Modeling basics

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Homer Navigation Improvement Study
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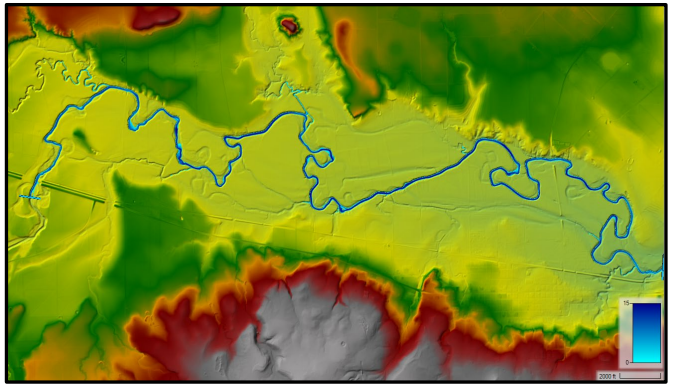
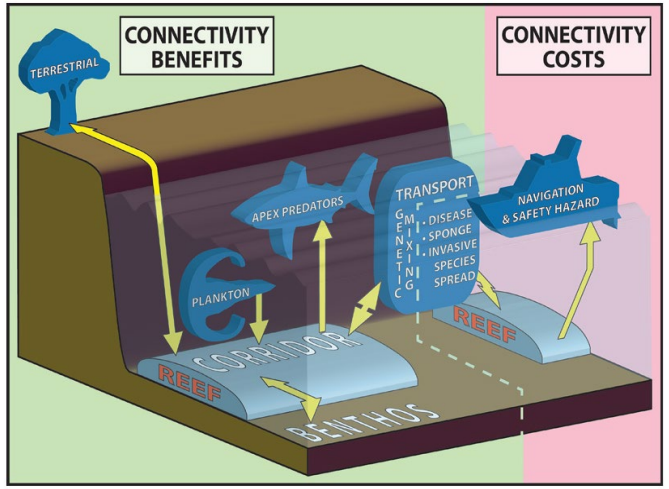
Lecture overview

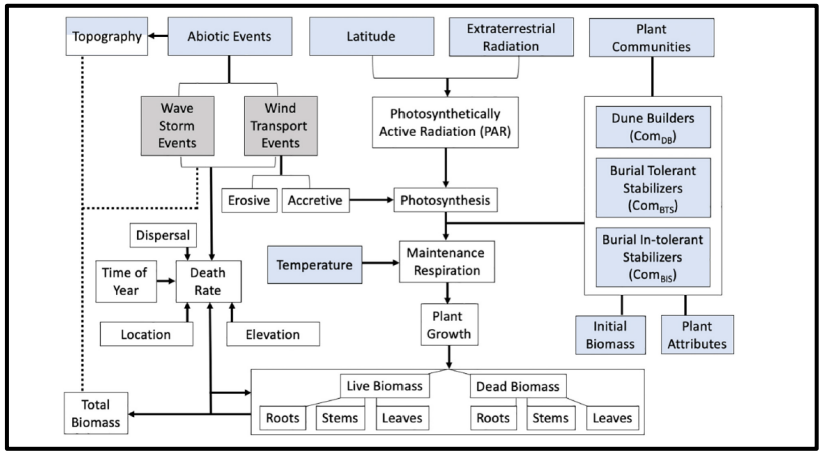
- What is a “model”?
- General notes on modeling
- Types of models
- Overview of the “modeling process”



San Saba River, Texas



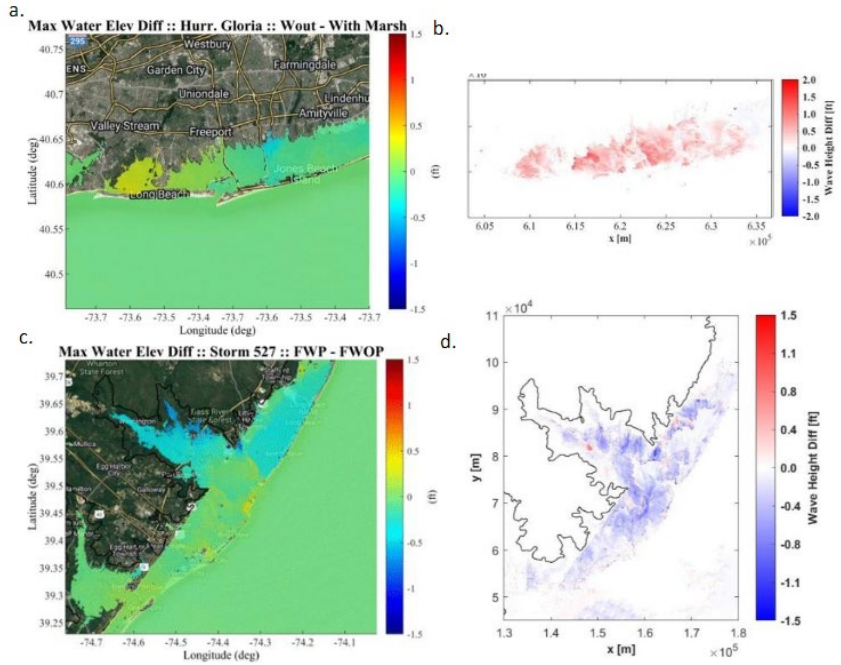
Altman et al. 2022



Charbonneau et al. 2022

Definitions of models

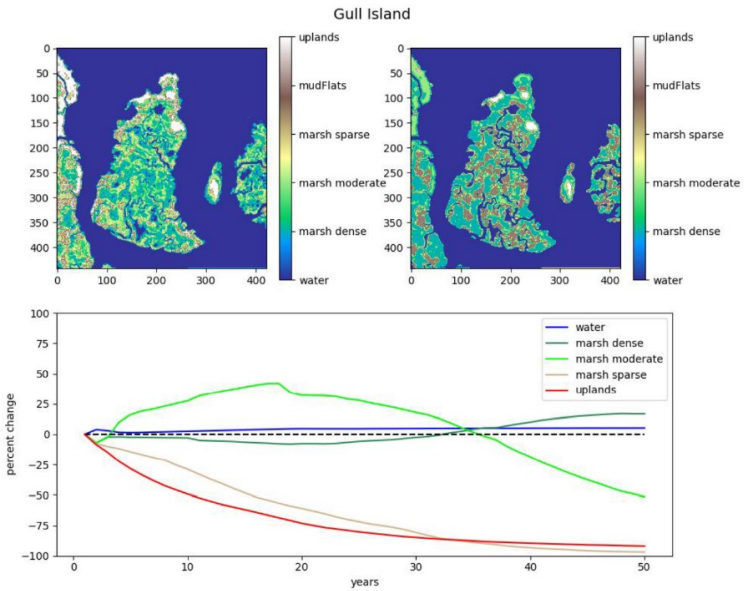
- **Commonly defined as “abstractions of reality”**
- **Model certification definition (EC-1105-2-412):**
  - “A representation of a system for a purpose”
  - “A way to represent a system for the purposes of reproducing, simplifying, analyzing, or understanding it”
- **How would <u>you</u> tell your family what a model is?**



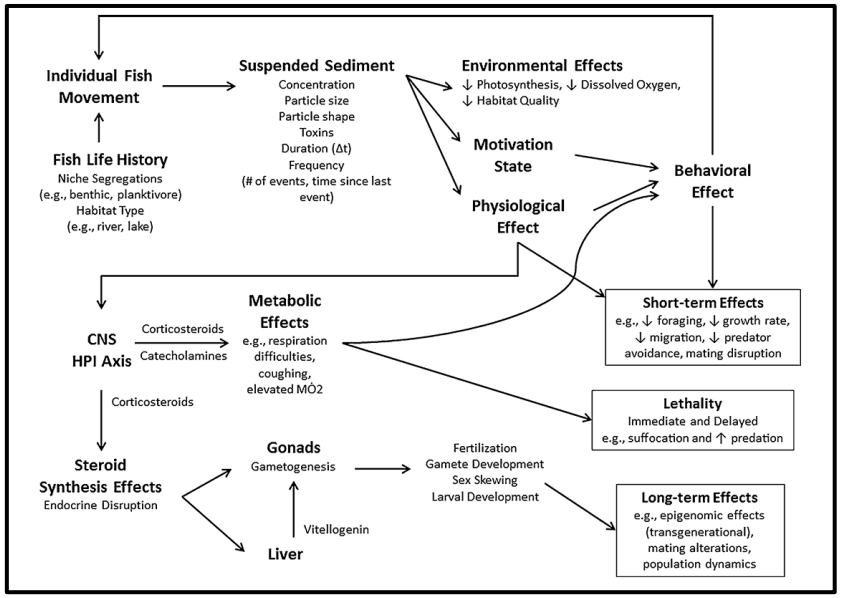
Piercy et al. 2023

Defining “models” for this course

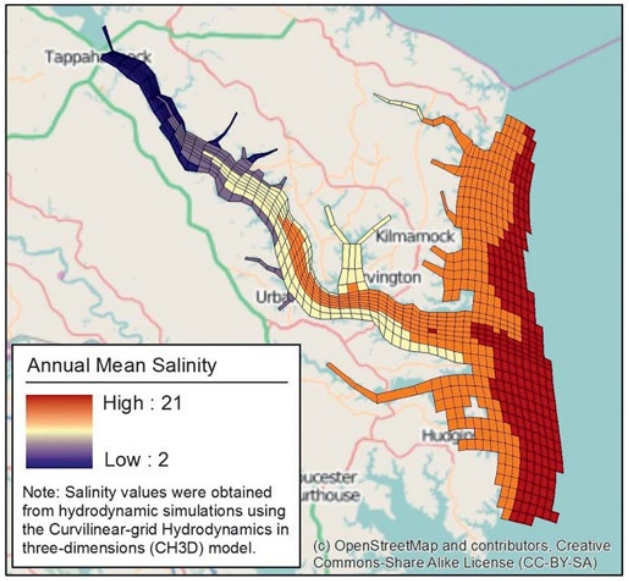
Representations of environmental, social, or ecological systems



Huff et al. 2024, EMRRP Webinar



Kjelland et al. 2015

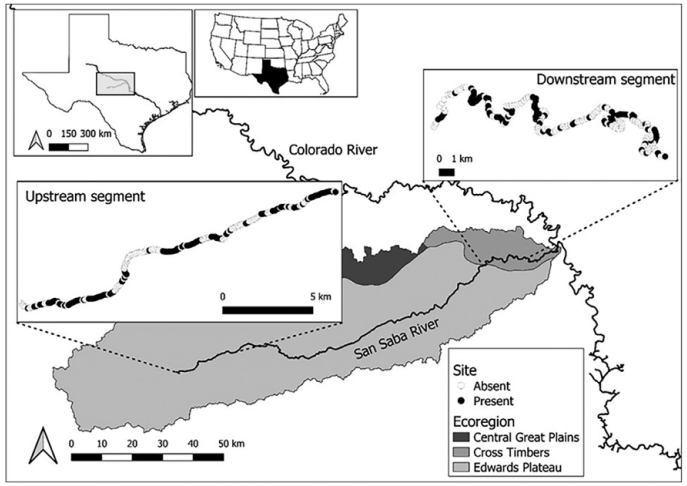


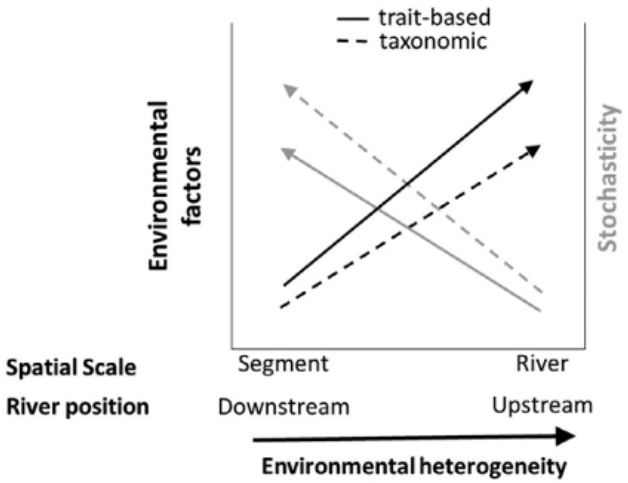
Swannack et al. 2014

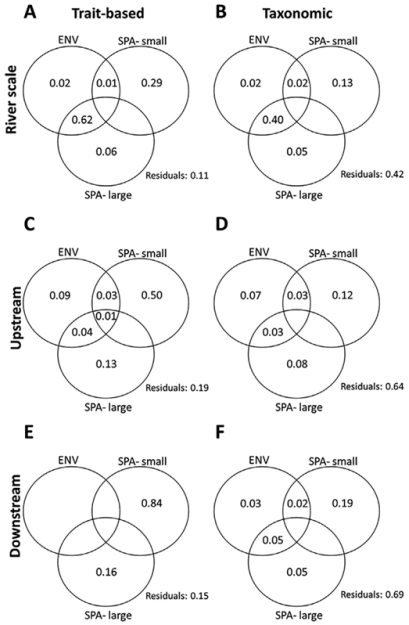
SIDE NOTE: **not** software applicable to any situation

Ecological modeling in the Corps

- **Ecosystems are inherently complex, interdependent systems**
- **Ecology is a question-driven discipline**
- **Models are developed ad-hoc (project-by-project) with little reuse**
  - Each species reacts differently to stimuli
  - Multiple approaches for a single problem
    - Habitat vs. population vs. meta-population vs. community vs. ecosystem
  - Trade-offs: detail, scale, expense

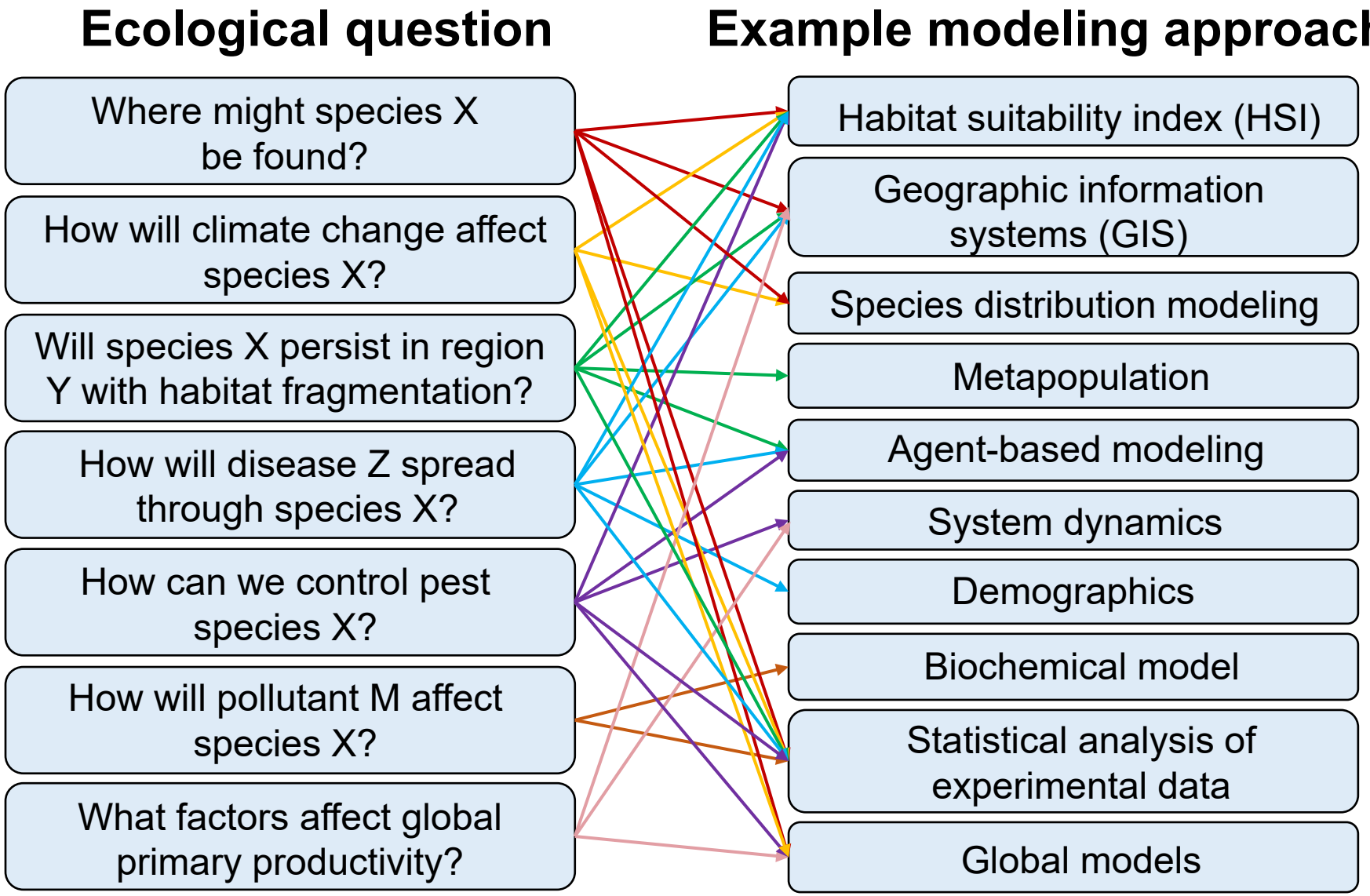






Figures: Mitchell et al. 2023

Ecological modeling approaches



Engineering vs. ecological models (part 1)

Characteristics	Engineering models	Ecological models
Primary basis	Physics Chemistry	Physics Chemistry Biology Interactions
First principles?	Sometimes (e.g., laws of motion)	Rare/never (often unknown)
Knowledge of dynamics	Medium-high	Low-medium
Model confidence	Medium-high	Low-medium
Science/art	**90**/10	25/**75**

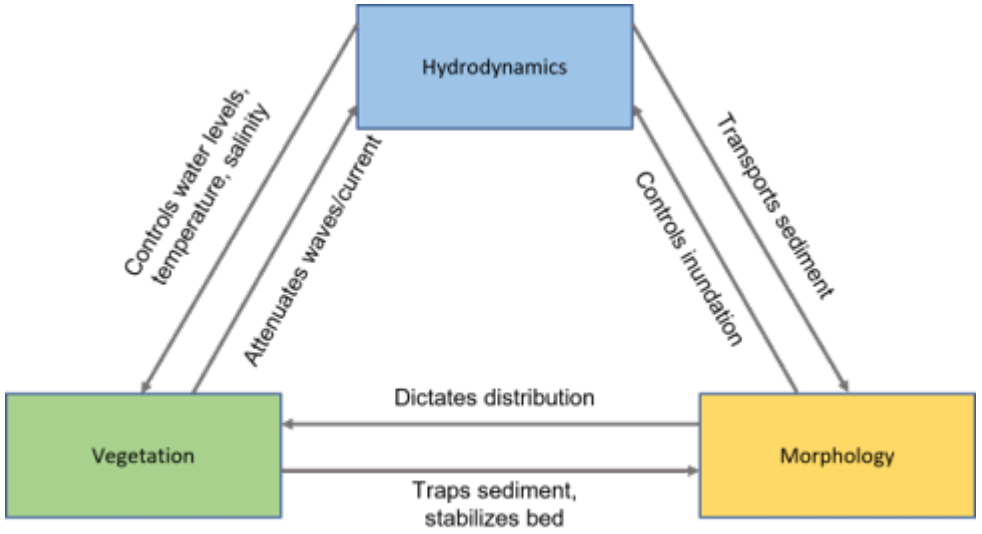
Engineering vs. ecological models (part 2)

Engineering models	Ecological models
Well-developed and reusable	Often single-use
New application uses old models	New application uses new models
A small set of models is sufficient	A toolbox of multiple approaches is required
Well understood model components	Most ecological systems are poorly understood
Used for prediction	Used for exploration and education
Heavily science-based	Often rely on local expertise
Often event-based	Often cover range of conditions or events

A few notes on models…

Why do we develop models?

- To increase understanding
- To organize thinking
- To forecast future conditions
- To inform decision-making

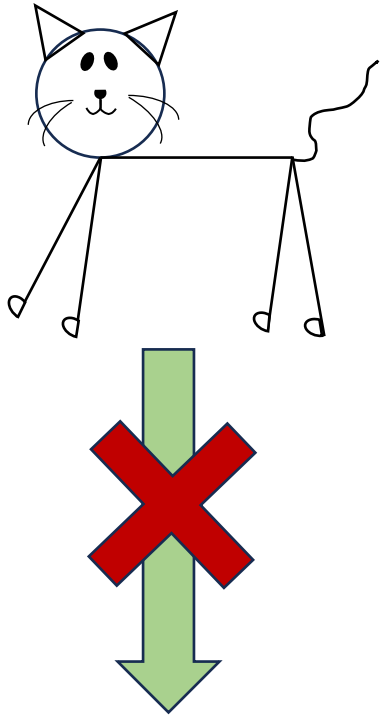


Russ et al. 2024

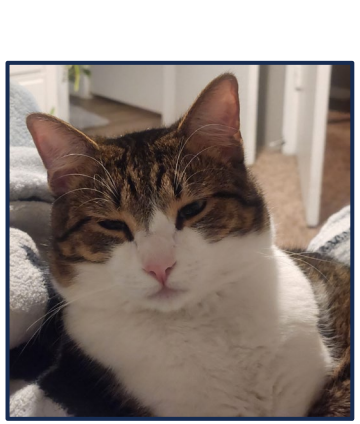
Questions to consider during model development

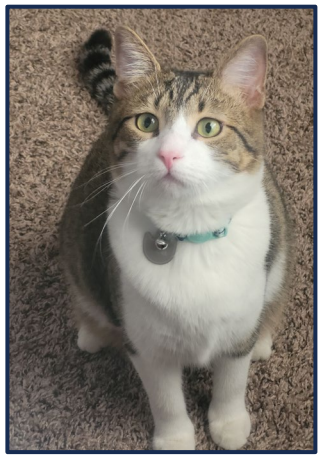
- Who is the intended user?
- What data and resources may the user have available?
- What costs may be incurred?
- What is the purpose of the model?
- What is NOT the purpose of the model?

Models are NEVER:



- **Answers or decisions**
  - People make decisions
  - Models inform people
- **Reality**
  - Inherently, a model is an abstraction of reality





Source: Bucc-ee

A few thoughts to consider at 10,000 feet before beginning…

Purpose/objectives:

- Why are you developing a model?
- What are you trying to accomplish?
- What is your question?
- What do you intend to simulate?

Fidelity:

- What level of accuracy is required?
- Exact vs. relative comparison

Space:

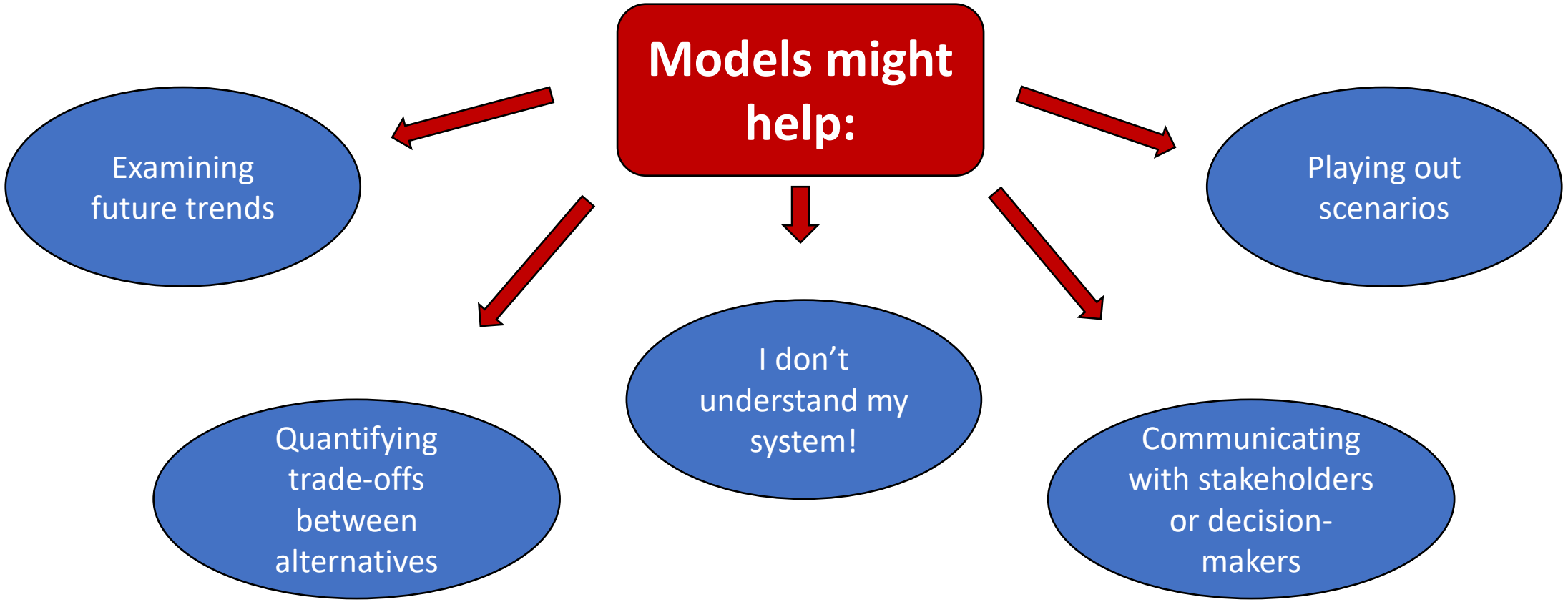
- Where is your target study area?
- What, if any, is your spatial resolution of interest?

Time:

- Is the model simulating time?
- How long and detailed (order of magnitude)?

Big picture:
Are these four categories commensurate?

When are models (in)appropriate?



When are models (in)appropriate?

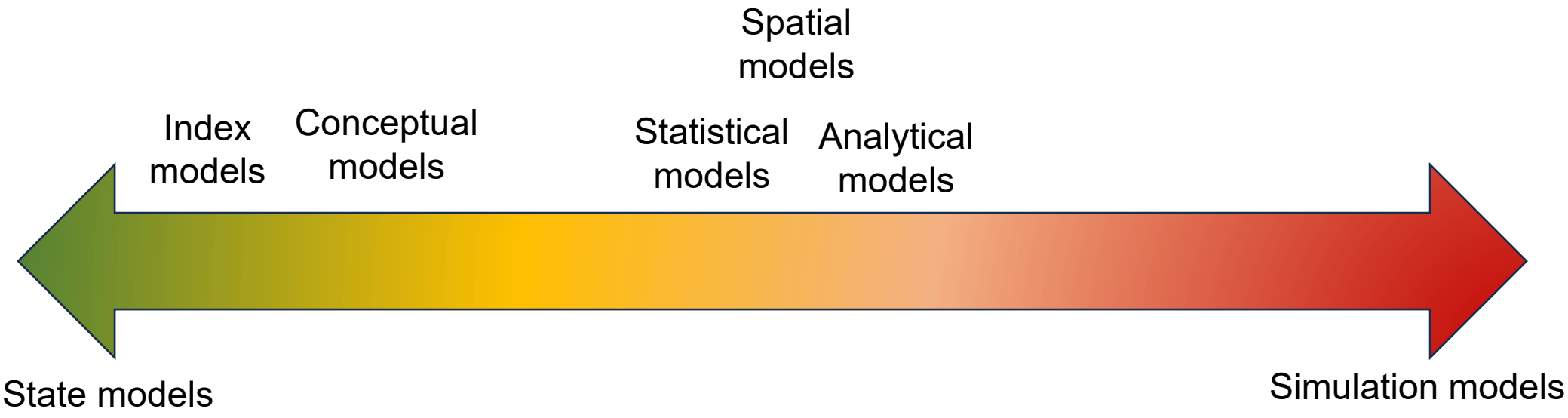
Common misconceptions

- **A model cannot be built with incomplete understanding**
  - Managers make decisions with incomplete information all the time! This should be an added incentive for model-building as a statement of current best understanding

- **A model must be as detailed and realistic as possible**
  - If models are constructed as 'purposeful representations of reality,' then design the leanest model possible. Identify the variables that make the system behave and join them in the simplest of formal structures. **Parsimony is key (*i.e.*, Einstein's aphorism…as simple as possible, but no simpler)!**

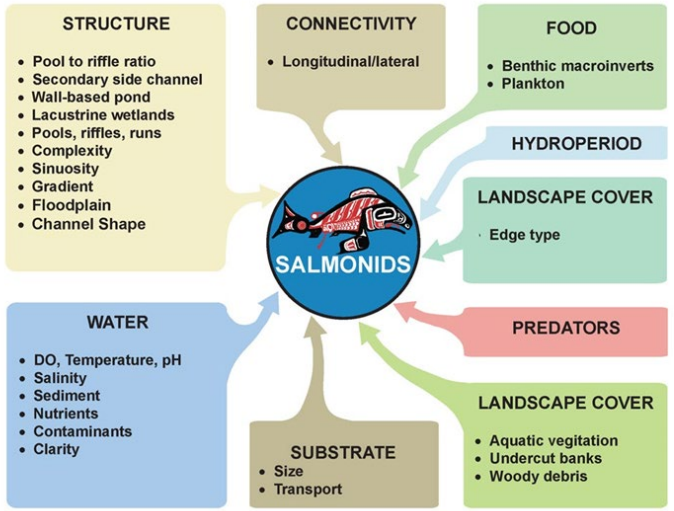
Starfield et al. (1997)

Types of models



Conceptual models

Uses: diagramming relationships among components, organizing information, determining data needs



Herman et al. 2020

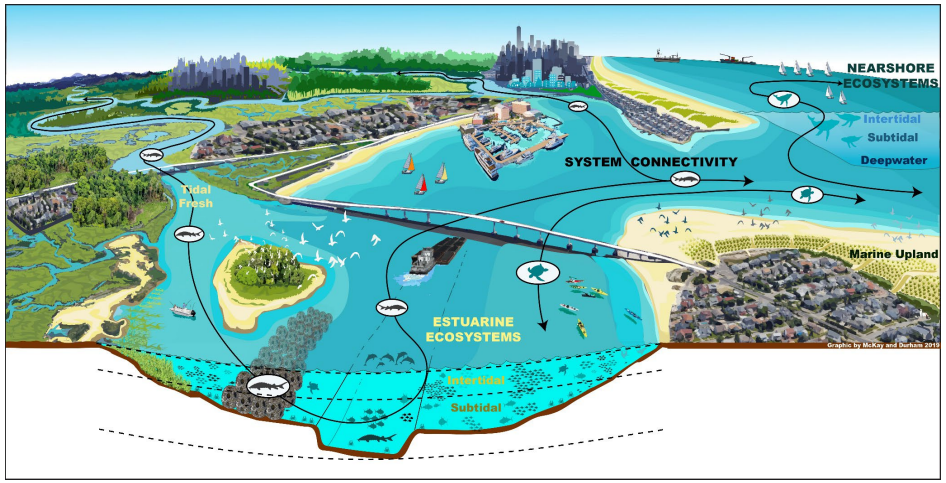
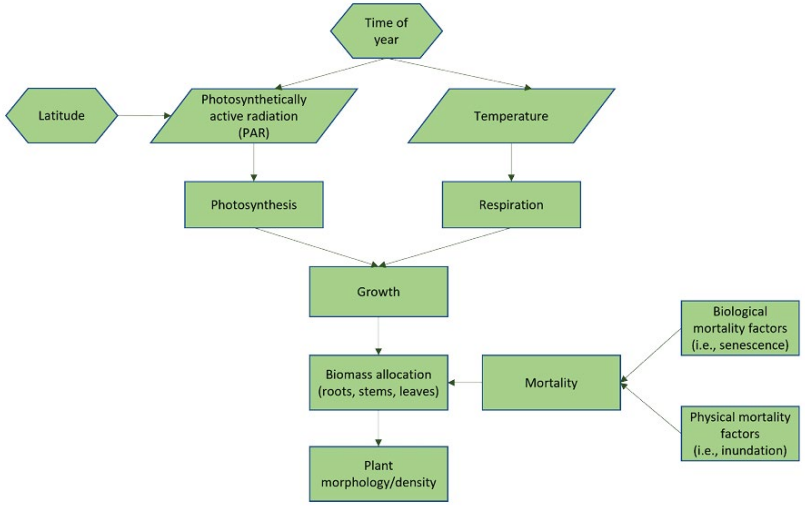


Figure: New York Bight Ecological Model (Durham and McKay)

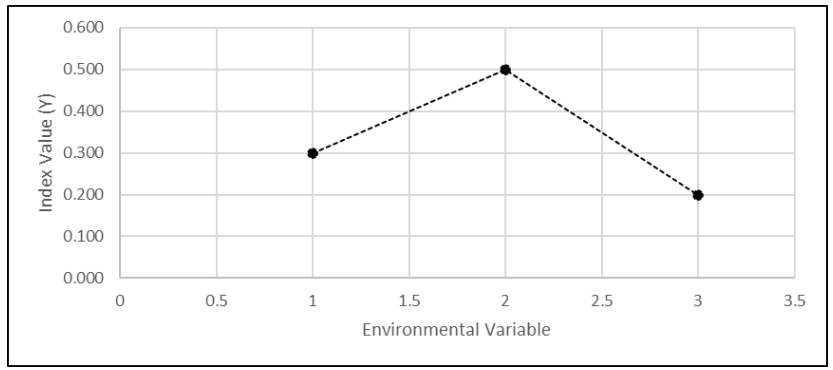


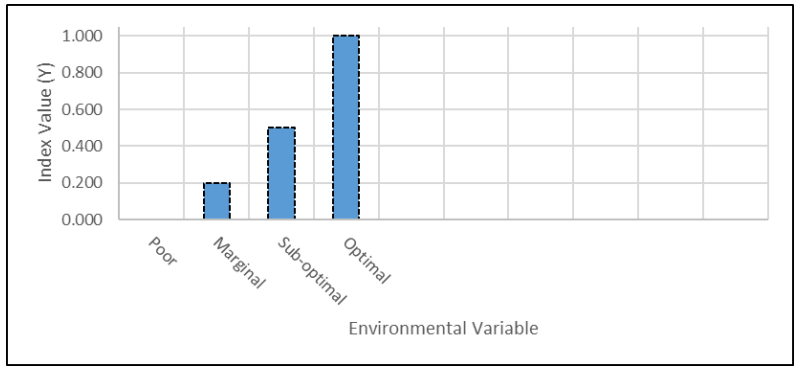
Russ et al. 2024

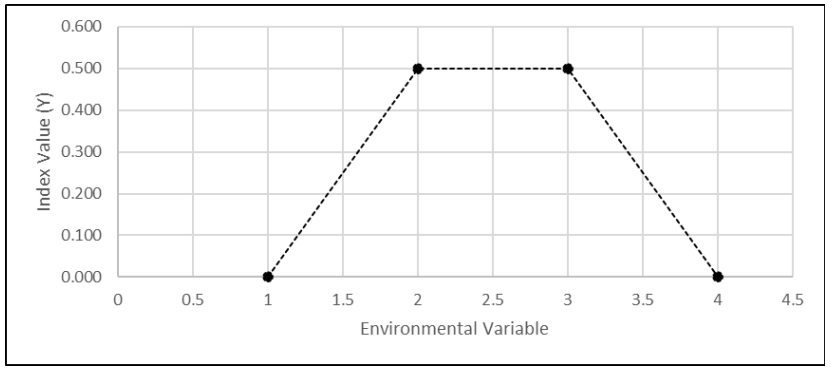
Index models

Uses: Determining ecosystem quality relative to environmental variables

- Quantity * Quality
- Quality for what?
  - Species – Habitat suitability indices (HSI)
  - Community – HSI
  - Function – Hydrogeomorphic models (HGM)



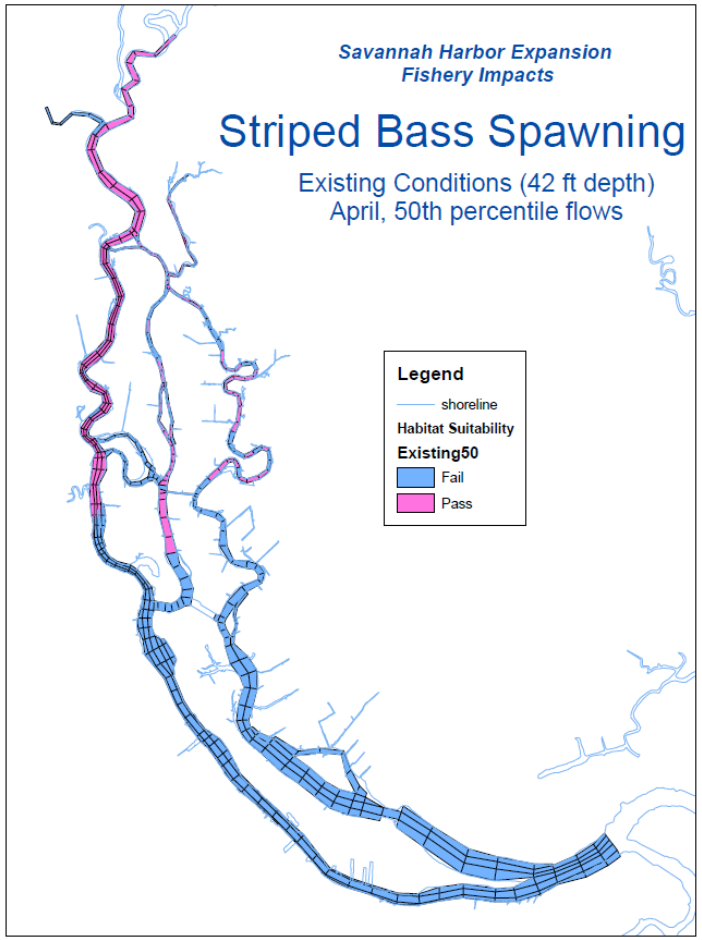


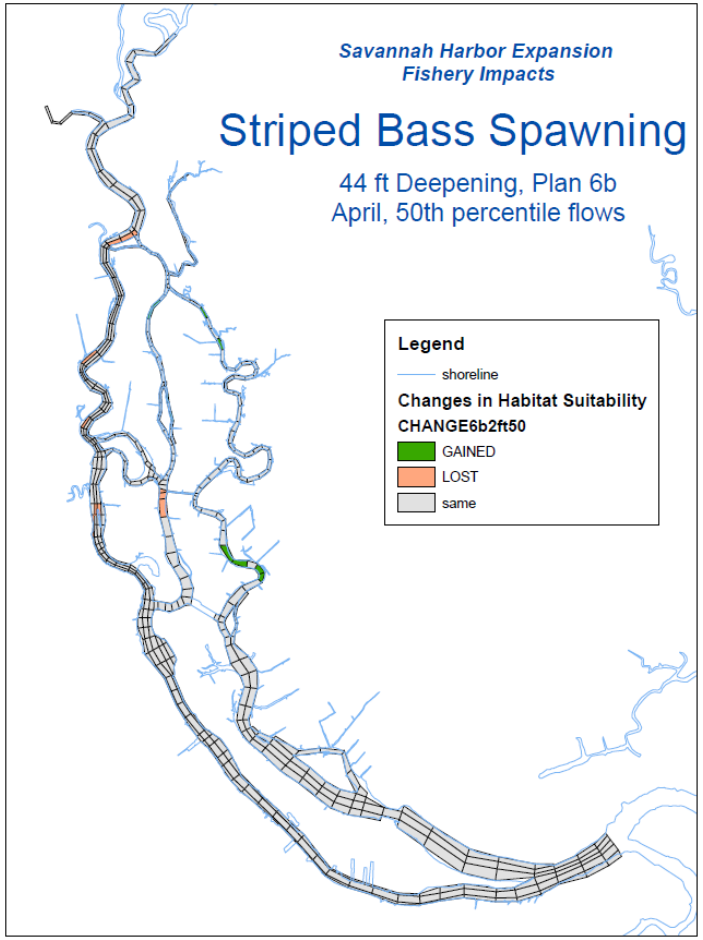


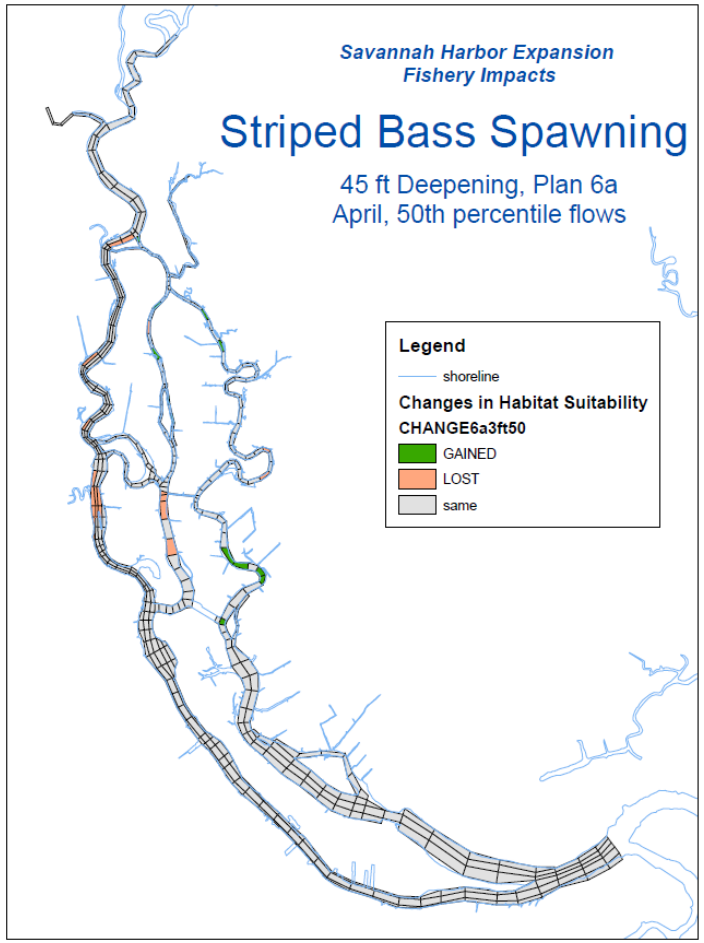
Carrillo et al., TAM

Spatially explicit models

Combination of spatial attributes, often coupled with simulation



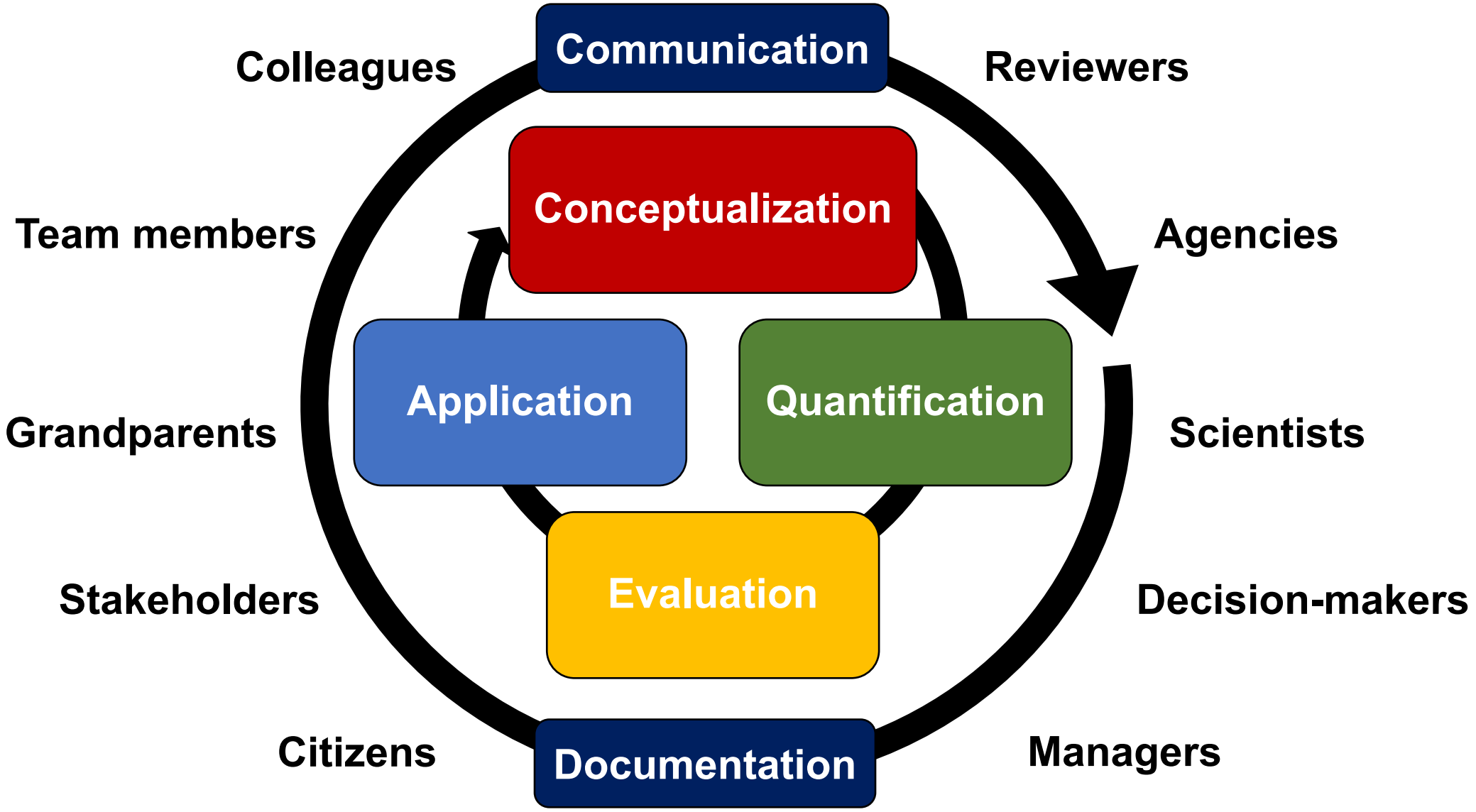




USACE, 2012

The modeling process

Ecological model development



Key attributes for model development teams

- Creativity
- Flexibility
- Quiet
- Determination
- Humility
- Constructive criticism
- Listening to local experts!

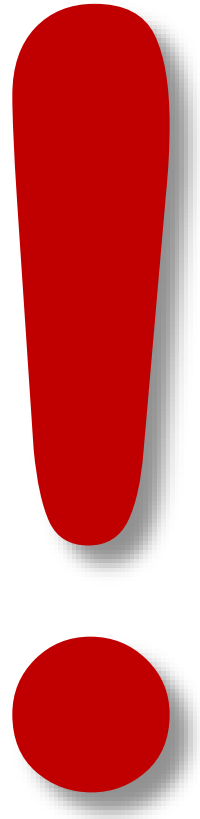
Develop, refine, collaborate, iterate!

Key points covered throughout the course

- **Developing good modeling practices is the key**
  - Don’t rely on good models; be a **good modeler**
  - Communication and documentation are underemphasized, but overly important
- **The value of a “straw-man” or alpha-version**
  - Don’t let the perfect be the enemy of the good
- **Key warnings**
  - Beware of plots without data points…
  - Beware of anyone claiming their ecological model is predicting exactly what the future will look like
  - Beware of an ecological model that is “well-behaved” (ecosystems are noisy, stochastic systems, not linear trajectories)

Key take-aways:

- **Models cannot cure all that ails you**
- **Models can serve as useful tools**
- **Many types (and combinations) of models exist**
- **Model development is iterative, but these loops can be rapid**
  - Iteration helps avoid the pitfalls



References for further reading

- Carrillo, C.C., McKay, S.K., Altman, S., and Swannack, T.M. 2022. Ecological model development: toolkit for interactive modeling (TAM). ERDC/TN EMRRP-SR-90, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

- DeAngelis, D.L., Franco, D., Hastings, A. et al. 2021. Towards building a sustainable future: positioning ecological modelling for impact in ecosystems management. Bulletin of Mathematical Biology. 83, 107. https://doi.org/10.1007/s11538-021-00927-y

- Harris, A.E., Richards, N.S., and McKay, S.K. 2023. Defining levels of effort for ecological models. ERDC/TN EMRRP-EM-11, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

- McKay S.K. Richards, N., and Swannack, T.M. 2019. Aligning ecological model development with restoration project planning. ERDC/TN EMRRP-SR-89, U.S. Army Engineer Research and Development Center, Vicksburg, MS.