A web-based decision support tool for forecasting the biological condition of South Carolina streams

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Overview

Abstract

The web-based South Carolina Stream Conservation Planning tool enables a spatially explicit understanding of how human activities affect the biological condition of wadeable streams. A web mapping application allows users to visualize predicted biological conditions based on their status and severity across all South Carolina wadeable stream catchments. Additionally, an interactive catchment management tool allows users to explore and forecast the impacts of customized land management scenarios on aquatic resource indicators at any user-specified location across South Carolina.

Objectives

1. Develop models using data collected during the South Carolina Stream Assessment to identify primary factors influencing ecological condition
2. Extrapolate models across state using National Fish Habitat Assessment data and create prediction maps of current biological condition statewide
3. Forecast biological response to alternative catchment management scenarios

Background

South Carolina Stream Assessment

The South Carolina Department of Natural Resources (SCDNR) in conjunction with Clemson University initiated a comprehensive assessment of South Carolina's wadeable streams in 2006 to determine the status of native fish assemblages and aquatic resources throughout the state. The assessment of nearly 500 wadeable streams was completed in 2011, with a collection of biological, chemical, physical, and landscape-level data necessary to support proactive decision making with respect to aquatic resources in the state (Figure 2). Sample locations were selected with a known probability using a multistage design from a list frame of all stream segments in the state, stratified by ecobasin and stream size. This site selection procedure insured independence among samples and allowed for statistically defensible estimates of statewide aquatic resource parameters.

Figure 1. SC stream assessment data collection locations

Data

1. We create biological response variables using SC Stream Assessment Data. These response variables are designed to reflect biological/aquatic health, and respond to anthropogenic stressors.
2. We associate our biological response variables with NHDPlus and National Fish Habitat Assessment (NFHA) spatial predictor data (USEPA and USGS 2005, Wang et al. 2011)

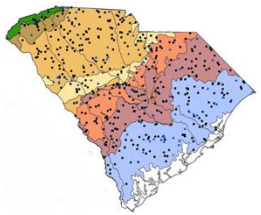


Figure 2. SC Stream Assessment Data Collection Locations

Modeling Methods

We used Random Forests with the R statistical software to:

1) Determine the most important spatial predictor variables that influence our biological response variables (Figure 3). Each predictor variable has a known functional response relationship with the biological outcome (Figure 4).

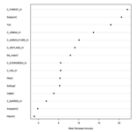


Figure 3. Variable Importance Plot

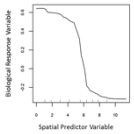


Figure 4. Partial Dependence Plot

1) Model extrapolation to map current biological condition across state (Figure

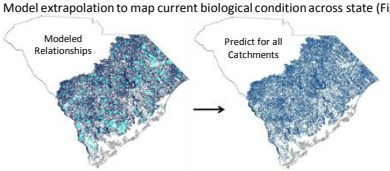


Figure 5. Observed and predicted biological condition

3) We can forecast the biological impacts of anthropogenic alteration to any given catchment, and its downstream network (Figure 6)

Figure 6. Downstream prediction based on anthropogenic alteration

Software Methods

Software Components

Figure 7. Software Components

Utilizes client- and server-side components (Figure 7). Dynamic 'R' prediction occurs on the server utilizing task parallelism. This allows simultaneous computation of predictions to occur.

Client-side components use HTML5 and Javascript, run entirely in web browser.

Downstream Calculation

Two variable spatial scales:

- 'LOCAL' is a summary of the immediate catchment.
- 'CATCHMENT' is a summary of the catchment watershed.

A 'CATCHMENT' variables requires that values are dynamically recalculated from upstream 'LOCAL' modifications. These changes are propagated downstream.

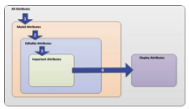
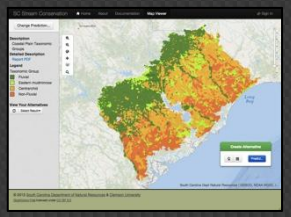


Figure 8. Attribute Display

Conservation Tool Development

Predicted biological condition maps

Map Viewer displays "static" predictions for South Carolina catchments based on extrapolations from random forest models. Each published predictive model includes a detailed report describing response variable construction, random forest model results, model performance, and error metrics.

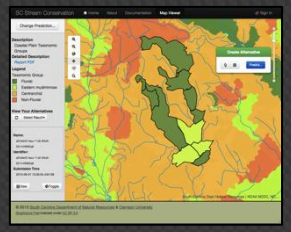


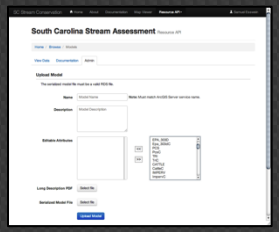
Catchment modification

- Users can select catchments that drain an area of less then 150 sq km (wadeable).
- Anthropogenic variables that influence the model outcome are displayed.
- Users adjust these parameters using a sliding scale.
- Multiple catchments may be modified.

Alternative management scenarios and downstream analysis

- The software recalculates attribute values for each selected catchment and conducts a downstream analysis (until 150sq km drainage limit is met).
- All catchments impacted by modifications are returned to the user and displayed in the map.
- Users have access to prediction results for 24 hours and may export results in csv, or JSON formats.





Web based data management

- Upload prediction datasets.
- Upload predictive models
  - Set the attributes the user can modify (typically anthropogenic)
  - Enter detailed model report as PDF
  - Upload a n R serialized model using the native 'RDS' format.

Public Deployment in August 2013
http://www.dnr.sc.gov

Discussion

Data-driven Stream Conservation

- The Southeastern U.S. has suffered long-term declines in native aquatic species, primarily resulting from stream habitat alterations related to human landscape alterations
- Proper data collection and statistical analyses can drive science-based conservation recommendations, guiding landscape decision-making activities down a sustainable path
- Website and tools publically available to decision-makers at all levels
- Potential uses include: municipal and county governments land planning and permitting; state agency permitting, land acquisition and management activities; federal agency land and resource management; non-governmental organizations with land management and/or advocacy responsibilities

Dynamic Prediction & Performance

- Round trip for prediction is ~1s.
- Predictions are isolated into worker tasks and can execute concurrently.
- The backend repository uses the Redis data structure store. The repository is accessed via a resource application programming interface (API) that follows the REST software architecture recommendations.
- The retrieval of catchment data occurs in constant time O(1). This allows the coverage area to expand to larger geographic areas with minimal performance penalty.

Future Work

- Continued expansion of biological response variables
- Support additional prediction datasets
- Software available for integration by additional universities, state and federal agencies

Acknowledgements

This work was supported by grants from the US Fish & Wildlife Service (F12AF01417) and matching funds from South Carolina Department of Natural Resources (SCDNR). SC Stream Assessment data collection performed by: Kevin kubach, Troy Cribb, William Poly, Andrew Gelder, Jeremy Pike, Alan Jones, Andrew Sayer, Molly Keaton, Jace Johnston, Annemarieke DeVlamming, Seth Mycko, Cory Guinn, Greg Satterfield, and Brandon Seda. Computing support provided by SCDNR IT/GIS and David White with Clemson Computing and Information Technology.

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