'Planning and decision-making can be improved by access to reliable forecasts of ecosystem state, ecosystem services, and natural capital. Availability of new data sets, together with progress in computation and statistics, will increase our ability to forecast ecosystem change.'
• Diversity of Modeling Approaches
• Transition in this Sequence of Model Development;
• ‘Concept to Construction’
- Identify, confirm cause and effect relationships;
- Formulate and verify predictive models;
- Document assumptions of how the System Works;

**Tiered Solutions**

- Integrates scientific knowledge for decision-making;

**Verification of Experimental Results**

- Identify, confirm cause and effect relationships;
- Formulate and verify predictive models;
- Document assumptions of how the System Works;

**Tiered Solutions**

- Tier 1: Trend Analysis
  - Initial and boundary condition statistics
- Tier 2: Desktop Modeling
  - Land area, sediment volume, vegetation
- Tier 3: Detailed Process Modeling
  - Land & waterway shape and patterns
CLEAR Program

• Coordinate modeling efforts from variety of sources into an integrated analytical framework;
• Support a variety of modeling, data collection, and reporting needs in integrated network;
• Stimulate collaboration among variety of research groups with variety of modeling tools that will support research and restoration planning efforts;
• Network information needs - monitoring, modeling, and evaluation (grids, model formulation, verification)
Proposed CLEAR Development Group

- Conceptual Models
- CLEAR Development Group
- CPRA-IPT; LaCPRA; LCA; Science Community

- Standard Data Formats

- FVCOM Model Development
  - LSU-others

- POM-FVCOM Models
  - UNO-others

- H3D-River model
  - UL Lafayette-others

- Box models
  - Nuttle-LSU-others

- ADCIRC Models
  - LSU-UNO-others

- CLEAR Integrated Modeling Module
  - Desktop
  - GIS
  - Clusters

- CHL-ERDC-Hydro-WQ models

- Environmental Benefits

- Output Statistics

- Maps

- SWAMP Monitoring Module - DNR/USGS

- Uncertainty Assessment Module/ UL-LSU
Reducing Flood Damage in Coastal Louisiana: Communities, Culture & Commerce

Based on Conceptual Ecological Model Workshop
November 2005

Louisiana's national contribution (% of US total)
- 27% of crude oil
- 15% of natural gas
- 33% of commercial fisheries
- 21% of waterborne commerce

The Mississippi River is the largest and longest river in North America, and its drainage area includes over 1.3 million square miles.

The river provides drainage for 41% of the continental US, including all or part of 31 states and two Canadian provinces.

Of the world's rivers, the Mississippi River ranks third in length, second in watershed area and fifth in average discharge.

Hydrodynamic Module
Landscape Change Module
Habitat Switching Module
Water Quality Module
Habitat Use Module

Environmental Benefits
Maps & Output Statistics

Reporting

Integrated Spatial Framework

Conceptual Models
CLEAR Office (Coordinating & Reporting)
Program Management (Planning & Decision Support)

Adaptive Ecosystem Assessment and Management Strategy

Protection and restoration of coastal Louisiana is a national priority

Coastal Louisiana is home to the nation's largest port complex in both tonnage and infrastructure, and produces or transports nearly one-third of the nation's oil and gas supply. In addition, the coastal Louisiana ecosystem provides nationally-important fish and wildlife habitat that supports the nation's second-largest commercial fishery and over $1 billion per year in recreational fishing and hunting revenues. All of these activities are supported in Louisiana because of the close proximity of its skilled workforce to the Gulf of Mexico. Coastal land loss has placed these economic and natural resources at increased risk of loss due to the intense effects of waves and storm surges from hurricanes. Restoration of the coastal ecosystem can work synergistically with levees and floodgates to provide an integrated flood protection system that allows continued resource production and sustains the ecosystem services on which the nation relies.

Historical and projected land loss from coastal Louisiana:

Flood damage following Hurricanes Katrina and Rita.
CLEAR Framework: Coastal Ecosystem Forecasting System

- Conceptual Models
- CLEAR Office (Coordinating & Reporting)
- Program Management (Planning & Decision Support)

- Hydrodynamic Module
- Landscape Change Module
- Habitat Switching Module
- Water Quality Module
- Habitat Use Module

- Integrated Spatial Framework
  - Environmental Benefits
  - Reporting
  - Maps & Output Statistics

- Uncertainty Assessment
- Monitoring
- Risk / Storm Surge Module

Adaptive Ecosystem Assessment and Management Strategy
Integrated Ecosystem Restoration and Hurricane Protection:
Louisiana’s Comprehensive Master Plan for a Sustainable Coast

CPRA
Coastal Protection and Restoration Authority of Louisiana

Louisiana Speaks Regional Plan
Vision and Strategies for Recovery and Growth in South Louisiana
May 2007

http://www.lacpbra.org/
http://www.louisianaspeaks.org/
Modeling Options for the Future
The Louisiana Speaks Regional Planning process utilized computer modeling to test the effects of different land-use, transportation, storm protection, and restoration scenarios for a variety of safety, livability, and transportation indicators. A series of scenarios represent possible futures based on historic patterns, emerging trends, and different policy directions. The following diagram shows some of the key variables and technical models used to develop the scenarios and their modeled consequences. Please see Appendix B for more information on the modeling process.

Indicators
Indicators measure the impacts or consequences of an option. Examples include area of wetland gain or loss, mix of new housing types, commute times, open land developed, new development in floodplains, or the cost of building a new transportation system. The Louisiana Speaks Regional Plan utilized these indicators to compare future options, querying the preferences of Louisiana residents in the 2007 Regional Vision Poll. Louisiana Speaks Regional Plan options and trade-offs are described in further detail in this section.

Sample Indicators
- Open Land Developed
- New Development in Floodplain
- Commute Time
- Housing Mix
- Highway Congestion
- Transit Ridership
- Wetland Gain & Loss
- Annual Household Expenses
- Infrastructure Costs
- Automobile Emissions
- Housing Density
CLEAR Land Change Algorithm

<table>
<thead>
<tr>
<th>Current Models</th>
<th>Future Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driven by physical processes</td>
<td>Combine physical and biological processes</td>
</tr>
<tr>
<td>Calibrated with extent of land</td>
<td>Calibrated with extent of habitats</td>
</tr>
</tbody>
</table>

**Salinity Reduction**

**Distance from diversion**

**Nourishment Factor**

**Land Loss Rate**

**Land Creation**

**Cell Year 0**

**Cell Year 5**

- River Sediment Load
- % River Discharge Diverted
- Diverted Sediment
- Dredged Sediment
Projections of Landscape Change at Year 50 with restoration plan

CLEAR "No Increased Action" Total Wetland Area Projection Year 50

CLEAR "No Increased Action" Wetland Change Projection Year 0 - Year 50

CLEAR "Draft Master Plan" Total Wetland Area Projection Year 50

CLEAR "Draft Master Plan" Wetland Change Projection Year 0 - Year 50
Build a comprehensive data inventory for modeling groups

- GIS inventories/DEM;
- CLEAR modeling data in multiple scale resolution;
- Elevation data of landscape; GEOMETRY
- Model output for linked modular models;
Coastal Processes Modeled (physical, geomorphology, ecological) in 0.25 km² cells across coastal landscape.
CLEAR Framework: Coastal Ecosystem Forecasting System

- Conceptual Models
  - Hydrodynamic Module
  - Landscape Change Module
  - Habitat Switching Module
  - Water Quality Module
  - Habitat Use Module

- CLEAR Office (Coordinating & Reporting)

- Program Management (Planning & Decision Support)
  - Environmental Benefits
    - Reporting
    - Maps & Output Statistics
  - Uncertainty Assessment
  - Monitoring
  - Risk / Storm Surge Module

Adaptive Ecosystem Assessment and Management Strategy
Our research setting is unique in that we can manipulate the duration and magnitude of water pulses at the landscape scale in two of the coastal basins (Breton Sound and Barataria Basin), and examine biogeochemical and ecological patterns over broad biological, temporal and spatial scales.

We will develop and apply a series of linked simulation models that will allow tracking the effects of pulsed freshwater inputs through hydrodynamics, biogeochemical cycling, primary production, zooplankton dynamics, fish growth, and landscape dynamics.
MORPHODYNAMIC MODEL - WAX LAKE DELTA

From Gary Parker, University of Illinois

PROJECTION FOR WAX LAKE DELTA FRONT TO 2081
Marsh Habitat

Spatially-Explicit Design and Analysis for Simulating Individual-Level Processes within a Tidal Marsh Community

LINK WITH ECOSIM (Carl Walters)

S.E. Sable and K. A. Rose
Department of Oceanography and Coastal Sciences
Louisiana State University
Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Research Facility: Ecosystem Forecasting System Using Barataria Basin as Test Domain

**Task 3.5: Box Model/ Water Quality Development**

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2 - Department of Oceanography and Coastal Sciences, LSU
3 – Consultant
4 - Wetland Biogeochemistry Institute, LSU
Physical and Numerical Modeling of River and Sediment Diversions in the Lower Mississippi River Delta
LSU, Department of Civil & Environmental Engineering
PI: Clinton S. Willson, Ph.D., P.E.

Vincent A. Forte Coastal and River Engineering Research Laboratory
Physical and Numerical Modeling - complimentary tools

Pointe-a-la-Hache

Empire (hypothetical diversion)
Uncertainty Analysis of the CLEAR Model

- **Uncertainty**: Knowledge Uncertainty, Inherent Uncertainty, Decision Uncertainty
  - Knowledge Uncertainty: Understanding Processes, Model Structure, Parameters, Data
  - Inherent Uncertainty: Spatial Variability, Temporal Variability (Not reducible)
  - Decision Uncertainty: Objectives, Evaluation Criteria, Performance Measures (values and targets)

Monte Carlo - Uncertainty Analysis:
- Input Distributions: Normal, Triangular, Uniform, Lognormal
- Feedback on the input distribution
- Generate a set of random inputs
- Variance decomposition
- Output Distributions
- Feedback on model structure
- Iteration > 100 times

- Select a Set of “True” Parameters
- Generate “True” Salinity Observations
- Introduce Single or Combined Uncertainty Source
- Apply SCEM-UA algorithm to estimate optimal parameters and their posterior probabilistic distribution
- Evaluate impact on: Parameter Retrieval, Prediction Uncertainty

Sources:
- Bencic et al. 2003
- Lopus et al. 2003
- LCA draft report, Chapter 13
Effect of rainfall spatial variability and sampling on salinity prediction in an estuarine system

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KEYWORDS

Salinity modeling; Rainfall sampling; Spatial variability; Uncertainty; NERRD; Estuary; Louisiana

Summary

Reliable and accurate forecasts of salinity changes are essential for the success of current and future management scenarios aimed at restoring and sustaining natural resources of coastal and estuarine ecosystems. Because of the physical complexity of such ecosystems, information on uncertainty associated with salinity forecasts should be incorporated into management and restoration decisions. This study focuses on the impact of spatial variability and limited sampling of rainfall on salinity prediction in an estuarine system. The analysis is conducted on the Barataria basin, which is a wetland-dominated estuarine system located directly west of the Mississippi Delta complex on the United States coast of south Louisiana. The basin has been experiencing significant losses of wetland at a rate of nearly 32 km²/year. Rainfall-runoff data with high spatial resolution are used to simulate various scenarios of hypothetical rainfall sampling densities over the basin. A mass balance-hydrologic salinity model is used to assess the effects of reduced rainfall sampling on salinity prediction in the basin. The results indicated that, due to the critical role played by rainfall in determining the overall balance of the basin freshwater budget, a high degree of uncertainty exists in salinity predictions when using typical average rainfall gauge densities (e.g., 1 gauge/100 km²). These uncertainties decline sharply as the number of available gauges is increased beyond the typically available density. Uncertainties in salinity predictions in the Barataria basin are larger in inland locations and smaller near the mouth of the basin, where salinity conditions in the coastal waters of the Gulf of Mexico exert a large influence. Rainfall-uncertainty also affects parameter estimation during model calibration, where the estimation of some parameters

INTRODUCTION

Ecological forecasting models play a central role in restoring and sustaining natural resources of estuaries and coastal waters. Ecological forecasting provides quantitative data that managers need to evaluate risks and benefits anticipated from different ecological trajectories and their associated management scenarios (Stern, 2003; Ford, 2003). Risk and benefit calculations might be based on ecological performance measures (Stern, 2003) or, as is likely in the wake of hurricanes Katrina and Rita, they might be based on simulating future losses from coastal flooding (Ford, 2003). In any case, managers need information on the uncertainty in the forecasts so that they can judge whether the risks and benefits presented by one trajectory differ significantly from those of another trajectory. The underlying question is whether different approaches to restoring coastal resources will have significantly different results. Uncertainty that arises in making ecological forecasts.

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Hurricanes on the Grid

- **SCOOP: SURA (NOAA/ONR)** project to automate & collect together different operational data sources and models around the SE
- **Partners:** LSU, GoMOOS, Texas A&M, UaH, UNC/MCNC, U. Florida, U. Miami, VIMS
- Grid data archive and portal at CCT provides wind, surge, wave etc data.
- Automating operational ensembles of models on the **SCOOP Grid** providing GIS images and verification services.
Data Driven Modeling

- **DynaCode**: New NSF project to develop “dynamic data driven” infrastructure for coastal and environmental modeling
- Partners: Center for Computation & Technology, LSU Hurricane Center, Coastal Studies Institute LSU, University of Notre Dame
- Coupling coastal models with realtime sensor data
- Adapting algorithms to current conditions.
- Incorporating new Grid capabilities e.g. notification, workflow, steering.
- CCT technologies: Grid Application Toolkit, Cactus Code, Triana, GridSphere Portal.
CLEAR Framework: Coastal Ecosystem Forecasting System

Model Calibrations/ Verification (QA/QC)
Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Program

CLEAR Program
Ecosystem Forecasting
   Systems:
   1) Conceptual Models
   2) Numerical Models
   3) Observation Systems
   4) Data Management Systems
Performance - Connectivity - Provide dialogue among modelers, monitoring, science, and agencies

Funding
   DNR
   CREST
   NSF

Models
   CELS
   H3D
   POM
   TABS
   CLEAR

Science Modules
   Benefits
   Water Quality
   Habitat Use
   Land Building
   Hydrodynamics

Monitoring/Data
   DEO
   USGS
   GOOS
   WAVCIS
   CRMS
Coastal Louisiana Ecosystem Assessment & Restoration (CLEAR) Program

www.clear.lsu.edu