by definition, all 20 must be protected within the ecoregion and the stratification goal must be relatively high (4 subregions). This translated into a total goal of five occurrences in the Adirondacks/Tughill region, five in the White/Green mountains, five in the Northern Boreal region, and five in the Southern Boreal ecoregion. For large patch or less restricted communities the goal was sequentially decreased (Table 4.6).

I emphasize that these numeric goals are initial minimum objectives used to scale priorities, measure the effectiveness of the reserve system, and uncover inventory gaps (chapter 4). As more empirical and theoretical work in this area becomes available, it may be possible to establish more realistic estimates of the number of occurrences needed for each community type and modify these preliminary goals into long-term objectives.

Table 4.6. Initial conservation objectives for community occurrences in the Northern Appalachian ecoregion.

<table>
<tr><td>MATRIX COMMUNITIES</td><td colspan="2">3 per each of the 10 primary subregions, distributed across primary gradients.</td></tr>
<tr><td>PATCH COMMUNITIES</td><td>Large Patch
Stratification goal in parentheses</td><td>Small Patch
Stratification goal in parentheses</td></tr>
<tr><td>Restricted/Endemic</td><td>16 (4)</td><td>20 (4)</td></tr>
<tr><td>Limited</td><td>8 (2)</td><td>14 (2)</td></tr>
<tr><td>Widespread</td><td>4</td><td>4</td></tr>
<tr><td>Peripheral</td><td>*</td><td>*</td></tr>
</table>

*Objectives determined on a case by case basis.

Establishing the Initial Conservation Goals for Matrix-forming Communities

I used a slightly different approach for establishing goals for matrix-forming communities as matrix occurrences were mosaics of several types. Most of the matrix-forming types were restricted (e.g., the red spruce forests and montane hardwood types), and some were limited (e.g., certain low elevation forests and early/mid successional types). Additionally, distribution information on the associated coarse-filter vertebrates suggested that the majority of them had independent range patterns that were correlated with the ecoregions themselves or other broad gradients within the ecoregion. Moreover, the role of the matrix sites in conserving the integrity of the ecoregion itself suggested that the sites be geographically distributed as thoroughly and evenly as possible.

An initial minimum of 1 for each of the 27 subsections seemed appropriate to insure a full geographic coverage. However, to make this more ecologically based and to allow more flexibility in the final solution, I adjusted this slightly to 3 matrix sites in each of the ten primary subregions with attention paid to the biophysical gradients within the ecoregion as expressed in the ELU analysis (Figure 3.8) and the subregions. Because the subregions partition the ecological diversity fairly evenly, this number could be thought of as parallel to the minimum number of samples it would take to represent the variation within each of the ten subregions. In theory, matrix occurrences could be added to a reserve network within each subregion in a complementary way until the amount of new ecological land units (ELUs) being added to the network levels out (analogous to plotting a species-area curve; Conner and McCoy 1979). In practice this is unlikely to be feasible as not all land is available nor is there money currently available to purchase it all. However, three per subregion is likely to provide a good starting point, an initial minimum, although ultimately it may not be enough to conserve all biodiversity.