

Model Development: Conceptualization

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Modeling Workshop

Swan Island Ecosystem Restoration

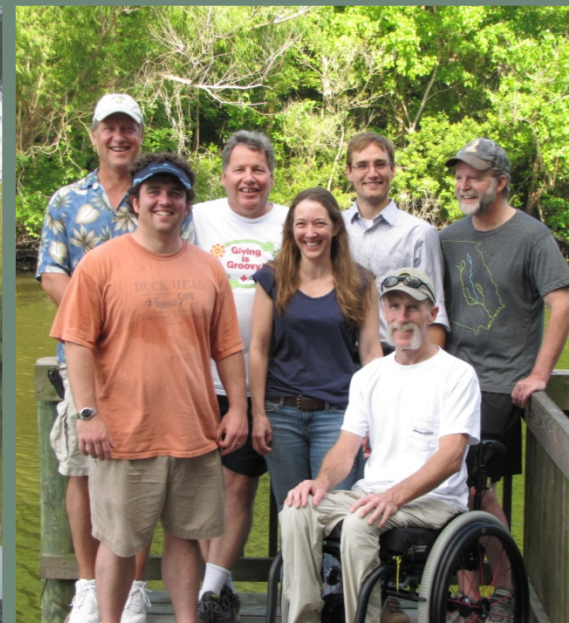
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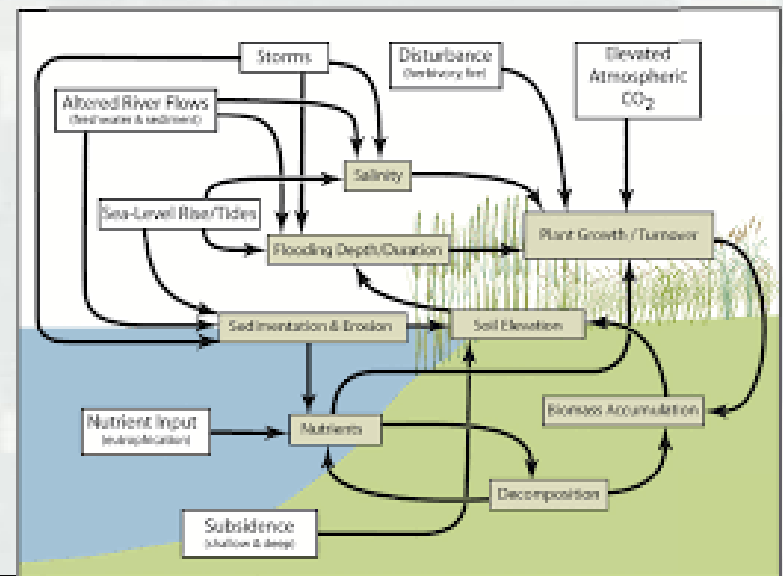
Lecture Overview

- What are conceptual models?
- Development of conceptual models
- Characteristics of useful conceptual models
- Pitfalls and good practices
- Documentation

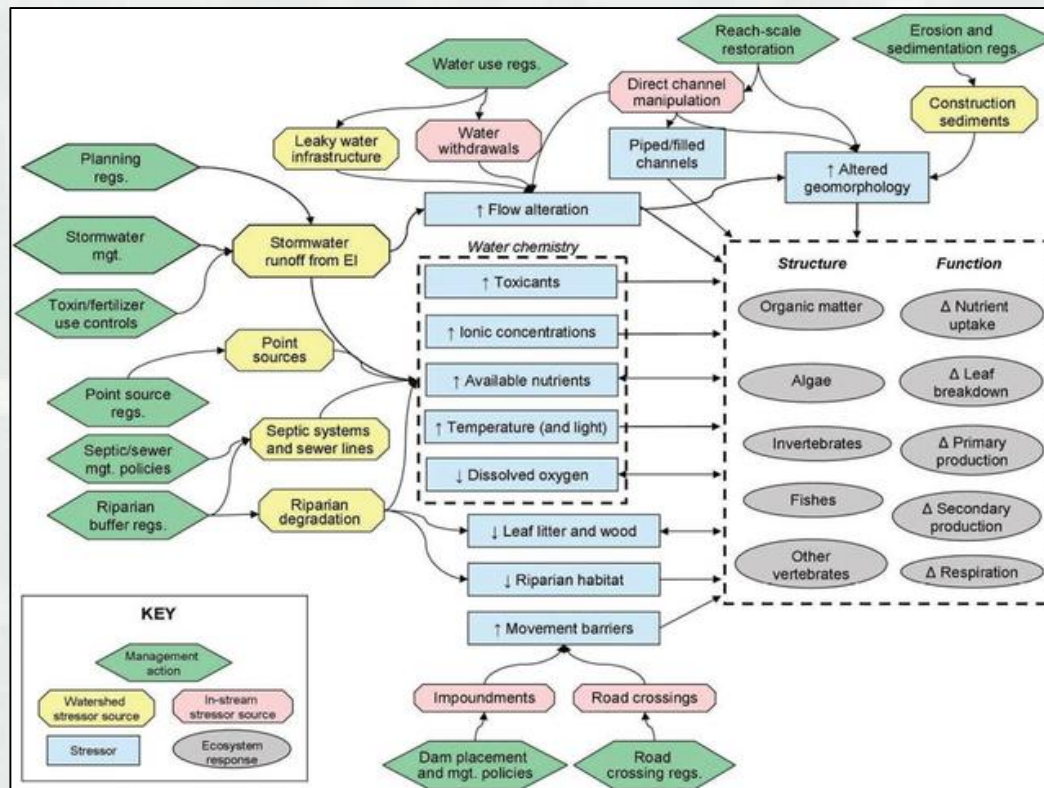
Much (i.e., most) of the content in this lecture was graciously provided by Drs. Craig Fischenich, Tomma Barnes, Kyle McKay and Todd Swannack (See references at end of lecture).



A conceptual model is a tentative description of a system or sub-system that serves as a basis for intellectual organization.



Conceptual models describe general functional relationships among essential ecosystem components. They tell the story of “how the system works.”



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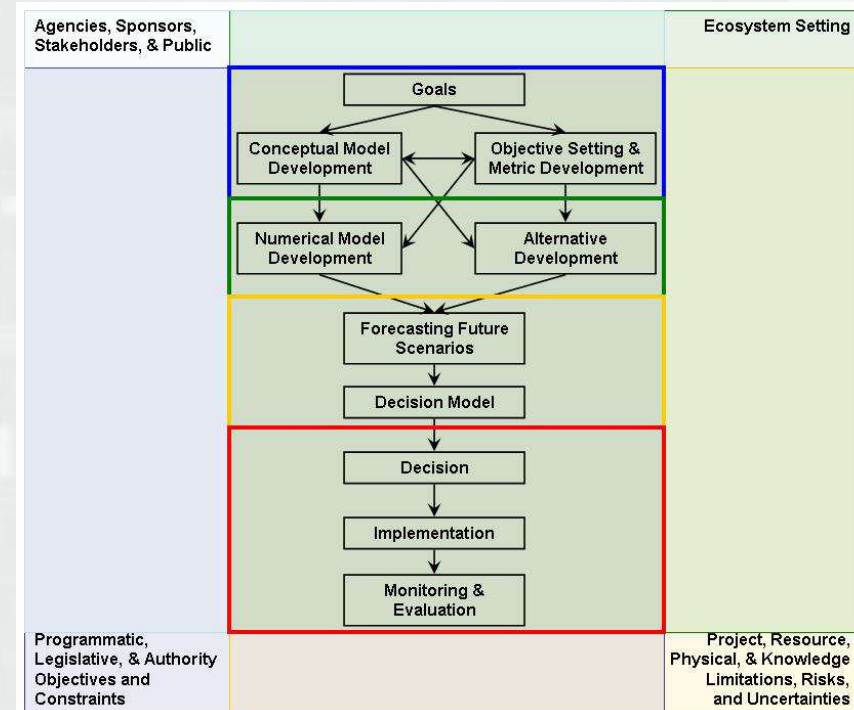
Figure: Wenger et al. (2009, JNABS)

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How are conceptual models used in ecosystem restoration?

- Communicate the restoration “process”
- Synthesize understanding of system function
- Understand and diagnose underlying stressors
- Develop a common “mental picture”
- Identify metrics for project planning, monitoring, and adaptive management
- **Guide numerical model development**
- Guide and plan restoration alternatives
- Identify R&D needs



A few stipulations...

- The same system can have many potential conceptual models
- CMs reflects our personal understanding and viewpoint
- Conceptual models are **NOT**:
 - ▶ **The truth** – they are simplified depictions of reality
 - ▶ **Comprehensive** – they focus only upon those parts of an ecosystem deemed relevant while ignoring other important (but not immediately germane) elements
 - ▶ **Final** – they provide a flexible framework that evolves as understanding of the ecosystem increases



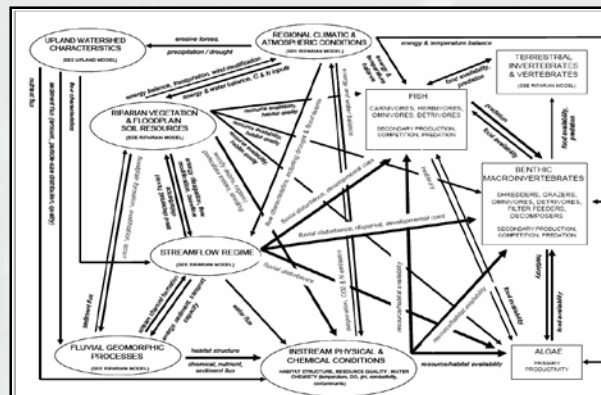
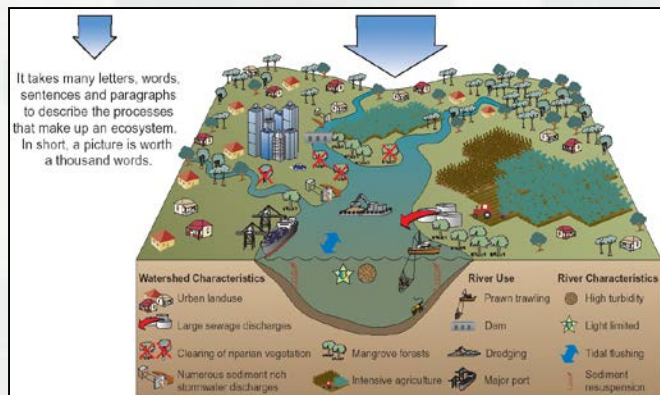
How are conceptual models used in ecological model development?

- Team building
- Communication and general understanding
- Sometimes two models are helpful to describe:
 - ▶ A team's complex thinking via a descriptive model
 - ▶ A simplified model as a basis for quantification
- BUT for model development a conceptual model must translate into quantifiable processes



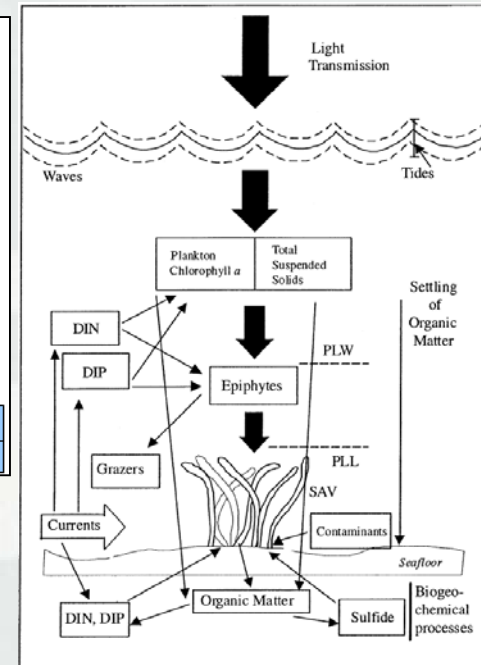
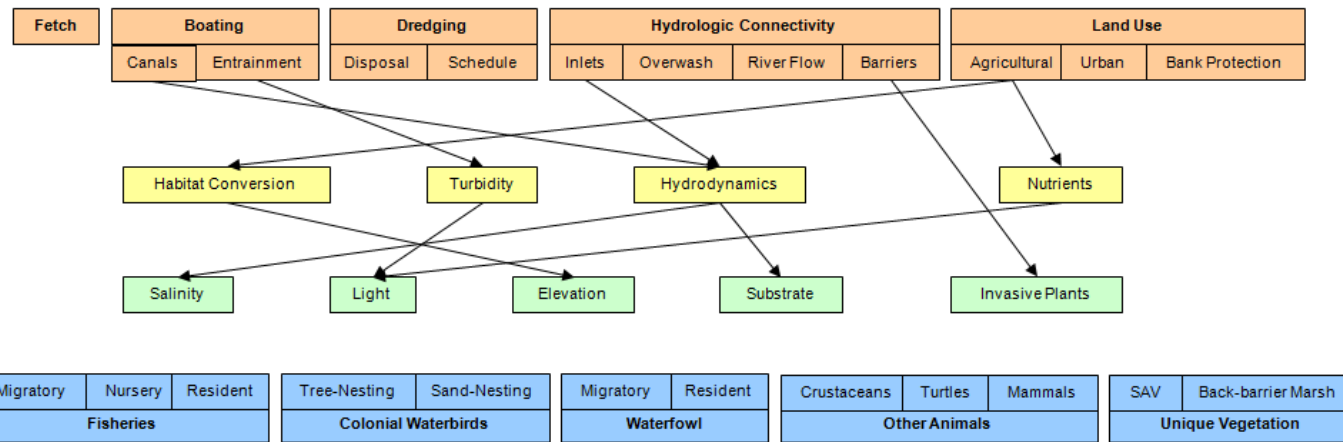
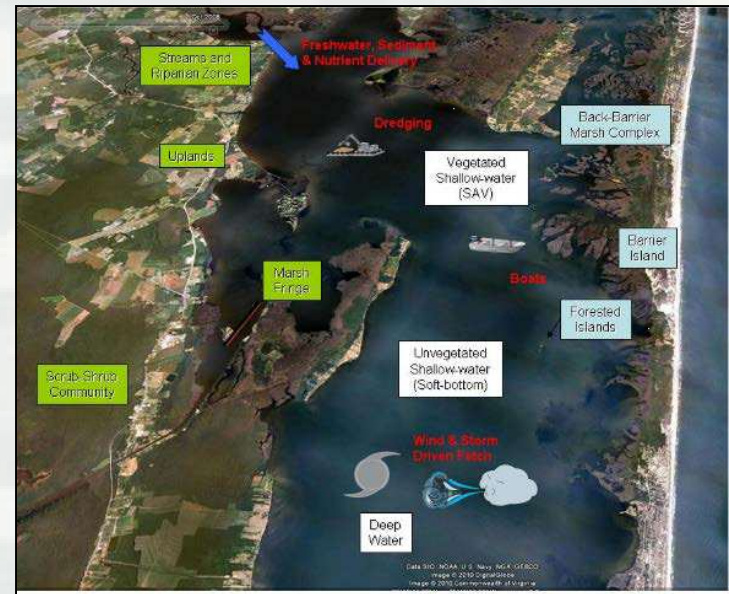
Types of Conceptual Models

Type of model	Description	Strengths	Drawbacks
Narrative	Use word descriptions, mathematical or symbolic formula	Summarizes literature, information rich	No visual presentation of important linkages
Tabular	Table or two-dimensional array	Conveys the most information	May be difficult to comprehend amount of information
Picture models	Depict ecosystem function with plots, diagrams, or drawings	Good for portraying broad-scale patterns	Difficult to model complex ecosystems or interactions
Box and arrow (Stressor model)	Reduce ecosystems to key components and relationships	Intuitively simple, one-way flow, clear link between stressor and vital signs	No feedback, few or no mechanisms, not quantitative
Input/output matrix (Control model)	Box and arrow with flow (mass, energy, nutrients, etc.) between components	Quantitative, most realistic, feedback and interactions	Complicated, hard to communicate, state dynamics may not be apparent



Habitat	Salinity (yearly average)	Source for Salinity Restrictions	Inundation (% of year)	Source for Inundation Restrictions
Bottomland Hardwood Swamp Forest	< 2 ppt	Conner et al. (1997)	< 30%	Conner et al. (1997)
Fresh Floating Marsh	< 4 ppt	Höppner (2002)	Up to whole year if not stagnant	Höppner (2002)
Fresh Attached Marsh	< 2 ppt	Chabreck (1970), Hester et al. (2002)	Not Applicable	
Intermediate Marsh	< 2 ppt	Chabreck (1970)	Up to whole year if not stagnant and below 30 cm of water on marsh	Evers et al. (1998)
Brackish Marsh	2-6 ppt	Chabreck (1970)	Up to whole year if not stagnant and below 30 cm of water on marsh	Evers et al. (1998)
Saline Wetlands	6-15 ppt	Chabreck (1970)	< 64%A	Sasser (1977)
	> 15 ppt	Chabreck (1970)	< 80%A	Sasser (1977)

Example: Currituck Sound Estuary Restoration



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Figure: Orth et al. (2006), Kemp et al. (2004)

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Development of conceptual models



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Conceptual Model Development

- State the model objectives.
- Bound the system of interest.
- Identify critical model components within the system of interest.
- Articulate the relationships among the components of interest.
- Represent the conceptual model.
- Describe the expected pattern of model behavior.
- Test, review, and revise as needed.



Craft Matters

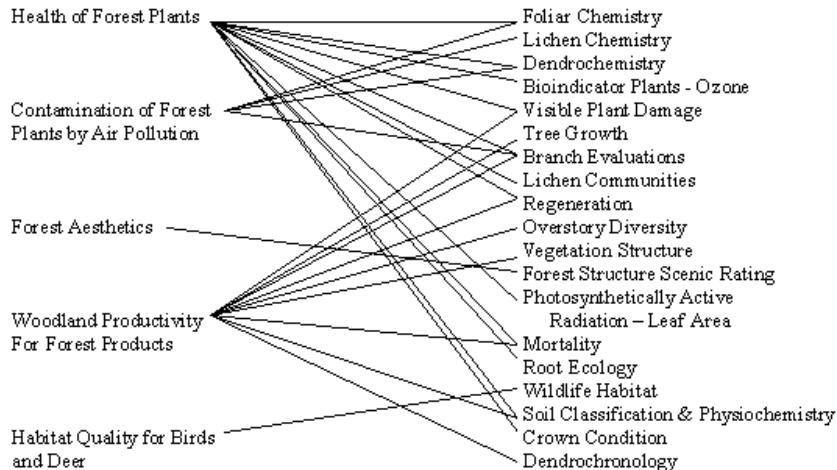
Help readers by grouping related elements, aligning elements, and minimizing crossed lines.

These are the same!



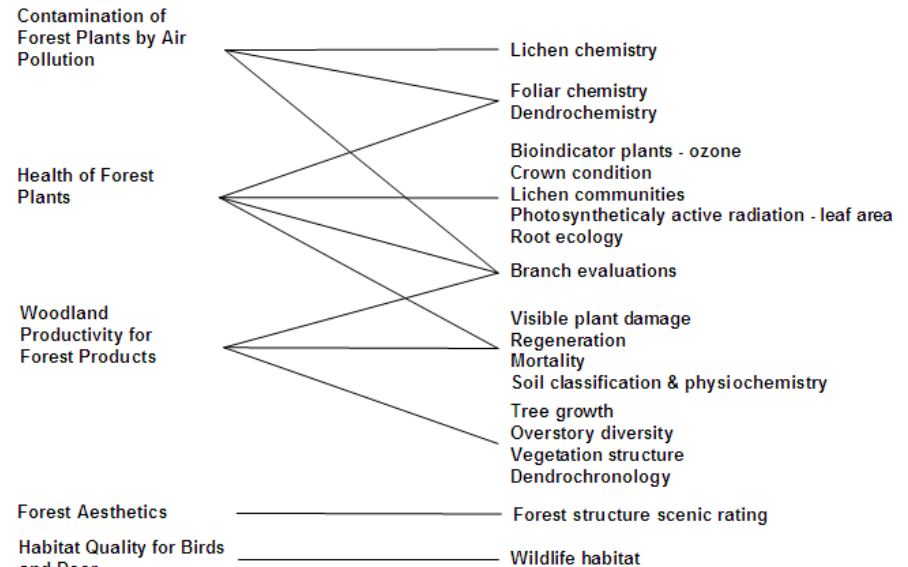
Common-Language Indicators

EMAP Indicator names for Forests



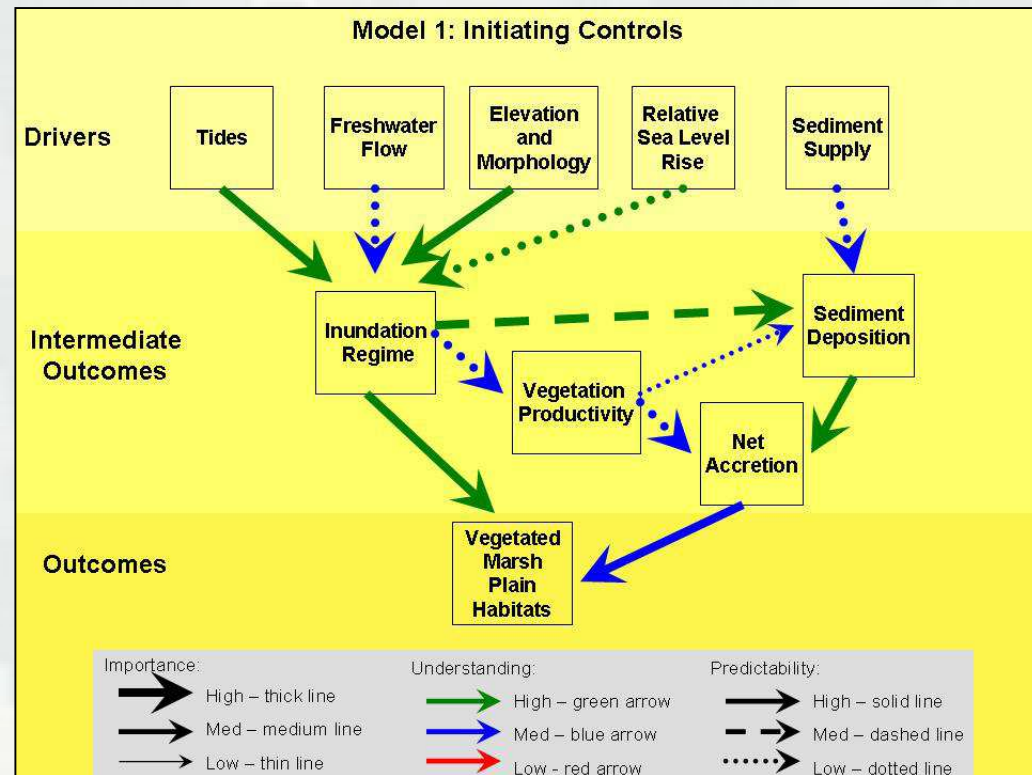
Common-Language Indicators

EMAP Indicator names for forests



Presentation Tips

- Combine graphical and narrative descriptions
- Align boxes, both horizontally and vertically
- Maximize 'content': eg. use line types or weights, shapes, and colors to show important information
- Avoid shaded boxes that photocopy poorly
- Limit complexity
- Aggregate lines when possible
- Adapt to target audience and presentation medium



Conceptual model development example: Marsh Vegetation



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State the model objectives

- Marsh restoration has become a major source of investment throughout the region for habitat, storm protection and fisheries.
- A comprehensive framework accounting for the benefits of these efforts has not been developed.
- Our objective is to develop a model for assessing the benefits of marsh vegetation restoration in the bay.



Bound the system

- Chesapeake Bay
- Current and potential tidal marsh areas



Identify model components

- Applied a driver-stressor framework
- Focused on ecosystem benefits and service oriented outcomes



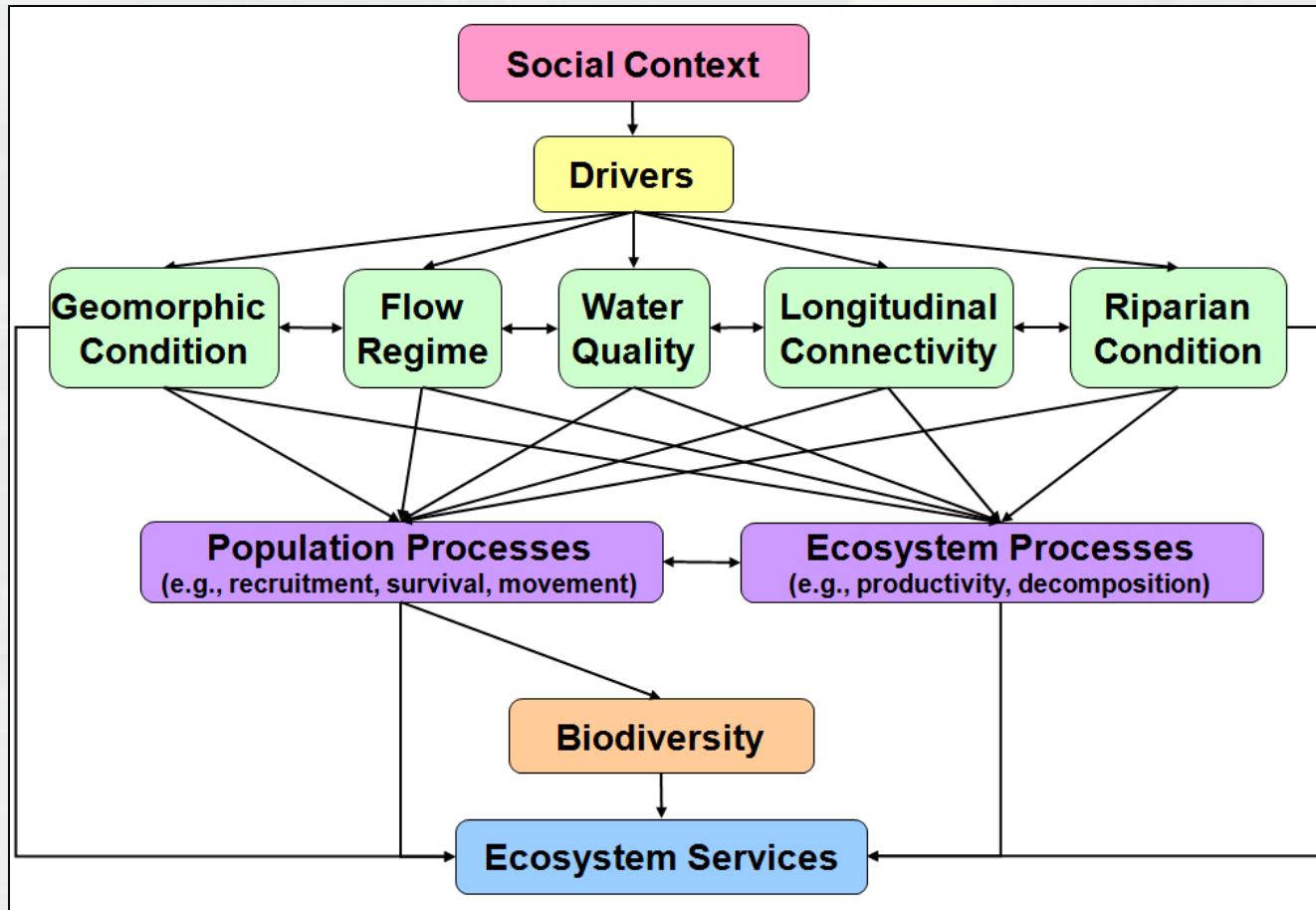
Social Context	Public opinion	Attitudes	Funding	Population growth
	Regulations	Legal constraints	Political jurisdiction	Policies
	Resource Usage	Quality of life	Demand / supply	
	Management actions	Construction	Restoration	Conservation
Drivers	Urban Land Use	Impoundments	Road Crossings	Bridges / Culverts
		Land Use Type/Intensity	Riparian Land Use	Temporary Land Uses
		Channel Alteration/Piping	Bank treatment	
		Wastewater	Industrial discharge	Power generation
Stressors	Agriculture Land Use	Non-Point Runoff	Septic/sewer discharge	
		Silviculture	Crop	Animals
		Timber	Mines	Sand and Gravel
		Beavers	Invasive species	
State	Resource Extraction	Transportation	Dams	Withdrawals
		Temperature	Precipitation	
Sub-State	Channel Form	CEM-I	CEM-II	CEM-III
	Flow Regime	CEM-IV	CEM-V	Engineered
	Water Quality	Minimally Impacted	Flashy	
	Connectivity	Damped	Damped with Peaking	
Services	Heritage / Future Use	Minimally Impacted	Nutrient Enrichment	
		Physio-Chemical Impact	Chemical Contamination	
		Upstream & Downstream	Upstream Only	
		Downstream Only	Isolated	
Existence Value	Cultural Value	Aesthetics	Spiritual	Historical
		Educational	Ecotourism	Social cohesion
		Boating	Fishing	Hunting
		Wildlife Observation	Water Contact	
Recreation	Flow Regime	Flood attenuation	Flood Conveyance	Hydropower
		Municipal Withdrawal	Industrial Use	Agricultural Withdrawal
		Treatment Cost	Waste Assimilation	
		Sand and gravel	Timber	
Water Quality	Resource extraction	Micro-climate regulation	Carbon sequestration	
		Disease regulation	Vector control	
Air quality	Public Health			

Identify relationships between components

- Literature and data resources cataloged (e.g., effects of urban land use on flow regime and resulting effects on recreational fishing)
- Model maintained in a very flexible format
 - ▶ Future versions of the model will eliminate some model components.
 - ▶ At this juncture, physical, chemical, and biological processes linking drivers, states, and services are not fully explained.



Develop representations of the model



Describe expected patterns of model behavior

Drivers

Channel Alteration (Straightening)

Processes

Channel Degradation

State

Geomorphic Condition

Flow Regime

Water Quality

Connectivity

Processes

Substrate &
Bedform Diversity

Riparian
Cover

Population Processes

Reproduction

Survival

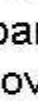
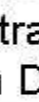
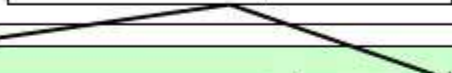
Colonization

Biodiversity

Persistence of Hypothetical Benthic Fish

Service

Existence Value of Hypothetical Benthic Fish



Test, review, document, and revise

- Generalized model was beta tested for a few key processes
- Model documented in reports and peer-reviewed at an external conference and internal outlet
- Model undergoing revision as part of a research program on urban streams

CONSTRUCTING A CONCEPTUAL MODEL LINKING DRIVERS AND ECOSYSTEM SERVICES IN PIEDMONT STREAMS

S. Kyle McKay¹, Bruce A. Pruitt¹, Christopher J. Anderson², Joana Curran¹, Ana Del Arco Ochoa¹, Mary C. Freeman¹, Brenda Runkle¹, and E. Dean Treviño¹

AUTHORS: ¹U.S. Army Engineer Research and Development Center, Athens, GA; ²School of Forestry and Wildlife Science, Auburn University, Auburn, AL; ³School of Engineering and Applied Science, University of Virginia, Charlottesville, VA; ⁴University of Coimbra, Coimbra, Portugal; ⁵Pennant Wildlife Center, U.S. Geological Survey, Adkins, GA; ⁶Ecosystem Research Division, U.S. Environmental Protection Agency, Adkins, GA; ⁷Mobile District, U.S. Army Corps of Engineers, Mobile, AL.

REFERENCE: *Proceedings of the 2011 Georgia Water Resources Conference*, April 11-13, 2011, University of Georgia.

Abstract: Under rapid land use change, high demand on freshwater ecosystem services, and a growing appreciation for the value of functioning ecosystems, the Appalachian Piedmont has developed a multi-million dollar stream restoration industry. A conceptual model is under development to link drivers of ecosystem services to project planning or model development.

variability is significantly reduced in regards to valley and stream slopes, soil properties, geology, climate, land use, and vegetative community types. Second, a regional conceptual model can be utilized in many projects throughout the area, and thus, provides a source of efficiency in project planning or model development.

The Piedmont ecoregion extends from central Alabama northwest almost to the Virginia-Maryland border and is bounded by the Appalachian Mountains and Blue Ridge to the northwest and the Atlantic Coastal Plain to the southeast (Figure 1). Elevations range from approximately 152 to 437 meters above sea level (500 to 1500 feet).

emrrp
Ecosystem Management and Restoration Research Program

An Approach for Developing Regional Environmental Benefits Models
by S. Kyle McKay¹ and Bruce A. Pruitt¹

OVERVIEW: Ecosystem restoration projects in a given region often have similar drivers, stressors, state conditions, and ecosystem services. Moreover, objectives and accompanying metrics may be similar enough to encourage regional model development. Regional approaches to environmental benefits analysis offer opportunities to streamline project evaluation by developing consistent understanding, metrics, and models. This technical note proposes a framework for developing regionally applicable environmental benefits models. The proposed framework is demonstrated for streams in the Appalachian Piedmont. This approach could serve as a basis for developing consistent restoration outputs that can be combined and compared at regional scales.

INTRODUCTION: Owing to the complexity and variability of natural systems, accounting for the benefits of ecosystem restoration, management, and mitigation efforts with scientifically based, repeatable, and transparent techniques can be challenging (Fischenich et al. in preparation). To overcome these obstacles, models of environmental effects have been developed in regions with similar hydrologic, geomorphic, and ecological processes (e.g., ecoregions or physiographic provinces). Some commonly applied regional models of environmental benefit and impact include indices of biotic integrity (Karr 1991, Smogor and Angermeier 2001, Georgia Department of Natural Resources ((GA-DNR) 2005), wetland assessments with hydrogeomorphic methods (Brinson 1993, Smith et al. 1995, Brinson and Rheinhardt 1996), and regional environmental flow standards (Poff et al. 2010, Snelder et al. 2011). Herein, these regional approaches are augmented with standard methods for conceptual and numerical model development. The result of this combined approach is a framework for developing regionally applicable models of environmental benefits. Although regional models have been developed for varying purposes (e.g., impact assessment, mitigation requirements), the focus of this technical note is on the regional approach as it pertains to the evaluation of proposed ecosystem restoration projects. The regional modeling approach outlined here may help USACE planners develop scientifically based models of environmental benefits and construct model documentation capable of addressing rigorous quality assurance standards typically highlighted during various internal and external peer review processes.

WHY DEVELOP A REGIONAL MODEL? Prior to examining the framework for regional model development, it is constructive to review strengths and weaknesses of regional models. The primary advantages of developing a regional model include:

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Figure 1: Level III Ecoregion (CEC 1997). The Piedmont is shaded in light green and labeled as 9.3.4.

Piedmont streams have been adversely affected by land use practices spanning nearly two centuries. Historical cotton farming practices of the 1800s and early 1900s induced significant erosion such that, in much of the Piedmont, the original topsoil has eroded away exposing red clay sub-soils (Jackson et al. 2001, Trimble 2006). At



Characteristics of useful conceptual models



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Characteristics of useful conceptual models

- Relevant to the problem
- Directed at the appropriate spatial and temporal scales
- Strike an appropriate balance between over-simplification and over-sophistication.
- Underpinned by sound scientific knowledge



Good conceptual ecological models should include:

- Most important components (e.g., drivers, both internal (e.g., flow rates) and external (e.g., climate)), that reflect the model objectives and help us answer questions about the system (how agencies can effect change).
- Critical thresholds of ecological processes and environmental conditions
- Discussion of assumptions and gaps in the state of knowledge, especially those that limit the predictability of restoration outcomes.
- Identification of current characteristics of the system that may limit the achievement of management outcomes.
- Adequate references to substantiate the model.



Reviewing conceptual models

- Does it appropriately identify the assumptions, limitations, areas of disagreement, and gaps in the state of knowledge?
- Will the model's functionality shift through time (e.g., will processes change with land use or climate)?
- Does it sufficiently account for long-term environmental variability and disturbance (e.g., drought, hurricanes)?



Pitfalls and good practices (Grant and Swannack 2008)



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Pitfalls: Scope

- Inadequate definition of model purpose
 - ▶ “To understand...” is dangerous
- Implicit criteria for model evaluation
 - ▶ What are the criteria that make this model useful?
- No description of model context
 - ▶ How will the model be applied in the “real-world”?



Pitfalls: Bounding the System

- Casual choice of scale for the system-of-interest
 - ▶ What is the spatio-temporal scale of decision making?
- Inclusion of too many components
 - ▶ It is easy to get lost in the weeds
- Careless categorization of system components
 - ▶ Categorize relative to model (not ecological) function
- Inclusion of excessive detail



Pitfalls: Logic Traps

- Inclusion of circular logic
 - ▶ Ecological processes often rely on feedback loops, but don't let your whole model be a feedback loop
- Lack of precision in conceptual model diagram
 - ▶ Modeling definitions are useful, so learning the language and process is time well-spent
- Reluctance to make initial hypotheses about system behavior
 - ▶ Write down some initial ideas. Does the model perform as expected?



Take-away Points:

- Conceptual models come in all shapes and sizes.
- We're focused on developing conceptual models that are transitioned into QUANTITATIVE TOOLS.
- Conceptual model development can be facilitated by iterative application of the steps summarized here.

Up Next:

- Step 2 of the Modeling process – Quantification

Later Today:

- Lab Exercise – Develop a Conceptual Model



References for Further Reading

- Fischenich J.C. 2008. The application of conceptual models to ecosystem restoration. ERDC/EBA TN-08-01.
- Grant W.E. and Swannack T.M. 2008. Ecological modeling: A common-sense approach to theory and practice. Malden, MA: Blackwell Publishing.
- Casper A.F., Efroyimson R.A., Davis S.M., Steyer G., and Zettle B. 2010. Improving conceptual model development: Avoiding underperformance due to project uncertainties. ERDC-TN-EMRRP-EBA-5.
- Henderson J.E. and O'Neil L.J. 2007. Template for conceptual model construction: Model review and Corps applications. ERDC TN-SWWRP-07-4.
- Henderson J.E. and O'Neil L.J. 2007. Template for conceptual model construction: Model components and application of the template. ERDC TN-SWWRP-07-7.

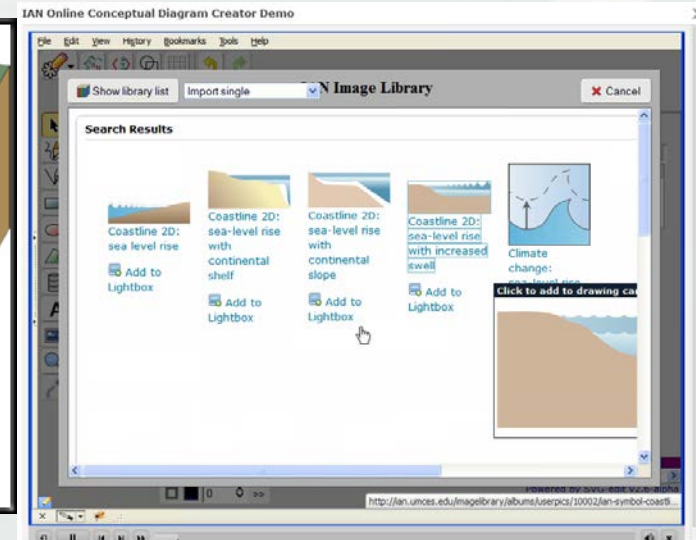
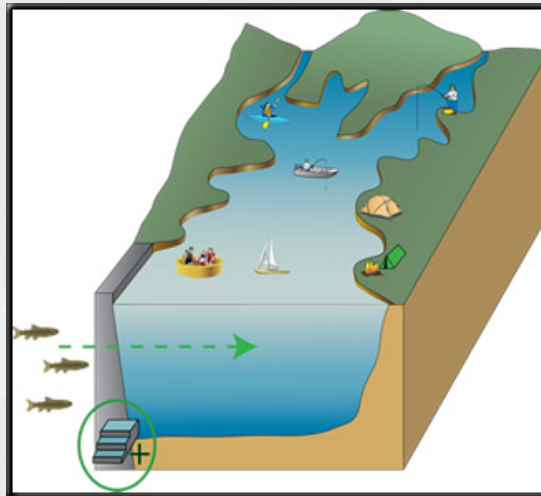


Conceptual Modeling Tools

- Quiet + Pencil + Paper (or maybe Powerpoint)
- Conceptual Ecological Model Construction Assistance Tool (CEMCAT)
- EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS, <http://www.epa.gov/caddis/>)
- Integration and Application Network (IAN, <http://ian.umces.edu/>)



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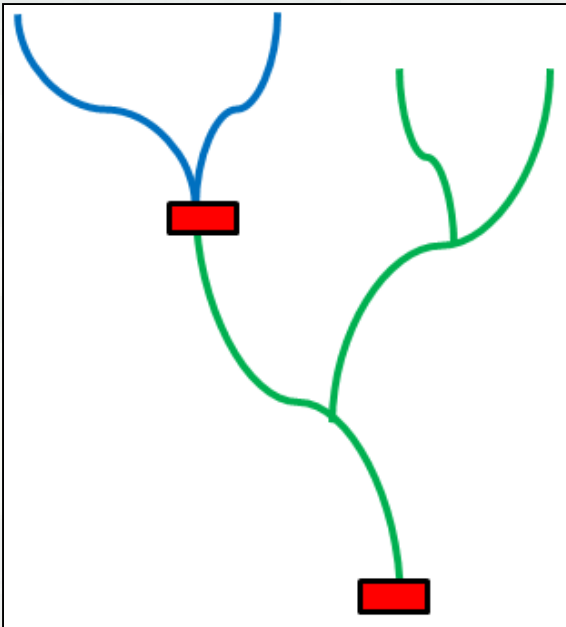
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Example: Watershed Networks

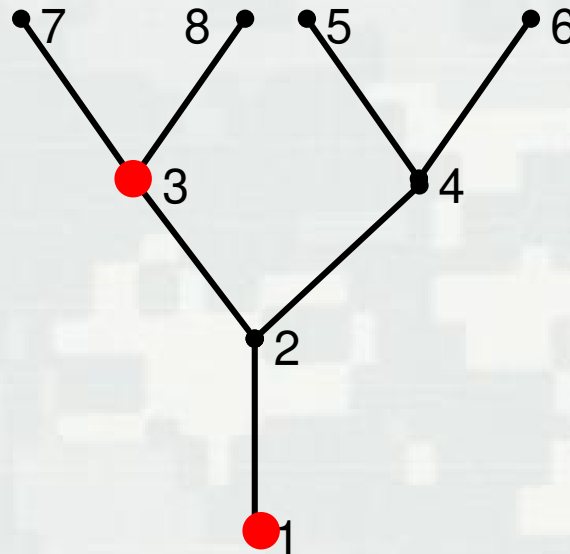
Narrative: A heart-shaped watershed with 30 miles of habitat and 2 small mill dams



Map



Network Diagram



Tabular / Matrix

Adjacency

Habitat

0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	1	0	0	0	0	0	0
0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0
0	0	1	0	0	0	0	0
0	0	1	0	0	0	0	0

1
2
2
2
0
0
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