## Landscape metrics:

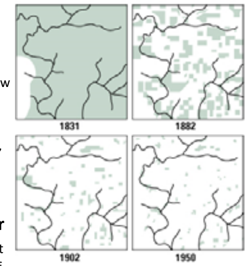
Mixed prairie and juniper woodland, western North Dakota

**Quantifying landscape composition**

**Reading: Chapter 5**

## Why quantify landscape patterns?

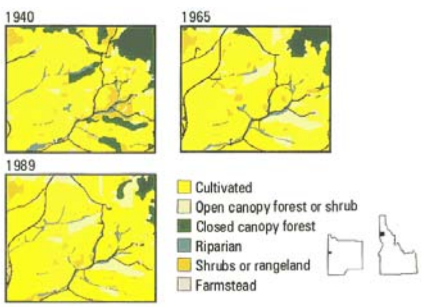
1. **Landscape ecology emphasis on interaction between pattern and processes**
2. **Quantify changes through time,** How have landscapes changed?
3. **Comparison of landscape patterns**, for example, ownership or political status can result in drastically different patterns
4. **The patterns may be important for landscape processes** such as movement patterns, distribution of nutrients, or spread of disturbance agents




Changes in forest patterns (green) in a township in southwestern Wisconsin

## Example from the Palouse

*Township near Viola north of Moscow*




Black et al: http://landcover.usgs.gov/luhna/chap10.php

## Information overload?

"We can currently quantify more about patterns than we understand in terms of its ecological importance."

"Relationships between patterns and processes remains a challenge and an important area of research."
Turner (2001)

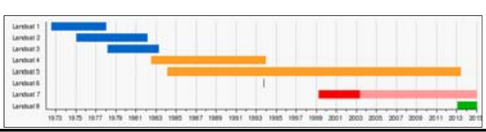
We have access to large amounts of information via a number of satellites and aerial modes of image acquisition but are the data at a scale that makes sense for the analysis we are working on ?

## Data used in Landscape Ecology

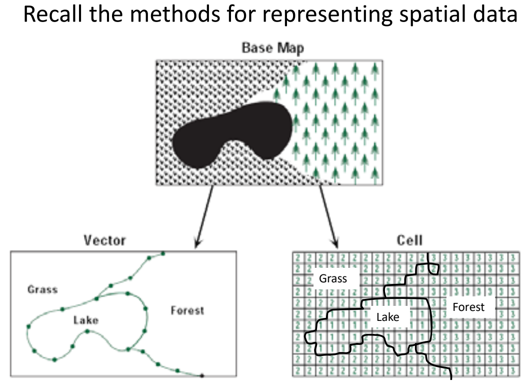
**Aerial photography**
- Since 1930s, B&W with sporadic coverage, ~1 m resolution
- Since ~ 2000 color with more consistent coverage, 1 m, annual

**Satellite remote sensing**
- Landsat, 1970s, 30 m resolution, 16 days
- MODIS, 1999, 250 m – 1 km resolution, 1-2 days
- Spot, 10-20 m resolution

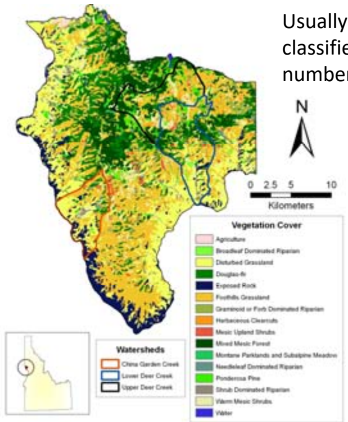
**GIS maps**
- Digitized from imagery (vector)
- Field mapped data (vector)
- Classified from imagery (raster)



## Recall the methods for representing spatial data



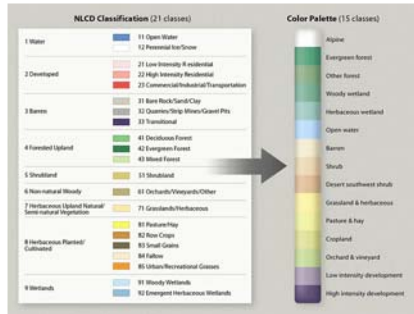

T,G & O 2001. Figure 5.4



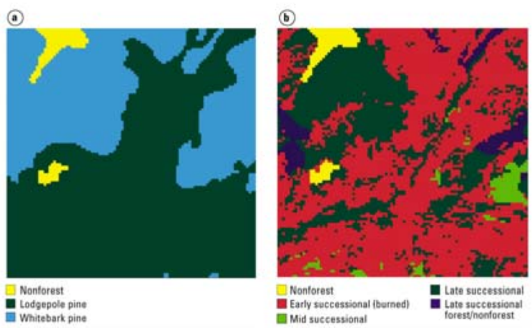

Usually the spatial data is classified in some meaningful number of categories

Vegetation coverage: Craig Mountain Wildlife Management Area

## Hierarchical classification patterns

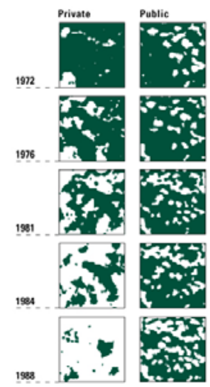



## Same landscape – different classification schemes




## Sources of potential errors in GIS data

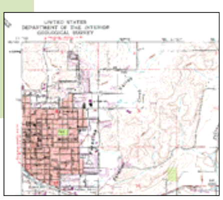
1. Age of data (changes have occurred since the data was collected)
2. Aerial coverage (incomplete coverage)
3. Map scale (can you detect the objects of interest in the map)
4. Changes at political boundaries, differences in mapping method
5. Positional accuracy (related to scale)
6. Content accuracy (accuracy of attributes)
7. Errors in data entry




**When is a forest no longer a forest?**

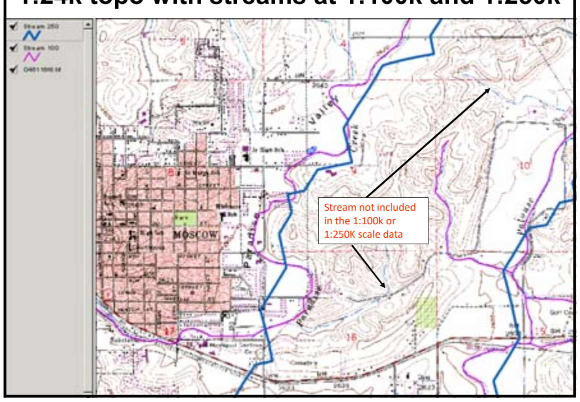
## Effects of Scale

| USGS standard formats | Raster |
|---|---|
| 1: 24,000 | 30 m |
| 1: 100,000 | 90 m |
| 1: 250,000 | 500 m |

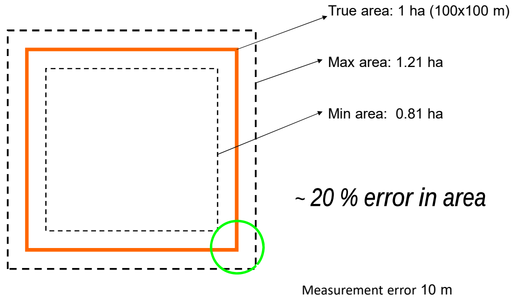


**40 ft is an acceptable error for the USGS 1:24,000 scale topographic maps.**

## 1:24k topo with streams at 1:100k and 1:250k



## Error in Area Measurements



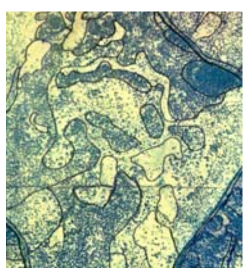

## Summary: Fine vs Broad Scale

Fine scale data
- more detail
- higher spatial accuracy
- usually has a small extent

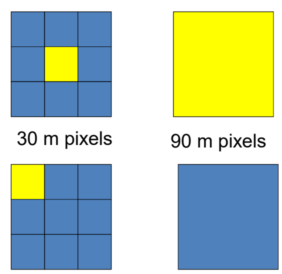
Broad scale data
- less detail
- lower spatial accuracy
- usually has a large extent

## Minimum Mapping Unit

The minimum mapping unit (MMU) of a map is the smallest object that is present in the map.

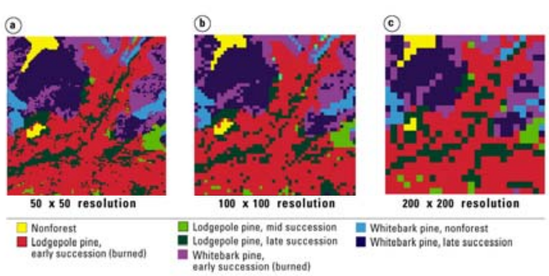


## How does the scale of the data affect your analysis?




Habitat area overestimated

Habitat area underestimated or lost




**The grain size should be <u>two to five</u> times smaller than the feature being analyzed and the extent should be <u>two to five</u> times larger than the largest patch.**

O'Neill et al. 1996

## Importance of scale

Broad

NALC

LandSat

SPOT

IKONOS

Hyperspectral

Fine

LIDAR

Scale

Specific

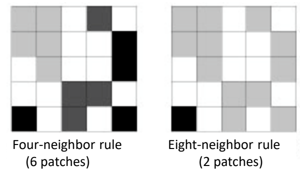
Question

General

## Quantifying landscape pattern

- Patch sizes
- Interior habitat
- Edge
- Patch shapes
- Number of patch types
- Number of patches by type
- Dominance
- Diversity
- Arrangement (configuration)
  - Arrangement of a single patch (community) type
  - Arrangement of all patch types

## What is a patch?




Does diagonal connectivity count?

## Most landscape metrics are correlated !

*Independent factors for qualities of patterns*

1. Number of classes, cover types, patch types
2. Texture of landscape (coarse or fine)
3. Degree to which patches are compacted or discrete
4. Whether patches are linear or planar
5. Whether patch perimeters are simple or complex

Riitters et al. 1995

## Levels of Landscape Analysis

*FRAGSTATS analysis software*

1. Patch level
2. Class level
3. Landscape level

## Types of landscape metrics:

1. Patch area (patch number, patch density, total patch type area, core area)
2. Patch perimeter (edge density, total patch length, edge contrast)
3. Patch shape (perimeter to area ratio, elongation index, shape indices, fractal dimension)
4. Core area metrics (core area is defined as the area within a patch beyond some specified edge distance or buffer width)

## Types of landscape metrics (continued):

5. Diversity and Evenness (proportional area of patch types)
6. Isolation/proximity indices (deals with the spatial context of the patch, not the patches themselves; nearest neighbor, proximity)
7. Contrast metrics (refers to the magnitude of difference between adjacent patch types with respect to attributes)
8. Interspersion metrics (tendency of aggregation)
9. Connectivity (refers to the degree to which a landscape facilitates/impedes ecological flows)

# 1. Patch area metrics

Patch metrics:
- Patch area

Class metrics:
- Total area by class
- Percent of landscape by class
- Number of patches
- Patch density
- Patch area distribution

Landscape metrics:
- Total area
- Number of patches
- Patch density
- Patch area distribution

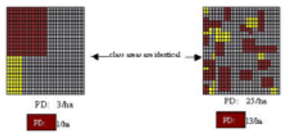
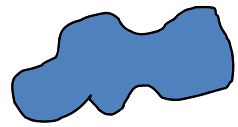


Figure 1.2: Patch density

## 2. Perimeter and edge metrics:

1. Another very straight forward metric. Calculated by counting edge pixels in raster systems and geometry in vector systems.

2. Twenty years ago land management attempted to maximize edge. Today we are reconsidering the wisdom of widely applying this approach. Edge is obviously very highly correlated to patch size and thus core area.

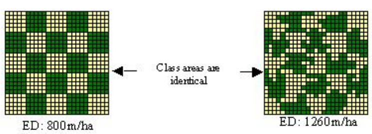


## 2. Perimeter and edge metrics (continued):

**Total perimeter** (edge) = sum of all patch or patch type perimeters

**Edge density** = $\sum$ all edge lengths (m)/[landscape area (m) x10,000]
= meters of edge / ha

Edge density may also be expressed in km/km$^2$ for large landscapes.

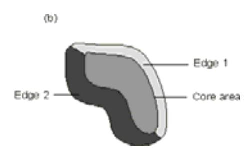



Edge density
Figure 1.3: Edge density

## Edge contrast metrics

**Edge contrast** is sometimes used to quantify the functional aspects of edge. The general approach is to assign a rank to a patch type edge (Ordinal ranking). The difference at the boundary between adjacent patches can then be roughly quantified.

**Edge Contrast Index - EDCON** (M&M 1995)
Description: EDCON equals the sum of the patch perimeter segment lengths (m) multiplied by their corresponding contrast weights, divided by total patch perimeter (m), multiplied by 100 (to convert to a percentage).




## 3. Shape metrics:

Indices of patch shape attempt to quantify the complexity of the patch. The shape is usually compared to the value of the metric for a circle (vector based) or square (raster based) for that given area.

- Limited by how patch shapes are portrayed in raster and vector images. Raster tends to bias the length upwards due to the stair-step approach of projecting non vertical or horizontal boundaries.
- The limitations of raster images become greater as the pixel size increases in relation to the size of patches represented.
- Perimeter-to-Area ratios do not adequately describe the patch morphology and many different shaped patches may have a similar P:A ratio.

## 3. Shape metrics (continued)
**Commonly used metrics related to shape include:**

1. **Perimeter-area ratio** (Farina 1998)= patch perimeter / patch area

   This metric varies with both changing patch shape and increasing patch size.

2. **Elongation index** (L:W ratio) (Forman 1995)
   = 1: (Length/width)
   range > 1, value increases as patch becomes more elongated

3. **Shape index** (McGarigal&Marks 1995)
   vector = $p_{ij}$ / 2 ($\pi$ x area of patch)$^{0.5}$
   raster = 0.25 $p_{ij}$ / (area of patch)$^{0.5}$

| |
|---|
| p = perimeter<br>i = ith patch type<br>j = jth patch of patch type i |

Remember the relationship of area to perimeter for squares and circles.

| Area ($m^2$) | Width or diameter (m) | Perimeter (m) | Perimeter/Area ratio |
|---|---|---|---|
| | | **Square** | |
| 1 | 1 | 4 | 4:1 |
| 4 | 2 | 8 | 2:1 |
| 16 | 4 | 16 | 1:1 |
| 64 | 8 | 32 | 0.5:1 |
| | | **Circle** | |
| 1 | 1.13 | 3.54 | 3.54:1 |
| 4 | 2.26 | 7.09 | 1.77:1 |
| 16 | 4.51 | 14.18 | 0.89:1 |
| 64 | 9.03 | 28.35 | 0.44:1 |

**Patch shape-** Ecological interpretations:

1. The ecological function of shape can be estimated by 4 easily measured attributes of the patch shape: elongation (width:length ratio), convolution, interior, and perimeter.

2. Compact forms are more efficient at conserving patch resources.
Elongated patches are less efficient at conserving resources than round patches. However, the orientation of the patch relative to the movement of species or process is extremely important.

3. Core or interior area is reduced for irregular patch shapes as compared to regular shapes of the same area. This has obvious influences on interior species.

(Forman 1995, pp. 124-132)

**Patch shape-** Ecological interpretations:

4. Convoluted forms are more effective in enhancing interactions with surrounding patches.

Convoluted patches increase the interchange between the patch and surrounding patches. For example, fire or grazing animals more likely enter "undesirable" patch types when they are lobed and very irregular in shape.

5. Perimeter is increased for a given patch size as the shape becomes more complex. This is beneficial for edge species or species utilizing more than 1 patch type, and the movement of propagules into new patches.

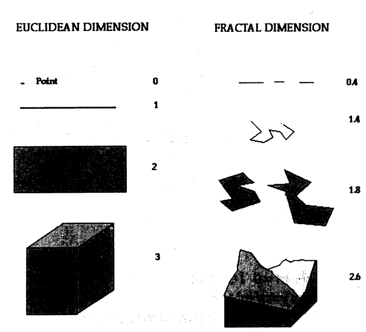
**Fractal dimension**

| | Euclidean dimension (regular shape) | Fractal dimension (irregular shape) |
|---|---|---|
| Point | 0 | |
| | | 0-1 |
| Line | 1 | |
| | | 1-2 |
| Area | 2 | |
| | | 2-3 |
| Volume | 3 | |

**Fractals are used in landscape ecology as an index of shape. We are primarily interested in the relationship of lines that enclose areas.**

**Thus, when we measure a perimeter of a polygon and adjust for the area of that polygon, we can see that as the polygon shape becomes increasingly complex, its fractal dimension increases from 1 to a maximum of 2. At 2, the perimeter entirely fills the interior of the polygon and is no longer a line but an area.**

**Fractal dimension**




A common example of fractal dimension
How long is the coastline of the UK?

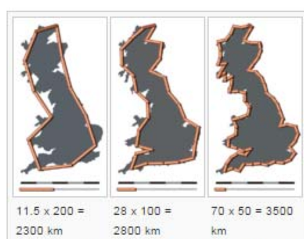
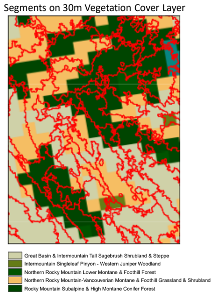



*Figure 1.* As the length of the measuring stick is scaled smaller and smaller, the total length of the coastline measured increases.

## Idaho vegetation at 1 m resolution?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Fractal dimension is calculated from the following formulas:

FRACT = $2 \ln p_{ij} / \ln a_{ij}$ (vector)

FRACT = $2 \ln (0.25\, p_{ij}) / \ln a_{ij}$ (raster)

Note: The perimeter is divided by 4 to correct for a pixel having 4 sides.

i = patch type
j = jth patch of patch type i

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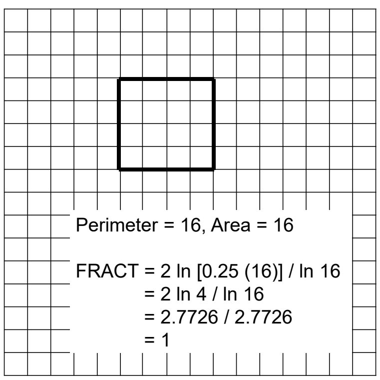


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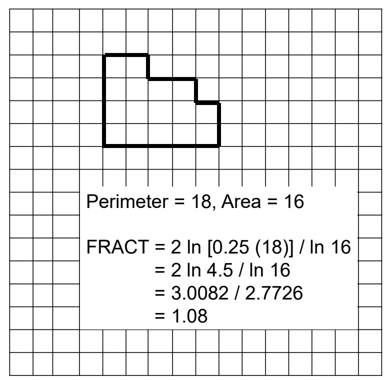


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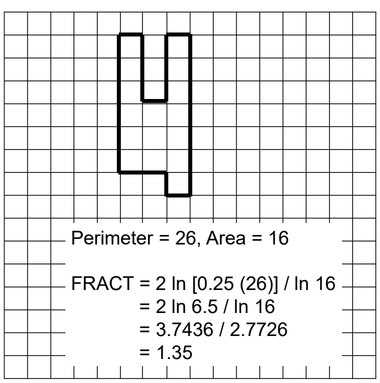


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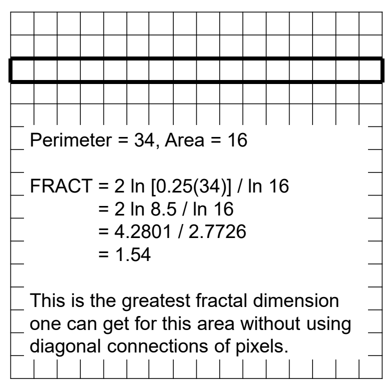
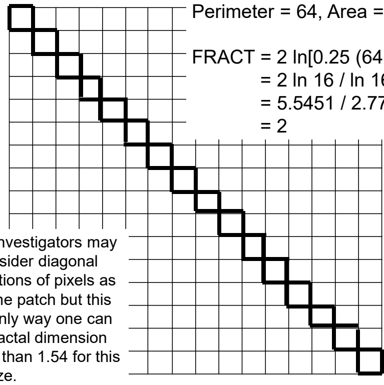




Perimeter = 64, Area = 16

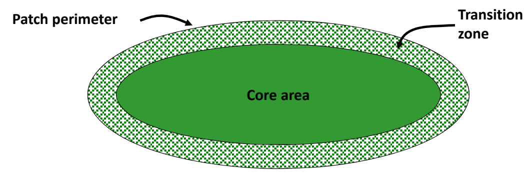
FRACT = 2 ln[0.25 (64)] / ln 16
= 2 ln 16 / ln 16
= 5.5451 / 2.7726
= 2

Some investigators may not consider diagonal connections of pixels as the same patch but this is the only way one can get a fractal dimension greater than 1.54 for this pixel size.

## 4. Core area metrics

**Core area** is obviously highly related to patch area. Also recall that we discussed how core area is very species or process specific because it is difficult to develop a transition edge width that is relevant to all species or processes.

Other metrics such as **total core area**, and **number of core areas** can be developed from this metric.




McGarigal, K., and W.C. McComb. 1995. Relationship between landscape structure and breeding birds in the Oregon Coast range. Ecological Monographs 65:235-260.

Photo by Mark Turner

Photo by National Park Service

McGarigal, K., and W.C. McComb. 1995. Relationship between landscape structure and breeding birds in the Oregon Coast range. Ecological Monographs 65:235-260.

Study design

1. Selected ten (250-300 ha) landscapes in each of 3 watersheds (n=30) reflecting a range of disturbance (amount of seral vegetation).
2. Mapped vegetation into 27 patch types (22 forested, 5 non-forested).
3. Sampled birds at 32-38 grid points in each landscape.
4. Bird sampling was done 4 times/year during 3 years.

Data analysis- 1

1. For each bird species an **index of abundance** was calculated.
2. Imported the landscapes into ARC/INFO which was then used to calculate **landscape metrics** including:

| | |
|---|---|
| Patch density | Mean patch size |
| Patch size coefficient of variation | Edge density |
| Mean shape index | Area-weighted mean shape index |
| Landscape shape index | Mean fractal dimension |
| Total core area | |

Data analysis- 2

3. Developed an **edge contrast index.**
4. Reduced the number of variables (25) for each patch type through a combination of correlation, multiple-correlation, regression and Principle Components Analysis (PCA).
5. Mean and 95% confidence intervals of bird abundances were located along the 3 fragmentation gradients.

Results- concentrated on the late-seral vegetation types

1. 89 species of birds were sampled. 12 were selected for further analysis based on the amount of observations.

2. Three principle components accounted for 78% of the variation within the patch types.

PC-1 was heavily weighted by **patch shape and edge contrast**

Landscapes with high positive values contained late-seral forest vegetation that was distributed in patches with complex shapes, greater edge density, less core area, and greater edge contrast than the average landscape for a particular amount of late-seral forest vegetation.

PC-2 was heavily weighted by **patch density**

High positive values were associated with late-seral forest vegetation that was more fragmented into more patches for a given amount of that type in the landscape.

PC-3 was heavily weighted by **patch size**

Landscapes positively associated with PC-3 contained late-seral forest patches that were small in size.

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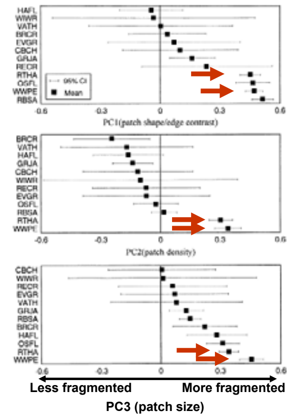
Bird abundance varied with different types of late-seral forest fragmentation.

The red-tailed hawk (RTHA) and western wood pewee (WWPE) were more strongly associated with all types of fragmented late-seral forest.




(McGarigal & W.C. McComb 1995)

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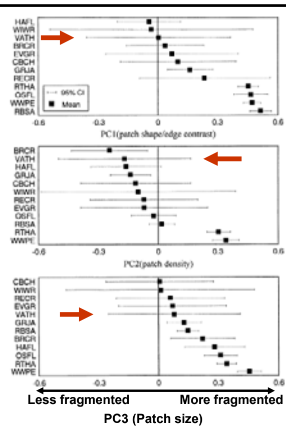
Bird abundance varied with different types of late-seral forest fragmentation.

Varied thrush (VATH) was more associated with less fragmented late-seral forests.




(McGarigal & W.C. McComb 1995)

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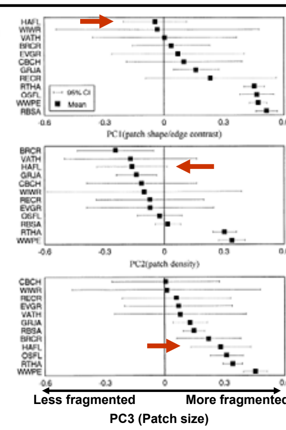
Bird abundance varied with different types of late-seral forest fragmentation.

Hammond's flycatcher (HAFL) had different relationships to different measures of fragmentation.

Some of this variation may have been related to associated habitats that are not measured with these metrics and they will be the focus of a later discussion.




(McGarigal & W.C. McComb 1995)

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