Methods for Generating Patch and Landscape Metrics

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What Are Landscape and Patch Metrics?

- Algorithms for quantifying spatial heterogeneity.
- Efforts to measure landscape patterns are often driven by the premise that patterns are linked to ecological processes.
Pattern-Process
Pattern-Process
Why Are Landscape and Patch Metrics Useful?

- More and more maps are becoming available for pattern-process predictions over large areas
- Permit a coarse approximation of various landscape processes
- Faster and less expensive than extensive surveys
- Facilitate efficient sampling for research and monitoring
- Many more...
Definitions

- **Landscape**: “Area that is spatially heterogeneous in at least one factor of interest.”

- **Patch**: “Surface area that differs from its surroundings in nature or appearance.”

- **Scale**: “…the spatial or temporal dimension of an object or a process.”
  - **Grain**: Smallest sampling unit (e.g., 30m pixel)
  - **Extent**: Entire area or time of consideration (e.g., a study region or state)

- **Level**: “…a place within a biotic hierarchy” or a relative precision of pattern characterization.

Examples of Metrics

- **Patch metrics**: summarize the shape or size of patches
  - *Area, perimeter, width*
  - *Core area*: requires a threshold distance to edge

- **Landscape metrics**: quantify the spatial relationships among patches within the landscape
  - *Composition*
    - *Fractional Cover*: what proportion of the landscape is occupied by a given class
    - *Richness*: the number of classes
    - *Evenness*: the relative abundance of classes
  - *Configuration*
    - *Contagion and Dispersion*: distinguish between landscapes with clumped or evenly distributed patches
    - *Isolation*: based on the distances between similarly classified patches

- **Neighbor metrics**: quantify spatial relationships among objects
  - Calculate distances between similarly classified features (patches, lines)
  - Quantify *distance road or water* *(distance to edge can be difficult)*
Data Types

- **Vector**: each object explicitly represented as points, lines or polygons.
  - Pros: small files; permits topology (i.e., explicit spatial relationships between connecting or adjacent objects)
  - Cons: complex data structure (Slow!); can require much more time to create; manipulations require complex algorithms

- **Raster**: data is divided into a grid consisting of individual cells or pixels. Each cell holds a numeric (e.g., elevation in meters) or descriptive (e.g., land use) value.
  - Pros: simple data structure; easy to represent continuous variables (e.g., intensity); filtering and mathematical modeling is relatively simple
  - Cons: Large files; no topology; objects are generalized (limited by cell size)
Vector vs. Raster
Vector vs. Raster

Inaccuracies due to less spatial precision
Vector vs. Raster

Explicitly defined as two objects

Two objects?
Vector vs. Raster

Shift in study region boundary
Software

• Stand alone
  – Various GIS & RS packages (e.g., ArcGIS, GRASS, Imagine)
  – FRAGSTATS http://www.umass.edu/landeco/research/fragstats/fragstats.html
  – APACK http://landscape.forest.wisc.edu/projects/apack/
  – IAN http://landscape.forest.wisc.edu/projects/IAN/

• GIS extensions
  – Patch Analyst for ArcView 3.x http://flash.lakeheadu.ca/~rrempel/patch/
  – r.le programs that interface with GRASS
Anthropocentric vs. Functional Landscape Descriptions

“...the choice of categories to include in a pattern analysis is critical.”
(Turner et al. 2001)

- **Anthropocentric**: human defined landscape heterogeneity
  - How would you divide the landscape?
  - Data limitations (e.g., sensor resolution, spectral variability)

- **Functional**: Heterogeneity defined by the process of interest
  - Example: descriptions that reflect how other species’ behaviors or population rates differ across the landscape
  - Knowledge limitations
## Crosswalk Anthropocentric to Functional

<table>
<thead>
<tr>
<th>Avian Habitat Types</th>
<th>NC-GAP Map Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estuarine emergent marsh</td>
<td>Tidal Marsh</td>
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<tr>
<td>Open Fresh Water</td>
<td>Open water</td>
</tr>
<tr>
<td>Atlantic white cedar</td>
<td>Seepage and Streamhead Swamps</td>
</tr>
<tr>
<td>Maritime forest</td>
<td>Maritime Forests and Hammocks</td>
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<tr>
<td>Early-successional hardwood and pine</td>
<td>Coniferous Regeneration</td>
</tr>
<tr>
<td>Pine plantations</td>
<td>Coniferous Cultivated Plantation (natural / planted)</td>
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<tr>
<td>Cypress-tupelo</td>
<td>Cypress-Gum Floodplain Forests</td>
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<tr>
<td>Early-successional hardwood and pine</td>
<td>Successional Deciduous Forests</td>
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<tr>
<td>Atlantic white cedar</td>
<td>Peatland Atlantic White-Cedar Forest</td>
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<tr>
<td>Pine sandhills</td>
<td>Xeric Longleaf Pine</td>
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<tr>
<td>Pine hardwoods</td>
<td>Xeric Oak - Pine Forests</td>
</tr>
<tr>
<td>Bottomland hardwood</td>
<td>Coastal Plain Oak Bottomland Forest</td>
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</tbody>
</table>
Avicentric Land Cover
Example of Documenting and Using Patch and Neighborhood Metrics by SE-GAP

Map Algebra
Stating Assumptions
Sources of Errors
Habitat Suitability

Species: ACFL
State: TX
Life History: Breeding
Cover Type: Wet: Riparian
Survey method: Transect

Importance: Low, Medium, High
No relationship

Suitability: Hostile, Marginal, Suitable, Optimal

Use: Avoided, None, Traveled, Complementary, Substitutable, Needed

ArticleID: 516
Endnote#: 8
Input: 1
Add new input for the reference below
Landscape Modifiers

Species: ACFL  
Life History: Breeding  
Cover Type: Wet: Riparian  
Survey method: Transect  
Importance: High  
Suitability: Suitable  
Use: Avoided  
Cover Type Modification: 
Categorical: Landform: Flats Wet  
Continuous: Distance to water  
Set thresholds for continuous variables: 
Optimal Low: 70  
Suitable Low: 50  
Marginal Low: 30  
Response Curve: skewed left
The Acadian Flycatcher (Empidonax virescens), Yellow-throated Vireo (Vireo flavifrons), and Yellow-billed Cuckoo (Coccyzus americanus) seemed to require at least 70 m of forest width before their abundance increased.

Input Comments:
Interpreted from Figure 1 that plots the mean number detected as a function of streamside zone width. Abundance calculated for 50m transects of 10m increments of riparian buffers but transects were of unknown width.
### Queries

<table>
<thead>
<tr>
<th>Species</th>
<th>Rate</th>
<th>sMin</th>
<th>sAvg</th>
<th>sMax</th>
<th>Standard units</th>
<th>Cover Type</th>
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</table>

Each record is one entry in the previous form
Map Algebra

Logistic (S-shaped)

\[ \frac{1}{1 + a \cdot \exp(-b \cdot (\text{Map Value} / c))} \]

Example: \[ \frac{1}{1 + 40 \cdot \exp(-6 \cdot (\text{Dist_Edge} / 90))} \]

- \(a\) affects where upturn begins.
- \(b\) affects slope of the “S”. Larger numbers shrink the curve.
- \(c\) also affects slope of the “S” but less so. Larger numbers stretch the curve.
Mapping Suitability Relationships

Acadian Flycatcher

Suitability (in this case density) ranked by distance to edge:
- Marginal = 0.3
- Suitable = 0.6
- Optimal = 0.9

Logistic curve fit to data and used to score map for habitat suitability.

Habitat Suitability Prediction

Input
Avicentric land cover

6 km
Lump Classes of Similar Suitability

Acadian Flycatcher

Input
Flycatcher-centric land cover

Suitability
-1 - 0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1

6 km
Calculate and Weight Distance to Edge

Acadian Flycatcher

Input Distance to Edge

6 km
Map Algebra 2: Combine Maps

- **Suitability** ranked from 0 to 1:
  - Suitability under all conditions = Map1 * Map2 * Map3

- **Abundance/Density Modeling**
  - Extrapolate research results from sample locations (e.g., Logistic Regression)

- **Population modeling**
  - Combine maps of vital population rates that vary under different spatial conditions:
    \[
    \frac{dR}{dt} = aR - bRF \\
    \frac{dF}{dt} = ebfRF - cF
    \]
  - Where:
    - R are the number of prey
    - F are the number of predators
  - and the parameters are defined by:
    - \(a\) is the natural growth rate of prey in the absence of predation,
    - \(c\) is the natural death rate of predators in the absence of prey,
    - \(b\) is the death rate per encounter of prey due to predation,
    - \(e\) is the efficiency of turning predated prey into predators.
Habitat Suitability Prediction

Multiply suitability given:
- Land cover
- Distance to water
- Distance to edge

Acadian Flycatcher
Explicitly State Assumptions!

- Allows testing to validate and refine predictions
- Example assumptions
  - Land cover, distance to water and distance to edge are all equally important considerations for mapping habitat suitability
  - Density, nesting success and predation rates are all equally relevant indications of habitat suitability
  - Relationships between patch/landscape/neighbor descriptions and habitat suitability are similar everywhere.
Some Sources of Error

- Age of data
- Precision and availability of information
- Positional accuracy
- Classification appropriateness and accuracy
- Inconsistencies during data creation
  - Different interpreters or methods
  - Different classification schemes
  - Different scales of precision
Example: Digital Line Graphs

Used in the National Hydrographic Dataset
Distance to Water
Different Scales of Precision
The Southeast Gap Analysis Project (SEGAP) is a regional representative of the National Gap Analysis Program sponsored by the Biological Resources Division of the United States Geological Survey (USGS-BRD).

"The intent of the Gap Analysis is to provide focus and direction for proactive rather than reactive land management activities at the community and landscape levels" (J Michael Scott, 1995).

A cooperative project by:

USGS Biological Resources GAP

For questions or comments related to this website, please contact us at segap@ncsu.edu