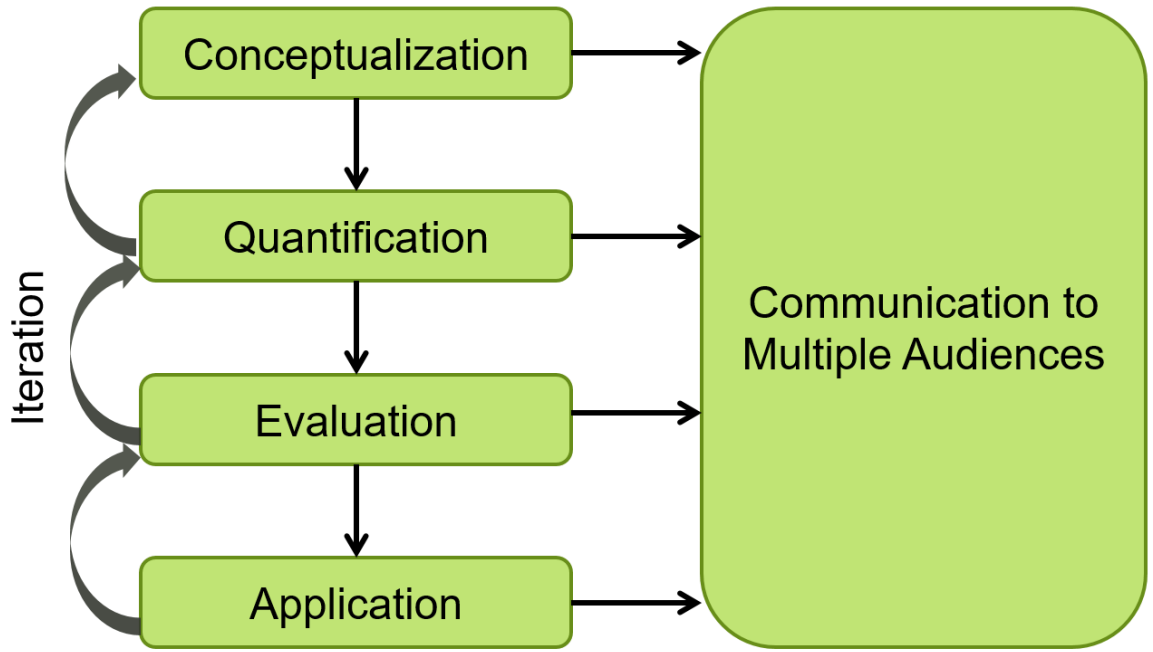
The modeling process and conceptual modeling

Overview

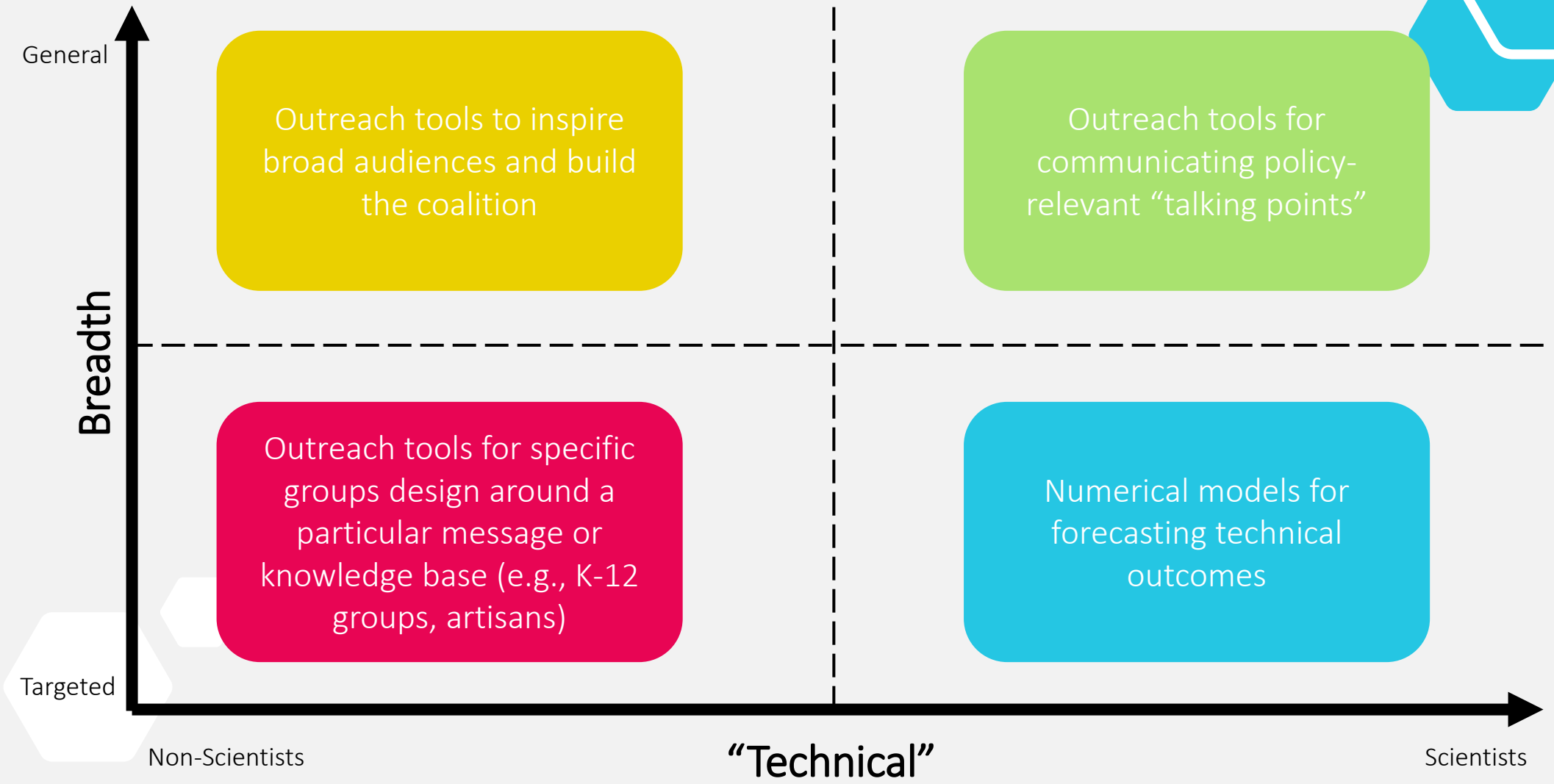
- Describe the modeling process
- What are conceptual models?
- Development of conceptual models
- Characteristics of useful conceptual models
- Pitfalls and good practices
- Documentation



Modeling process

Iterate, iterate, sleep on it, iterate, talk about it, iterate

Different audiences need different models

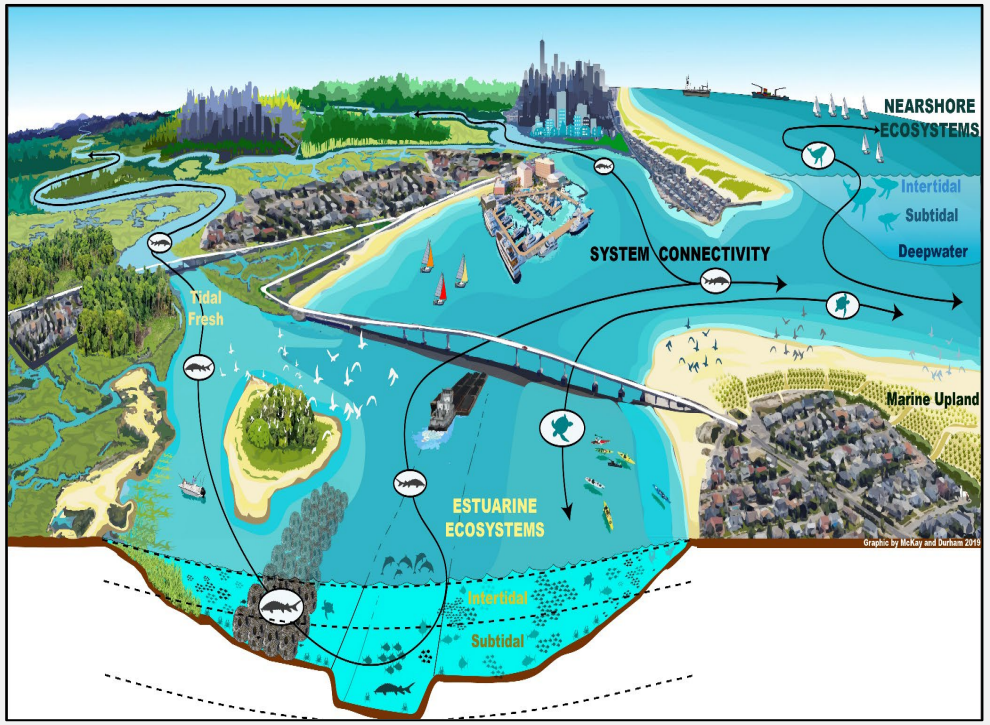


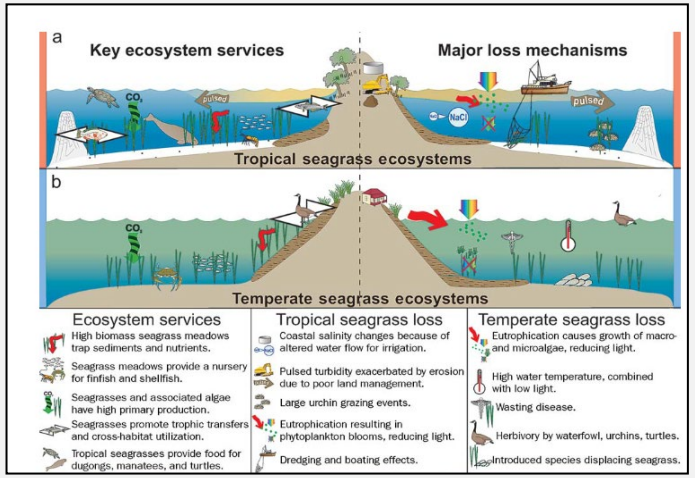
What are conceptual models?

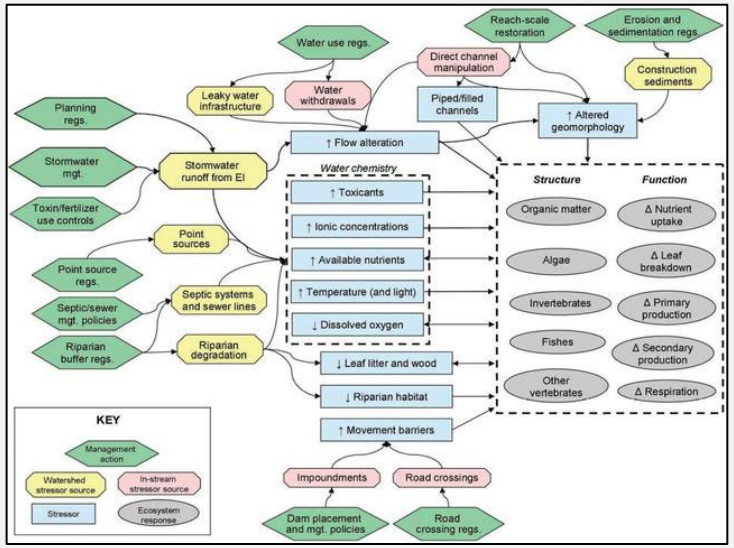
Visual Storytelling

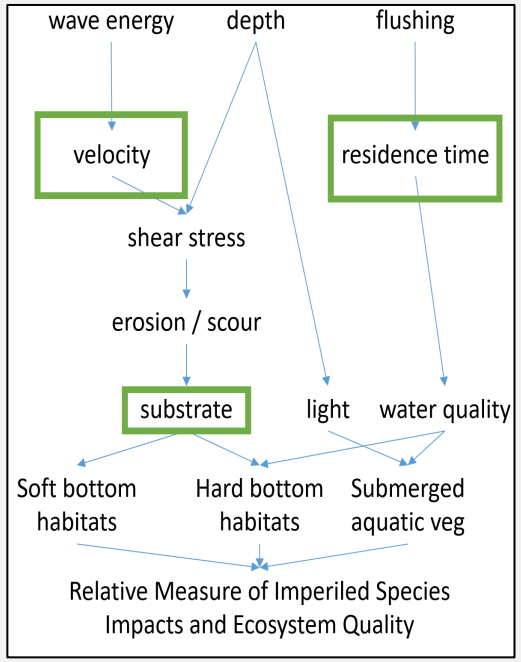
A conceptual model is a tentative description of a system or sub-system that serves as a basis for intellectual organization.

- Describe functional relationships among **essential** system components
- Tells the story of how the system works









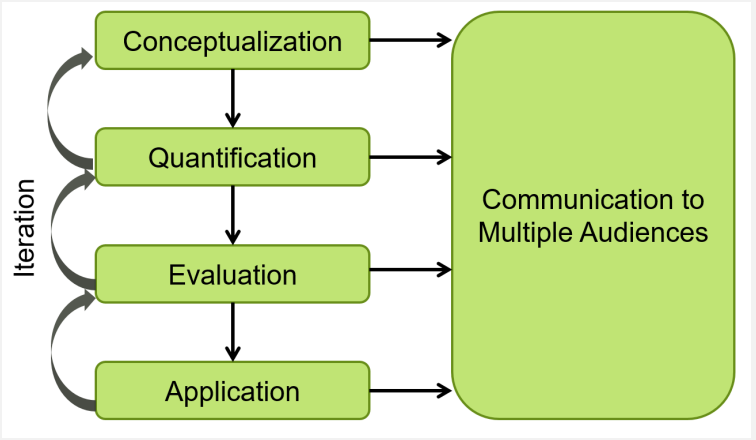
How are conceptual models used?

Develop a shared understanding:

- Synthesis of different perspectives
- Team building
- Communication
- Compilation of collective knowledge

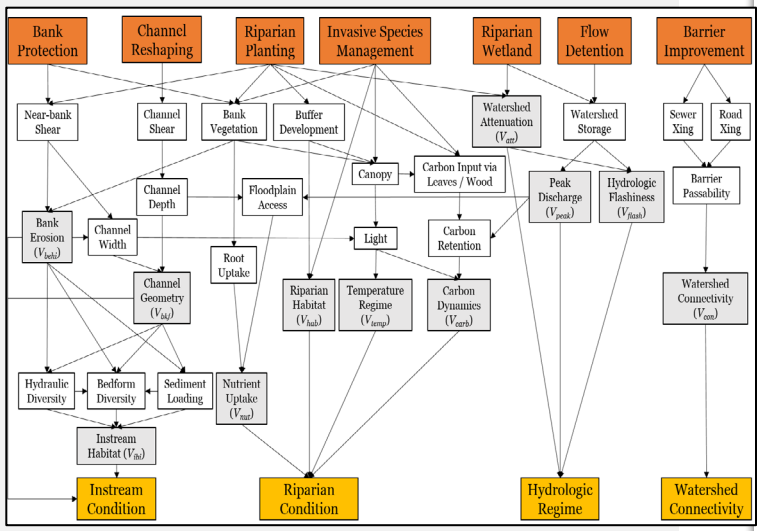
Set the stage for numerical models:

- Identify important variables
- Describe critical processes
- Articulate flow of logic
- Define key data gaps



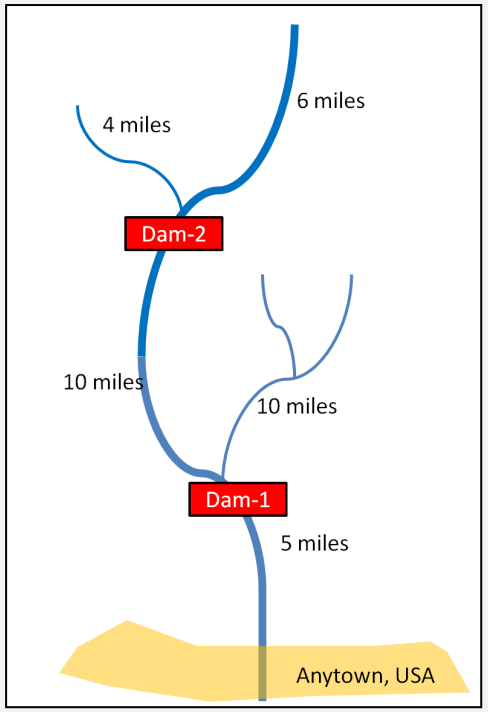
Inform restoration decisions:

- Diagnose problems
- Guide management actions
- Identify key decision metrics
- Inform monitoring plans

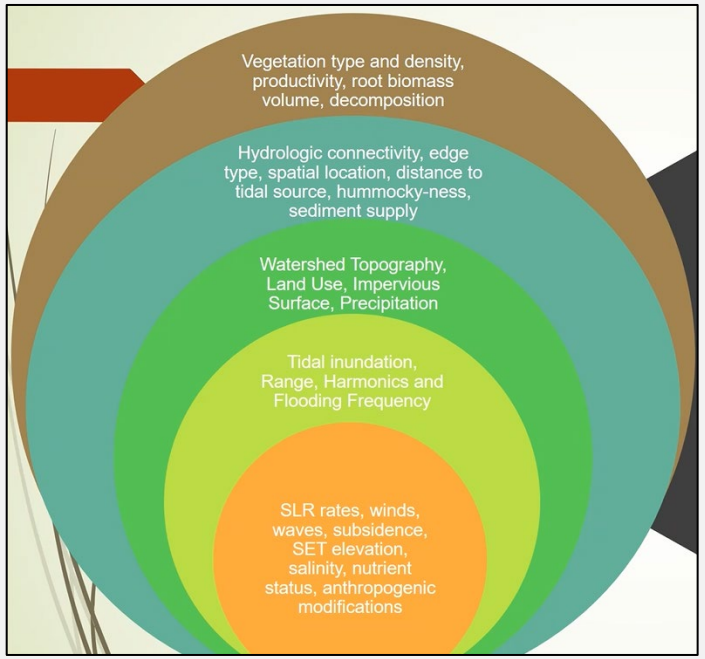


Different Types of Conceptual Models

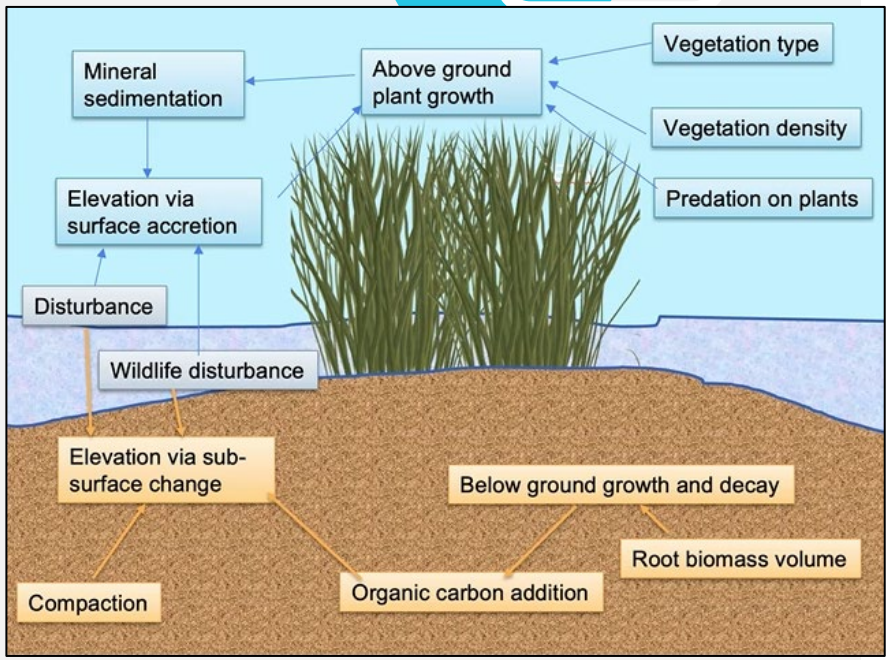
Map (not always georeferenced)



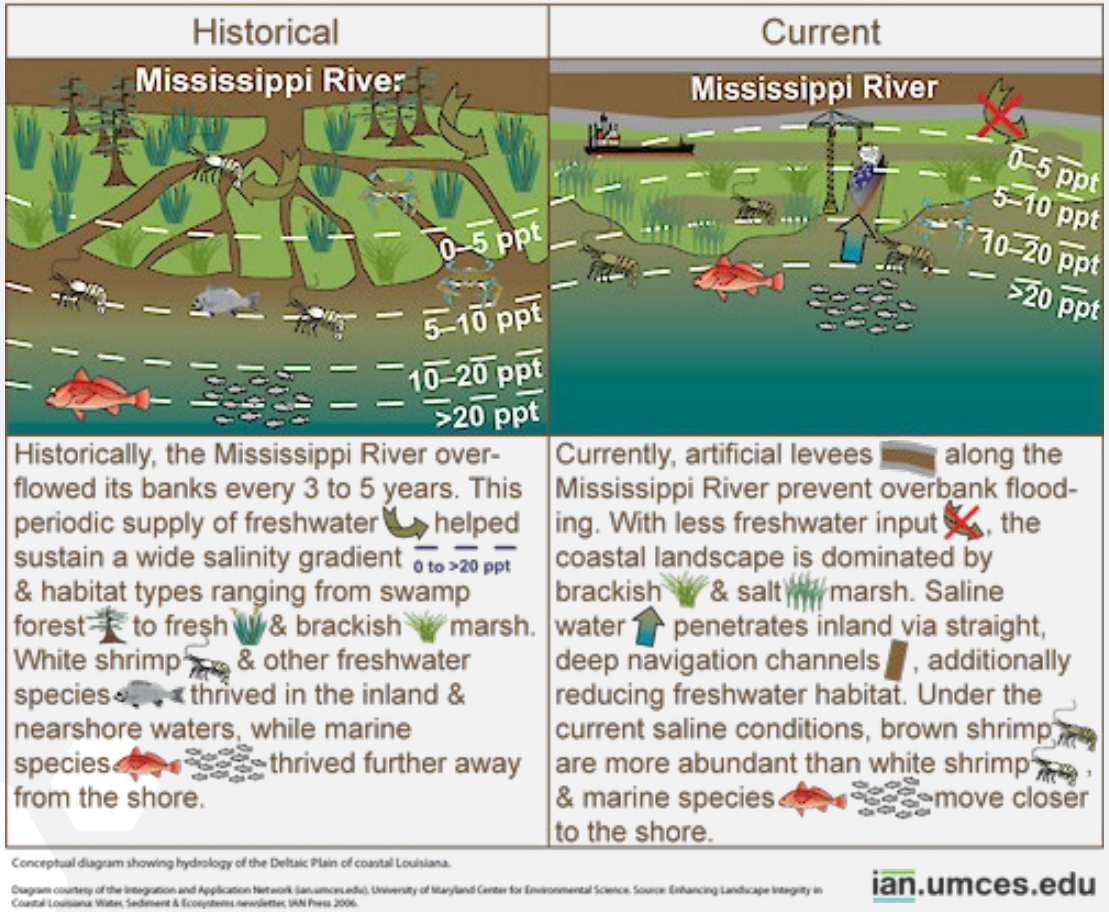
Pictures & Diagrams

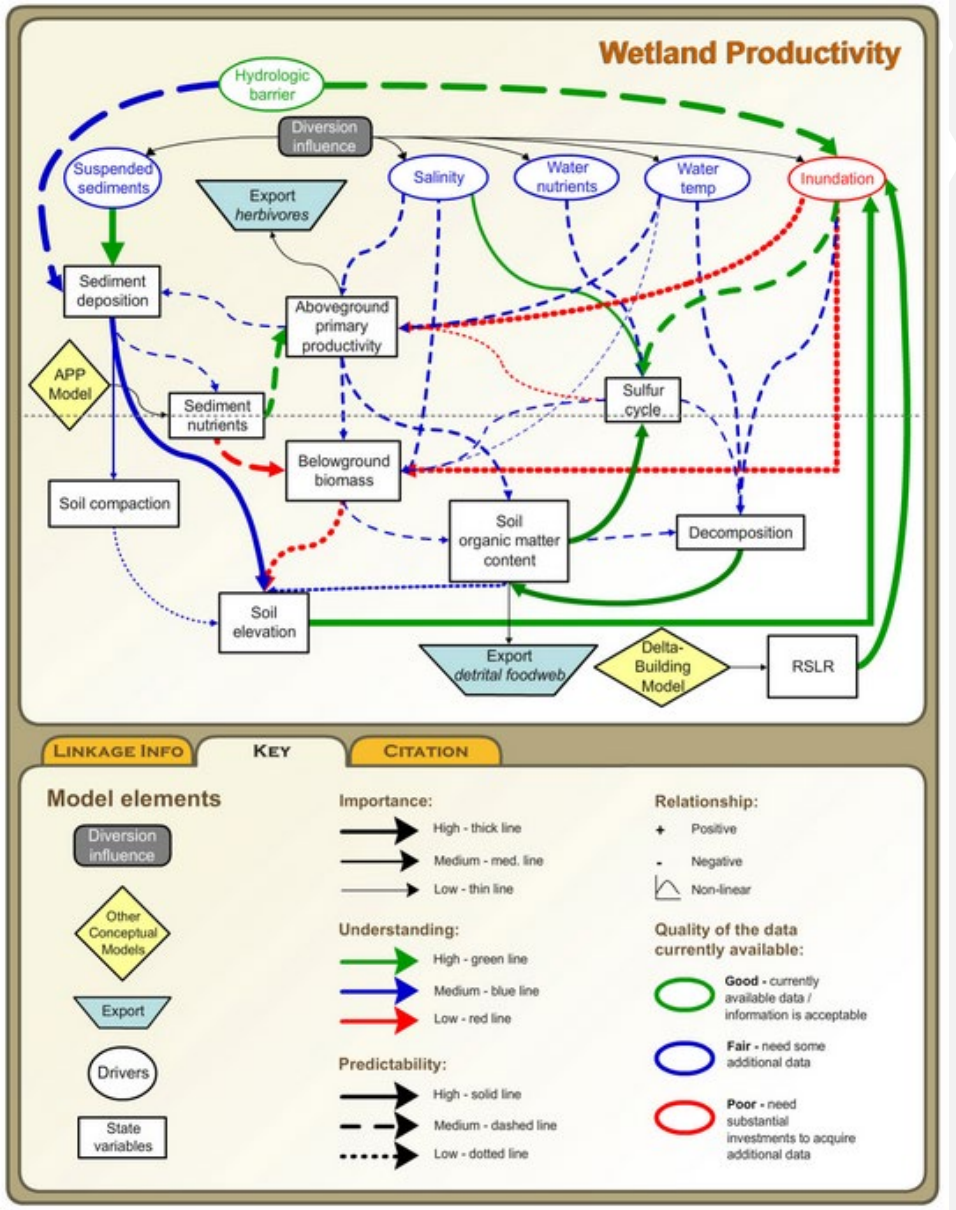


Box-and-Arrow Models



The same system can have many conceptual models

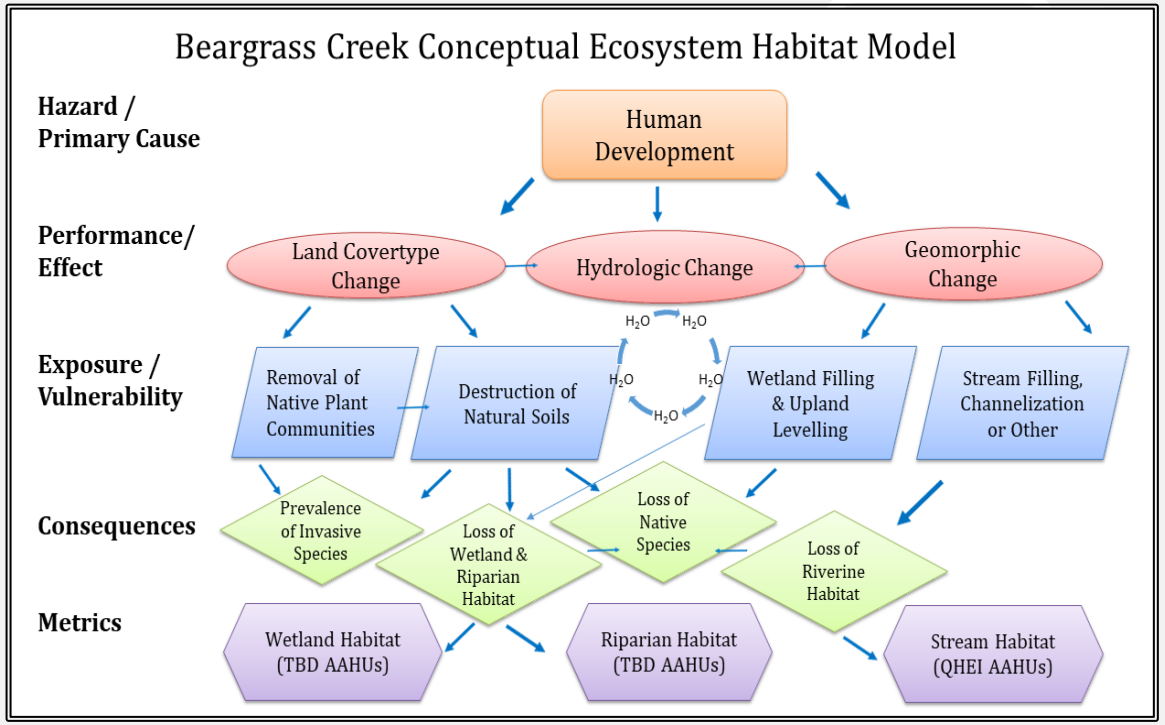


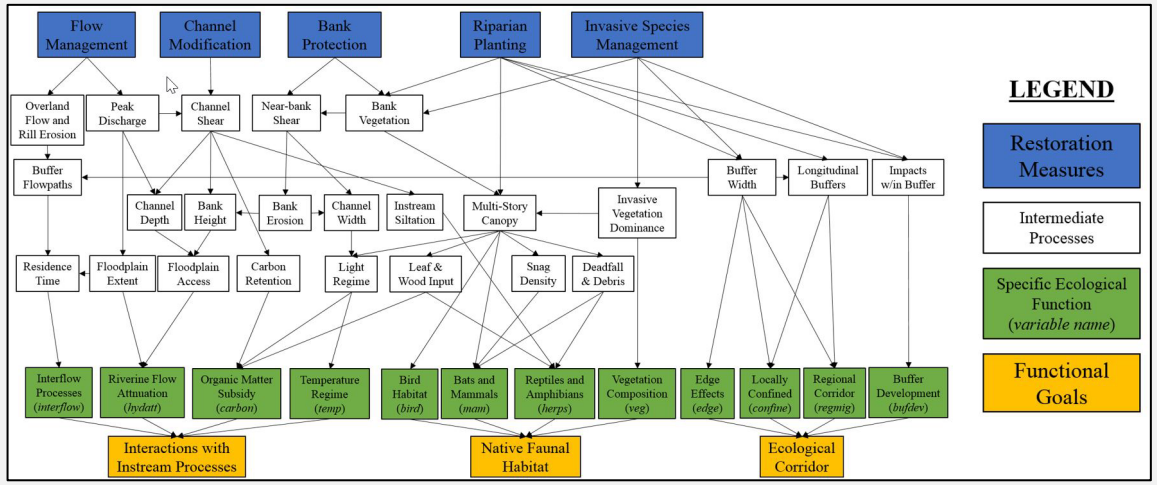


Figures: ian.umces.edu, Louisiana Coastwide Reference Monitoring System

Conceptual models are **NOT**…

- **The truth** – they are simplified depictions of reality
- **Comprehensive** – they focus only upon 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

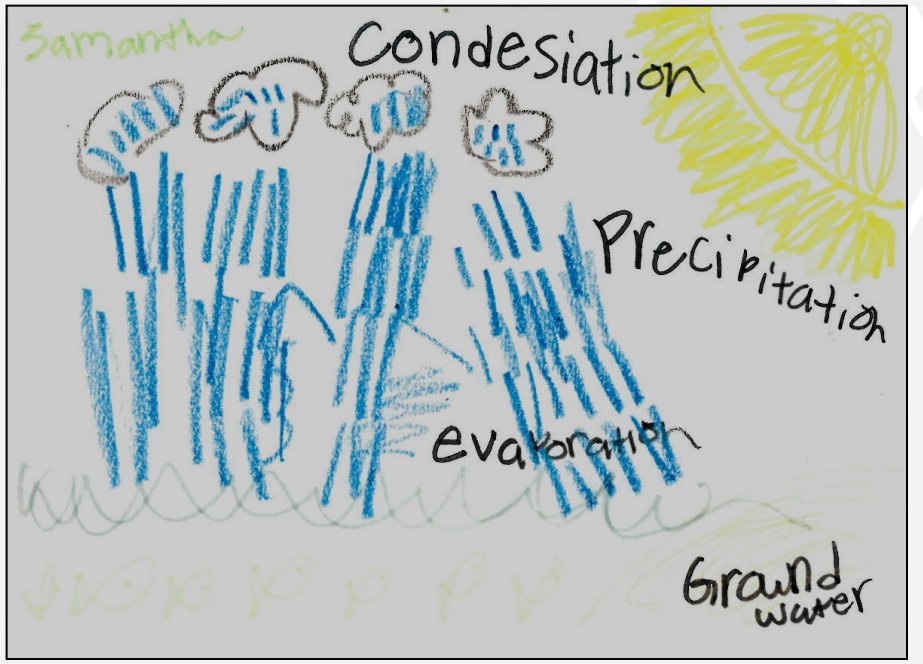


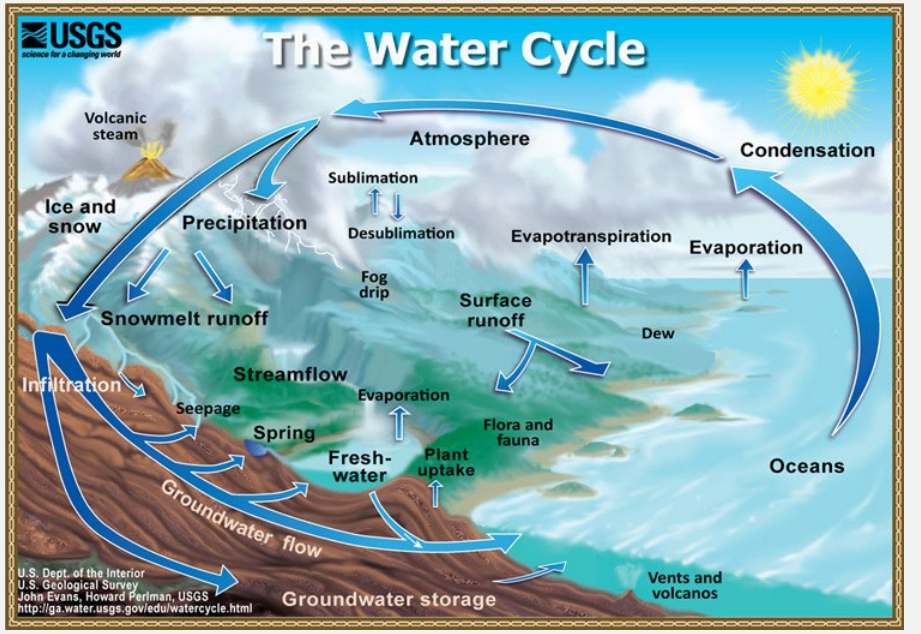


Figures: USACE feasibility study on the Three Forks of Beargrass Creek, Louisville, Kentucky

Common Misconceptions

- A model cannot be built with incomplete understanding.
  - FALSE: Incomplete information is the norm in environmental management!
- A model must be as detailed and realistic as possible.
  - FALSE: “Lean” models are often the most elegant. Remember Einstein’s aphorism…As simple as possible, but no simpler!





Figures: Sarah Miller’s niece, USGS

Conceptual Model Development

Conceptual Model Development

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

Document each step!

Characteristics of useful conceptual models

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

Good conceptual ecological models should include:

- Those physical, chemical and biological attributes of the system that drive dynamics.
- The mechanisms by which ecosystem drivers, both internal (e.g., flow rates) and external (e.g., climate), cause change
- Critical thresholds of processes and environmental conditions
- Discussion of assumptions and gaps in the state of knowledge, especially those that limit the predictability of outcome
- Identification of current characteristics of the system that may limit the achievement of management outcomes.
- Adequate references to substantiate the model.

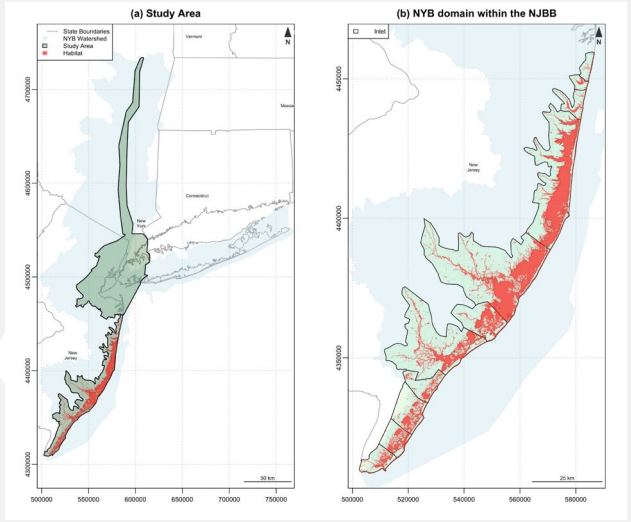
Reviewing conceptual models

- 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, floods)?

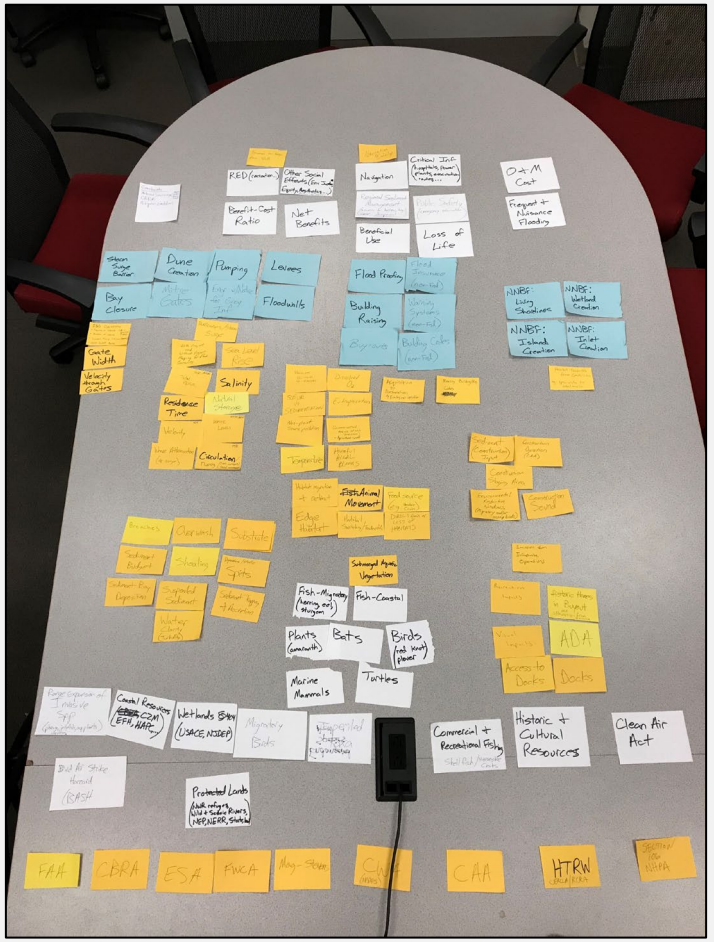
Think of conceptual modeling as storytelling

What audience are you reaching?

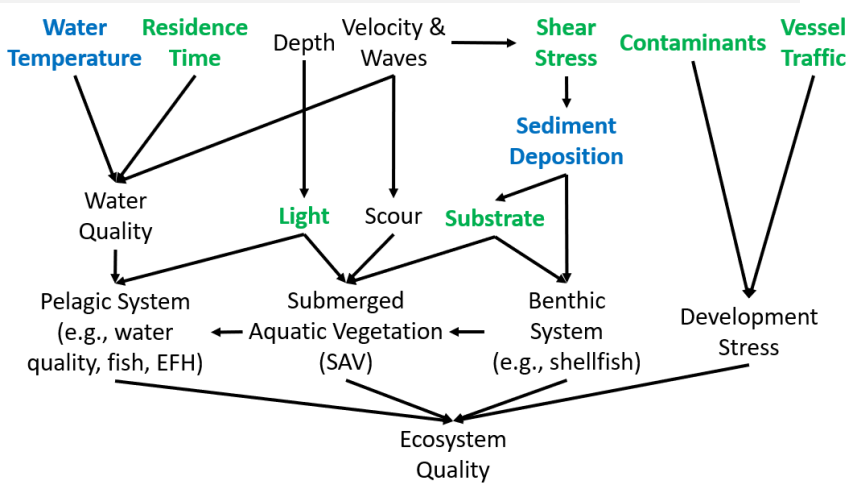
What is the setting of your story?



Who are the characters?

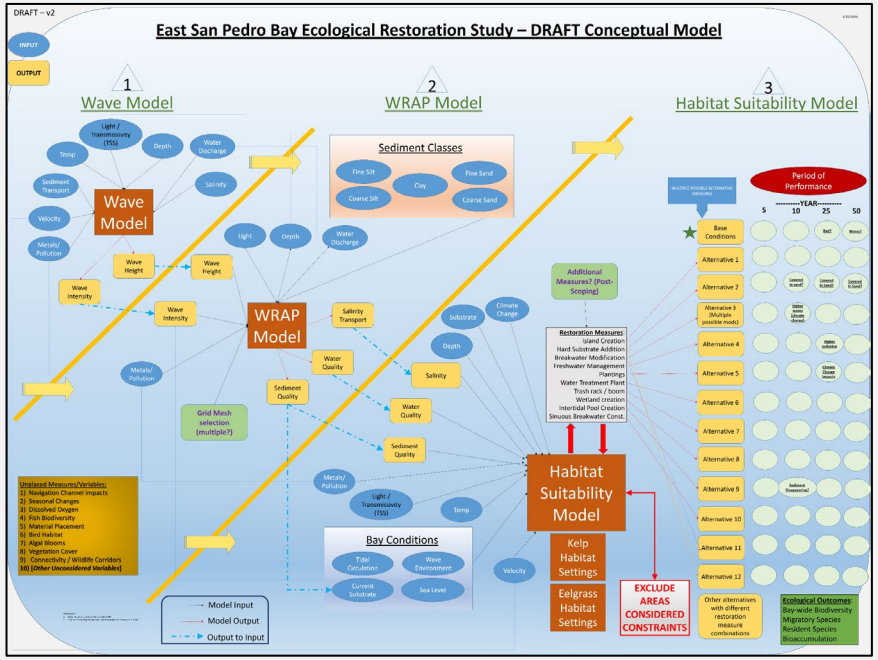


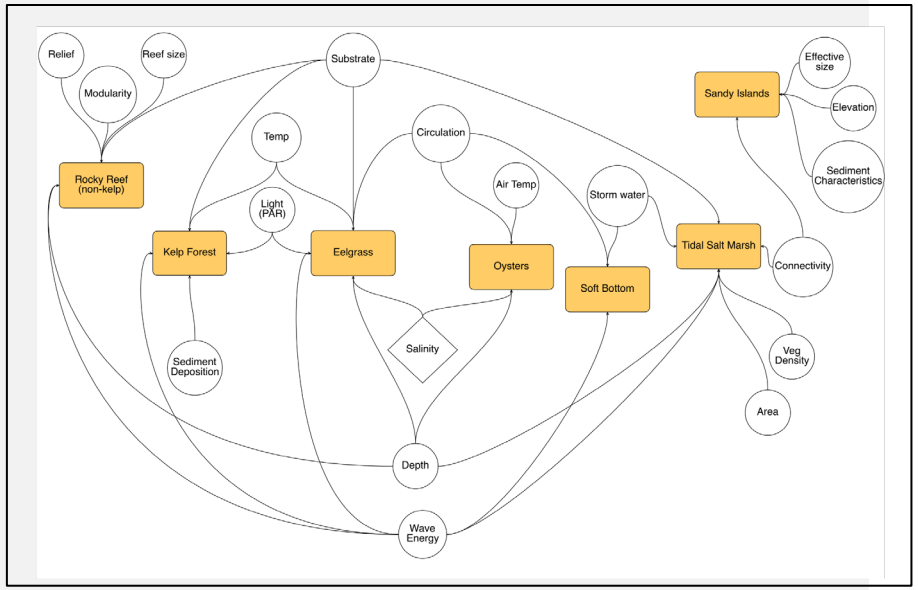
What is the plot?



Figures: New York Bight Ecological Model (McKay)

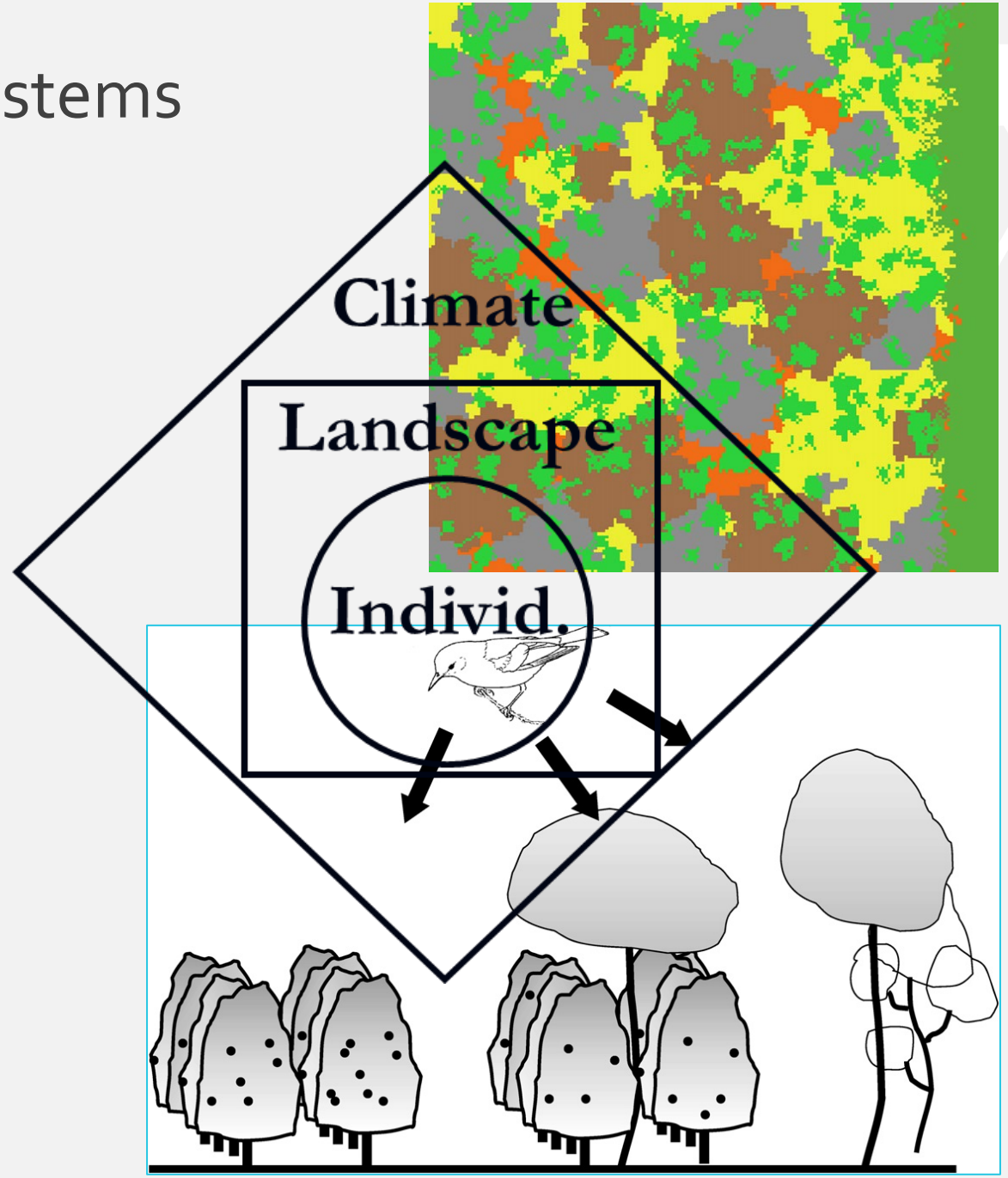
The “art” of conceptual modeling is in iterating



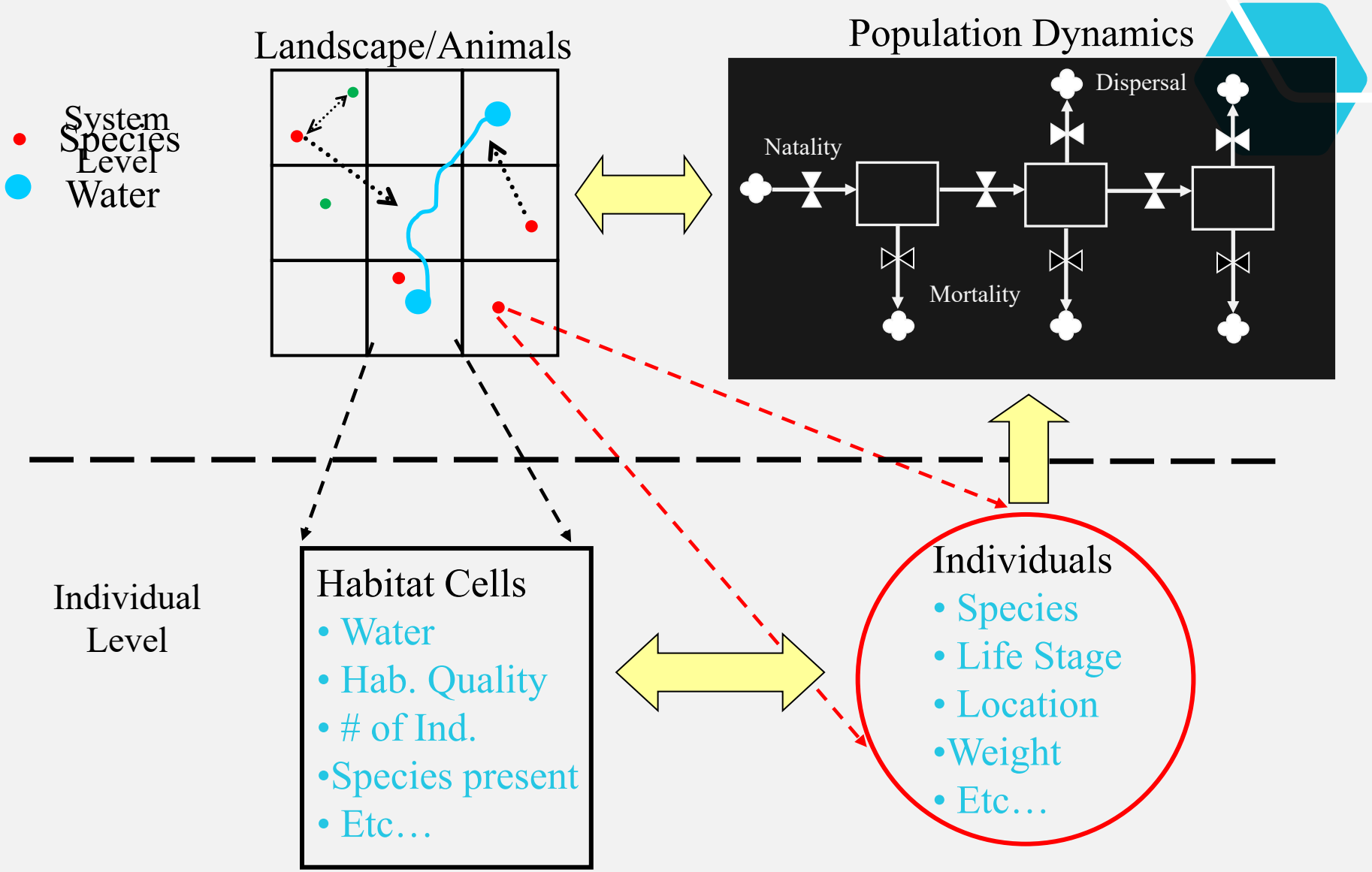


Conceptualizing agent-based systems

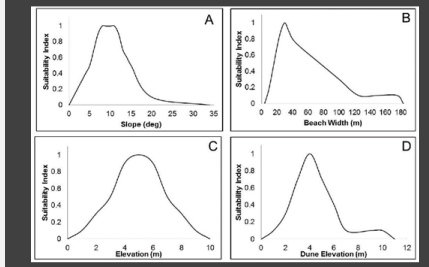
- ABMs are difficult to conceptualize due to complexity.
  - Agentsets can have extensive “owned” characteristics
  - Multiple temporal and spatial scales are nested
  - Essentially a computer program
- Multiple approaches for conceptualizing ABMs

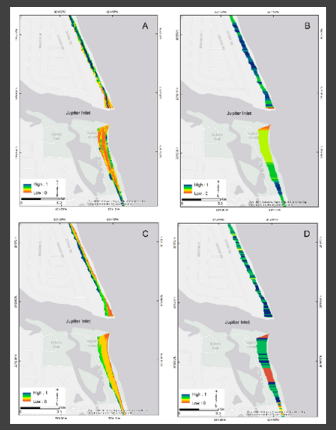


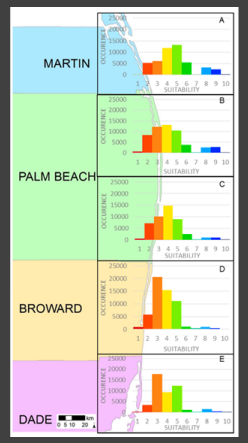
Individual-based model
Conceptual overview

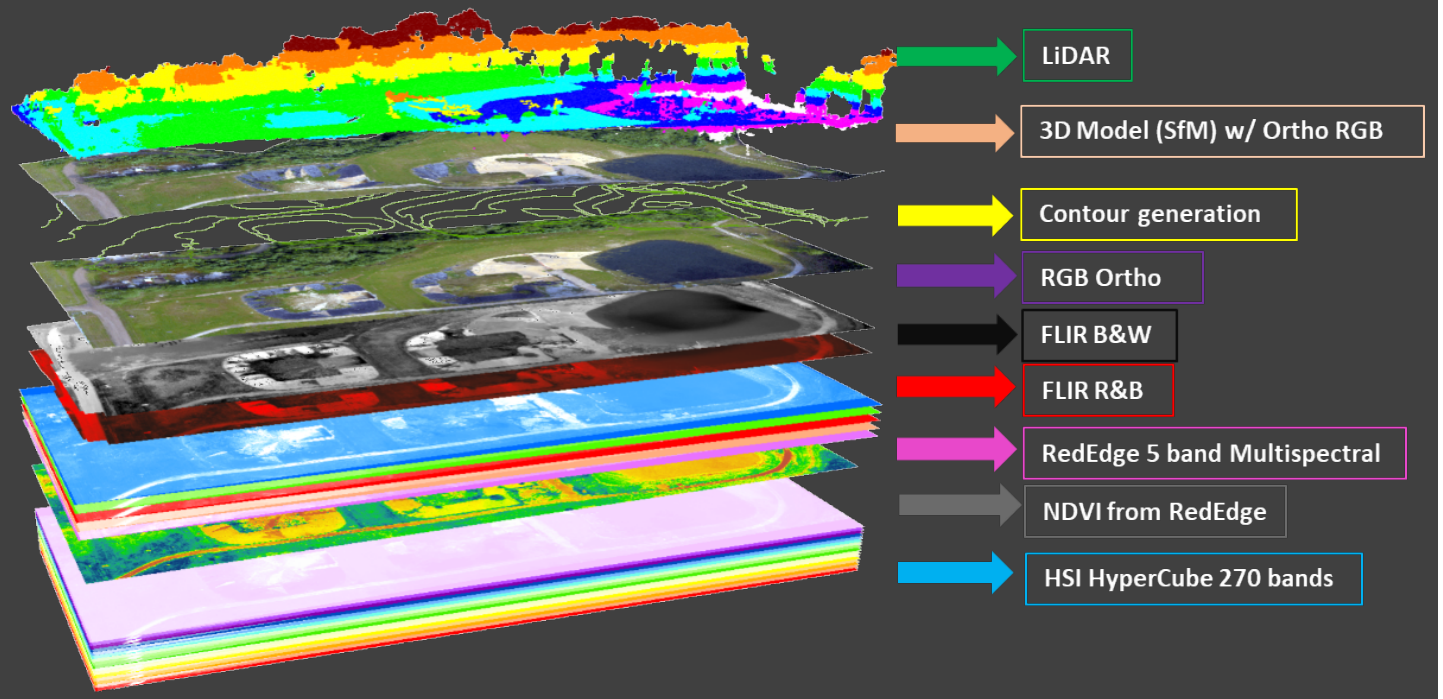


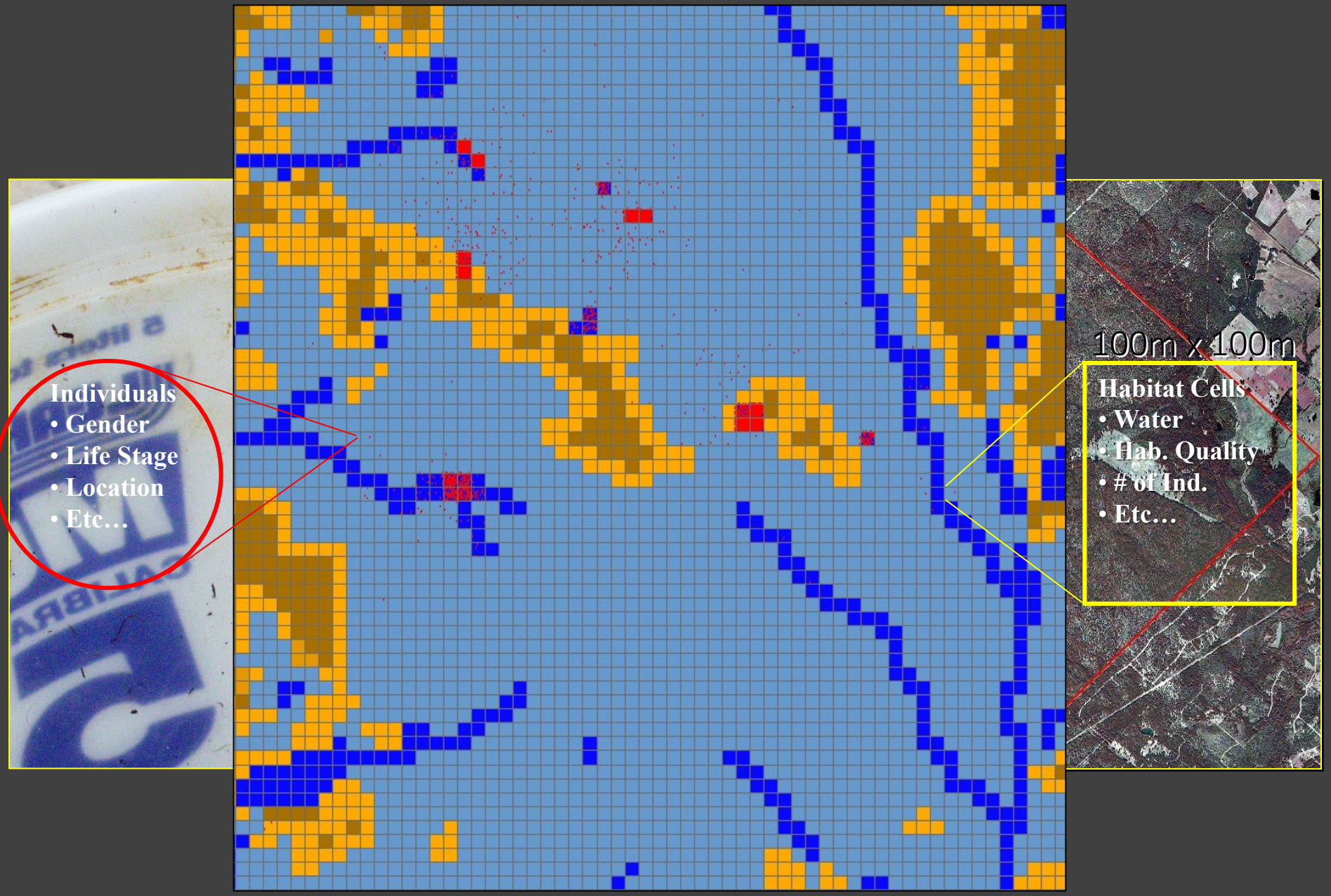
Spatial dimensions



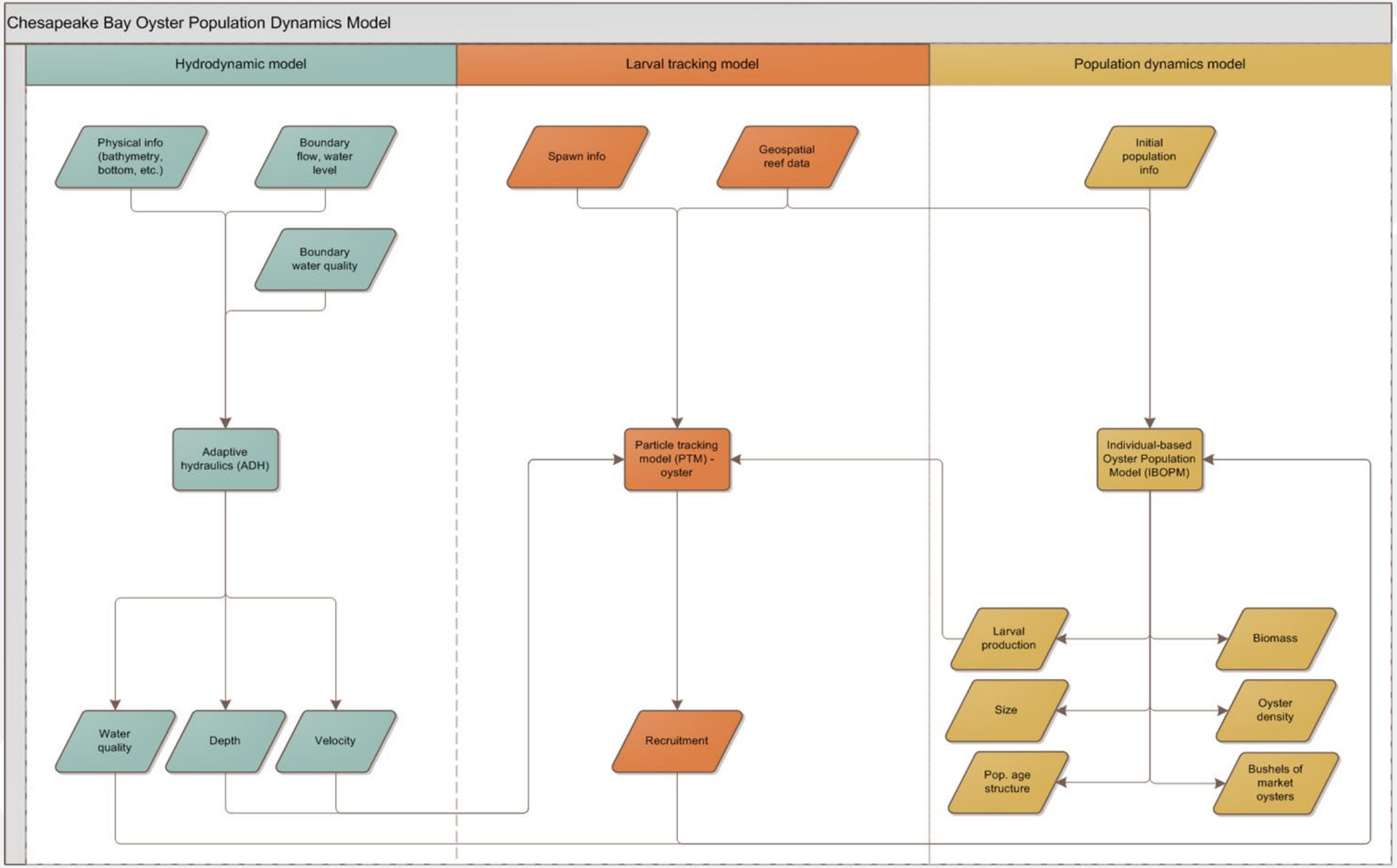


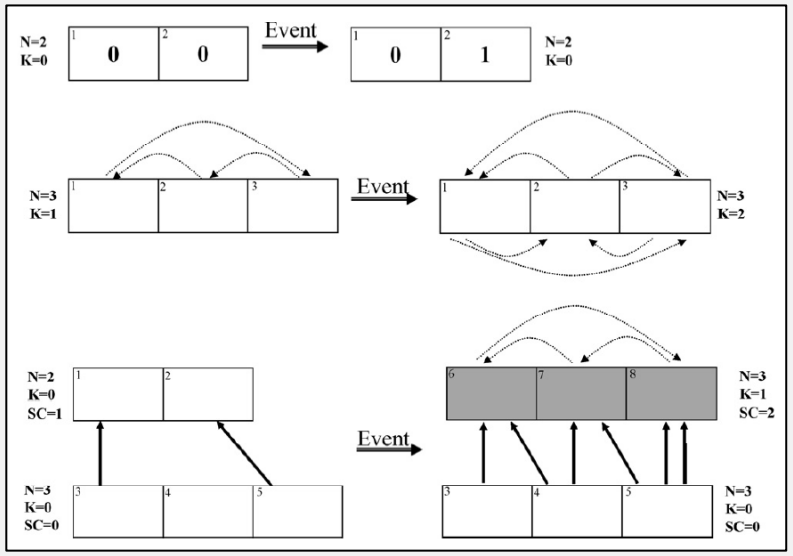


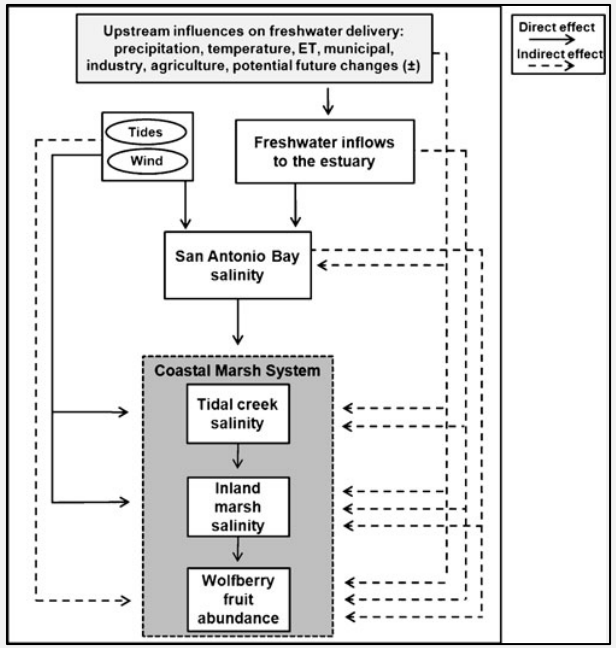


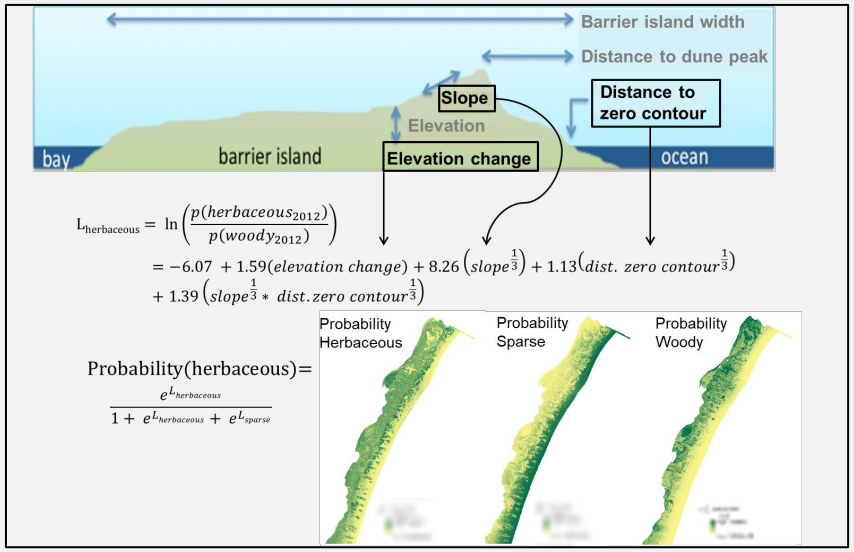


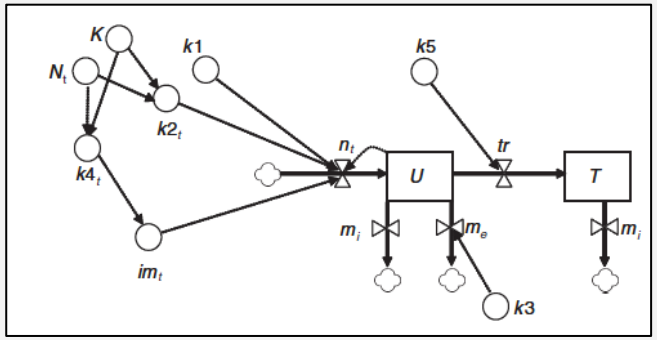
It’s tricky to conceptualize multiscale systems

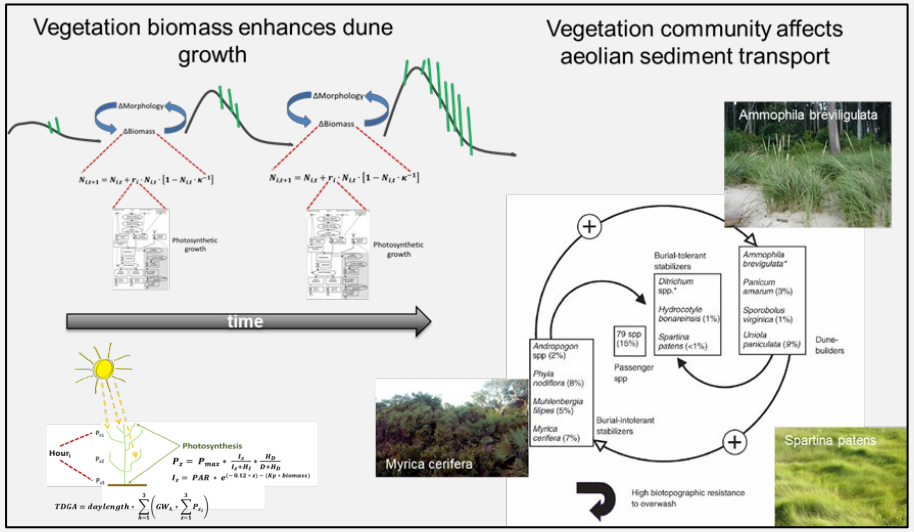

Chesapeake Bay Oyster Population Dynamics Model
Hydrodynamic model
Larval tracking model
Population dynamics model
Physical info (bathymetry, bottom, etc.)
Boundary flow, water level
Boundary water quality
Adaptive hydraulics (ADH)
Water quality
Depth
Velocity
Spawn info
Geospatial reef data
Particle tracking model (PTM) - oyster
Recruitment
Initial population info
Individual-based Oyster Population Model (IBOPM)
Larval production
Size
Pop. age structure
Biomass
Oyster density
Bushels of market oysters

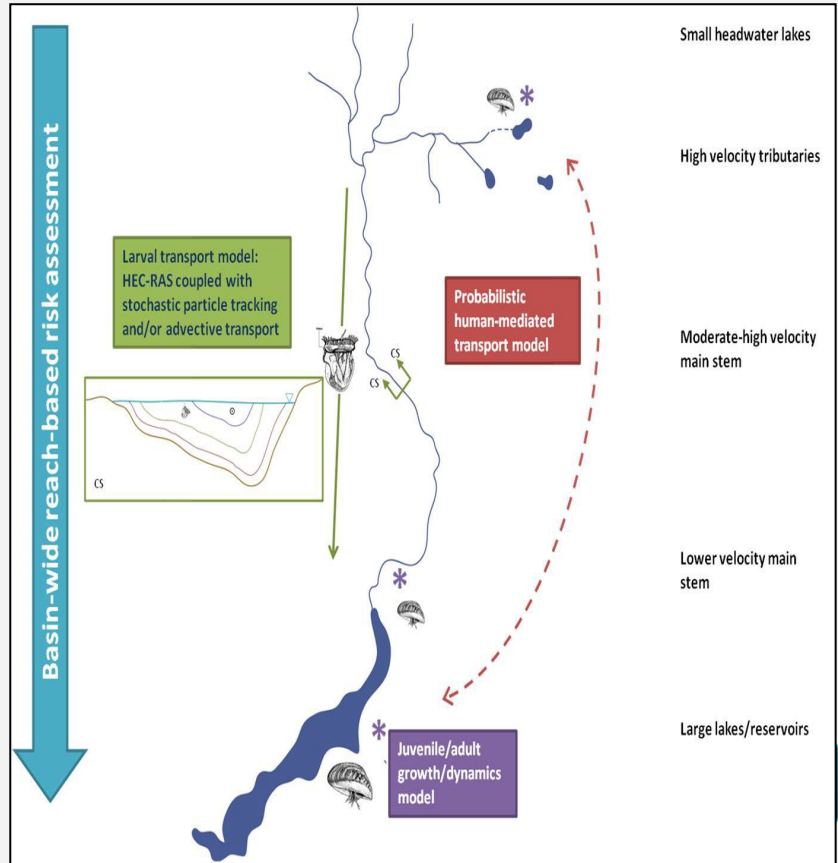

N=2
K=0
0
0
Event
0
1
N=2
K=0
N=3
K=1
Event
N=3
K=2
N=2
K=0
SC=1
Event
N=3
K=1
SC=2
N=5
K=0
SC=0
N=3
K=0
SC=0

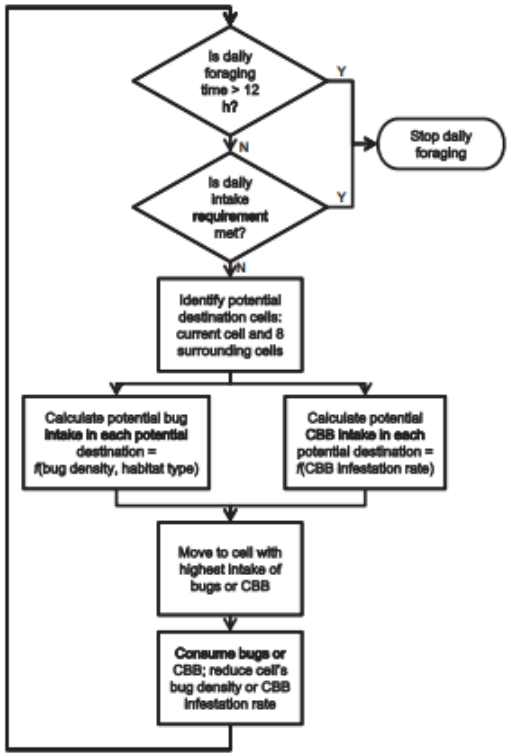

Upstream influences on freshwater delivery: precipitation, temperature, ET, municipal, industry, agriculture, potential future changes (±)
Direct effect
Indirect effect
Tides
Wind
Freshwater inflows to the estuary
San Antonio Bay salinity
Coastal Marsh System
Tidal creek salinity
Inland marsh salinity
Wolfberry fruit abundance

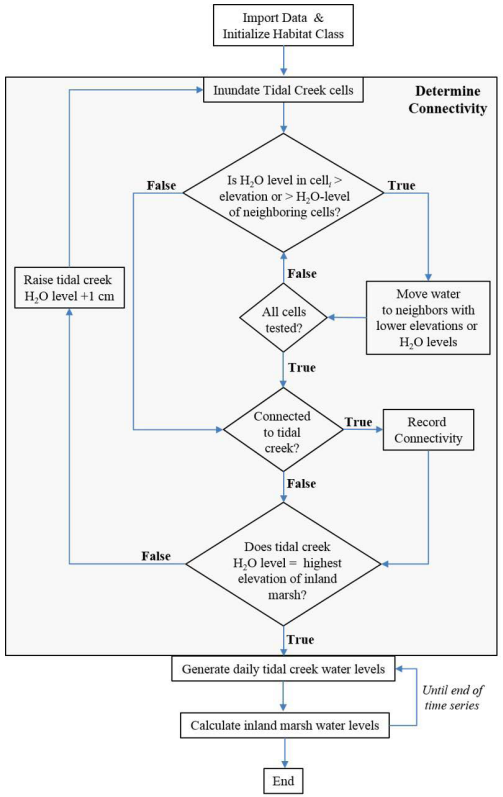

Barrier island width
Distance to dune peak
Slope
Distance to zero contour
Elevation
Elevation change
bay
barrier island
ocean
$L_{herbaceous} = \ln\left(\frac{p(herbaceous_{2012})}{p(woody_{2012})}\right)$
$= -6.07 + 1.59(elevation\ change) + 8.26\left(slope^{\frac{1}{3}}\right) + 1.13\left(dist.\ zero\ contour^{\frac{1}{3}}\right)$
$+ 1.39\left(slope^{\frac{1}{3}} * dist.zero\ contour^{\frac{1}{3}}\right)$
$Probability(herbaceous) = \frac{e^{L_{herbaceous}}}{1 + e^{L_{herbaceous}} + e^{L_{sparse}}}$
Probability Herbaceous
Probability Sparse
Probability Woody

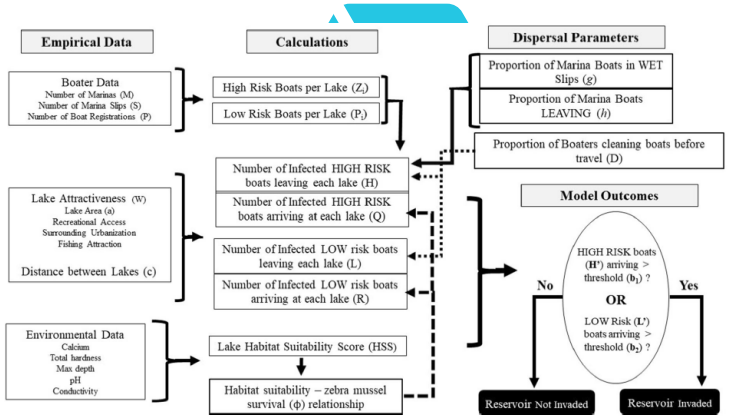

K
N_t
k1
$k2_t$
$k4_t$
im_t
n_t
U
tr
T
k5
m_i
m_e
m_i
k3


Vegetation biomass enhances dune growth
ΔMorphology
ΔBiomass
Photosynthetic growth
time
Photosynthesis
Hour
TDGA = daylength · $\sum_{k=1}^{n}\left(GW_k \cdot \sum_{z=1}^{n} P_{z_i}\right)$
Vegetation community affects aeolian sediment transport
Ammophila breviligulata
Myrica cerifera
Spartina patens
Burial-tolerant stabilizers
Ammophila breviligulata*
Oltrichum spp.*
Panicum amarum (3%)
Hydrocotyle bonariensis (1%)
Sporobolus virginica (1%)
Spartina patens (<1%)
Uniola paniculata (9%)
79 spp (15%)
Passenger spp
Dune-builders
Andropogon spp (2%)
Phyla nodiflora (8%)
Muhlenbergia filipes (5%)
Myrica cerifera (7%)
Burial-intolerant stabilizers
High biotopographic resistance to overwash


Basin-wide reach-based risk assessment
Larval transport model: HEC-RAS coupled with stochastic particle tracking and/or advective transport
Probabilistic human-mediated transport model
Juvenile/adult growth/dynamics model
CS
Small headwater lakes
High velocity tributaries
Moderate-high velocity main stem
Lower velocity main stem
Large lakes/reservoirs







Coding diagrams

Documenting ABMs using ODD protocol (Chapter 3), part 1

- Purpose and patterns
- Entities, state variables, scales
- Process overview & scheduling

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

Conceptual Modeling Exercise

- Develop a conceptual model for your research question
- Start big and write everything down.
- Then group
- Then connect
- ID expected patterns with graphs (no specific numbers needed)
- There are no “right” or “wrong” answers.
  - Your story is your story. There are no expectations about what will (or will not) emerge from these sessions.
  - Choose your own adventure.

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

Homework – Design your ABM

- Using your conceptual models, start designing your ABM.
- Answer the questions on page 42. No more than 2 pages.
- Don’t worry about being super thorough, we’ll work through any trouble spots

Homework – Netlogo Dictionary