Project Completion Report
Rocky Mountains Cooperative Ecosystem Studies Unit (RM-CESU)

Project Title: Investigating Graphical Models for Predicting Wetland Vegetation: Bayesian Belief Networks and Bayesian Graphical Models

Type of Project (Research, Technical Assistance or Education): Research

Funding Agency: USGS

Partner University: Montana State University

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Funding Amount: 68,909.75

Number of Students Involved, and Type of Student (Undergraduate, Graduate, Post Doctorate): 1 Graduate Student, MS in Environmental and Ecological Statistics

Project Summary, including descriptions of project deliverables, work accomplished and/or major results. If the information is restricted (e.g. location of endangered species or cultural resources), indicate the title and location of the final report.

We proposed to explore two methods for modeling complex multivariate wetland vegetation systems: Bayesian Belief Networks (BBN) and Bayesian Graphical Models (BGM). Both approaches represent the complex multivariate system by a graph composed of edges and nodes. Variables are represented by nodes and edges can be directed representing a 'causal' relationship or undirected representing a correlation (spatial or temporal).

A BBN is considered a special case of a Bayesian graphical model, in which all the variables are discrete and the relationships between variables are directed or "causal." BBN and their variant, influence diagrams, are commonly used as a tool to determine the implications of management decisions. BBN allow for incorporation of expert input to develop a hypothetical causal structure (ADG) and then explore the ramifications of different scenarios on the probability distribution of an output (response) of interest. We plan to explore the use of a BBN to model the wetland vegetation at Red Rock Lakes NWR. In this system, it is of interest how climate change may affect the abundance of sago pondweed, water milfoil and other submergent plants. The abundance of certain submergent plants is thought (known) to be related to waterfowl abundance which is of interest to managers. Although climate change is not directly measureable, we plan to investigate the utility of a BBN to address questions about the sensitivity of associations between different variables under climate change. For example, we can explore whether wetland water level patterns changes the associations between the abiotic variables and wetland vegetation abundance; i.e. is the causal structure sensitive to changes in water level patterns.

On the other hand, a Bayesian graphical model allows for greater flexibility compared to the BBN in that discrete and continuous variables can be modeled simultaneously. Furthermore spatial and temporal correlation, common in ecological systems, can be accounted for within a Bayesian Graphical Model through undirected edges between nodes. Using Bayesian inference allows for easily interpretable posterior intervals as well as the incorporation of prior knowledge---an advantage for modeling ecological and environmental data. The Red Rock Lakes NWR data has various time scales which presents unique challenges for modeling using BBN or BGM.

In this project we pursued the following research objectives:

1. Build a predictive model of wetland vegetation species abundance as a function of abiotic factors within the Red Rock Lakes NWR using BBN and/or BGM that incorporates time lags at different temporal scales.

2. Investigate tools for BBN and BGM model selection. Are the typical information theoretic criteria appropriate to use to select among different hypothetical causal structures? Are the criteria appropriate in a system with spatial and/or temporal correlation?

3. Determine if a BBN or BGM could be a useful tool for practitioners to address the effects of climate change on natural systems.

Deliverables from this project included a masters writing project in the Department of Mathematical Sciences, a presentation at the 2011 Wildlife Society Meeting in Snowbird Utah, a

a submitted paper to a peer-reviewed journal. As well as interim reports in January 2010 and June 2010. This paper was submitted manuscript to the journal of “Ecological Modelling.” The paper is provided as an electronic attachment (also attached).

Through this research effort we identified future research needs in the application of Bayesian networks to ecological data and decision making. Specifically, a measure of uncertainty concerning the causal structure is rarely reported, more commonly a sensitivity analysis or predictive performance is reported. The evaluation of the effects of an incorrect linkage structure on both interpretation and prediction should be undertaken. A “good” predictive model does not necessarily provide an appropriate representation of interrelationships among ecological processes.