An Ecological Approach for Monitoring Change Around Protected Areas

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Sponsored by the National Park Service: Greater Yellowstone Network, Heartlands Network, Inventory&Monitoring Program

Thanks to: Brent Frakes, Janet Eckhoff, Phyllis Adams, Rob Bennett, Rob Daly, Cathie Jean, John Gross

The Concept of Nature Reserves

Thomas Moran, *Grand Canyon of the Yellowstone*, 1872, Department of the Interior Museum, Washington, D.C.

Thomas Moran Hayden Expedition 1871

By removing humans, natural ecosystems were expected to continue to maintain ecological processes and native species.

Loss of Reserve Function

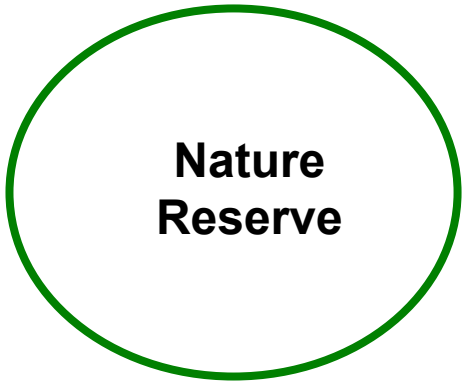
- Ecological Processes
  - Climate
  - Disturbance
  - Nutrients
- Biodiversity
  - Invasive species
  - Extinction of native species
    - 11 of 13 western US national parks have lost 5-21% of original large mammal species (Parks and Harcourt 2002)

Land Use Intensification Around Reserves

Boundary of Greater Serengeti Area

What are the consequences of land use change around reserves for biodiversity within reserves?

Nature Reserves as Parts of Larger Ecosystems



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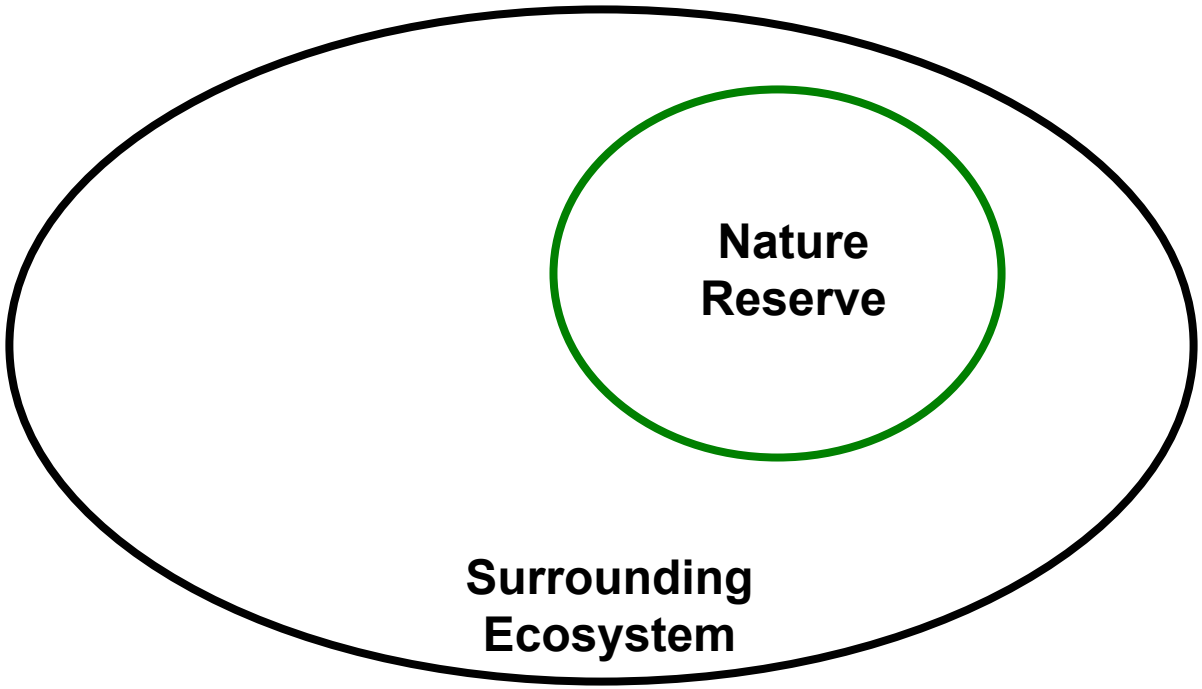

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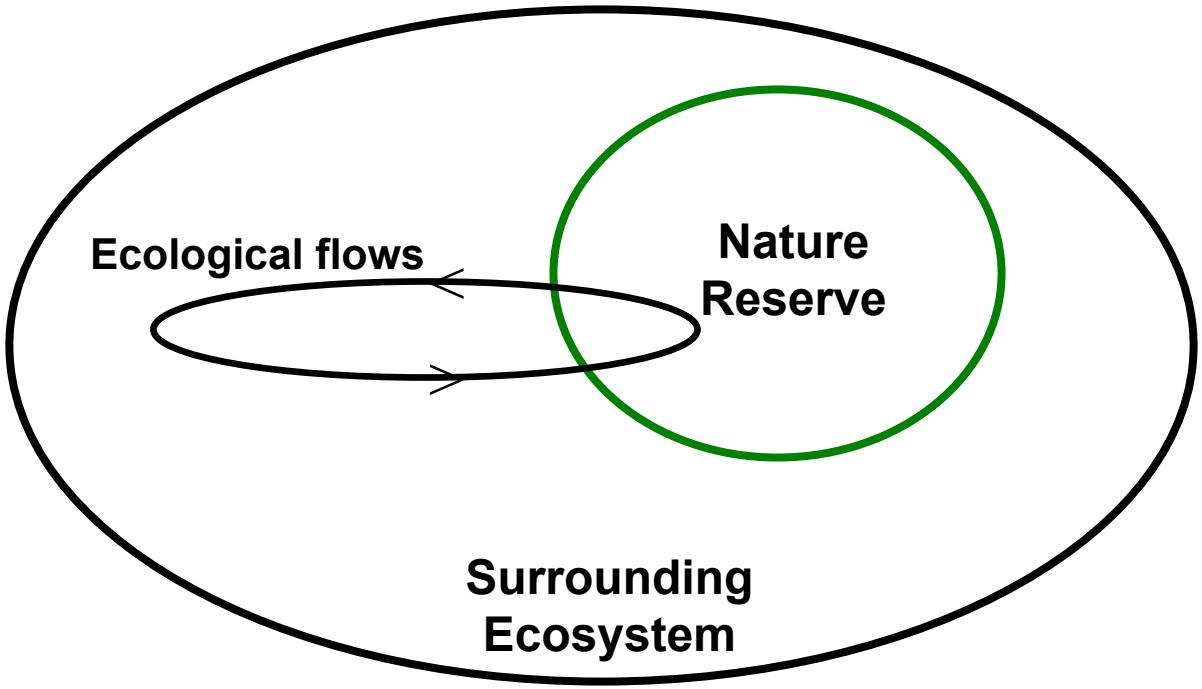
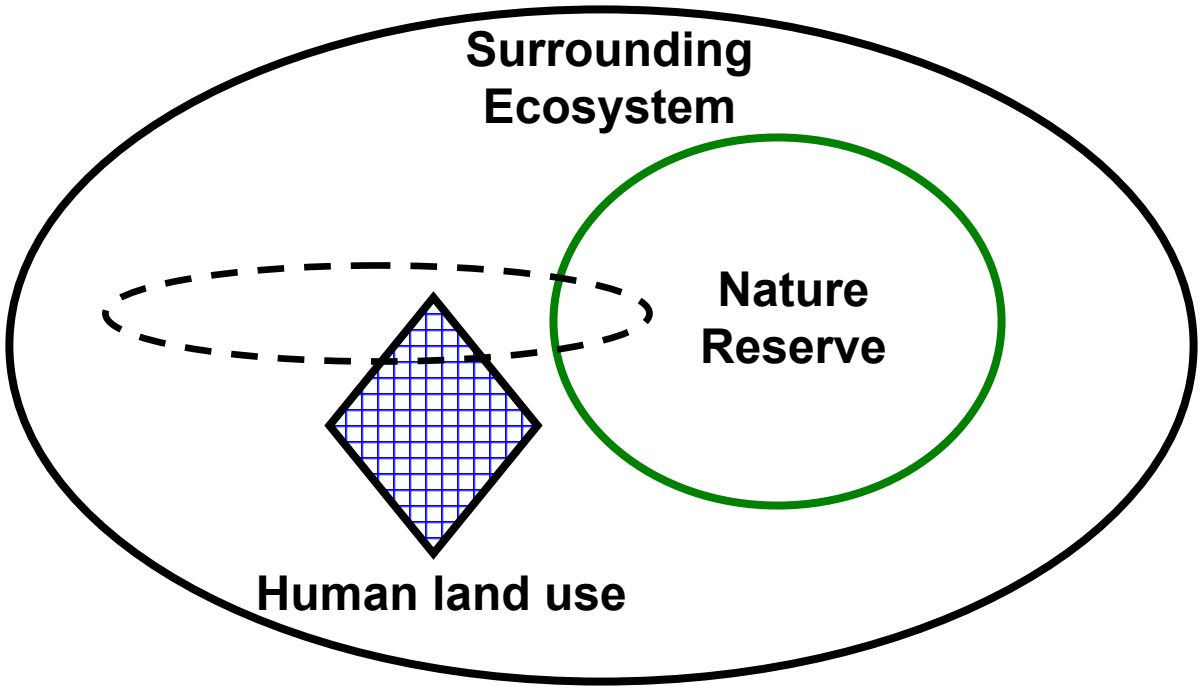


Nature reserves are often connected to the surrounding landscape by movements of materials, disturbance, and organisms

Nature Reserves as Parts of Larger Ecosystems



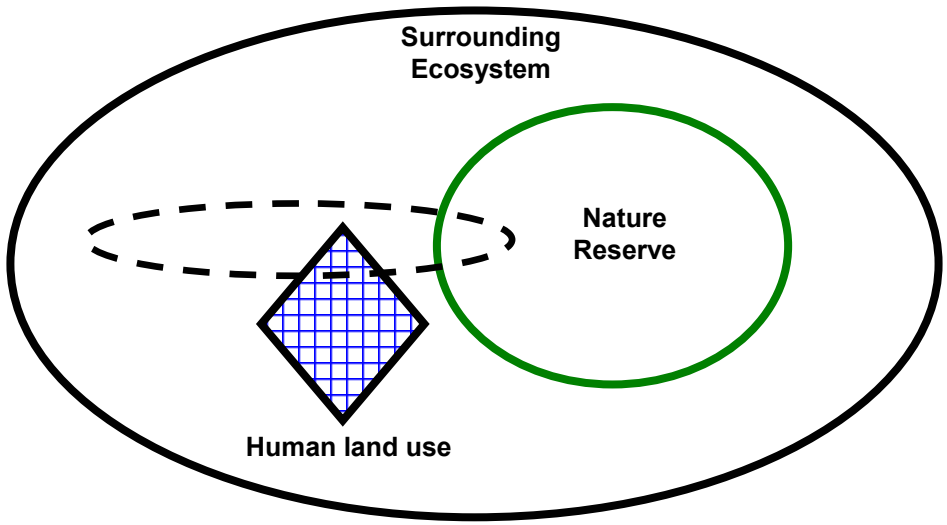
Land use intensification outside of nature reserves may disrupt these flows and alter ecological processes and biodiversity within reserves.

Larson's Conceptual Model of Nature Preserves

Wildlife preserves

Critical Needs

- Monitor and manage across the functional ecosystem.



Topics

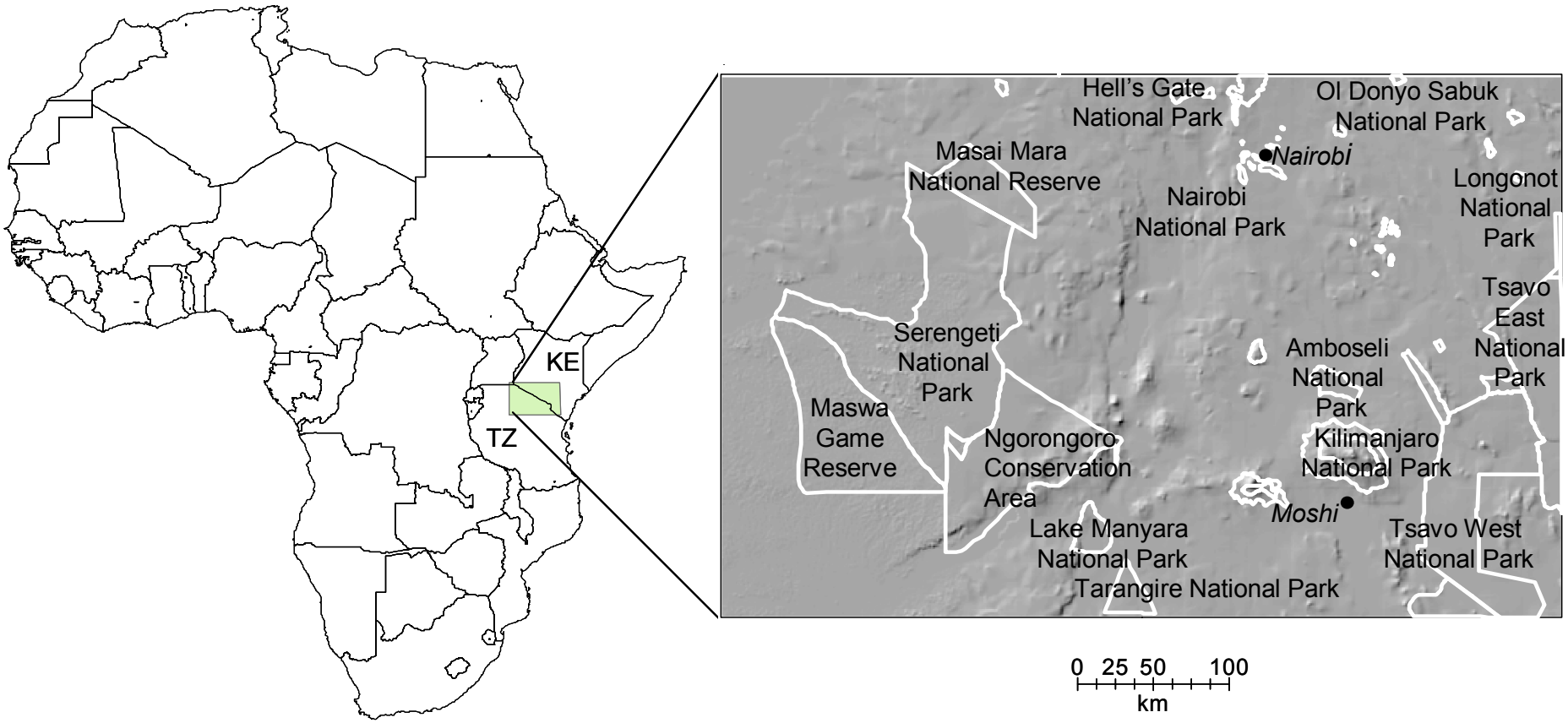
- Ecological framework for monitoring
- Case study from Heartlands Network
- Monitoring as part of adaptive management across networks

Study Regions

With Ruth DeFries, Emilio Moran, Robin Reid, Billie Turner, Lisa Curran, Jack Liu

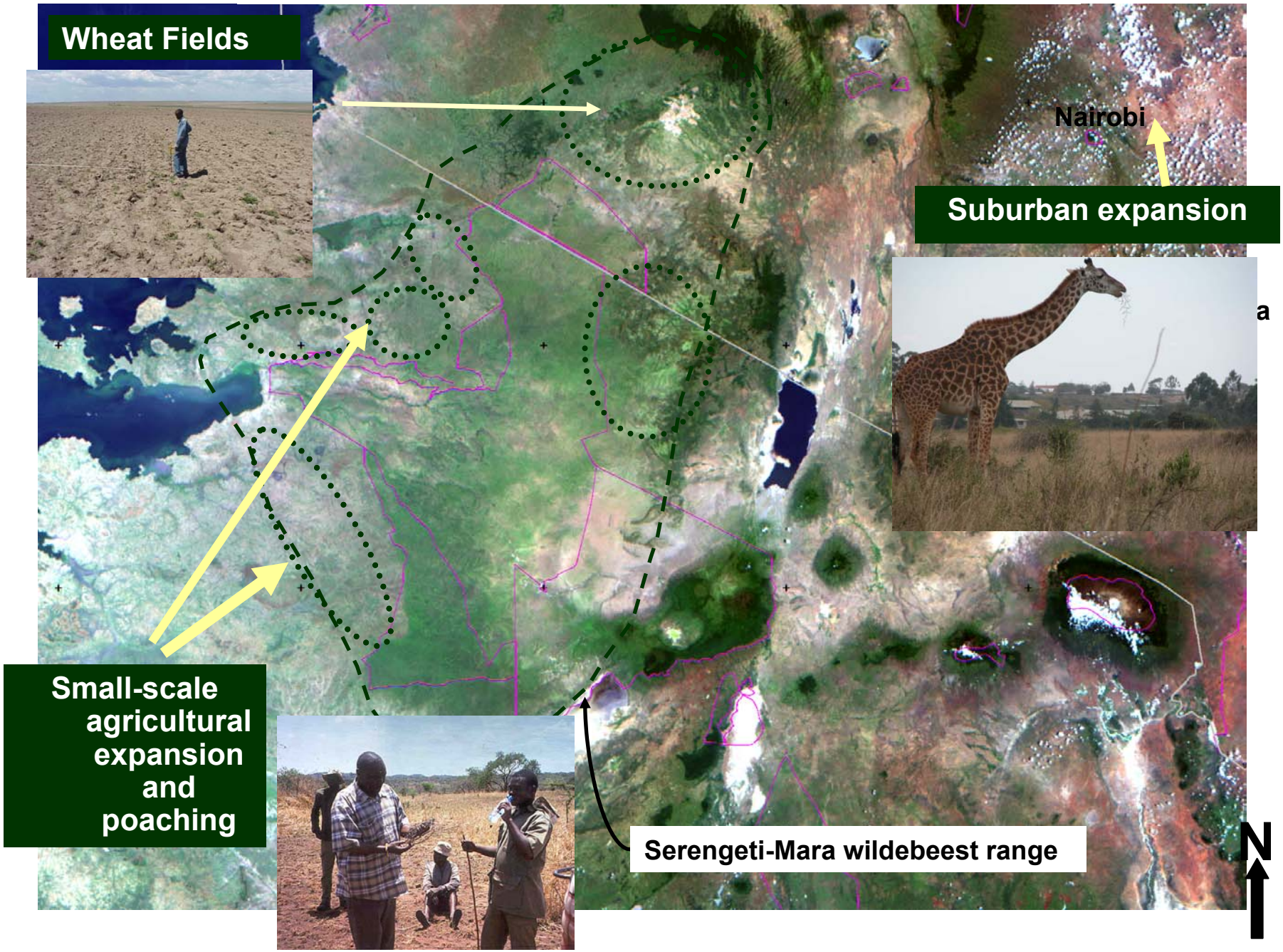
NASA LCLUC

Maasai East Africa Study Area

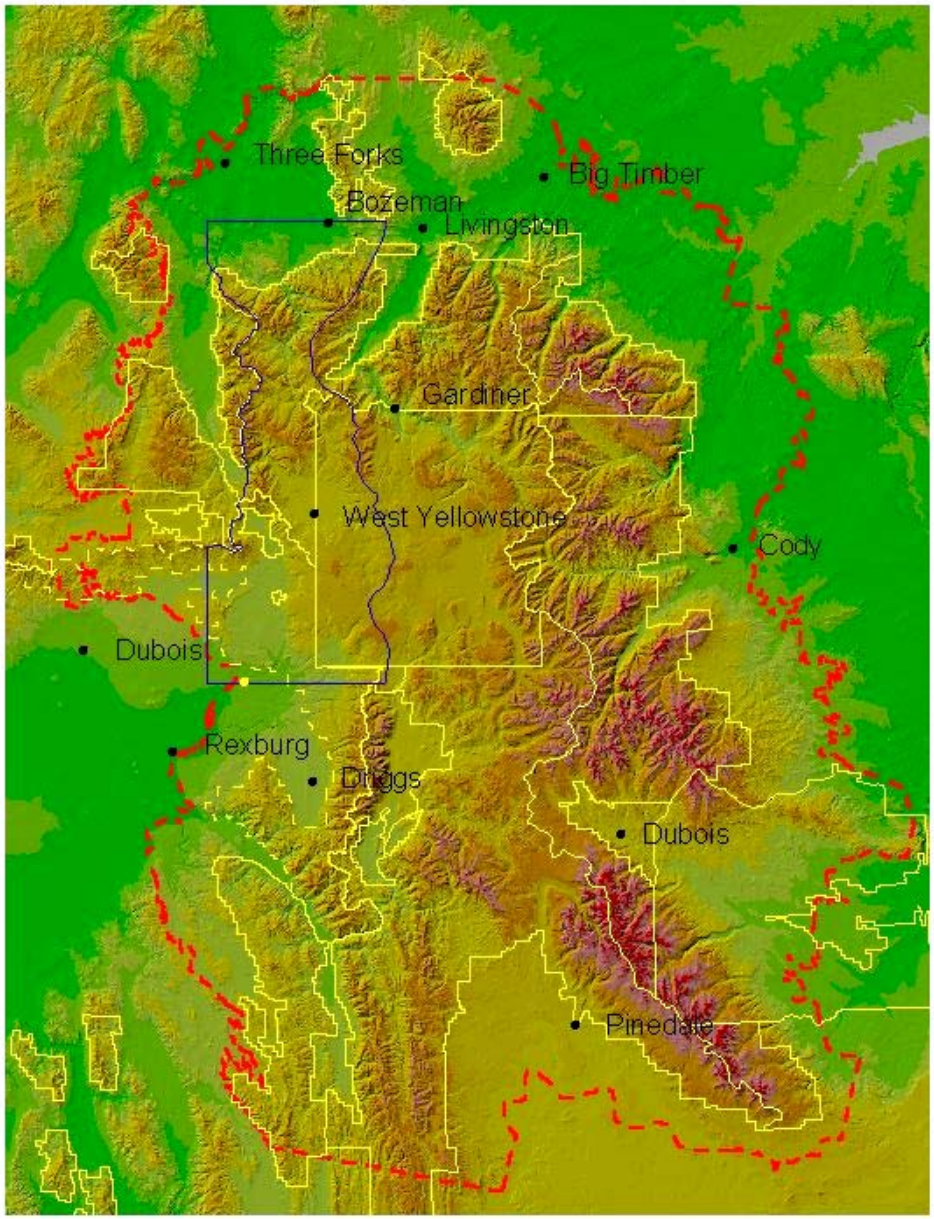


Maasai East Africa: Nomadic Pasturalism

Maasai East Africa: Land Use Change



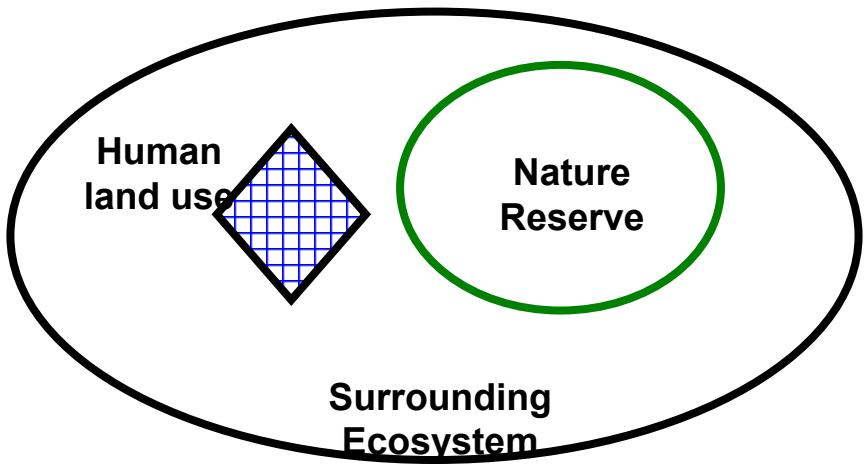
Greater Yellowstone Ecosystem



GYE Rural Residential Development

Ecological Mechanisms

- Change in effective size of reserve
- Changes in ecological flows into and out of reserve
- Loss of crucial habitat outside of reserve
- Increased exposure to human activity at reserve edge



Ecological Mechanisms

Mechanism	Type
Change in effective size of reserve	Species Area Effect Minimum Dynamic Area Trophic Structure
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Hansen and DeFries (in prep)

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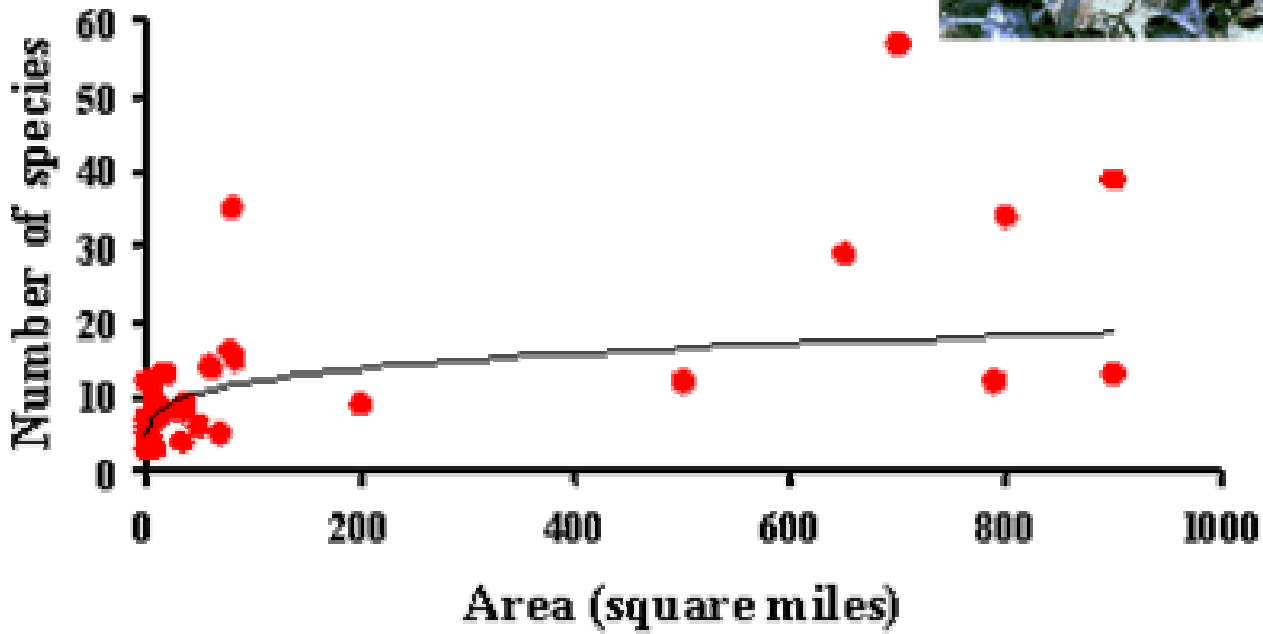
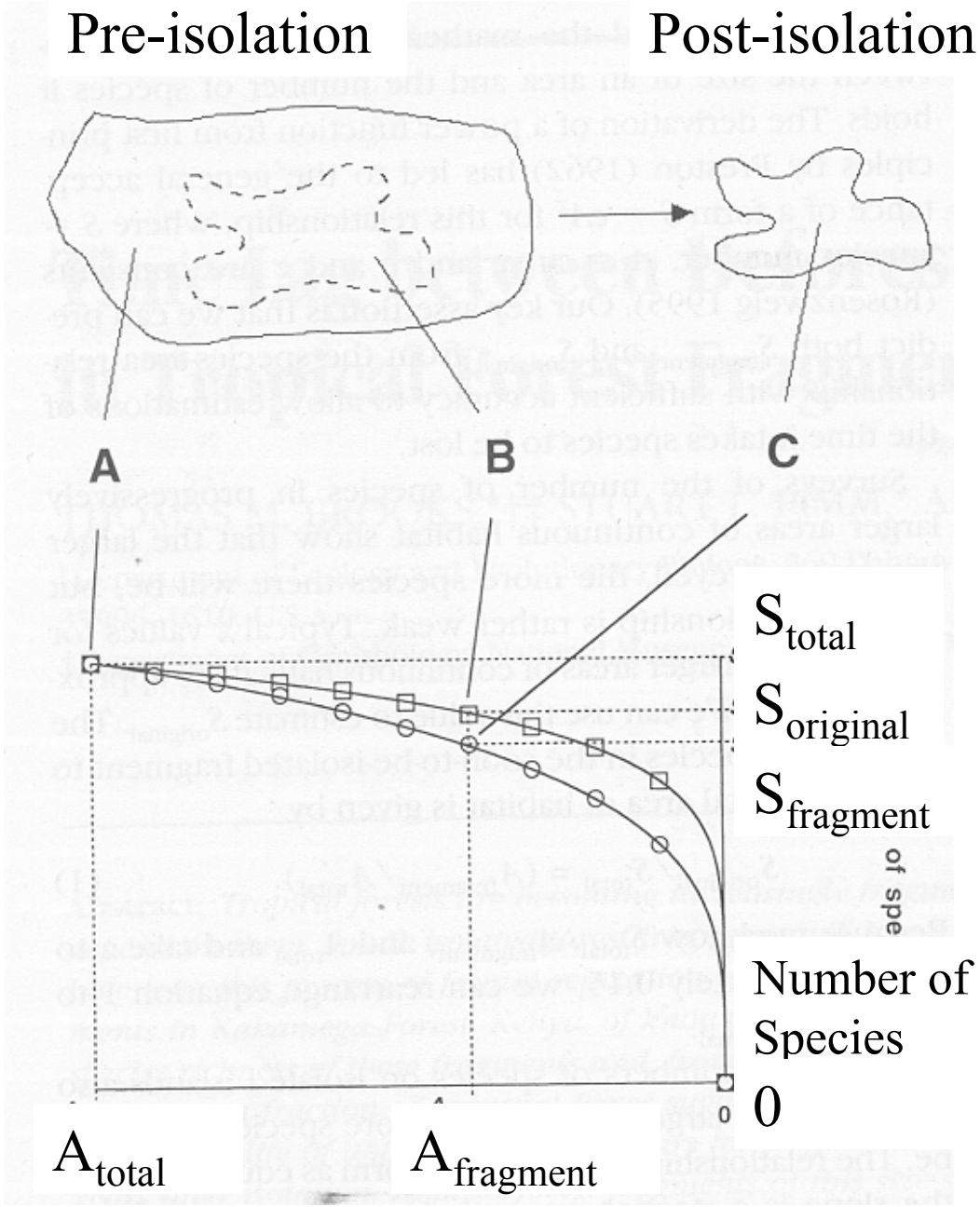
Species Area Relationship

Polynesian Ants



Species Area Effects: Habitats Fragments



Brooks et al. 1999

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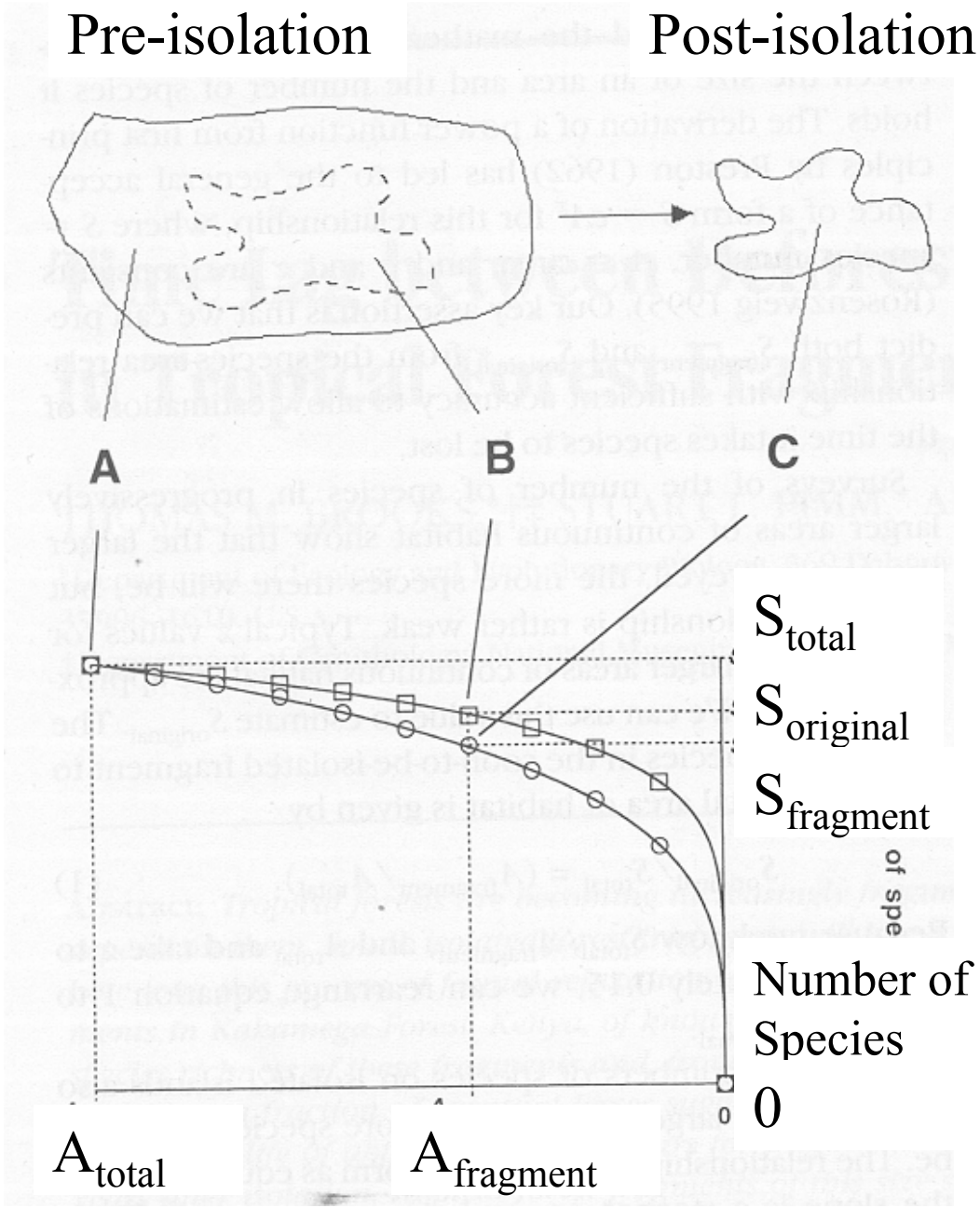


Brooks et al. 1999

<u>Implication:</u>
Nature reserves will loose species as the natural habitats around them are reduced in size

Species Area Effects: Methods

1. Estimate current area of natural habitats (subtract from total areas in urban, ag, rural housing, 1.6 km buffer around rural homes in GYE, 5 km buffer around settlements in EA)

2. Determine the number of bird and mammal species known to be present and breeding in each region from range maps.

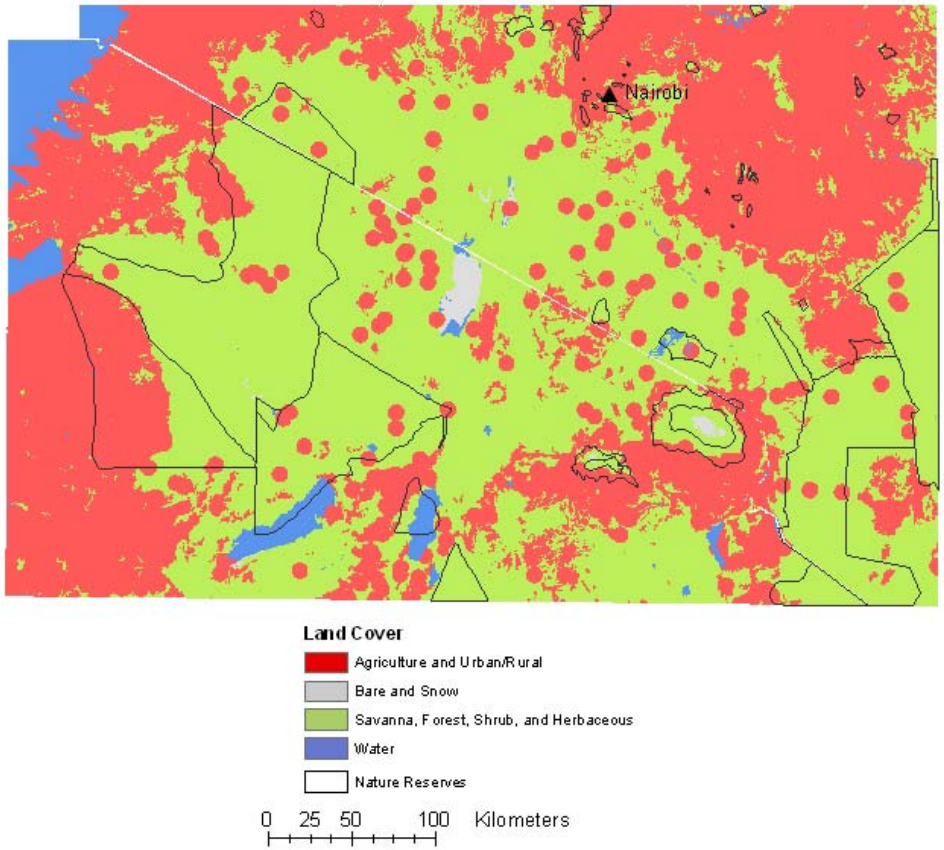
3. Estimated species richness based on ratio of remaining to original area (entire study area) of natural habitat based on Brooks et al. 1999:

$$S_n = S_o (A_n/A_o)^z$$

New species richness=original species richness (new area/original area)$^{.25}$

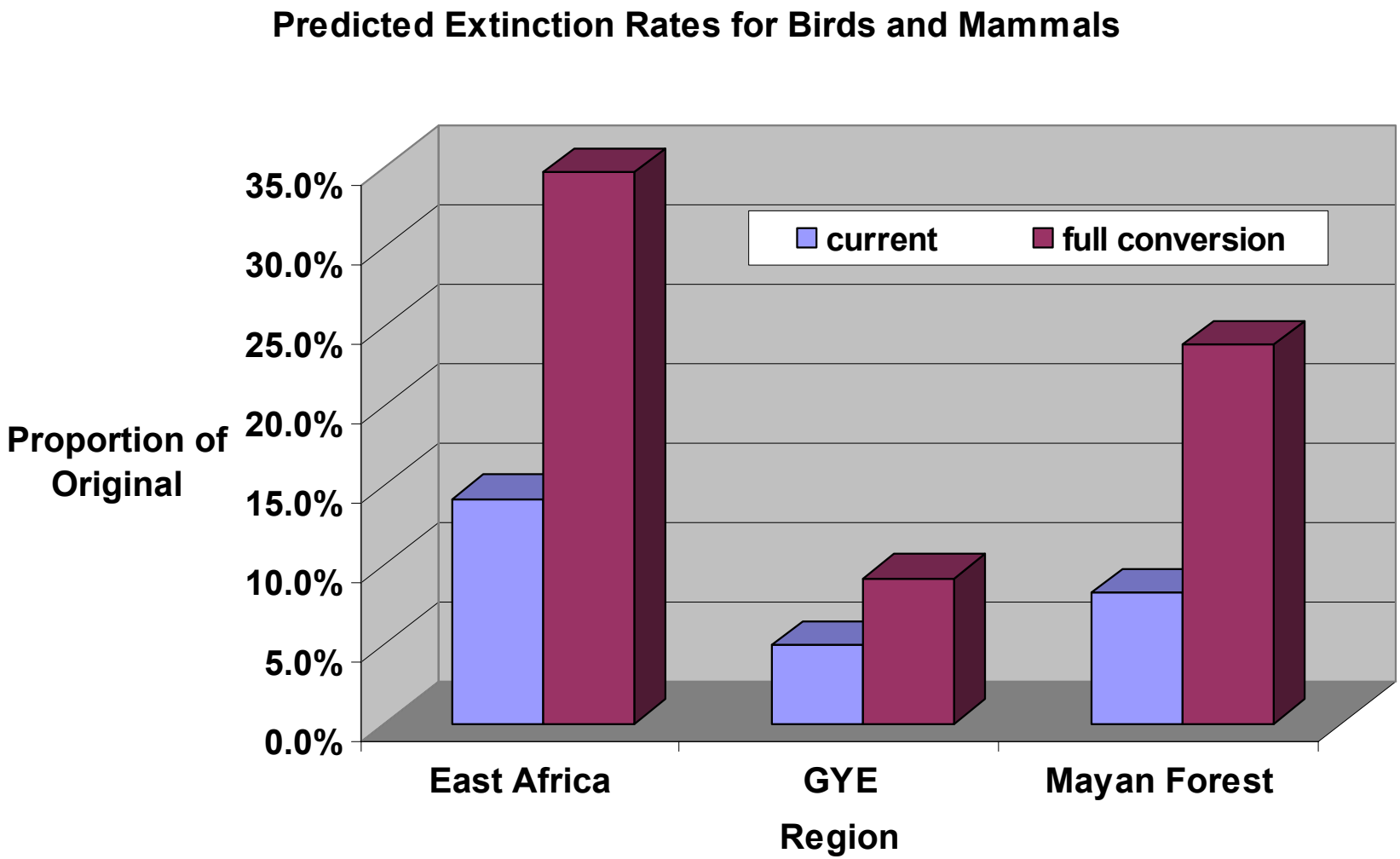
4. Validated our results against the number of threatened species in each region.

Maasai East Africa: Loss of Wildland Habitats



Site	Total Area (km^2)	Total % Converted	% Unprotected Lands Converted	% Remaining Habitat Found Outside Reserves
Maasailand	193,405	45	53	66

Species Area Effect: Results



- 9-14% of species in these greater ecosystems are predicted to go extinct based on habitat loss to date.
- If all unprotected wildlands are converted, 9-35% of species are predicted to go extinct.

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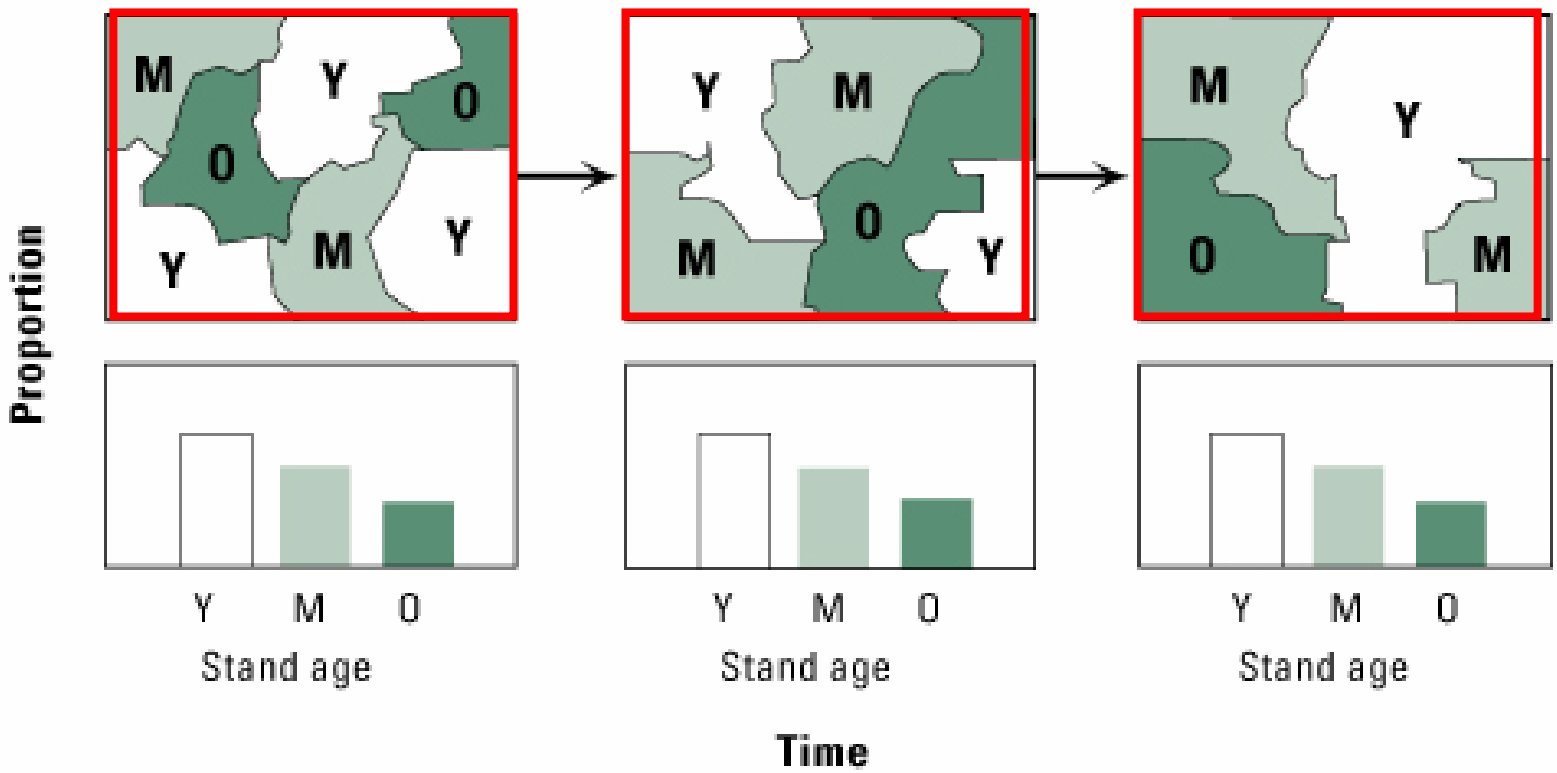
Minimum Dynamic Area

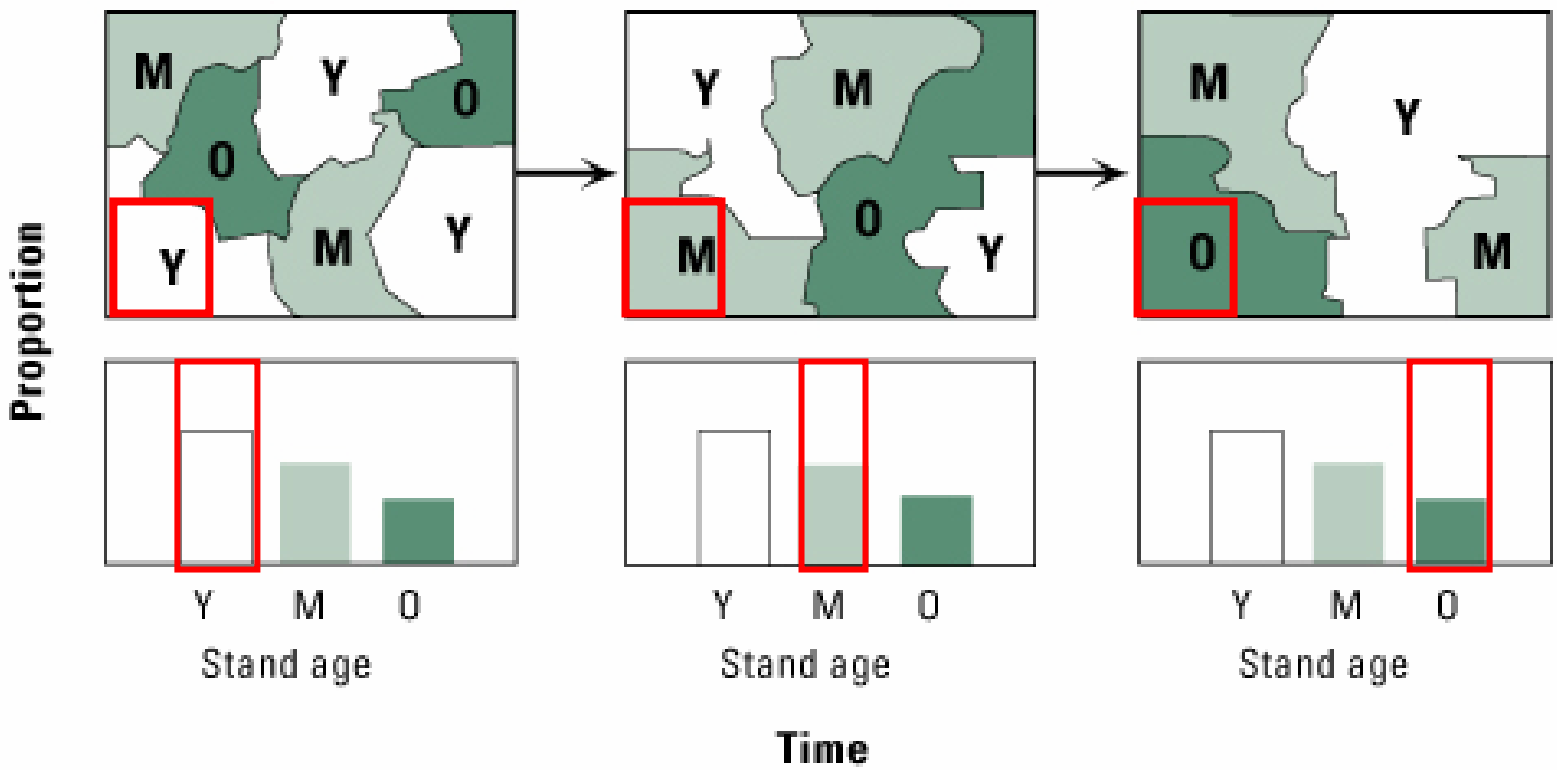
Nature reserve



Minimum Dynamic Area – Smallest landscape where a collective behavior of individual patches displays equilibrium.

Minimum Dynamic Area

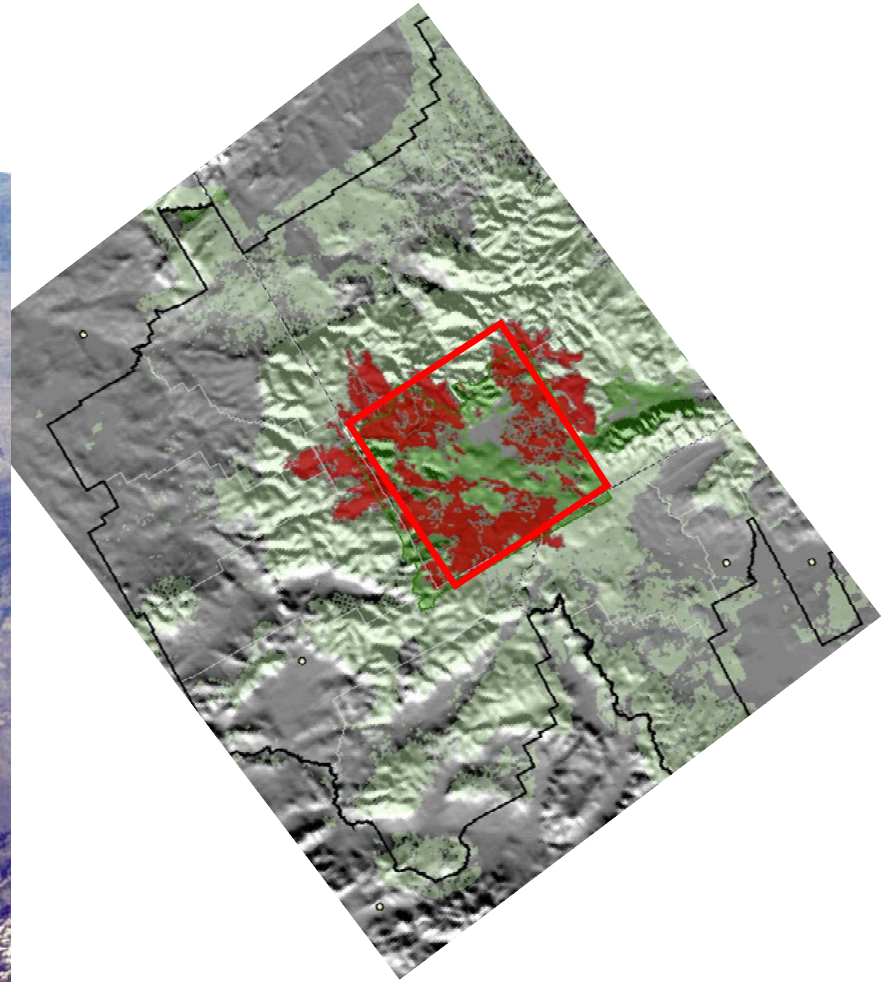
Nature reserve



Minimum Dynamic Area – Smallest landscape where a collective behavior of individual patches displays equilibrium.

Consequences: Loss of Minimum Dynamic Area?

GYE from Space: 1972



1988 Yellowstone Fires

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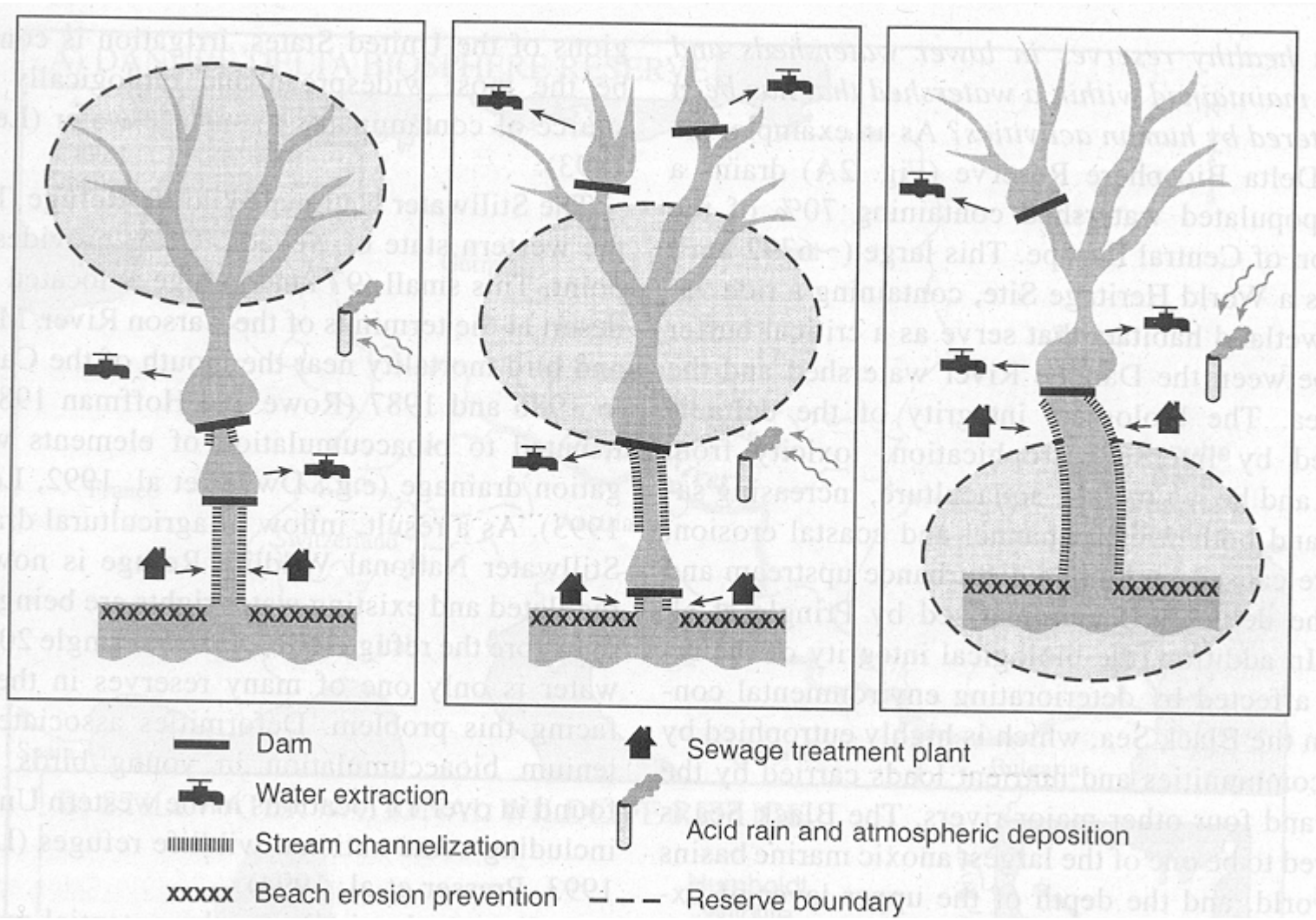
Hansen and DeFries (in prep)

Placement in Watershed



From Pringle 2001

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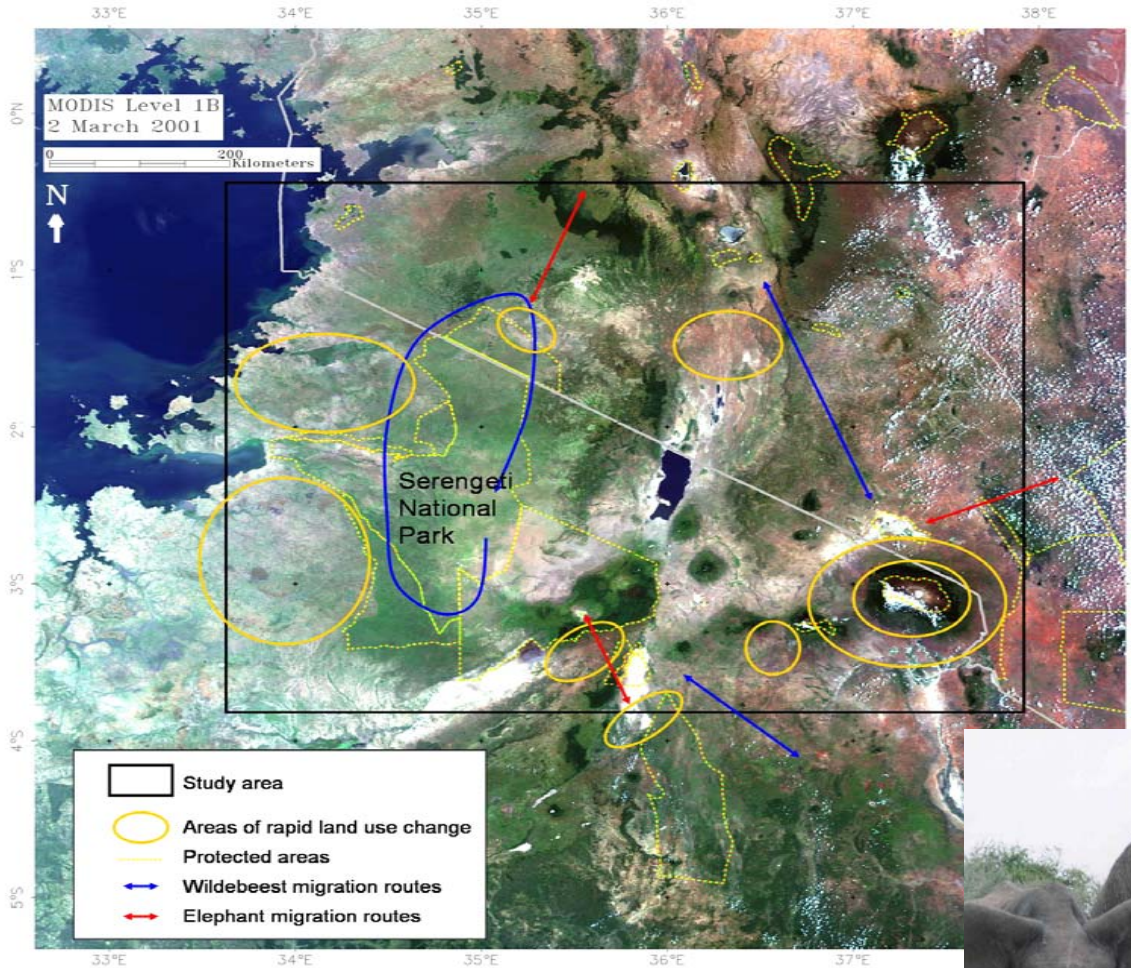
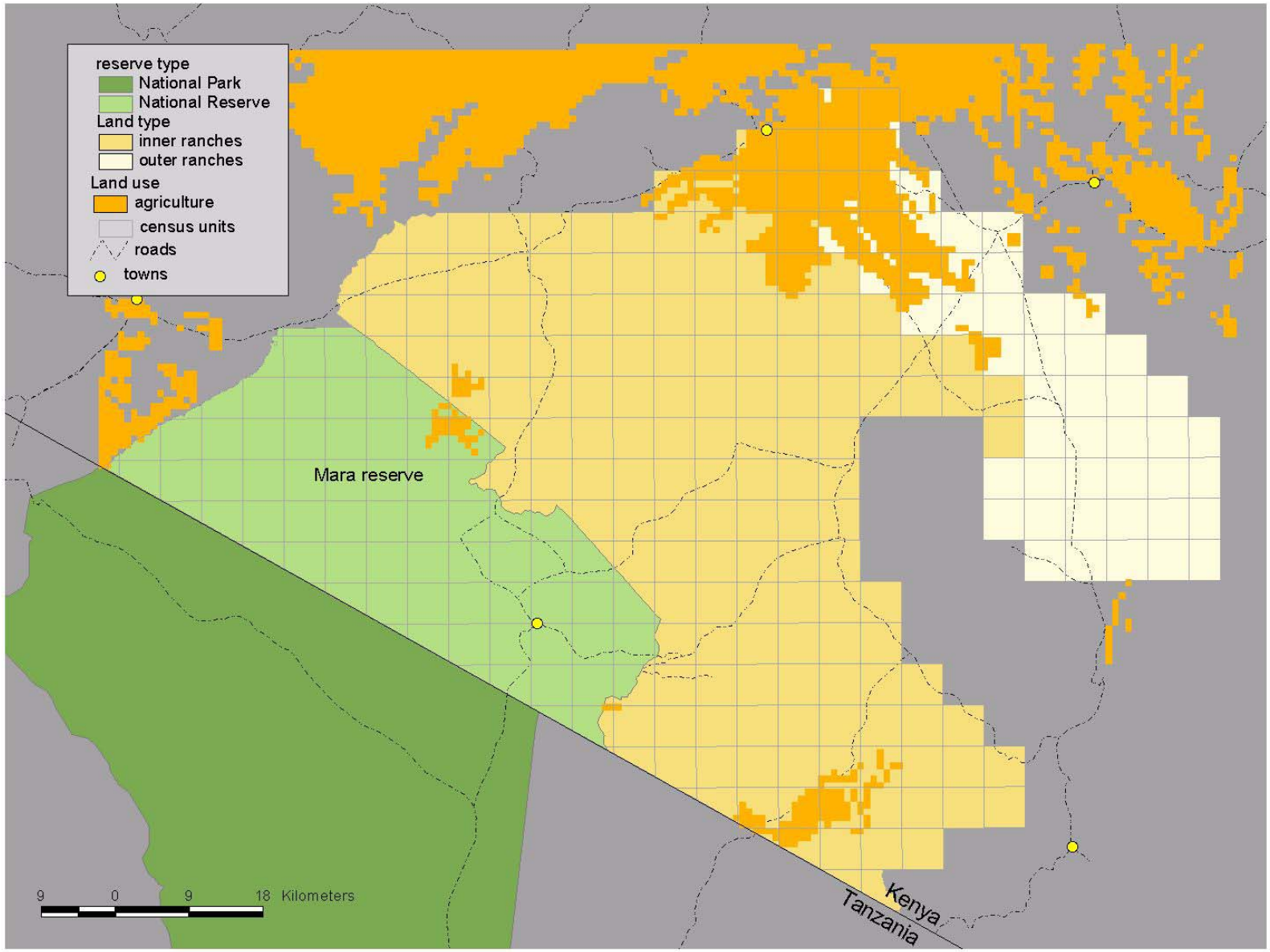
Hansen and DeFries (in prep)

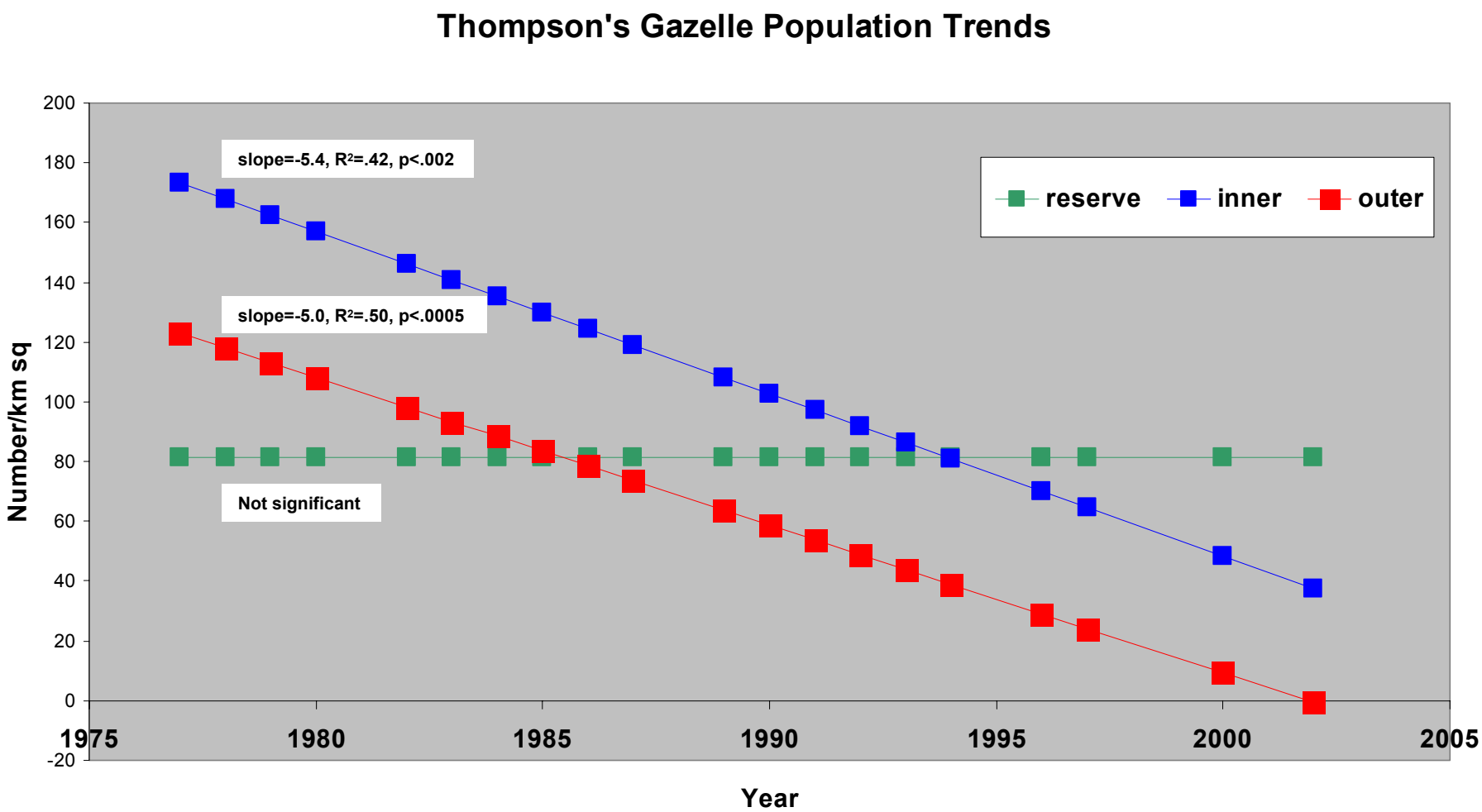
Migration Habitats



Maasai Mara Greater Ecosystem

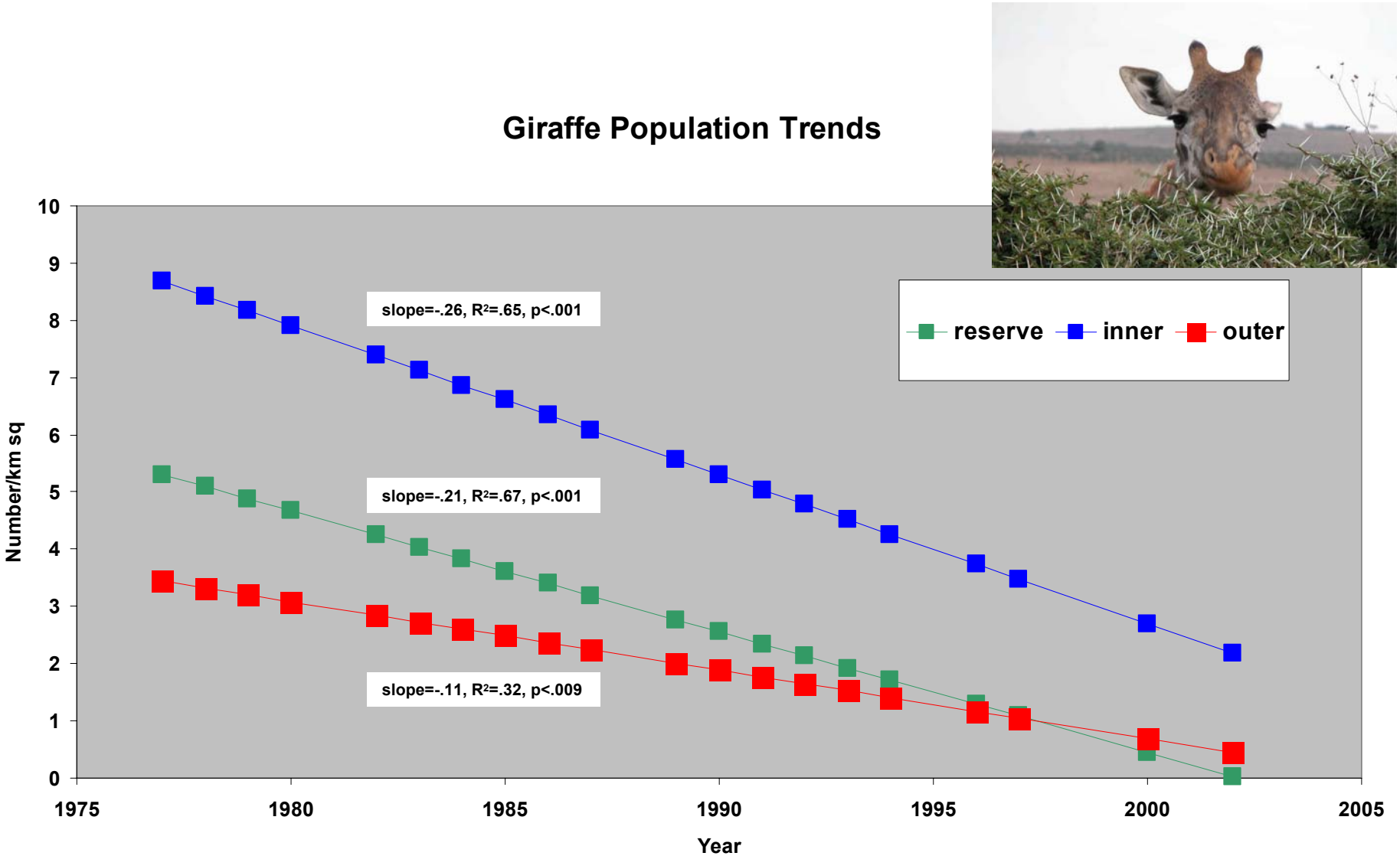


Species Abundances



Similar Results

Burchell's zebra, Grants Gazelle



Similar Results

wildebeest, kongoni, impala, Thompson's gazelle, buffalo, warthog, waterbuck

Great Maasai Mara Ecosystem: Large Mammal Population Trends 1977-2000

13 Species Analyzed

- 3 species and species richness maintained in reserve but declined outside reserve.
- 8 species declined both inside and outside reserve.
- 1 species did not change across the study area (elephant)
- 1 species increased outside reserve (ostrich)

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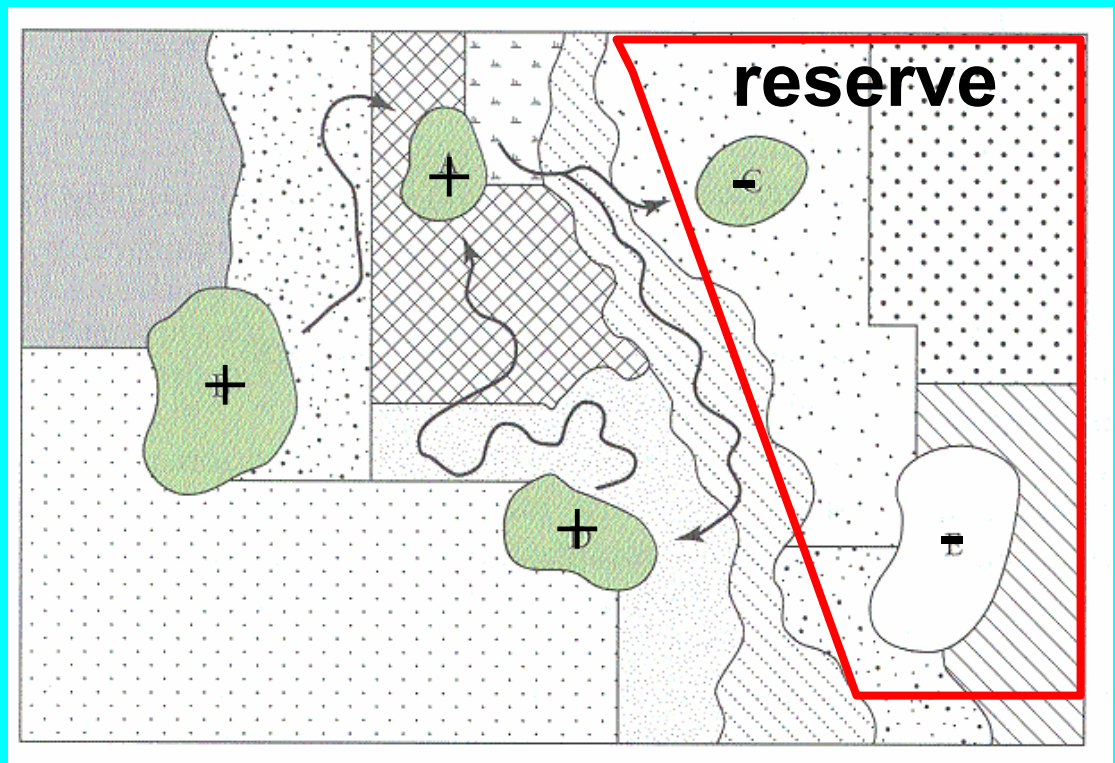
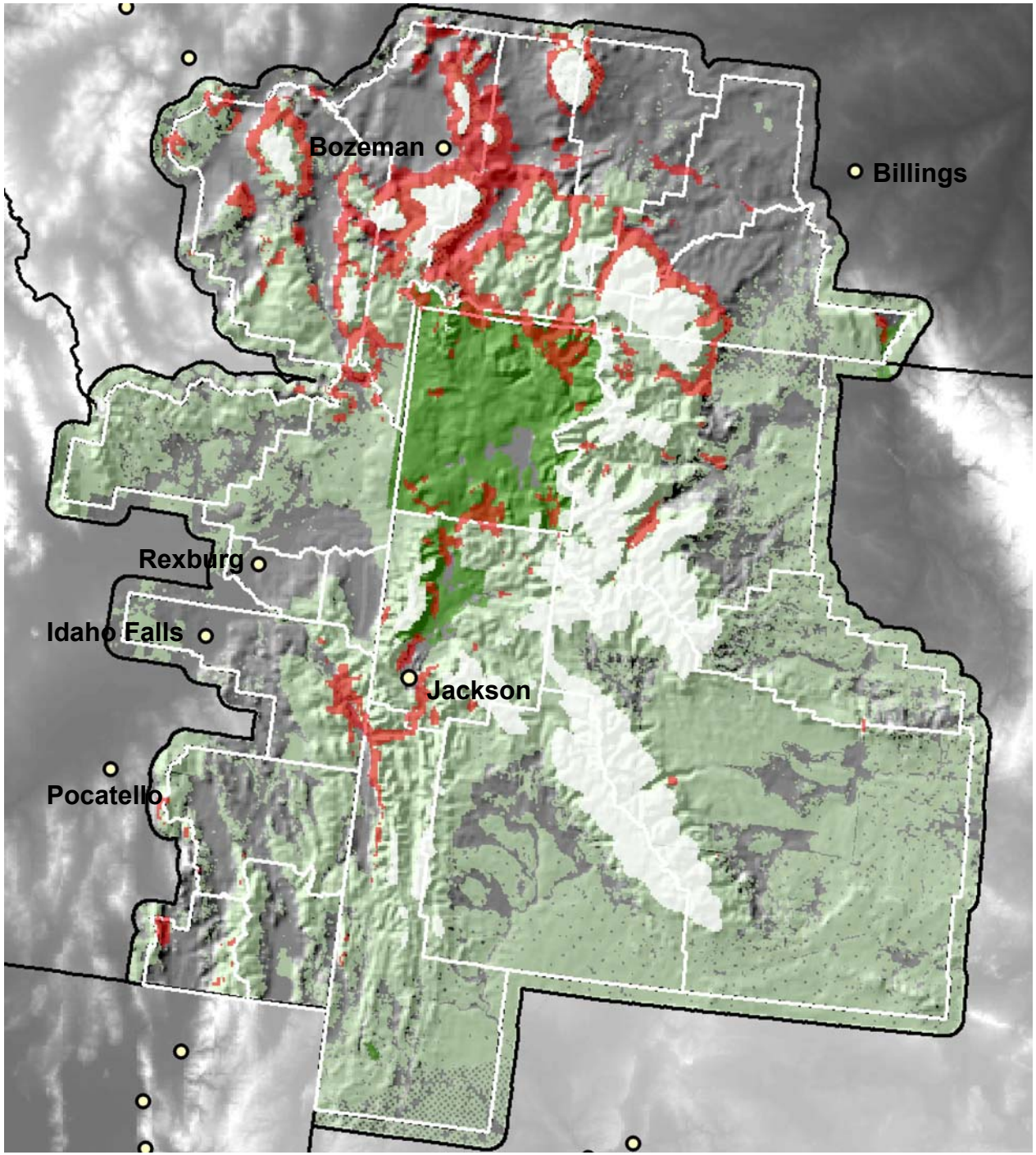
Source/Sink Population Model





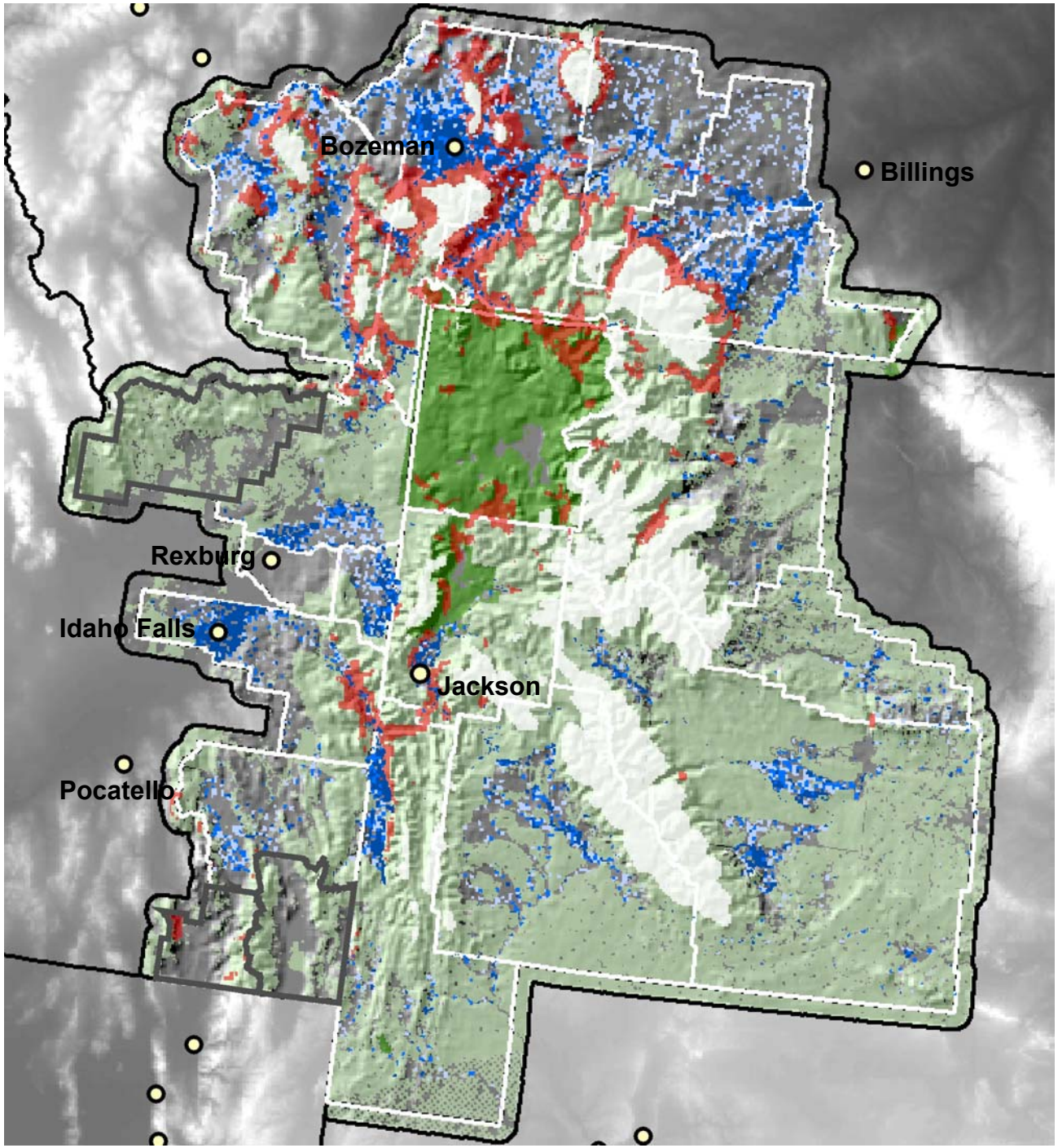
Predicted Bird Hotspots

- National Park Service
- Other federal lands
- County boundaries
- Biodiversity hotspots
- unclassified

Places where bird species richness and abundance are >60% of maximum

<u>Hotspots cover 6.4% of area</u>

Bird Hotspots and Rural Homes



- National Park Service
- Other federal lands
- County boundaries
- Biodiversity hotspots
- Biodiversity modeling mask

Home density

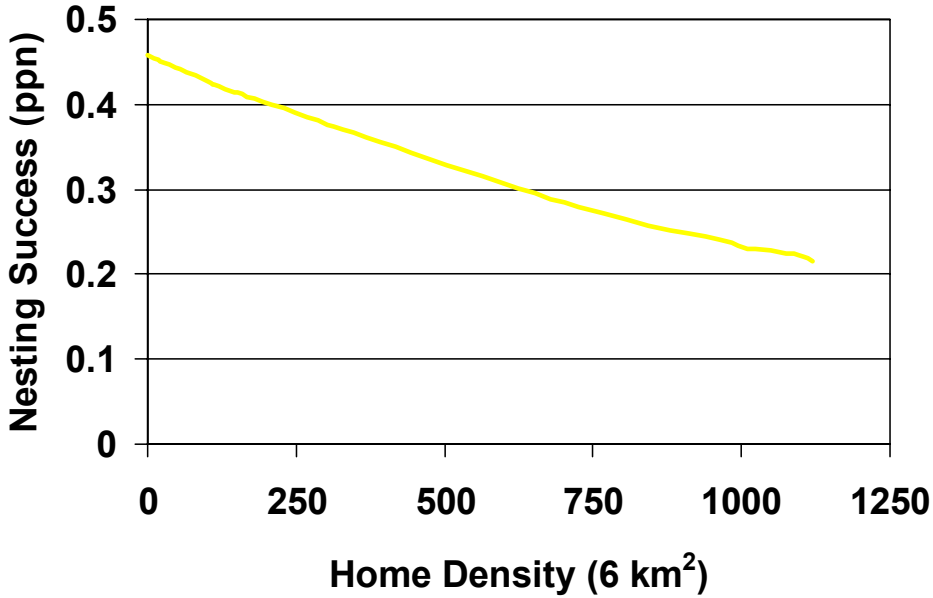
Low ⟷ High

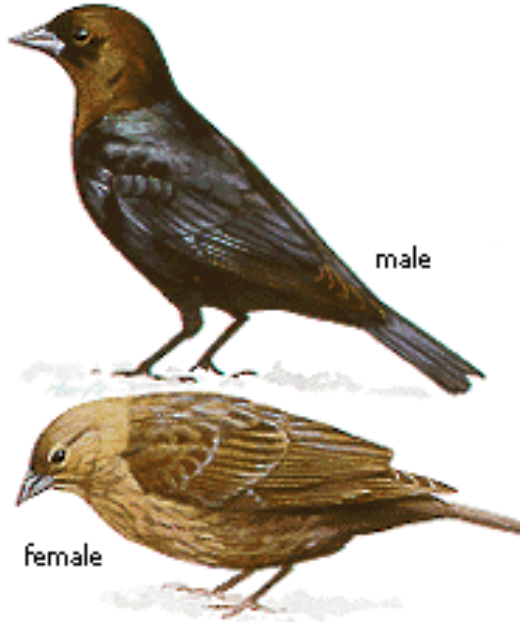
- Counties without home density data

Percent of hotspots on:

Private land: 41%

National parks: 12.3%



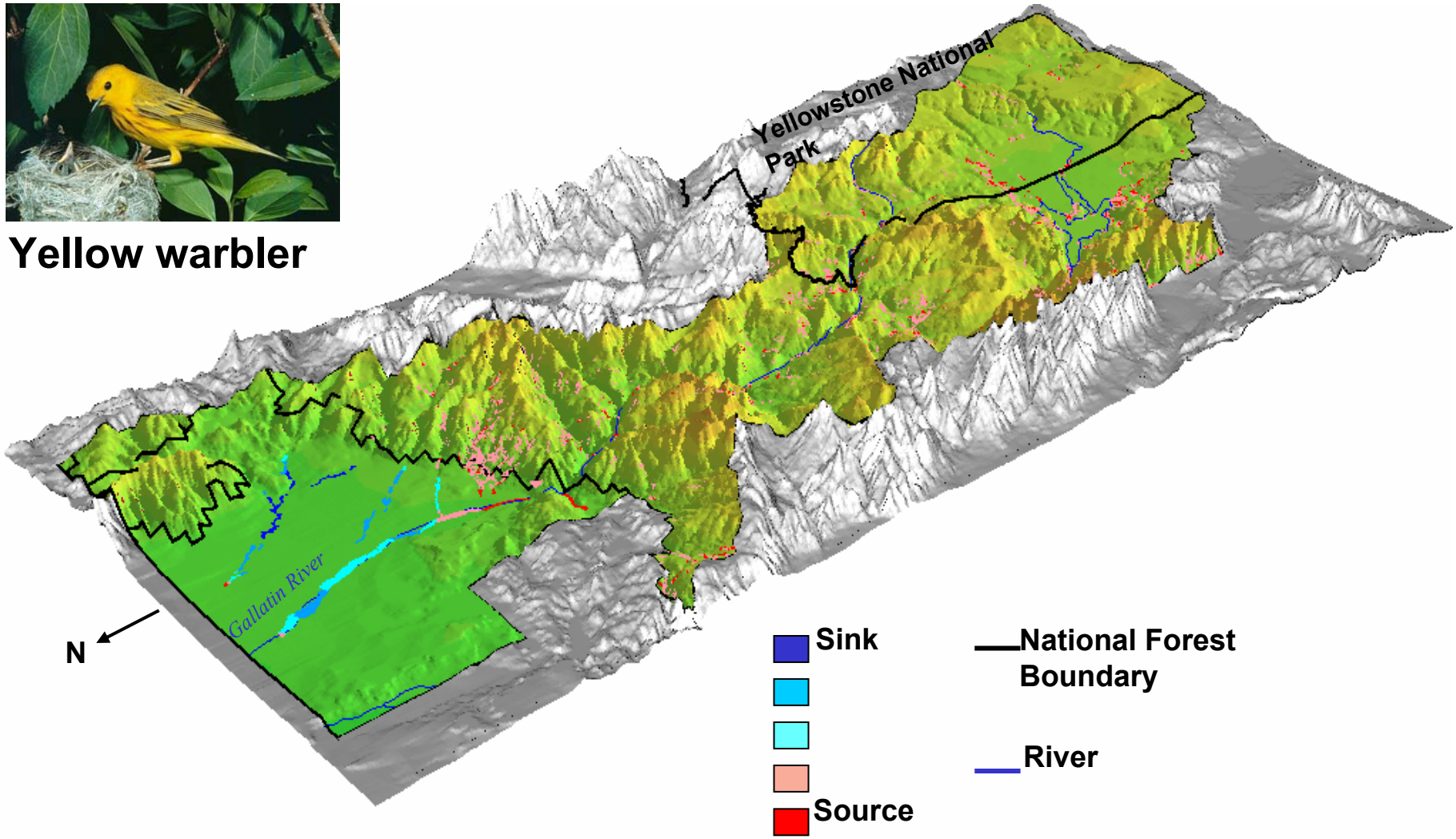


Brown-headed Cowbirds

Yellow warbler

Consequences for Nature Reserves: Source Sink Dynamics

Yellow warbler



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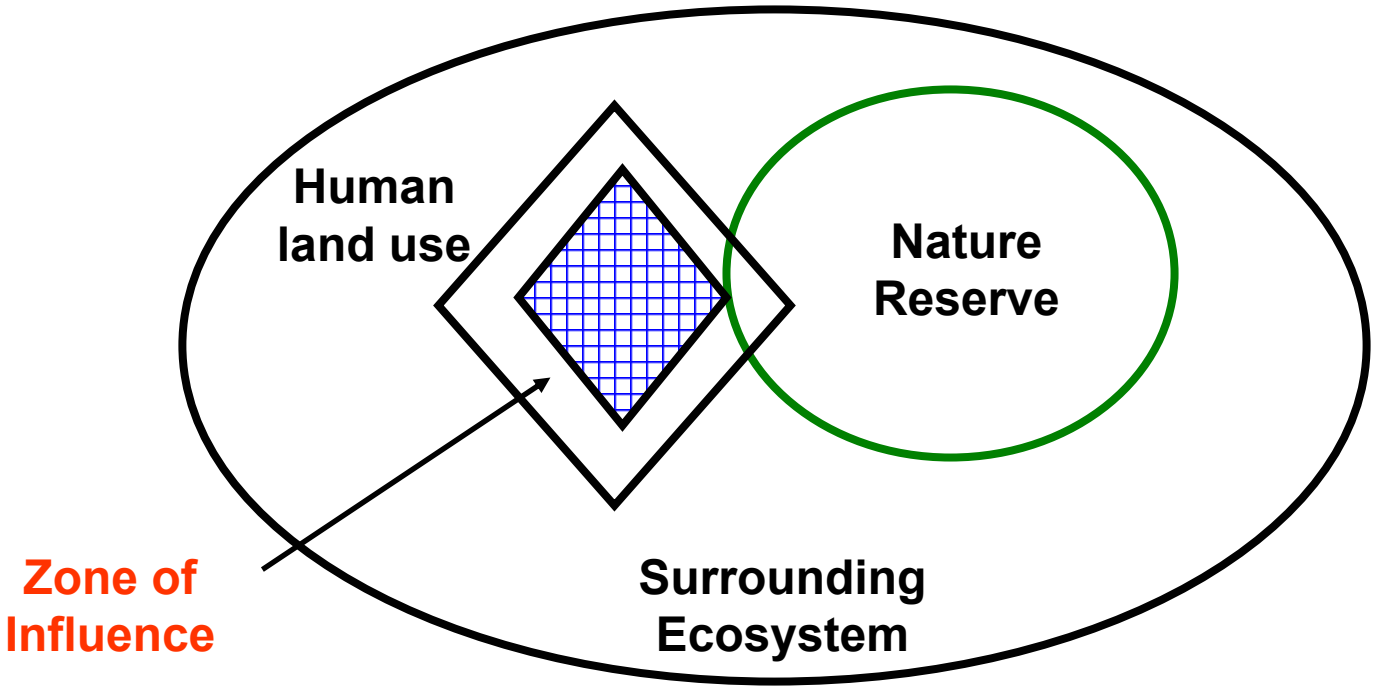
Hansen and DeFries (in prep)

Edge Effects



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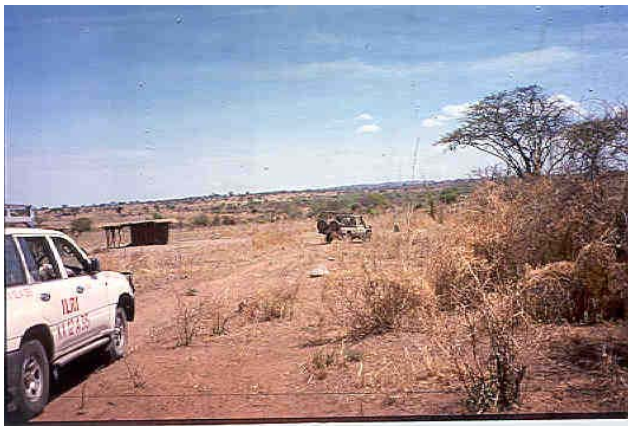
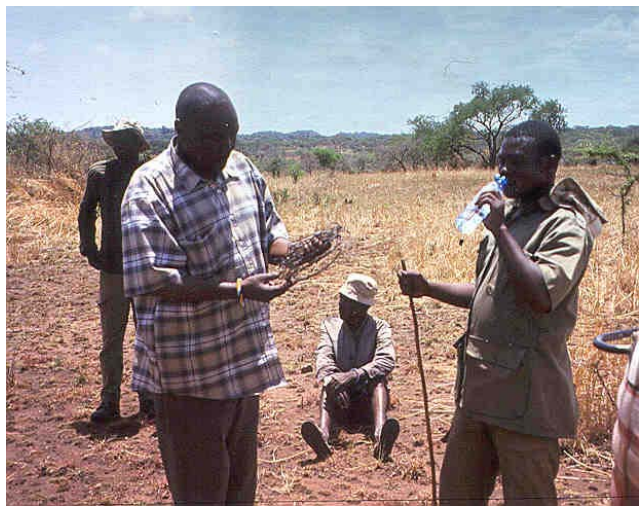


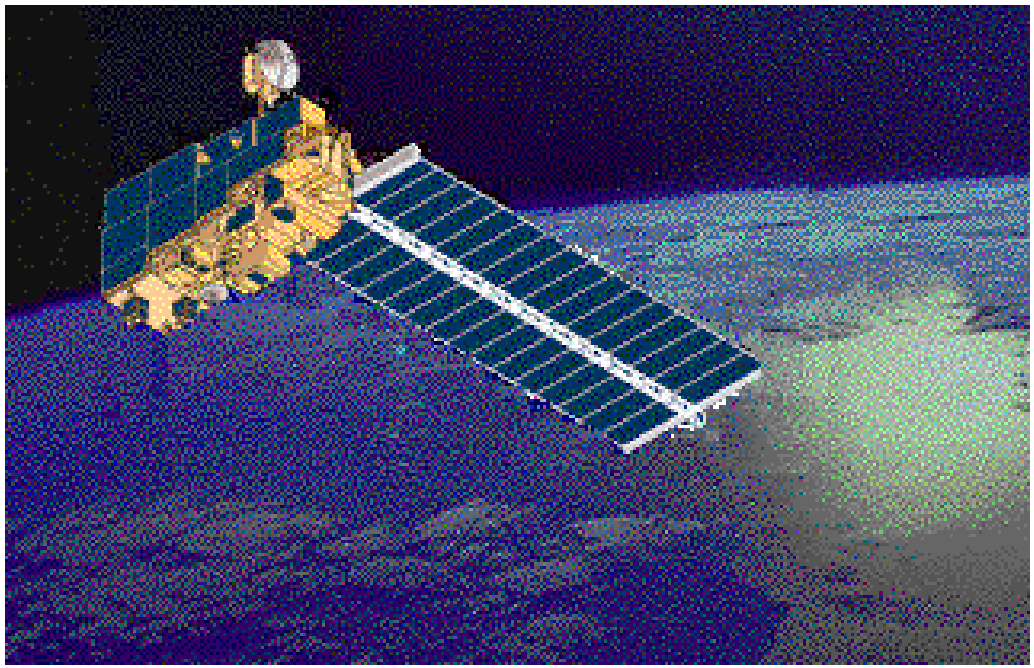


GSE – e.g., bushmeat hunting

GYE – e.g., pets, recreation

Monitoring

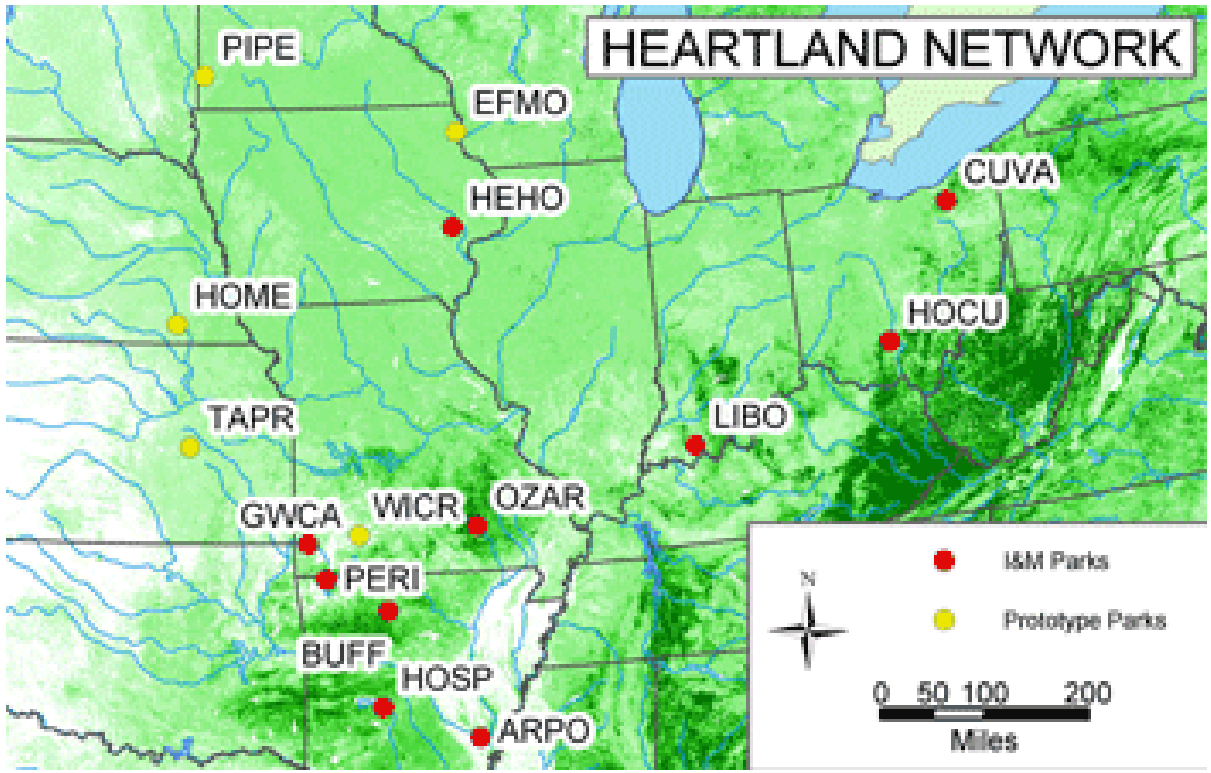
- Knowledge of ecological mechanisms provides basis for what to monitor



Guidance for Monitoring

Mechanism	Type	Monitor
Change in effective size of reserve	Species area effect Minimum dynamic area Trophic Structure	Land use and habitat area Disturbance patterns Wildlife populations
Changes in ecological flows into and out of reserve	Disturbance initiation and runout zones Placement in watershed or airshed	Disturbance patterns Water and air quality
Loss of crucial habitat outside of reserve	Ephemeral habitats Dispersal or migration habitats Population source sink habitats	Land use and habitat location Animal movements Animal demography
Increased exposure to human activity at reserve edge	Poaching Displacement Exotics/disease	Human density Human activity Exotics/diseases

Case Study: Heartlands Network Inventory and Monitoring Program



Methodology

Identify Key Objectives and Drivers

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Characterize Current Landscape Setting and Change

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Develop Conceptual Models Linking Land Use Change and Ecological Functioning

↓

Develop Potential Indicators and Monitoring Protocols

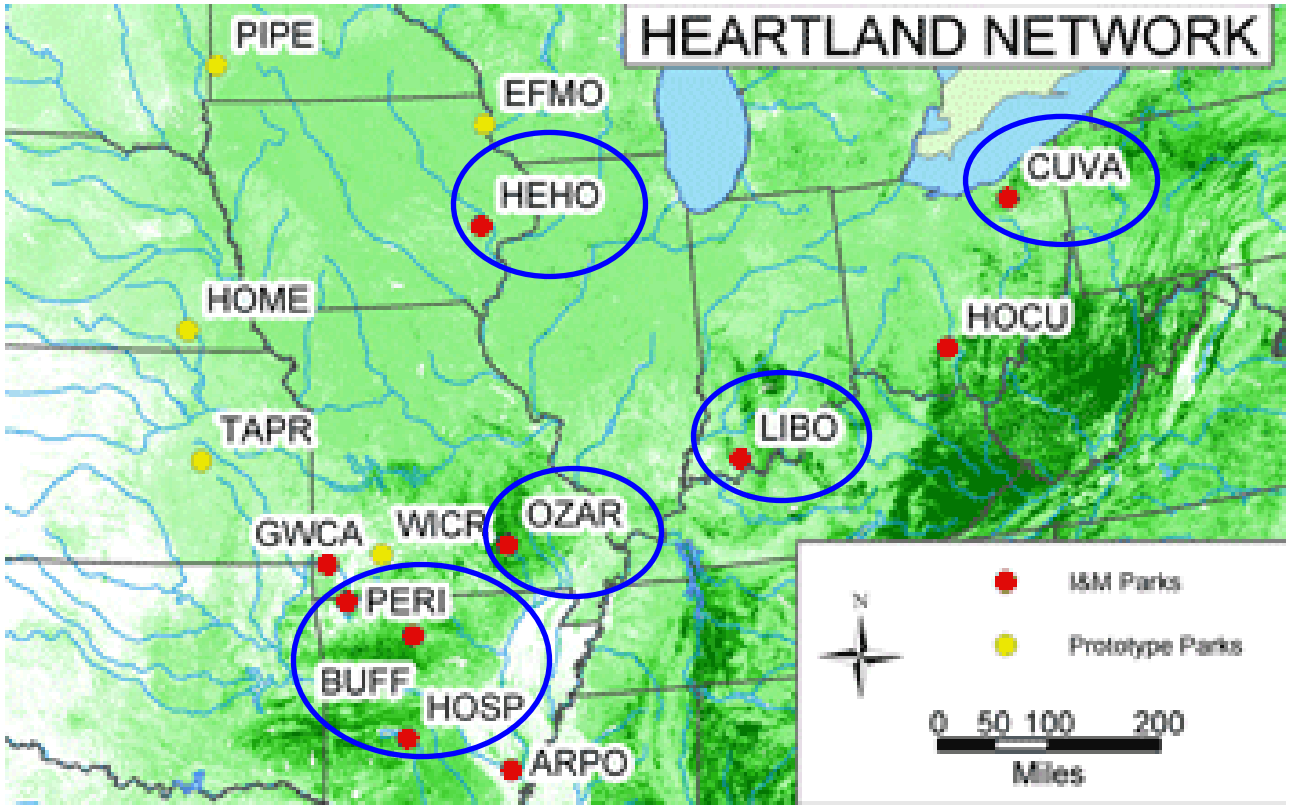
Step 1:Objectives and Drivers

- Include parks with biodiversity objectives

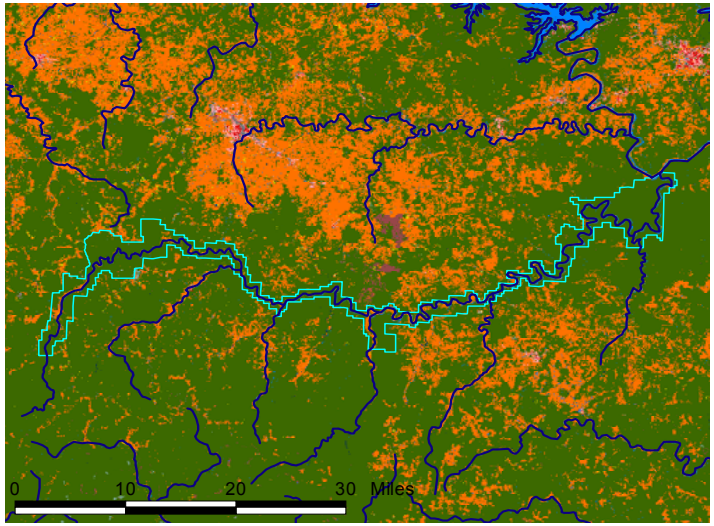
- Include parks where managers have identified land use change as an important issue

- Separate parks into functional groups: forest matrix, agricultural matrix, land-based, river-based

Parks with Land Use Change Concerns

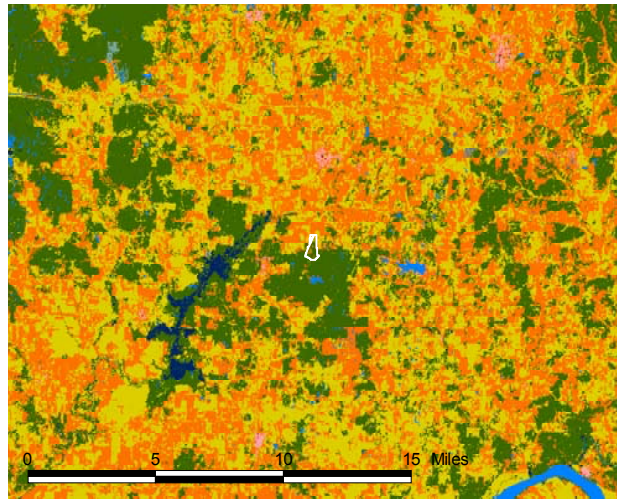


Forest Parks: Aquatic



BUFFALO NATIONAL RIVER

Agricultural Parks: Terrestrial



LINCOLN BOYHOOD NATIONAL MEMORIAL

- Water
- Industrial
- Low intensity urban
- High intensity urban
- Bare ground
- Transitional
- Forest
- Shrub
- Agricultural crops
- Pasture/Hay
- Wetlands

Step 2: Characterize Current Landscape Setting and Change

- Analyze regions surrounding each park based on county and watershed boundaries

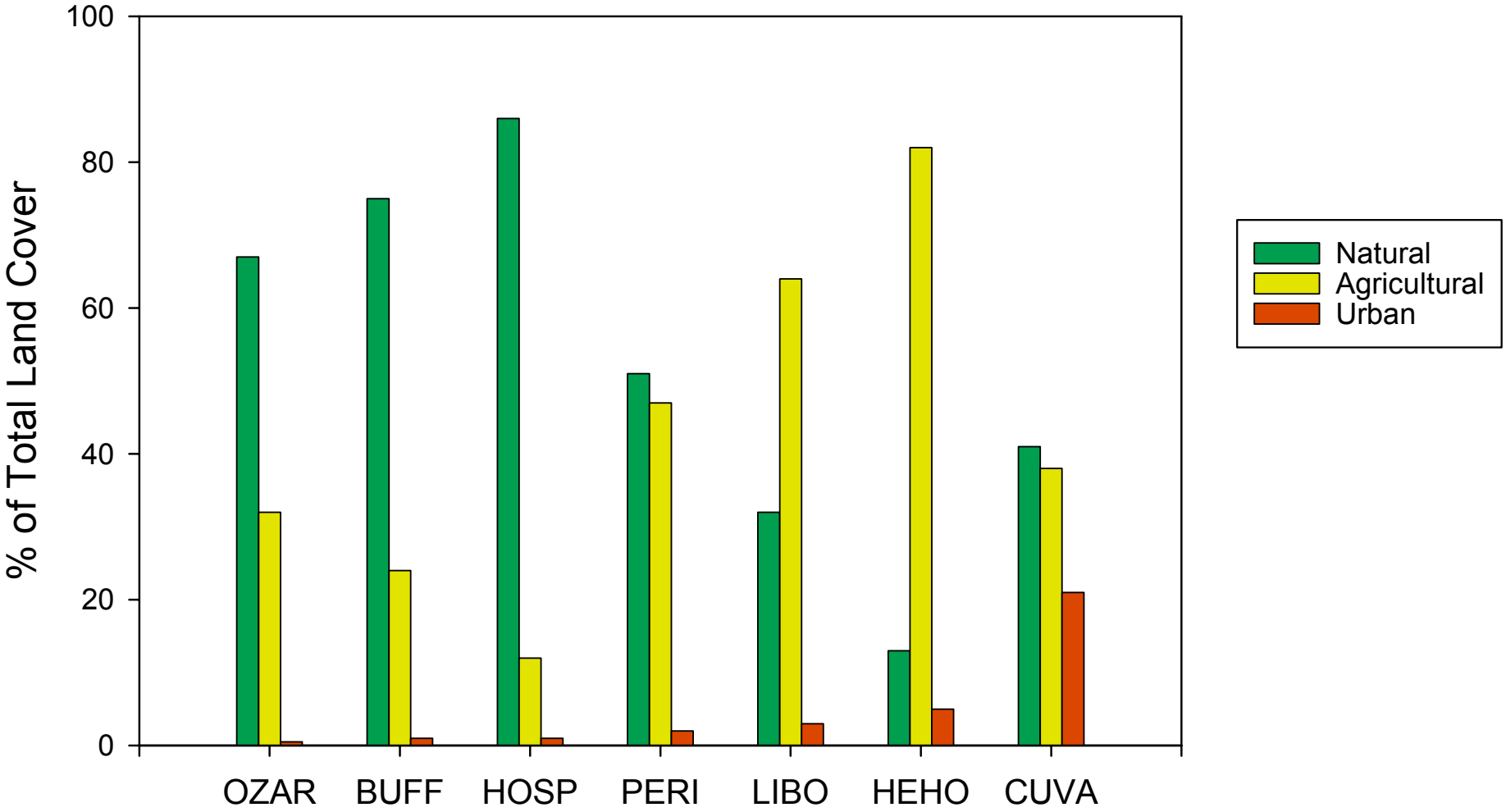
- Variables: Housing density, human population density, industrial activity, water pollution, dams, land cover/use

- Time period: 1950-2000

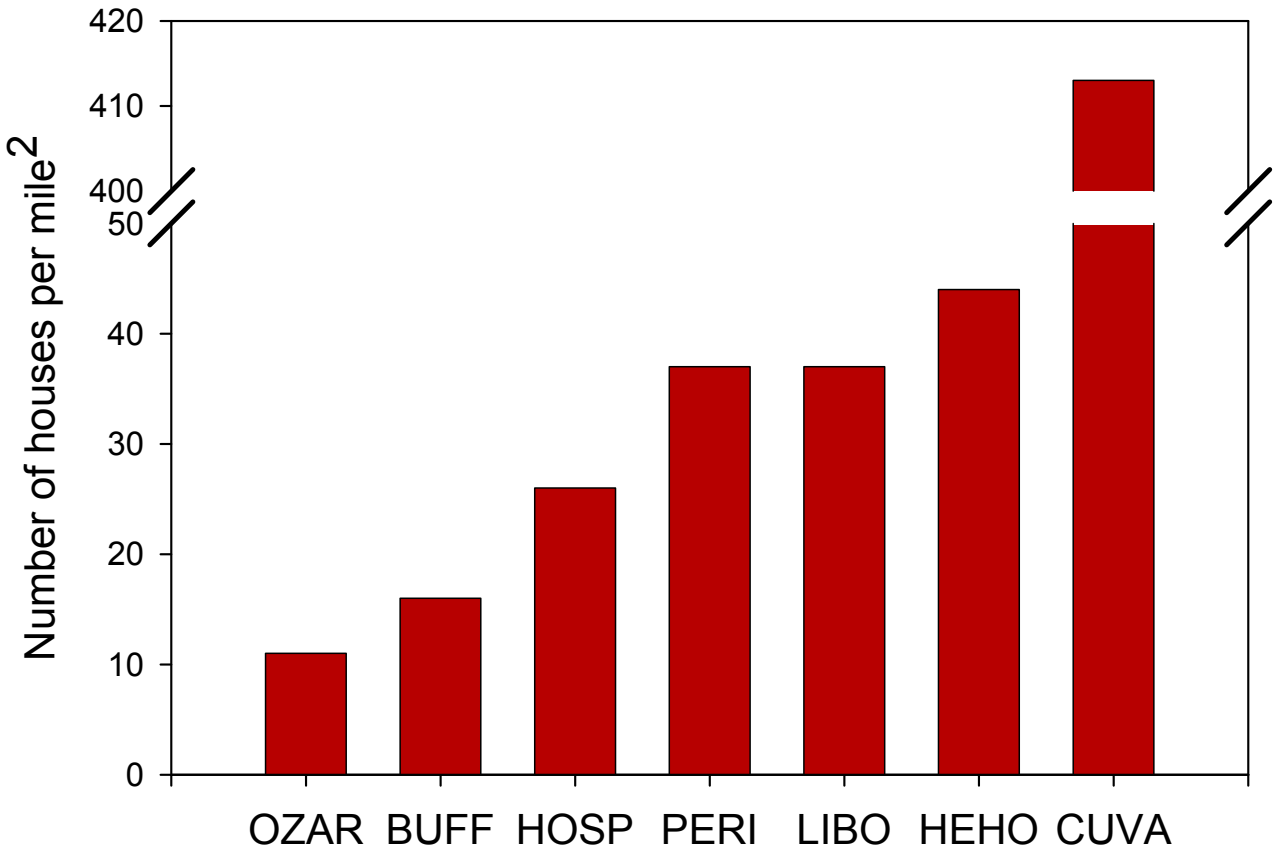
Examples of Variables Used in Characterization

Spatial Dataset	*Source*	*Source Location*	*Measure*	*Scale*
Housing and population density	U.S. Census Bureau (2000)	www.census.gov	Average number per square mile	County
Land cover	USGS, National Land Cover Dataset (1992)	http://edc.usgs.gov	Land cover classified into cover types depicting industrial, urban, wetlands, shrub, pasture, crops, and forest. Percent of each land cover type measured as % of total pixels.	30 meter pixel
Overall population change	U.S. Census Bureau (1950 -2000)	www.census.gov	Percent population growth	County
Change in farmland acreage	U.S. Census of Agriculture (1950 – 1997); State (MO, IA, IN, OH, KY) Agriculture Statistics Services	www.nass.usda.gov/census/ http://agebb.missouri.edu www.nass.usda.gov/ia/ www.nass.usda.gov/in/ www.nass.usda.gov/ky/ 1950 Census of Agriculture (Published by U.S. Census Bureau-Ag. Division, by state)	Percent change in "acres in farms"	County
Change in housing density	U.S. Census Bureau, "Profile of Selected Housing Characteristics" (2000)	www.census.gov	Number of houses built per decade from 1950-2000, based on extrapolation from "Year Structure Built" category	County

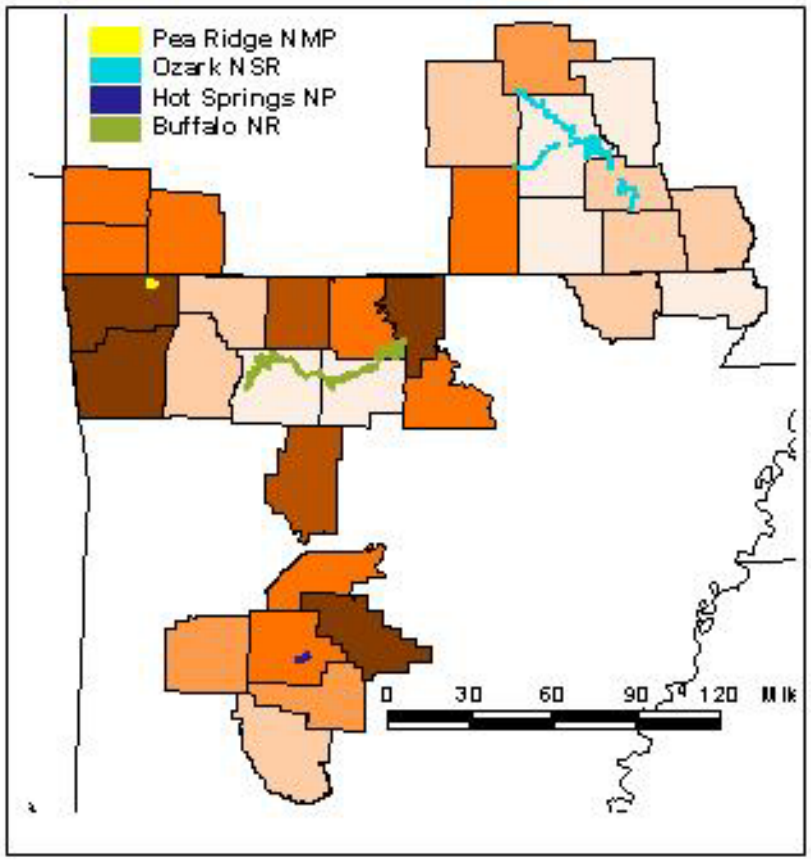
Current Land Cover Around Heartland Parks

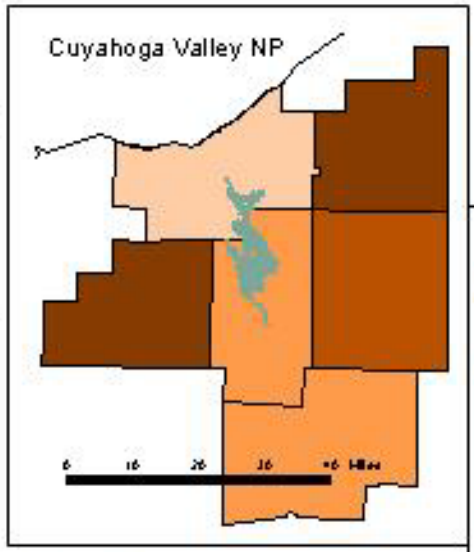


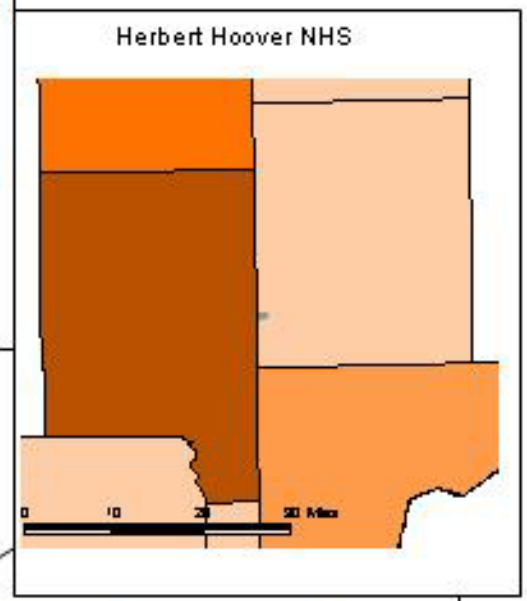
Current Housing Densities Around Heartland Parks

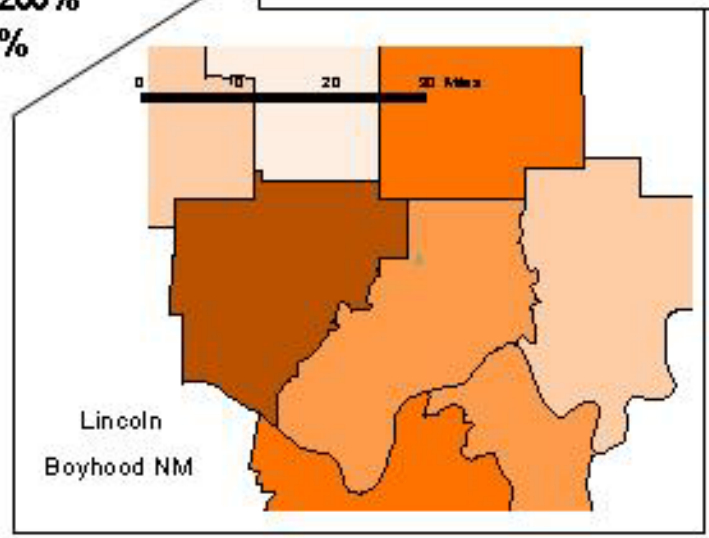


Percent Population Growth by County, 1950-2000





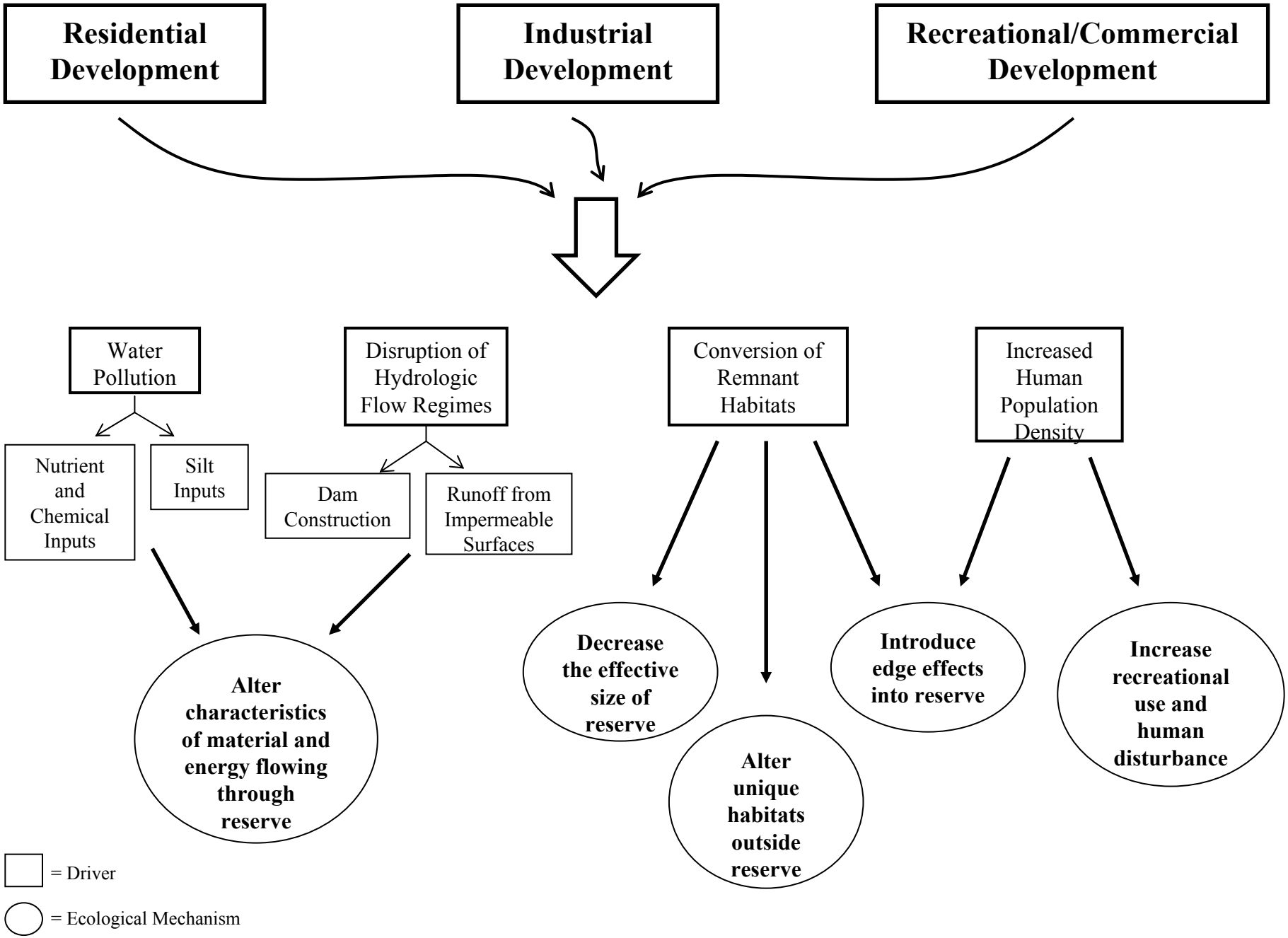


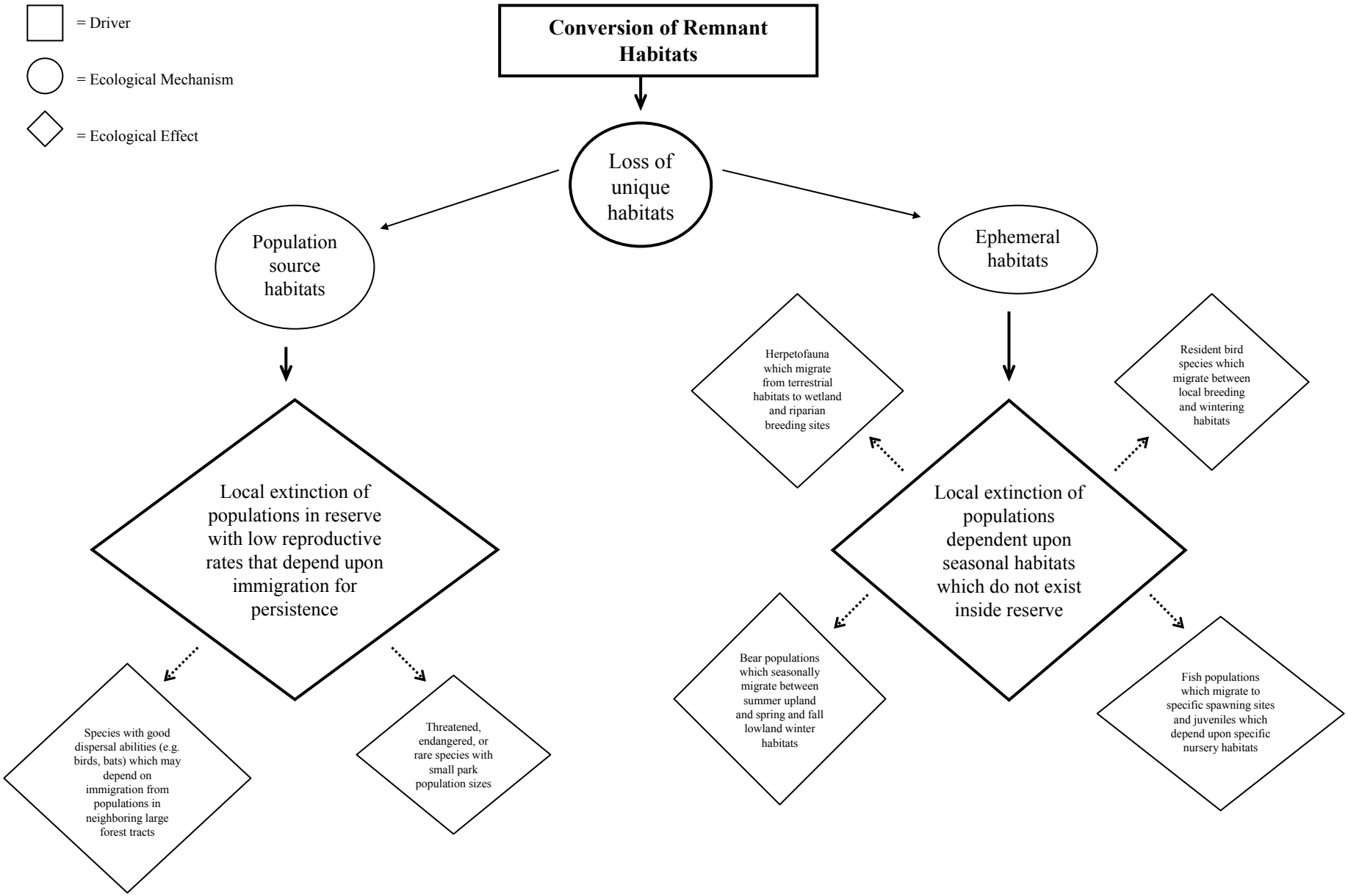


- < 0%
- 0 - 25%
- 25 - 50%
- 50 - 100%
- 100 - 200%
- > 200%

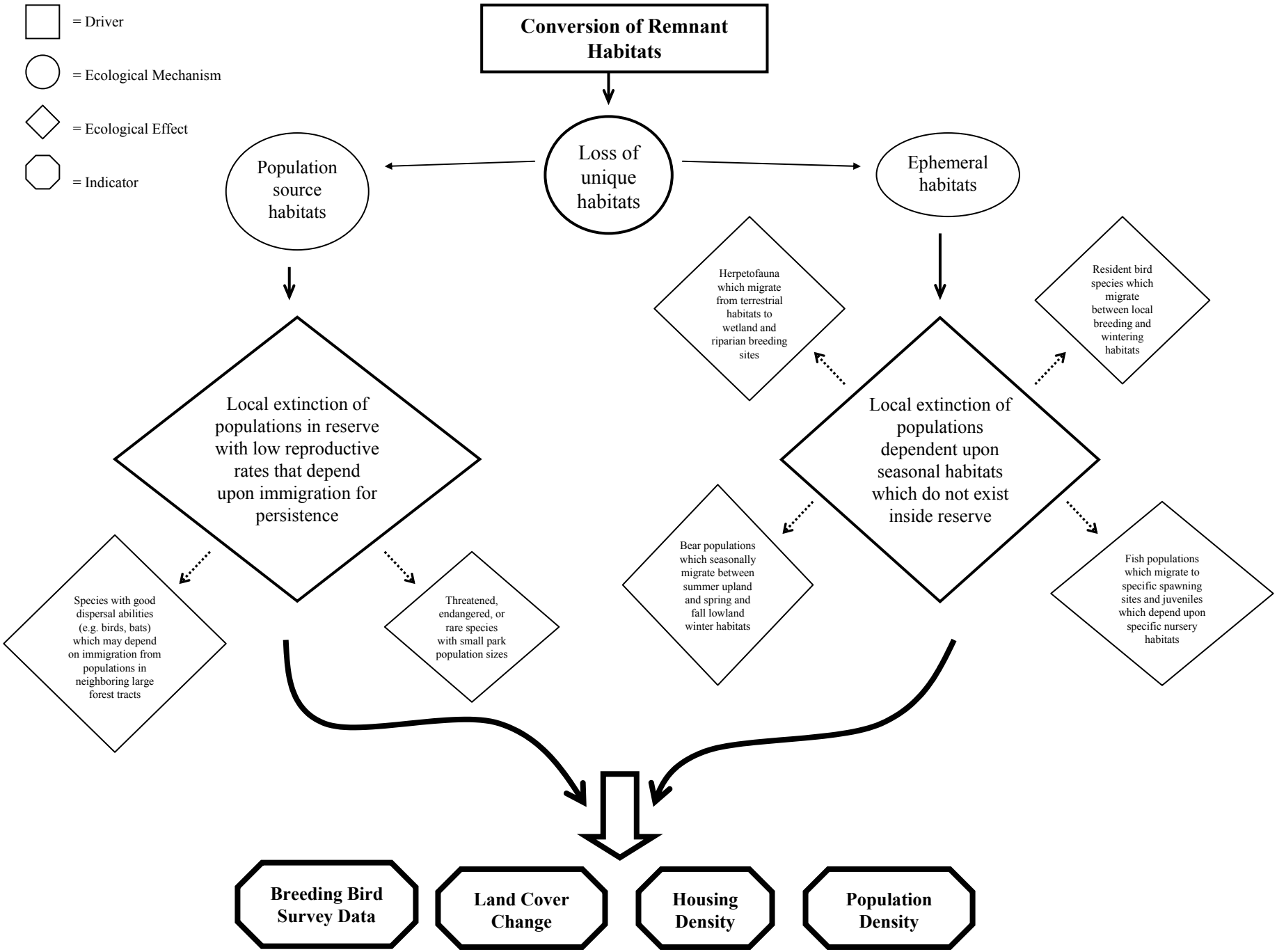
Data Source: US Census Bureau and state Census Data Centers

Step 3: Development of Conceptual Models Linking Land Use Change and Ecological Functioning


Residential Development
Industrial Development
Recreational/Commercial Development
Water Pollution
Nutrient and Chemical Inputs
Silt Inputs
Disruption of Hydrologic Flow Regimes
Dam Construction
Runoff from Impermeable Surfaces
Conversion of Remnant Habitats
Increased Human Population Density
Alter characteristics of material and energy flowing through reserve
Decrease the effective size of reserve
Alter unique habitats outside reserve
Introduce edge effects into reserve
Increase recreational use and human disturbance
= Driver
= Ecological Mechanism


= Driver
= Ecological Mechanism
= Ecological Effect
Conversion of Remnant Habitats
Loss of unique habitats
Population source habitats
Ephemeral habitats
Local extinction of populations in reserve with low reproductive rates that depend upon immigration for persistence
Species with good dispersal abilities (e.g. birds, bats) which may depend on immigration from populations in neighboring large forest tracts
Threatened, endangered, or rare species with small park population sizes
Herpetofauna which migrate from terrestrial habitats to wetland and riparian breeding sites
Resident bird species which migrate between local breeding and wintering habitats
Local extinction of populations dependent upon seasonal habitats which do not exist inside reserve
Bear populations which seasonally migrate between summer upland and spring and fall lowland winter habitats
Fish populations which migrate to specific spawning sites and juveniles which depend upon specific nursery habitats

Step 4: Development of Potential Indicators and Monitoring Protocols


= Driver
= Ecological Mechanism
= Ecological Effect
= Indicator
Conversion of Remnant Habitats
Loss of unique habitats
Population source habitats
Ephemeral habitats
Local extinction of populations in reserve with low reproductive rates that depend upon immigration for persistence
Species with good dispersal abilities (e.g. birds, bats) which may depend on immigration from populations in neighboring large forest tracts
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Breeding Bird Survey Data
Land Cover Change
Housing Density
Population Density

Step 4: Development of Potential Indicators and Monitoring Protocols

- Land Cover Change
- Population Density
- Housing Density
- Wildlife Monitoring: Breeding Bird Survey
- Biological and Physical Aquatic Surveys
- Hydrologic Flow Regimes

Challenges

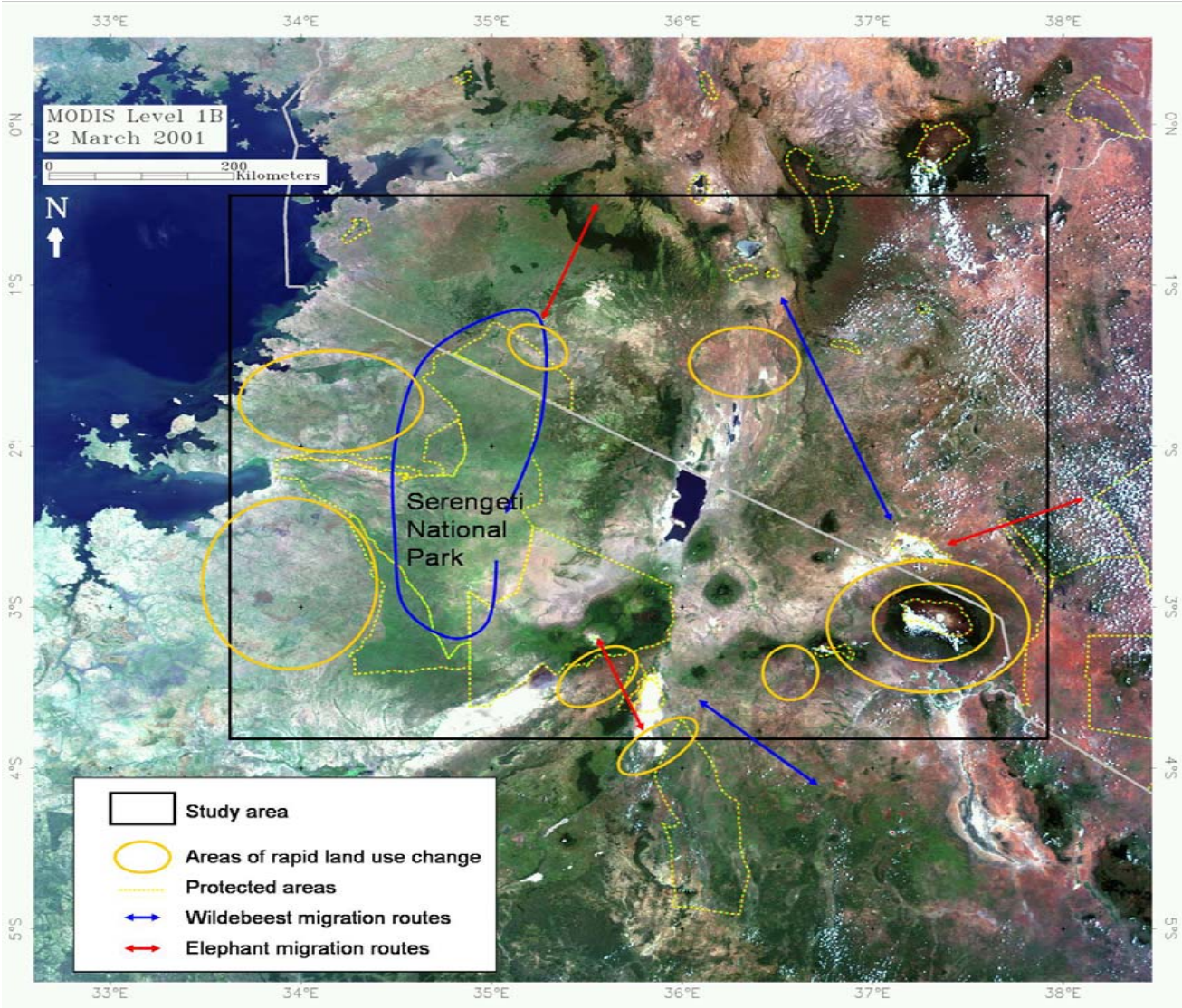
- Ecological framework for monitoring
- Data and methods of monitoring
- How to integrate monitoring with research and management

Role of Monitoring in Adaptive Management

- The long term goal may be to manage the park and surrounding lands to maintain park function

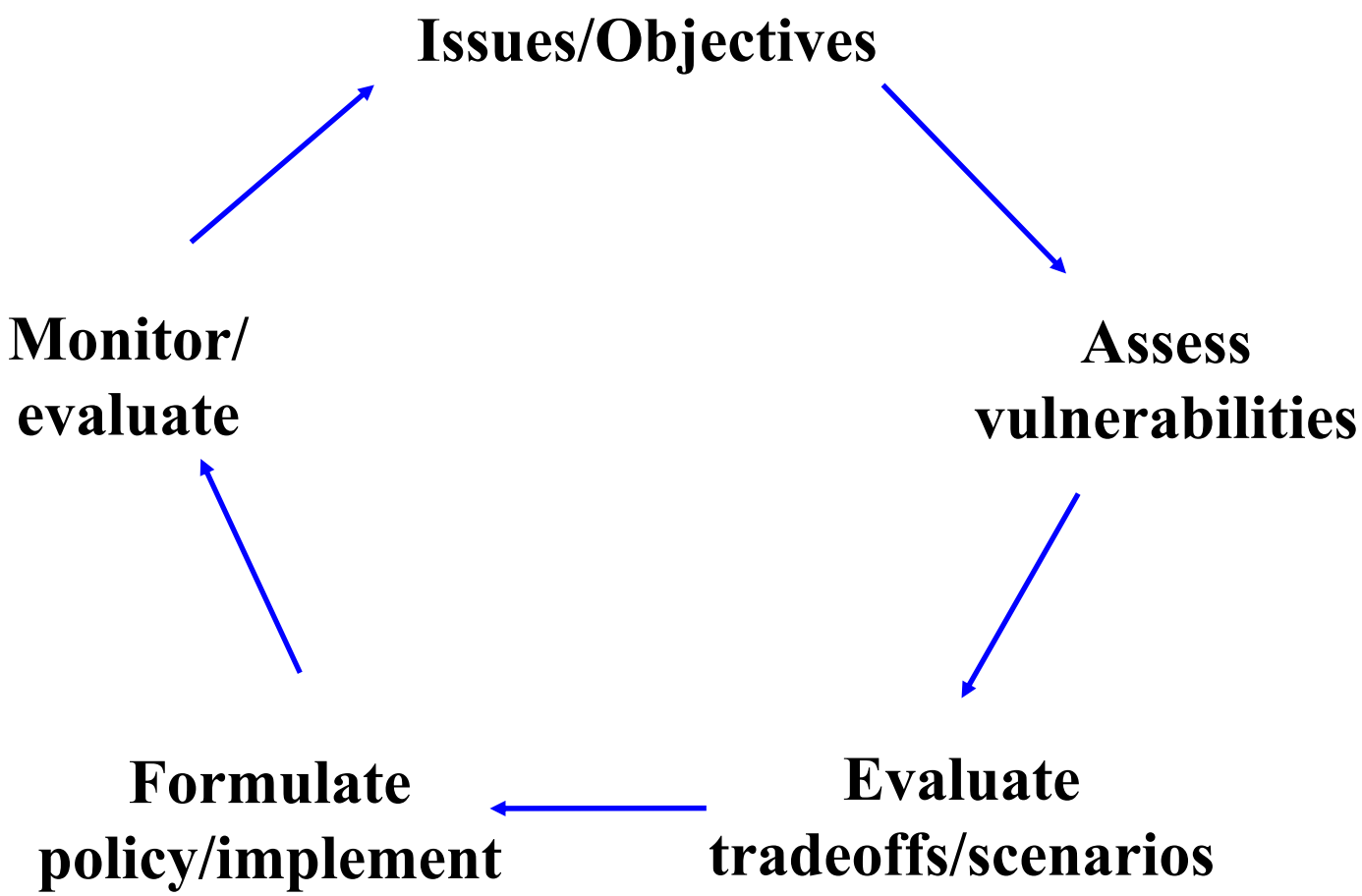
- Monitoring can be seen as a component of adaptive management that aims to integrate research and management in the region including the park networks.

- Such a approach provides a basis for what to monitor and how to use the resulting data to improve park management.

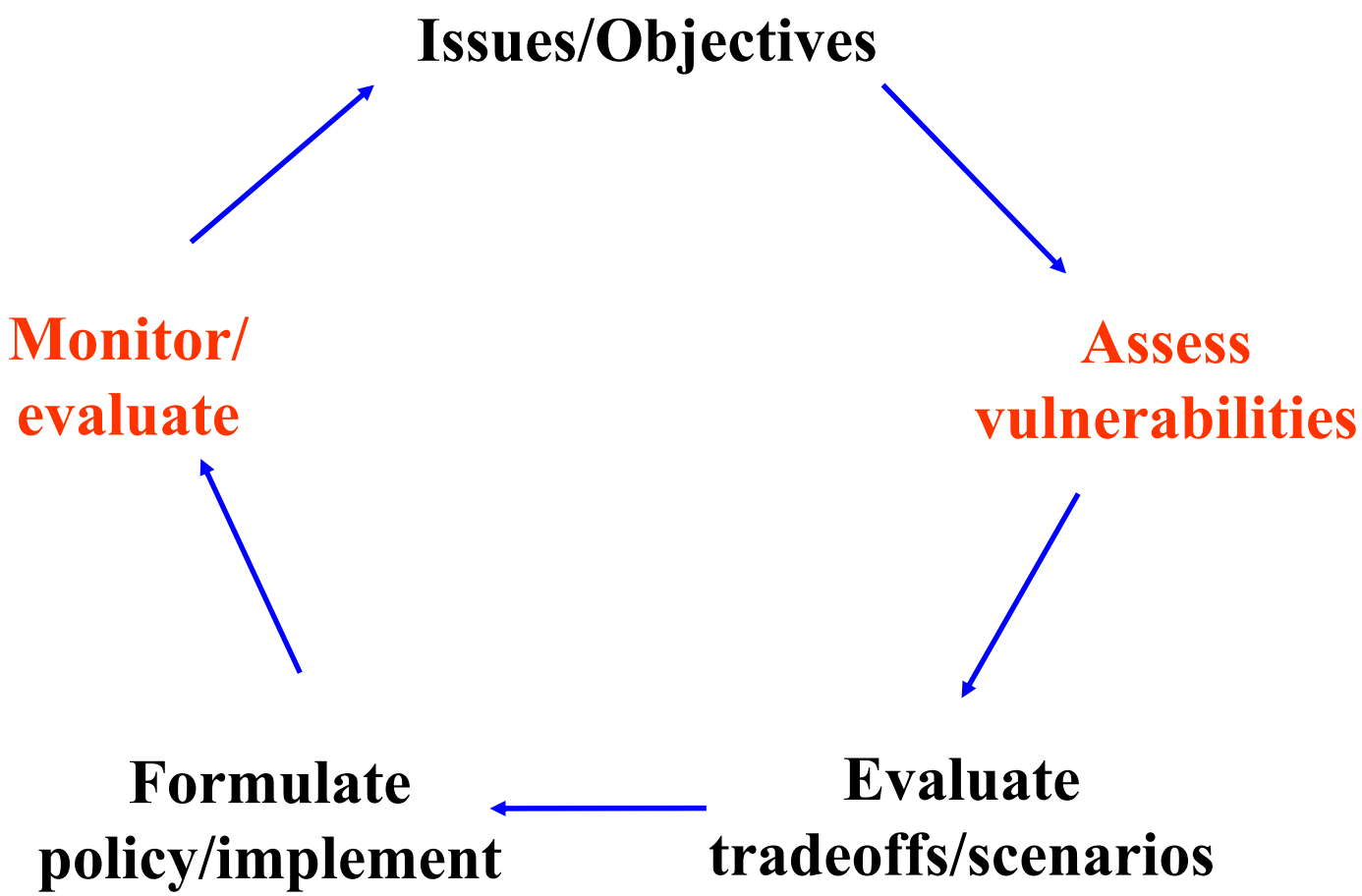


Regional Management

Research and Management Approach



Research and Management Approach



Guidance for Monitoring

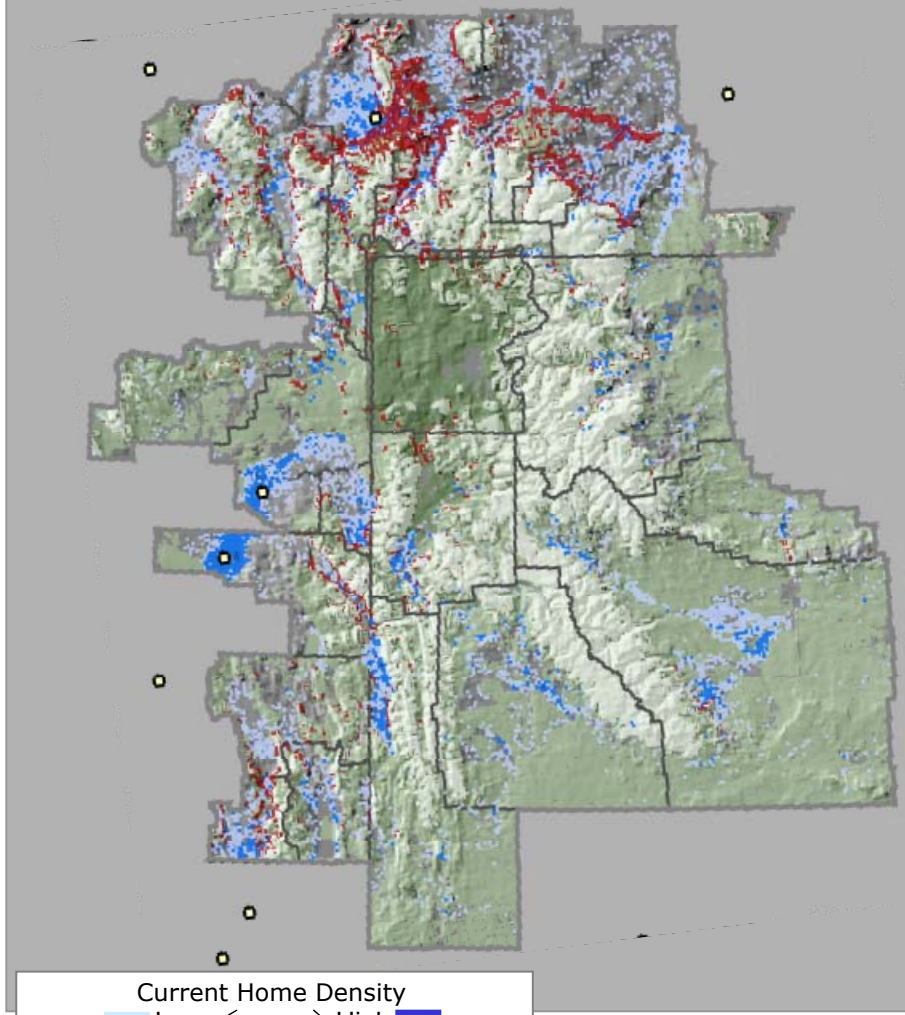
Mechanism	Type	Monitor
Change in effective size of reserve	Species area effect Minimum dynamic area Trophic Structure	Land use and habitat area Disturbance patterns Wildlife populations
Changes in ecological flows into and out of reserve	Disturbance initiation and runout zones Placement in watershed or airshed	Disturbance patterns Water and air quality
Loss of crucial habitat outside of reserve	Ephemeral habitats Dispersal or migration habitats Population source sink habitats	Land use and habitat location Animal movements Animal demography
Increased exposure to human activity at reserve edge	Poaching Displacement Exotics/disease	Human density Human activity Exotics/diseases

Criteria for Regional Management

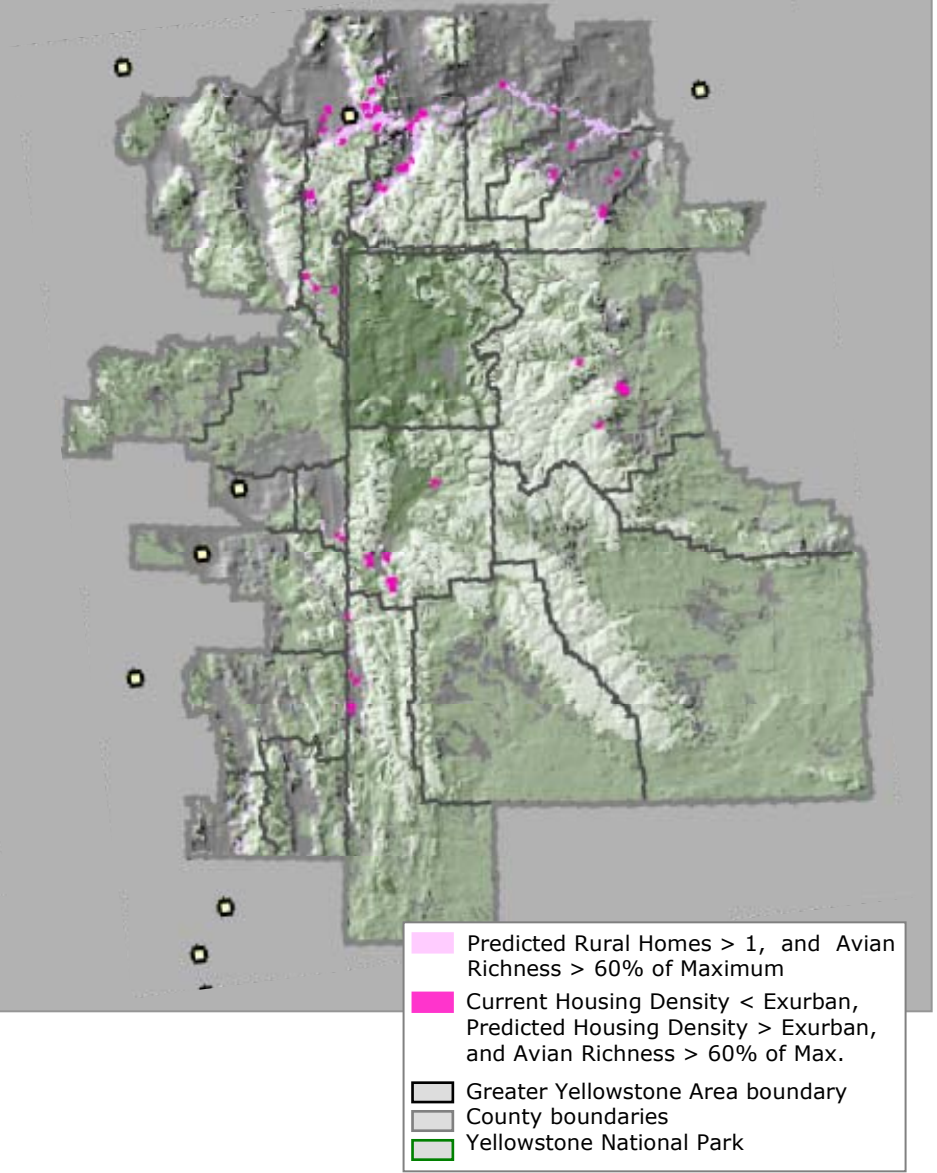
Mechanism	Type	Design Criteria	Indicators
Change in effective size of reserve	Species Area Effect Minimum Dynamic Area Trophic Structure	Maximize area of functional habitats	Habitat Area
Changes in ecological flows into and out of reserve	Disturbance initiation and runout zones Placement in watershed or airshed	Identify and maintain ecological process zones	Fire, disturbances, water/air quality/quantity
Loss of crucial habitat outside of reserve	Ephemeral habitats Dispersal or migration habitats Population source sink habitats	Maintain key migration and source habitats	Connectivity, habitats, biotic interactions
Increased exposure to human activity at reserve edge	Poaching Displacement Exotics/disease	Manage human proximity and edge effects	Land use, human activities, exotics, disease

Vulnerability Assessment

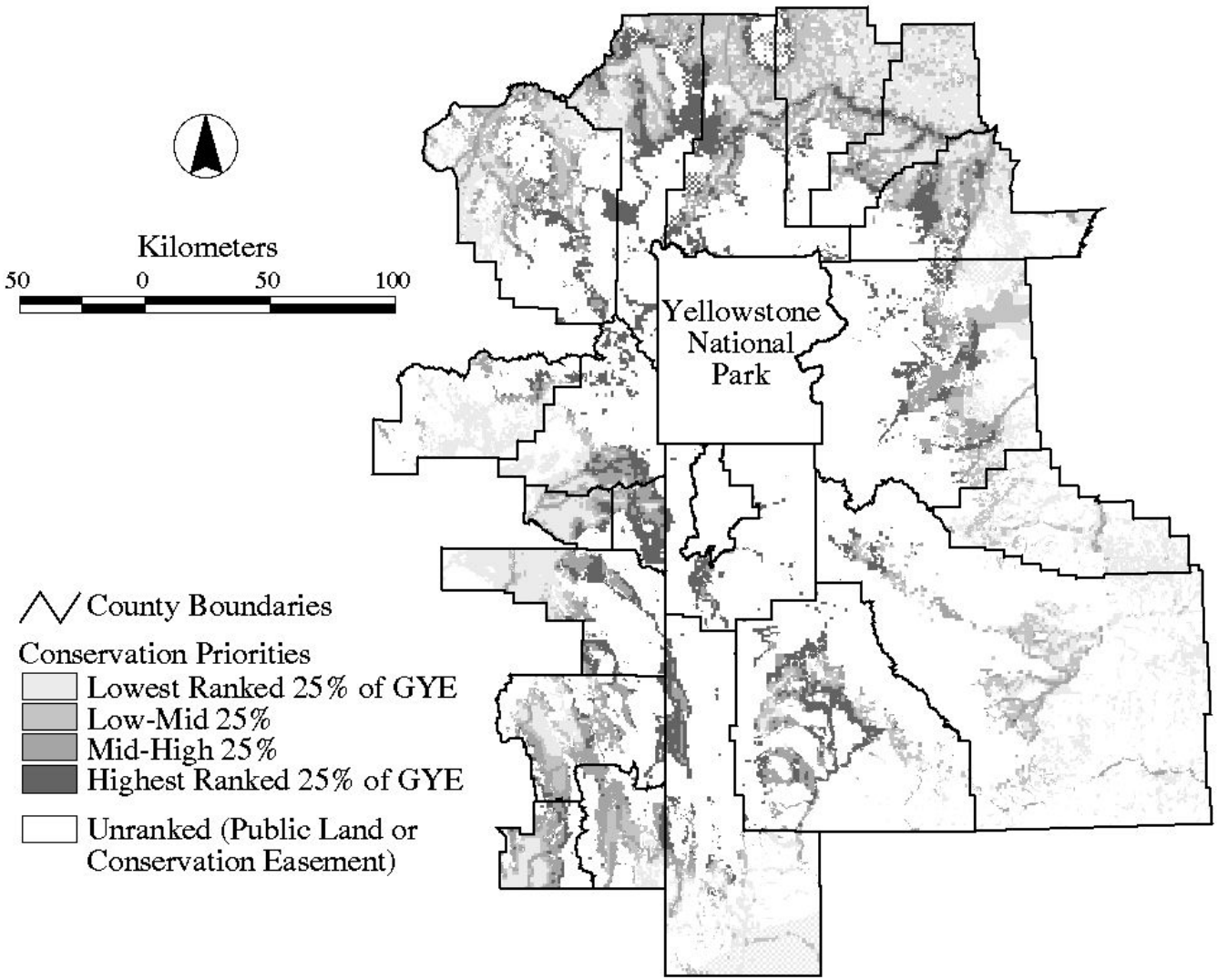
Integrate species abundance data into hotspots;
Monitor rural homes



Analyze to determine places :
Hotspots, low land use, likely to become high land use..

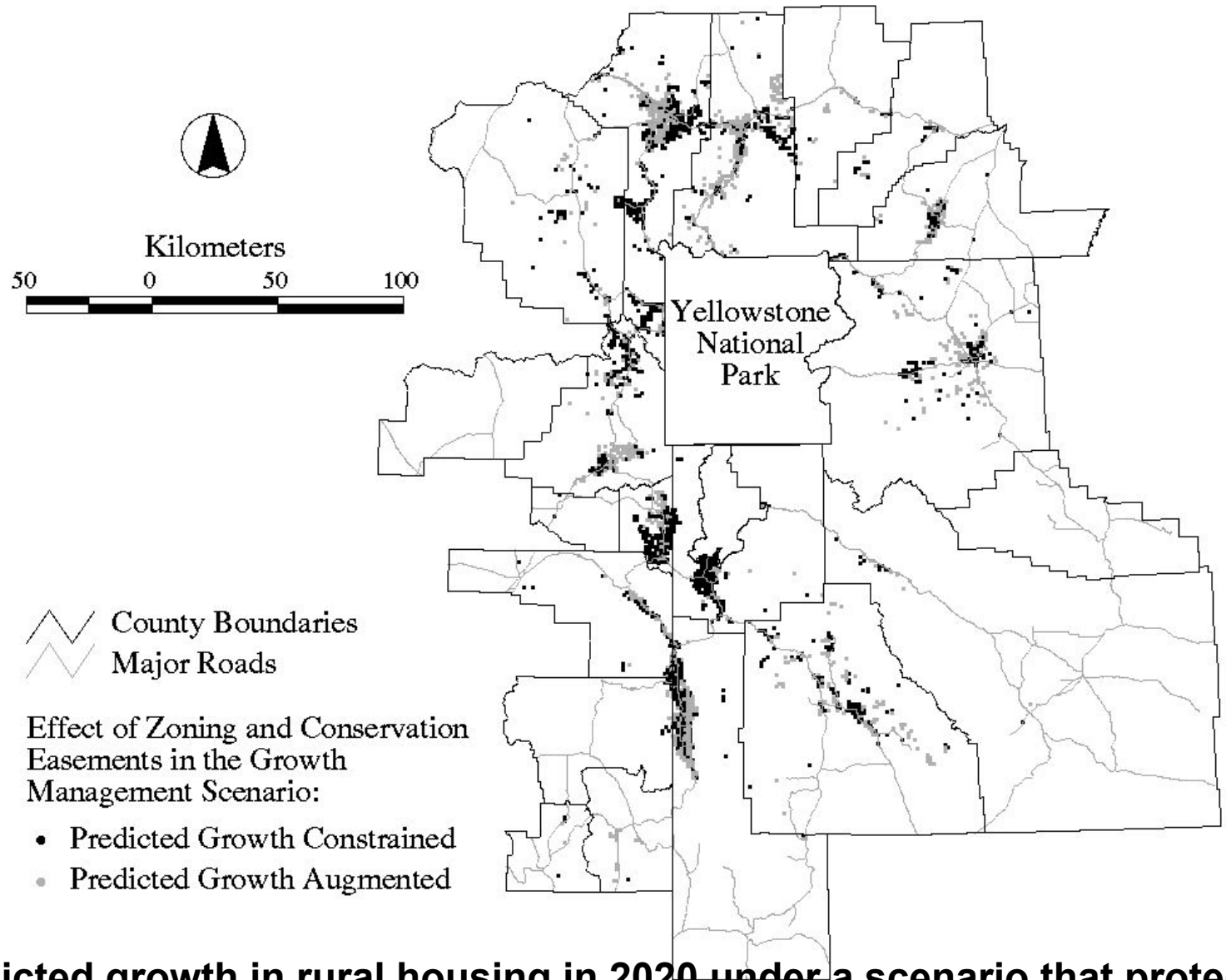


Areas of High Conservation Value



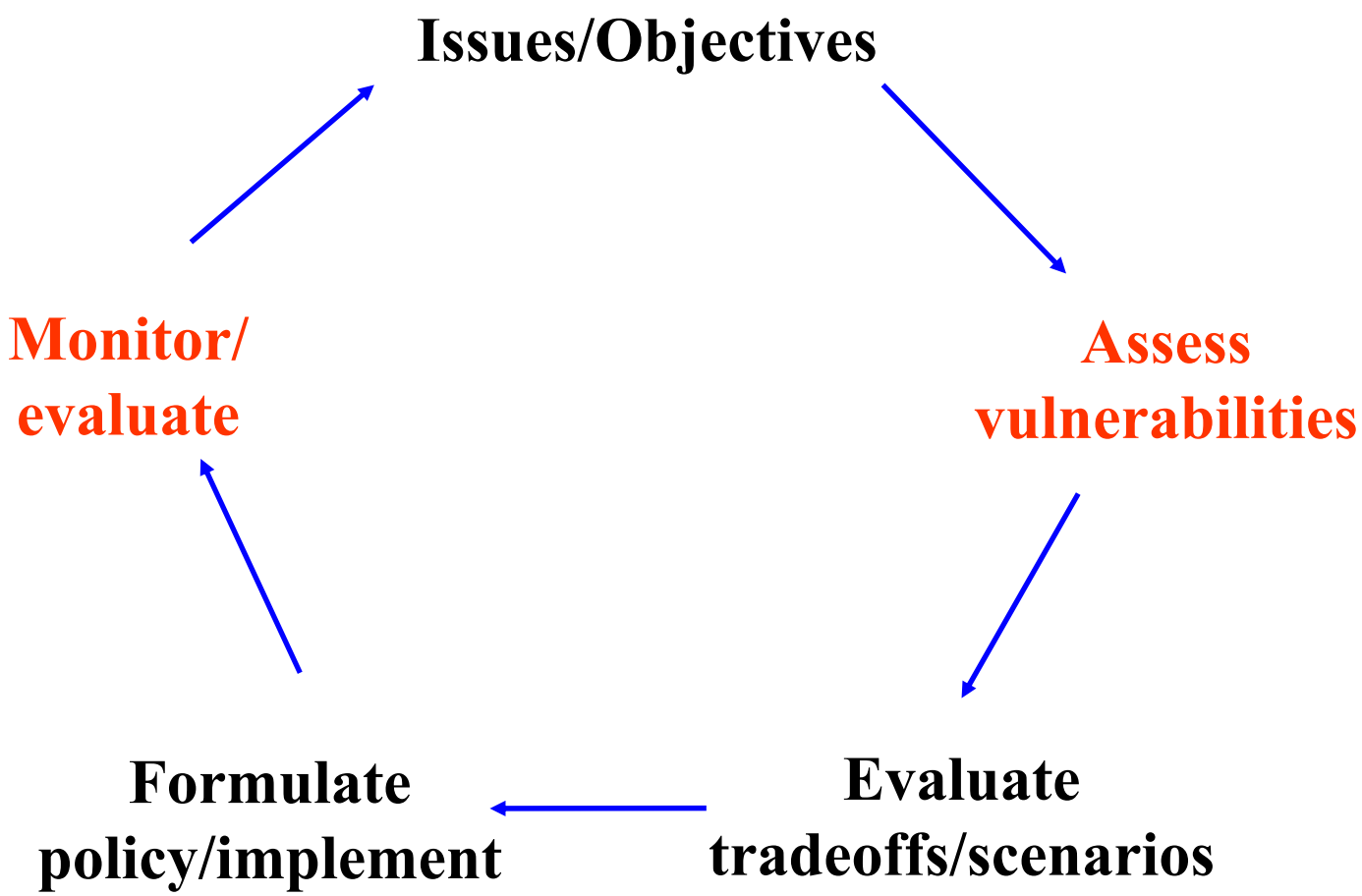
Based on four indices of biological irreplaceability, connectivity, biodiversity and riparian habitat. From Hernandez et al. 2004

Model Alternative Futures – Sustainability Scenario



Predicted growth in rural housing in 2020 under a scenario that protects 25% of the high-priority conservation lands. From Hernandez et al. 2004

Research and Management Approach



Challenges

- Ecological framework for monitoring
- Data and methods of monitoring
- How to integrate monitoring with research and management for regional sustainability