Modeling Hydrologic Alteration and Ecosystem Response to Climate Change in the Southeastern U.S.

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Southeast Regional Assessment Project

SERAP is a pilot study for the USGS NCCWSC and CSC that integrates climate change, land-use change, and sea-level rise projections with habitat and species response models to assess future climate effects on terrestrial and aquatic species

- Regional Climate Change Projections
- Coastal Assessment
- Terrestrial Assessment
- Aquatic Assessment
- Optimal Conservation Strategies
Project Team Members

Regionally Downscaled Probabilistic Climate Change Projections—Adam Terando, Murali Haran, Katharine Hayhoe, Klaus Keller

Integrated Coastal Assessment—Nathaniel Plant, Glenn Gutenspergen, Van Wilson, Cindy Thatcher, Alexa McKerrow, Adam Terando, Scott Wilson, Rob Thieler, Peter Howd

Integrated Terrestrial Assessment—Alexa McKerrow, Adam Terando, Steve Williams, Jamie Callazo, Barry Grand, Jim Nichols, Andrew Royle, John Sauer

Integrated Aquatic Assessment—Jim Peterson, Lauren Hay, Kenneth Odom, Brian Hughes, Robb Jacobson, John Jones, Mary Freeman, Jacob LaFontaine, Carrie Elliot, Steve Markstrom, Jeff Riley

Optimal Conservation Strategies—Barry Grand, Max Post van der Burg, Kevin Kliner, Allison Moody,

Dissemination of High-Resolution National Climate Change Dataset—Jamie Collazo, Lauren Hay, Katharine Hayhoe, Nathaniel Booth, Adam Terando, Jason Hopkins, Roland Viger
Basic Questions Addressed by SERAP

What effects will climate changes have on terrestrial and aquatic ecosystems?

- What are the likely impacts of future sea level rise on coastal habitats?
- How will stream flow changes alter habitat conditions necessary for healthy fish and mussel populations?
- Will changes in vegetation and land use affect terrestrial habitats for bird populations?

What can we do to avoid the worst effects of climate change?

- What are the causes and degree of uncertainty in forecasts of climate change and responses?
- What are the benefits and effectiveness of adaptation strategies?
Probabilistic Global Climate Change Projections
Intermediate Complexity Model Projections
Statistically Downscaled Climate Projections
Simulation of Climate Dynamic Processes
Probabilistic Global Climate Change Projections
Intermediate Complexity Model Projections
Statistically Downscaled Climate Projections
Simulation of Physical, Social, and Economics Dynamic Processes
Landscape Dynamics
Channel Classification
Stream Temperature
Watershed Modeling
Sea-Level Rise Projections
Urban Growth
Coastal Habitat Change
Species-Habitat Relations
Succession-Disturbance Models
Future Habitat Conditions
Simulation of Ecological Dynamic Processes
Fish and Mussel Occupancy Models
Avian Range Dynamics
Develop Climate Change Adaptation Strategies
Optimal Conservation Strategies
Probabilistic Global Climate Change Projections

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Simulation of Climate Dynamic Processes

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Urban Growth

Intermediate Complexity Model Projections

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Simulation of Physical, Social, and Economics Dynamic Processes

Sea-Level Rise Projections

Succession-Disturbance Models

Future Habitat Conditions

Simulation of Ecological Dynamic Processes

Coastal Habitat Change

Species-Habitat Relations

Vegetation Dynamics

Fish and Mussel Occupancy Models

Avian Range Dynamics

Optimal Conservation Strategies

Develop Climate Change Adaptation Strategies

Landscape Dynamics

Channel Classification

Stream Temperature

Watershed Modeling

SERAP COMPONENTS DATA FLOW
Climate Scenarios Simulated

Currently using only two emission scenarios representing worst case and best case scenarios.
Regional Climate Downscaling

Present
Regional Climate Change Projections
Climate Models

Projections
- GCMs (n = ~8)
- EMIC (n = ~200)

Methods
- Bayesian Model Averaging
- Statistical Downscaling

Output
- Downscaled Probabilistic Projections
Four-cluster multivariate channel classification of the Potato Creek stream network using LiDAR for validation.
Landscape Dynamics - Urban Growth

- Slope,
- Land Cover,
- Exclusion,
- Urbanization,
- Transportation, and
- Hillshade

Urban Growth Model Gigalopolis
SLEUTH-R (Jantz et al 2009)
Landscape Dynamics - Vegetation

Example: Dry longleaf pine

Habitat-specific succession and disturbance models

Future landscape conditions
Input for habitat distribution models: priority species
Landscape Dynamics – Disturbance

Temperature → Evapotranspiration

Precipitation

Evapotranspiration ← Drought

Drought

Fire Frequency → Disease

Insect Outbreak
Hydrologic Modeling - PRMS

- PRMS is being used to develop coarse- and fine-scale watershed models.
- Both coarse and fine scale models will incorporate probabilistic downscaled climate change projections to predict daily streamflow through 2100.
Simulating Water Quality – PRMS/SNTEMP

- Stream temperature is being simulated using a coupled PRMS/SNTemp model
- SNTemp developed by USFWS and USGS to predict how changes in flow regime affect water temperature
- Uses PRMS output parameters and physical channel characteristics
- Daily minimum and maximum temperatures through 2100 will be predicted
Coupled PRMS/SNTEMP

- Climate (station data)
- Watershed Attributes
- Daily Components of Flow, by stream segment
- Daily Air Temperature, solar radiation, by stream segment
- Channel Attributes
- Mean and Max Daily Water Temperature, by stream segment
- PRMS
- PRMS/SNTemp
- SNTemp

Input Files:
- Meteorology
- Hydrology
- Shade
- Topology
- Geometry

Key:
- PRMS/SNTemp
- Models
- User Input
- Simulated
- Output
Ecological Modeling - Fish and mussel occupancy

- Empirical multi-state, multi-season occupancy model.
- Models estimate the occupancy (presence) of fish species in a stream segment (defined as a section of stream from tributary junction to tributary junction).
- The dynamics of the populations (colonization, reproduction, extinction) are modeled as a function of geomorphic channel characteristics, stream size, seasonal discharge statistic, and stream temperature.
- Specific species characteristics (preferred habitat, locomotion mode, body size, spawning duration, etc.) are used in models.
Integrated Aquatics Assessment
Modeling Fish Occupancy

Composite estimates
Fish species richness 2004 (post-drought)

Number of species
- < 10
- >10 - 15
- >15 - 20
- >20 - 25
- >25
Integrated Terrestrial Assessment
Habitat models for priority species

- Vegetation Dynamics
- GAP Terrestrial Vertebrate Models
- Urban Growth
- Habitat Availability through Time
- Optimal Conservation Strategies

Cerulean Warbler
*Dendroica cerulea*

Maps showing suitable habitat in 2001 and 2100.
Questions?

• What kinds of water quality parameters can be predicted under future climate scenarios with any certainty?

• Which of these are the most relevant for ecosystem and human health?
SNTEMP

• Developed by USFWS and USGS to predict how changes in flow regime affect water temperatures
• Uses output parameters from PRMS and physical channel characteristics
Climate Adaptation Strategies
Final Products

• Spatially explicit decision support tool to allow management agencies to prioritize conservation actions based on a range of predicted future habitat conditions, including:
  – Portfolio of best conservation actions
  – Locations of sites with greatest marginal gain
  – Incorporates land-use projections, climate change projections, and vegetation succession
Coastal processes such as sea level rise, subsidence, and erosion will be modeled to support coastal resource management

- Develop Bayesian statistical framework for predicting coastal erosion and inundation
- Assess affects of sea level rise on coastal ecosystems and wildlife
- Direct observations
- Develop visualization tools for resource managers

**Integrated Coastal Assessment**

**Coastal Assessment**

**Climate Change & Sea Level Rise**

**Groundwater Impact**

**Wetland Loss**

**Coastal Erosion**

**Inundation**

**Habitat Loss**

**Safety**

**Physical & Biological Processes**

**Initial Conditions**

**Driving Forces**

**Potential Impacts**

**Management Decisions**

**Adaptation Planning Response**
Integrated Coastal Assessment
Modeling Habitat Loss

Developed 606 terrestrial vertebrate species models for the Southeastern U.S.

Relationships

- Shoreline Erosion
- Inundation
- Gap Terrestrial Vertebrate Distributions
- Potential Habitat Loss Due to Sea Level Rise

Products

Maps and summaries potential habitat loss by species under a variety of SLR projections.
Integrated Coastal Assessment
Sea Level Rise Viewer

- Developing Google™ Thematic Mapper based map view that depicts inundation as sea level rises
- User friendly environment for resource managers and public to visualize impacts of sea-level rise
- Interactive map displays elevations of 1, 3, and 6 feet above Mean Higher High Water datum
Integrated Terrestrial Assessment
Linking landscape, climate, and urbanization models

A decision making process that accounts for the uncertainty associated with predicting environmental dynamics and population responses, and the uncertainty associated with conservation policies and whether they will be effective.
Basic objective: Test hypotheses about avian range dynamics as function of climate change and other relevant factors.

Probabilities of local extinction and colonization predicted as function of:
- Climate change
- Land-use change
- Location within overall species range
- Neighbor effects (occupancy of nearby locations)

Ranges are likely to shift or contract and can be modeled by varying rates of extinction/colonization.
Integrated Terrestrial Assessment
Modeling occupancy dynamics

Loggerhead Shrike (
*Lanius ludovicianus*)

BBS data for 1996-2006

Probability of occurrence

% of occupied neighbors site

colonization

extinction
Determine optimal conservation strategies through:

- Implementation of Strategic Habitat Conservation using Adaptive Management
- Incorporation of potential effects of climate change on fish and wildlife population
- Development of strategy at an ecoregional scale.
Climate Adaptation Strategies
Simple model example

Compare among sites

Incorporate species value

Compare alternatives

\[ \text{Marginal gain} = \frac{\text{Management} - \text{No Management}}{\text{Cost}} \]
Questions?