Conserving Biodiversity across Biophysical and Land Use Gradients

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Joint Workshop on NASA Biodiversity, Terrestrial Ecology, and Related Applied Sciences

August 21-25 2006

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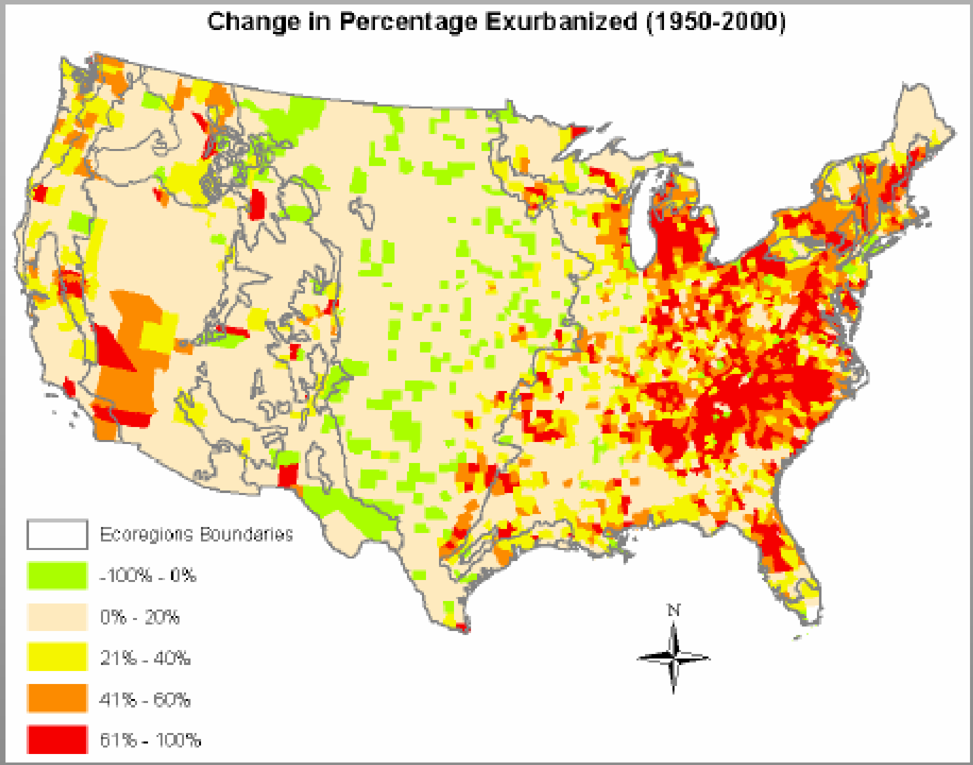
NASA

Human Expansion and Loss of Habitat



Increase in exurban development.
Brown 2005

How can we conserve biodiversity given more people and land consumption?

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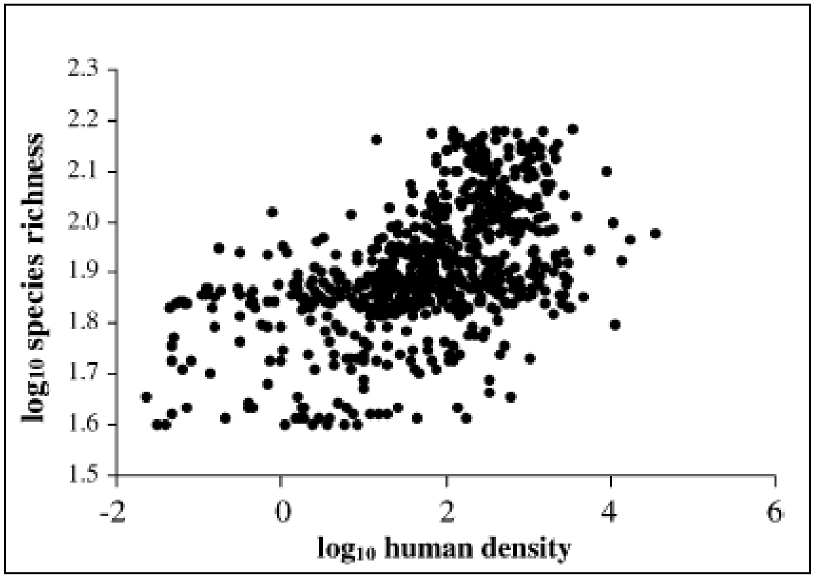
Need to Know:

- How native species are distributed spatially.
- Where humans are relative to biodiversity.
- How people influence native species?



Relationship between mammal species richness and human population density for Mexico. From Vazquez and Gaston 2005

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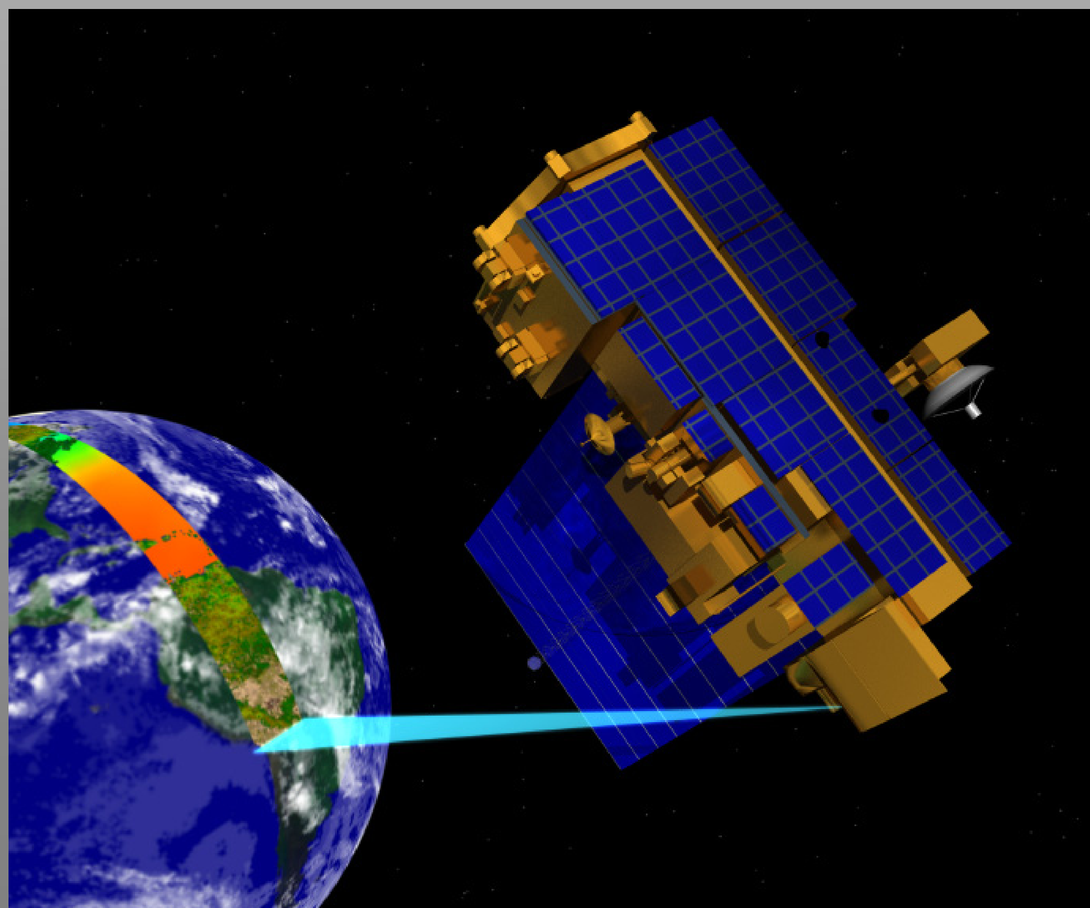
Promising Approaches: Satellite Data

The NASA Earth Observing System is a $7.3 billion program planning satellite-based earth monitoring for 15 years, and is the heart of global change science for the United States.



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Promising Approaches: Species Energy Theory

Biodiversity is often strongly correlated with energy.

Energy

Heat – e.g., temperature, potential evapotranspiration

Ecological productivity – e.g., NPP

Why?

Abundant food resources or warmer thermal conditions allow higher survival and reproduction of individuals within a population, and larger population sizes reduce the chance of species extinctions (Wright 1983).

"Measures of energy (heat, primary productivity)…[and water balance]…explain spatial variation in richness better than other… variables in 82 of 85 cases", Hawkins et al. 2003.

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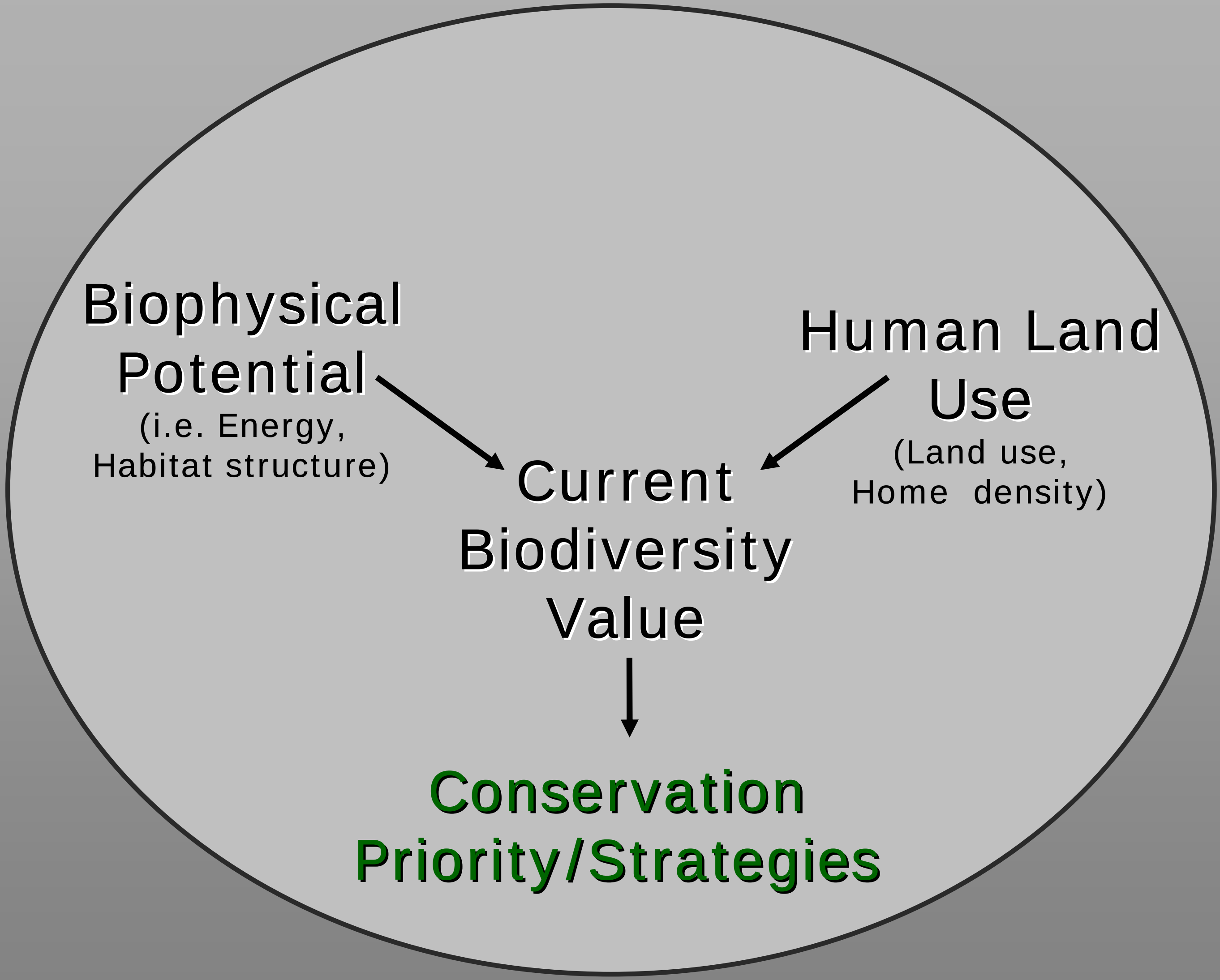
Conceptual Model



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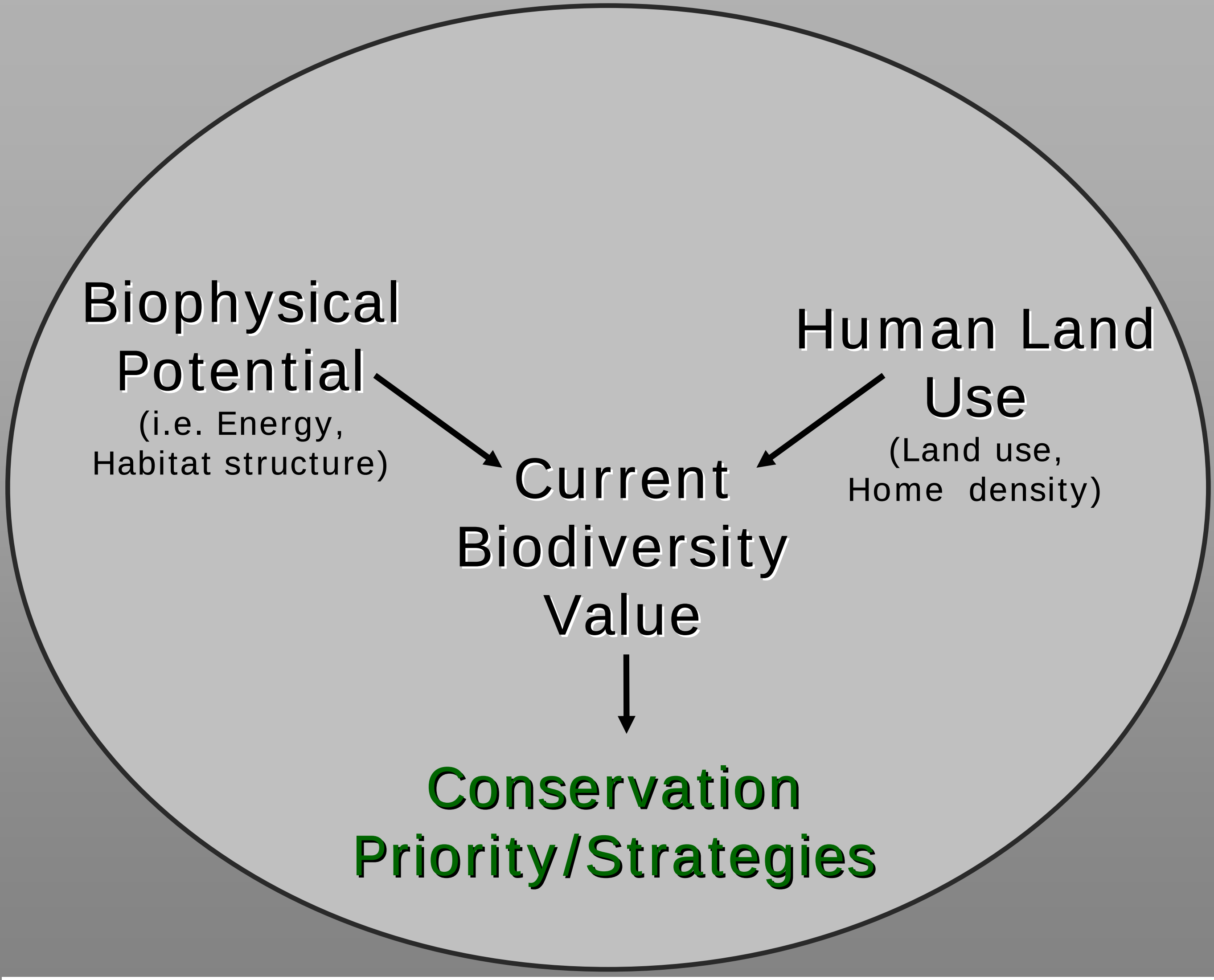
Conceptual Model



The marriage of species energy theory and satellite data provides an important new framework for organizing conservation along biophysical and human gradients.

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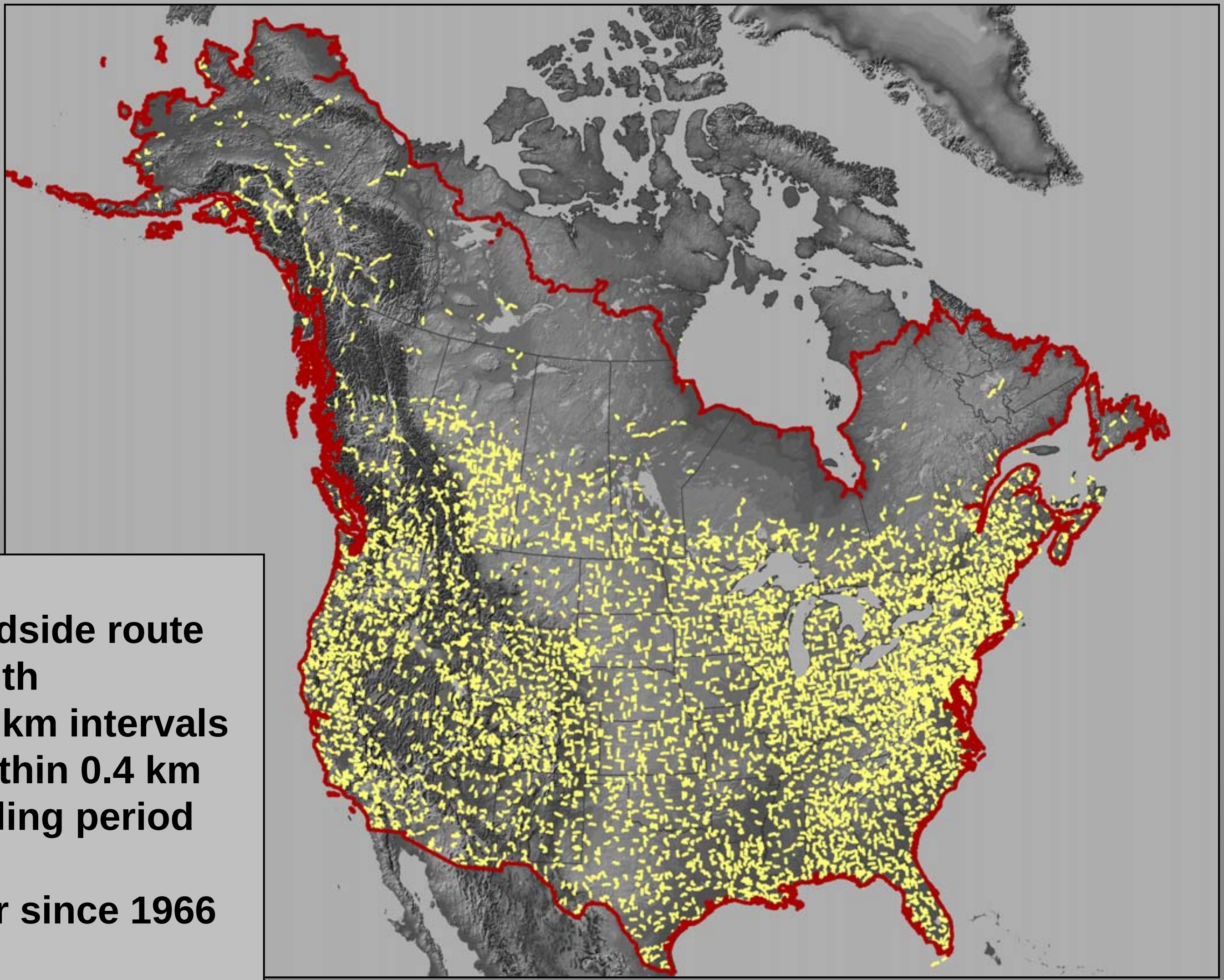
Questions

- How well do MODIS vegetation products account for bird species richness across North America?
  - Best predictor?
  - Shape of relationship?
  - Spatial distribution of energy/bird relationship?

- How are humans distributed relative to ecosystem energy and how does this influence species richness?

- How should conservation be tailored to biophysical and human gradients?

USGS Breeding Bird Survey



- Survey unit is a roadside route
    - 39.4 km in length
    - 50 stops at 0.8 km intervals
    - Birds tallied within 0.4 km
    - 3 minute sampling period

- One survey per year since 1966

- Water birds, hawks, owls,
- and nonnative species excluded in this analysis

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Predictor Data

MODIS Vegetation Products	Gross primary productivity Net primary productivity Enhanced vegetation index Normalized difference vegetation index Leaf area index
Other Data	Land cover (MODIS) Human density (US and Canadian censuses)

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BBS Issues: Sampling Biases

Issue	Treatment
• Road-side survey. • Nonrandom habitats? • Road-side bird species?	• Uniqueness of data set outweighs bias
•Species detectability. • New observers tend to • miss species. • Ability to detect a bird • differs among species • and habitats.	• Mark recapture statistical methods
•Representation of species richness. • Average annual or cumulative	•Average annual for 2000-2004
•Land use effects. • Humans may alter natural biodiversity	•Omit routes >30% human agriculture, mosaic, urban for biophysical analyses

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Statistical Techniques

- Patterns of association evaluated with regression techniques.

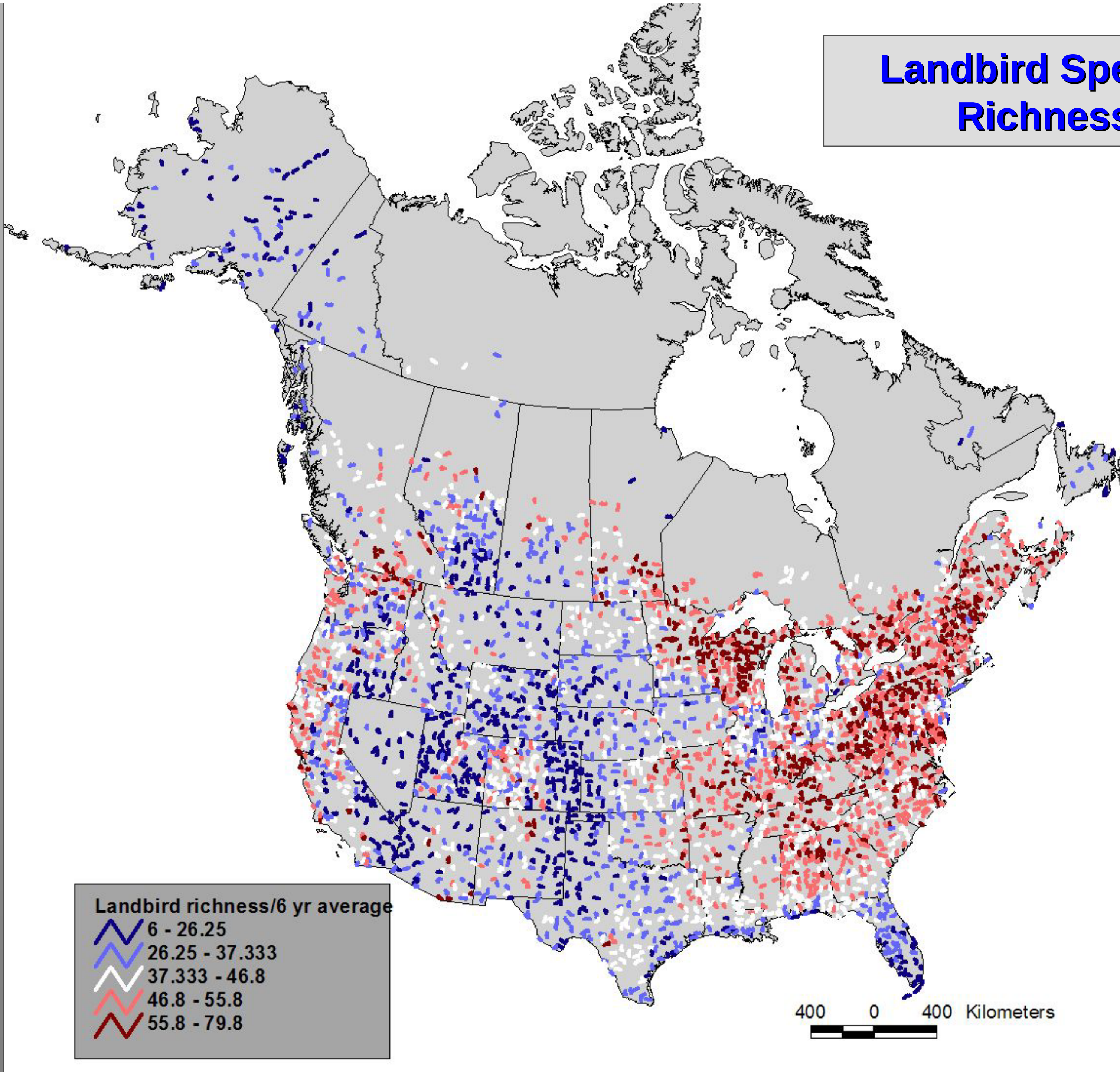
- Model selection based on AIC (distance between specified model and reality).

- Coefficient of determination for amount of variance explained.

- Bird species richness transformed (log+1) to improve normality.

- Mixed models will be used to control for spatial and temporal autocorrelations, but not done yet.

Landbird Species Richness



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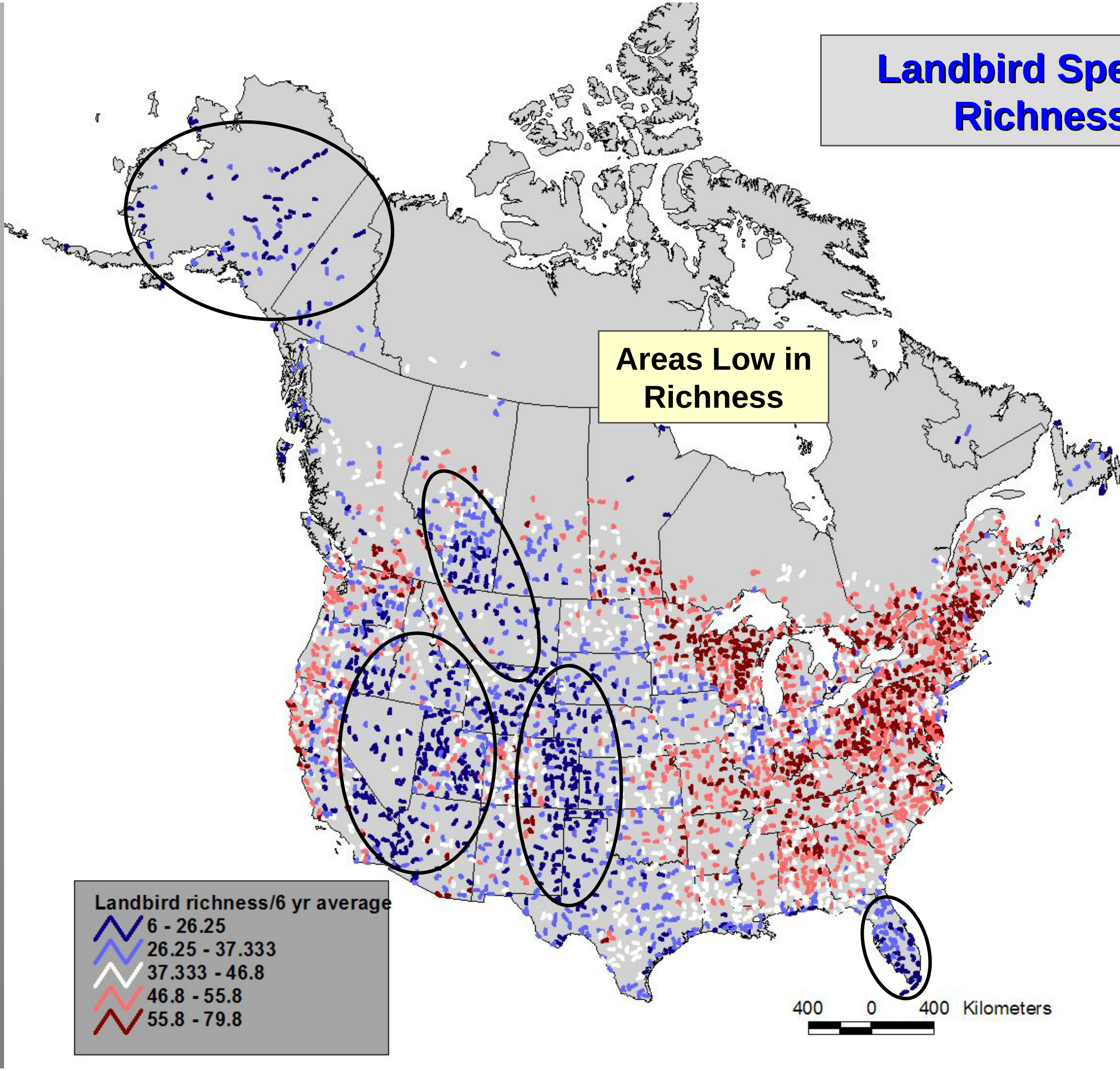
Landbird Species Richness



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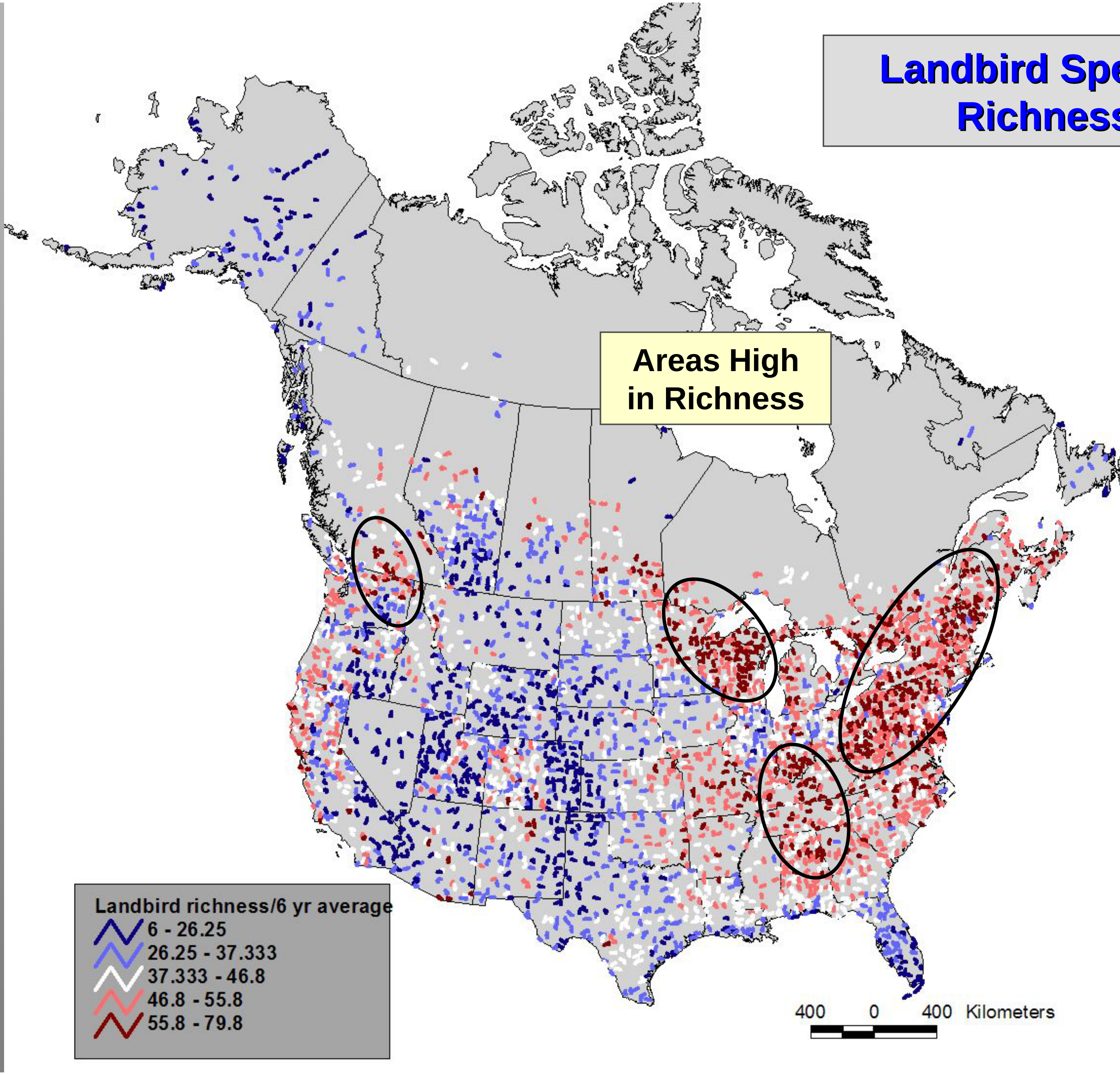
Landbird Species Richness



MODIS Products and Bird Diversity

N=1617

	R^2	adj R^2	AIC
GPP	0.4952	0.4936	-6518.4
NPP	0.4677	0.4671	-6435.9
EVI	0.4118	0.4111	-6288.2
NDVI	0.4588	0.4581	-6418.1

***Rural routes only**

Summary of Results

- **GPP was strongest predictor (.50).**
- Annual predictors were stronger than breeding season (GPP=.40) predictors.
- Observed richness (GPP=.62) was stronger than estimated richness.

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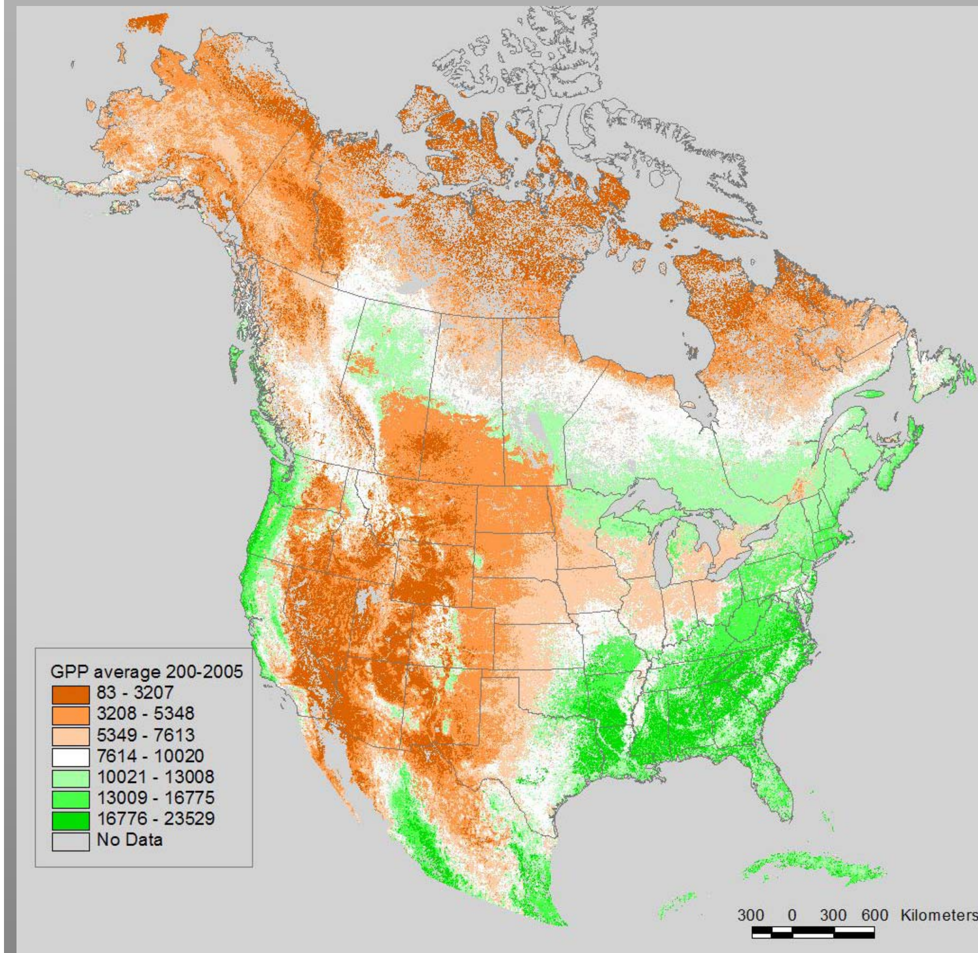
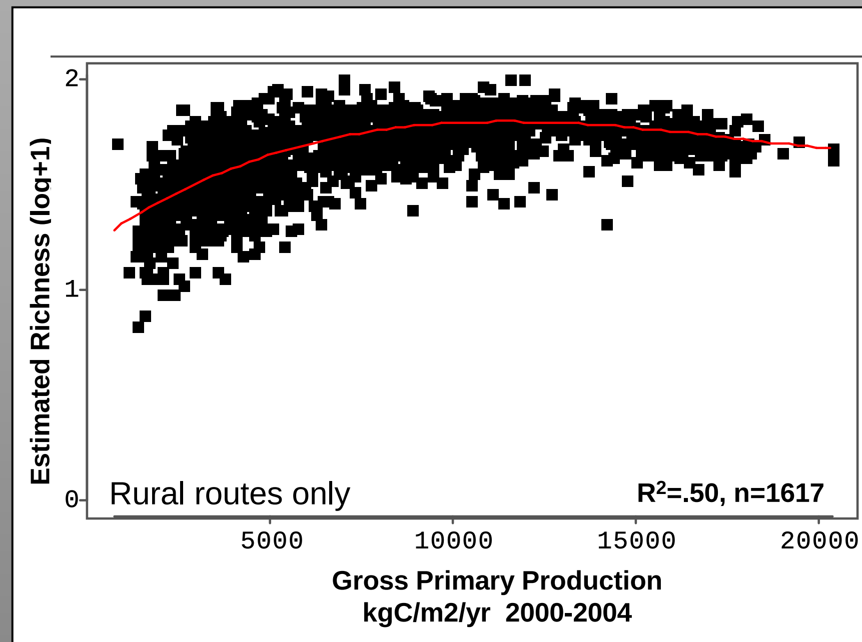
MODIS Products and Bird Diversity





The relationship is unimodal.

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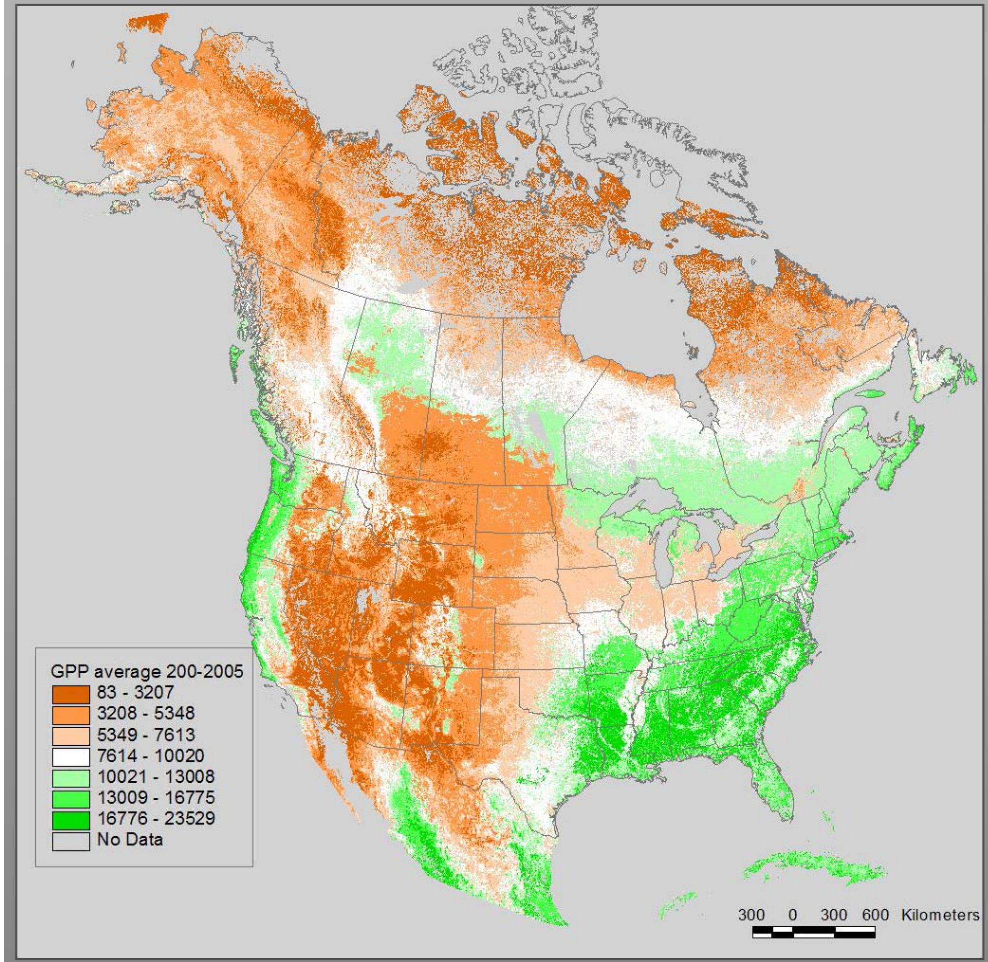
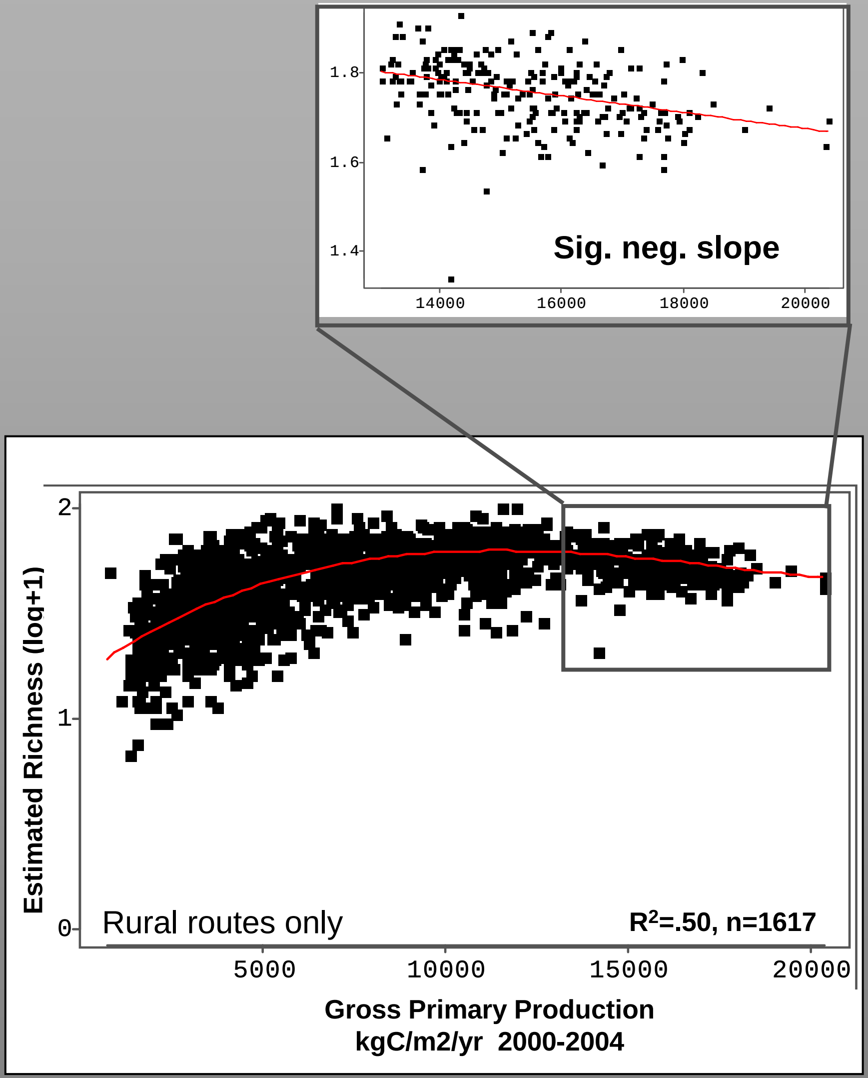
MODIS Products and Bird Diversity





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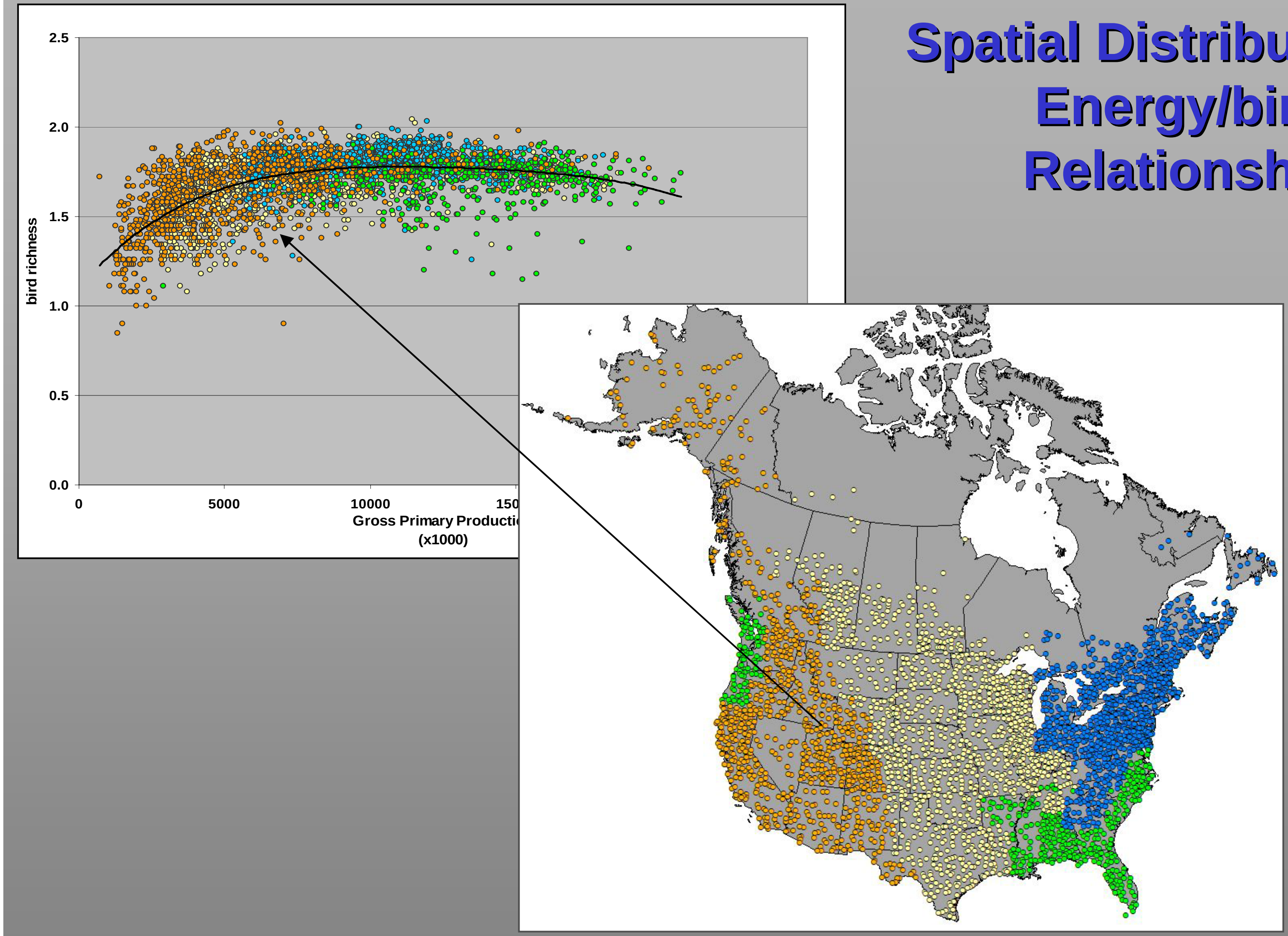
Spatial Distribution of Energy/bird Relationship



Ecoregions lie on different portions of the unimodal relationship.

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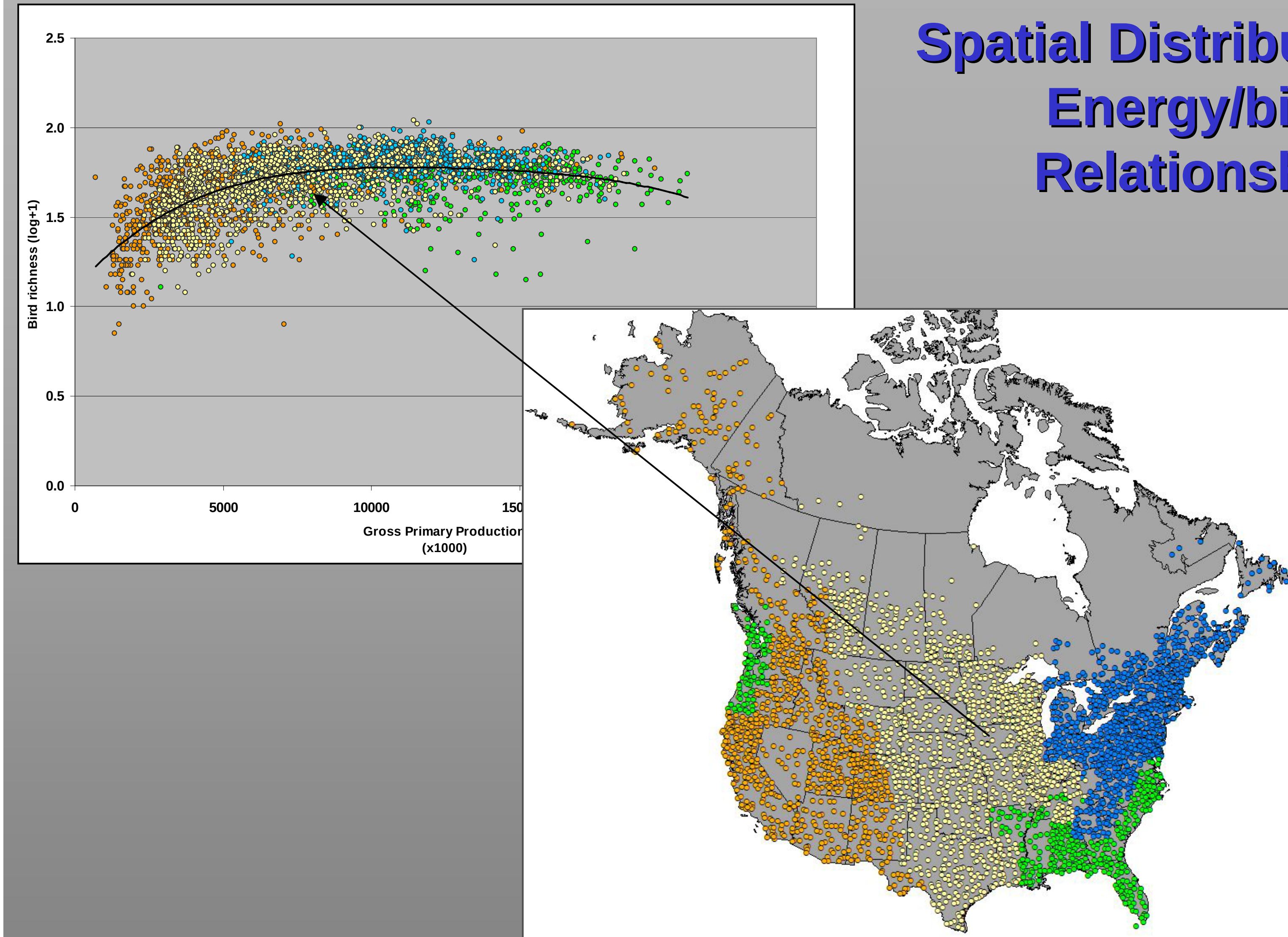

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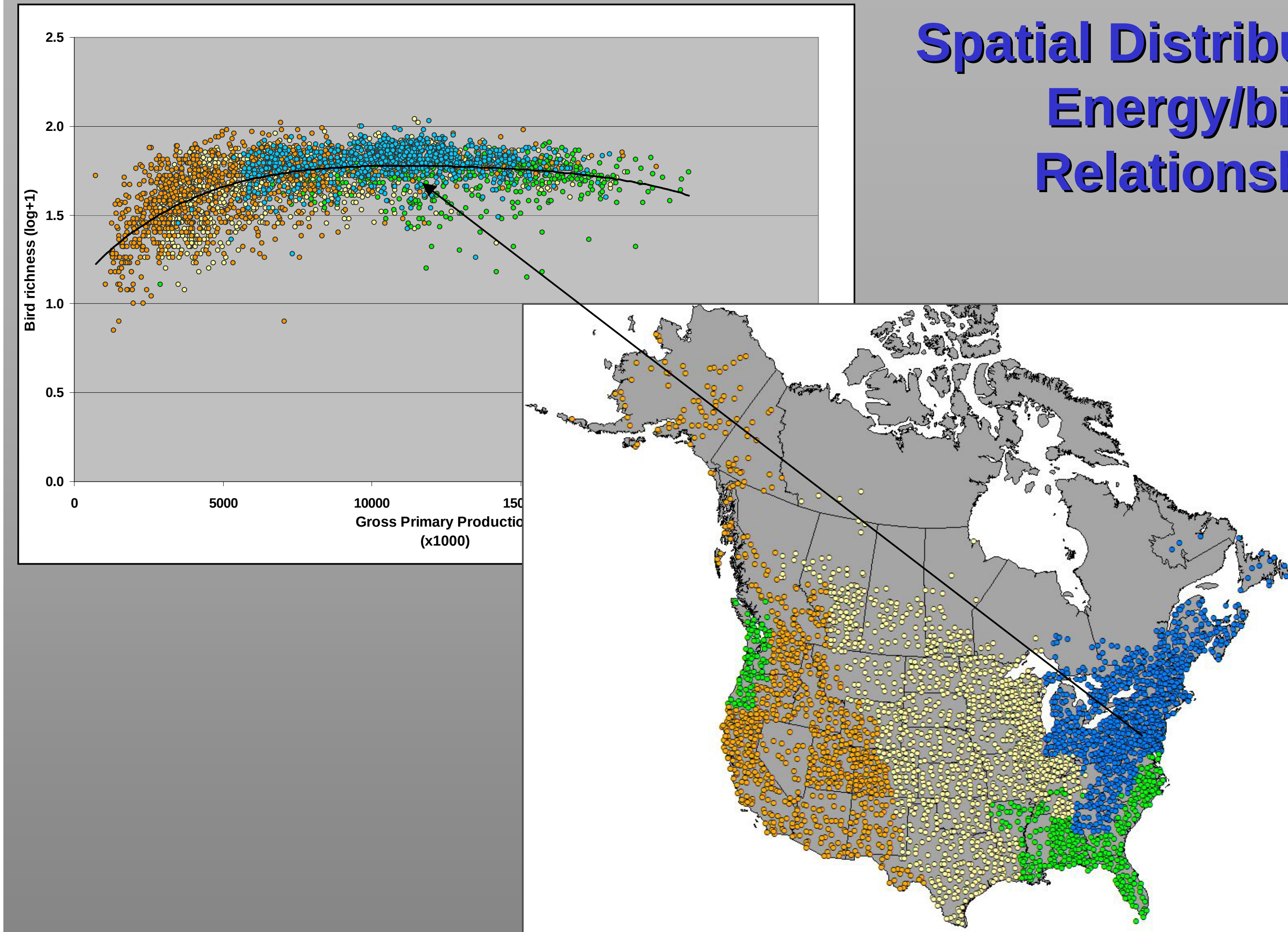

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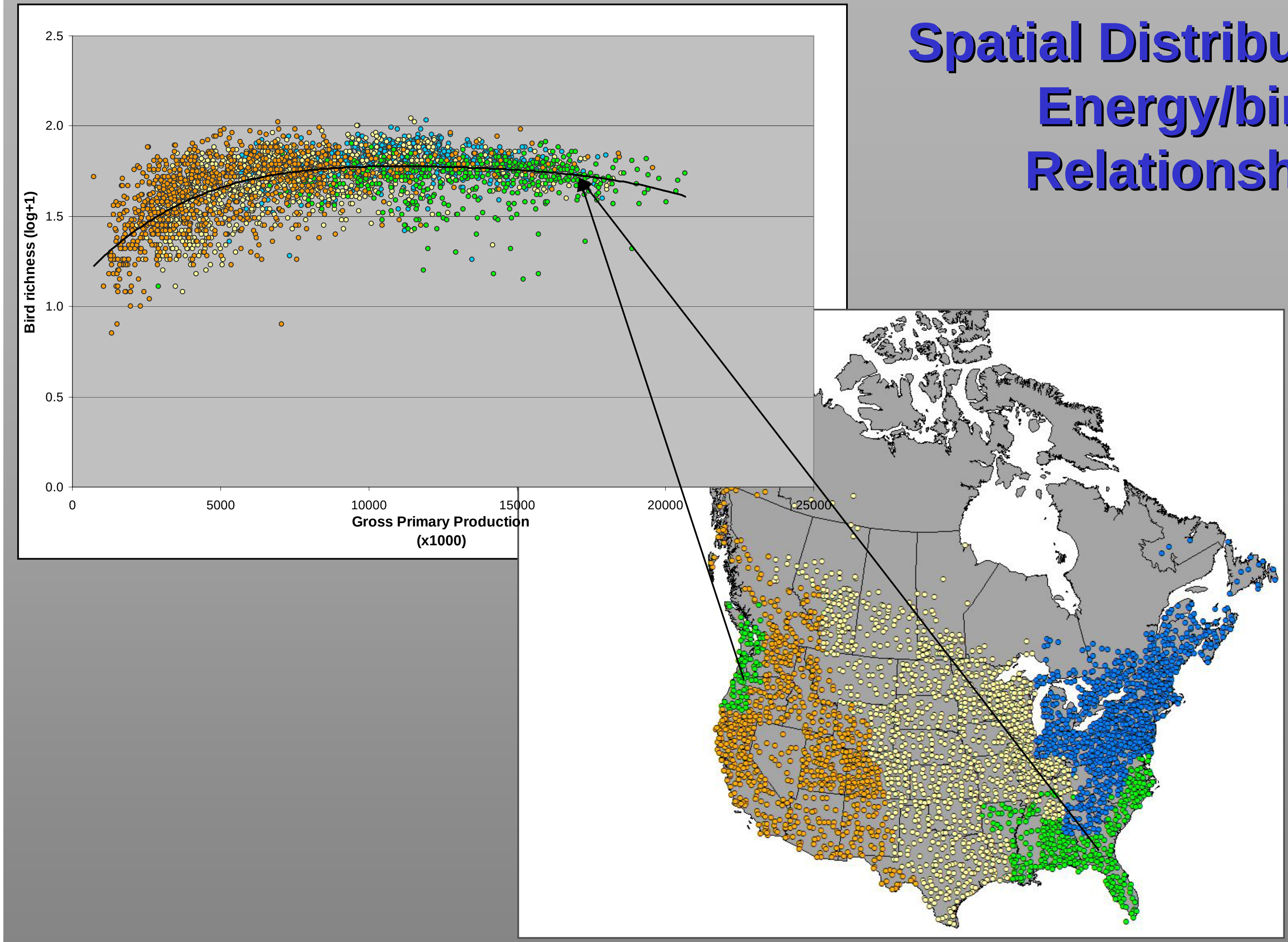

Ecoregions lie on different portions of the unimodal relationship.

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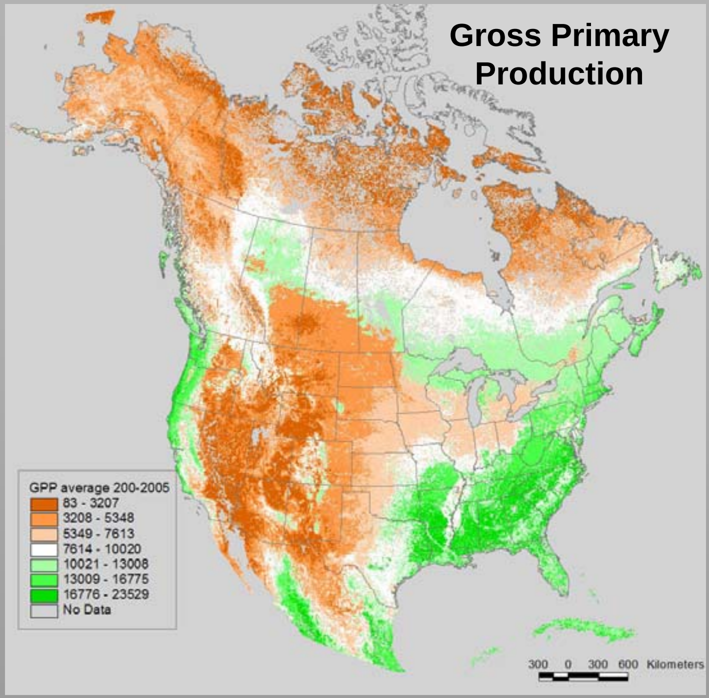
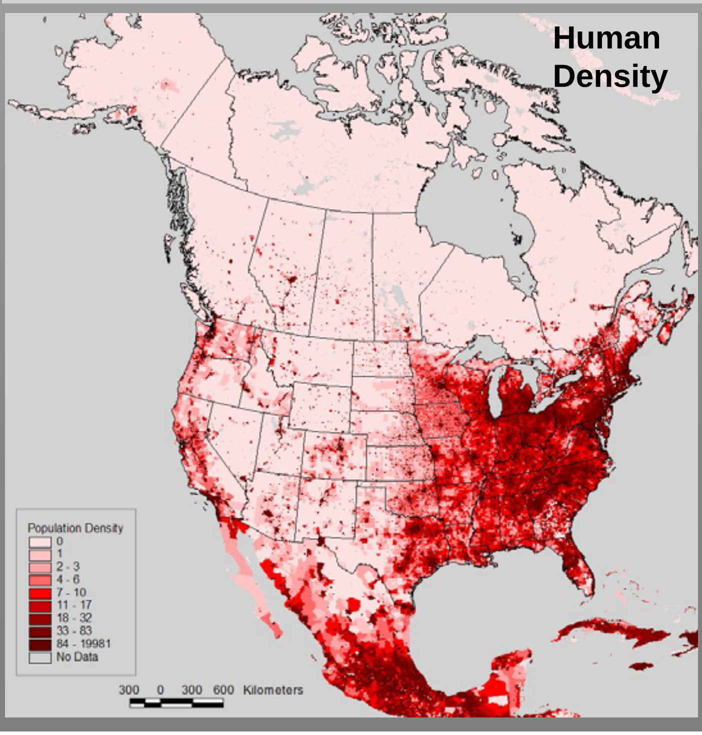
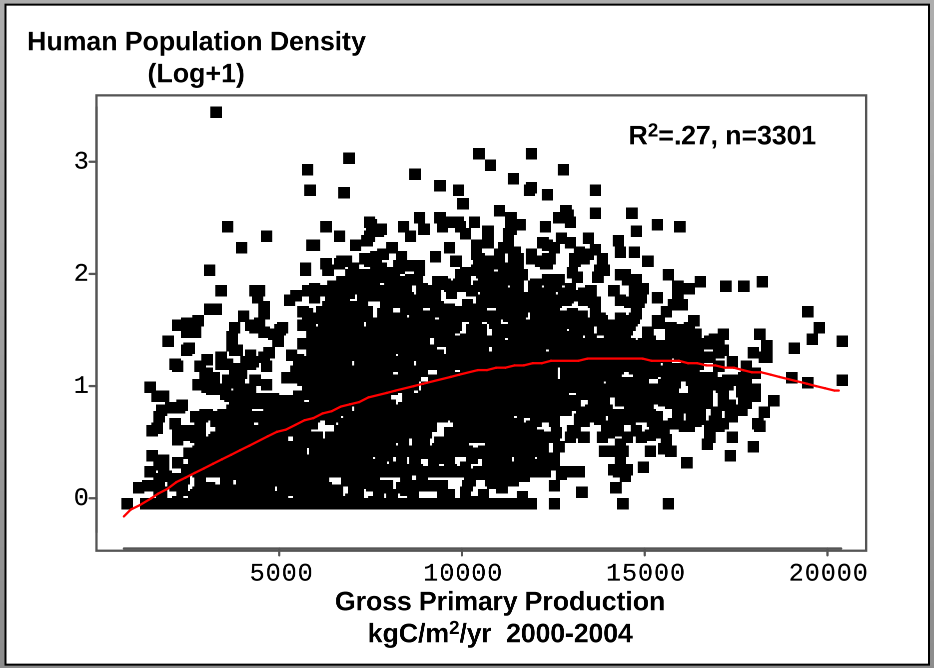
Biophysical Correlates with Human Density







Human density is also correlated with GPP.

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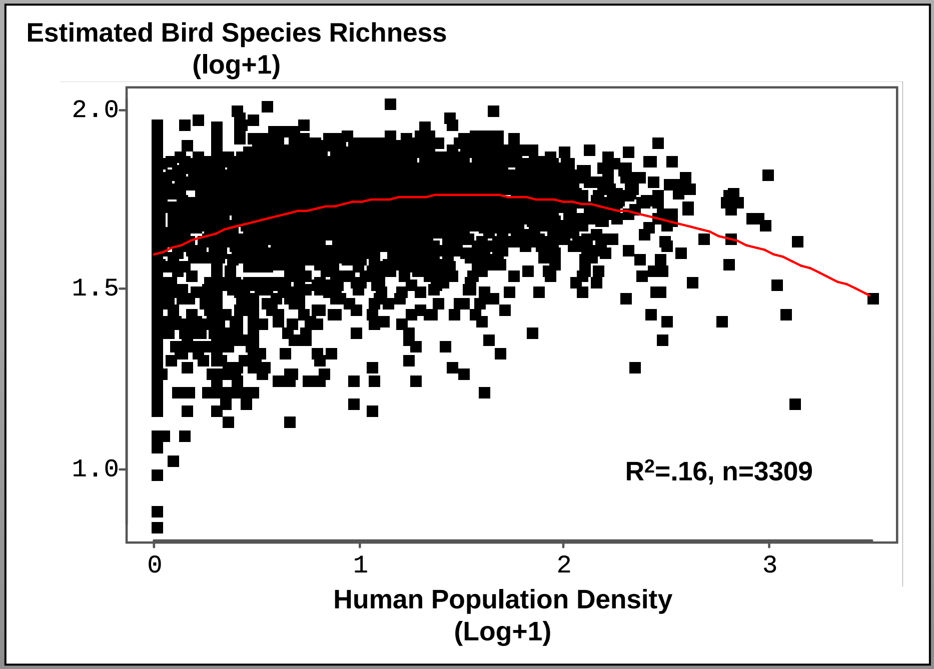
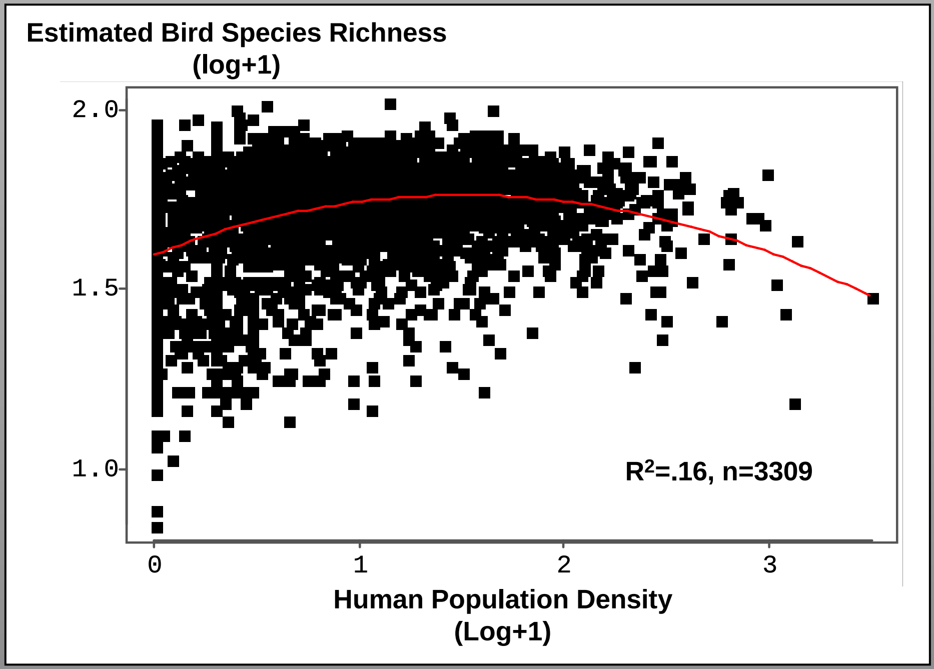
Human Density and Biodiversity



Birds are correlated with human density.

Human Density and Biodiversity



Birds are correlated with human density.

Is there a human effect on birds beyond GPP?

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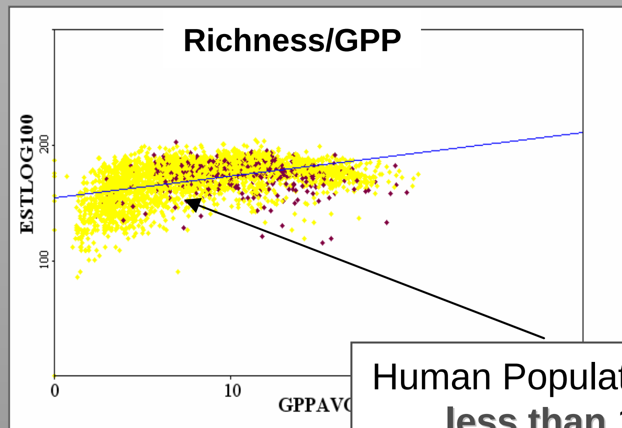
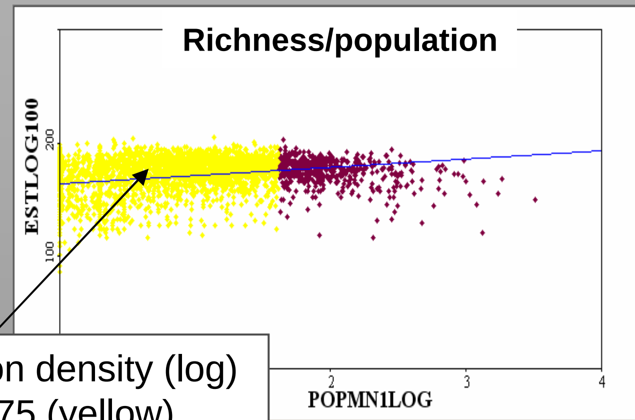
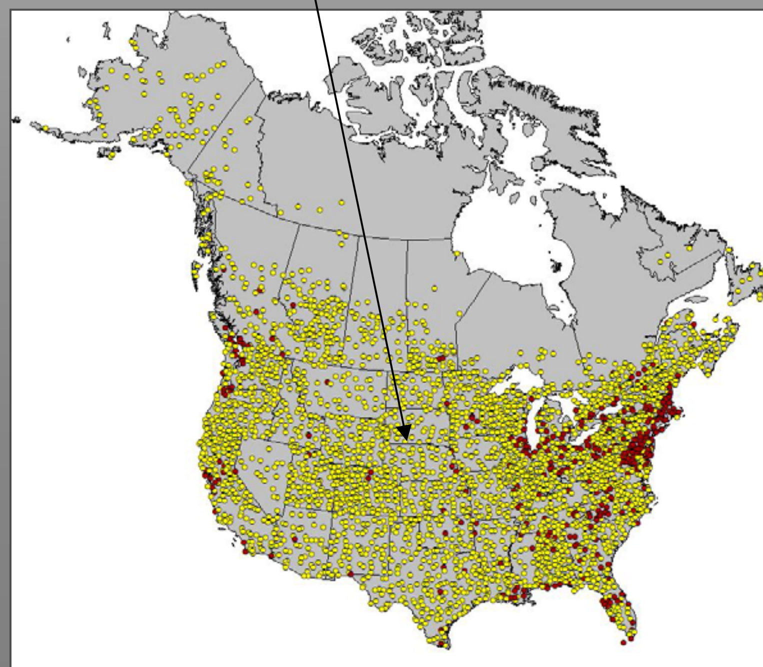
Human Density and Biodiversity

Low population routes





Model	AIC	R^2	P value
POP POP^2	-11184	.155	.0001
GPP GPP^2	-12313	.422	.0001
POP POP^2 GPP GPP^2	-12328	.426	.0001



For lower population routes (yellow in these graphics) human population density contributes little to the best model.

Human density has little effect on birds at lower human densities.

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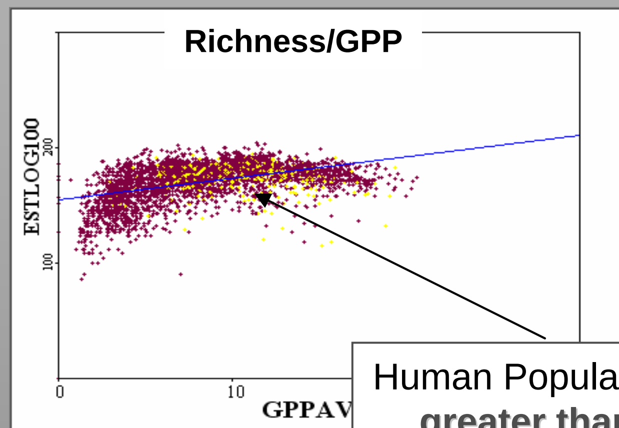
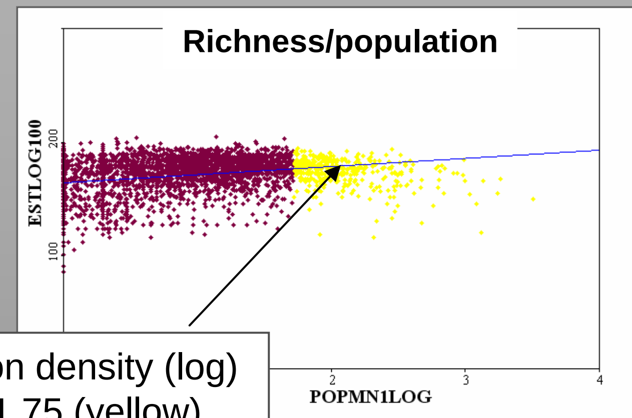
Human Density and Biodiversity

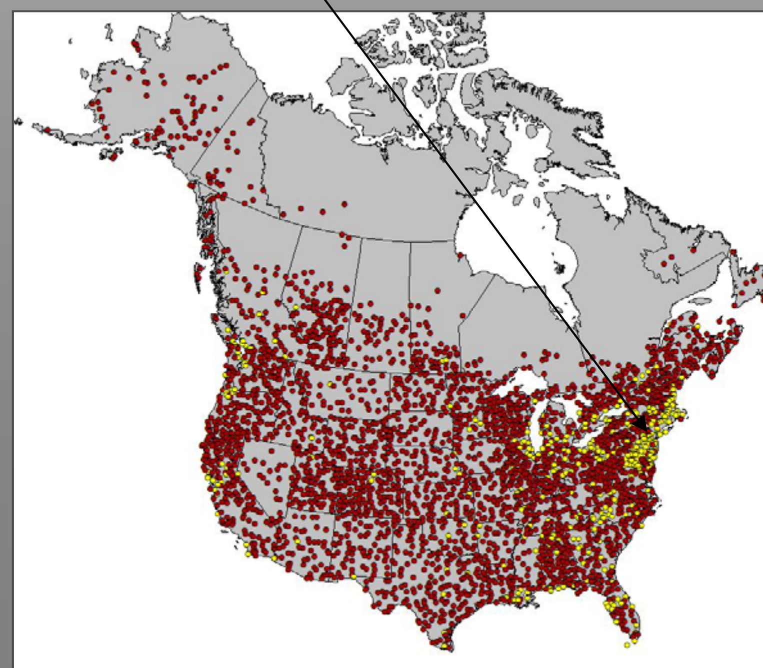
High population routes





Human Population density (log) **greater than** 1.75 (yellow)

Model	AIC	R^2	P value
POP POP^2	-1535	.106	.0001
GPP GPP^2	-1524	.070	.0001
POP POP^2 GPP GPP^2	-1559	.1743	.0001



For higher population routes, above the 1.75 threshold, human population density explains more variation than GPP.

Humans may reduce birds at higher human densities.

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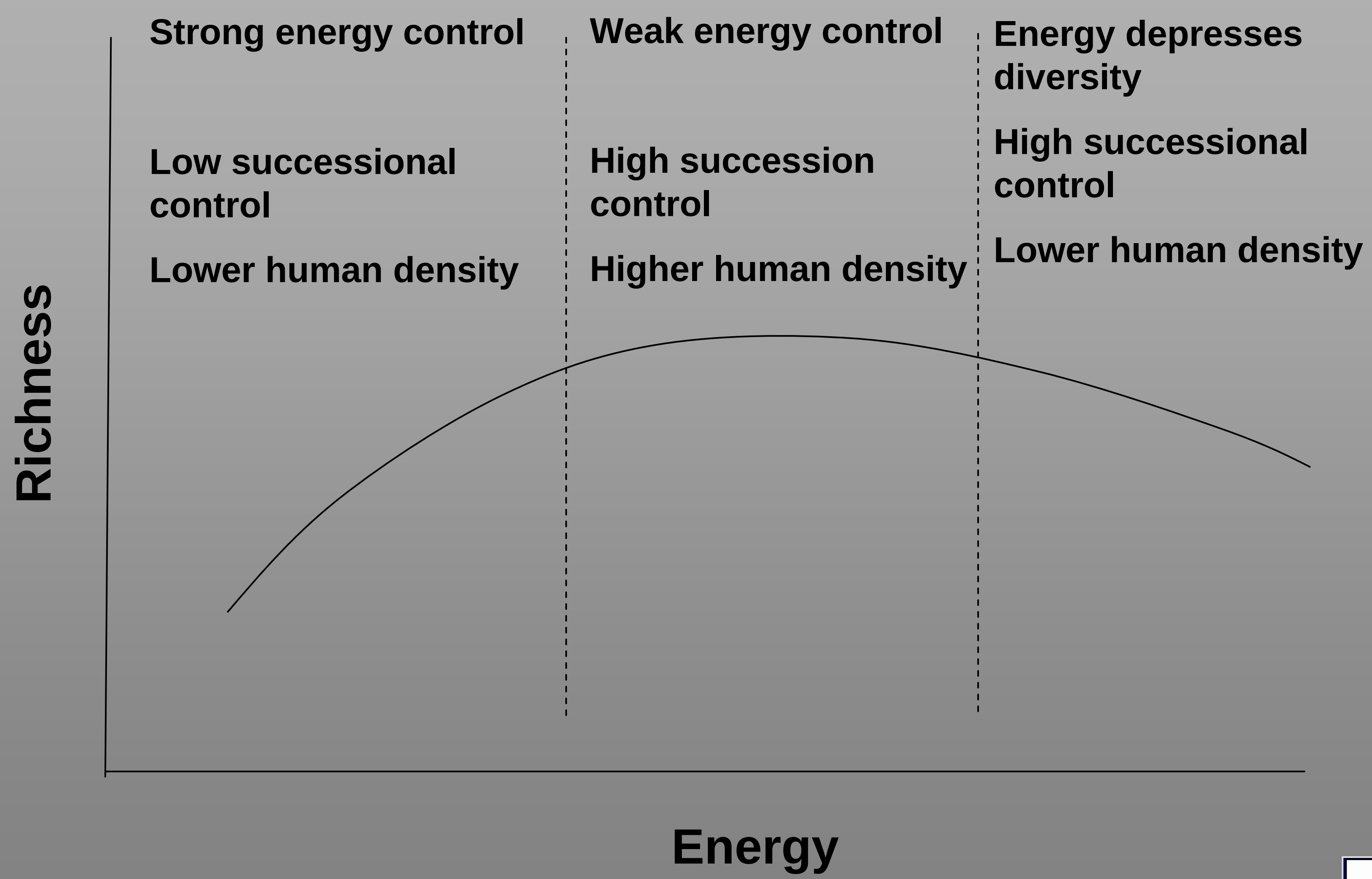
Conservation Implications

- The conservation implications of species energy theory are not yet well developed in the literature.
- The key strategies of conservation biology are currently applied without regard to biophysical gradients.
- Species energy theory may offer an organizing framework.

Managing along Biophysical Gradients



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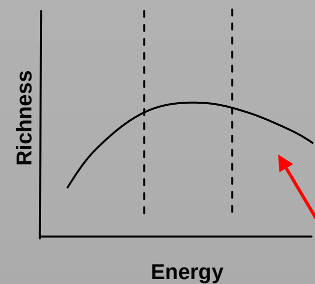
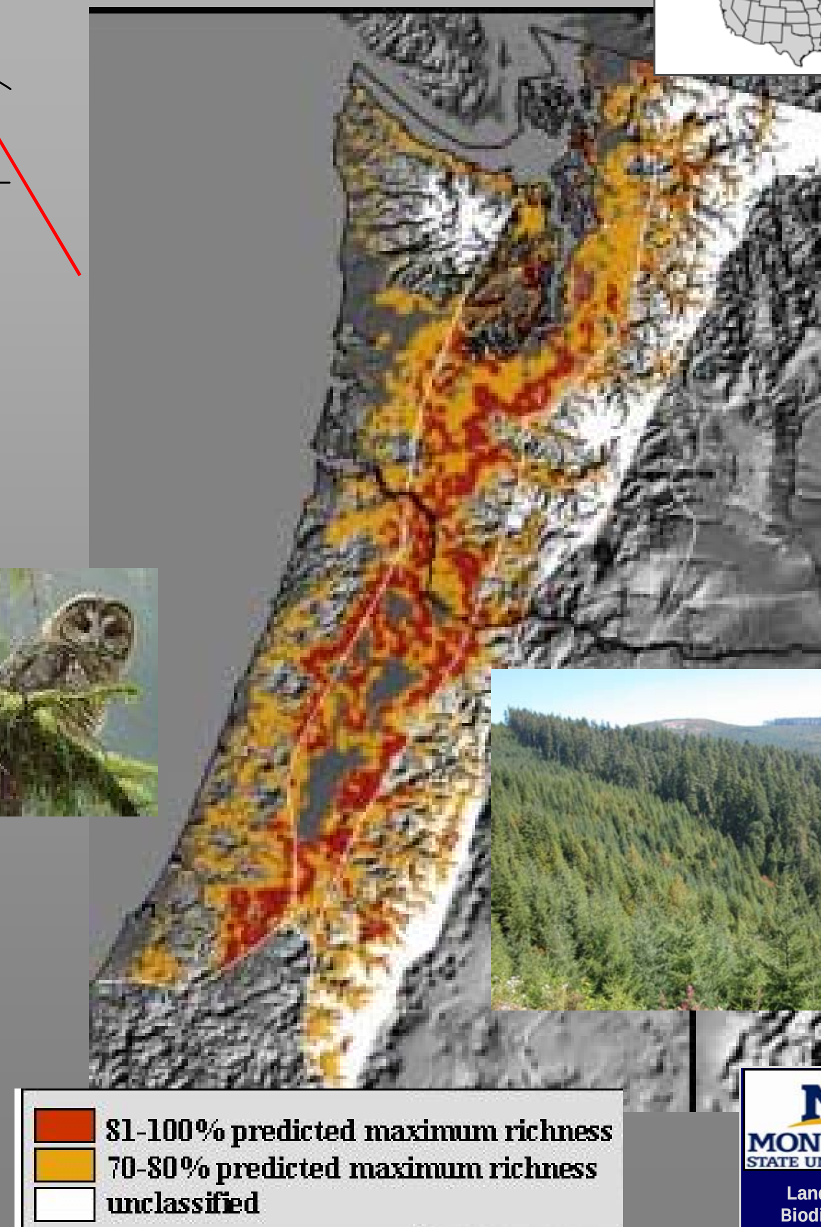
HIgh-Energy Ecoregions: Pacific Northwest



Conservation Category	Management strategy
Conservation Zones	Protect low energy places
Disturbance	Use disturbance to break competitive dominance
	Use shifting mosaic harvest pattern
	Maintain structural complexity
Landscape Pattern	Manage for patch size and edge
Sensitive Species	Forest interior species
	Open canopy species
Protected Area Size	Smaller
Land Use	Allow more random placement



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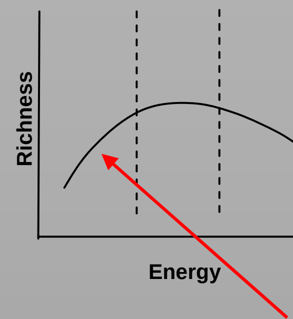
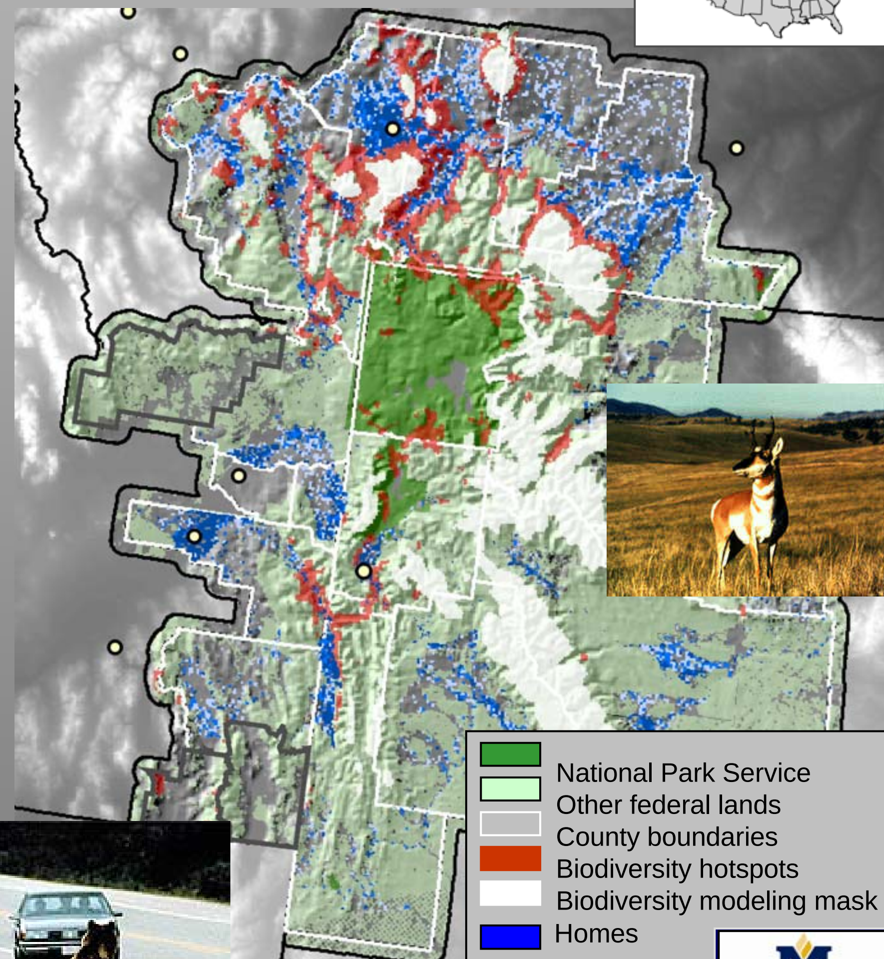
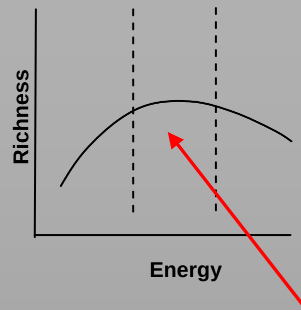
Low-Energy Ecoregions: Greater Yellowstone

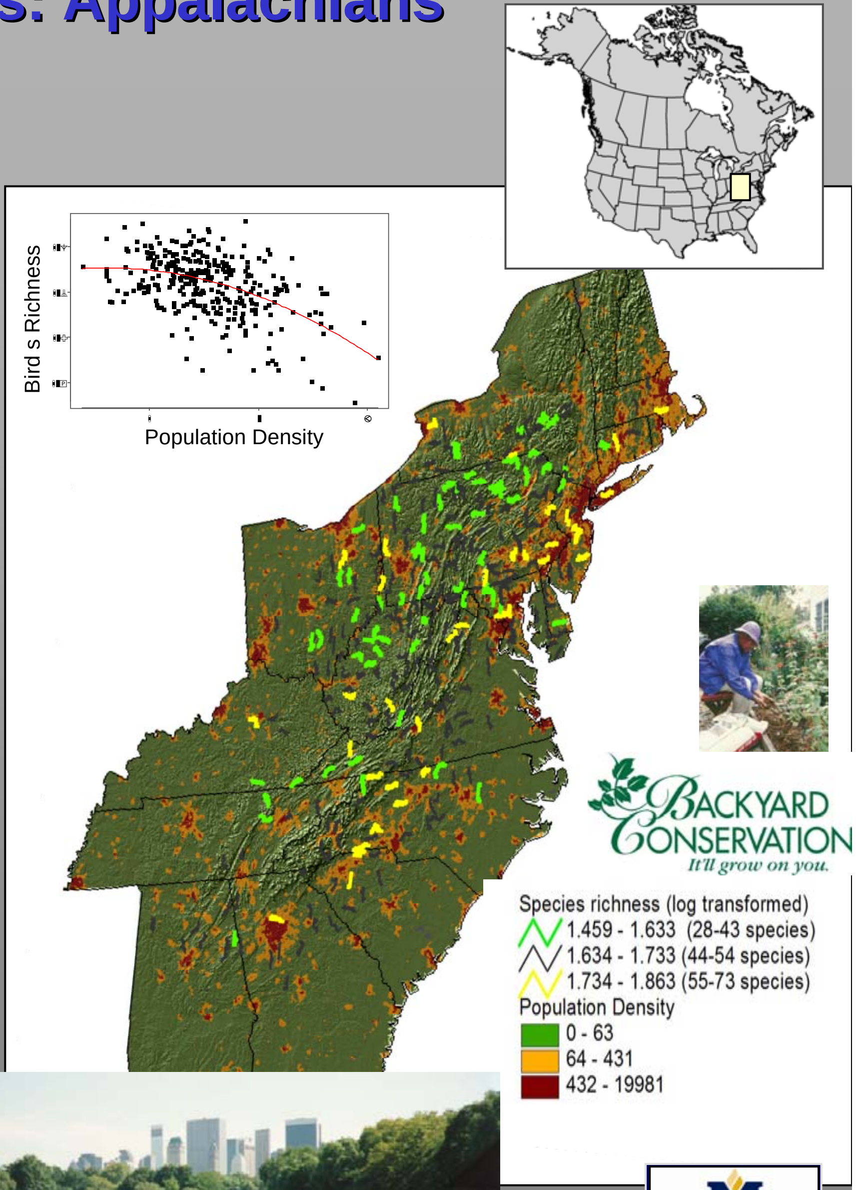




Conservation Category	Management strategy
Conservation Zones	Protect high energy places
Disturbance	Use fire, flooding, logging judiciously in hotspots
Landscape Pattern	Maintain connectivity due to migrations
Sensitive Species	Many species with large home ranges and low population sizes due to energy limitations
Protected Area Size	Large
Land Use	Low overall
	Focused on hot spots
	Plan development outside of hotspots

Mid-Energy Ecoregions: Appalachians





Conservation Category	Management strategy
Conservation Zones	Protect more natural areas
Disturbance	Similar to “Descending”
Landscape Pattern	Similar to “Descending”
Sensitive Species	Synanthropic species will dominate natives
Exotics	High exotics likely due to productivity and high land use
Protected Area Size	Smaller
Land Use	Focus away from remaining natural areas
	Emphasize “backyard” conservation
	Apply restoration

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Conclusions

- Biophysical factors such as energy set a natural potential for biodiversity.

- Land use may modify biodiversity from this potential.

- The “hump-shaped” energy curve leads to the need to tailor conservation to the three zone of species/energy curve.

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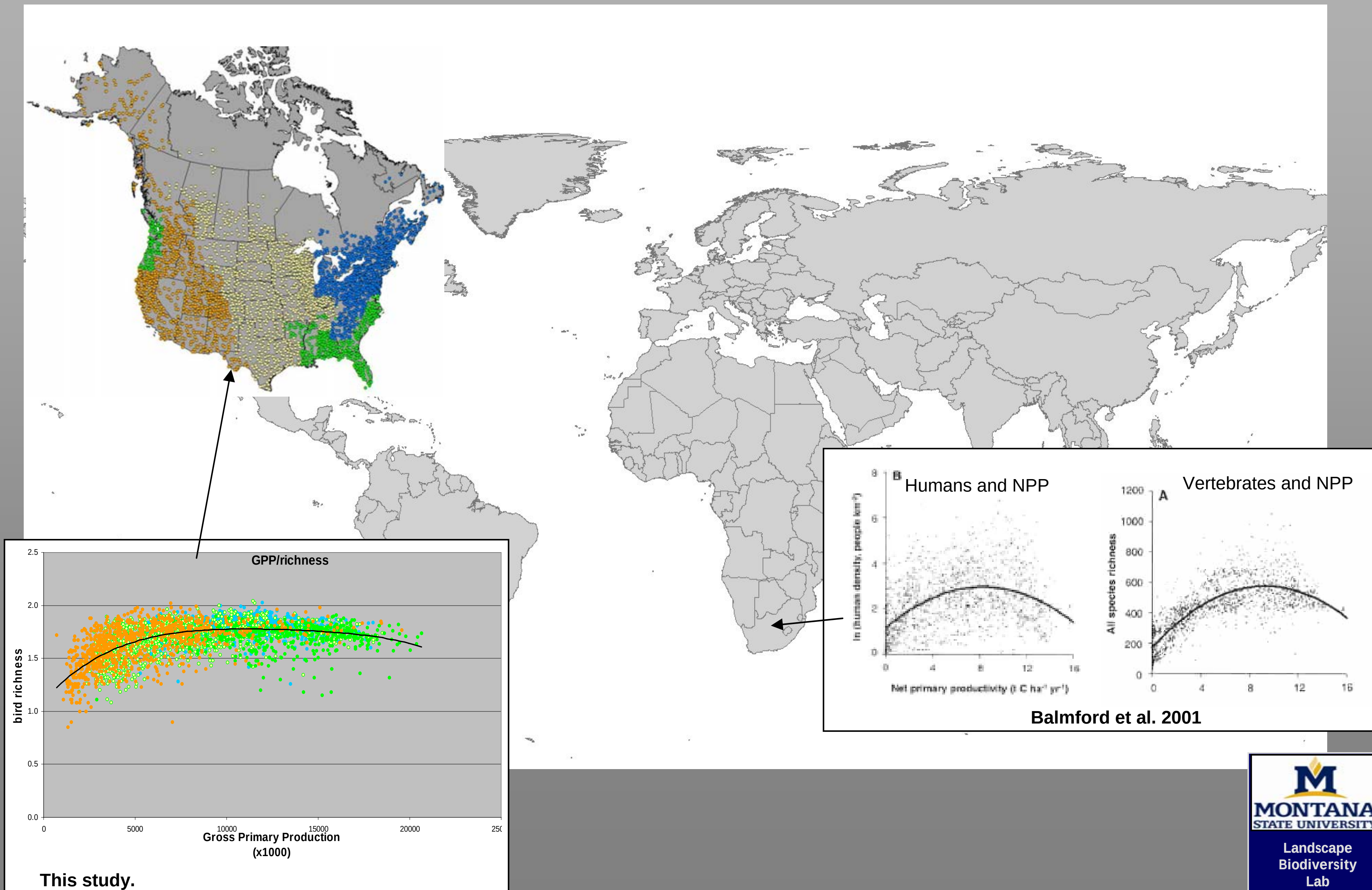
Broader Applications?

Where are the zones of energy and human density on other continents?



This study.

Balmford et al. 2001

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Acknowledgements

NASA EOS Program

NASA Land Cover Land Use Change Program

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Publications

Land Use Change Around Nature Reserves: Implications for Sustaining Biodiversity

In Press. Ecological Applications

Introduction – A. Hansen and R. DeFries.

Ecological mechanisms linking nature reserves to surrounding lands: A conceptual framework for assessing implications of land use change.

A. Hansen and R. DeFries.

Sustaining regional biodiversity in the Mayan Forest.

B. Turner, Ron Eastman, H. Vester, S. Calme, et al.

Regional land use effects on panda populations and other species in the Wolong Reserve, China.

J. Jiu.

Effects of alternative future growth scenarios on biodiversity in Greater Yellowstone

P. Hernandez, A. Hansen, D. Jones, L. Phillips.

Towards regional management of nature reserves and surrounding lands

R. DeFries, A. Hansen, R. Reid, B. Turner, L. Curran, J. Liu, E. Moran.

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Next Steps

- Include sensitive species in the analyses

- Map for North America zones of energy and land use and recommend conservation strategies

- Test these hypotheses for other taxa and for other continents

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