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Model Development: Conceptualization

Brook Herman
601-634-3248
brook.d.herman@usace.army.mil

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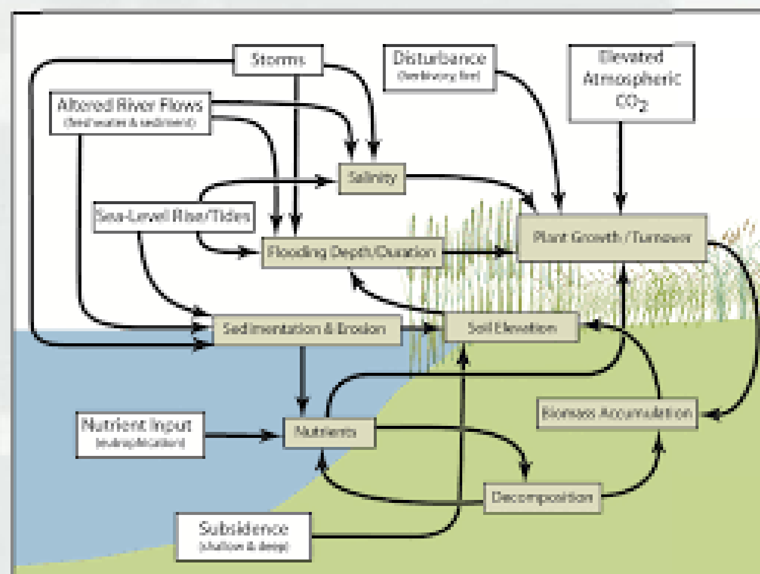
Lecture Overview

- 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."

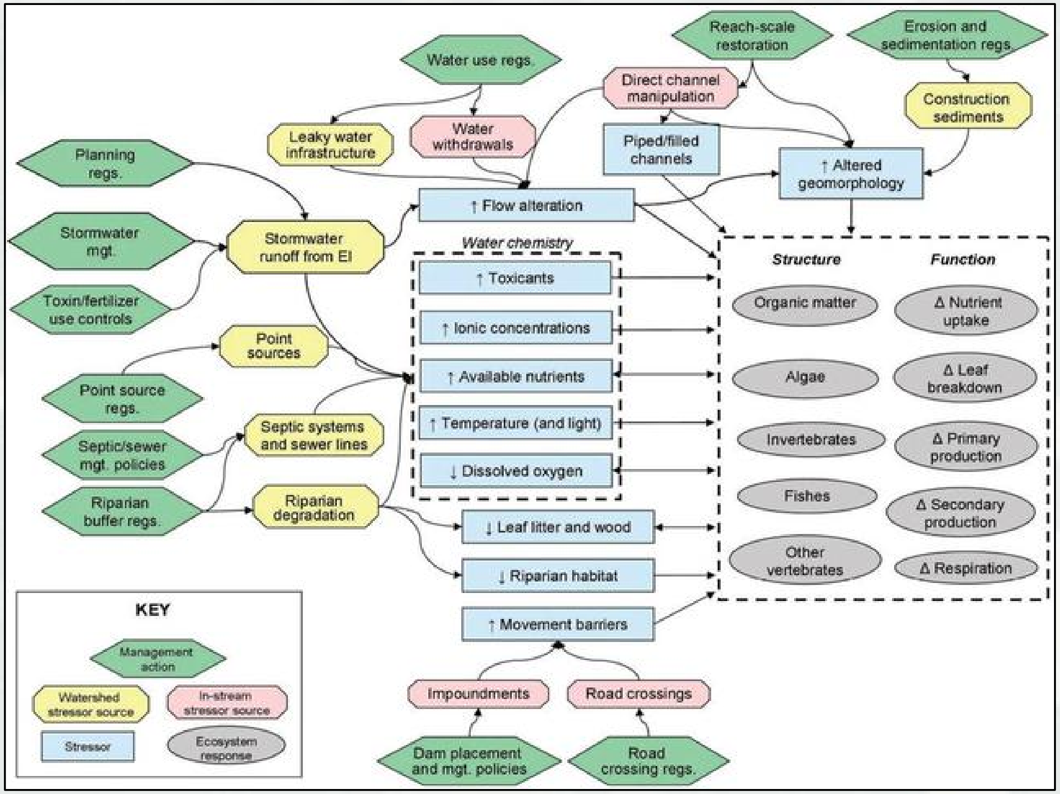


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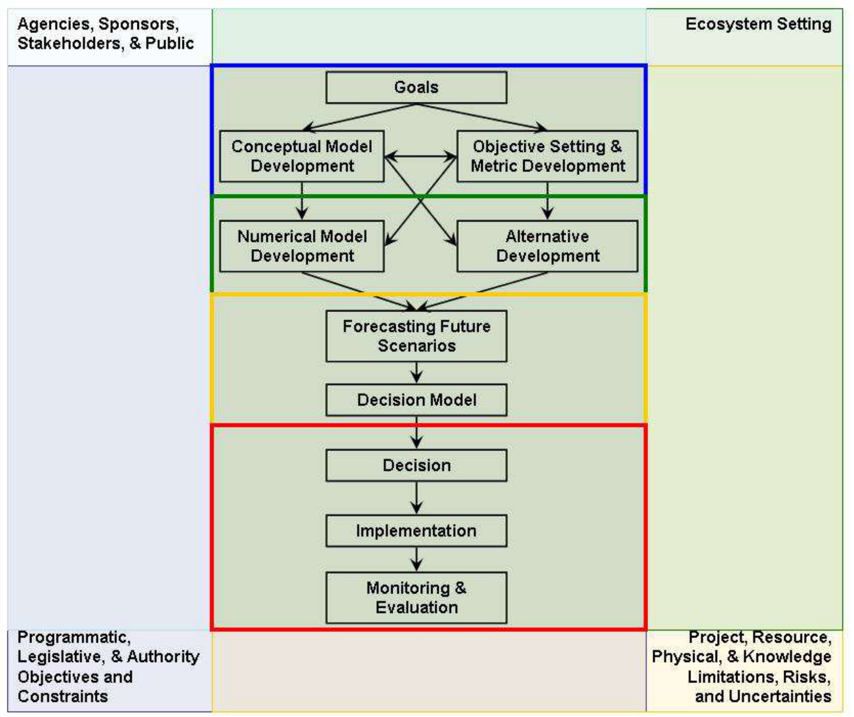
Figure: Wenger et al. (2009, JNABS)

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…

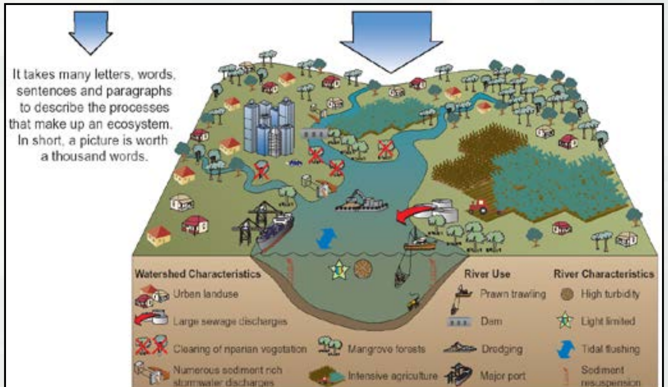
- The same system can have many potential conceptual models
- CMs reflects our personal understanding and viewpoint
- Conceptual models are **NOT**:
  - **The truth** – they are simplified depictions of reality
  - **Comprehensive** – they focus only upon those parts of an ecosystem deemed relevant while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

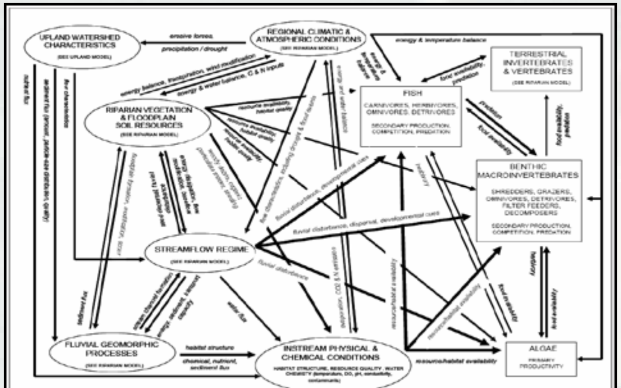
How are conceptual models used in ecological model development?

- 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

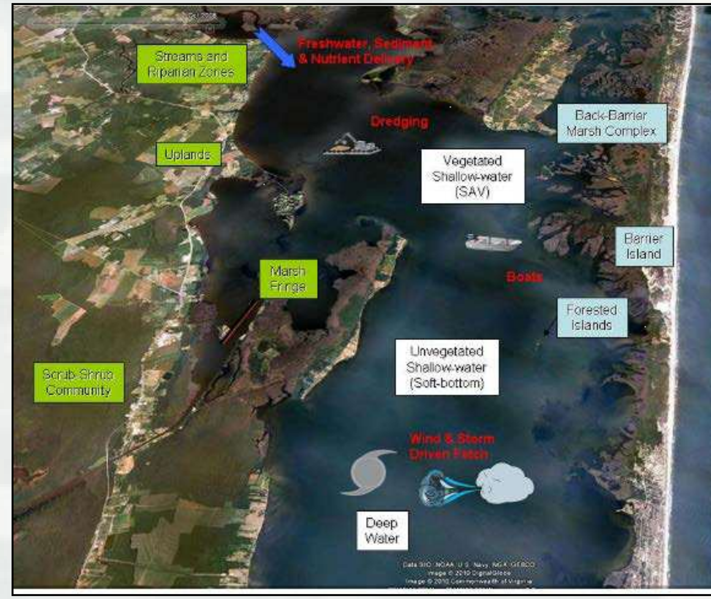


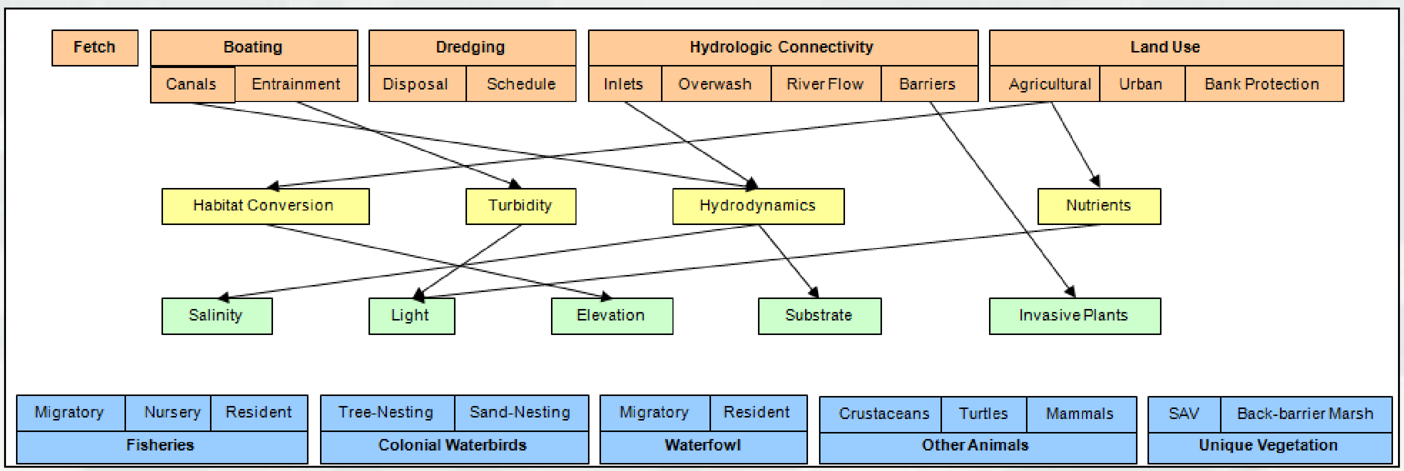


Habitat	Salinity (yearly average)	Source for Salinity Restrictions	Inundation (% of year)	Source for Inundation Restrictions
Bottomland Hardwood	< 2 ppt	Conner et al. (1997)	< 30%	Conner et al. (1997)
Swamp Forest	< 4 ppt	Höppner (2002)	Up to whole year if not stagnant	Höppner (2002)
Fresh Floating Marsh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

Table: Gucciardo et al. (2004), Fischenich (2008)

Example: Currituck Sound Estuary Restoration





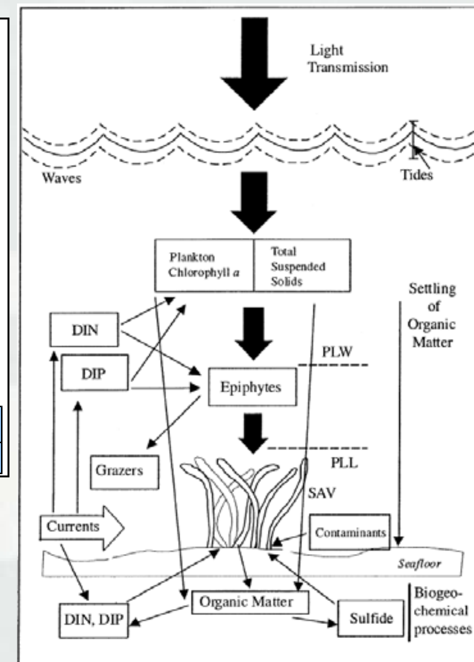


Figure: Orth et al. (2006), Kemp et al. (2004)

Development of conceptual models

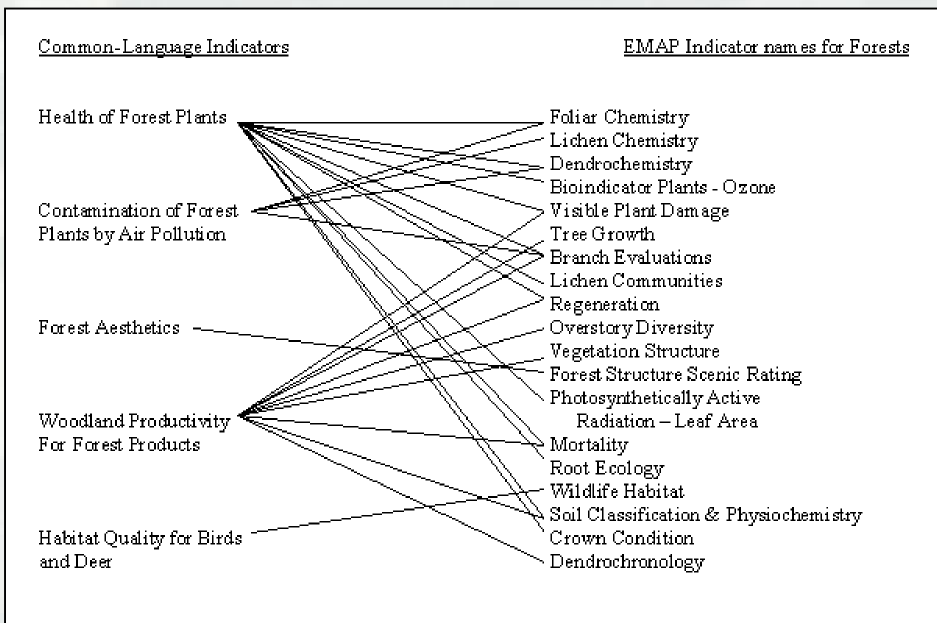
Conceptual Model Development

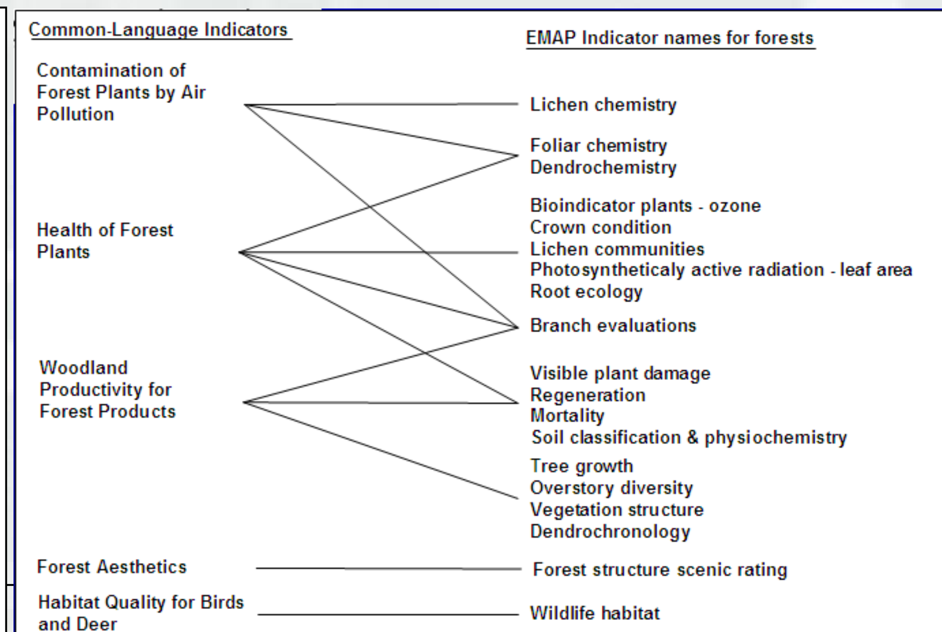
- State the model objectives.
- Bound the system of interest.
- Identify critical model components within the system of interest.
- Articulate the relationships among the components of interest.
- Represent the conceptual model.
- Describe the expected pattern of model behavior.
- Test, review, and revise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

Craft Matters

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

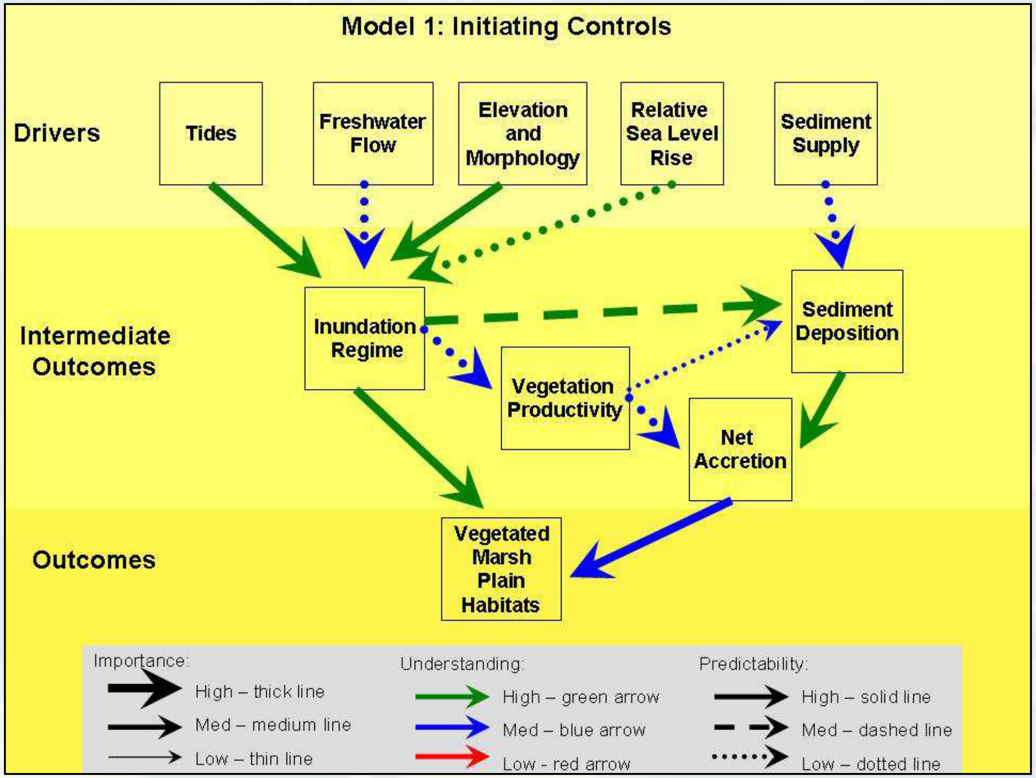
These are the same!





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

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

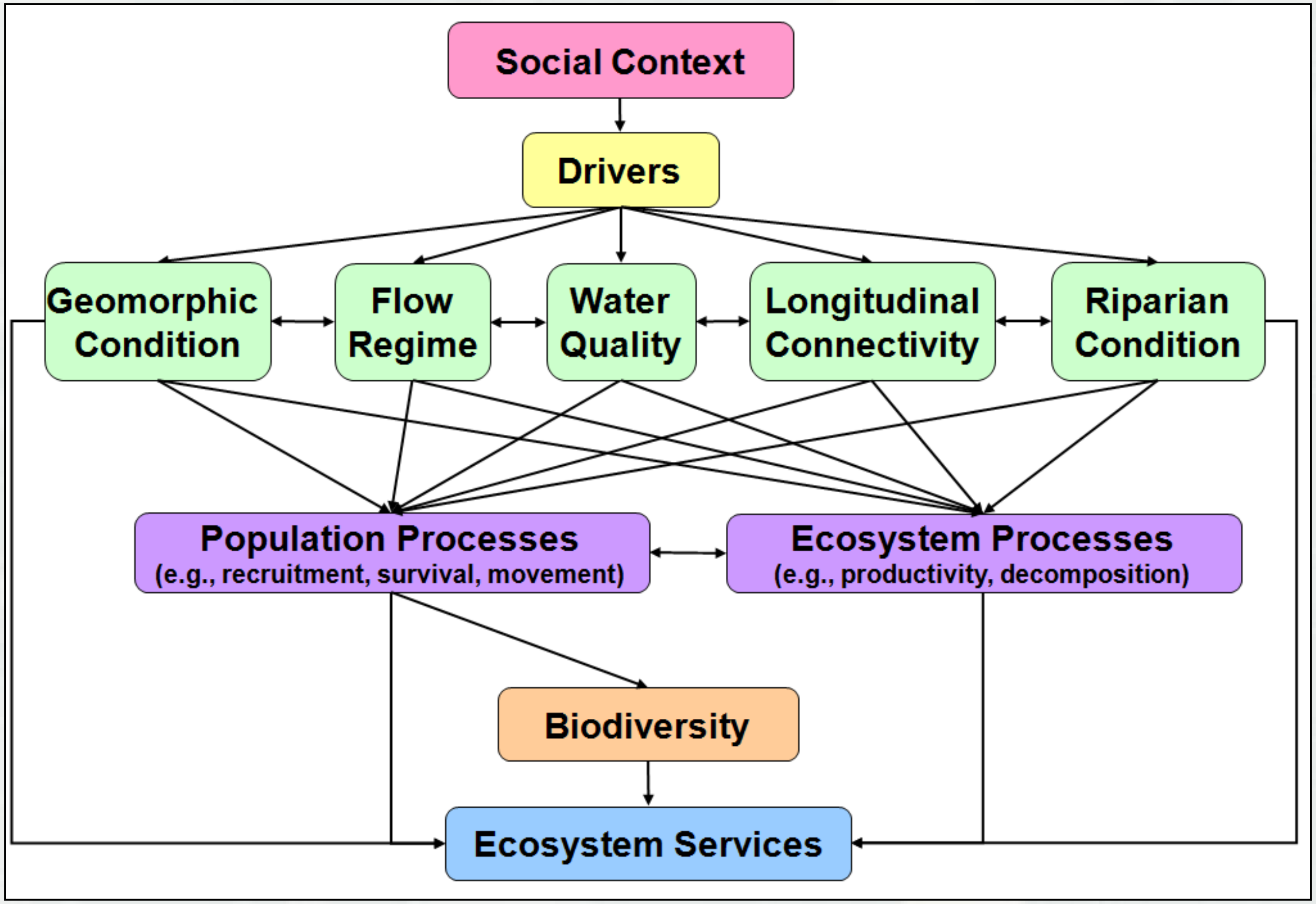
- Applied a driver-stressor framework
- Focused on ecosystem benefits and service oriented outcomes

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 Stressors	**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
		Non-Point Runoff	Septic/sewer discharge	
	Agriculture Land Use	Silviculture	Crop	Animals
	Resource Extraction	Timber	Mines	Sand and Gravel
	Ecosystem engineers	Beavers	Invasive species	
	Infrastructure	Transportation	Dams	Withdrawals
	Climate Change	Temperature	Precipitation	
State Sub-State	**Channel Form**	CEM-I	CEM-II	CEM-III
		CEM-IV	CEM-V	Engineered
	Flow Regime	Minimally Impacted	Flashy	
		Damped	Damped with Peaking	
	Water Quality	Minimally Impacted	Nutrient Enrichment	
		Physio-Chemical Impact	Chemical Contamination	
	Connectivity	Upstream & Downstream	Upstream Only	
		Downstream Only	Isolated	
Services	**Existence Value**			
	Heritage / Future Use			
	Cultural Value	Aesthetics	Spiritual	Historical
		Educational	Ecotourism	Social cohesion
	Recreation	Boating	Fishing	Hunting
		Wildlife Observation	Water Contact	
	Flow Regime	Flood attenuation	Flood Conveyance	Hydropower
		Municipal Withdrawal	Industrial Use	Agricultural Withdrawal
	Water Quality	Treatment Cost	Waste Assimilation	
	Resource extraction	Sand and gravel	Timber	
	Air quality	Micro-climate regulation	Carbon sequestration	
	Public Health	Disease regulation	Vector control	

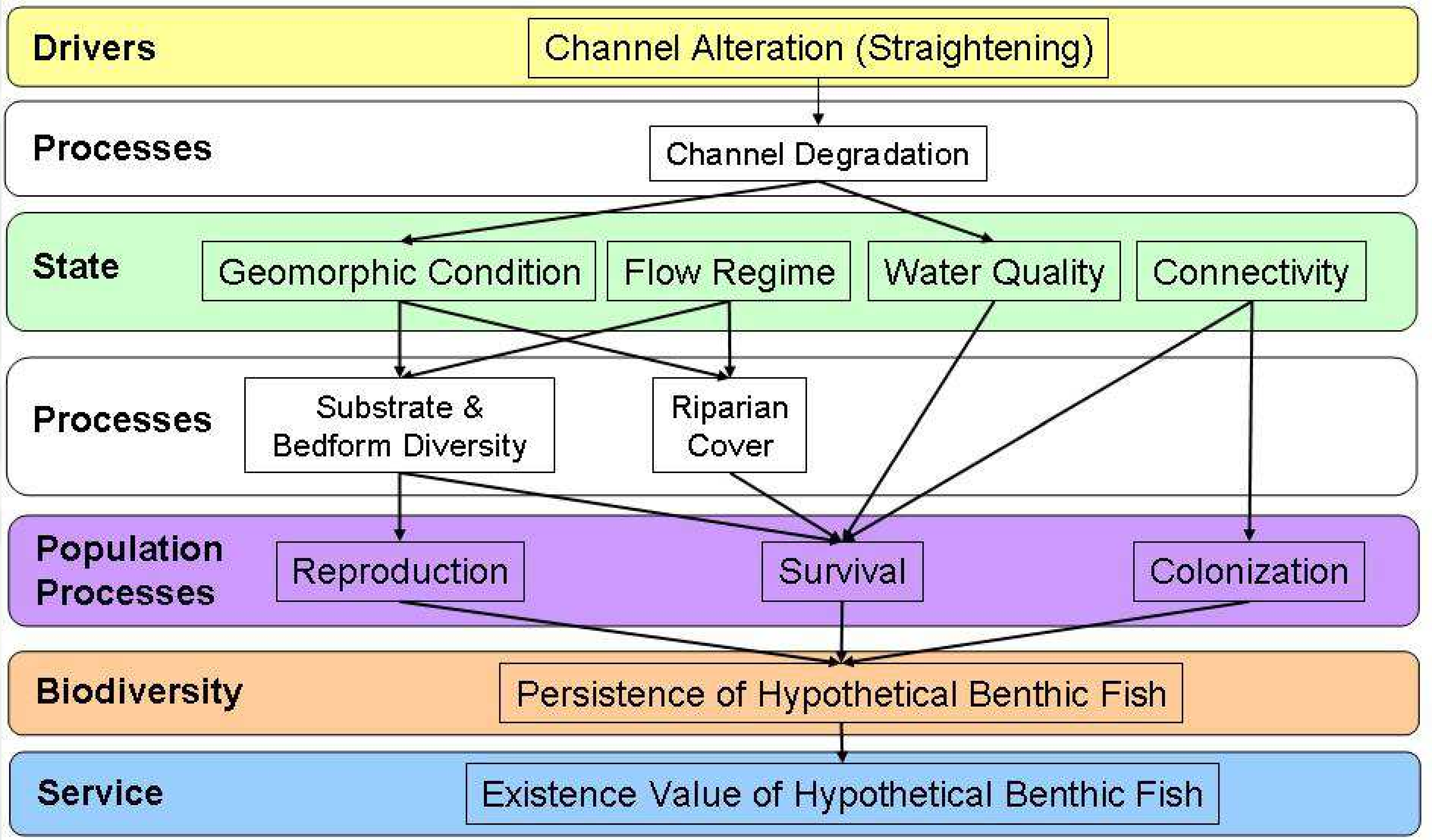
Identify relationships between components

- 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



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

Characteristics of useful conceptual models

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)

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.

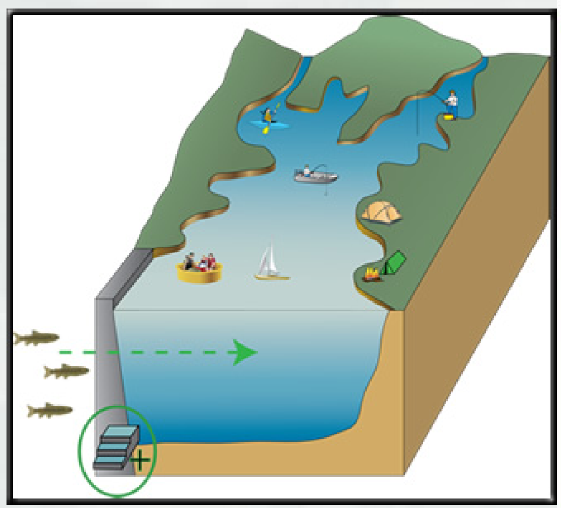
- Casper A.F., Efroymson R.A., Davis S.M., Steyer G., and Zettle B. 2010. Improving conceptual model development: Avoiding underperformance due to project uncertainties. ERDC-TN-EMRRP-EBA-5.

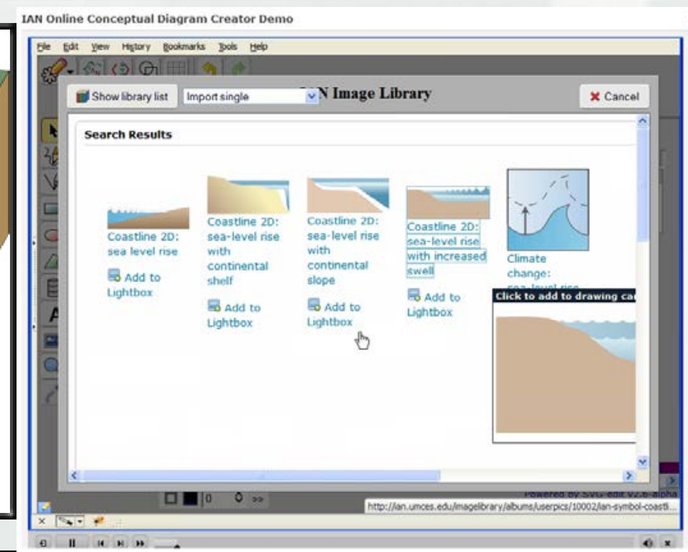
- Henderson J.E. and O'Neil L.J. 2007. Template for conceptual model construction: Model review and Corps applications. ERDC TN-SWWRP-07-4.

- 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/)

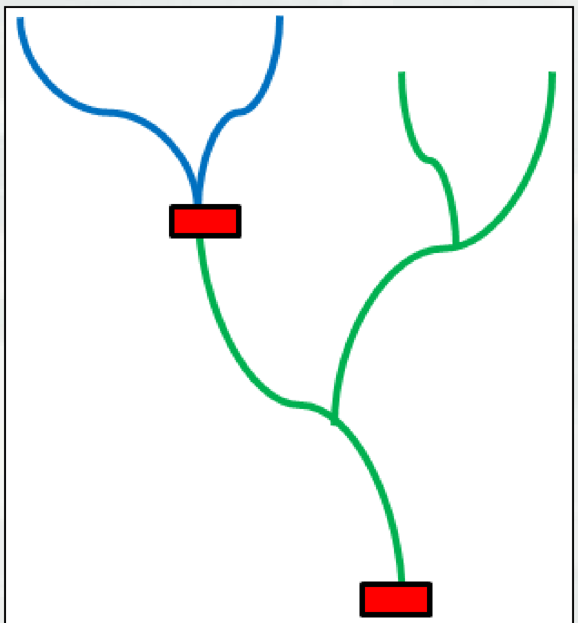




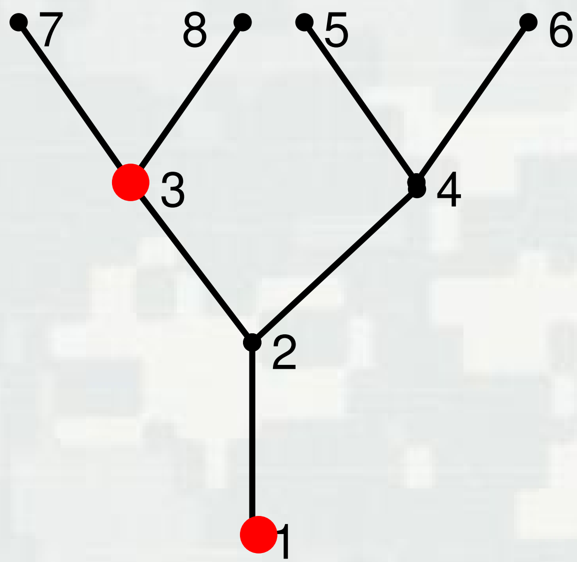
Example: Watershed Networks

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
1	0	0	0	0	0	0	0	2
0	1	0	0	0	0	0	0	2
0	1	0	0	0	0	0	0	2
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	1	0	0	0	0	0	0