Biophysical and Land Use Influences on Avian Biodiversity at Multiple Scales: Study Design

MODIS Science Team Meeting

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Abstract

We are initiating research to understand the relationships between biophysical factors and human land use in structuring biodiversity at multiple spatial scales. The research will advance conservation planning, demonstrate the utility of satellite data for conservation, and provide a framework for global application. Ecological theory suggests that biodiversity varies across biophysical gradients. At the continental scale, species energy theory predicts that the number of species in a community is determined by atmospheric energy and energy fixed by green plants. Biodiversity studies at local scales have focused on habitat structure and spatial patterns across patches and landscapes. This study will determine which biophysical variables strongly influence bird diversity at regional to continental scales, analyze resulting spatial patterns. Furthermore, we hypothesize that land use reduces native biodiversity below the potential set by the biophysical environment. We will evaluate the effect of land use and identify areas of high biodiversity potential low land use impacts for conservation interests. The study will rely on Moderate-Resolution Spectrometer (MODIS) and Advanced Microwave Scanning Radiometer (AMSR-E). Products from these sensors may provide a breakthrough in our ability to understand patterns of biodiversity.

Current Study

Study Design

This study will determine the biophysical variables that strongly influence bird species richness at multiple scales, analyze resulting spatial patterns, determine the modification of biodiversity potential by land use, and identify biodiversity hot spots. Specific objectives and general approach are as follows.

Objectives

Objective 1: Determine which biophysical predictors are most strongly associated with bird biodiversity potential in areas without intense human land use.

We will test the contributions of biophysical and land use variables in influencing bird species richness across the study area.

Objective 2: Analyze the biophysical and land use predictors at the regional scale along a environmental gradient from harsh to mesic systems.

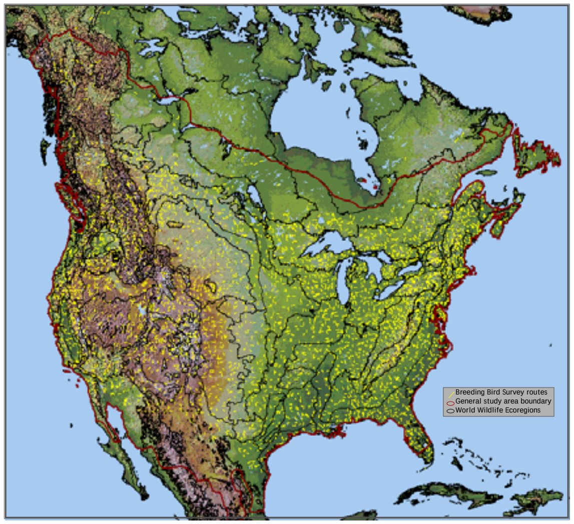
We will test the relative contributions of biophysical and land use variables in explaining species richness within ecoregions that represent the full environmental gradient of North America. We hypothesize that energy related predictors will contribute to structuring biodiversity patterns in ecoregions with harsher biophysical conditinos than in more mesic ecoregions.

Objective 3: Extrapolate and analyze geographic patterns of bird biodiversity potential and evaluate these patterns relative to conservation planning.

We will analyze spatial patterns of distribution of species diversity and species abundances between mesic to harsh ecosystems.

Objective 4: Test hypotheses on modification from biophysical potential due to land use changes.

We will conduct a systematic evaluation of responses of native and exotic guilds to land use intensity. Additionally we will examine the extent to which thresholds exist in the responses of various levels of biodiversity to land use.

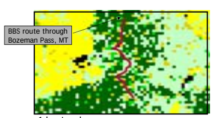


Study Area
Analyses will be conducted across the portion of North America which has been sampled by the USGS Breeding Bird Survey.

Spatial Database and Statistical Analysis

Response Data

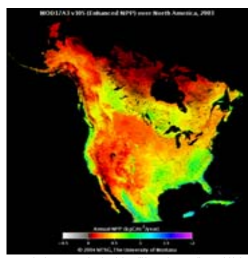
There are 5000 USGS Breeding Bird Survey routes in the study area; many have been surveyed annually since 1968. Bird richness will be calculated for each route based on species accumulation curves. For analyses, continuous predictor data will be averaged over BBS routes, majority and variety filters will be used with categorical predictors.



1 km Land cover

Predictor Data

Category	Parameter	Source
Habitat structure		
Leaf area index	Plant canopy area	MODIS
Enhanced vegetation index	Plant canopy structural parameters and phenology	MODIS
Normalized difference vegetation index	vegetation photosynthetic activity and phenology	MODIS
Landscape structure	Patch characteristics	Landsat TM derived USGS NLCC 30m
Topography	Elevation, slope, aspect	USGS 1 km digital elevation model
Habitat composition		
Land Cover type	Vegetation cover from 17 classes	MODIS
Annual vegetation Continuous fields	Life form, leaf type and leaf longevity	MODIS
Energy		
Annual net primary productivity	Plant growth	MODIS
Net photosynthesis 8-day	Growing season productivity	MODIS
Evapotranspiration/surface resistance 8-day	Dryness of land surface	MODIS
Climate (growing season, breeding season and annual measures for all)	Precipitation, vapor pressure deficit, solar radiation, frost days/month, temperature, growing degree days	DAYMET
Land Use		
Land Use	Land use on developed lands	USGS Landsat derived Land Cover Characterization Data (MLRC)
Land Use trends	Temporal changes in land use	Brown et al. in review
Road Density	Human impacts via roadways	US Census TIGER line data



Example of a MODIS product (NPP) that will be used as a predictor variable in this study.

It is now possible to explore biodiversity/biophysical relationships at the continental scale with the advent of the MODIS and AMSR-E sensors. These products offer relatively high temporal and spatial resolution data on plant energy, vegetation structure, and land use. New data sets on climate, human land use intensity will also be analyzed.

Statistical Analysis

The analysis will involve selection of multiple regression models, controlling for spatial autocorrelation. Model selection techniques will be used to choose between competing models. Mixed models will be used to account for the spatial autocorrelation between samples. Coefficient of determination will be used to assess the amount of variation in biodiversity explained by the predictors.

Implications and Relevance of the Research

This study will make several unique and significant contributions including

-A comprehensive evaluation of the utility of eight MODIS and AMSR-E products for understanding and mapping avian biodiversity at regional to continental scales. If these products prove informative, our study would lay the foundation for application of these products to biodiversity issues globally.

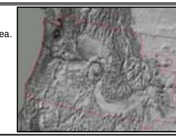
-Test of current and new scientific theory on controls on biodiversity.

-Provide the first maps of biodiversity potential across the continent and provide a quantitative assessment of how land use modifies biodiversity from this natural potential.

Pilot Study

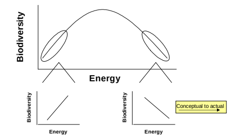
We addressed some of these questions in an earlier study across the Pacific and Inland Northwest. Below are conceptual diagrams illustrating the hypotheses and some of the results from this study. For the current research we will additionally incorporate and test vegetation structure variables and land use variables.

The Pacific and Inland Northwest (PINW) study area.

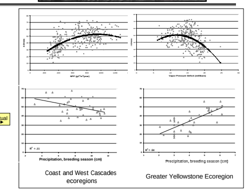


Previous work on Objectives 1

Our previous research indicated a positive or unimodal relationship with many energy related predictor variables. Also the strength and slopes of relationships varied from mesic systems like the West Cascades to the harsher ecoregions (Greater Yellowstone).



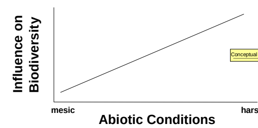
Where the relationship between energy and biodiversity is unimodal, number of species increases with energy in ecoregions low in energy and descreases with energy in the most productive ecoregions.



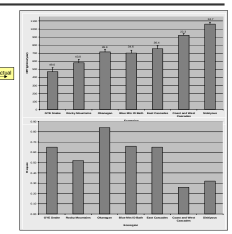
We found positive or unimodal relationships with energy related variables. The strength and slope of the relationships changed across biophysical conditions.

Previous work on Objective 2

Energy-related variables explained more variation in species richness along a gradient of biophysical harshness. This likely followed because in harsher systems, biodiversity is directly limited by climate, water, and plant productivity. In more mesic systems, these factors are less constraining and vegetation structure becomes the primary limiting factors.



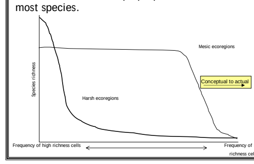
Energy is predicted to explain relatively more variation in biodiversity along a gradient from mesic to harsh abiotic conditions.

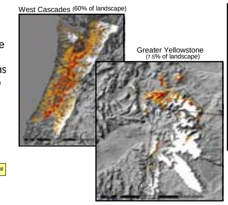


We found that among ecoregions, the coefficient of determination increased as MODIS net primary productivity decreased.

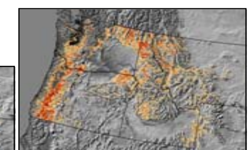
Previous work on Objective 3

Spatial patterns of species diversity and species abundances differed between mesic to harsh ecosystems. We suggest that mesic systems have a higher landscape proportion within the tolerances of most species, while harsher systems have a smaller landscape proportion tolerable to most species.





Proportion of landscape in hotspots differed between West cascades (mesic) and GYE (harsh) ecoregions



70-79% of max species

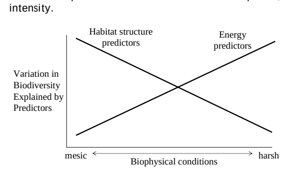
80-100% of max species

Masked area, outside reference data

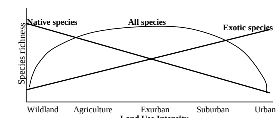
Regression equations were extrapolated throughout the study area to identify biodiversity hotspots shown above.

Implementation

We will examine the hypotheses above across the North American Study Area. Additionally, MODIS products contain information regarding vegetation structure that were not available at broad scales. We will test the contributions of vegetation structure and the biophysical factors along a biophysical gradient. The effects of land use on Species richness of native and exotic species, and guilds of native species will also be examined. intensity.



We will test if controls on bird biodiversity vary such that habitat structure is the best predictor in relatively mesic systems and climate and plant productivity are the best predictors in relatively harsh ecoregions



We will test if native and sensitive species richness decrease with increasing land use intensity, exotic species richness increase with land use intensity, and total bird species richness peaks at intermediate land use intensities.

Acknowledgements

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