

National Park Service

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Measure Description Summary

Landscape Pattern

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Revision History

Revision #	Date	Revision Summary	Revised by
0.1	20090206	Initial version	John Gross
0.2	20090619	Extensive revisions throughout	John Gross
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Background and Justification

Landscape pattern – the spatial attributes of habitat patches and landscapes - profoundly influences ecosystem properties such as the flow of materials, species movements, effects of edges between patches, and the dynamics of populations (Levin 1981; Andrén 1994; Hansen and deFries 2007; Turner 2005). Landscape patterns in the United States reflect the dynamics of natural ecological processes (Watt 1947), biophysical constraints (Whittaker 1967; Stephenson 1990), and extensive modification resulting from a very long history of human occupation (Riitters et al. 2002; Heilman et al. 2002; Mann 2005).

For evaluating effects on park resource, the attributes of landscape pattern of most interest are typically those modified by human activities. Altered landscape patterns are the result of converting natural habitat to an altered state, usually accompanied by a loss of habitat. I.e., a conversion from habitat (e.g., forest) to a non-habitat type (road, agricultural field, parking lot, etc.). Habitat loss, per se, is usually measured as the area of a land cover type, perhaps modified by proximity to something else (water, road, etc.), and while area and pattern are usually correlated, they are typically measured via independent methods. Nonetheless, the effects of area and shape are difficult to separate and they are often closely related (Trzcinski et al. 1999). Landscape composition, as described by proportion of cover types, is a very important attribute of a system, and there are strong theoretical relationships between cover and attributes like landscape percolation (Gardner and O'Neill 1991).

McIntyre and Hobbs (1999) provide a useful framework for conceptualizing human effects of landscape pattern. With little or no human intervention, landscapes are initially intact. As impacts increase, landscape are described as variegated, fragmented, and relictual, reflecting increasing degrees of habitat destruction, isolation of patches, and degree of modification.

Loss and the resulting fragmentation of habitat is one of the most pervasive effects of land use intensification. The effects of fragmentation have been extensively studied, debated, and reviewed (Andren 1994; Harrison and Bruna 1999; Debinski and Holt 2000; Fahrig 2003; Ewers and Didham 2006). In summary, the effects of habitat fragmentation vary tremendously with the habitat preferences and requirements of different species, effects on predators and competitors, parasites, scale, at the time and magnitude of habitat changes (Cousins 2009). Landscape patterns at multiple scales affect species, and the effects of landscape composition or pattern may be detectable only at an appropriate scale (Wiens et al. 1987; Thompson et al. 2002).

Long-lived plant species or communities may not respond significantly to landscape changes for decades or centuries. While there is a consensus that landscape pattern is extremely important, the factors must noted (and others) mitigate against broad generalizations about the impacts of landscape pattern on ecological resources.

Despite all the complexity, pattern metrics seek to describe elements of the landscape that reflect attributes that are ecologically relevant to many species. Important spatial attributes include landscape composition, patch area, patch shape, isolation or connectance of patches, density of habitat at different scales, core habitat, and the contrast between patches (edge contrast). Table 1 articulate some of the effects of landscape pattern, and how they may vary with scale. Multiple

metrics are required to capture these features, and no single metric or small set of metrics will address information at all scales or for all issues.

Monitoring Questions and Objectives

We provide general monitoring questions, recognizing that parks or I&M Networks will likely need to be more specific to address regional ecosystem characteristics, the area of analysis, and suitable comparisons. General questions include:

- How has the size and number of forest and non-forest patches of natural habitats changed the lands surrounding parks? For large parks, how have the sizes of patches within the park changed?
- How has the area of ‘core’ habitat changes over time?
- How has the shape of patches in lands within and adjacent to parks?
- How has the connection of patches of natural habitats changed within parks and in connections to key habitats outside parks?
- How has the isolation of parks changed over time?

Anticipated Inferences and Uses

- Provide information to facilitate assessments of species-specific habitat requirements.
- Evaluate condition and integrity of the landscape at a very broad level.
- Provide context for evaluating status, trends, and consequences of changes in other metrics, such as changes in housing density, roads, and land use.
- Identify locations that retain the larger and more important intact areas of habitat that may be important to sustain park resources.
- Identify opportunities for cooperative management, conservation, and education.

Metrics

Pattern metrics can be categorized in many different and non-exclusive ways. Pattern metrics can describe individual patches (size, shape), properties of a cover classes (connectivity, isolation), or landscape-level metrics that are functions of the composition and arrangement of patches throughout the entire area of analysis (richness, evenness, diversity). Landscape

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composition metrics respond to the abundance and variety of patches within the entire landscape, but they do not explicitly consider the location, size, shape, or spatial configuration of patches.

Spatial configuration is difficult to quantify in simple measures, and most measures of spatial configuration are of little value by themselves. Some metric, like patch size distribution, reflect the aggregate of individual patch characteristics across an area of analysis, while others measures, like isolation or connectivity, describe the specific spatial relationship between patches.

Description of pattern metrics can further be divided between those that describe *structural* versus *functional* characteristics of the landscape. Structural metrics measure physical attributes without regard to any specific species or ecological function. Patch size distribution, and nearest-neighbor distances between patches are examples of structural pattern metrics. The determination of structural pattern measures are (in theory) invariant across applications.

By contrast, *functional* pattern metrics measure spatial landscape attributes that are relevant to properties of specific species or processes. Functional metrics thus require parameters that apply to focal species or process, and different applications may yield different results. Connectivity measures are typically functional, and they include parameters that account for dispersal abilities of a species or group of species. For example, graph analyses can evaluate landscape connectivity at a scale relevant at the relatively short movements characteristic of amphibians (Lookingbill et al. 2008), or at broader scales that reflect the movement abilities of species like spotted owls (Keitt et al. 1997). A key factor in all these analyses is the selection of what constitutes the ‘patch’ and what constitutes the ‘matrix’.

There are many excellent reviews of landscape metrics. The FRAGSTATS web site provides a particularly lucid overview.

There is a confusing plethora of landscape metrics that easily calculated using widely available software such as *r.le* (Baker and Cai 1992), FRAGSTATS (McGarigal and Marks 1995), and Patch Analyst (Rempel 2009). These packages facilitate computations using vector or raster-based landscape maps. The basic attributes of most of these measures have been studied, and it is apparent that many measures are highly correlated (Cain et al. 1997; Riitters et al. 1995; Calabrese and Fagan ; Cushman et al. 2008).

We selected pattern metrics (Table 1) that are informative and relevant to many natural resource issues, that can be repeated over time, and that are likely to be sensitive to the more common types of landscape change.

Table 1. Landscape pattern metrics and their importance. These metrics can be sensitive to both the area of analysis, and to the scale at which the metric is defined.

Metric	Description	References
Composition	Proportion of area. Usually an aggregate class (forest/non-forest, natural/converted). Can be elegantly expressed at multiple scales.	Heinz Center 2008a (pattern report); Riitters et al. 2002; Wickham et al. 2007, 2008
Patch size distribution	Simple and understandable measure. Does not describe spatial relationships between patches.	Turner 1989; Gardner et al. 2008 (and many others)
Landscape	A pixel-based, structural approach to identify specific	Vogt et al. 2007a, 2007b, 2009;

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morphology	types of landscape elements. The key types are described below. Analyses used by NPScape are based on maps that aggregate classes in to forest/non-forest, or natural grassland/non-natural-grassland. See text for a more detailed and complete description.	Riitters et al. 2007, 2009.
- Core	Pixels that are within a patch, and more than a defined 'edge' distance from a non-patch type.	See morphology refs.
- Edge	Pixels within a defined distance from the boundary of a patch (e.g., forest) and non-patch (e.g, non-forest). We report analyses with edges of 30 m (1 pixel) and 120 m (4 pixels).	See morphology refs.
- Connector	A cluster of non-core pixels connected at two or more locations to edge.	See morphology refs.

Morphological Pattern Analysis: Core, edge, corridors, perforations, etc.

Morphological spatial pattern analysis (MSPA) is based on pixel-level analysis of cover maps, using image segmentation to classify individual pixels into a set of pattern types. The core types are core, islet, perforation, edge, loop, bridge (=corridor), branch, and background. Vogt et al. (2007a) describe the advantages of this method over approaches that require identification and delineation of specific patches. For NPScape, two key advantages are (1) an ability to apply the algorithms over very large spatial extents, and (2) the greater sensitivity of pixel-based maps and analyses to detect changes in patterns over time.

Vogt et al. (2007a) describe the process of MSPA and provide an example application. Riitters et al. (2007, 2009) and Ostapowicz et al. (2008) examined the behavior of the metrics across scales and in landscapes with various statistical properties. Vogt et al. (2007b, 2009) focused on the use of MSPA to characterize landscape connectivity and identify corridors. Software used to calculate the landscape measures is part of the GUIDOS package, available from the European Commission Joint Research Centre (<http://forest.jrc.ec.europa.eu/download/software/guidos/>).

We provide results of pattern analysis at multiple scales because species and processes response across such a broad range of scales (see Table 1).

Forest and Grassland Density

Forest and grassland area density are calculated using a moving window analysis. First, a square neighborhood (window) for analysis is defined by the number of pixels on each side. Then proportion of pixels in the window of a particular type (forest or grassland in this case) is calculated and assigned to the pixel in the center of the window (Riitters et al. 2002; Wickham et al. 2007, 2008).

The files names 'fden' and 'gden' indicate 'forest' or 'grassland' density, respectively. The number (7, 13, ...729) in the filename refers to the number of pixels on a side in the moving window analysis.

The equivalent window sizes in hectares are $(7*7) / 0.09 = 4.41$ and so on for maps created from Landsat (30 m resolution) data. The last two characters in the input file names are lower case state abbreviations.

Issues and Assumptions

A key assumption is that land cover land use classes represent a single homogeneous category based on the dominant vegetation type. At the level of the NLCD, data do not differentiate patch/stand characteristics such as stand age or understory composition. In many cases, the classes do not isolate disturbances. For example, an area with a great deal of forest clearing (e.g., logging) may be classified as forest, grass, or shrub. The quality of a particular patch, or large area, can vary considerably simply due to the heterogeneity within a class.

Boundaries between vegetation types along real environmental gradients are seldom as sharp as implied by land cover maps. Transition areas between classes represent gradients of condition that likely change positively and negatively with time. Similarly, aggregating thematic classes (e.g., 'natural' versus 'converted') implies simple relationships when realistically they are also gradients variable with temporal and spatial scale. Many pattern metrics represent the landscape as a binary map, and patches are either 'habitat' or 'matrix'. Few species are likely to view the world in such a black-and-white way.

Estimate of metrics will not account for land units smaller than the minimum mapping unit of the input datasets and they are valid only at the point in time that the data were acquired. In all spatial analyses, inaccuracies in the input data will multiply in the output.

The morphological spatial pattern analyses are less well studied than most of the more traditional pattern measures. A key advantage of this technique is the ability to objectively classify landscape elements. Additional research is still needed to better quantify the effects of e.g. corridors on species movements or population performance.

Data Descriptions

National Land Cover Data (NLCD)

Analyses of landscape pattern are based on land cover data from the National Land Cover Dataset (NLCD; Homer et al. 2004; Fry et al. 2008). These data and the data attributes most relevant NPSCape are described in detail by Story and Svancara (2009).

There are strong arguments to include or exclude roads. For all the morphological pattern analyses, we did not include the effects of roads. This decision was founded on two key factors. The first was simply our ability to adequately process the data. Efforts to 'burn' roads into the land cover datasets results in many processing errors that could not be easily corrected. The second consideration is that we conducted extensive analyses based on our roads metrics, and these metrics (road density, distance to a road) supplied highly detailed information that can easily be used to extend our analyses.

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