Ecological Forecasting Tools and Planning of Ecosystem Restoration Projects

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Outline

- Forecasting in planning
- Model Selection
- Classification of tools
- Use of tools for forecasting
- General conclusions

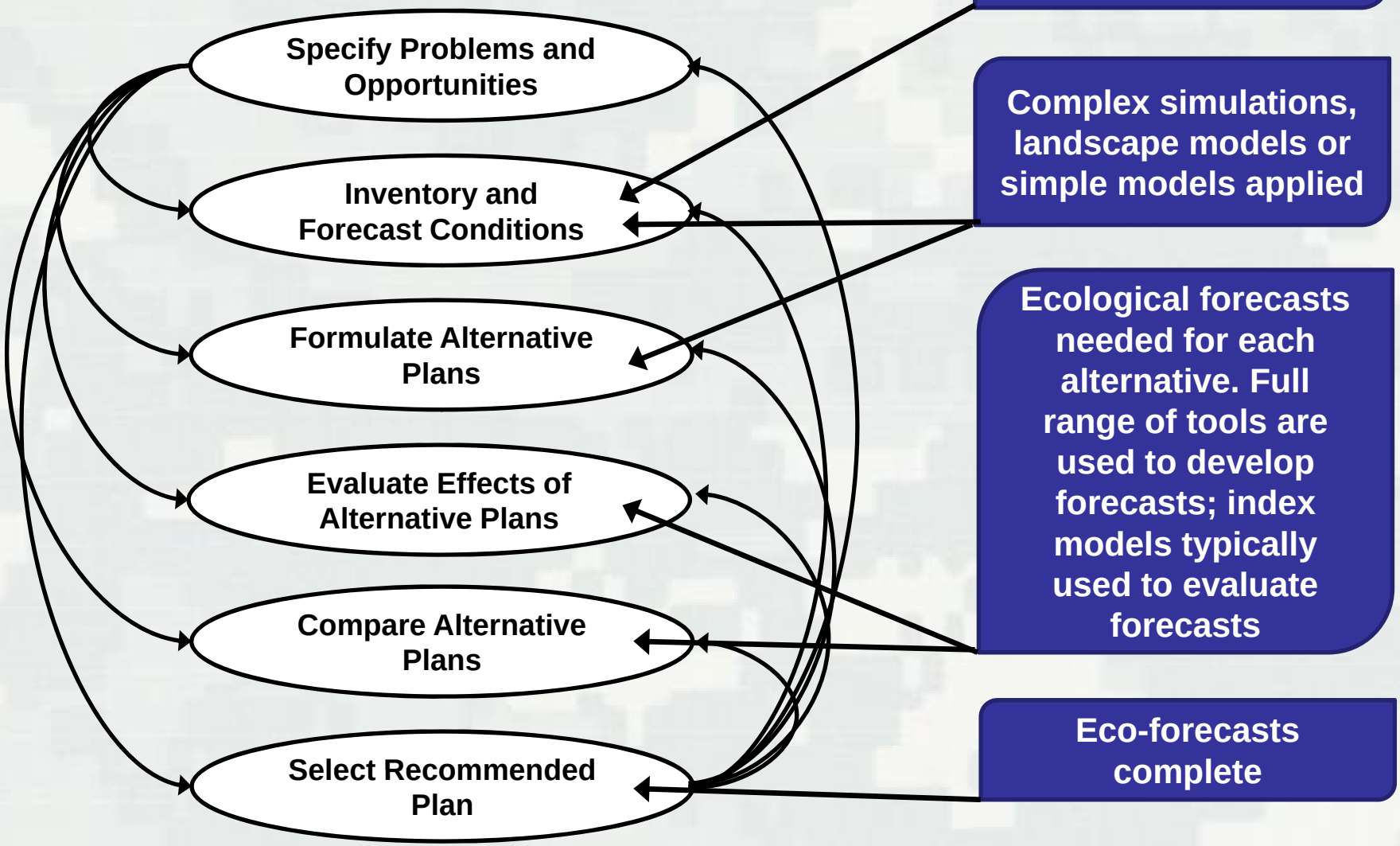
Objectives

- Overview of model types, selection, evaluation
- Outline an approach for the classification of models in the context of forecasting ecological outcomes
- Develop a clearer perspective of the forecasting needs of planners for ERDC researchers

Ecosystem Restoration

Galilee Salt Marsh constructed by New England District
- finished in 1997
-1999 Coastal America Partnership Award

USACE PLANNING PROCESS



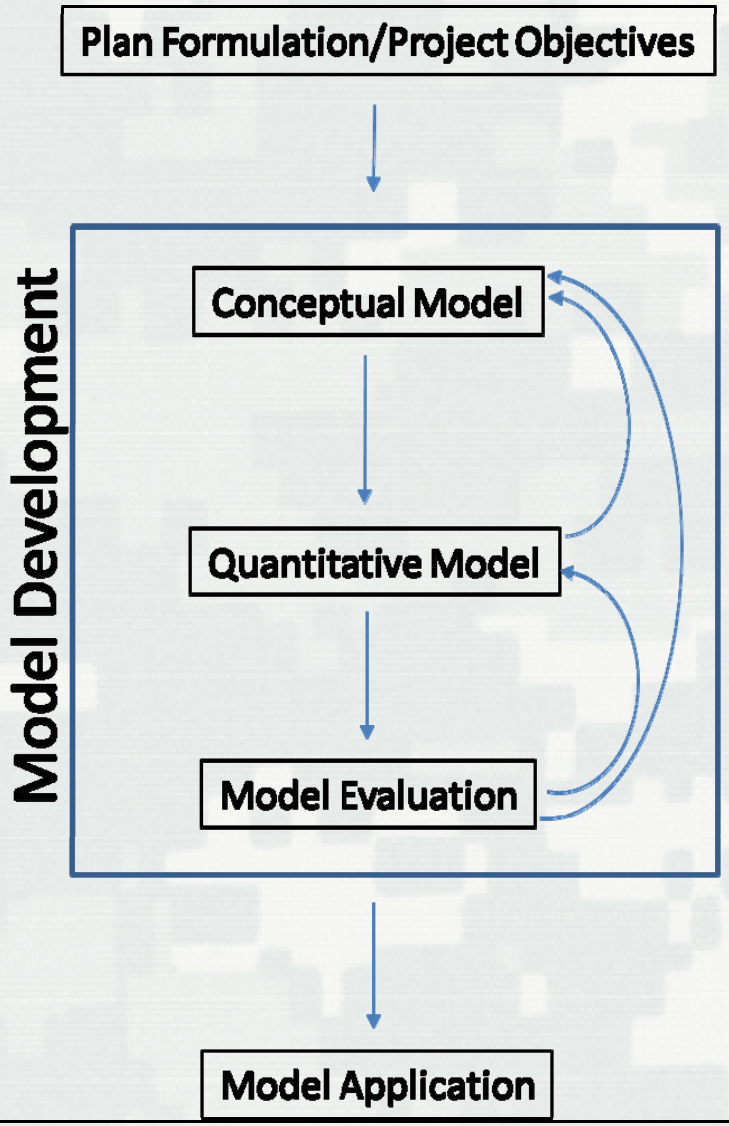
Model Selection

- Choosing appropriate tool
  - ▶ Nature of the problem
  - ▶ Understanding appropriate use of existing models
    - Assumptions and limitations of models
  - ▶ Does model capture essential system components as they apply to the specific project?

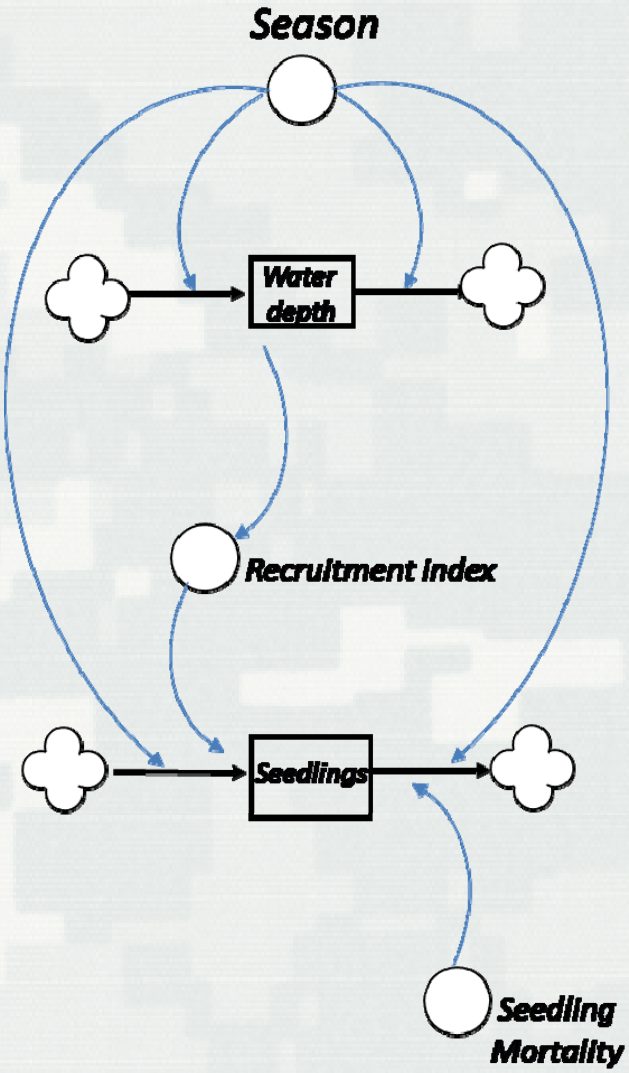
Model Types

Model	General Use	Example
Analytical	Systems where solution to closed form equations	Population growth, Lotka-Volterra models,
Conceptual	Diagramming relationships among components, organizing information, determining data needs	CEMCAT, see Fischenich, 2008, for more examples
Index	Determining habitat quality across a landscape,	HSI, HGM
Simulation	Modeling dynamics of complex systems	Agent-based models, ADH-CASM, ELAM, ICM,
Statistical	Analysis of datasets	ANOVA, goodness-of-fit, regression, t-test,
Spatial	Considers space explicitly	GIS, EDYS

Model Development



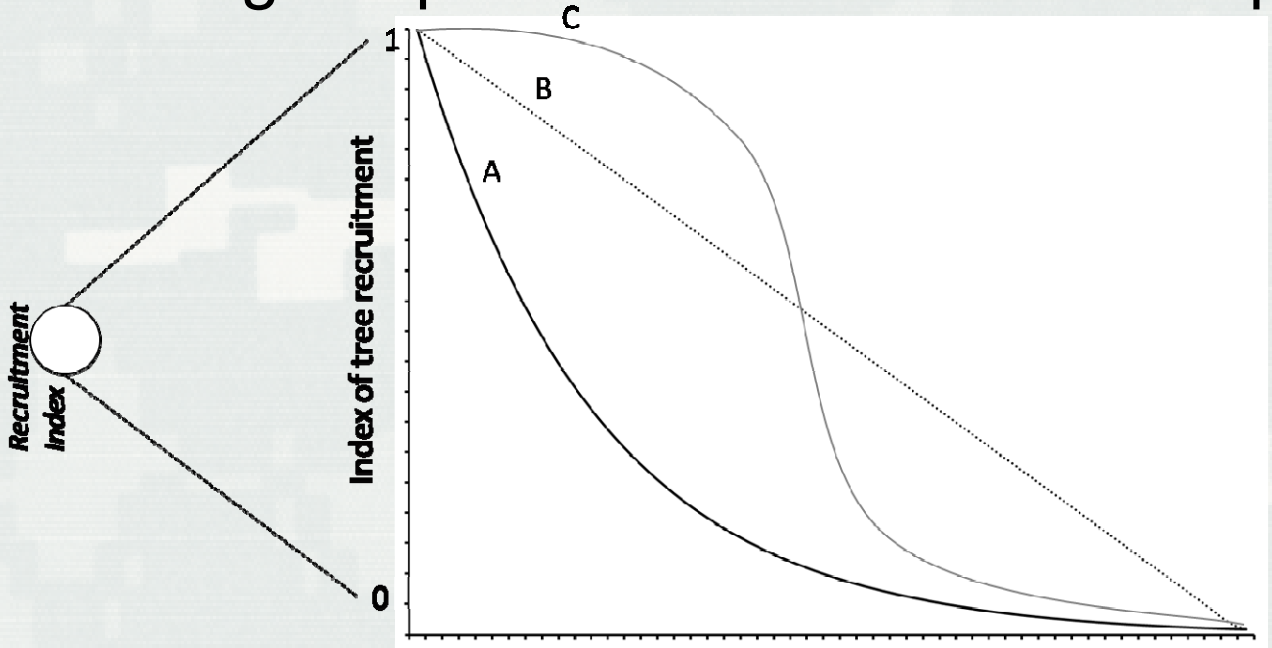
Conceptual Model



1. Precisely define objectives and criteria for evaluation
2. Bound the system-of-interest
3. Represent the conceptual model
4. Describe the expected patterns of model behavior
5. Identify data quality and quantity
6. Identify context for model use

Quantitative Model

1. Linking to the conceptual model
2. Selecting the general quantitative structure, time unit and spatial scale for the model
3. Identifying functional forms of model equations
4. Estimating the parameters of the model equations



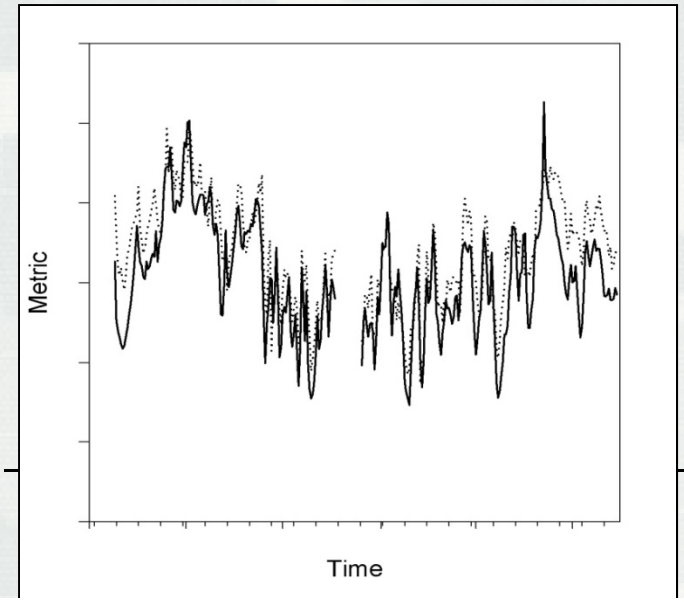
Forest Floodplain Example

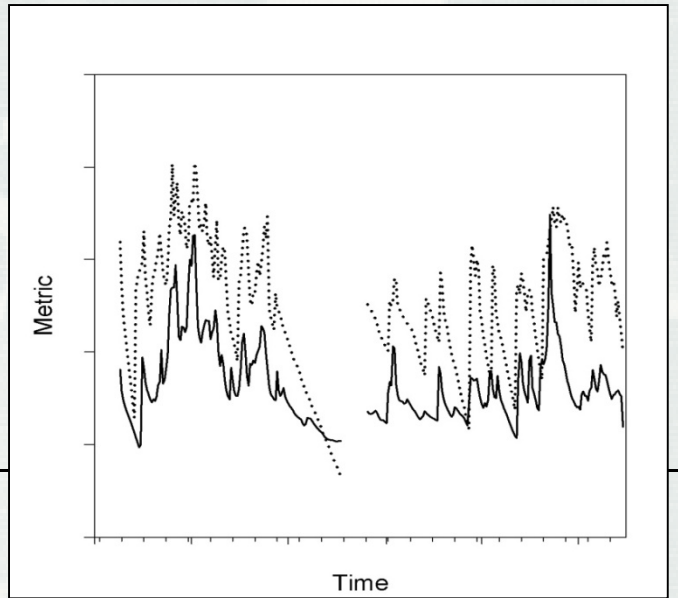
Model Evaluation

1. Evaluate correspondence between model results and expected patterns of model behavior (*model verification*)

2. Examine correspondence between model projections and data from real system (*model validation*)

3. Adjust empirical parameters to match a known behavior, expert opinion or reference site data (*model calibration*)





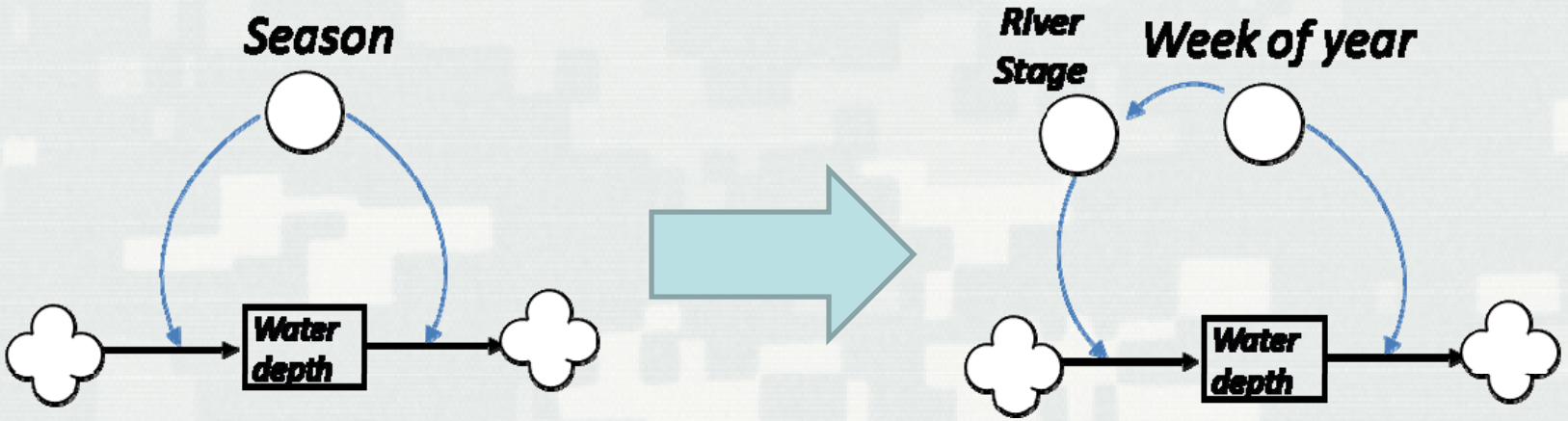
Model Evaluation con't.

5. Determine levels of uncertainty associated with model forecasts (Uncertainty analyses)

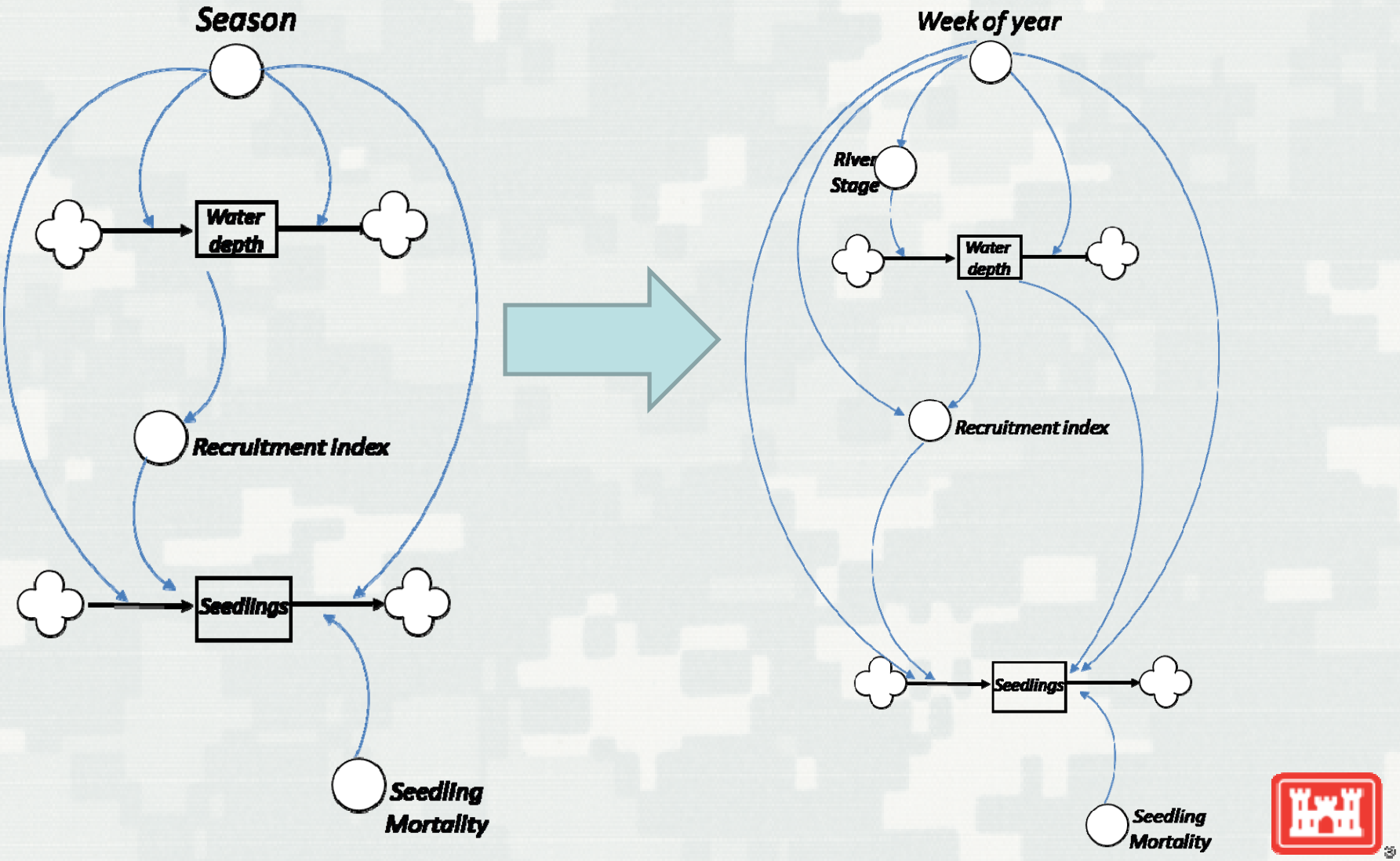
6. Identify data gaps and research needs that may not have been obvious during conceptual model development

Modeling in Practice

- Modeling is best done using an iterative approach, where you quantify and evaluate small sections of the larger model, the entire conceptual model is represented



Modeling in Practice con't.



In a Nutshell:

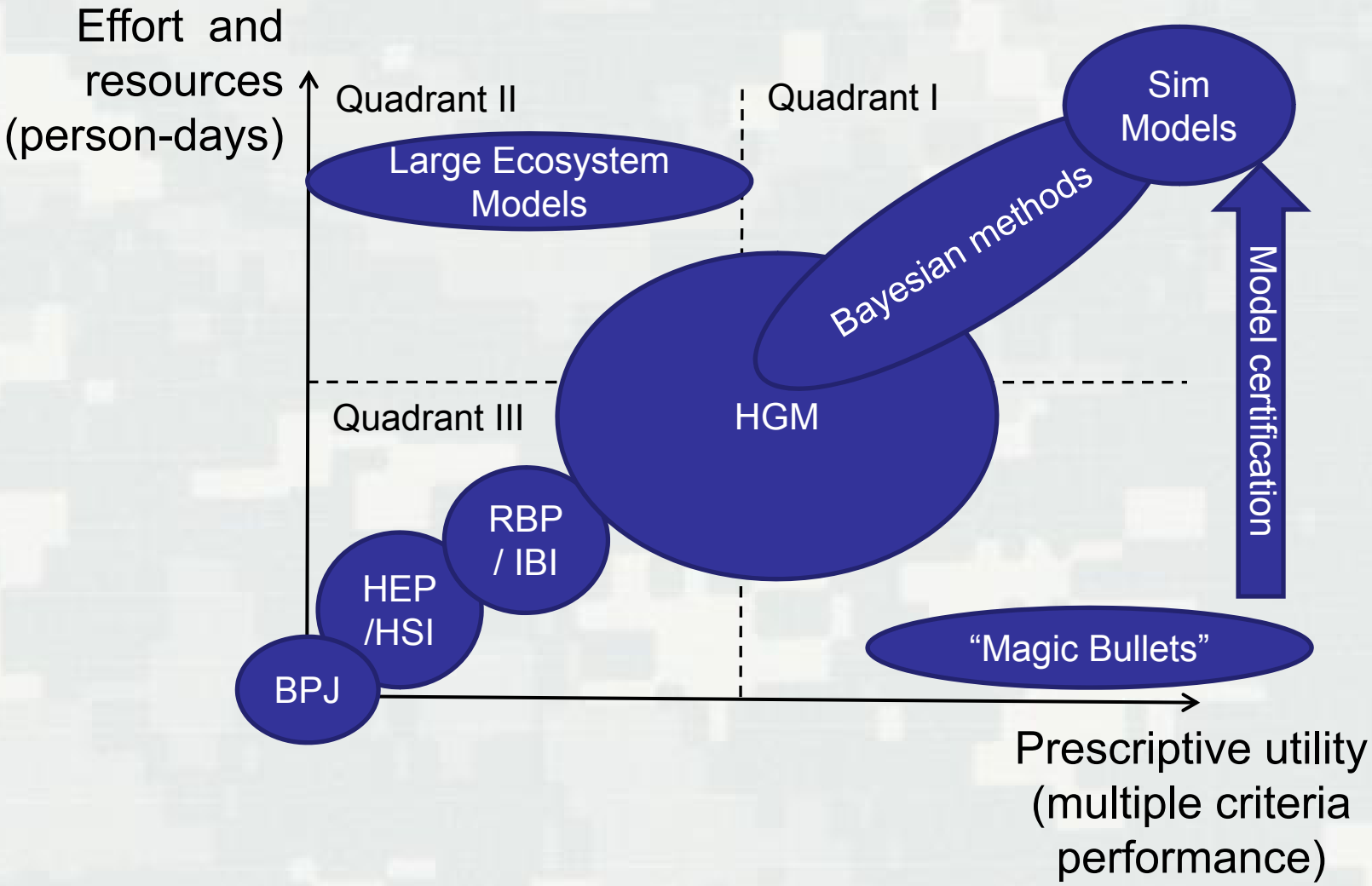
- Modeling efforts should begin by precisely indentifying objectives for the project with stakeholders. Once the objectives have been identified, a conceptual model should be developed and then used as the template for quantitative model development

- Modeling is a dynamic process and models are best developed through an iterative approach where a preliminary conceptual model is developed, then small sections of that conceptual model are quantified, evaluated and documented in a piecewise fashion until the system is represented quantitatively, which facilitates transparency and scientific defensibility

Classification of tools

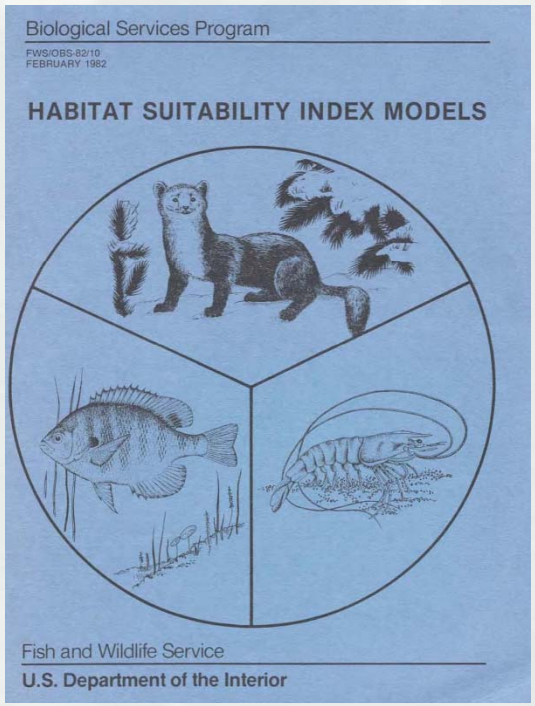
- Consider a comparison of tools based on the effort it takes to apply them (person-days to collect data and perform analyses) and the utility of the outcome.
- Prescriptive utility should encompass the relevance, uncertainty, accuracy and precision of the model output.
- The uses and limitations of different types models was examined.
- The classification should help identify the trade-offs in selection of a forecasting tool as well as the areas that need to be strengthened.

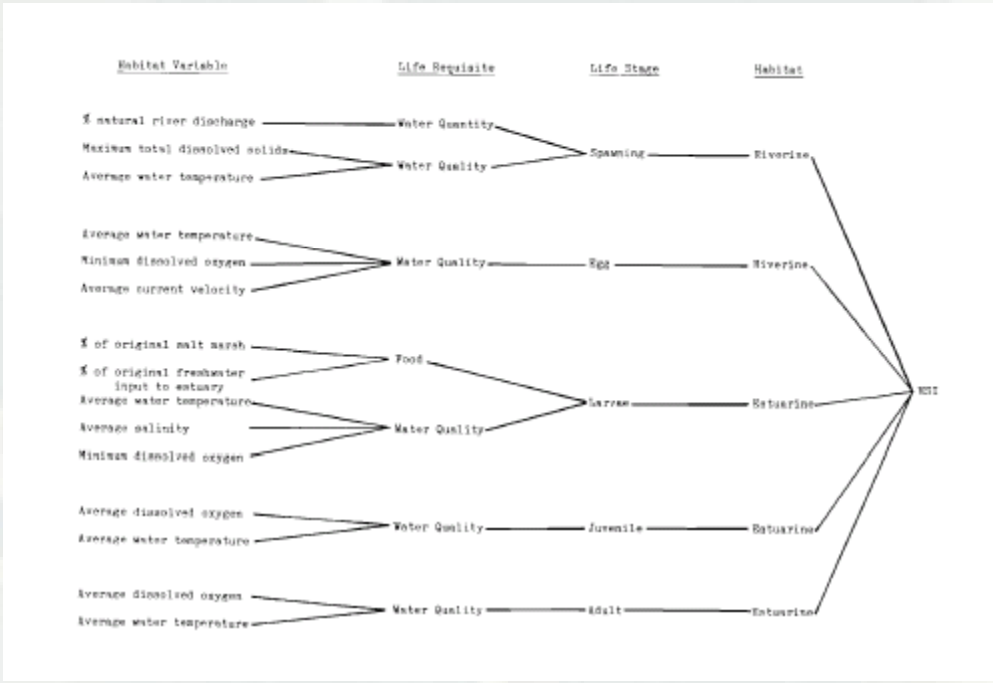
Classification of Tools



Example – simple tools

- Species of concern for a specific site – used of Habitat Suitability Index (HSI)





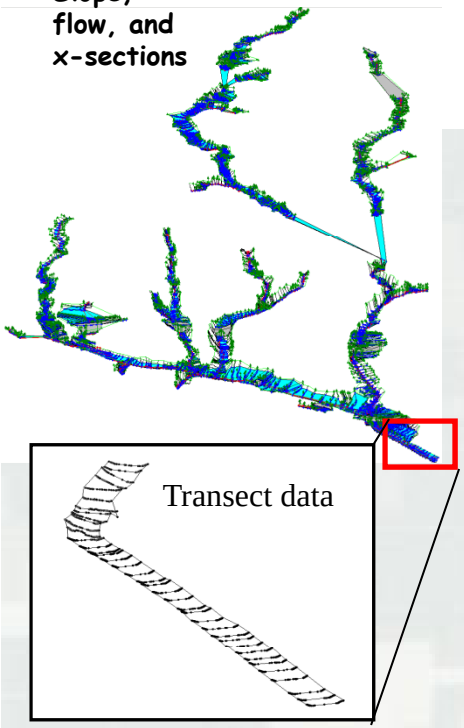
- VS next slide from Ecomodeling talk from SWWRP

SHAPE – Stream Habitat Analyses Package

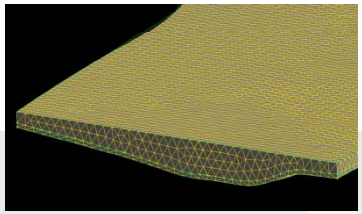
MultiD high fidelity ecological simulations from readily available data

Start with a HEC-RAS model

Slope, flow, and x-sections

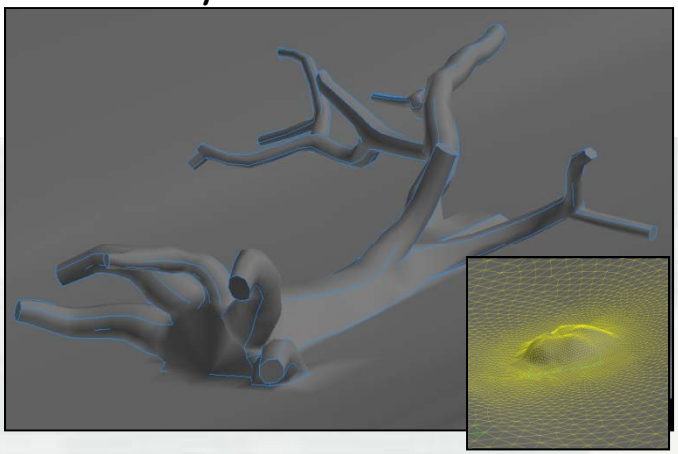


Develop MultiD environment



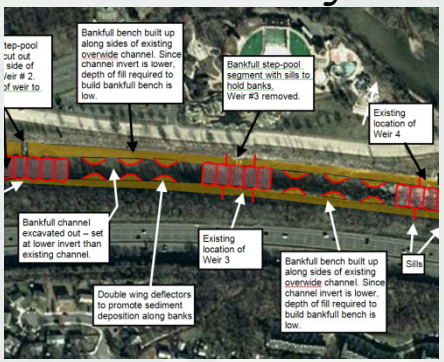
Model bathymetry between transects

Add important habitat features

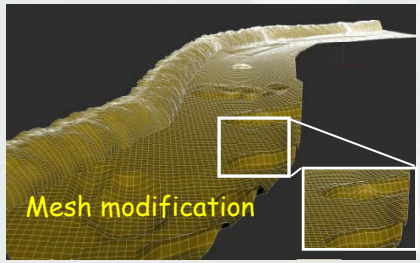


Consider desired future conditions

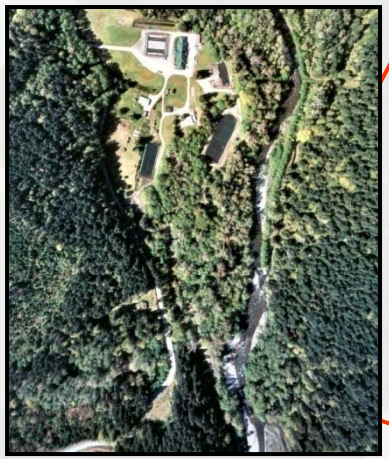
Alternative channel designs



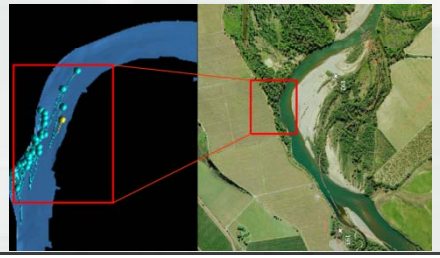
Meanders, bank protection, engineered log jams

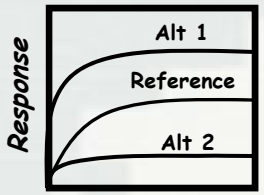


Supplement with aerial photos → ***Highlight important habitat features (LWD, etc)***



Analyze multiD simulation with risk-based biological model





Δ Flow, channel morphology etc

Large Ecosystem Models

Magic Bullets

"Magic bullets" are low-effort tools with high prescriptive utility. These tools, if they exist, are unlikely to be reliable.

Model Certification

"Use of certified models for all planning activities is mandatory. This policy is applicable to all planning models currently in use, models under development and new models."

ASSURING QUALITY OF PLANNING MODELS,
Circular No. 1105-2-412 , 31 March 2011

Name	Description	Uses	Major Limitations/ Comments	Outcome?[a]	Predict from range?	Needed current action?	Reference/ ERMIS Page
Best Professional Judgment (BPJ)	Advice of an expert with extensive experience in the field or region.	Predict outcomes, practicality, and potential obstacles	Bounded by limits of experience, skewed by background	Yes	Yes	N/A	
Habitat Suitability Index (HSI)	Evaluation of physical parameters to determine if conditions permit specific species to thrive in the area.	Determine potential of habitat conditions to support a specific species.	Non-dynamic, no prescriptive information.	No	Maybe	No	http://el.erdc.usace.army.mil/emrrp/emris/emrishelp3/list_of_habitat_suitability_index_hsi_models_pac.htm
Hydrogeomorphic Model (HGM)	Rapid assessment of "wetland functions, compute potential project impacts, calculate mitigation requirements, and project future … scenarios."	Assess wetland functions; assess project impacts or calculate wetland mitigation using probable index of function.	Needs detailed regional assessment - first - to allow easy, rapid further assessments.	Yes	Yes	No	http://el.erdc.usace.army.mil/emrrp/emris/emrishelp6/hydrogeomorphic_approach_tools.htm
Habitat Evaluation Procedure (HEP)	A spatial, temporal application of HSI descriptions. Integration of "suitability" over the aerial extent and time.	Designed to "quantitatively compare… alternative management practices."	Same as HSI.	No	Yes	No	http://www.fort.usgs.gov/Products/Software/HEP/
EPA Rapid Bioassessment Procedure (RBP)	"An evaluation of the condition of a waterbody using biological surveys and other direct measurements of the resident biota in surface waters."	Used to assess habitat impairment through biological measurements and surveys.	Require developed indices of biotic integrity (IBI); indices not conductive to identifying source of impairment.	No	Maybe	No	http://www.epa.gov/bioiweb1/html/rbps.html
Environmental Fluid Dynamics Code (EFDC)	Hydrodynamic model to simulate water quality constituent movement in 3D.	Movement of suspended sediments, contaminants, deposition, resuspension and transport.	Long term data needed for calibration and verification.	Yes	Yes	No	http://www.epa.gov/ATHENS/wwqtsc/html/efdc.html
Adaptive Hydraulics & Transport Model (ADH)	"Modular, parallel, adaptive finite-element model for one-, two-, and three-dimensional flow and transport."	Groundwater, overland flow, Navier-Stokes flow and shallow water.	Requires technical knowledge and significant data input	Yes	Yes	No	http://adh.usace.army.mil/
Landscape Model (ELM)	"Regional-scale, integrated ecological assessment tool designed to understand and predict the landscape response to different water management scenarios in south , "	Landscape responses to water and nutrient management scenarios.	Designed for specific region, limited data availability, intended for use as one of a set of management tools.	Yes	Yes	No	http://my.sfwmd.gov/elm
Bayesian methods	Probabilistic treatment of outcomes and linkages between models for quantitative predictions.	Specifies connectivity between models and probability of outcomes.	Used in conjunction with other methods, may compound the errors from those methods	Yes	N/A	Yes	

[a] Does the application estimate the probable outcome of actions?

[b] Does the application predict the outcome from a range of alternatives?

[c] Does the application estimate current actions needed for a future condition?

General Conclusions

We suggest a number of efforts which begin to bridge the gaps in forecasting needs:

-Transfer of techniques and analytical methodologies of forecasting as well as the potential lessons and limitations of the relevant research.

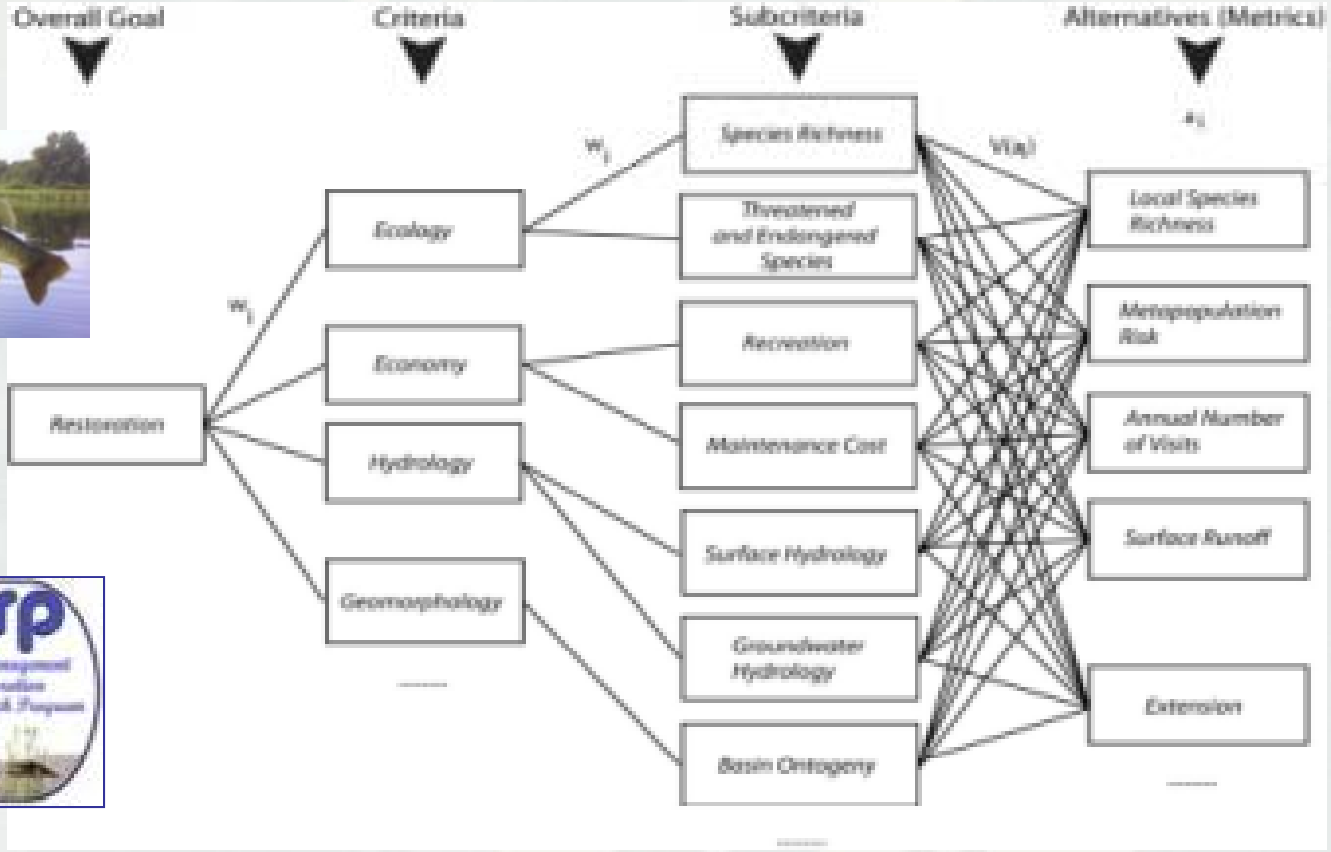
- Develop probabilistic, predictive tools with limited data requirements for common types of restoration projects.

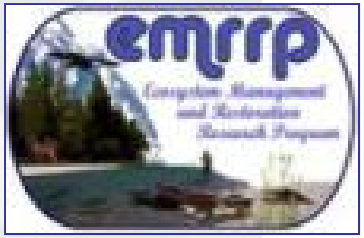
- A system of cumulative analysis or oversight – ideally including both communities – is necessary to evaluate the impact of multiple projects.

Consequences of Restoration

Restoration necessarily includes “with” and “without” project conditions. Use of forecasting models would provide quantitative outcomes for different actions. As well, measurement of the actual outcomes of restoration are an opportunity to refine forecasting models to predict the effects of a disturbance.

Environmental Benefits Analysis: Risk Management and Uncertainty in Ecosystem Restoration Projects; Development of Project Level Objectives and Metrics

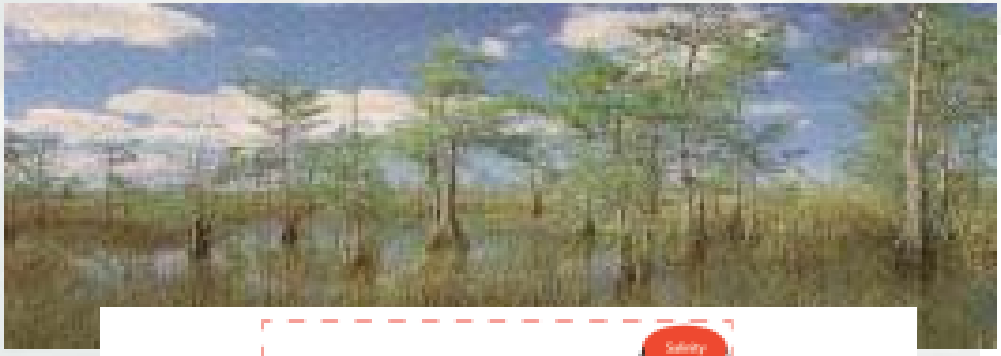


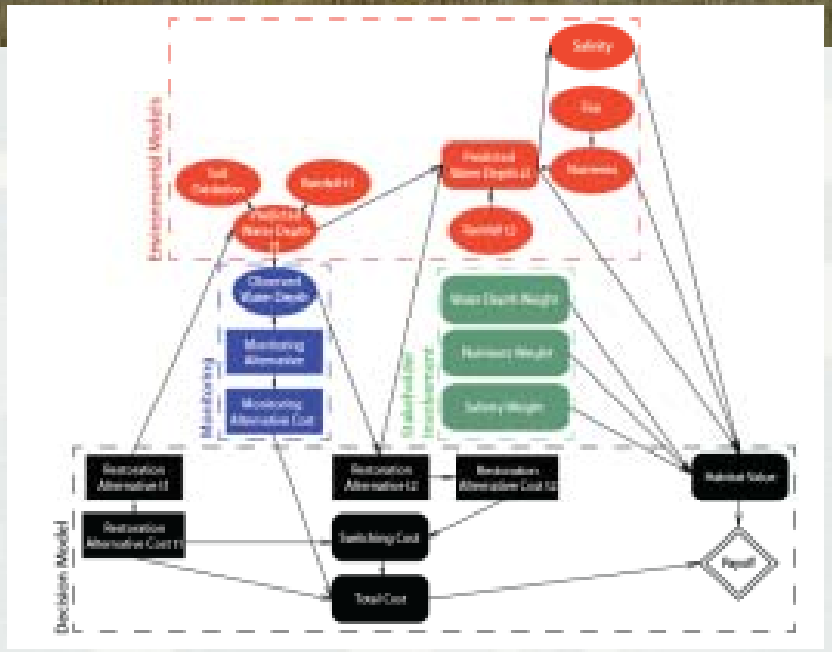


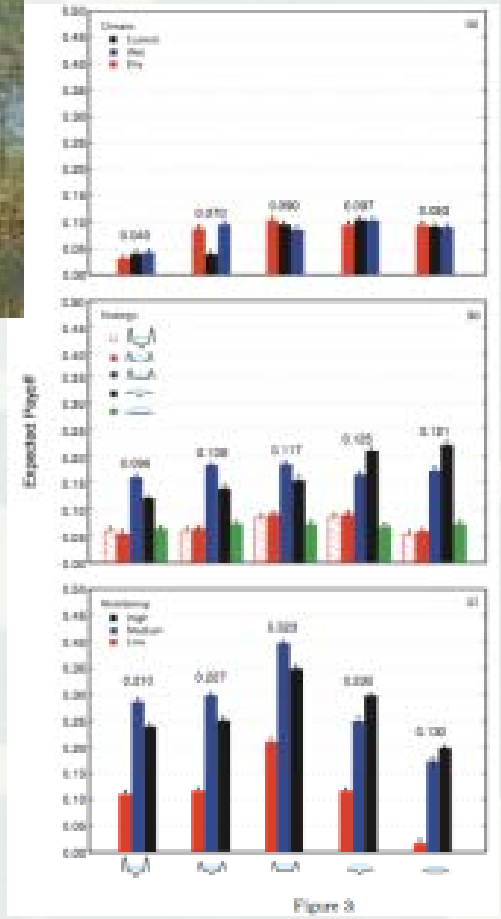
A suite of technical notes on risk and uncertainty in ecosystem restoration projects and the development of project level objectives and metrics in restoration planning. Research has been presented at several professional conferences, i.e. SETAC.

Adaptive Management for Everglades Restoration

An Enhanced Adaptive Management (EAM) approach that has in its core a decision model that provides managers a framework for selecting restoration alternatives.







Research needs

- The potential for existing models to be used to determine the uncertainty and probabilistic risk associated with the projected outcome.

- Inclusion of ecosystem services - versus species-specific habitat quality – as the goal of a restoration, and development of indices that define those same functional services.

-The outcomes of restorations in terms of the objectives and methods used need to be archived and shared.

- A system of cumulative analysis or oversight is necessary to evaluate the impact of multiple projects.

Discussion, Questions

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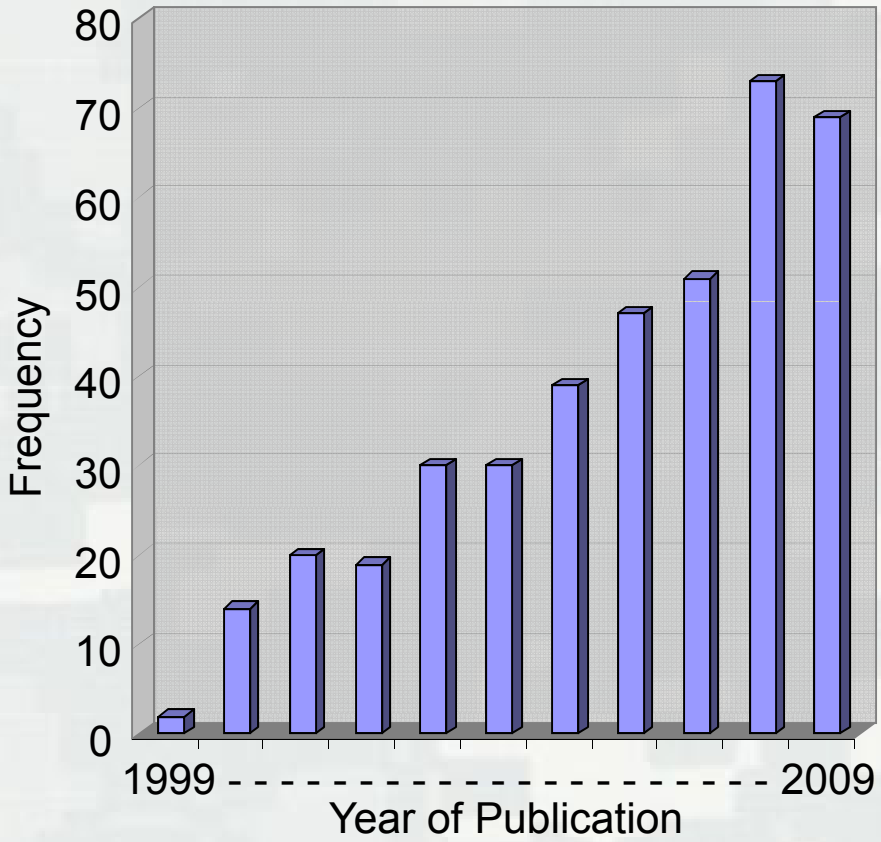
Forecasting Research



The frequency of published papers with “ecological forecast*” as a search topic in Web of Science, separated by year of publication. Projections for 2010 indicate nearly 100 papers were published that year.

In a nutshell:

•Ecological forecasting provides a series of methods to estimate the probability of future conditions.

•Environmental interventions, such as ecological restoration undertaken by the USACE, contain implicit predictions of future conditions or functions.

•Despite the interrelatedness of these two fields, there is very little cross-utilization of either the outcomes of forecasting research or the “experimental conditions” created through environmental planning.

•The disconnect between these two fields is a source of risk for negative outcomes and potential for new areas of research.