Methods for Generating Patch and Landscape Metrics

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What Are Landscape and Patch Metrics?

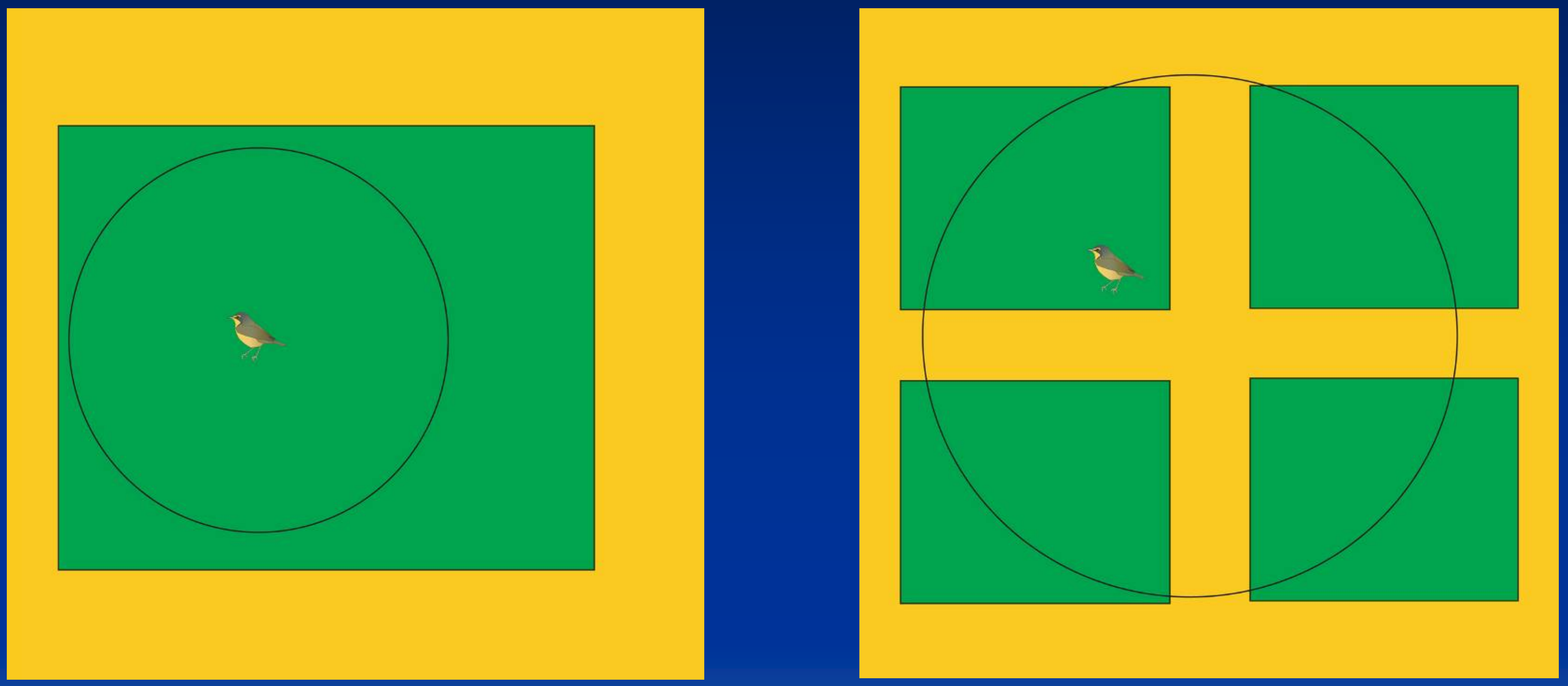
- Algorithms for quantifying spatial heterogeneity.

- Efforts to measure landscape patterns are often driven by the premise that patterns are linked to ecological processes

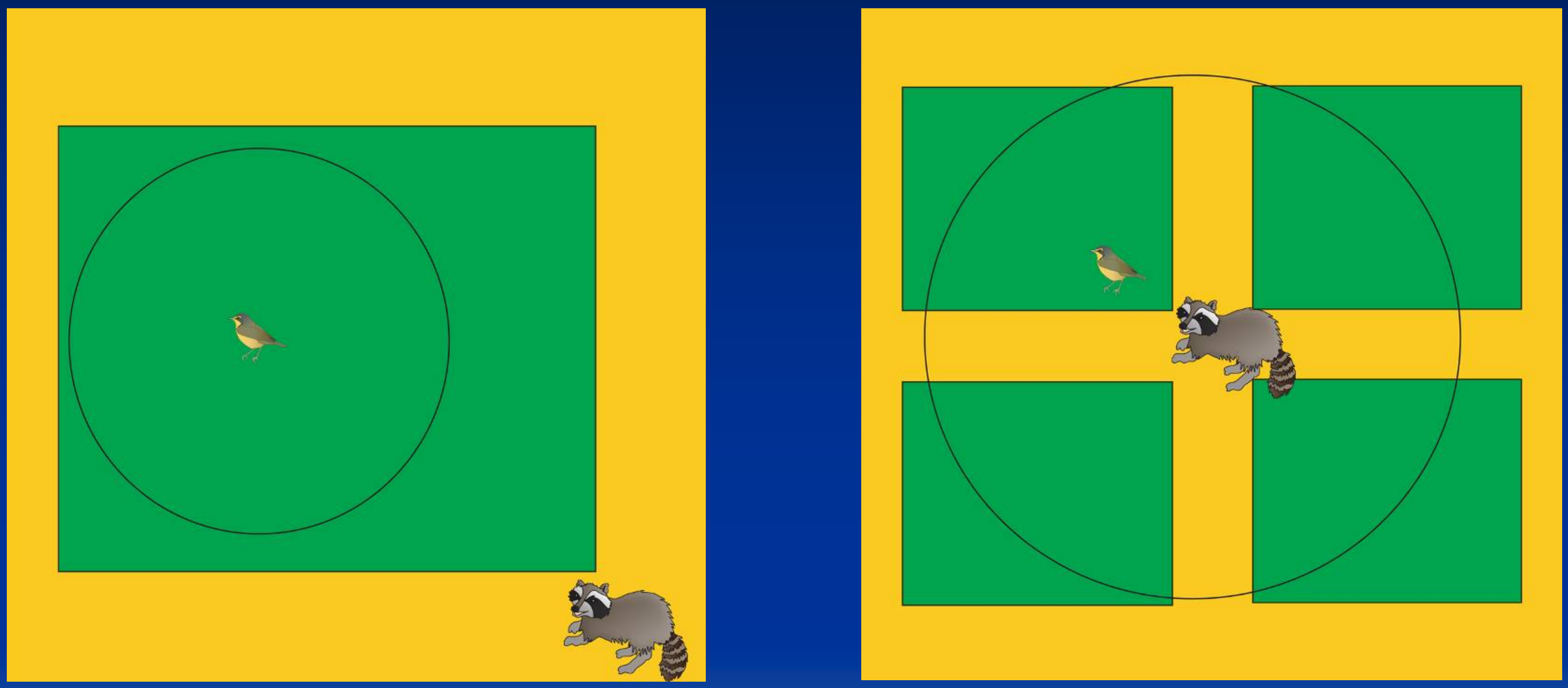
Edges → Predation

Fragmentation → Energy Expenditure

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.

Turner et al. 2001. Landscape Ecology in Theory and Practice. Springer-Verlag

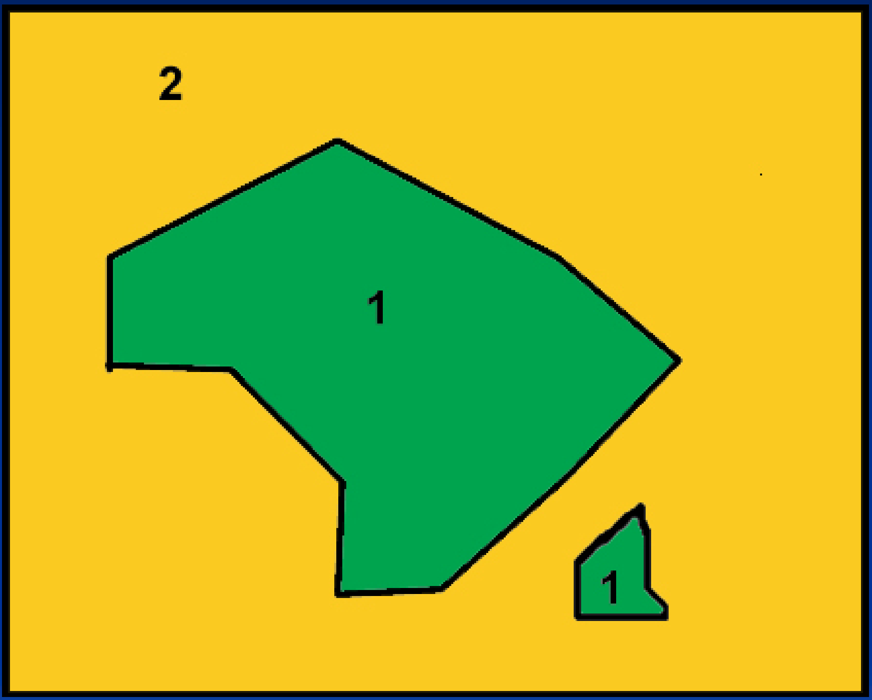
Examples of Metrics

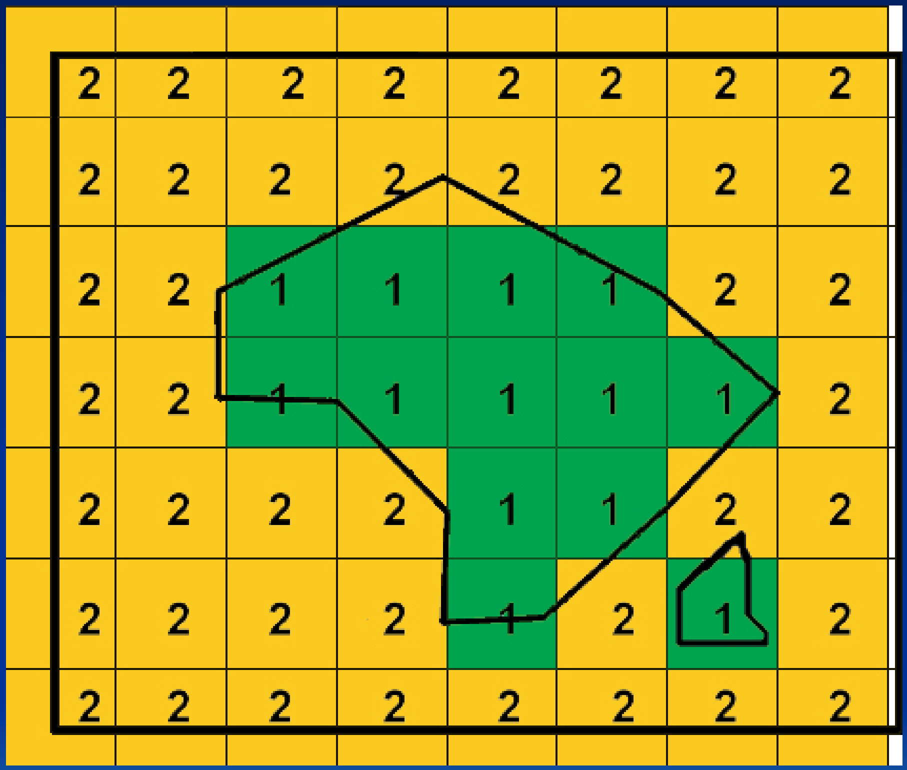
- Patch metrics: summarize the shape or size of patches
  - Area, perimeter, width
  - Core area: requires a threshold distance to edge
- Landscape metrics: quantify the spatial relationships among patches within the landscape
  - Composition
    - Fractional Cover: what proportion of the landscape is 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

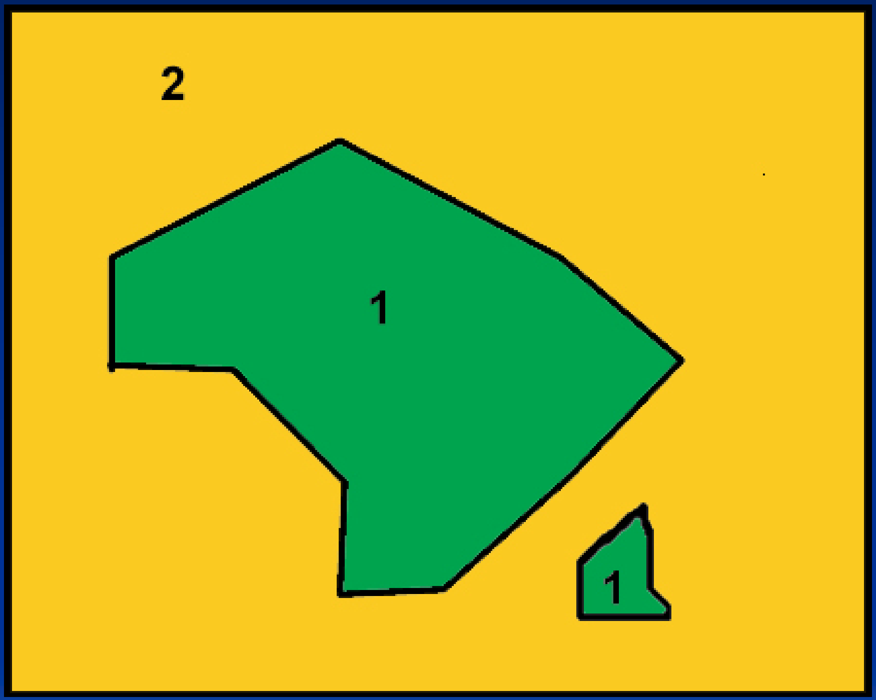
- Vector: each object explicitly represented as points, lines or polygons.
  - Pros: small files; permits topology (i.e., explicit spatial relationships between connecting or adjacent objects)
  - Cons: complex data structure (Slow!); can require much more time to create; manipulations require complex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

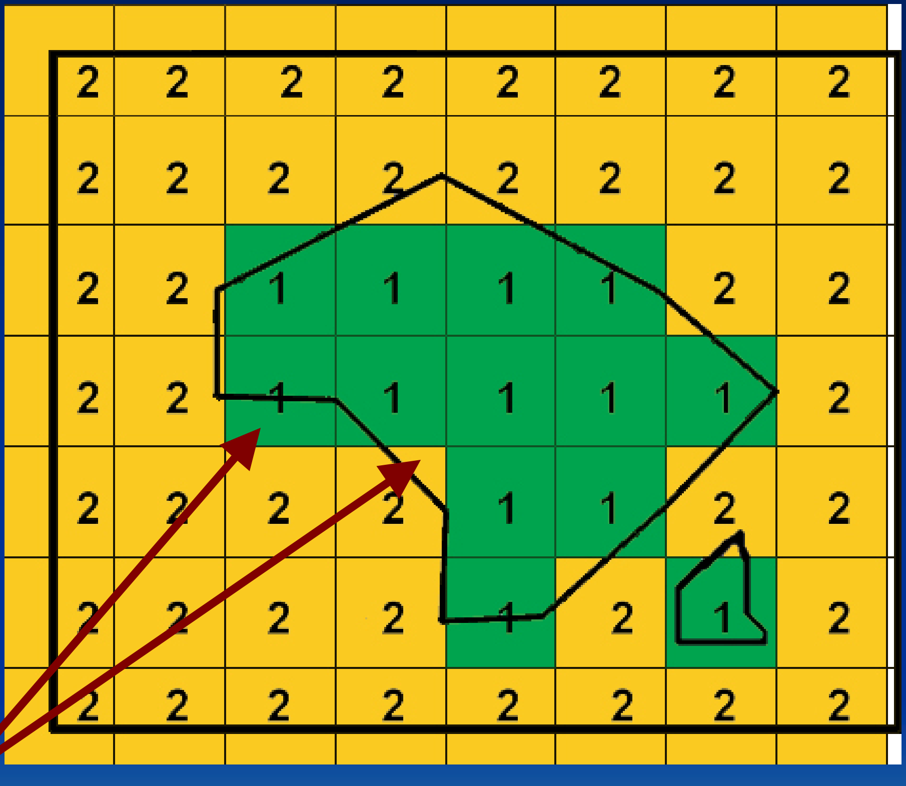
Vector vs. Raster





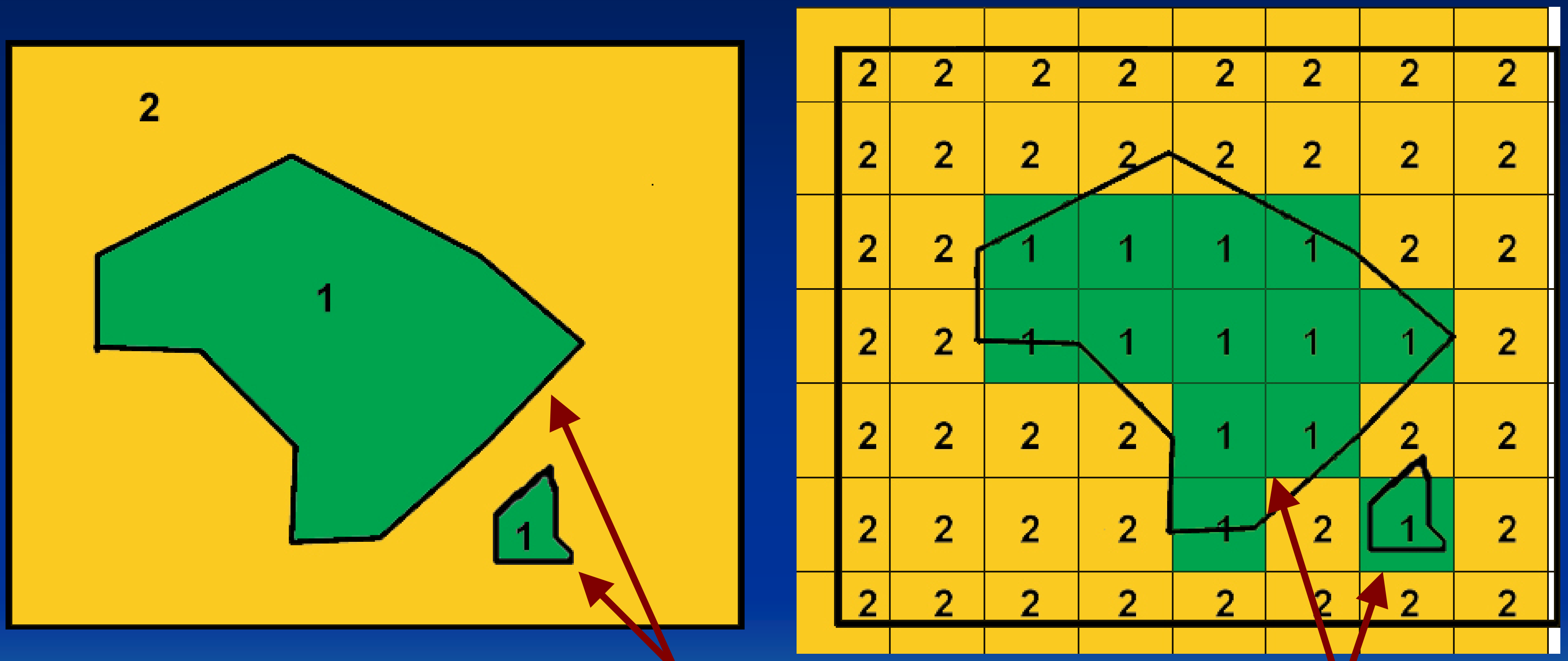
Vector vs. Raster





Inaccuracies due to less spatial precision

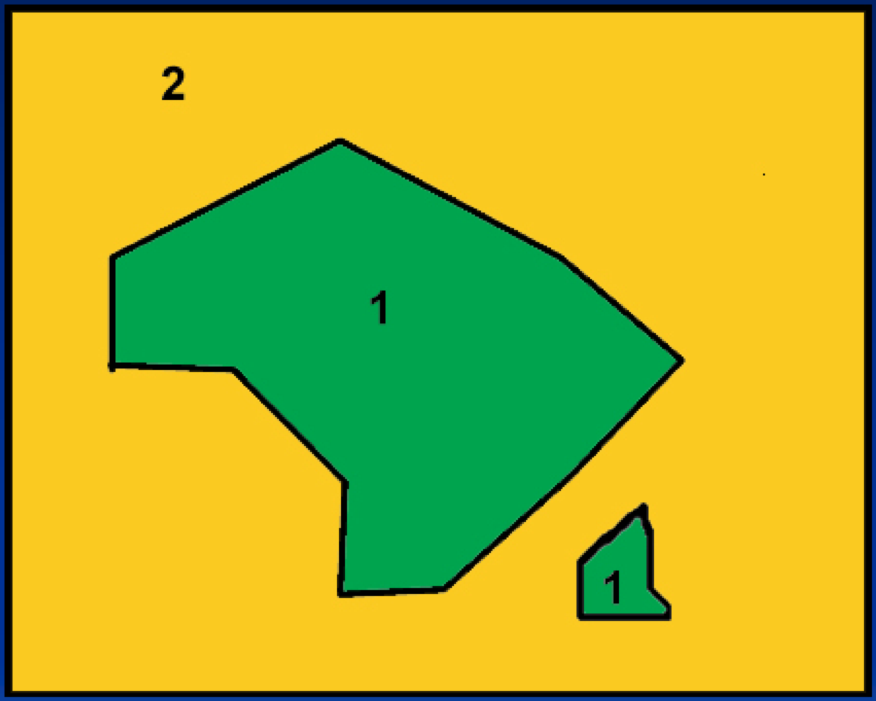
Vector vs. Raster

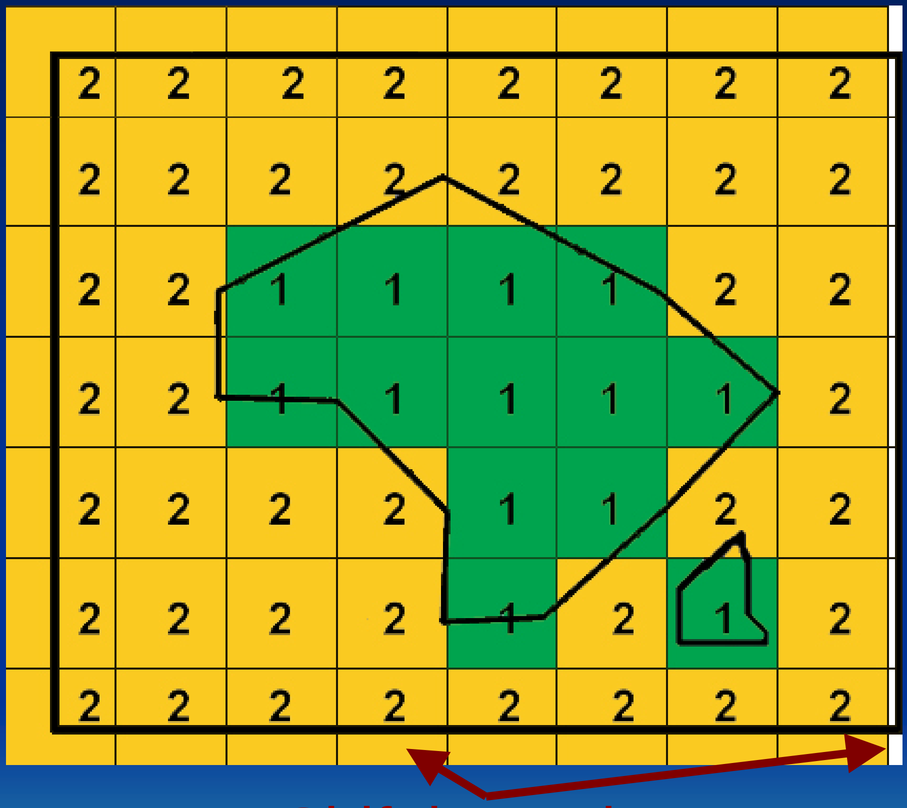


Explicitly defined as two objects

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

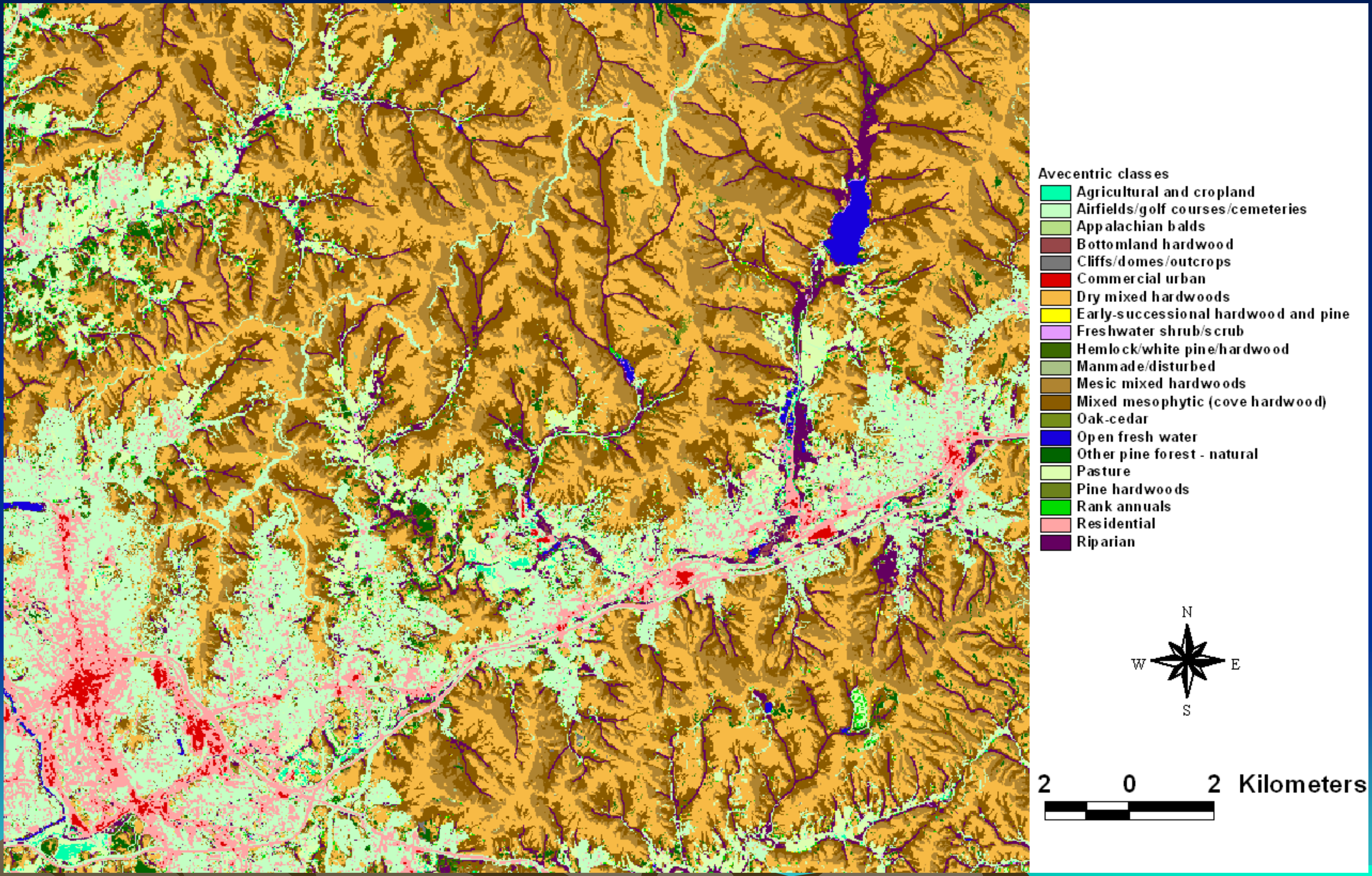
"...the choice of categories to include in a pattern analysis is critical."
(Turner et al. 2001)

- 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

Avian Habitat Types		NC-GAP Map Units
Estuarine emergent marsh	←	Tidal Marsh
Open Fresh Water	←	Open water
Atlantic white cedar	←	Seepage and Streamhead Swamps
Maritime forest	←	Maritime Forests and Hammocks
Early-successional hardwood and pine	←	Coniferous Regeneration
Pine plantations	←	Coniferous Cultivated Plantation (natural / planted)
Cypress-tupelo	←	Cypress-Gum Floodplain Forests
Early-successional hardwood and pine	←	Successional Deciduous Forests
Atlantic white cedar	←	Peatland Atlantic White-Cedar Forest
Pine sandhills	←	Xeric Longleaf Pine
Pine hardwoods	←	Xeric Oak - Pine Forests
Bottomland hardwood	←	Coastal Plain Oak Bottomland Forest

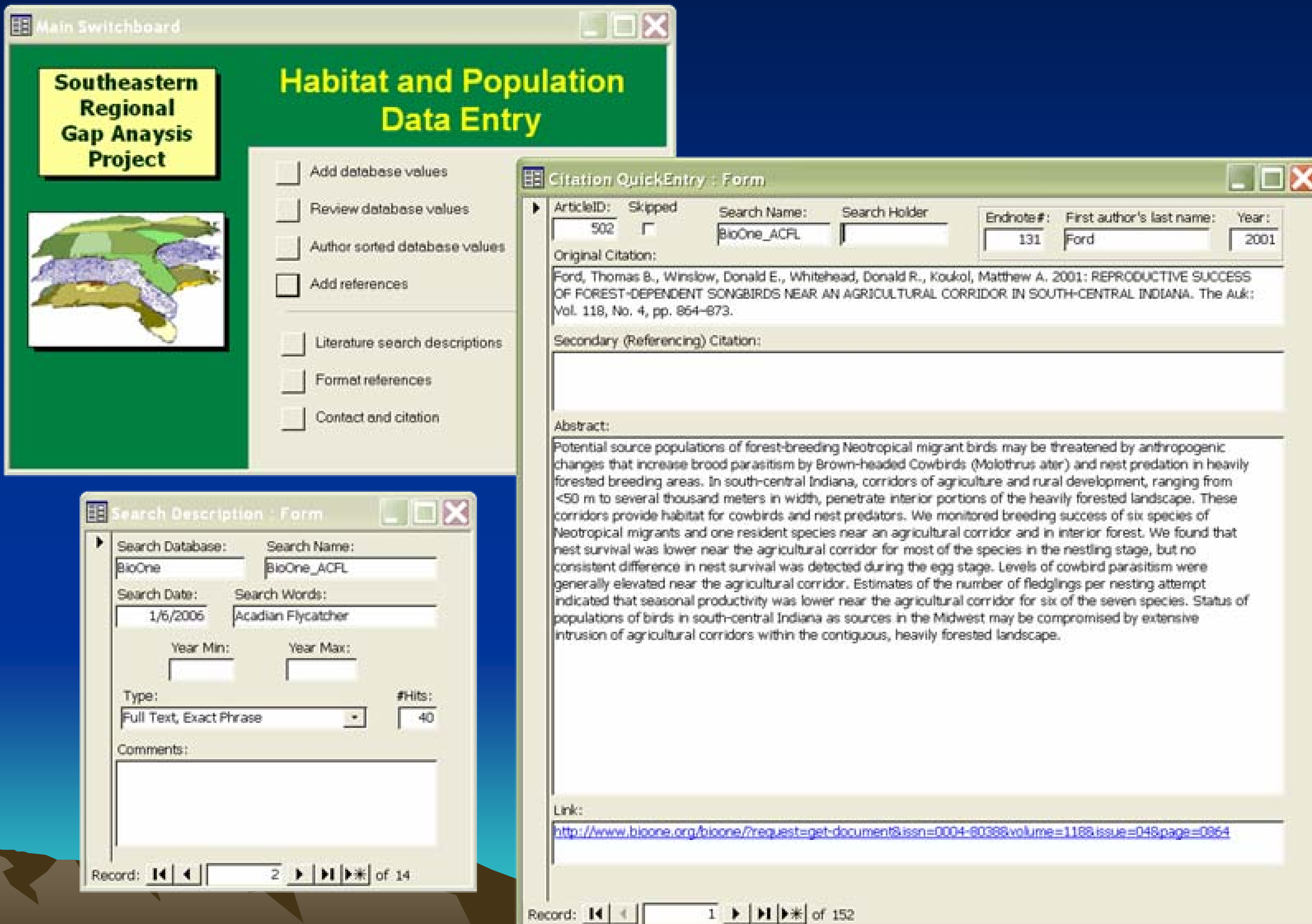
Avicentric Land Cover



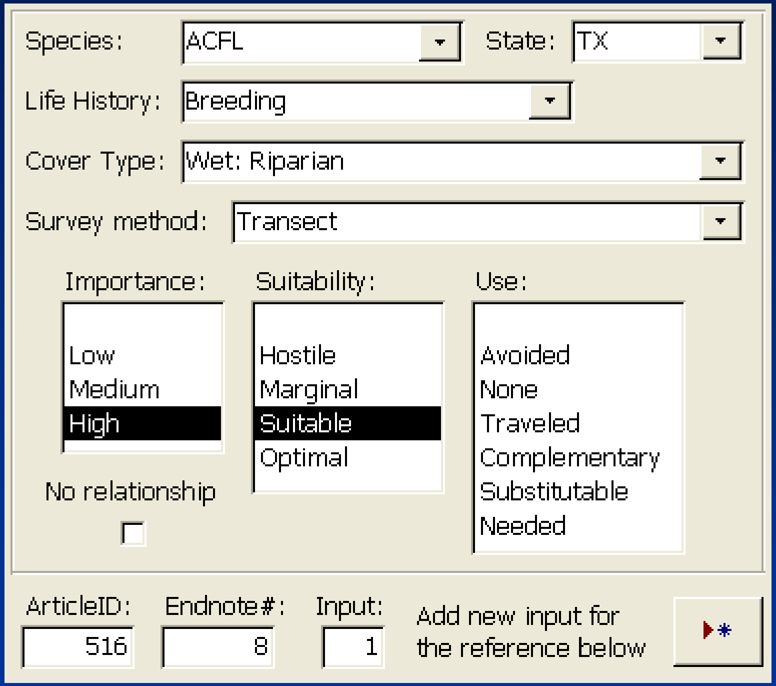
Example of Documenting and Using Patch and Neighborhood Metrics by SE-GAP

Map Algebra
Stating Assumptions
Sources of Errors

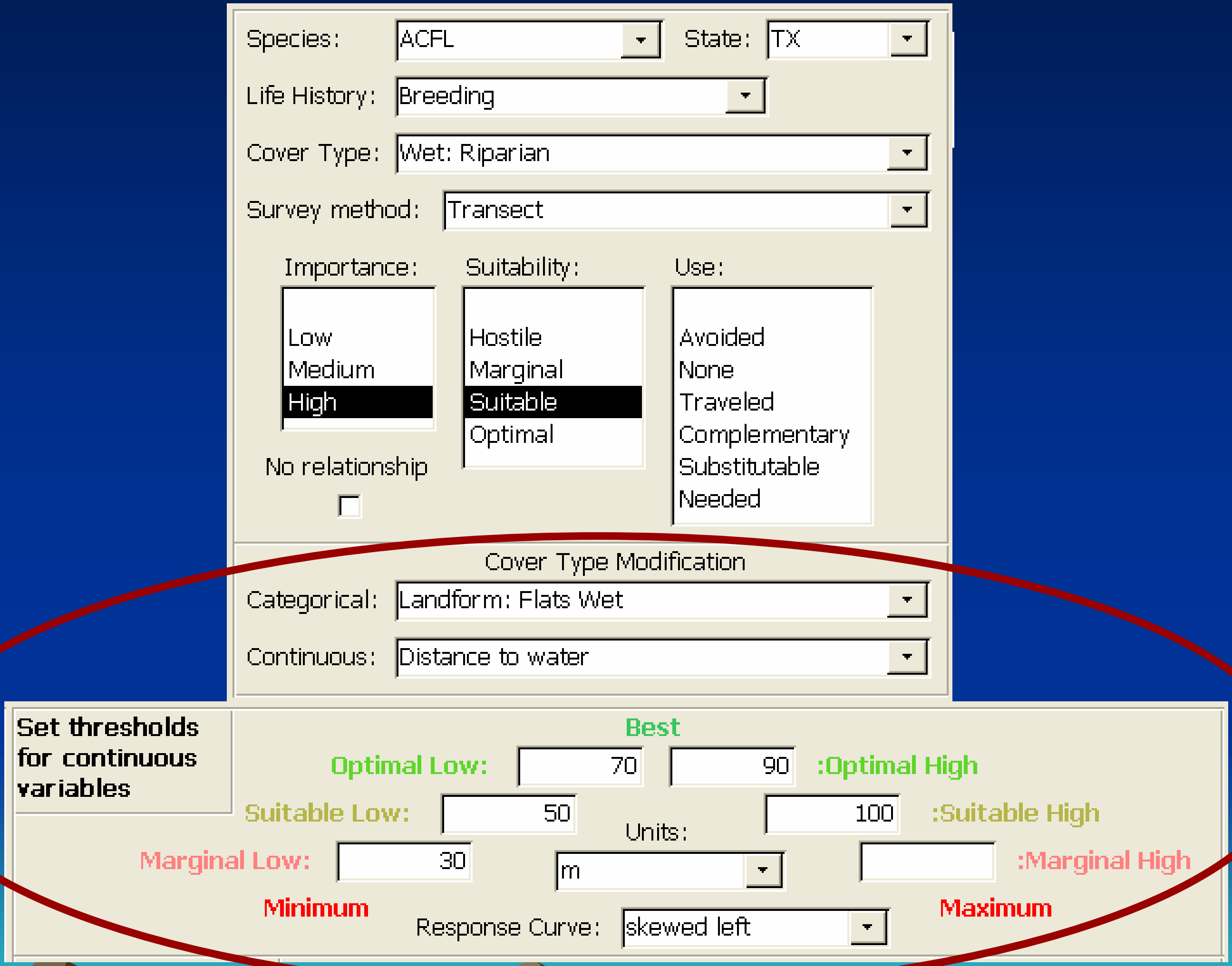
Literature Review Database



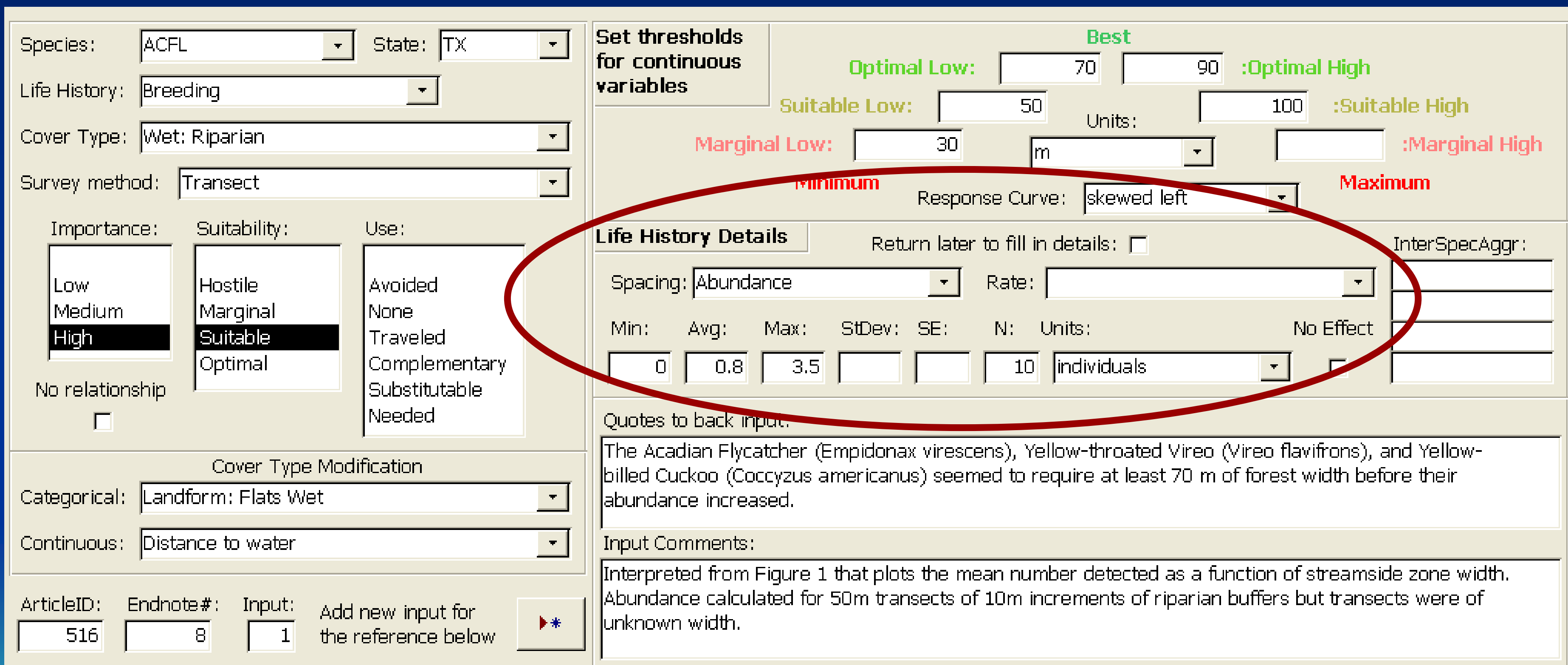
Habitat Suitability



Landscape Modifiers



Spatially Explicit Population Descriptions



Queries

Species	Rate	sMin	sAvg	sMax	Standard units	Cover Type	Categorical	Continuous
ACFL	Breeding synchrony	0.2	0.3	0.3	unitless	Wet: Riparian		
ACFL	Daily nest failure (last egg)	0.3		1.2	%	UpForest: Dry mixed hardwoods		
ACFL	Daily nest mortality	1.3	3.8	5.7	% (Mayfield corrected)	UpForest: Dry mixed hardwoods		Canopy Cover
ACFL	Daily nest predation		2.8		% (Mayfield corrected)	UpForest: Dry mixed hardwoods		
ACFL	Daily nest survival	73.0		92.0	% (Mayfield corrected)	UpForest: Dry mixed hardwoods		Stand Age
ACFL	Daily nest survival	94.7	95.6	96.5	% (Mayfield corrected)	UpForest: Dry mixed hardwoods		
ACFL	Daily nest survival		97.8		% (Mayfield corrected)	UpForest: Mesic mixed hardwooc		
ACFL	Daily nest survival		94.2		% (Mayfield corrected)	Wet: Bottomland hardwood		Stand Age
ACFL	Daily nest survival	92.0	94.8	96.5	% (Mayfield corrected)	Wet: Bottomland hardwood		
ACFL	Daily nest survival	81.8	95.1	100.0	% (Mayfield corrected)	Wet: Bottomland hardwood		
ACFL	Daily nest survival				fledglings	UpForest: Dry mixed hardwoods		Non-contiguous Pa
ACFL	Daily survival during incubation	97.5		98.0	% (Mayfield corrected)	UpForest: Dry mixed hardwoods	Edge: Forest/Ag	Non-contiguous Pa
ACFL	Daily survival during incubation		97.6		% (Mayfield corrected)	UpForest: Mesic mixed hardwooc		
ACFL	Daily survival during incubation	92.0	94.9	96.6	% (Mayfield corrected)	Wet: Bottomland hardwood		
ACFL	Daily survival during nestling sta	93.8		96.2	% (Mayfield corrected)	UpForest: Dry mixed hardwoods	Edge: Forest/Ag	Non-contiguous Pa
ACFL	Daily survival during nestling sta		97.9		% (Mayfield corrected)	UpForest: Mesic mixed hardwooc		
ACFL	Daily survival during nestling sta	91.5	94.5	97.0	% (Mayfield corrected)	Wet: Bottomland hardwood		
ACFL	Eggs per nest		2.8		eggs	UpForest: Mesic mixed hardwooc		
ACFL	Eggs per nest	1.0	2.5	4.0	eggs	Wet: Riparian		
ACFL	Extrapair young		41.0		%	Wet: Riparian		

Each record is one entry in the previous form

Map Algebra

Logistic (S-shaped)

1/(1+ a *EXP(- b *([Map Value] / c)))

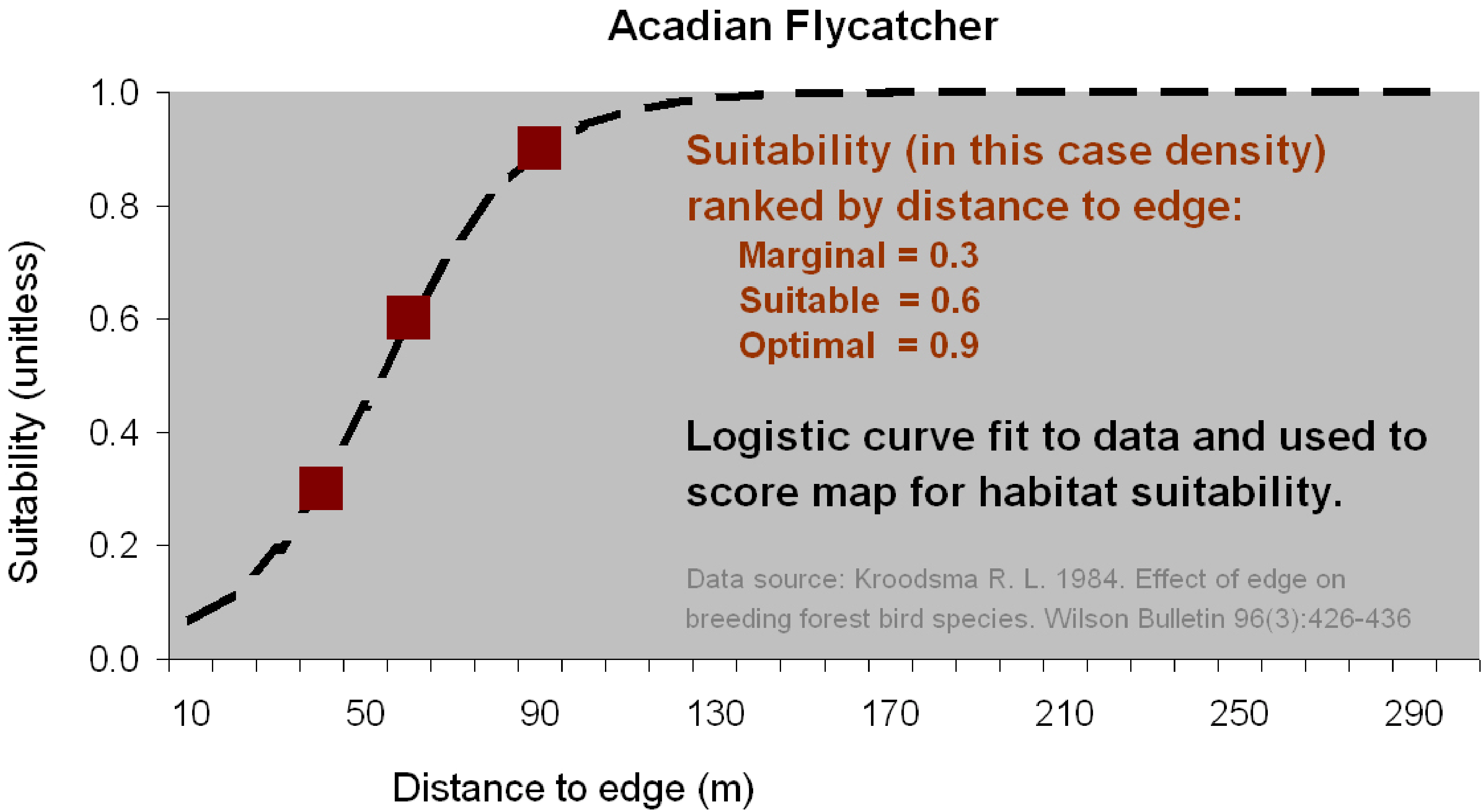
Example: 1 / (1+ 40 *EXP(- 6 *([Dist_Edge] / 90)))

a affects where upturn begins.

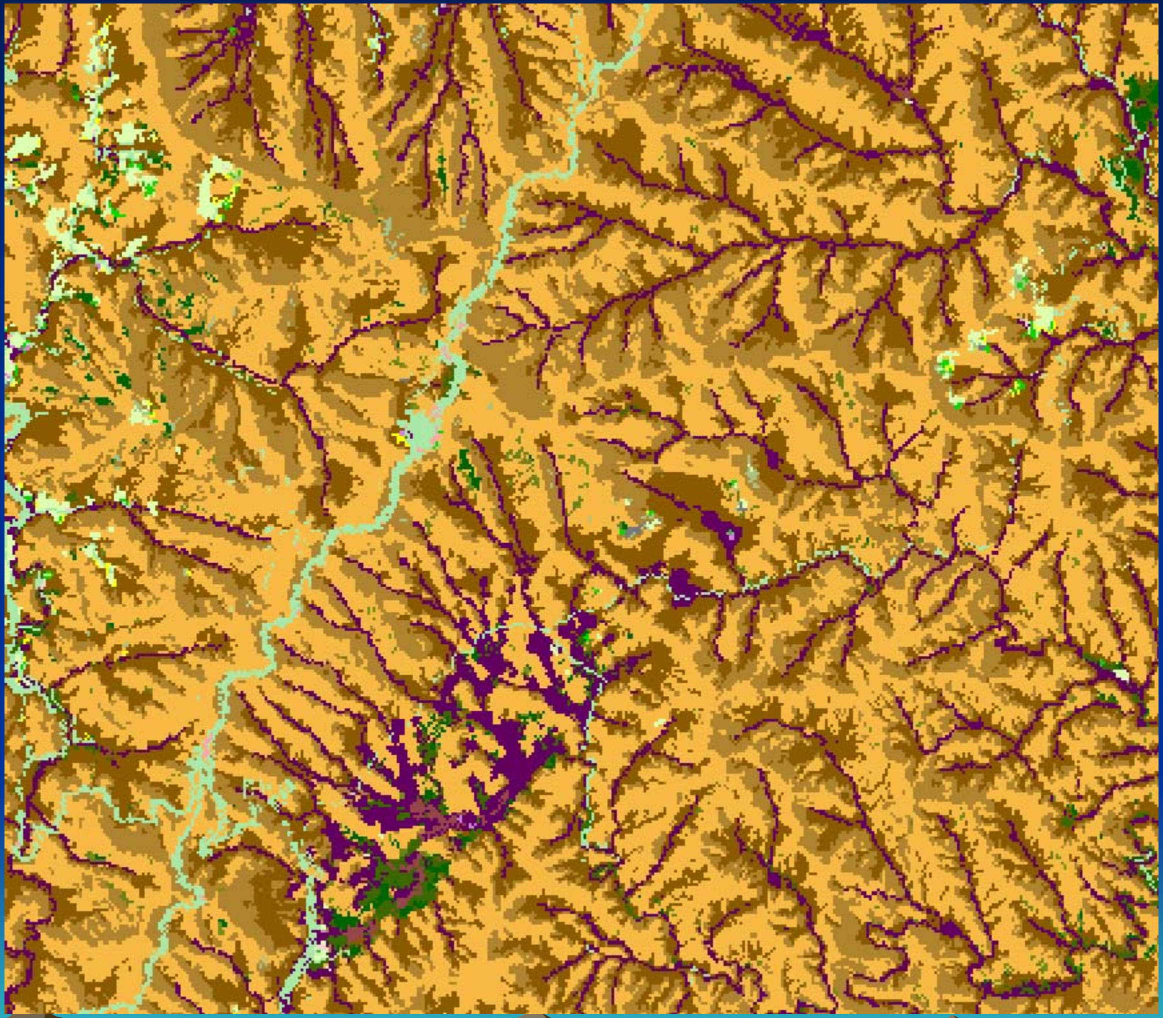
b affects slope of the “S”. Larger numbers shrink the curve.

c also affects slope of the “S” but less so. Larger numbers stretch the curve.

Mapping Suitability Relationships



Habitat Suitability Prediction



6 km

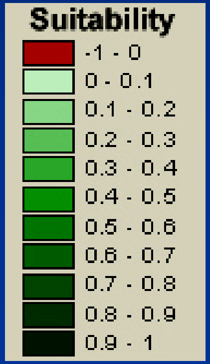
Input

Avicentric land cover

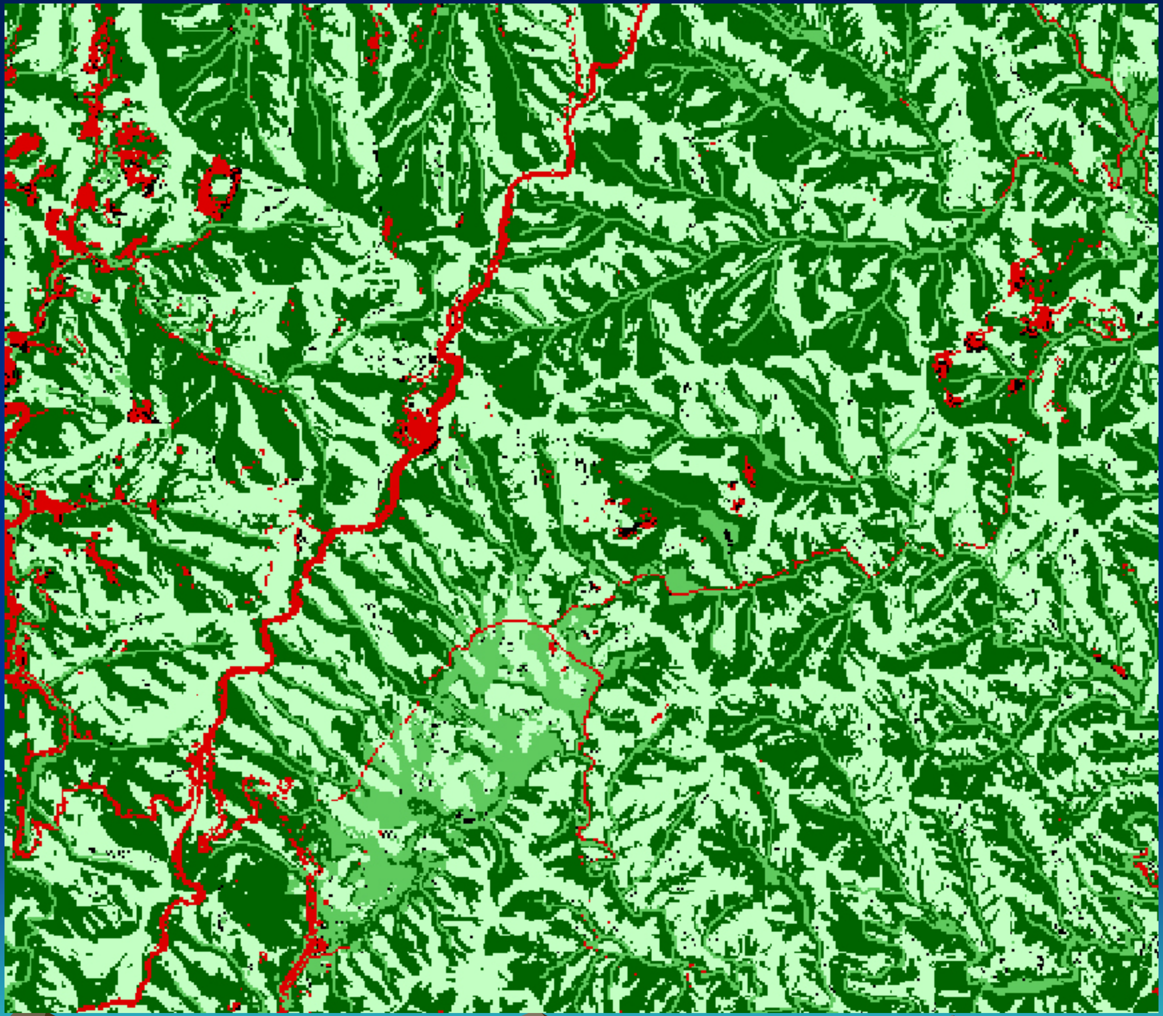
Lump Classes of Similar Suitability

Acadian

Flycatcher



6 km



Input

Flycatcher-centric land cover

Calculate and Weight Distance to Edge

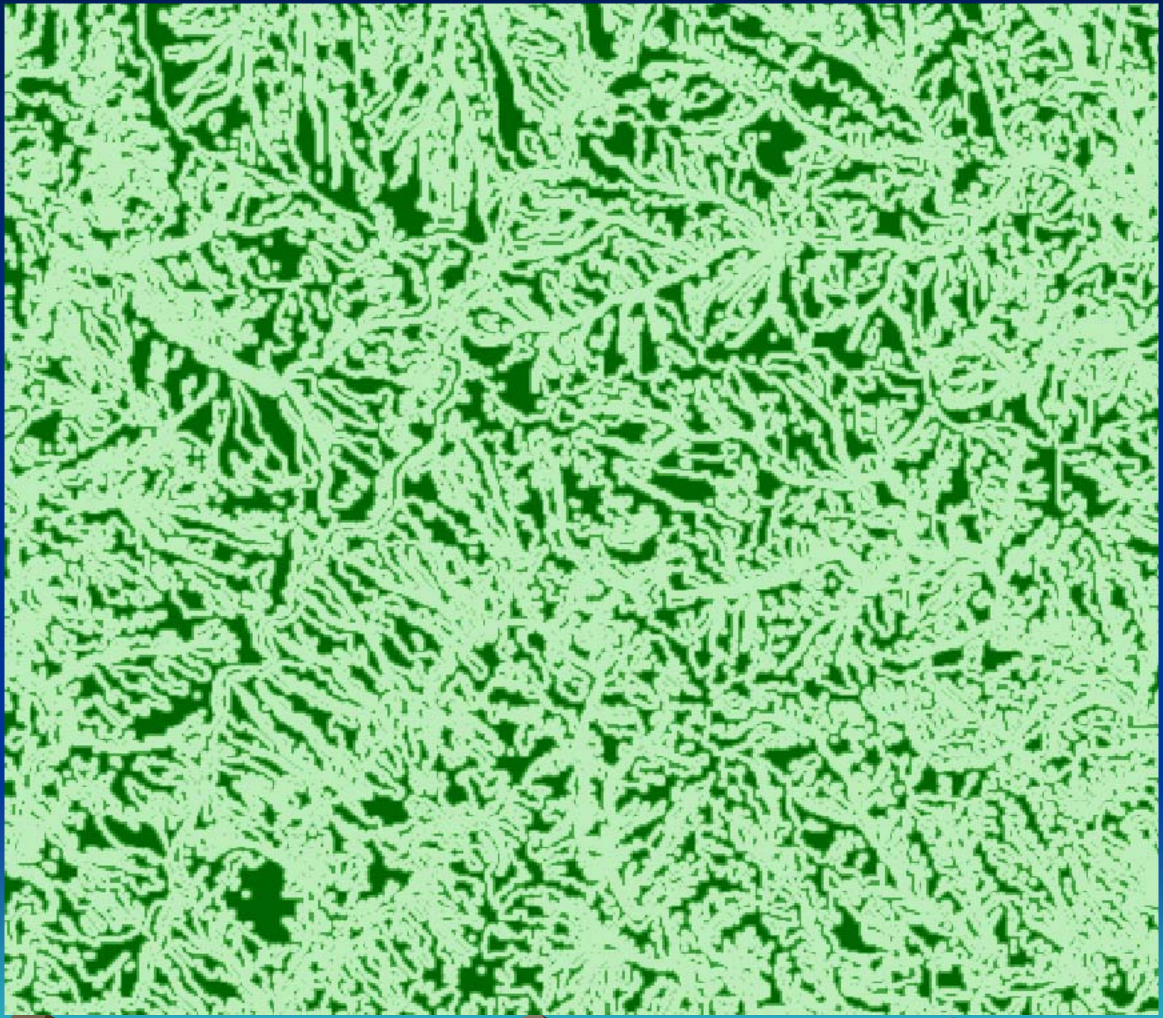
Acadian

Flycatcher

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



Input

Distance to Edge

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:

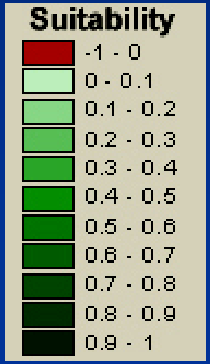
$$dR/dt = a*R - b*R*F$$
$$dF/dt = e*b*R*F - c*F$$

  - 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.

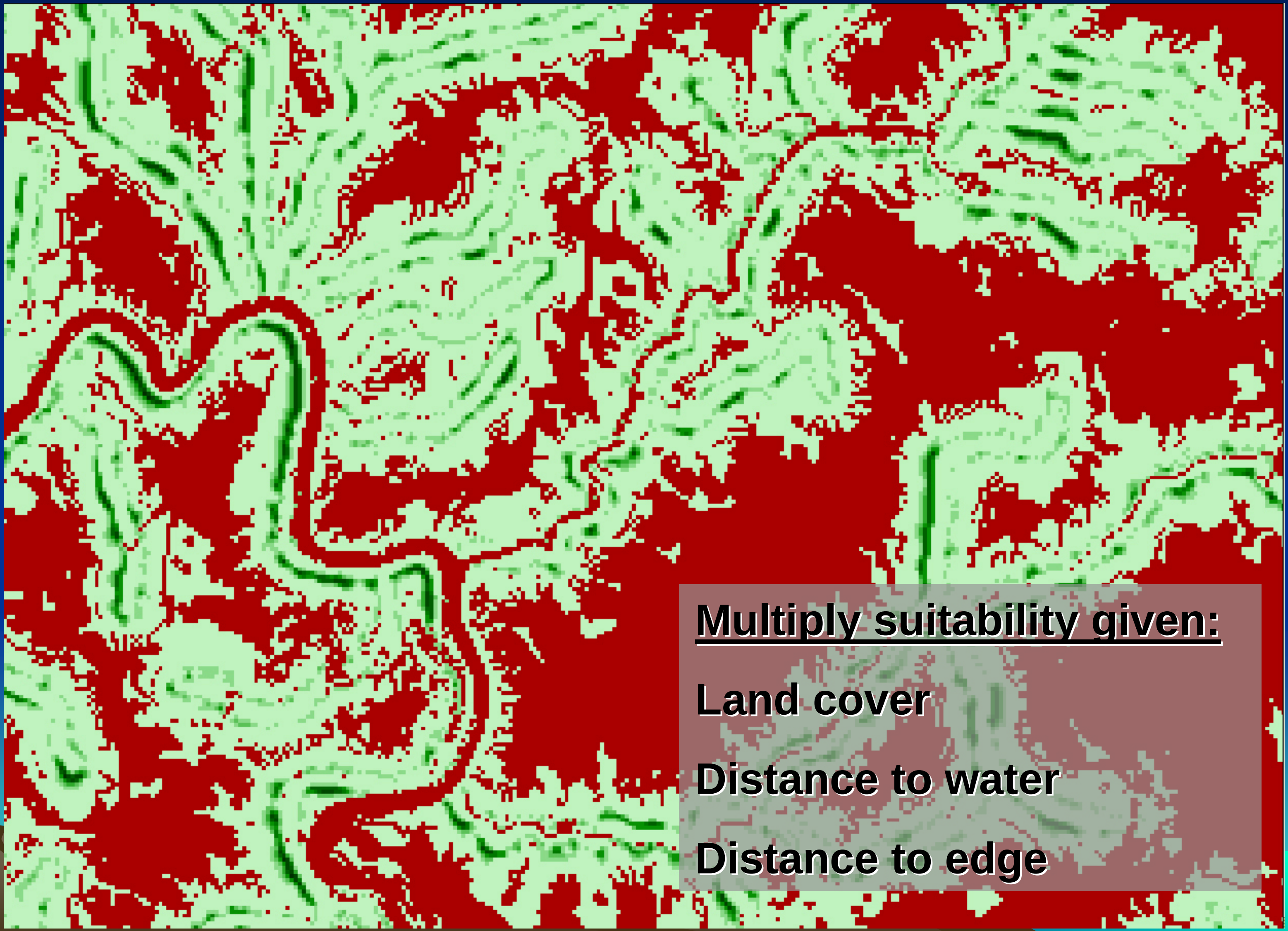
Habitat Suitability Prediction

Acadian

Flycatcher



1 km



Multiply suitability given:

Land cover

Distance to water

Distance to edge

Explicitly State Assumptions!

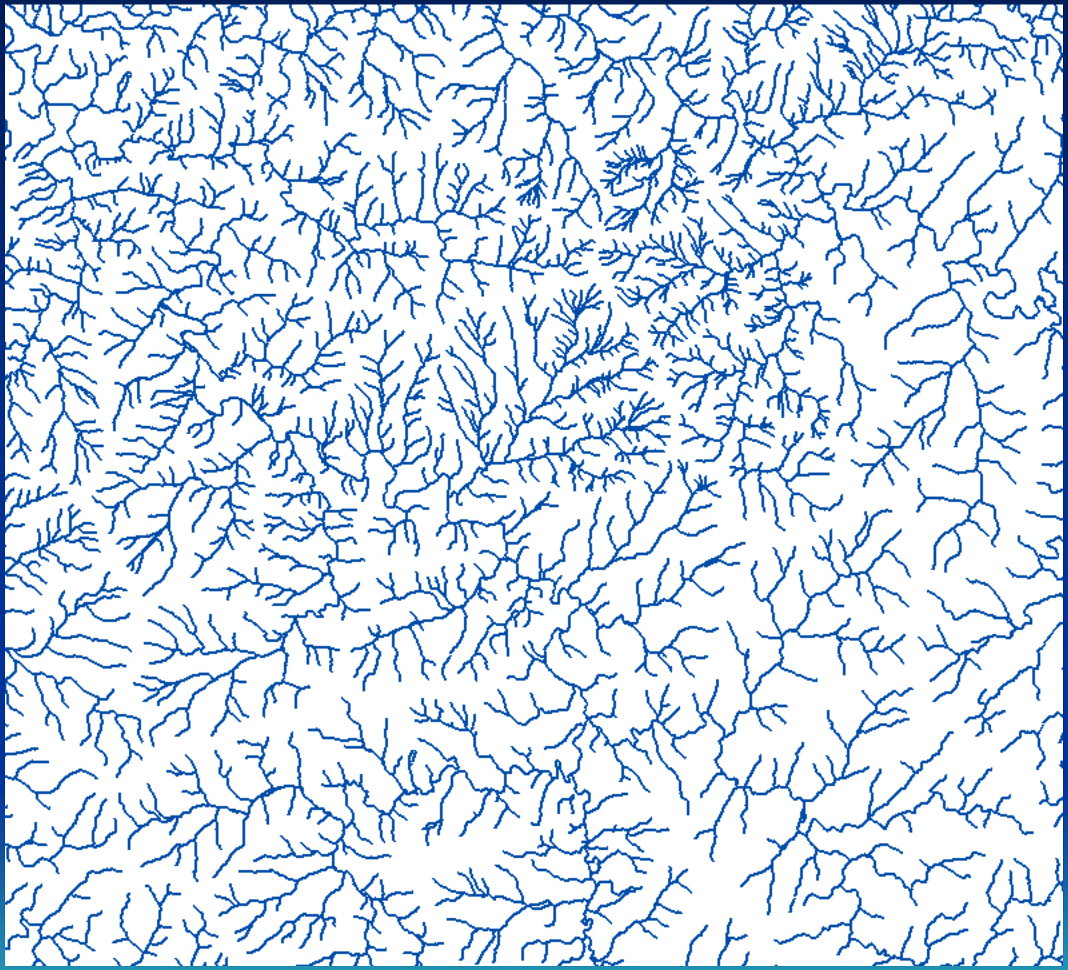
- Allows testing to validate and refine predictions

- 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

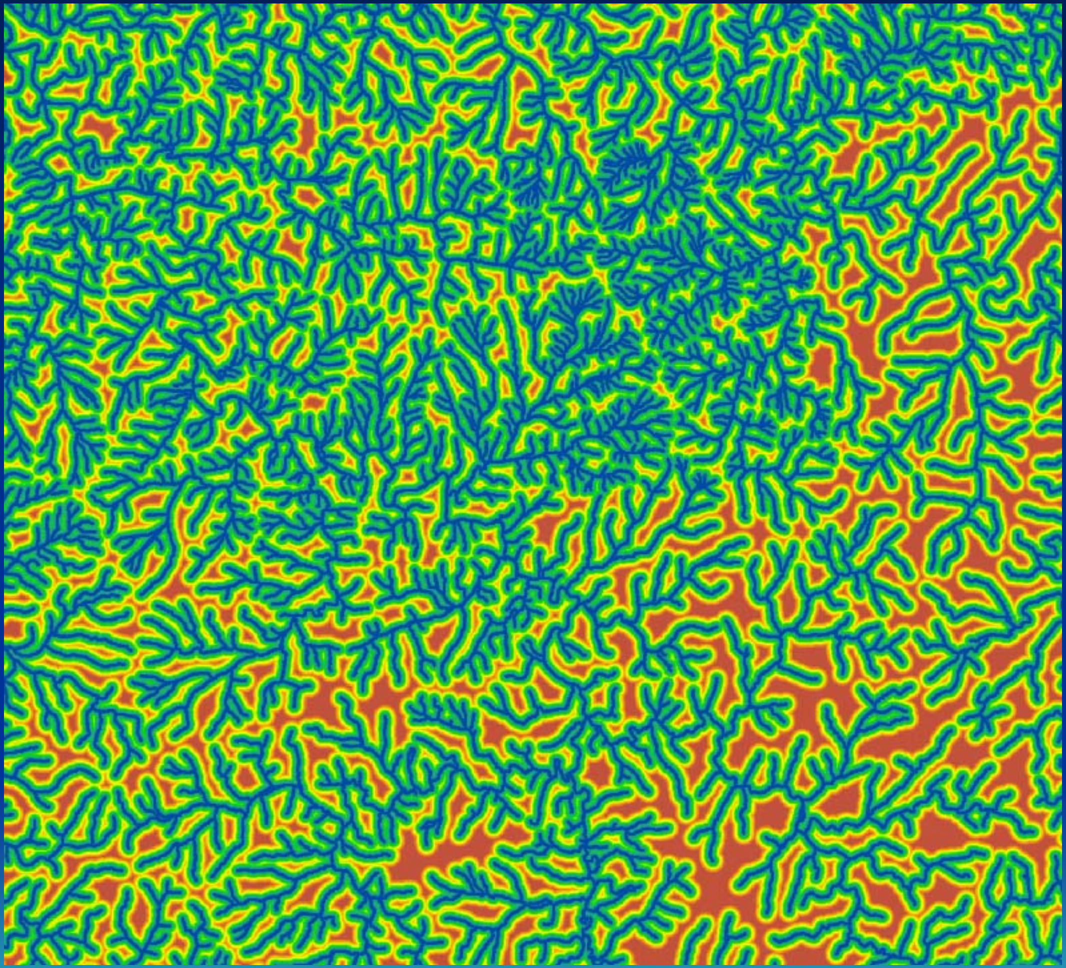
- Age of data
- Precision and availability of information
- Positional accuracy
- Classification appropriateness and accuracy
- Inconsistencies during data creation
  - Different interpreters or methods
  - Different classification schemes
  - Different scales of precision

Example: Digital Line Graphs

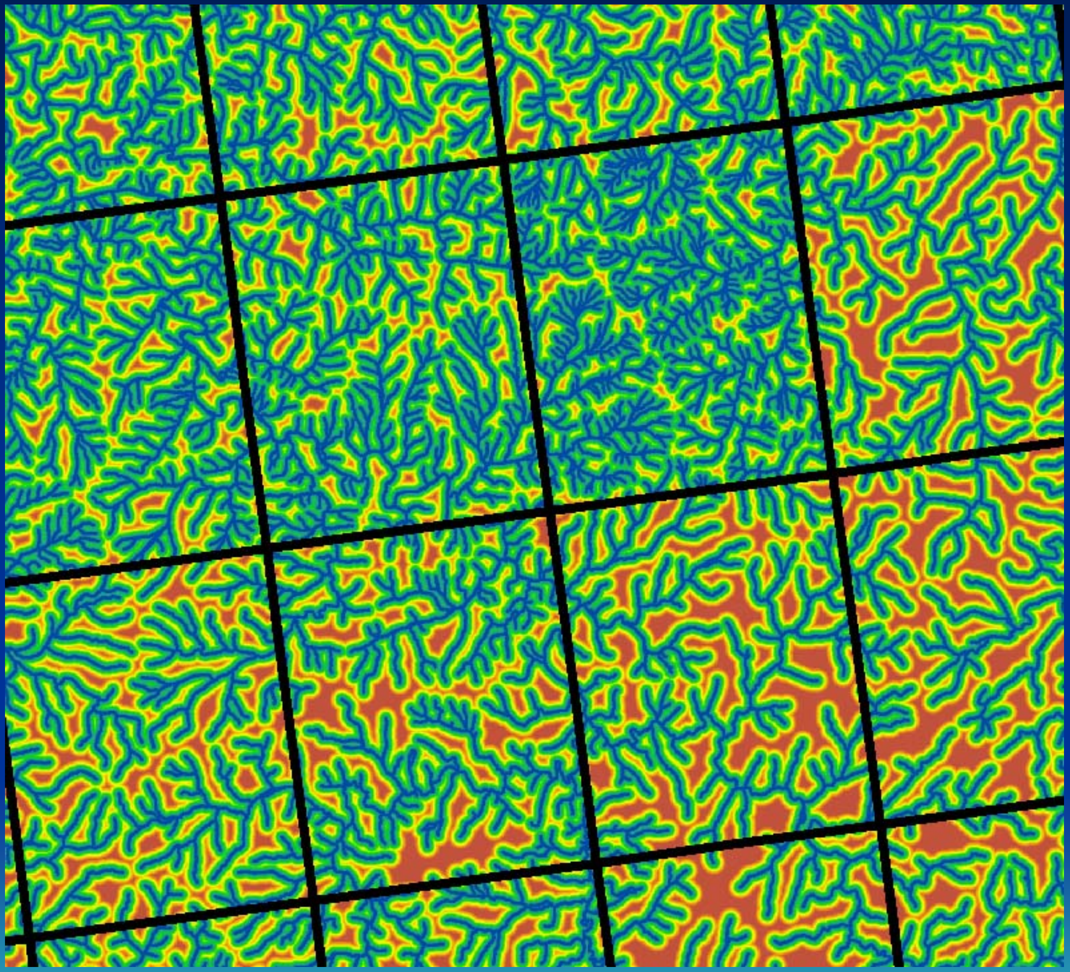


Used in the National Hydrographic Dataset

Distance to Water



Different Scales of Precision



www.basic.ncsu.edu/segap