Proceedings from the US Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA)–National Ocean Service (NOS)

Ecological Habitat Modeling Workshop

April 11–12, 2019

US Fish and Wildlife Service Blackwater National Wildlife Refuge Visitors Center
2145 Key Wallace Drive, Cambridge, MD 21613

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Ecological Habitat Modeling Workshop

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ABSTRACT

This special report summarizes the activities of the Ecological Habitat Modeling Workshop held April 11–12, 2019, at the US Fish and Wildlife Service (USFWS) Blackwater National Wildlife Refuge Visitors Center in Cambridge, Maryland.

The workshop guided 21 participants through the process of conceptualizing, quantifying, evaluating, and communicating ecological responses to inform guidance and management decisions for ecological restoration projects. Working in interactive groups, participants used the restoration work already in progress at nearby Swan Island as the basis for their model development. Over the course of the two-day workshop, participants learned the mechanics and challenges of applying modeling processes to shape the restoration of dynamic ecosystems. Through group work and brainstorming, they identified a number of benchmarks to assess restoration success and future resilience. To accommodate the changeable and often unpredictable natural events that can shape ecosystems, workshop facilitators emphasized building iterative, fluid ecological habitat models.

Next steps include publishing this special report and scheduling a follow-up workshop that will include a site visit to Swan Island.

Contents

Figures

PREFACE

This report summarizes the collaborative activities of a workshop conducted on the topic of ecological habitat modeling. It was held April 11–12, 2019, at the US Fish and Wildlife Service (USFWS) Blackwater National Wildlife Refuge Visitors Center in Cambridge, Maryland.

The workshop was coordinated by Ms. Paula Whitfield, research ecologist, of the National Oceanic and Atmospheric Association's (NOAA) National Ocean Service (NOS)–National Centers for Coastal Ocean Science (NCCOS) in Silver Spring, Maryland and facilitated by Drs. Brook Herman, research ecologist, and Todd Swannack, research ecologist, of the Integrated Ecological Modeling Team at the US Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi. The workshop was made possible by support offered through USACE's Engineering With Nature® (EWN®) initiative.

The organizers would like to thank Mr. Matt Whitbeck, supervisory wildlife biologist, of the USFWS and manager of the Blackwater National Wildlife Refuge, for providing the conference venue and facilitating on-site computer and facility support. Additionally, the organizers wish to thank all of the workshop participants who shared their knowledge and experience, which made it possible to advance the collaborative Swan Island Project and the ecological models that will support future monitoring and restoration efforts.

At the time of publication of this report, Dr. Ilker Adiguzel was Director of ERDC's Environmental Laboratory. COL Teresa A. Schlosser was Commander of ERDC and Dr. David W. Pittman was Director of ERDC.

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EXECUTIVE SUMMARY

This ecological modeling workshop is the result of a relationship that has grown in recent years between the US Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA). At the heart of that relationship is a mutual interest in prioritizing collaborative projects that support the Engineering With Nature (EWN) initiative. Having identified areas of mutual research interest through earlier collaborative workshops (Bridges, Banks, and King 2016, 12–20), the pursuit of a large, collaborative project was a natural next step.

In summer 2018, NOAA and USACE began the process of dedicating resources that would allow for the pre- and postconstruction monitoring of a restored island, Swan Island in the Chesapeake Bay. Swan Island, adjacent to Smith Island in Somerset County, Maryland, functions as a natural breakwater for the town of Ewell.

In fall 2018, Baltimore District began dredging and placing 61,000 cu yd[1] of sediment on the island as part of the restoration effort. This work culminated in late April 2019, shortly after the workshop. The Baltimore district established natural and nature-based features (NNBF), including high and low marsh and beach and dune vegetation. They completed the planting in July 2019. A joint effort between USACE Baltimore District, the USACE Engineer Research and Development Center (ERDC), NOAA–National Ocean Services' (NOS) National Centers for Coastal Ocean Science (NCCOS), the US Fish and Wildlife Service (USFWS), and the Maryland Department of Natural Resources (MD DNR) will study the island for the next three years to better understand its ecological and engineering performance.

Upon completion of the initial, preconstruction sampling of the island, NOAA and ERDC investigators recognized the value of leveraging the collected data to pursue ecological modeling for future management decisions while quantitatively evaluating the long-term performance of Swan Island. USFWS and MD DNR scientists and resource managers also agreed that introducing a modeling element would help achieve the project's overall goals. Thus, the workshop arose out of the project team's desire to identify and validate the appropriate parameters for this study, establish predictive tools using ecological habitat models, define successful outcomes for the project, contribute findings and improved methodologies, and create new, innovative methodologies to address island performance.

[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

The workshop used Swan Island as a case study to teach participants the process of conceptualizing, quantifying, evaluating, and communicating ecological responses, with a goal of informing guidance and management decisions for ecological restoration projects. The workshop was held April 11–12, 2019, at the USFWS Blackwater National Wildlife Refuge Visitors Center in Cambridge, Maryland. There were 21 participants representing a variety of organizations, including USACE, NOAA's NCCOS and National Marine Fisheries Service, USFWS, MD DNR, the University of Pennsylvania, and the University of Toronto. Please see appendix A for a full list of conference participants and their respective organizations.

There were three primary objectives associated with the workshop:

1. Support modeling as a tool to drive the design, monitoring, and evaulation of ecological restoration projects using hands-on learning modules
2. Review sampling parameters, determine additional sample collection needs (if any), and collaboratively pursue the development of models that guide the future monitoring and evaluation of the Swan Island restoration project
3. Achieve consensus on the best approach for harnessing the power of ecological modeling to advance the overall project outcomes and the broader objectives of the EWN initiative

The two-day workshop began with introductions by all attendees. Next, representatives involved in the Swan Island restoration project from NOAA, ERDC, and USACE–Baltimore District presented, among other things, an overview of the project's goals, work completed on site, work that remains on site, and information about the environmental and hydrodynamic parameters being monitored and collected before project construction (completed before the workshop) and after project construction (completed after the workshop in August 2019).

Workshop facilitators presented an overview of the concepts, processes, and challenges of ecological habitat modeling. Participants then worked in small groups to create their own models for the Swan Island project.

Break-out sessions were held the afternoon of the first day and the morning of the second. During these sessions, participants identified restoration goals, anticipated likely challenges when pursuing these goals, identified important system components, and diagrammed conceptual models for the Swan Island restoration work. Participants presented and compared their draft models in the workshop's final session.[2] Trainers

2 Shortly after the workshop, the project team refined one of the general, linear-conceptual models, which was developed in the workshop, to produce a simplified model that specifically targeted the funded project objectives. Both models are presented in these proceedings (figures 2 and 4).

then presented the next steps in model development, including approaches for quantification, evaluation, and application. The group then discussed the usefulness of such models to inform monitoring and adaptive management plans and communicate with stakeholders and funding agencies.

The project team is currently planning a follow-up workshop, which will include a Swan Island site visit.

1 Introduction

The US Army Corps of Engineers' (USACE) Engineering with Nature (EWN) initiative began in 2010 with the goal of increasing project value using natural systems and processes, developing solutions through partnerships and collaborations, and encouraging innovation in water infrastructure development through field-scale demonstrations. Since its inception, the EWN portfolio has grown considerably, with research and development distributed across the navigation, ecosystem restoration, and flood-risk management business lines. EWN continues to produce practical tools and solutions by supporting efforts to engineer with nature.

The National Oceanic and Atmospheric Association's (NOAA) National Centers for Coastal Ocean Science (NCCOS) has a similar research and development profile in their Coastal Change Portfolio. This portfolio analyzes the ecosystem services that improve a community's resistance to the impacts of weather and changing climate conditions. NCCOS provides timely and actionable scientific assessments, information, and tools that coastal communities use to make risk management decisions.

Within USACE's EWN initiative and NCCOS's Coastal Change Portfolio exists a subset of research interests specifically focused on natural and nature-based features (NNBF). NNBF are those features that define coastal landscapes, including barrier islands, beaches and dunes, maritime forests, wetlands and seagrass beds, biogenic reefs, and more (figure 1). Using and restoring NNBF to provide ecosystem services, reduce storm risks, and enhance coastal resilience is a prime example of how engineering with nature achieves multiple benefits. NNBF include both natural features and those that are nature-based, that is, features designed and constructed to provide functions and services comparable to natural features. Please visit www.engineeringwithnature.org and https://coastalscience.noaa.gov/category/zcoastal-change/natural-and-nature-based-features/ for more information on efforts pertaining to NNBF.

In March 2016, researchers affiliated with USACE's EWN initiative and NCCOS's Coastal Change Priority attended a collaborative workshop on NNBF in Charleston, South Carolina (Bridges, Banks, and King 2016). This workshop developed connections between the two organizations' leaders and staff, resulting in several project ideas. Over the next two years, the scientists and engineers affiliated with these organizations continued their discussions, participated in subsequent workshops, and identified opportunities to collaborate. Ultimately, those engagements and continued interest in NNBF research contributed to the identification and funding of the Swan Island Research Project.

Through a series of communications starting in spring 2018, NCCOS and

US Army Engineer Research and Development Center (ERDC) researchers engaged project managers in Baltimore District to learn more about the proposed restoration of Swan Island. In October 2018, USACE–Baltimore District began dredging the navigation channel that runs between Swan and Smith Islands near the Maryland-Virginia border and beneficially used 61,000 cu yd of the dredged sediments to restore the footprint of Swan Island (figure 2). The district completed dredging and sediment placement in April 2019, shortly after the workshop, and planting in July 2019, which included establishing NNBF such as high and low marsh and beach and dune vegetation. Planting was completed in July 2019. The creation and expansion of these habitats will have significant benefits: ecosystem service provision, increased resilience of Swan Island to future sea-level rise, and abatement of erosive losses for the town of Ewell on adjacent Smith Island. However, there is currently no mechanism in place to evaluate whether the project achieved these intended outcomes, and therefore there exists an urgent need to properly quantify and substantiate the widely held beliefs. Long-term monitoring of USACE projects, which can fill the gaps that exist within research and development, is difficult given that USACE construction, operations, and maintenance requirements often do not allow for such strategic actions. However, this project will address the previously described information gap by gathering and evaluating the ecological and physical data necessary to evaluate the outcomes of the Swan Island restoration (see appendix B for additional information specific to Swan Island and the research and development project).

Figure 1. Example natural and nature-based (NNBF) found in coastal environments (From Bridges, Todd S., Cynthia J. Banks, and Jeff K. King. 2016, 2)

NCCOS researchers visited the site in late summer of 2018 to collect preconstruction data that provided the baseline information to evaluate impacts of sediment placement on the intertidal and subtidal vegetative communities and nearshore oyster populations. Likewise, ERDC engineers constructed and deployed three platforms prior to construction in an effort to better understand the hydrodynamic conditions that existed prior to restoration activities. In early 2019, the principal investigators acknowledged that the data sets generated over the course of this study would include several complex hydrodynamic parameters. Moreover, they realized that an opportunity existed to expand overall project outcomes through the use of modeling, which they could accomplish through the collection of each data set. Therefore, by leveraging the data in this way, researchers could construct, update, and improve ecological models over the project lifecycle to inform real-time decisions pertaining to adaptive management.

To that end, the principal investigators invited members of ERDC's

Integrated Ecological Modeling Team to share information that would support the development of ecological models applicable to Swan Island. This initial engagement ultimately resulted in enthusiastic support for a workshop that would allow participants to learn how to conceptualize, quantify, evaluate, and communicate ecological responses to inform guidance and management decisions for restoration projects such as the Swan Island project.

The Ecological Habitat Modeling Workshop was held April 11–12, 2019, in support of the Swan Island Restoration project.

There were three primary objectives associated with the workshop:

1. Support modeling as a tool to drive the design, monitoring, and evaulation of ecological restoration projects using hands-on learning modules
2. Review sampling parameters, determine additional sample collection needs (if any), and collaboratively pursue the development of models that guide the future monitoring and evaluation of the Swan Island restoration project
3. Achieve consensus on the best approach for harnessing the power of ecological modeling to advance the overall project outcomes and the broader objectives of the EWN initiative

Embedded within the above objectives are targeted outcomes that support the development of a monitoring and adaptive management plan (MAMP) for the island, including a description of the model and how to quantify and evaluate it as the data become available. The overarching goal of the model is to measure and evaluate several anticipated outcomes associated with the Swan Island project including, but not limited to, the following:

- How have the restoration actions enhanced the coastal protection capacity? (for example, modeling action and no-action scenarios to quantify reductions in wave energy/attenuation provided by the island)
- What is the coastal protection capacity of Swan Island under various sea level rise projections? (that is, comparing action and no-action scenarios)
- How has the sediment deposition and vegetation planting affected the habitat benefits provided by the island? (for example, modeling vegetation, diversity, density, and species distribution as well as inundation period; vegetation period and inundation data as proxy for birds and fisheries species)

The subsequent sections of this special report provide details and outcomes from the workshop.

2 Workshop Process

The Ecological Modeling Workshop served as a venue for scientists and engineers to work together to develop an ecological model and learn the importance and value of codifying project-level details in an MAMP for an ecological restoration project. The Swan Island project serves as an example throughout the workshop to demonstrate the ecological model development process.

At the time the workshop was conducted, the restoration of Swan Island was already underway, with dredging of the channel and placement of the sediment completed while the workshop was taking place. Thus, attendees of the workshop needed to accomplish several tasks in order to support the overall outcomes of the three-year, monitoring and adaptive management aspect of the Swan Island restoration project. First, participants identified the ecological systems affected by the restoration. Then they defined the critical system parameters for the model. They considered parameters outside the scope of the proposed monitoring (if money and logistics were not an issue) and within the scope of the monitoring (for example, to meet the funded objectives). The participants used this exercise to develop the initial conceptual models. The facilitators then guided participants through the model conceptualization, quantification, evaluation, and application process with a series of examples and break-out group exercises relevant to the Swan Island project. Finally, workshop facilitators briefed participants on developing a MAMP and the overall use and value of such a plan, including how to use it as a communication tool between project participants and external stakeholders.

3 Agenda and Workshop Structure

The full workshop agenda can be found in appendix C.

3.1 Background and Introductions

The two-day workshop began with introductions and an overview of the Swan Island restoration work, presented by Danielle Szimanski (USACE) (appendix D and E), Jenny Davis (NOAA) (appendix F), and Duncan Bryant (USACE) (verbal presentation only)—scientists involved in the project. Background presentations included a status update on the Swan Island restoration and the hydrodynamic and ecological monitoring completed to date. Again, preconstruction monitoring of the vegetation (sub/intertidal), sediment, and elevations—as well as installation of three platforms with acoustic Doppler velocimeter (ADV) sensors—was completed in August and September 2018, prior to the workshop in April 2019.

3.2 Measuring Ecological Outcomes/Modeling Basics and Process

After the overview presentations about the Swan Island project, workshop facilitators Brook Herman and Todd Swannack from USACE provided an introduction to ecological modeling concepts, including the basics of developing a model, processes for measuring outcomes, practicing adaptive management, and carrying out ongoing project monitoring. Please see appendices G and H for their presentation slides.

They emphasized that, unlike an engineering model, which generally has predictable, static outcomes, developing an ecological model is an iterative process that may sometimes require best professional judgment based on expert opinion and qualitative data, because there may be unknown factors and unpredictable events (for example, storms, climate change) affecting project outcomes. This ecological modeling overview was placed within the context of the Swan Island restoration project objectives.

The general modeling process is as follows (Grant and Swannack 2008, 52):

1. Conceptualization: Develop conceptual model with specific cause-effect relationships between relevant parameters.
2. Quantification: Quantify relationships between the parameters (that is, mathematical equations) based on data collected in the field (depicted in table at bottom of figure 3).

3. Evaluation: Evaluate the usefulness of the model to simulate island processes under known scenarios and future scenarios. Also called model validation, at this stage in the process, if model results do not match reality, other forcing factors and processes would be included to improve model performance.
4. Application: Once validated, apply the model by conducting simulations to address specific project objectives and questions.

Key overview concepts include the following:

- Ecological modeling is an iterative process; model development needs fluidity.
- Each person's/group's model will be different, because of different priorities and concerns, and may change over time.
- Focus on capturing important system-level socio-ecological changes as a response to restoration, and identify important components that drive system resilience.
- Long-term, the model should help communicate the value and benefits of ecosystem restoration.

3.3 Modeling 1: Conceptualization

The trainers first provided an overview presentation (appendix H) describing conceptual models, how they are used, and how to develop one. This overview included the characteristics of useful conceptual models and how to avoid pitfalls.

Development of a conceptual model is primarily about identifying the important system components and parameters, understanding the relationship between those parameters, and predicting how they will change as a result of the project restoration. Each model will be different, because each model developer has their own priorities, concerns, and objectives—all of which change over time. Thus, we should expect different conceptual models for similar systems.

After the modeling basics and overview presentations by the trainers, the workshop facilitators split the participants into two interactive working groups, each with a trainer, to develop a conceptual model for Swan Island.

The following model objectives were used as a guide:

1. Inform an MAMP for Swan Island

2. Capture important system-level socio-ecological and hydrodynamic changes as a response to restoration
3. Identify important components that drive system resilience (that is, ability to recover from disturbance)
4. Communicate the benefits of ecosystem restoration

Each team first determined the relevant system components and the processes (cause-effect relationships) acting on those components, keeping the overall project objectives in mind. Figure 2 below shows the primary system components and processes used in the initial conceptual model. Next, participants identified metric(s) and a unit of measurement for each component. A listed version of the components and parameters from figure 2 and a table of the links between the participants' understanding of the system, metrics for monitoring and data collection, and the initial conceptual model are illustrated in figure 3.

The first component of the model (orange rectangle at top, figure 2) indicates the stressors and drivers that affect the system but are unlikely to change as a result of restoration. That is, the system will be subjected to a host of stressors beyond what the model measures (in this example, climate, storms, sea-level rise, dredging, run-off, human activities and development, subsidence, pollution, boat wakes, ice, recreation, and herbivory). These stressors can be incorporated as stochastic events if relevant to the system. The primary components of the initial model are the hydrodynamics, geomorphology, and water quality components. These components contain parameters that influence, or will change as a result of, the restoration, and several aspects of these components can/will be measured during sampling. Hydrodynamics' parameters include infrastructure, tidal prism, water level, and current; water quality's parameters include nutrients, dissolved oxygen, turbidity and clarity, and pH; and geomorphology's parameters include the transition zone, topographic design, elevation, infrastructure, vegetative design, shoreline structure and change, and habitat complexity. Finally, the middle of the figure shown with the large blue arrows contains parameters that are the most important in terms of monitoring for ecosystem change as well as how they relate to the restoration project objectives. These parameters are waves, sediment, biomass, and habitat (including SAV, dunes, high marsh, low marsh, and oysters). The arrows indicate the direction of the cause-effect relationships between the parameters. So, for example, waves affect sediment, which affects biomass, which affects habitat, and all of these affect the component geomorphology. Of the components, hydrodynamics affects waves and sediment while water quality affects biomass. Of particular note is the way biomass affects shoreline structure and change and the way biomass also affects sediment, which together with waves affect elevation (figure 2).

Figure 3 depicts monitoring metrics (in table) that are linked to the conceptual model of Swan Island (graphic above the table).

The table in figure 3 describes the metrics, measurements, and predicted changes over time, and the elements of that table are organized in the outline below:

- Waves
    - Metric: currents
    - Measurement: ADVs on three platforms
    - Prediction: stable (neutral)
- Waves/sediment
    - Metric: turbidity
    - Measurement: ADVs on three platforms
    - Prediction: decrease (-) on south side; stable on north side (neutral)
- Waves
    - Metric: waves
    - Measurement: pressure differential; ADVs on platforms
    - Prediction: decrease (-) on south side; stable on north side (neutral)
- Biomass/habitat
    - Metric: establishment
    - Measurement: quadrats, percent cover, density, and species along transect
    - Prediction: increase (+) followed by stable (neutral)
- Sediment/biomass/habitat
    - Metric: elevation
    - Measurement: real-time kinematic (RTK) GPS points along transect
    - Prediction: increase (+) followed by stable (neutral) as vegetation establishes
- Sediment/habitat
    - Metric: sediment characteristics
    - Measurement: sediment cores on transect
    - Prediction: dominant class; size stabilizes
- Sediment/biomass/habitat

    - Metric: pH and acidification
    - Measurement: porewater cores
    - Prediction: unknown

- Waves/sediment/habitat

    - Metric: submerged bathymetry
    - Measurement: Light Detection and Ranging (LIDAR) and/or boat surveys
    - Prediction: habitat and hydrodynamic modeling

- Habitat

    - Metric: salinity, oxygen, pH, temperature, and chlorophyll
    - Measurement: to be determined
    - Prediction: unknown

- Waves/sediment/biomass/habitat

    - Metric: shoreline change
    - Measurement: LIDAR and/or boat surveys
    - Prediction: shoreline will accrete (+) or slow erosion once vegetation established

The workshop participants created the table in figure 3 using the Swan Island conceptual model in figure 2. The graphic headers in figure 3 (that is, hydrodynamics, water quality, and geomorphology) link to the conceptual model in figure 2, and this depiction offers the reader a method of organizing and binning a diverse set of metrics that will inform future models.

Figure 2. Swan Island conceptual model.

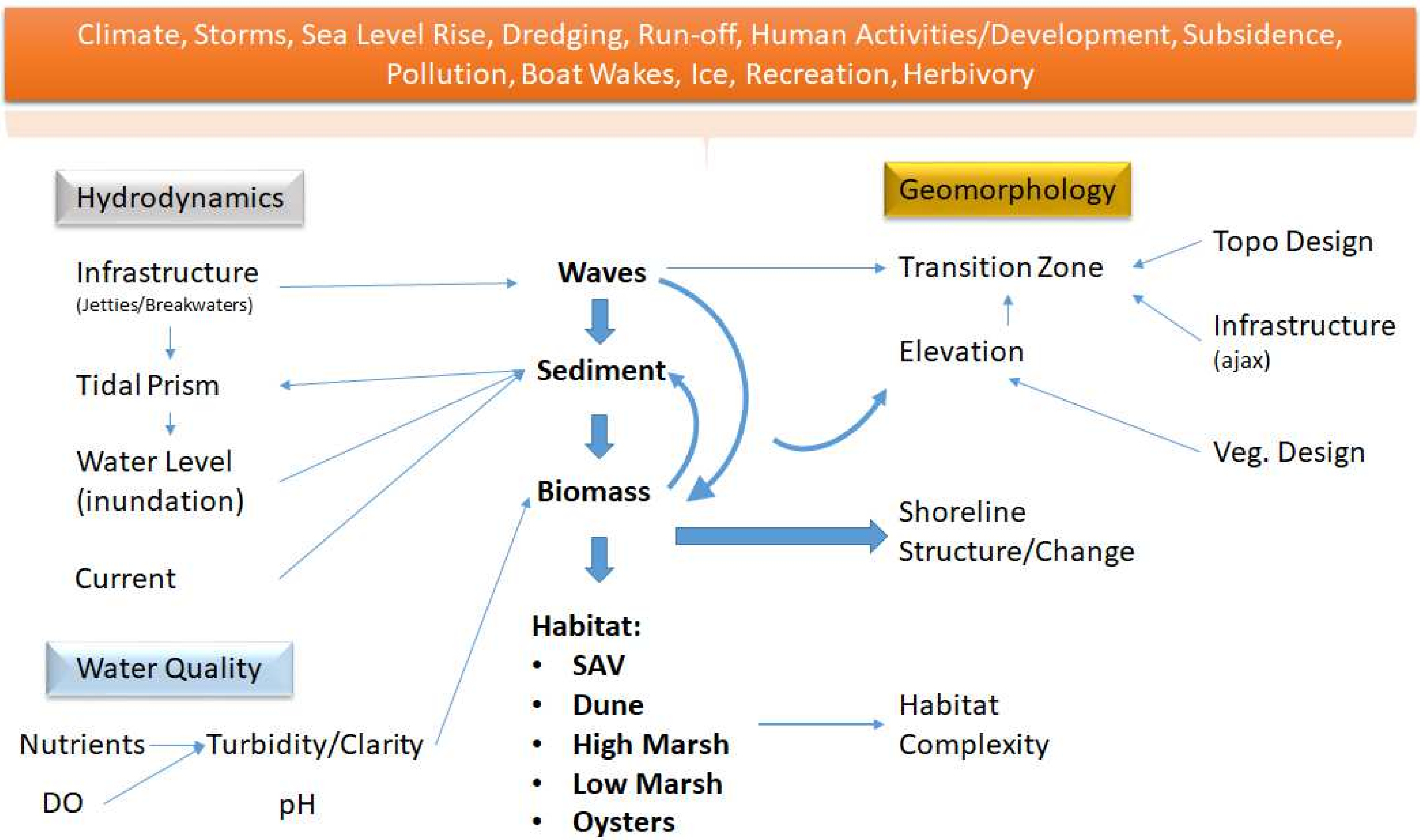


Figure 3. Monitoring metrics (in table) that are linked to the conceptual model of Swan Island (graphic above table).

Hydrodynamics

- Infrastructure (Jetties/Breakwaters)
- Tidal Prism
- Water Level
- Current

Water Quality

- Nutrients
- Dissolved Oxygen
- Turbidity/Clarity
- pH

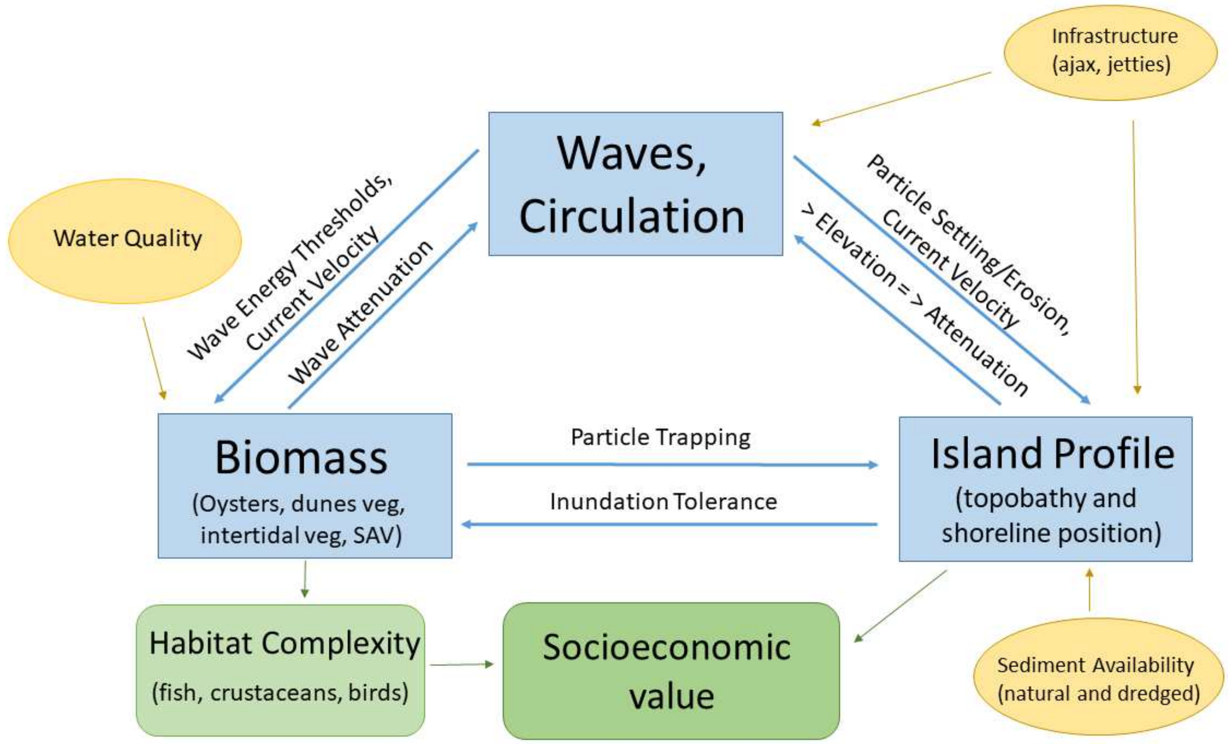
Geomorphology

- Transition Zone
- Elevation
- Topo Design
- Infrastructure (Ajax)
- Veg. Design
- Shoreline Structure/Change
- Habitat Complexity

Waves Sediment Biomass Habitat

Parameter(s)	Metric	Measurement(s)	Prediction Overtime
Waves	Currents	ADVs three platforms	Stable (neutral)
Waves/Sediment	Turbidity	Acoustic; ADVs platforms	Decrease (-) on southside, no change on northside (neutral)
Waves	Waves	Pressure Differential; ADVs platforms	Decrease (-) on southside, no change on northside (neutral)
Biomass/Habitat	Establishment	Quadrats, percent cover, density, species along a transect	Increase (+),followed by stable (neutral)
Sediment/Biomass/Habitat	Elevation	RTK GPS points along transects	Positive Increase (+), followed by stable (neutral) as vegetation establishes
Sediment/Habitat	Sediment Characteristics	Sediment cores on a transect	Dominant Class, Size Stabilizes
Sediment /Biomass/Habitat	pH/acidification	Porewater cores	Unknown
Waves/Sediment/Habitat	submerged bathymetry	LIDAR and/or boat surveys	Habitat & hydrodynamic modeling
Habitat	salinity	TBD	Depends on habitat
Habitat	oxygen	TBD	Depends on habitat
Habitat	pH	TBD	Depends on habitat
Habitat	temperature	TBD	Depends on habitat
Habitat	chlorophyll	TBD	Depends on habitat
Waves/Sediment/Biomass/ Habitat	Shoreline Change	RTK GPS, LIDAR and/or boat surveys	Shoreline will accrete (+) or slow erosion once vegetation established.

Figure 4. Refined conceptual model reflecting the three main measureable components (blue rectangles), each comprised of multiple measureable parameters (blue labeled arrows, not all included here). Note the waves component was modified to also include circulation and the measureable parameter of current velocity. The yellow ovals are nonmeasured components, and the green rounded rectangles will be inferred from the data collected.



Key Model Development Concepts

- Identify the crucial elements for consideration and monitoring in the model (for example, hydrodynamics, geomorphology, water quality, biotic components). Determine the most important components within each of these parameters (for example, impact of waves, tides, ice; important plants or fish habitat).
- Determine or estimate the relationships between the identified components connected in the system.
- Identify the external drivers that cannot be controlled but must be considered (for example, storms, climate change, sea level, pollution).

3.4 Modeling 2: Quantification

During this section, the ERDC trainers provided participants with an overview of the purpose and functional forms of quantitative models (appendix I). This overview included a discussion of the type of math that may be required and decisions on time steps. In many cases, having a general understanding of the cause-effect relationship between parameters or components (*parameter* is often used interchangeably with *component*)—for example, the main parameters in the final Swan Island model in figure 4—will suffice to develop a quantitative model. The trainers emphasized that capturing critical processes is paramount, not defining a comprehensive mathematical equation for every process. The types of data used varies from quantitative (field data, literature), to qualitative (expert opinion, hypotheses), and often the model itself reveals trends and patterns. Workshop facilitators demonstrated with examples how to capture feedbacks and thresholds in the model and how to integrate multiple models. Finally, the facilitators emphasized the iterative nature of developing a quantitative model as a natural part of investigating the validity of the model relationships. Workshop participants discussed common pitfalls, including inappropriate math and choosing the wrong time step or unit of measure.

There are five basic steps to develop a quantitative model (Grant and Swannack 2008, 67–78):

1. Select the general quantitative structure for the model.
2. Choose the basic time unit for the simulations.
3. Identify the functional forms of the model equations.
4. Estimate the parameters of the model equations.
5. Execute the baseline simulation.

After this background on quantification, the two working groups split up to generate the quantitative process for the specific model parameters and relationships for the initial conceptual model (figure 2). (Again, the project team developed the simplified conceptual model shortly after the workshop.)

Key Model Development Concepts

- Determine an appropriate time frame for the model: how many years will data collection happen? how frequently will the model be updated? how long will the assessments run?
- Determine an appropriate measurement unit based on the growth cycle of what is being measured (for example, annually for certain species; every 25 years for a tree).
- Modeling is an iterative process; keep learning about the model and its system. Do not put a model into practice until it is well tested and rigorous.

3.5 Modeling 3: Evaluation and Application

The ERDC trainers started this section by providing the background on what model evaluation is and how to do to it (appendix J). Along with presenting practical evaluation techniques, they provided advice on how to deal with uncertainty and avoid pitfalls. Evaluation is the process of rigorously assessing model components, structure, parameter values, and assumptions, but not scenario results.

There are five steps to evaluate an environmental model (Grant and Swannack 2008, 79–87):

1. Assess the reasonableness of model structure.
2. Assess functional relationships and verify code (math).
3. Evaluate model behavior vs. expected patterns.
4. Assess model correspondence to data from real system.
5. Document uncertainty.

The trainers emphasized model *evaluation* over model *validation*, as it is commonly called, because this step is not about validating what is true or false but rather about evaluating whether the model accomplishes its intended purpose. In addition, evaluation is an iterative process that determines the model's limits, strengths, weaknesses, and replicability. Different disciplines expect different things from model performance, which represents a challenge for model evaluation. Another challenge is the failure to document the entire evaluation process in enough detail, including the iterative approach that is inherent to the evaluation process.

The trainers also focused on the methods and challenges of building evaluation tools into their ecological models. They taught participants how to assign values (data management) to the models to measure adaptive management and enable monitoring of the model. They also discussed the importance, and challenges, of communicating about the model to both technical audiences and the general public.

3.6 Modeling 4: Communication, Data Management, Monitoring and Adaptive Management

The last phase of ecological modeling development links it to monitoring and adaptive management decisions and uses it as a communication tool for various audiences, including the project team. First, the trainers emphasized the need to develop an MAMP that would serve as a living document to codify data management protocols and to link the modeling component to the adaptive management of the site. Evaluation of the conceptual model, monitoring metrics, and predictions will continue as the MAMP is developed in more detail (appendices K and L).

In the final working sessions, participants developed measurement criteria for their models, and then each group elected a spokesperson to present and explain their model to the plenary. Although the diagrams and processes the individual groups used to develop their models were different, their final models considered largely the same elements.

Next steps in model development include the following:

1. Review conceptual model/parameters.
2. Determine if monitoring metrics should be added or removed.
3. Review and adjust predictions as necessary.
4. Build an MAMP with the synthesis information.

Key Outcome Measurement Concepts

- The model must reflect what is happening in nature—not what is convenient. Determining measureable parameters (for example, current velocity, elevation) ensures accurate measurement and communicates change in the project.
- Let the model run long enough to enable accurate measurements. For example, if planting is done tomorrow, the project team cannot go back the next week to evaluate; plants need a couple of years to grow before assessment.
- When using data management software to assign values to a model, remember that not all formats lend themselves to a given problem. Statistical models can limit creative problem-solving (for example, using a linear system to assess a nonlinear model).
- The desired data will not always be available when making decisions. Be transparent and upfront about gaps in the data and information. It is acceptable to use expert opinions to parameterize equations until other data sets are available.
- Validation is not possible in an ecological model—*evaluation* captures the essence of a formal validation.
- Document the entire evaluation process. This information will be used in technical communications and with the general public—and potentially funding agencies.
- When developing a communications strategy about the project, first get an understanding of the audience's pre-existing thoughts before determining how to explain the project plan (for example, perceptions of

working waterfront communities, whose livelihoods might be impacted by a restoration).

- Develop two levels of communications about the project:
    1. A technical level for a scientific audience so that the model can be recreated—what assumptions were put in, what equations were used, full technical documentation
    2. A layperson's level for explaining the project to policy makers, citizens, and the general public; putting the project activities into narrative form will help explain it plausibly to laypeople and funding agencies.

4 Closing Session and Workshop Conclusion

The workshop uncovered some differences between the two groups and their understanding of the system; however, there was generally a wide overlap of important components and parameters. The group agreed that the conceptual models were a good start, but they needed to firm up the monitoring metrics and the interpretation of the metrics to best understand the system and make adaptive management decisions. In addition, participants wanted to practice quantifying the model using best available data to better understand this aspect of model development.

The following is a description of additional participant feedback requested by the trainers:

- Participants expressed interest in a site visit to Swan Island. There was general agreement that in the future it would be valuable to include a site visit prior to beginning work on the conceptual model.
- The two-day workshop agenda did not allow for the development of a complete model. Many said they would have liked the opportunity to develop a complete model from beginning to end (including design of the construction/sediment placement component) to use as a reference for other projects, instead of starting midproject.
- There was support for an additional group working session to develop monitoring metrics (for example, how to do the model, and from that model, how to decide which strategic monitoring parameters are needed).
- Participants suggested having material showing examples where ecological habitat modeling of this kind was applied and using the workshop to discuss results and applications.
- Holding a follow-up workshop to jointly put a model together, with monitoring criteria.
- Holding a follow-up webinar to walk people through how to put a model together.

5 Workshop Products, Recommendations, and Next Steps

The next step is a follow-up workshop to continue work on model quantification and evaluation. Participants will primarily include the project team and others with an interest in the geographic area.

Anticipated Workshop Products

1. Workshop Proceedings (this document)
2. Monitoring and Adaptive Management Plan (currently in development)

REFERENCES

Bridges, Todd S., Cynthia J. Banks, and Jeff K. King. 2016. *Proceedings from the US Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA) Natural and Nature-Based Features Workshop*. Vicksburg, MS: US Army Engineer Research and Development Center. http://hdl.handle.net/11681/20322.

Grant William E. and Todd M. Swannack. 2008. *Ecological Modeling: A Common Sense Approach to Theory and Practice*. Malden, MA: Blackwell Publishing.

Acronyms and Abbreviations

Term	Definition
ADV	acoustic Doppler velocimeter
ERDC	Engineer Research and Development Center
EWN	Engineering With Nature
LIDAR	light detection and ranging
MAMP	monitoring and adaptive management plan
MD DNR	Maryland Department of Natural Resources
NCCOS	National Centers for Coastal Ocean Science
NNBF	natural and nature-based features
NOAA	National Oceanic and Atmospheric Administration
SAV	submerged aquatic vegetation
SLR	sea level rise
USACE	US Army Corps of Engineers
USFWS	US Fish and Wildlife Service

Appendix A: Conference Participant List

	Last Name	First Name	email	Affiliation	Role
1	Balthis	Len	len.balthis@noaa.gov	NOAA/NCCOS	participant
2	Bryant	Duncan	duncan.bryant@usace.army.mil	USACE ERDC	participant
3	Burkholder	Sean	seanburk@design.upenn.edu	University of Pennsylvania	participant/landscape architect
4	Chasten	Monica	monica.a.chasten@usace.army.mil	USACE Philadelphia	participant
5	Davis	Jenny	jenny.davis@noaa.gov	NOAA NCCOS	participant
6	Garfield	Nina	nina.garfield@noaa.gov	NOAA Office for Coastal Management	participant
7	Golden	Becky	rebecca.golden@maryland.gov	MD DNR	participant
8	Herman	Brook	brook.d.herman@erdc.dren.mil	USACE ERDC	trainer
9	Holzman	Justine	justine.holzman@daniels.utoronto.ca	University of Toronto	participant/landscape architect
10	Ramsay	Laura	lramsay@decisionpartners.co	Decision Partners	recorder
11	Roach	Andrew	andrew.a.roach@usace.army.mil	USACE Baltimore	participant
12	Seiple	Jacqueline	jacqueline.a.seiple@usace.army.mil	USACE Baltimore	participant
13	Sekoni	Tosin	tosin.a.sekoni@usace.army.mil	USACE ERDC	participant
14	Specht	Jackie	jackie.specht@maryland.gov	MD DNR	participant
15	Spires	Jason	jason.spires@noaa.gov	NOAA NCCOS	participant
16	Subramanian	Bhaskar	bhaskar.subramanian@maryland.gov	MD DNR	participant
17	Swannack	Todd	todd.m.swannack@usace.army.mil	USACE ERDC	trainer
18	Szimanski	Danielle	danielle.m.szimanski@usace.army.mil	USACE Baltimore	participant
19	Vogt	Bruce	bruce.vogt@noaa.gov	NOAA Chesapeake Bay Office	participant
20	Whitbeck	Matt	matt_whitbeck@fws.gov	USFWS	participant
21	Whitfield	Paula	paula.whitfield@noaa.gov	NOAA NCCOS	participant

Appendix B: National Centers for Coastal Ocean Science (NCCOS) Project Proposal

(Note: For an accessible version of appendix B, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-B.pdf.)

Evaluating the Efficacy of Island Restoration and Enhancement for Coastal Protection: Swan Island

Project Summary

In October 2018, the Baltimore District of the US Army Corps of Engineers (USACE) will dredge the navigation channel that runs between Swan and Smith Islands near the Maryland- Virginia border and beneficially use 78,000 cubic yards of dredged sediments to restore the footprint of Swan Island (Figure 1). The restoration plan includes creation of dunes and high and low intertidal marsh (Figure 2). Planting is scheduled for spring 2019. The creation/expansion of these habitats is expected to have significant benefits in terms of ecosystem service provision, increased resilience of Swan Island to future sea level rise, and abatement of erosive losses for the town of Ewell on adjacent Smith Island. However, there is currently no mechanism in place to evaluate whether these predicted outcomes are achieved.

Figure 1. Google Earth image showing location of Swan Island in relation to the Town of Ewell, Maryland and the beneficial use placement area scheduled for October 2018 (image from: Environmental Assessment Twitch Cove and Thorofare Federal Navigation Channel Project, Dec 2015).

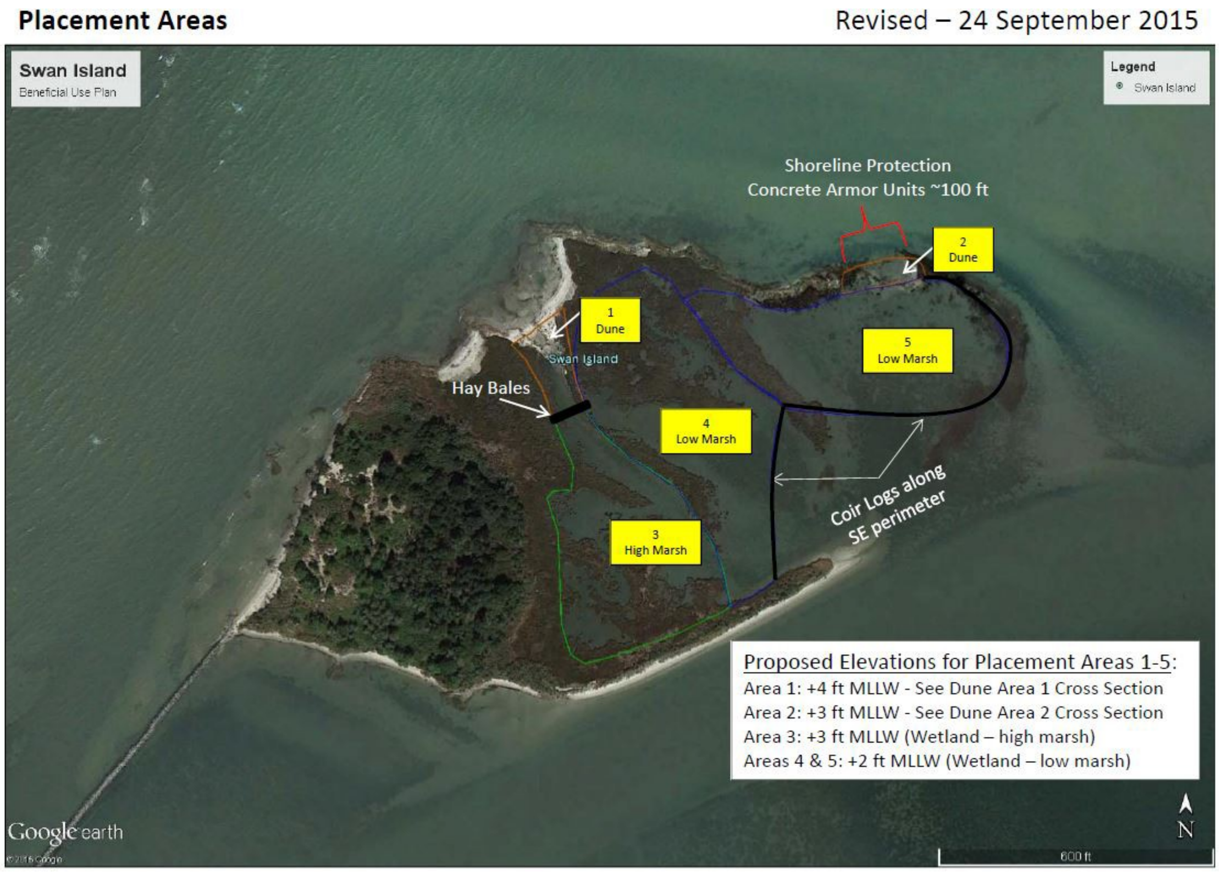


Figure 2. Google Earth image of Swan Island, with the beneficial use plan overlaid. Natural and nature-based features to be restored include low marsh, high marsh, dunes and strategic use of concrete armor units (image from: Environmental Assessment Twitch Cove and Thorofare Federal Navigation Channel Project, Dec 2015)

This project will capitalize on the imminent restoration of Swan Island, to address research gaps specific to our understanding of island system function, area of influence and ecological/engineering benefits, by gathering and evaluating the ecological and physical data necessary to evaluate the Swan Island restoration/placement. NCCOS scientists from Beaufort conducted pre-placement sampling (intertidal and subtidal vegetation, sediments and porewater and elevation profiles) of the island and MDDNR staff conducted annual SAV surveys in August 2018 to establish baseline conditions (Figure 3).

USACE will be installing up to three small platforms (Figure 4) for the attachment of an Acoustic Doppler Velocimeter (ADV) that will collect continuous wave, current and turbidity data (Figure 5). In addition, USACE proposes to conduct additional LIDAR surveys and nearshore boat surveys to provide information on dredged sediment spreading outside the construction prism. Additional surveys are proposed at 3, 6, and 9 months post construction to evaluate evolution of the island platform.

Figure 3. Satellite image of Swan Island indicating the location of the temporary benchmark and the marsh and seagrass transects surveyed in August 2018, prior to restoration of the islands natural features with the placement of dredged sediments.

Figure 4. Image of the ADV platform type to be installed by USACE staff.

Figure 5. Site locations proposed for ADV instrumentation to be installed by USACE staff.

In summary, sampling will include environmental and hydrodynamic parameters to quantify island performance (e.g. how they change over time, longevity), benefits (ecological and storm risk reduction) and the island's area of influence on surrounding features (Table 1). These data are also critical to the development/validation of sediment transport models, habitat models, guidance/tools and best practices that can be applicable beyond the Chesapeake to other regions with a similar tidal range (e.g. Gulf Coast, southeast, mid-Atlantic etc.), making island features common practice in the future.

We propose three years of post-restoration monitoring to occur annually (or more depending on the parameter) and before and after storm events for the next three years.

Table 1. Parameters to be collected during monitoring efforts.

Parameter Category	Parameter Type	Metric-Collection method	Purpose	Agency collecting the data
Ecological Parameters	terrestrial vegetation	Quadrats, percent cover, density, species along a transect	Habitat modeling	NCCOS
	terrestrial elevations	RTK GPS points along transects	Habitat modeling	NCCOS

	sediment characteristics	Sediment cores on a transect	Habitat modeling	NCCOS
	porewater	Porewater cores	Habitat modeling	NCCOS
	underwater vegetation/benthic environment	Quadrats, percent cover, density, species at random locations	Habitat modeling	MDDNR/NCCOS
Topography/bathymetry	submerged bathymetry	LIDAR and/or boat surveys	Habitat & hydrodynamic modeling	Existing data?
	island bathymetry	LIDAR (existing or otherwise)	Habitat & hydrodynamic modeling	Existing data?
Hydrodynamic parameters	Currents	ADVs deployed on three platforms	Hydrodynamic modeling	USACE-ERDC
	Turbidity	ADVs deployed on three platforms	Hydrodynamic modeling	USACE-ERDC
	Waves	ADVs deployed on three platforms	Hydrodynamic modeling	USACE-ERDC
Water Quality	salinity	TBD	Habitat modeling	
	oxygen	TBD	Habitat modeling	
	pH	TBD	Habitat modeling	
	temperature	TBD	Habitat modeling	
	chlorophyll	TBD	Habitat modeling	

ANTICIPATED PROJECT OUTCOMES:

There are several advantages to developing a comprehensive understanding of the system where island projects occur and the benefits they provide. Research outcomes may include, but are not limited to:

1. **OUTCOME -** Quantification of island performance metrics and benefits (e.g. protection of adjacent land from erosion, breaking of offshore/storm waves, attenuation of wave energy, etc) over time will demonstrate how restoring these islands, by combining natural and engineered processes, can achieve ecological, economic and social benefits making these projects common practice in the future.

2. **OUTCOME -** Monitoring of the island ecological benefits over time, using vegetation as a proxy, (e.g. T&E species, migratory birds, etc), including documenting changes to the shallow water habitats around and in the 'lee' of the island footprint. Documenting the latter may address the "habitat switching' debate long considered a barrier to permitting and implementation of these kinds of projects. As follow-up, we will document island ecology and develop best-practices guidance for other sites based on data from this study.

3. **OUTCOME -** Data from this project will support new and existing hydrodynamic and ecological habitat models that will be used to evaluate island benefits and the island's influence on adjacent sites.

4. **OUTCOME -** Guidance will be developed for applying models that are refined or developed as part of Outcome 3. Guidance documents will aide practitioners in applying models for use in determining the utility and performance of future-proposed islands. In addition, guidance will include information specific to model benefits, limitations, applications, data needs, etc.

5. **OUTCOME -** Monitoring this island will produce data that informs future island construction projects around the nation. For example, the performance data will be integrated with other applicable data sets, and other tools and models that support future construction of island-based, natural and nature-based features (NNBF) for the purpose of storm risk reduction.

PROJECT TEAM (TO-DATE):

<u>USACE</u>
Baltimore District - Danielle Szimanski - Project Manager
ERDC - Joe Gailani - Sediment Transport Processes and Modeling
ERDC - Jeff King - Research Civil Engineer, EWN Deputy
National Lead
ERDC – Todd Swannack – Lead Habitat Modeler
ERDC – Brook Herman – Habitat Modeler / Research Ecologist

<u>NOAA</u>
Paula Whitfield - Research Ecologist/Environmental Compliance,
Jenny Davis - Research Ecologist/Coastal Restoration Specialist,
Don Field - Research Biologist/Ecologist and Remote Sensing Expert
Carolyn Currin – Research Ecologist/Microbiologist
Jason Spires – Marine Biologist
JD Dubick - Biologist

USFWS – Matt Whitbeck - Blackwater Refuge Manager
MDDNR - Brooke Landry - Natural Resource Biologist; Chair, CBP SAV Workgroup
MDDNR - Becky Golden - Program Manager; Vice-chair, CBP SAV Workgroup

Appendix C: Workshop Agenda

(Note: For an accessible version of appendix C, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-C.pdf.)

US Army Corps of Engineers®

Engineering With Nature®

Ecological Habitat Modeling Workshop April 11 - 12, 2019
USFWS Blackwater National Wildlife Refuge Visitors Center
2145 Key Wallace Dr, Cambridge, MD 21613

Overarching Objective:

1. The Ecological Habitat Modeling Workshop facilitated by the Integrated Ecological Modeling Team of the US Army Engineer Research and Development Center will allow participants to learn the process for conceptualizing, quantifying, evaluating and communicating ecological responses to inform guidance and management decisions for restoration projects such as the Swan Island Project.

Thursday April 11, 2019: All times listed are Eastern Time

Time	Action	Lead or Speaker
8:00	Arrive at USFWS Blackwater National Wildlife Refuge, 2145 Key Wallace Dr., Cambridge, MD 21613	
8:30-845	Welcome Remarks, Logistics, introductions	Paula Whitfield – NOAA Matt Whitbeck - USFWS
8:45 – 9:15	Background – 1. Swan Island Restoration Project Status 2. Swan Island Parameters: before/after	Danielle Szimanski - USACE Jenny Davis - NOAA Duncan Bryant - USACE
9:15 – 9:45	Measuring Ecological Outcomes/Monitoring & Adaptive Management	Brook Herman
9:45 – 10:15	Modeling Basics and Process	Todd Swannack
10:15 – 10:30	Break	
10:30– 11:15	Modeling 1: Conceptualization	Todd Swannack/Brook Herman
11:15 – 12:30	Lab 1: Conceptualization	ALL
12:30 – 1:45	Lunch	ALL
1:45 – 2:30	Modeling 2: Quantification	Todd Swannack/Brook Herman

2:30 – 3:30	Lab 2: Quantification (Break as needed)	ALL
3:30 – 4:00	Team Report Outs	ALL

4:00 – 4:30	Daily Review: Goods and Betters	ALL
4:30	Adjourn	
4:30-5:30pm	Optional trip to BWNWR TLP Site	
	Group Dinner TBD	

Friday April 12, 2019: All times listed are Eastern Time

Time	Action	Lead or Speaker
8:00-8:30	Coffee	
8:30-9:30	Modeling 3: Evaluation & Application	Todd Swannack/Brook Herman
9:30-9:45	Break	
9:45 – 10:30	Modeling 4: Communication/Data management/Monitoring & Adaptive Management Plan	Todd Swannack/Brook Herman
10:30 – 12:00	Lab 3: Monitoring Plan (Breaks as needed)	ALL
12:00 – 1:15	Lunch	ALL
1:15 – 2:00	Team Report Out	Todd Swannack/Brook Herman
2:00 – 4:30	Parking lot discussions Issues Goods and Betters Next steps	ALL
4:30	Adjourn	

Appendix D: Danielle Szimanski, Swan Island Project Update, US Army Corps of Engineers–Baltimore District

(Note: For an accessible version of appendix D, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-D.pdf.)

SWAN ISLAND PROJECT UPDATE

Danielle Szimanski
Project Manager
Operations Division – Navigation Section
11 April 2019

U.S. ARMY

US Army Corps of Engineers®

CURRENT STATUS

1. Dredging Began November 2018
2. Dredging completed at Swan Island end of February 2019
3. Approximately 55,000 cubic yards of material placed
4. Final grading to be completed by mid-May 2019
5. Planting to be completed by July 2019

December 2018

SWAN ISLAND PROGRESS

January 2019

SWAN ISLAND PROGRESS

January 2019

A-JACKS PLACEMENT

February 2019

QUESTIONS?

Appendix E: Restoration Status of Swan Island April 2019

(Note: For an accessible version of appendix E, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-E.pdf.)

Objective	Action	Needs
Deepen federal navigation channel between Swan and Smith Islands to enable safe navigation for fishing boats and Smith Island residents who rely on boats to get to mainland	• Dredging of Smith Island federal channel completed April 12, 2019	• Monitoring and maintenance plan for channel • Expectation that dredging will need to be repeated in 10 years

Beneficially used 61,000 cubic yards of dredged sediment to restore the footprint of Swan Island, create dunes and high and low intertidal marsh	• Pre-construction consultation conducted with F&WS to determine restoration needs for each part of the island: (high marsh, low marsh, dunes, protect Heron rookery).
	• Island surveyed; elevations marked to establish benchmarks
	• Took pre-construction sediment/vegetation samples to assess baseline conditions, and determine the optimal growth elevation for *Spartina alterniflora*.
	• Developed metrics for successful restoration of marshes, dunes to create optimal conditions; help predict resilience to long-range rise in sea level
	• Placement, grading of dredged material completed May 2019
	• Planting of 200,000 plugs of various species of site-appropriate plants (eg; low/high marsh plants; switch grass in dunes, etc.) to be completed in July 2019.
		• Determine accretion benchmarks
		• Monitor for 3 years post-construction to evaluate and compare:
		  • elevation
		  • shoreline erosion
		  • vegetative success
		  • SAV abundance and distribution
		  • sediment characteristics
		  • fish access using habitat complexity, inundation as a proxy.
		  • oyster population
		    • Need for funds to develop a plan for long-term monitoring. Funds secured for up to three years only.
		    • Funds/strategy for communicating with Island residents, funding agencies about the restoration

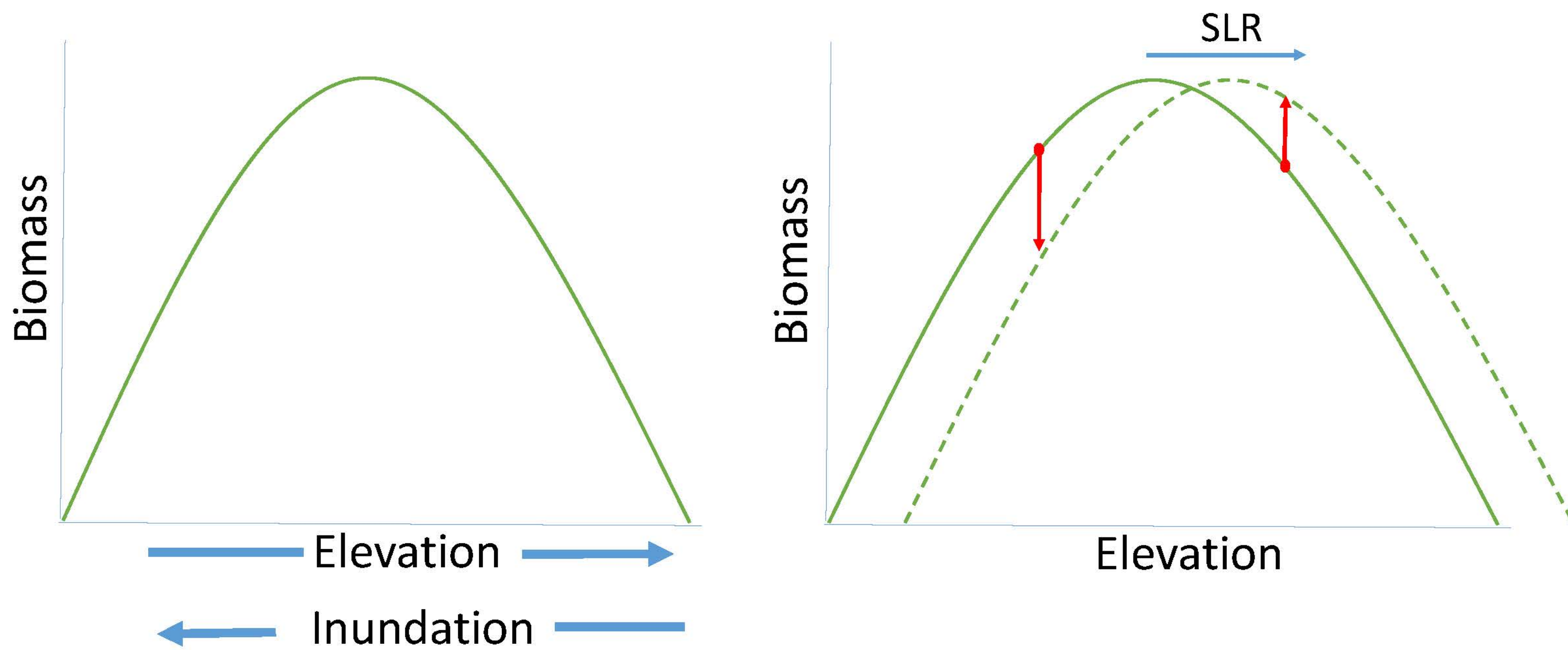
Improve/Maintain habitat value of intertidal areas for fish	1. Part of the unvegetated subtidal bight will be converted to low intertidal marsh. This represents a balance between increasing resilience of the island to SLR (by adding elevation) and maintaining access for fish..	• Re-evaluate in 3 years to determine if habitat complexity and inundation are sufficient to support fish accessibility. • Other monitoring metrics to use: Species diversity, vegetation and inundation as a proxy for habitat value to fisheries species.

Erosion/storm protection to increase resilience for the town of Ewell on nearby Smith Island	**2.** Three monitoring platforms installed around the Island to record, currents, sea levels, wave heights etc **3.** Construction of breakwater using concrete 'A-Jack' armor units for underwater support **4.** Planting of dunes and high and low marsh, and successful establishment of these vegetative communities will facilitate elevation gain (through sediment trapping and production of belowground biomass) in response to future SLR	5. Monitoring plan is in development (by partners) but initial funding was for design, construction (USACE Operations and Maintenance). (1) Hay bales placed on top of breakwall will eventually break down. (2) Dredging will likely have to be done again in 10 years – may revisit this then (3) Establish a mechanism to evaluate predicted outcomes
Monitor hydrodynamics	• Three monitoring platforms installed around the Island to record, currents, sea levels, wave heights etc.	**1)** Ice storms, ice accumulation, extreme weather events may affect monitoring stations
Monitor oyster colonies	• Pre-reconstruction survey found an intact oyster population around the Island with multi-year classes (generations) of oysters. • No oysters were found in the channel	2) Re-assess oyster population in 3 years
Funding for monitoring, future restoration, impact of climate change (sea level rise; ice storms)	3) Funding secured for up to three years for hydrodynamic, ecological and topographic monitoring	4) Develop communications and outreach strategy as part of the monitoring and adaptive management plan

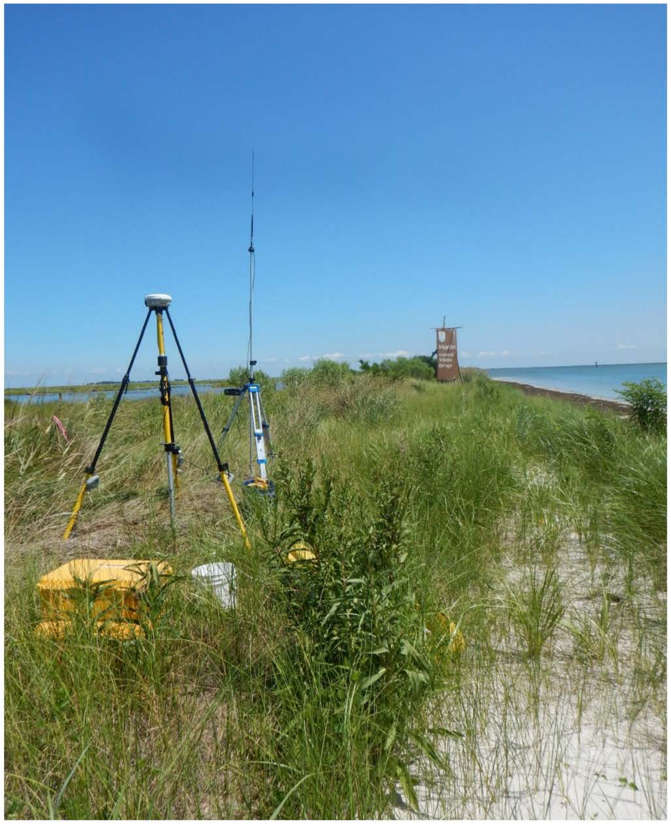
Appendix F: Jenny Davis, Swan Island Sampling Update, National Centers for Coastal Ocean Science

(Note: For an accessible version of appendix F, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-F.pdf.)

Spartina alt. distribution as an indicator of resilience to SLR

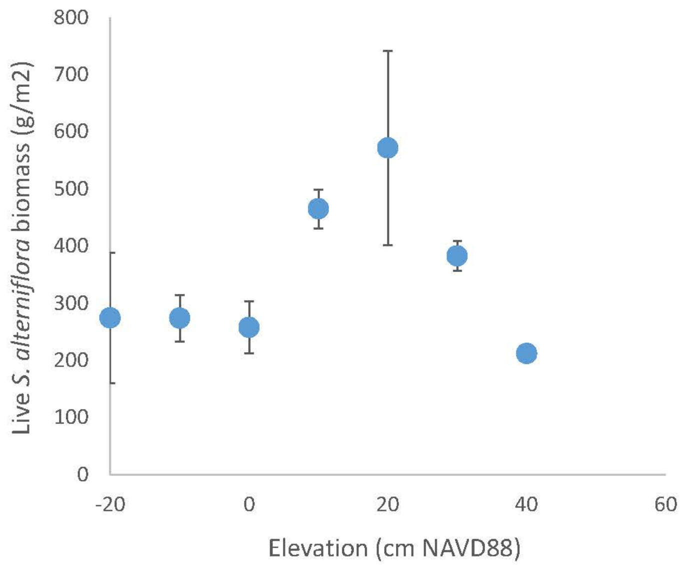


Elevation Benchmark
(0.95m NAVD88)

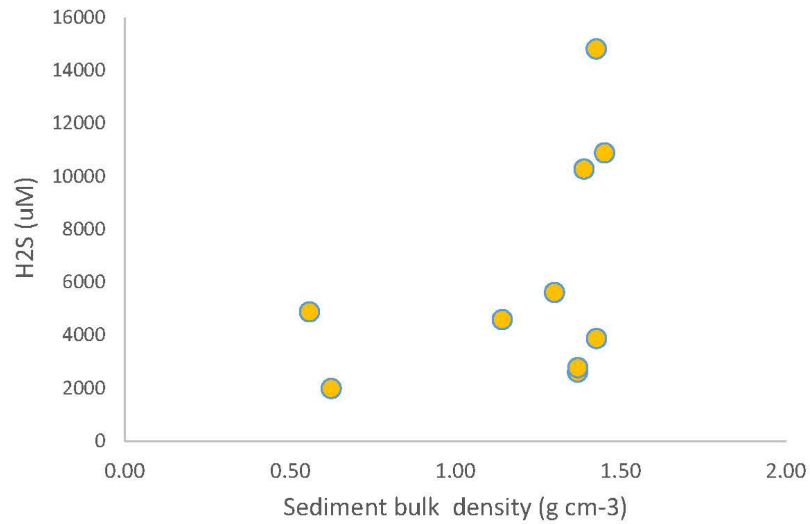


Transect surveys to establish full elevation range occupied
by *S. alterniflora*

Intertidal Marsh - Pre-placement conditions



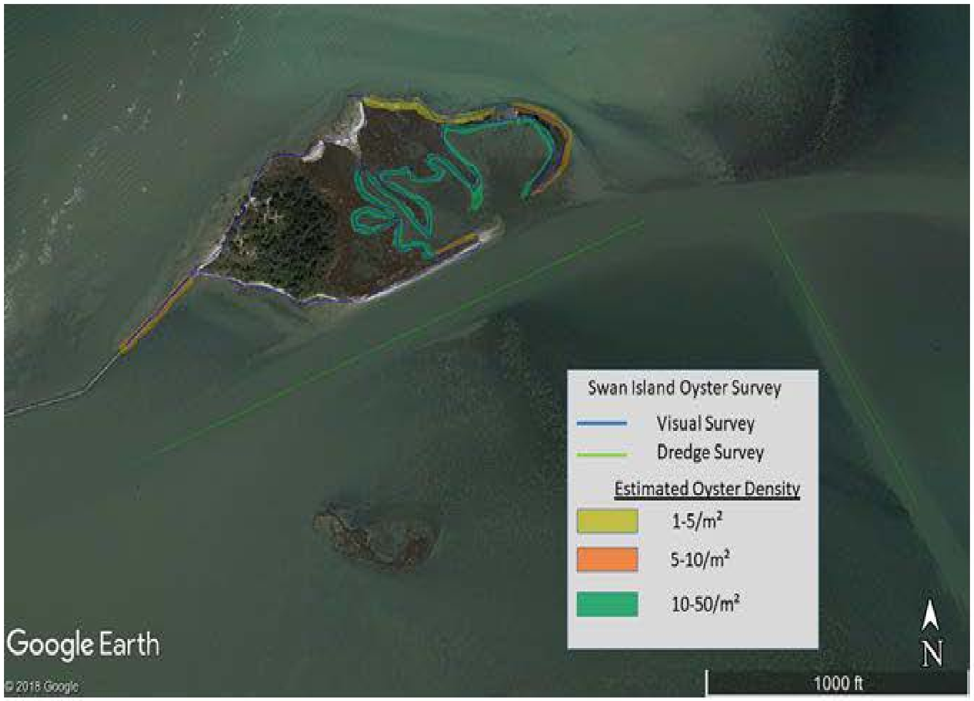
S. alterniflora grows over a ~60 cm elevation range



Sediment characteristics and porewater sulfide concentrations widely variable

SAV – percent cover, stem height, plot elevation

Oyster presence/absence/ size range



Intact intertidal oyster community
- multiple year classes
- no oysters found in channel

What we envision doing

- elevation
- shoreline position
- vegetative success – intertidal and SAV
- sediment characteristics (grain size/carbon)
- accretion?
- oysters
- inundation of intertidal areas (fish access)

NATIONAL CENTERS FOR **COASTAL OCEAN SCIENCE**
National Ocean Service

Appendix G:

a. Models: A Simple Approach to Complex Problems

(Note: For an accessible version of appendix Ga, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-Ga.pdf.)

models

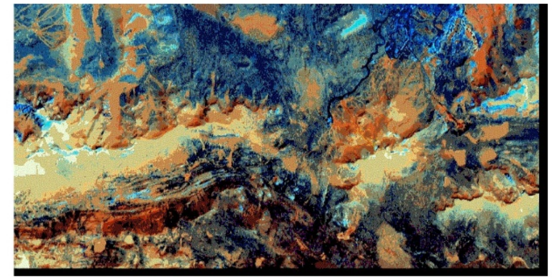
A simple approach to complex problems

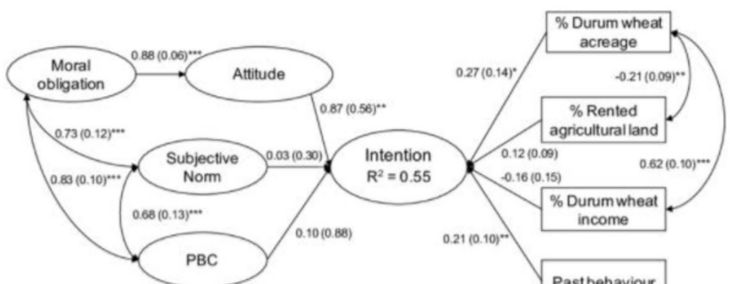
2

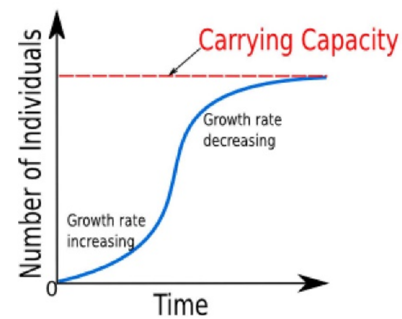
Overview

- Intro to systems thinking
- What is a "model"?
- General notes on modeling
- Types of models
- Overview of the "modeling process

$$
\begin{aligned}
f'(3) &= \lim_{h \to 0} \frac{(3+h)^2 - 3^2}{h} \\
&= \lim_{h \to 0} \frac{9 + 6h + h^2 - 9}{h} \\
&= \lim_{h \to 0} \frac{6h + h^2}{h} \\
&= \lim_{h \to 0} (6 + h) \\
&= 6
\end{aligned}
$$







3

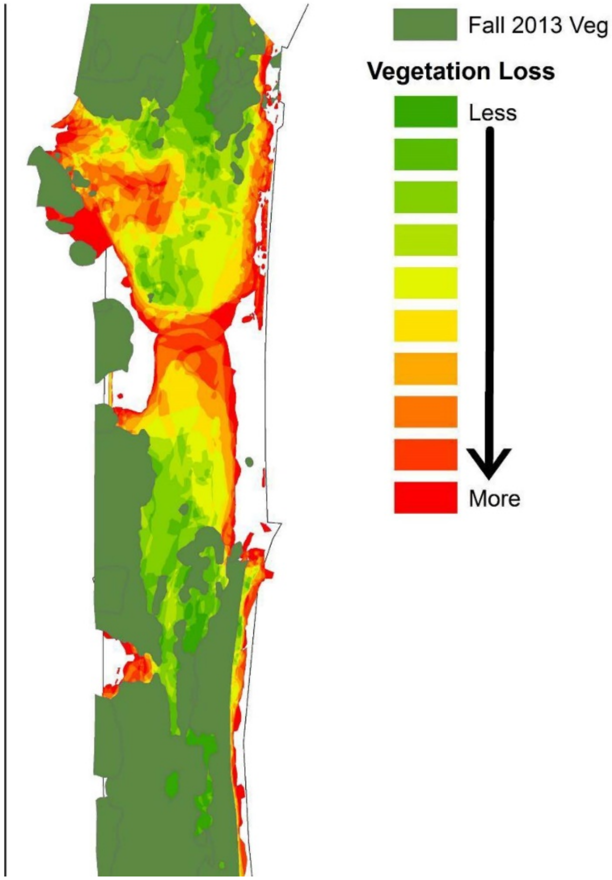
Systems

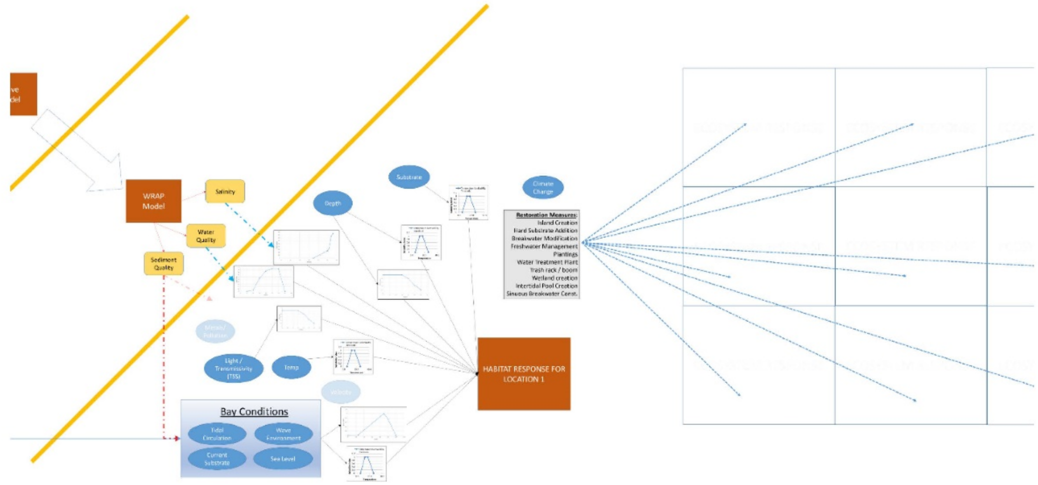
A system consists of a particular set of objects that interact in space and time. Systems are organized collections of interrelated physical components characterized by a boundary and functional unity.

System behavior is intrinsically difficult to model due to the dependencies, competitions, feedback loops, indirect/direct relationships, or other interactions

Ecosystem: Complex of ecological communities and their environment, forming a functional whole in nature (Patten & Jørgensen, 1995)

4





Definition of models

You are a modeler.

- Commonly used in the nerd world: “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 your tell your family what a model is?

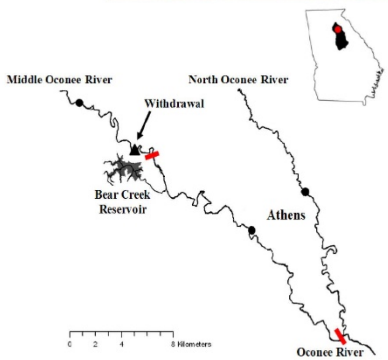
5

Definition of model for this class

Conceptual **and** numerical representation of environmental and ecological system

SIDE NOTE: **<u>not</u>** software applicable to any situation

6



Ecological modeling

Represents environment based on point of view of model builders

- Ecosystems are inherently complex, interdependent systems
- Ecology is a question-driven discipline
- Models are developed ad-hoc (project-by-project) with little reuse
  - Each system reacts differently to stimuli
  - Multiple approaches for a single problem
  - Trade-offs: detail, scale, expense
- Models for monitoring **must be** adaptable

Ecological Modeling Approaches

Ecological Question	Example Modeling Approaches
Where might species *X* be found after 5 years?	Habitat suitability index (HSI), GIS-based regression
How will climate change affect system *X*?	Individual (agent) , HSI modeling
Will species *X* persist in region *Y* with habitat fragmentation?	GIS, Metapopulation, Agent-based
How rapidly will species *X* invade area *Y*?	Agent-based ,GIS, System dynamics
How will disease *X* spread through species *Y*?	Demographic, Agent-based, GIS
How will pollutant *M* affect species *X*?	Biochemical model, statistical analysis of experimental data
How much timber can be harvested	Forest growth model
How can we control pest species *X*?	HSI, Agent-based, System dynamics

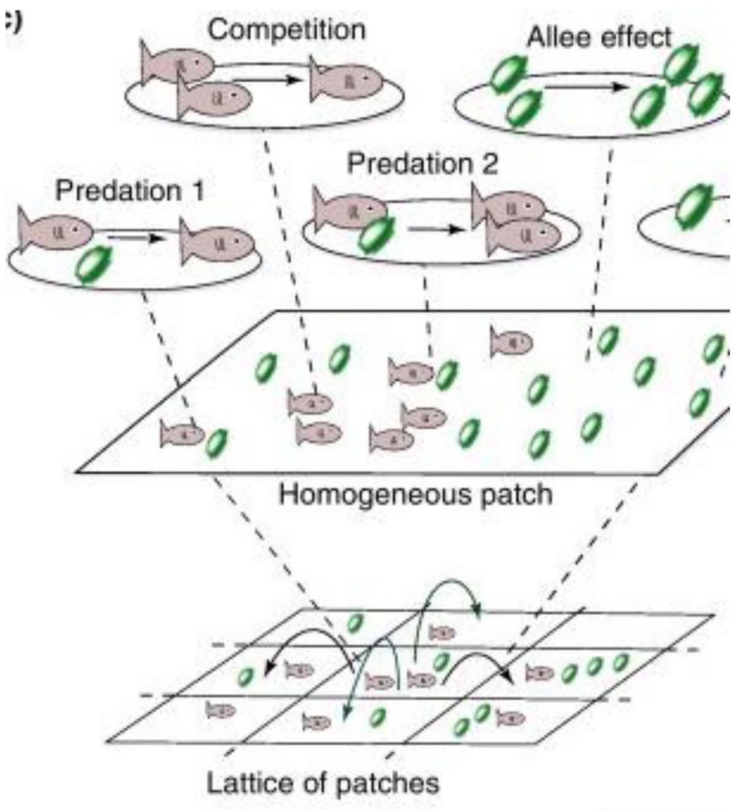
Engineering v. Ecological Models (Part 1)

	Engineering Models	Ecological Models
Primary Basis	Physics Chemistry (water quality)	Physics Chemistry Biology INTERACTIONS THEREOF
First principles?	Sometimes (e.g., Laws of Motion)	Rare / Never (Often do not exist)
Knowledge of dynamics	High	Low
Model Confidence	High	Low
Science/Art	90/10	25/75

Engineering v. Ecological Models (Part 2)

Engineering Models	Ecological Models
Models are well developed and reusable	Most models are single-use
New application uses old models	New application uses new models
A small set of models is sufficient	A toolbox containing a dozen modeling approaches is required
The model components are well understood	Most ecological systems are poorly understood
Models are used for prediction	Models are used for exploration and education
Models are heavily science-based	Models rely on local expertise

10



Why do we develop models?

Models!

To increase understanding

To organize thinking

To forecast future conditions

To inform decision-making

Provide a platform for critical thinking

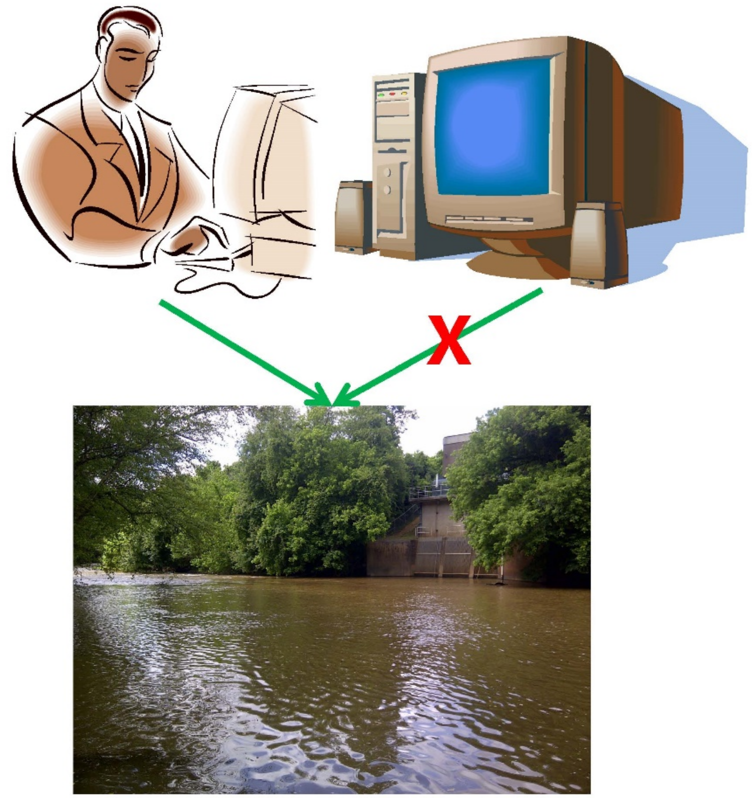
Models are never

Answers or Decisions

People make decisions. Models inform people.

Reality

Inherently a model is an abstraction of reality.



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

Think About	Ask Yourself
Purpose / Objectives	Why are you developing a model (understanding, forecasting, informing, etc.)? What are you trying to accomplish with a model? What question is being asked of the model? What is the model simulating?
Fidelity	What level of accuracy is required (exact v. relative comparison)?
Space	Where is the model targeting? What spatial resolution is of interest (none, order of magnitude)?
Time	Is the model simulating time? How long and detailed (order of magnitude)?
The Big Picture	Are the prior four categories commensurate?

13

When are models (in)appropriate?

Models might help	Don’t waste your time
•I don’t understand my system! •Examining future trends •Playing out scenarios •Quantifying trade-offs between alternatives •Communicating with stakeholder or decision-makers	•I want to predict EXACTLY what is going to happen •I want “the answer” •Determining value judgments •Replacing critical thinking

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 most simple of formal structures. **Parsimony is key (i.e., Einstein's aphorism…as simple as possible, but no simpler)**!

Starfield et al. (1997)

15

Types of Models

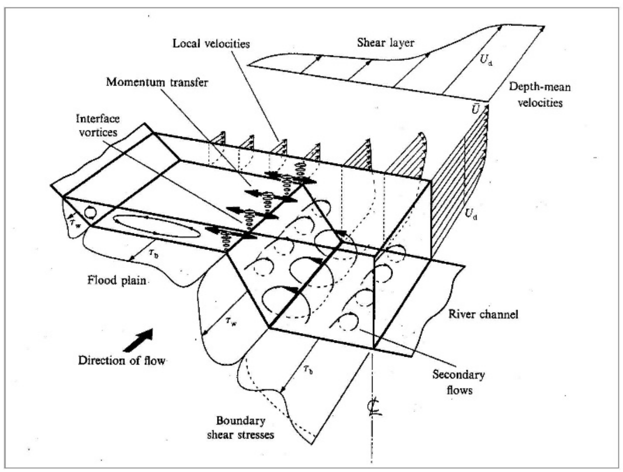
Table 1. Description of model types often used for modeling environmental benefits.

Model	General Use	Example
Analytical	Systems where solution to closed form equations represent system	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, relates species presence to environmental variables	HSI, HGM
Simulation	Modeling dynamics of complex systems that have multiple factors interacting across scales, often have spatial components	Agent-based models, ADH-CASM, ELAM, ICM, system dynamic models
Statistical	Analysis of datasets to determine distributional properties of the data	ANOVA, goodness-of-fit, regression, t-test,
Spatial	Projects where particular spatial attributes are important can be incorporated into simulation models	GIS, EDYS

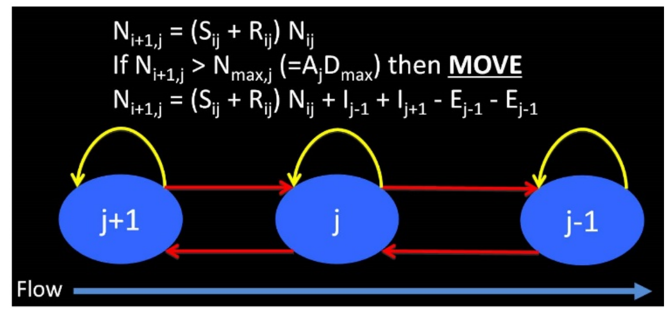
Analytical Models

Solution of closed form equations representing the system

$$\rho g H S_0 + \frac{\partial}{\partial z}\left(\rho\lambda\sqrt{\frac{f}{8}}H^2 U_d \frac{\partial U_d}{\partial z}\right) - \rho {U_d}^2 \frac{f}{8}\sqrt{1+{S_{0z}}^2} = \Gamma$$



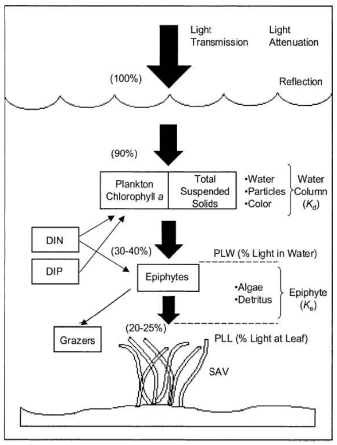
$$\begin{bmatrix} n_0 \\ n_1 \\ \vdots \\ n_{\omega-1} \end{bmatrix}_{t+1} = \begin{bmatrix} f_0 & f_1 & f_2 & f_3 & \dots & f_{\omega-1} \\ s_0 & 0 & 0 & 0 & \dots & 0 \\ 0 & s_1 & 0 & 0 & \dots & 0 \\ 0 & 0 & s_2 & 0 & \dots & 0 \\ 0 & 0 & 0 & \ddots & \dots & 0 \\ 0 & 0 & 0 & \dots & s_{\omega-2} & 0 \end{bmatrix} \begin{bmatrix} n_0 \\ n_1 \\ \vdots \\ n_{\omega-1} \end{bmatrix}_{t}$$

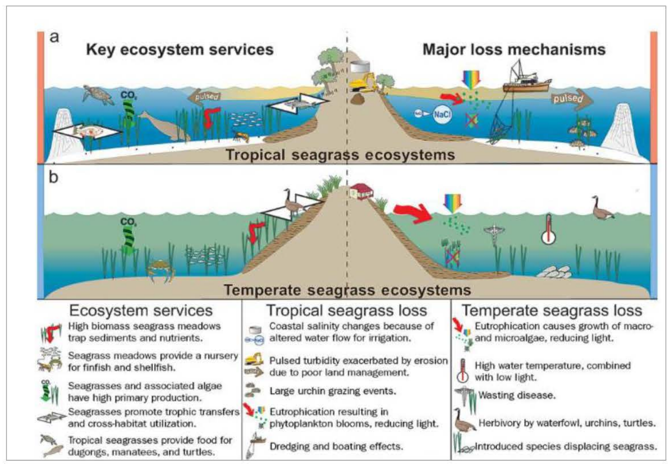


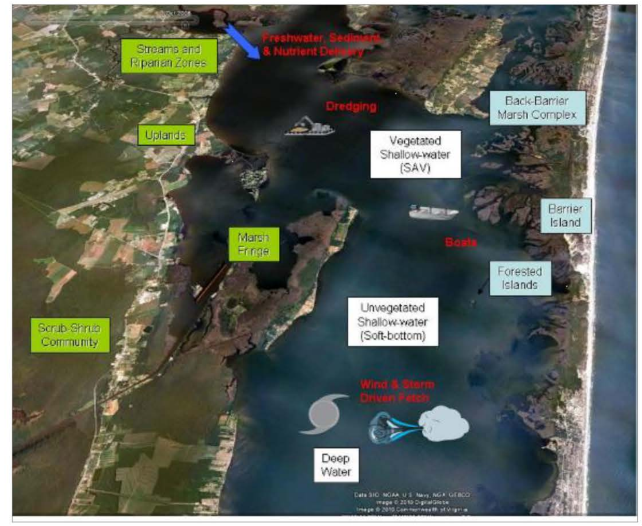
18

Conceptual Models

Diagramming relationships among components, organizing information, determining data needs, framework for critical thinking







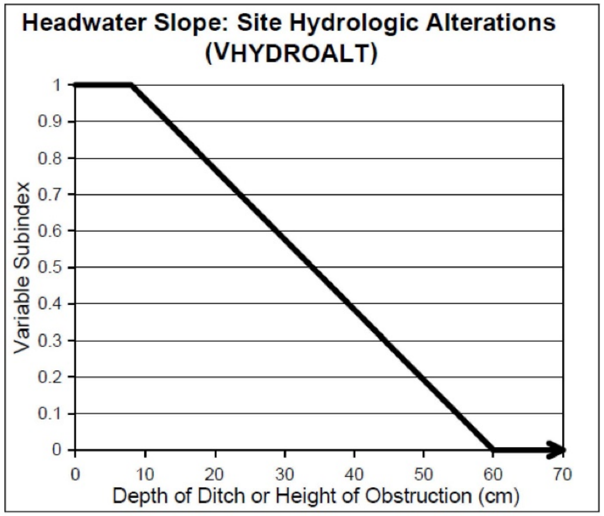
Index models

Determining ecosystem quality relative to environmental variables

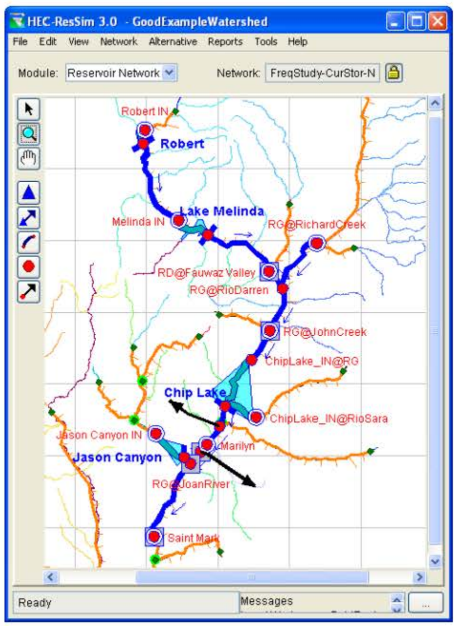
Quantity * Quality

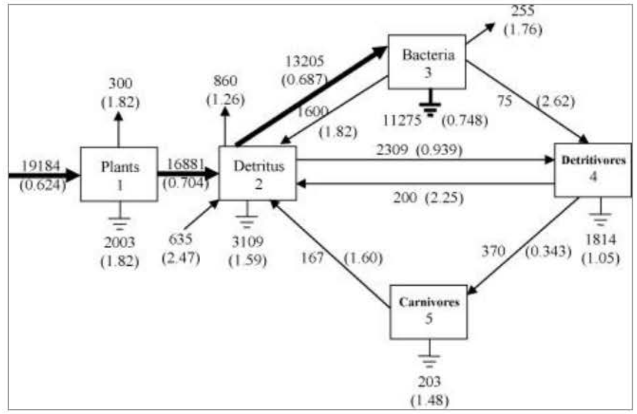
Quality for what?

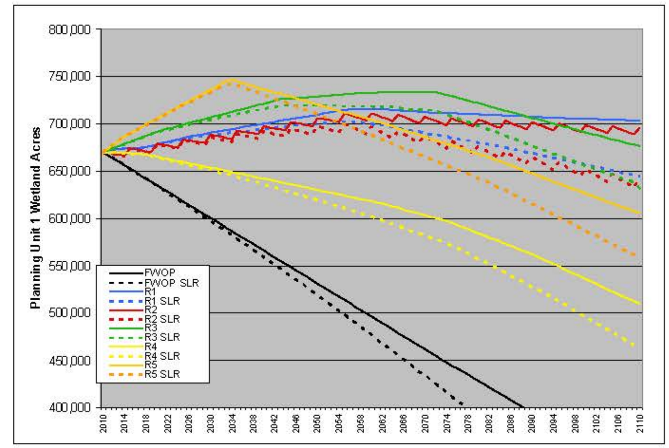
- Species – HSI
- Community – HSI
- Function – HGM



$$FCI = \sqrt{Hydro * \left(\frac{Catch + Upuse + Big3 + Tden}{4}\right)}$$



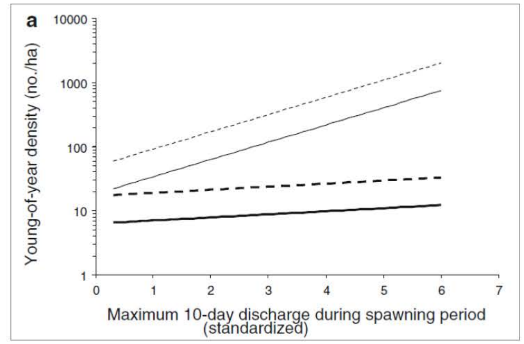




Simulation models

Statistical Models

Analysis of datasets to determine distributional properties of the data



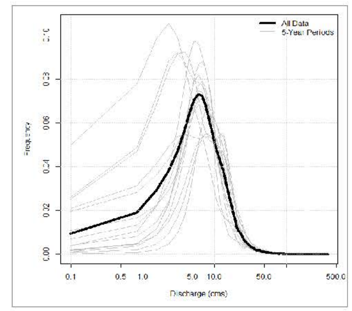
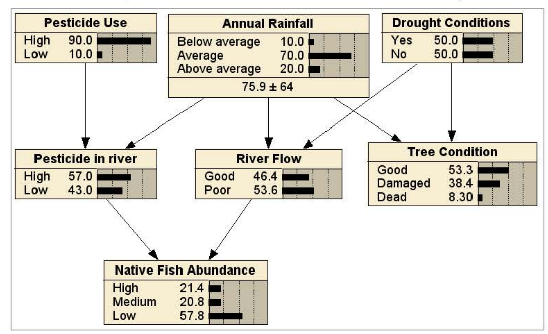
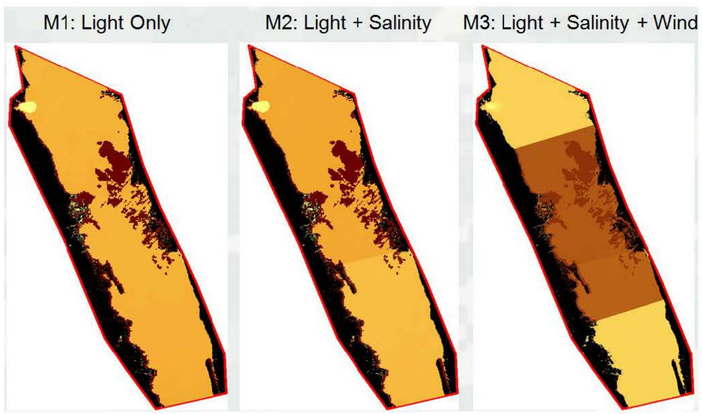
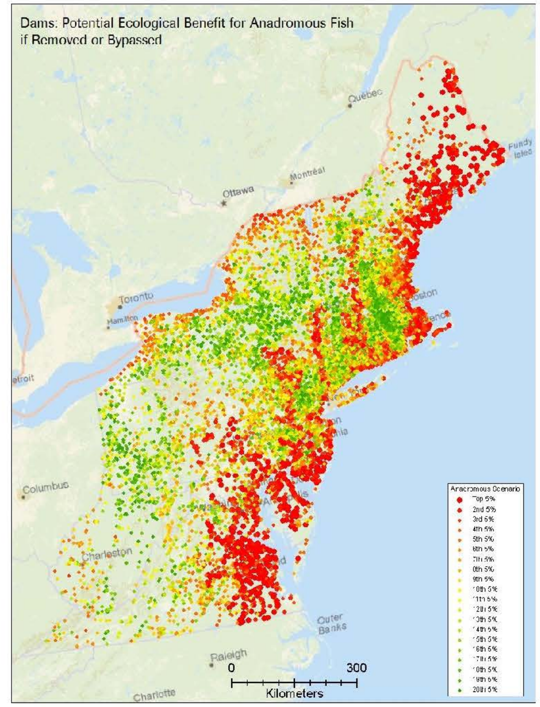


Table 3 Model selection criterion for the top ten Pradel reverse time, tag-recapture models of mussel survival (*Phi*), capture probability (*p*) and recruitment (*f*)

Model	−2Log *L*	*K*	Δ AIC$_c$	w_i
Phi(Maximum 10-day summer discharge), *p*(Discharge during sampling, species) *f*(Median summer discharge lag 2)	4574.1	8	0.000	0.071
Phi(Maximum 10-day summer discharge), *p*(Discharge during sampling, species) *f*(Maximum 10-day summer discharge lag 2)	4574.1	8	0.007	0.070
Phi(Maximum 10-day summer discharge), *p*(Discharge during sampling, species) *f*(Minimum 10-day spring discharge lag 2)	4574.1	8	0.056	0.069
Phi(Maximum 10-day summer discharge), *p*(Discharge during sampling, species) *f*(Minimum 10-day summer discharge lag 2)	4574.1	8	0.065	0.068
Phi(Maximum 10-day summer discharge), *p*(Discharge during sampling, species) f(Median spring discharge lag 2)	4574.2	8	0.120	0.067
Phi(Maximum 10-day summer discharge), *p*(Discharge during sampling, species) *f*(Maximum 10-day spring discharge lag 2)	4574.3	8	0.204	0.064
Phi(Median summer discharge), *p*(Discharge during sampling, species) *f*(Median spring discharge lag 2)	4574.9	8	0.848	0.046
Phi(Median summer discharge), *p*(Discharge during sampling, species) *f*(Maximum 10-day spring discharge lag 2)	4575.0	8	0.896	0.045
Phi(Median summer discharge), *p*(Discharge during sampling, species) *f*(Minimum 10-day spring discharge lag 2)	4575.0	8	0.897	0.045
Phi(Median summer discharge), *p*(Discharge during sampling, species) *f*(Maximum 10-day summer discharge lag 2)	4575.0	8	0.988	0.043







Spatial Models

Combination of spatial attributes often coupled with simulation

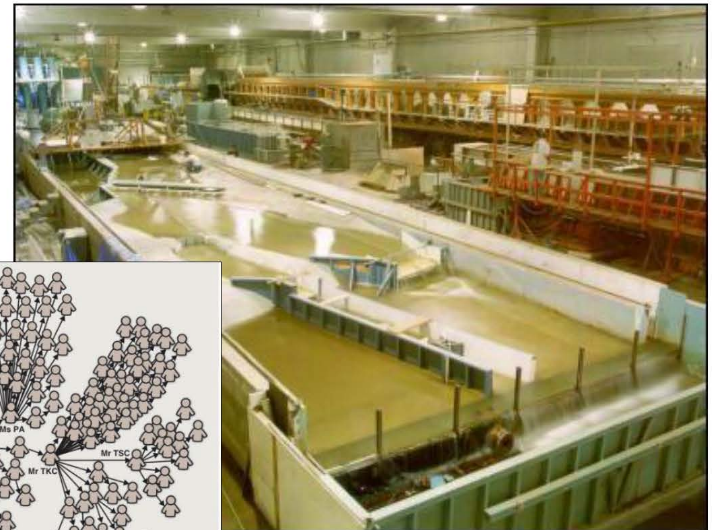
23

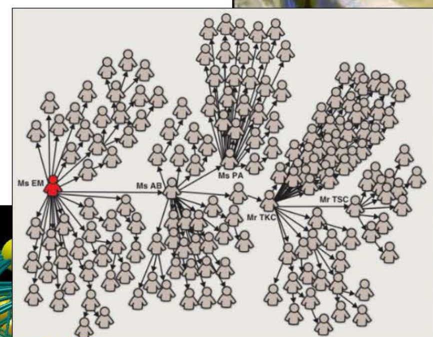
Other Notable Model Types

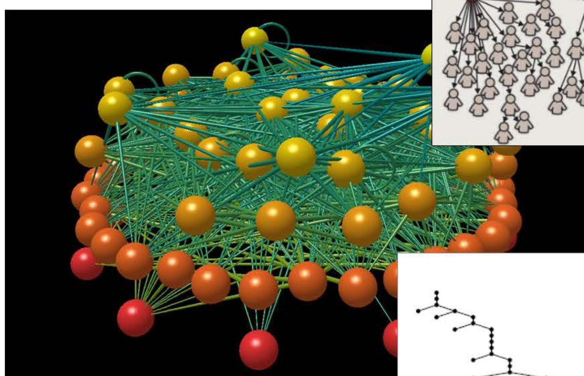
Physical

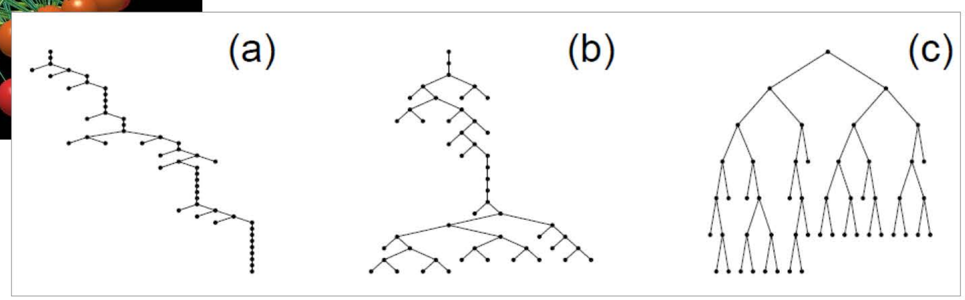
Systems

Networks

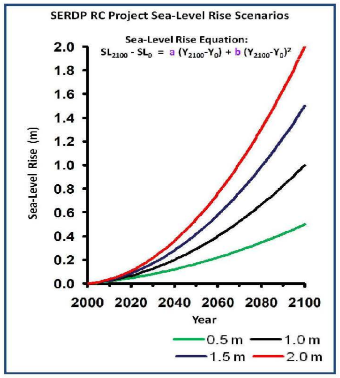


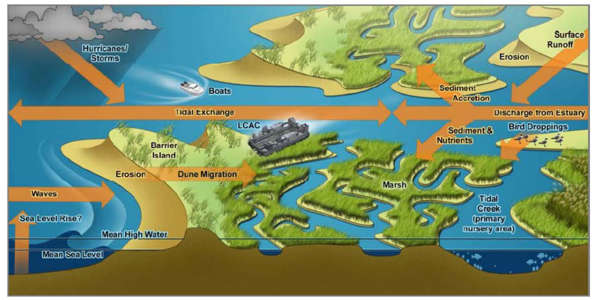


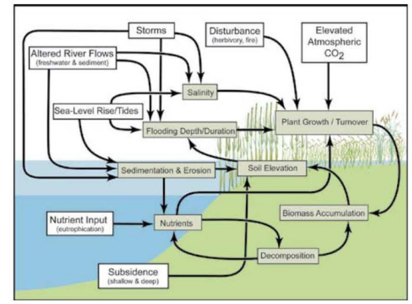


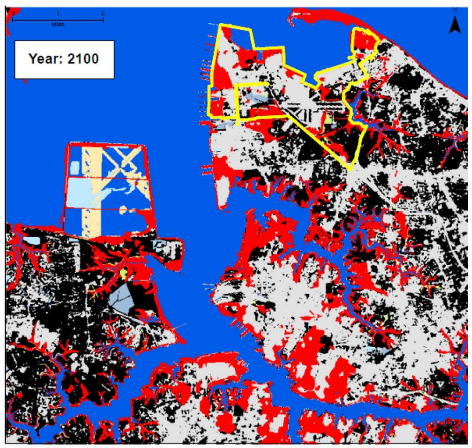


Integrated Modeling









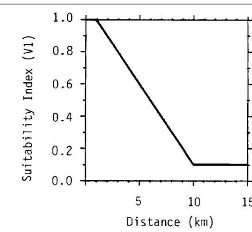
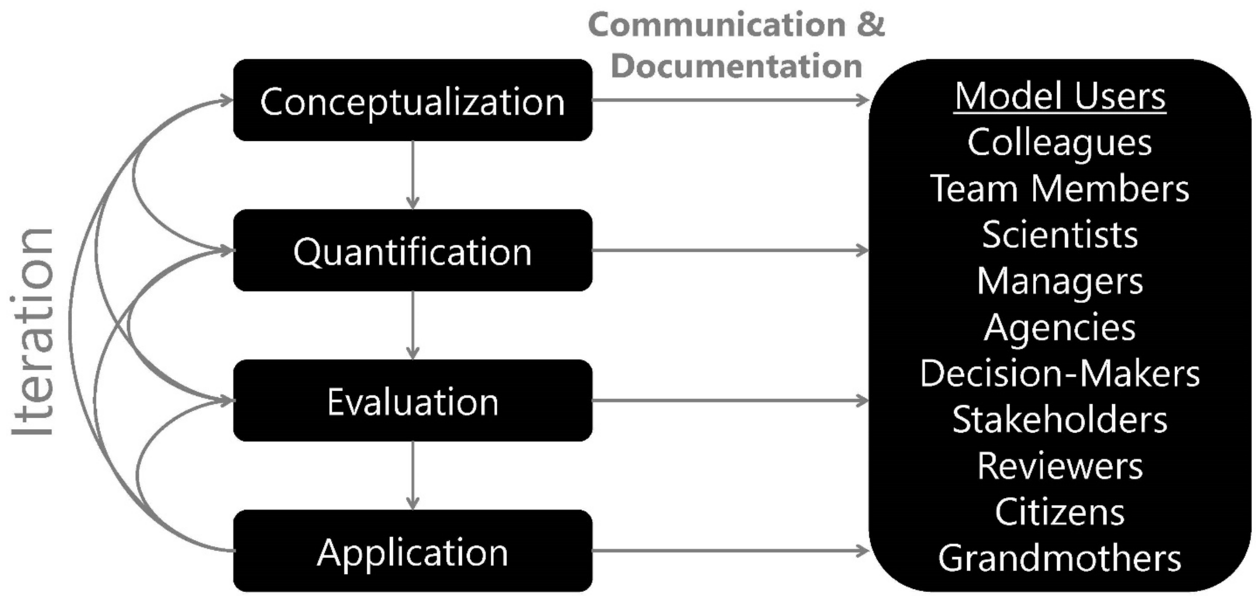


Figure 2. Distance between foraging areas and heronry sites modifies SI values.

The Modeling Process

Ecological Model Development



Key attributes for model development teams

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

Dr. Kyle McKay, modeling

Develop, refine, collaborate, iterate!

28

Covered throughout this course, but worth emphasizing

- 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 “strawman” or alpha-version
- 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)

29

Take-away Points:

- 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

Grant W.E. and Swannack T.M. 2008. Ecological modeling: A common-sense approach to theory and practice. Malden, MA: Blackwell Publishing.

Schmolke A., Thorbek P., DeAngelis D.L., and Grimm V. 2010. Ecological models supporting environmental decision making: A strategy for the future. Trends in Ecology and Evolution, 25: 479-486.

Swannack T.M., Fischenich J.C., and Tazik D.J. 2012. Ecological Modeling Guide for Ecosystem Restoration and Management. ERDC/EL TR-12-18, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

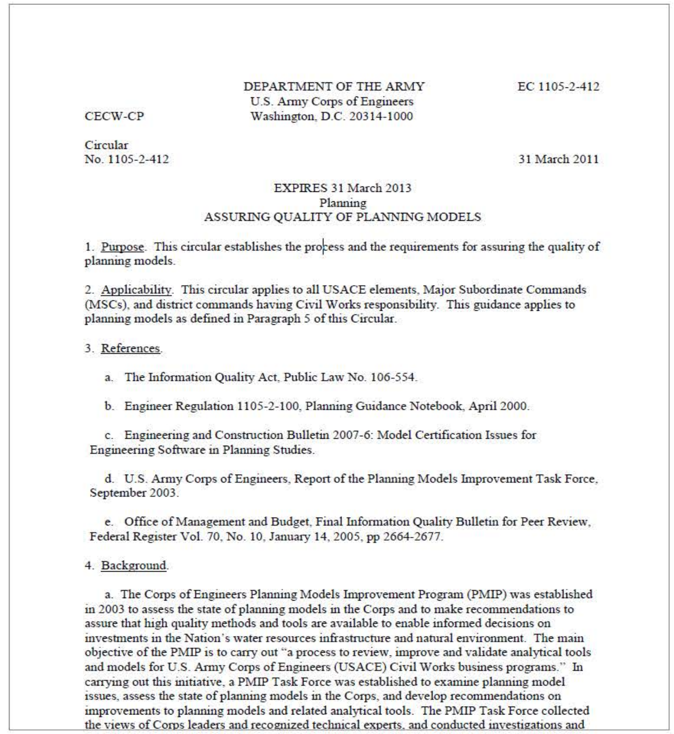
McKay S.K. and Pruitt B.A. 2012. An Approach for Developing Regional Environmental Benefits Models. EMRRP-EBA-14, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Model Certification

32

Policy and Guidance

- Present – EC 1105-2-412
  - PB 2013-02 – Continued EC 1105-2-412
  - PGN Update to include model certification and process
  - New guidance to align with principles of SMART Planning
- Model Cert SOP
  - Includes details of the certification process
  - Also being updated in near future



DEPARTMENT OF THE ARMY — EC 1105-2-412
U.S. Army Corps of Engineers
CECW-CP — Washington, D.C. 20314-1000

Circular
No. 1105-2-412 — 31 March 2011

EXPIRES 31 March 2013
Planning
ASSURING QUALITY OF PLANNING MODELS

1. Purpose. This circular establishes the process and the requirements for assuring the quality of planning models.

2. Applicability. This circular applies to all USACE elements, Major Subordinate Commands (MSCs), and district commands having Civil Works responsibility. This guidance applies to planning models as defined in Paragraph 5 of this Circular.

3. References.

a. The Information Quality Act, Public Law No. 106-554.

b. Engineer Regulation 1105-2-100, Planning Guidance Notebook, April 2000.

c. Engineering and Construction Bulletin 2007-6: Model Certification Issues for Engineering Software in Planning Studies.

d. U.S. Army Corps of Engineers, Report of the Planning Models Improvement Task Force, September 2003.

e. Office of Management and Budget, Final Information Quality Bulletin for Peer Review, Federal Register Vol. 70, No. 10, January 14, 2005, pp 2664-2677.

4. Background.

a. The Corps of Engineers Planning Models Improvement Program (PMIP) was established in 2003 to assess the state of planning models in the Corps and to make recommendations to assure that high quality methods and tools are available to enable informed decisions on investments in the Nation's water resources infrastructure and natural environment. The main objective of the PMIP is to carry out "a process to review, improve and validate analytical tools and models for U.S. Army Corps of Engineers (USACE) Civil Works business programs." In carrying out this initiative, a PMIP Task Force was established to examine planning model issues, assess the state of planning models in the Corps, and develop recommendations on improvements to planning models and related analytical tools. The PMIP Task Force collected the views of Corps leaders and recognized technical experts, and conducted investigations and

33

Policy and Guidance

- Continuing Authorities Program Planning Process Memo – Jan 2011
  - Approval of planning models not required
  - MSC responsible for assuring quality of models
  - ATR used to ensure models and analyses are:
    - Compliant with Corps policy
    - Theoretically sound
    - Computationally accurate
    - Transparent
    - Described to address limitations and use
    - Documented appropriately

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
WASHINGTON, D.C. 20314-1000

JAN 19 2011

CECW-P

DIRECTOR OF CIVIL WORKS' POLICY MEMORANDUM # 1

SUBJECT: Continuing Authority Program Planning Process Improvements

1. The U.S. Army Corps of Engineers (USACE) seeks to be more flexible and agile in the execution of the Continuing Authority Program (CAP). The goal is to fund and execute the projects that can move forward and remove funds from projects that cannot be executed. Districts and Major Subordinate Commands (MSC) must make these decisions more quickly so we do not have, literally, hundreds of millions of dollars assigned to projects that are not proceeding. This memorandum modifies existing guidance with the goal of implementing improvements to the CAP planning process to facilitate program execution and simplifying policy requirements for this program. Accountability for compliance with existing policy and these modifications remains with the MSC. Inspections will be conducted to ensure that the program is being executed in accord with guidance.

2. The individual authorities known collectively as the CAP are:

a. Section 14, Flood Control Act of 1946 (PL 79-526), as amended, for emergency streambank and shoreline erosion protection for public facilities and services;

b. Section 103, River and Harbor Act of 1962 (PL 87-874), as amended, amends PL 727, an Act approved August 13, 1946 which authorized Federal participation in the cost of protecting the shores of publicly owned property from hurricane and storm damage;

c. Section 107, River and Harbor Act of 1960 (PL 86-645), as amended, for navigation;

d. Section 111, River and Harbor Act of 1968 (PL 90-483), as amended, for mitigation of shoreline erosion damage caused by Federal navigation projects;

e. Section 204, Water Resources Development Act of 1992 (PL 102-580), as amended, for beneficial uses of dredged material;

f. Section 205, Flood Control Act of 1948 (PL 80-858), as amended, for flood control;

g. Section 206, Water Resources Development Act of 1996 (PL 104-303), as amended, for aquatic ecosystem restoration;

34

Definitions

What is "model certification"?

"… a corporate approval that the model is sound and functional."

What is a planning model?

Models and analytical tools that planners use to define water resources management problems and opportunities, formulate potential alternatives, evaluate potential effects of alternatives, and support decision-making.

Includes all models used for planning, regardless of their scope or source

What is a "certified" planning model?

"… A planning model reviewed and certified by the appropriate Planning Center of Expertise (PCX) in accordance with the criteria and procedures specified in EC 1105-2-412."

35

Certification Criteria

What criteria used by the PCX as basis for certification?

- Technical Quality – Contemporary theory, consistent with design objectives, documented, tested
- System Quality – Computational integrity, appropriately programmed, verified or stress-tested
- Usability – Ease of use, availability of input, transparency, error potential, education of user

36

Easier Model Approval

- Develop and use Conceptual Models
  - Excellent tool to communicate stressors and drivers
  - Inform level of detail
  - Selection of model

- **EARLY, EARLY, EARLY** Communication with ECO-PCX
  - During identification of problems and opportunities
  - Selecting models and level of detail necessary
  - Selection and review should be in-progress or complete by the Alternatives Milestone
  - Preparation of plan for review, testing, and documentation (i.e., Model Review Plan)
  - In advance of any kind of internal, external, formal, or informal review

37

Easier Model Approval

- Complete model documentation
  - Address model certification criteria including application to planning
  - Documentation of prior model review and testing
    - Reviewers' qualifications,
    - Review charge
    - Comments and responses,
    - Proposed revisions to the model

- Early identification of model review needs facilitates:
  - Review process setup
  - Concurrent review with model development

38

Easier Model Approval

- Already reviewed model?
  - Provide review documentation including:
    - reviewers' qualifications,
    - Review charge
    - comments and responses,
    - proposed revisions to the model.
- Don't overlook Quality Control of your spreadsheets to ensure computational correctness and usability.
- Early identification of model review needs facilitates:
  - Review process setup
  - Concurrent review with model development

b. Measuring Ecological Outcomes and Monitoring & Adaptive Management (MAMP)

(Note: For an accessible version of appendix Gb, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-Gb.pdf.)

- Workshop
  - Presentation/Labs (Group Participation)
  - Modeling Basics
  - Conceptualization + (Lab 1)
  - Quantification + (Lab 2)
  - Evaluation/Application
  - Communication/Monitoring Plan + (Lab 3)
- Presentation
  - Ecological Restoration
  - Measuring Ecological Outcomes

OVERVIEW

Ecosystem Restoration: the assisted recovery of ecosystem structure, function or process that had been degraded, damaged or destroyed

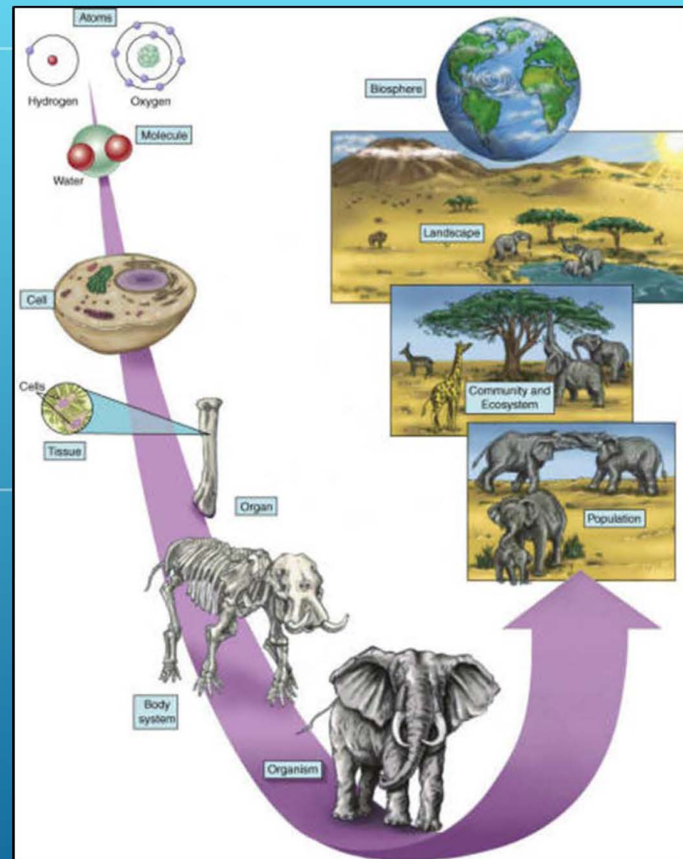
Monitoring and Adaptive Management: deliberate collection of data in order to understand impact of actions (restoration) to system of interest, to make informed management decisions and to apply understanding to future projects.

SWAN ISLAND ECOSYSTEM RESTORATION

MONITORING REQUIRES UNDERSTANDING OF SYSTEM DYNAMICS

An ecosystem is greater than the sum of its parts.

-Eugene P. Odum



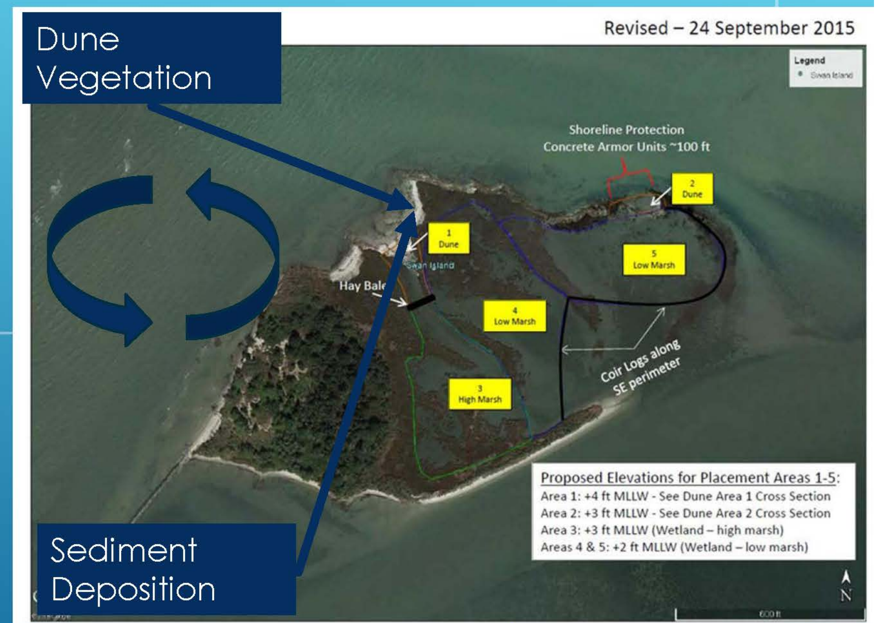
Increasing uncertainty and complexity

ECOLOGICAL SYSTEMS

Structure: “refers to both the composition of the ecosystem (i.e., its various parts) and the physical and biological organization defining how those parts are organized”

Function/Process: “describes a process that takes place in an ecosystem as a result of the interactions of plants, animals, and other organisms in the ecosystem with each other or their environment”

- Comprised of numerous ongoing processes



ECOSYSTEM STRUCTURE AND FUNCTION/PROCESS

Component	Description	Examples
Hydrogeomorphology	**Physical processes** governing geologic setting, climate, hydrologic cycling, and watershed land use with implications for channel morphology, sediment regimes, channel hydraulics, and hydrologic connectivity	Sediment Transport
Biogeochemistry	**Chemical processes** driving the concentration, fate, and transport of nutrients, contaminants, and other constituents	Salinity
Biological Systems	**Reproduction, survival, and movement** of living components of an ecosystem	Vegetation
Socio-economics	**Instrumental value** of ecosystems to humans	Storm Protection
Cultural-personal values	**Intrinsic value** of ecosystems to humans and resulting influence of humans on ecosystems	Loss of Bay Islands

COMPONENTS OF ECOSYSTEMS

TEMPORAL VARIABILITY

What natural disturbances govern ecosystem structure and function?

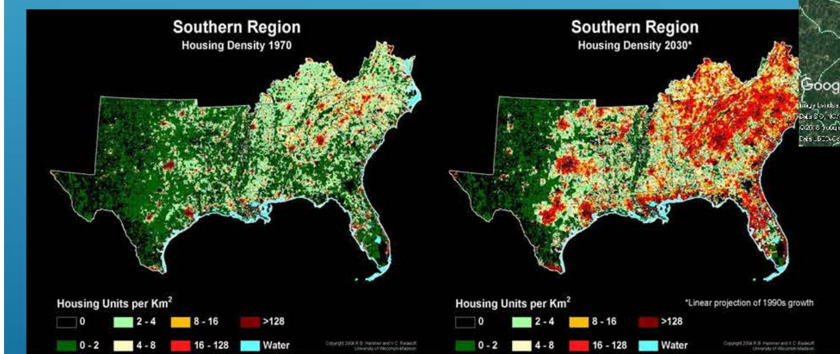
- Pulses: discrete events (e.g., **Storms**)
- Presses: slowly escalating events (e.g., **Boat Wake, Recreation**)
- Ramps: slowly changing conditions (e.g., **Sea Level Rise**)

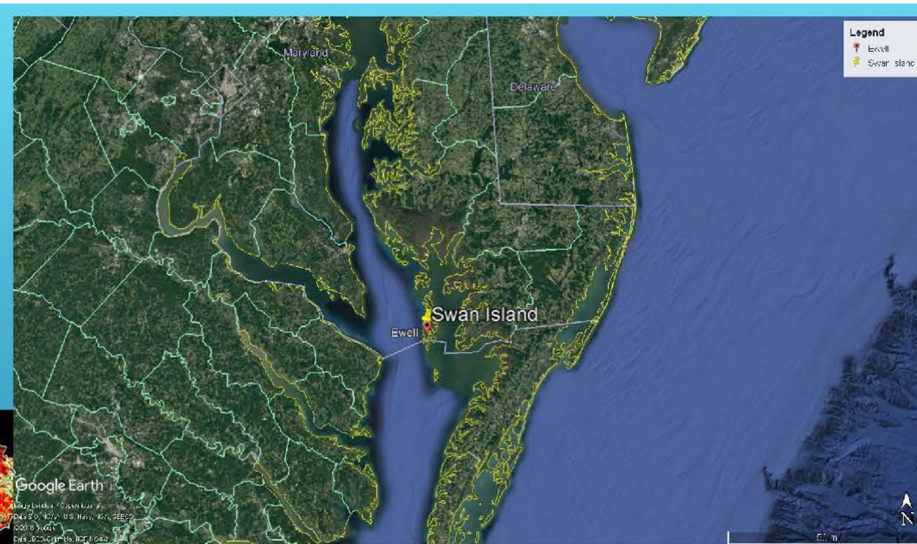
What is the disturbance regime?

i.e., magnitude, frequency, duration, timing, and rate of change (sensu, Poff et al. 1997)

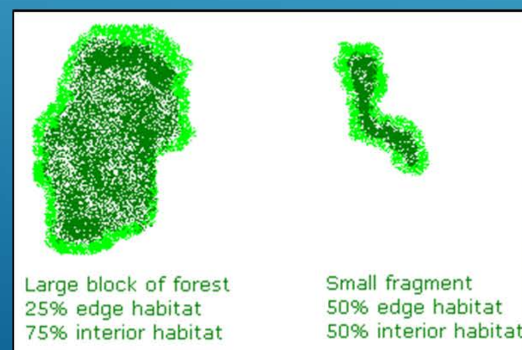
Is the system "stationary"? Are disturbance regimes changing?

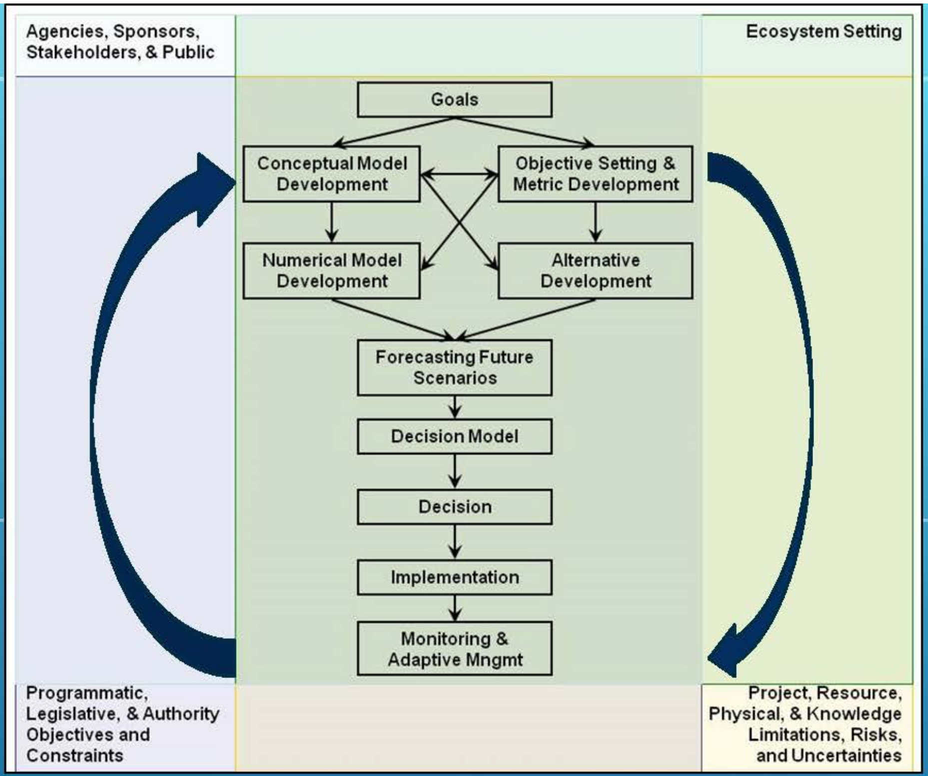
- Composition
- Configuration
- Connectivity
- Location





SPATIAL CONSIDERATIONS





ECOSYSTEM RESTORATION PLANNING PROCESS

WHY MODELS?

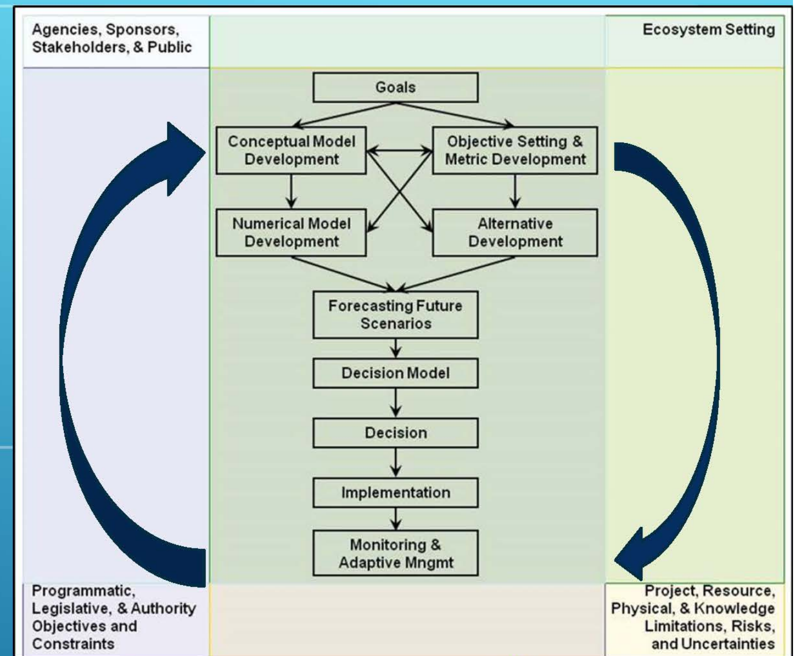
- Ecosystems are complex, self-organizing, interacting systems
- Modeling provides mechanism to capture current knowledge of the system, identify important process/interactions, facilitate communication, and increase transparency

HOW ARE CONCEPTUAL MODELS USED IN ENVIRONMENTAL MONITORING?

- Communicate the "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

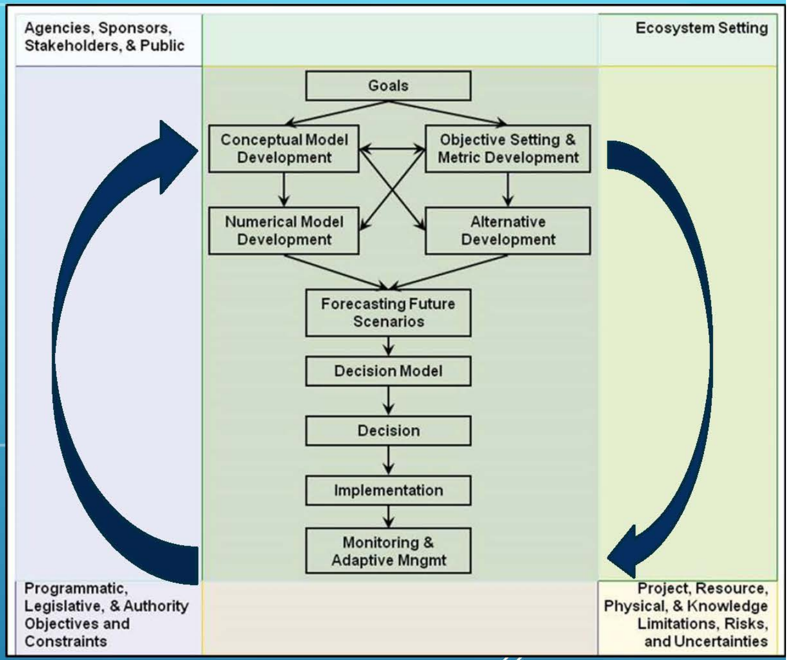
1. Review project goals and objectives
2. Identify important components/drivers/stressors of the system
3. Determine measurable metrics to collect data
4. Forecast/predict change in metrics over time



MEASURING ECOLOGICAL OUTCOMES

Example

1. Objective: Increase marsh vegetation coverage
2. System Components: substrate, hydrology, herbivory, storms, stem density
3. Metrics:
   1. a) stem density: number of stems per plot
   2. b) depth: average depth of plot at low tide
4. Predictions:
   1. Stem density will increase over time (Years 1-5) to reach a maximum of 50 stems (over predefined area)
   2. Depth will be maintained at an average of 0.05 meters after sediment placement (Years 1-5)



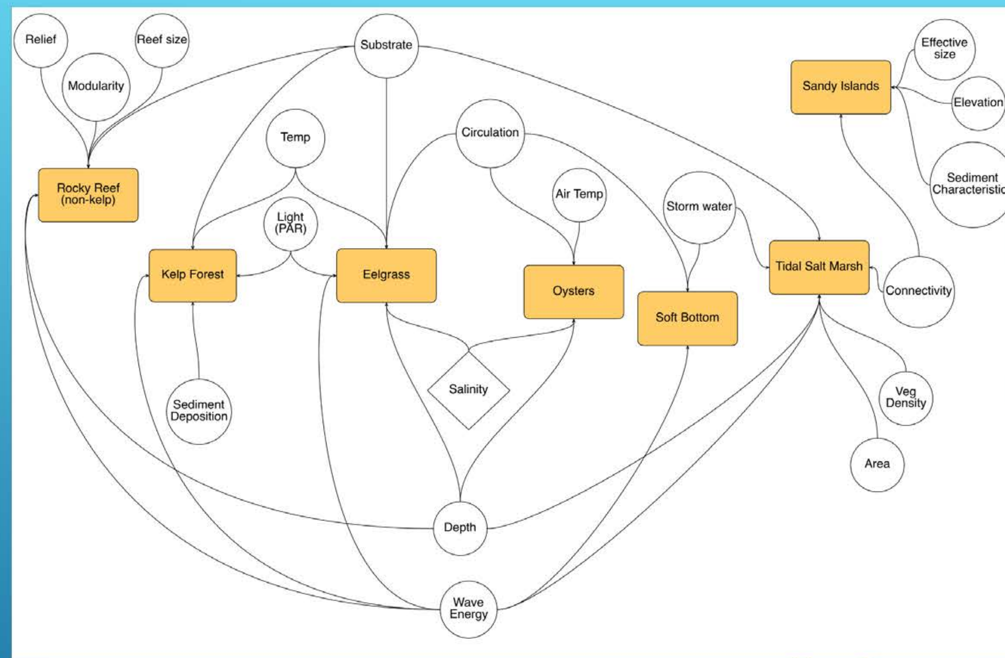
MEASURING ECOLOGICAL OUTCOMES

Monitoring Ecosystem Restoration Considerations:

1. What is restoration "success"?
2. Compare monitoring results to reference conditions?
3. Will you use monitoring data to determine when success has been met?

MEASURING ECOLOGICAL OUTCOMES

Conceptual model used as template for quantitative model development, which better identifies metrics for monitoring (i.e., don't collect unnecessary data)



MEASURING ECOLOGICAL OUTCOMES

- Environmental restoration projects are complex and identifying metrics for monitoring benefits is crucial
- Ecological modeling provides tool to conceptualize system in an adaptive framework
- Models are developed for a specific purpose. Consider how monitoring data will be used before collecting it.
- Clearly documenting each step of the process increases transparency and scientific defensibility

TAKE HOME POINTS

Appendix H: Model Development: Conceptualization

(Note: For an accessible version of appendix H, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-H.pdf.)

Model Development: Conceptualization

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Modeling Workshop
Swan Island Ecosystem Restoration
April 11, 2019

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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).

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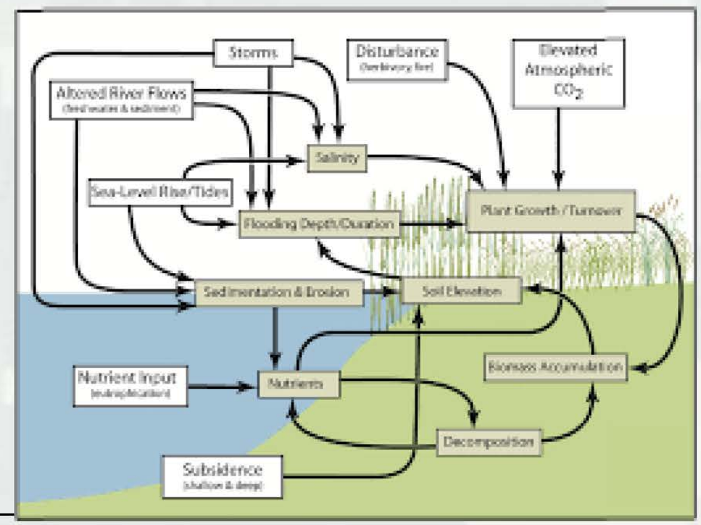
A conceptual model is a tentative description of a system or sub-system that serves as a basis for intellectual organization.



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

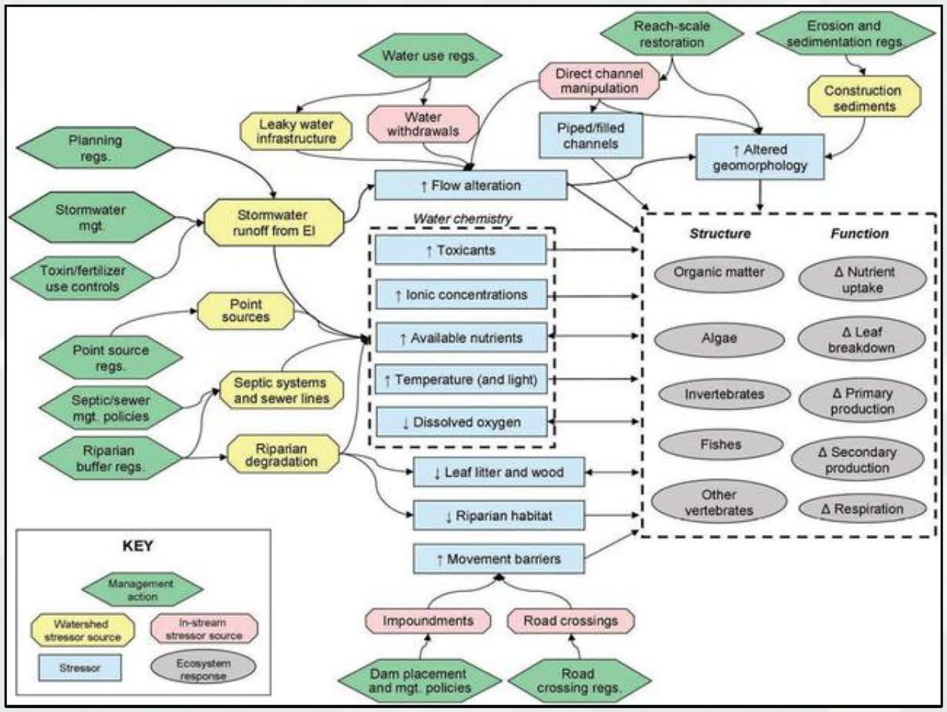


Figure: Wenger et al. (2009, JNABS)

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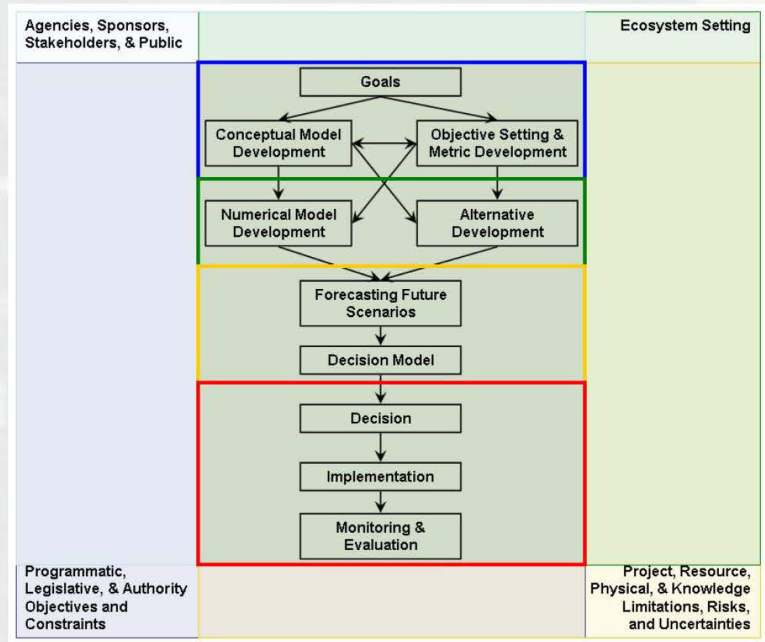
How are conceptual models used in ecosystem restoration?

- 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



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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

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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

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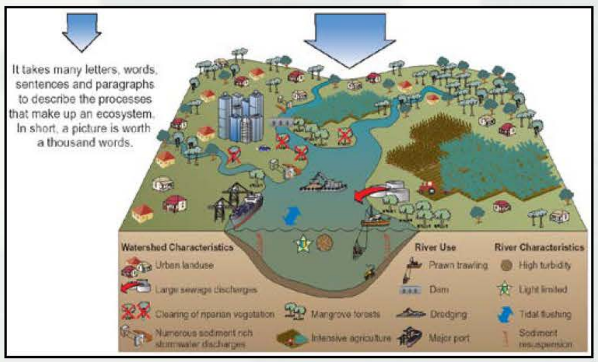
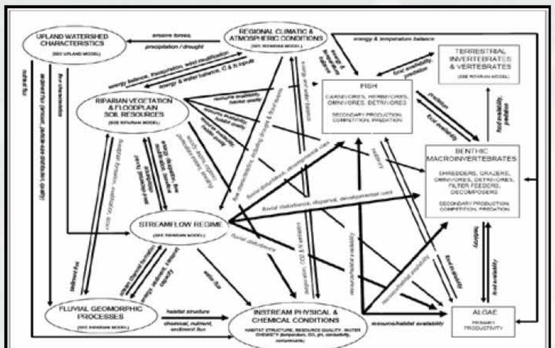
Types of Conceptual Models

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

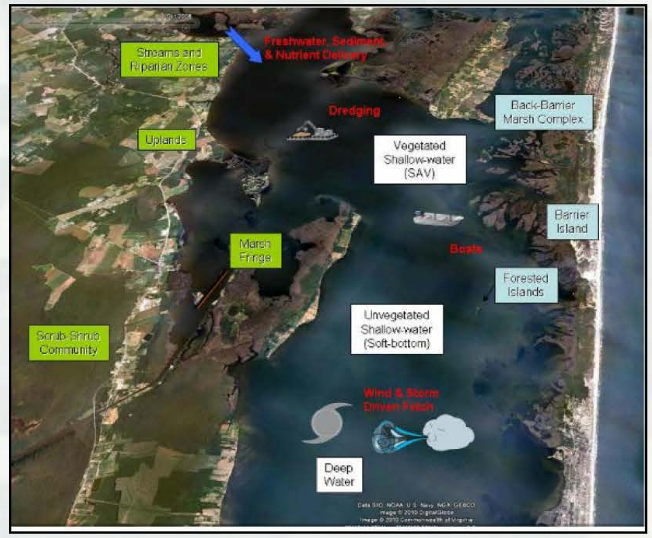


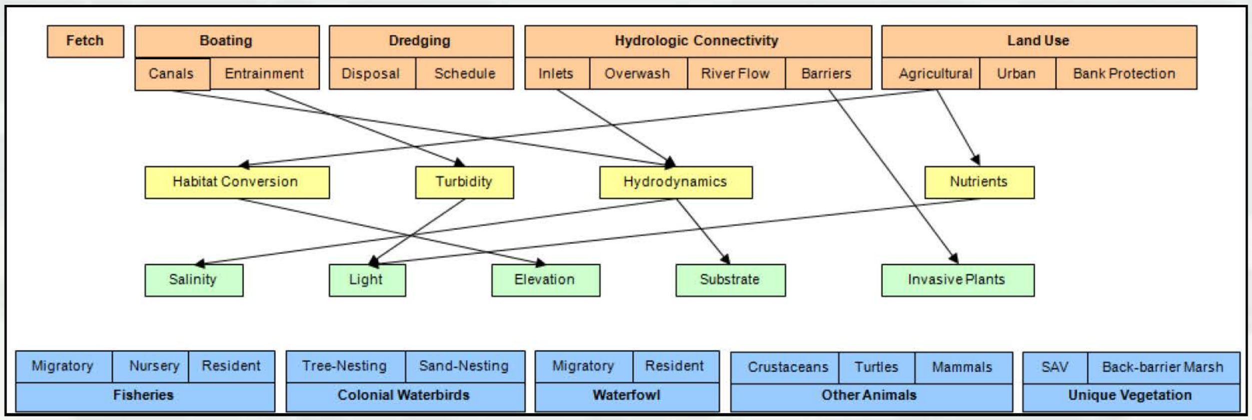


Habitat	Salinity (yearly average)	Source for Salinity Restrictions	Inundation (% of year)	Source for Inundation Restrictions
Bottomland Hardwood	< 2 ppt	Conner et al. (1997)	< 30%	Conner et al. (1997)
Swamp Forest	< 4 ppt	Höppner (2002)	Up to whole year if not stagnant	Höppner (2002)
Fresh Floating Marsh	< 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





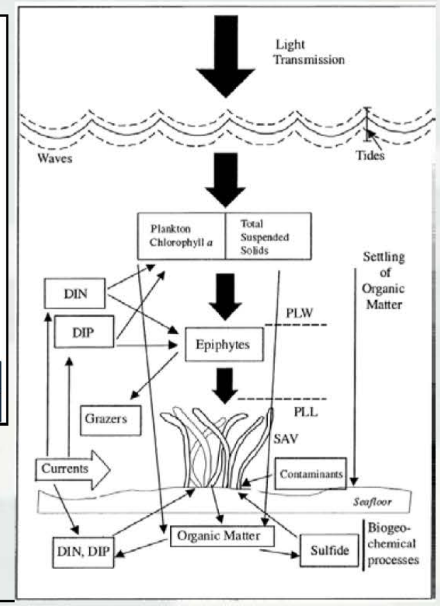


Figure: Orth et al. (2006), Kemp et al. (2004)

Development of conceptual models

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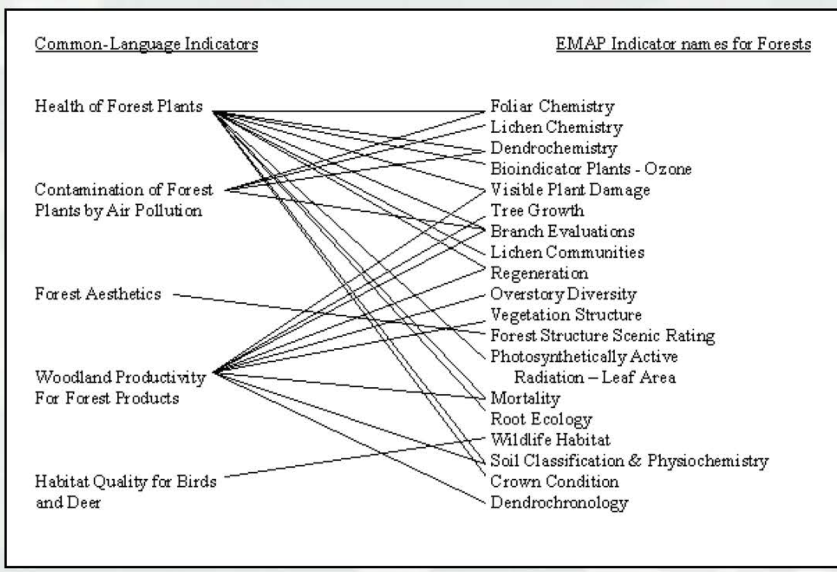
Conceptual Model Development

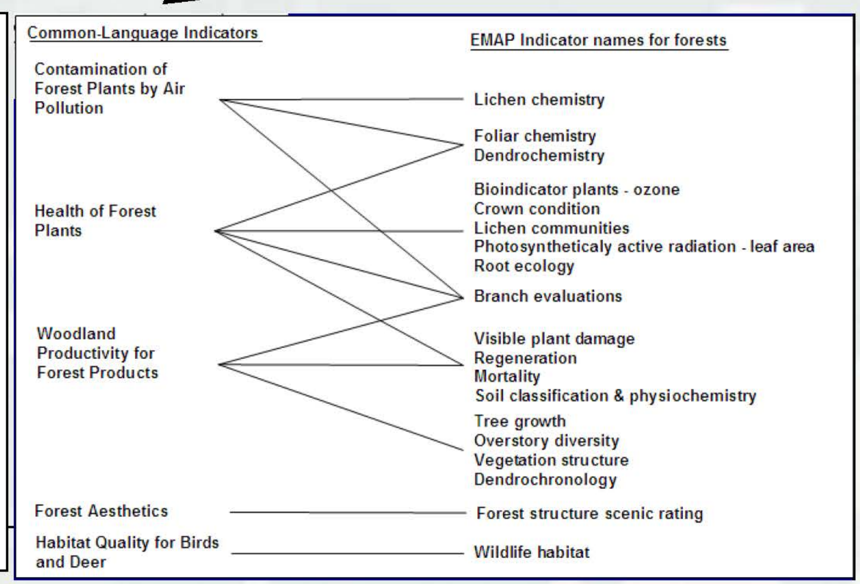
- State the model objectives.
- Bound the system of interest.
- Identify critical model components within the system of interest.
- Articulate the relationships among the components of interest.
- Represent the conceptual model.
- Describe the expected pattern of model behavior.
- Test, review, and revise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

Craft Matters

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

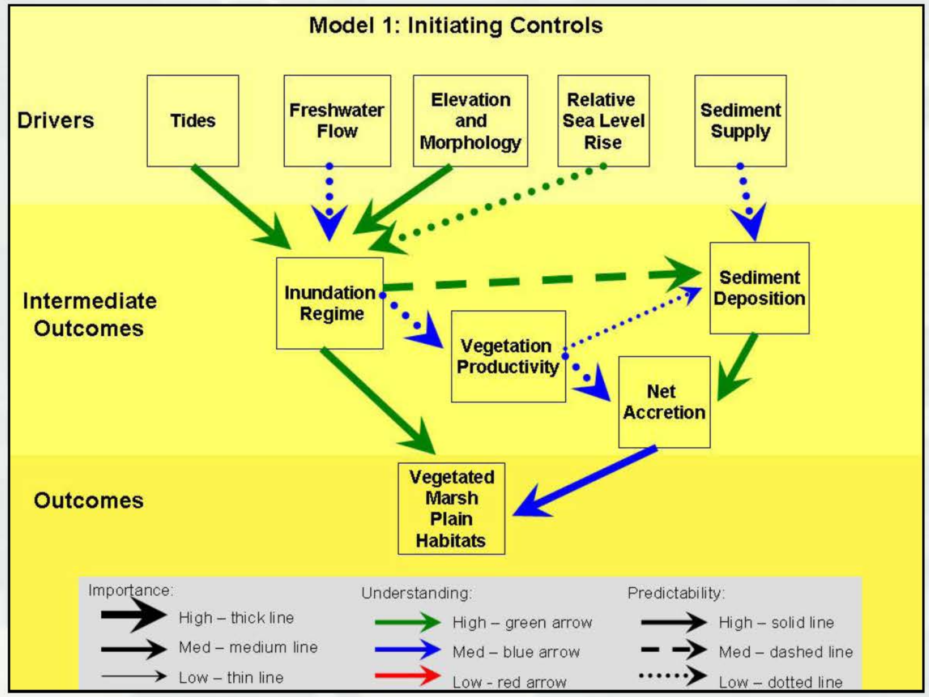
These are the same!





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



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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.

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Bound the system

- Chesapeake Bay
- Current and potential tidal marsh areas

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Identify model components

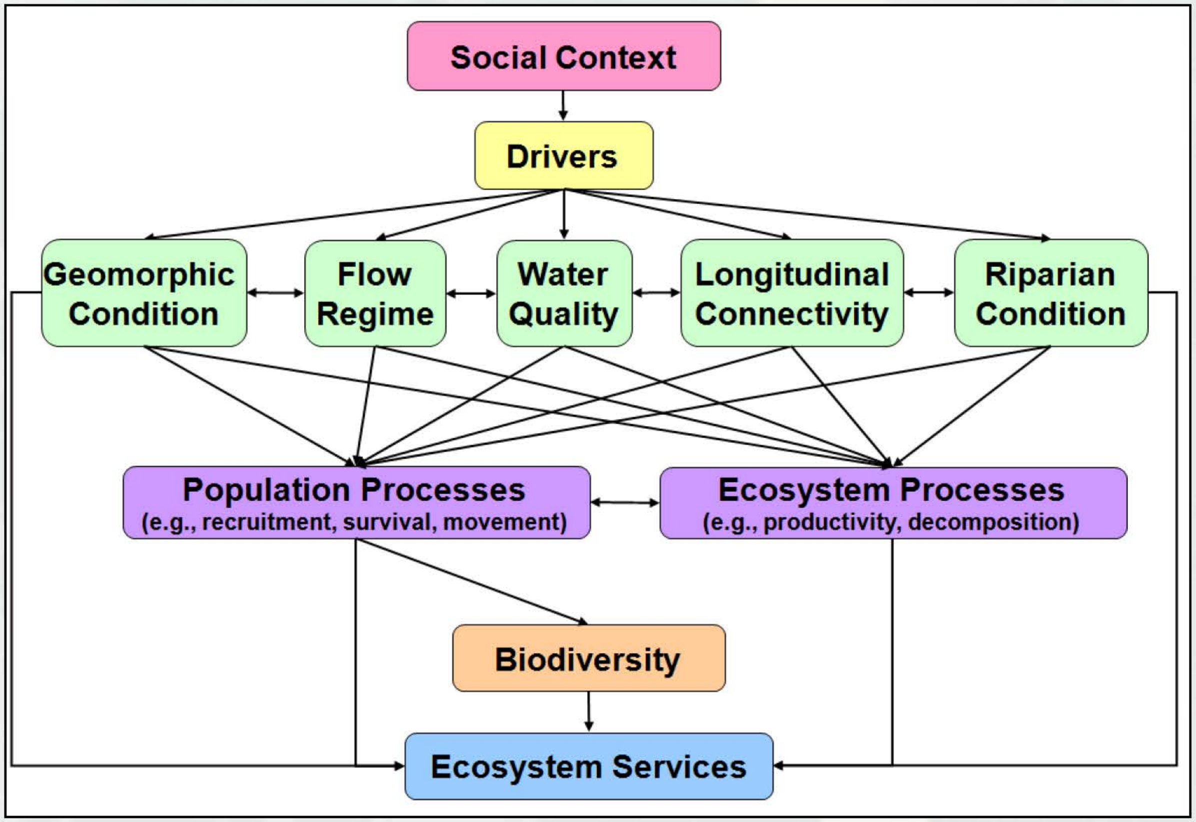
- Applied a driver-stressor framework
- Focused on ecosystem benefits and service oriented outcomes

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



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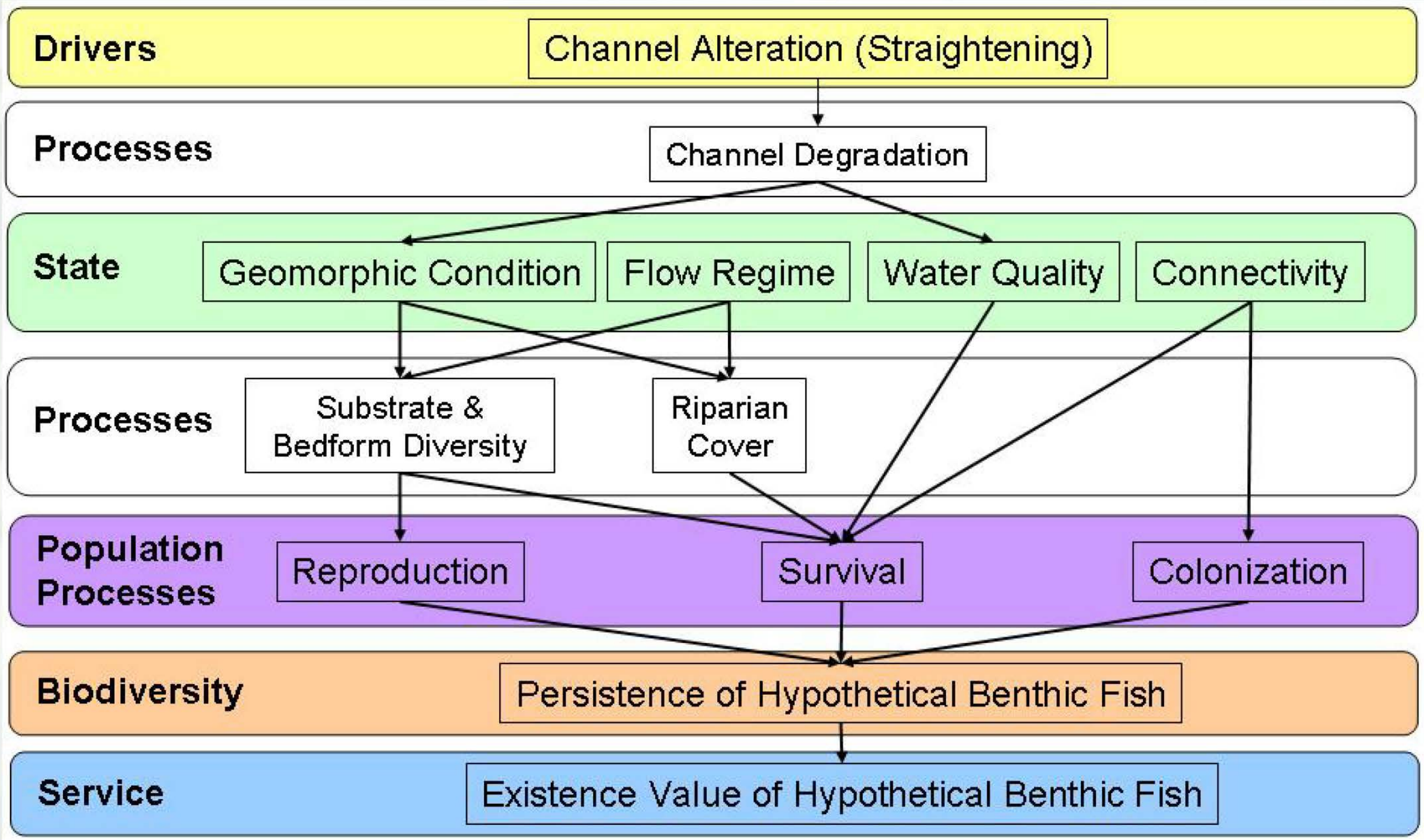
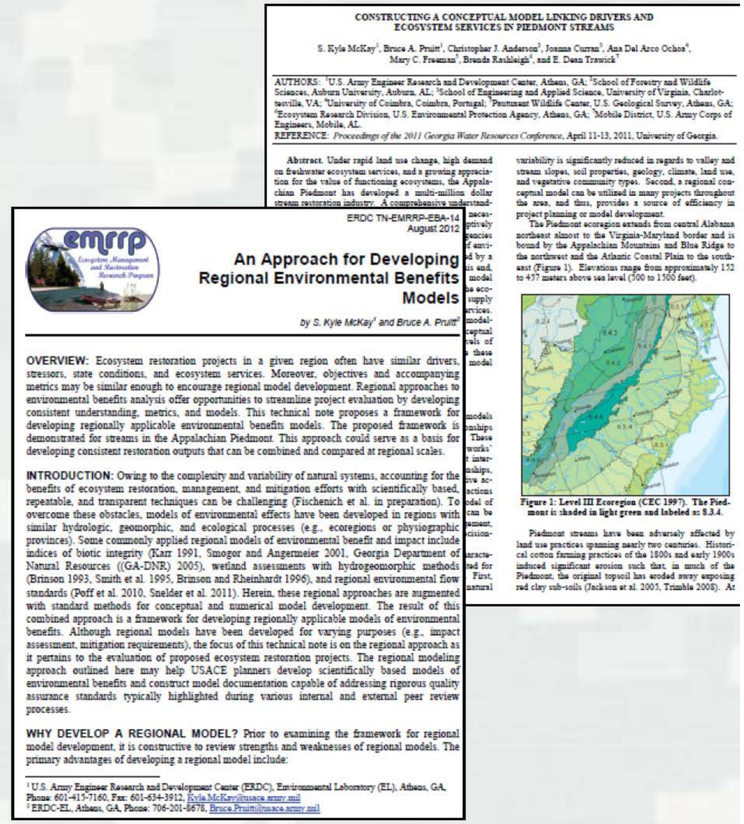
Describe expected patterns of model behavior



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



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

S. Kyle McKay[1], Bruce A. Pruitt[1], Christopher J. Anderson[2], Joanna Curran[3], Ana Del Arco Ochoa[4], Mary C. Freeman[5], Brenda Rashleigh[6], and E. Dean Trawick[7]

AUTHORS: [1]U.S. Army Engineer Research and Development Center, Athens, GA; [2]School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL; [3]School of Engineering and Applied Science, University of Virginia, Charlottesville, VA; [4]University of Coimbra, Coimbra, Portugal; [5]Patuxent Wildlife Center, U.S. Geological Survey, Athens, GA; [6]Ecosystem Research Division, U.S. Environmental Protection Agency, Athens, GA; [7]Mobile 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 comprehensive understand- …

… 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 northeast almost to the Virginia-Maryland border and is bound 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 457 meters above sea level (500 to 1500 feet).

Figure 1: Level III Ecoregion (CEC 1997). The Piedmont is shaded in light green and labeled as 8.3.4.

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. 2005, Trimble 2008). At

ERDC TN-EMRRP-EBA-14
August 2012

emrrp Ecosystem Management and Restoration Research Program

An Approach for Developing Regional Environmental Benefits Models

by S. Kyle McKay[1] and Bruce A. Pruitt[2]

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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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.

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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)?

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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?

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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

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References for Further Reading

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- 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.

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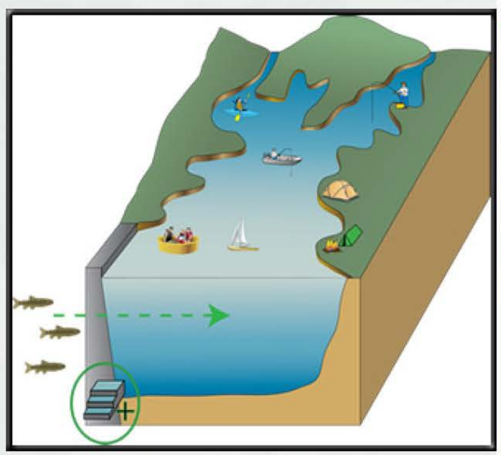
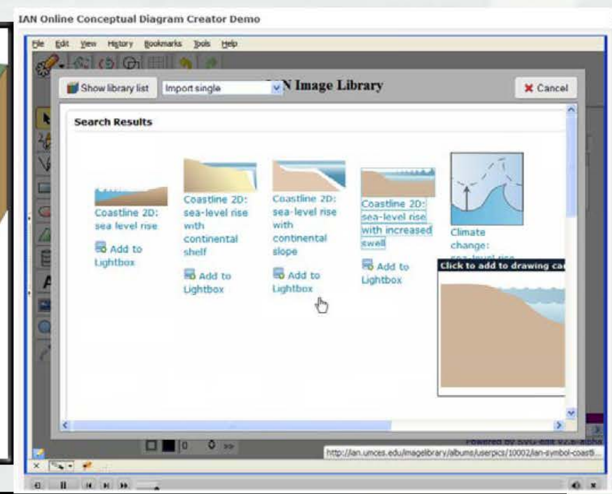
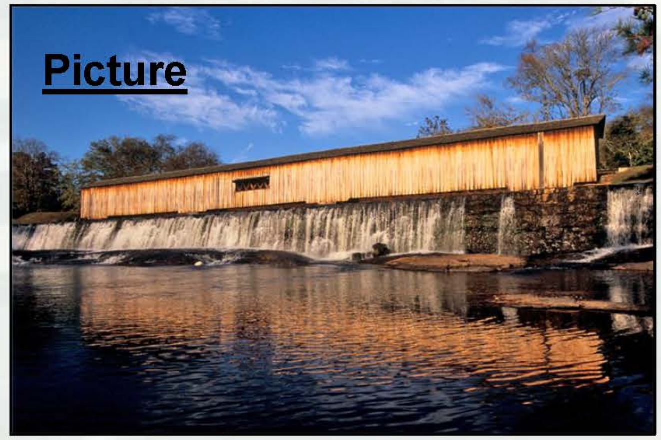
Conceptual Modeling Tools

- 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/)



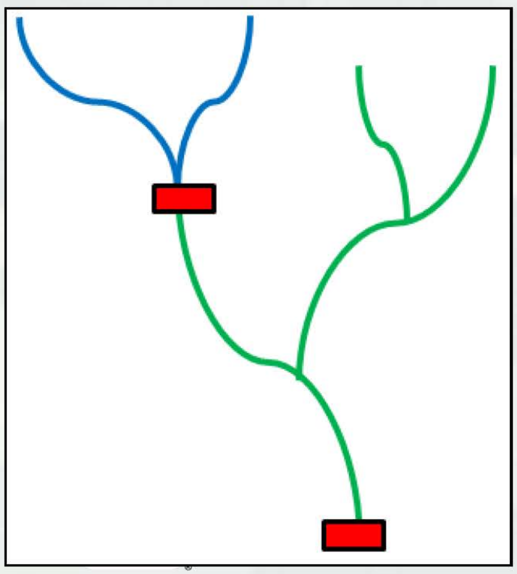


Example: Watershed Networks

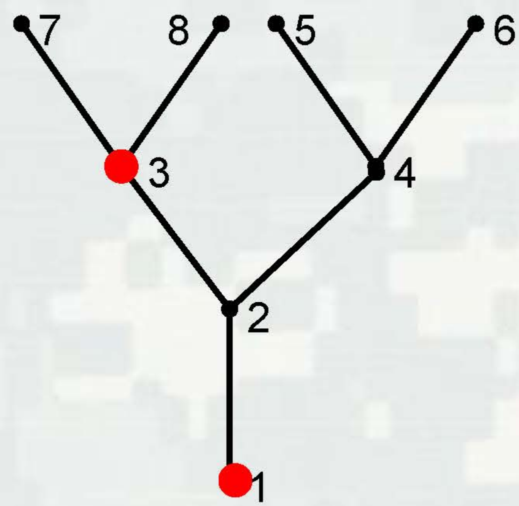


Narrative: A heart-shaped watershed with 30 miles of habitat and 2 small mill dams

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

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Photo: Athens Banner-Herald

Appendix I: Model Quantification: Gettin' Mathy With It

(Note: For an accessible version of appendix I, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-I.pdf.)

Model Quantification

GETTIN' MATHY WITH IT.

Outline

Why quantify?

What type of math?

What's the time step?

Functional forms

Parameter estimates

Quick, dirty, yet scientifically defensible tricks to generate patterns

Pitfalls

Don't have to be good at math!

Biologists and ecologists have deep understanding of their systems, but generally aren't exposed to advanced mathematical techniques

Elegant mathematical solutions are neat, but they're not the only approach

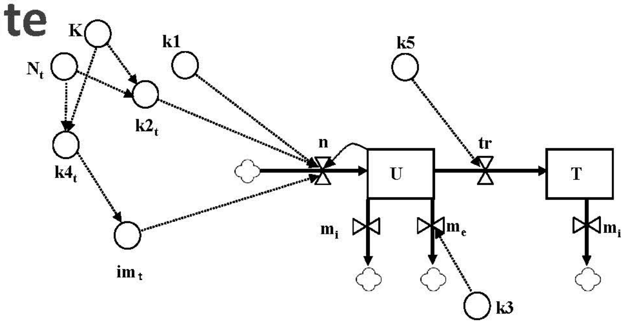
If you have an understanding of your system, you can model it

Quantification

Quantifying models provides ability to understand numerical consequences of ideas, scenarios, system dynamics, etc..

Conceptual Model should be used a template

- Equations should be tightly coupled with conceptual model
- Helps with communication and transparency
- Don't hide behind the math/code



Choosing appropriate mathematics & software

In Theory:

- Results should not depend on software or advanced math
- What is important is that the critical processes are captured

In Practice:

- Software/Mathematics affect efficiency and computation time
- Need to identify up-front how model will be quantified
- Mechanistic (process-based) models aren't developed that often for USACE planning
  - Statistical equations (correlations) used as proxies

How do you choose the approach?

Experience

Comfort-level

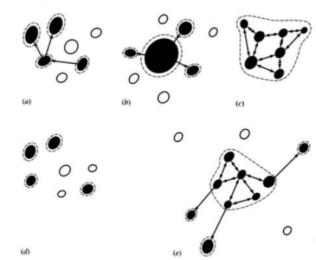
Deadlines

Question being asked

$$N_{t+1} = N_t + (births\ - deaths)$$

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

$$\mathbf{M}_A = \begin{bmatrix} F_0 & F_1 & F_2 & \cdots & F_{m-1} & F_m \\ P_0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & P_1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & P_2 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & P_{m-1} & 0 \end{bmatrix} \quad \mathbf{n}_A = \begin{bmatrix} N_0 \\ N_1 \\ N_2 \\ \vdots \\ N_{m-1} \\ N_m \end{bmatrix}$$



Simpler is better – Don't make it too complicated!

Choosing the time step

Have to choose how often the model is updated, and how long to run it.

- We plan for 50 yr horizon, but how often do you need to calculate changes in order to get an accurate idea?
  - What processes are you interested in? How often do they occur?
  - Time step needs to reflect what's happening in nature, not what's convenient
  - Don't have to choose familiar units
    - Can use 12 seconds, 3 days, 14 months, 50 yrs, etc…

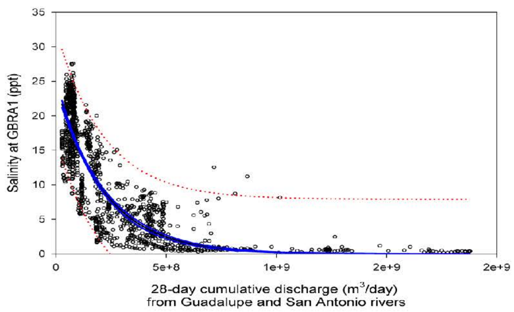
Time step, con't.

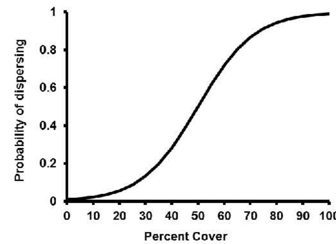
Can have nested time-steps within a model

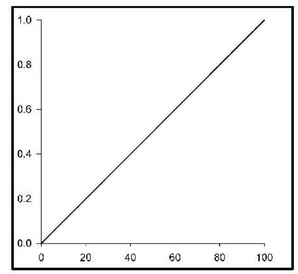
What level of precision is necessary?

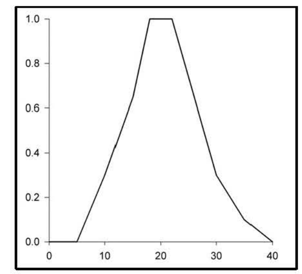
Functional Forms of Equations

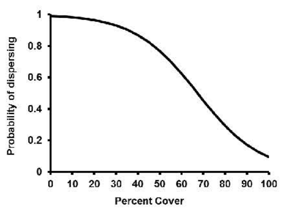
How should relationships be quantified?











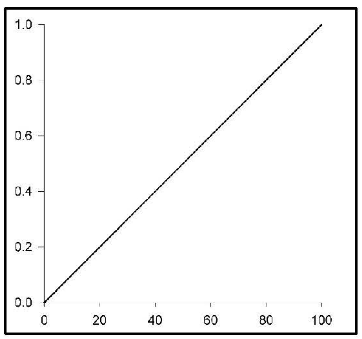
$$p(j) = \frac{e^{V_j/\theta_k} \cdot \left(\sum_{i \epsilon C_k} e^{V_i/\theta_k}\right)^{\delta_k - 1}}{\sum_{k'}\left(\sum_{i \epsilon C_{k'}} e^{V_i/\theta_{k'}}\right)^{\delta_{k'}}}$$

$$I_A + I_B - (I_A * I_B), \text{ if } I_A > 0, I_B > 0$$
$$I_A + I_B + (I_A * I_B), \text{ if } I_A < 0, I_B < 0$$
$$\frac{I_A + I_B}{1 - \min[|I_A|, |I_B|]}, \textit{ otherwise}$$

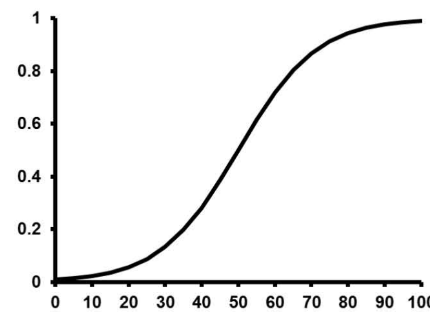
What if functional forms are unknown?

Use verbal descriptions and graphical functions

- Try to explain the relationship in a minute, then draw a picture
- Graphical representations provide an intermediate step between verbal and mathematical representations.



Linear functions: simplest relationship; the general relationship between two variables is understood (e.g., variable A increases when variable B decreases), but the exact form is not



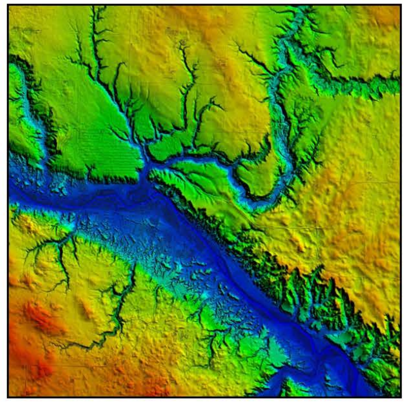
Logistic functions: more complex; allows threshold effects, and periods of stasis and rapid change

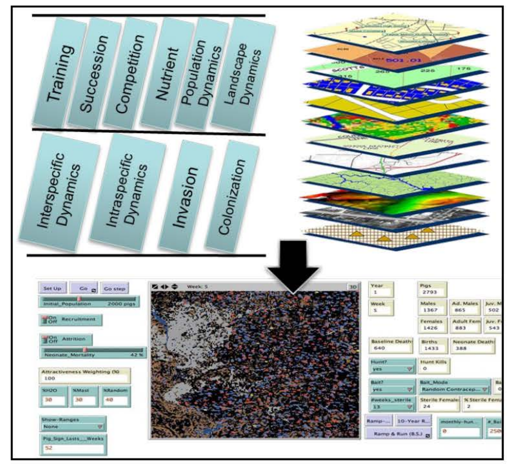
Types of data and parameterizations

Quantitative Data
- Field work
- Remotely sensed
- Other models
- Literature
- Theory

Qualitative data
- Expert opinion
- Hypotheses

The model itself
- Experimenting with model can reveal trends and patterns





Capturing feedbacks and thresholds

All environmental systems have feedback (positive/negative) and thresholds

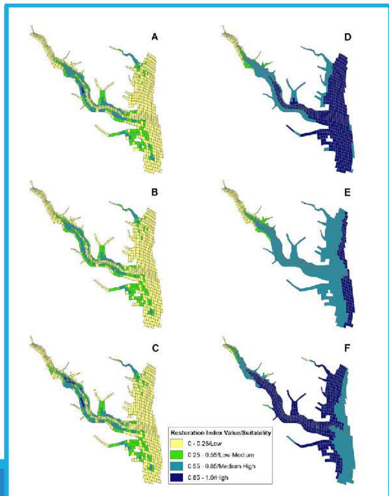
- E.g., crowding in populations is a negative feedback
- Species viability changes under different environmental conditions

These effects are often difficult to determine precisely in nature

Integrated Models

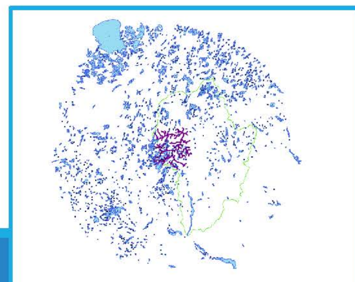
Using Hydrodynamic Models

- *Integrated Models* are models composed of multiple models
- USACE modeling generally combines hydrodynamic and ecological models



CH3D temperature, salinity, used as inputs for Oyster Restoration model

Oyster metapopulation used ADH velocity, flow, and WQ data



SWAT (watershed model) calculated flow, and velocity to determine Zebra mussel larval mortality

Quantifying inputs from hydrodynamic models

Important considerations

- What time scale is important to the ecological components of the system?

  - Hydrodynamic models can run at small time steps that might not be link well with ecological processes.
    - Cumulative effects are more important (E.g., does seagrass care what happens every 30 seconds, or are exposures over weeks or months more important?

  - Requires aggregation of Hydro model data to reasonable scales

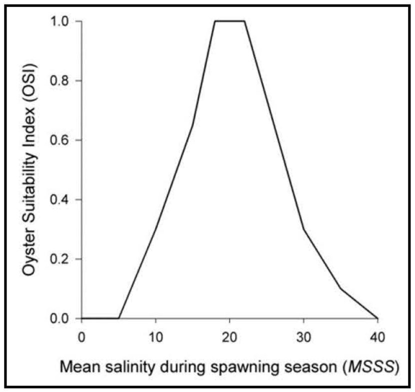
Quantifying inputs from hydrodynamic models

- Are you interested in historical patterns or future patterns?
- Does the hydro data contain a range of values that can show wide range of ecological response? If not, inference from eco model limited.
- Critical to organize with Hydro modeling team to ensure data will be delivered in appropriate format/scales
  - Costly and time-consuming to redo simulations

Quantifying Thresholds

Quickest way is with step-functions or if-then statements

- Equations are almost never reported

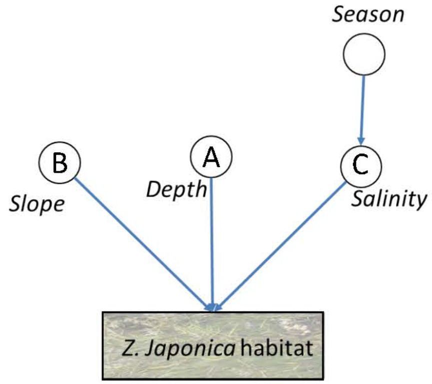


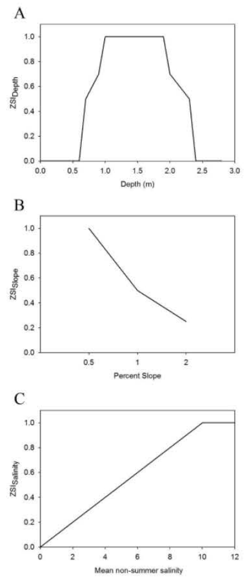
Typical HSI Representation

$MSSS \leq 5$ or $MSSS > 40$	$OSI_{MSSS} = 0$
$5 < MSSS \leq 10$	$OSI_{MSSS} = -0.3 + (0.06 * MSSS)$
$10 < MSSS \leq 15$	$OSI_{MSSS} = -0.4 + (0.07 * MSSS)$
$15 < MSSS < 18$	$OSI_{MSSS} = -1.1 + (0.1167 * MSSS)$
$18 \leq MSSS \leq 22$	$OSI_{MSSS} = 1$
$22 < MSSS \leq 30$	$OSI_{MSSS} = 2.925 - (0.0875 * MSSS)$
$30 < MSSS \leq 35$	$OSI_{MSSS} = 1.5 - (0.04 * MSSS)$
$35 < MSSS \leq 40$	$OSI_{MSSS} = 0.8 - (0.02 * MSSS)$

Take advantage of the math!
(equations look smarter)

Seagrass quantification (Yaquina Bay, OR)

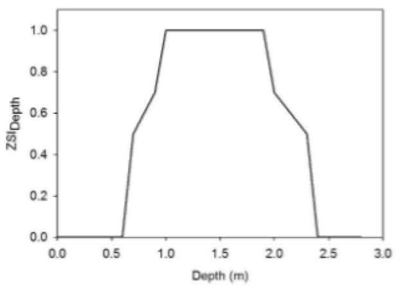


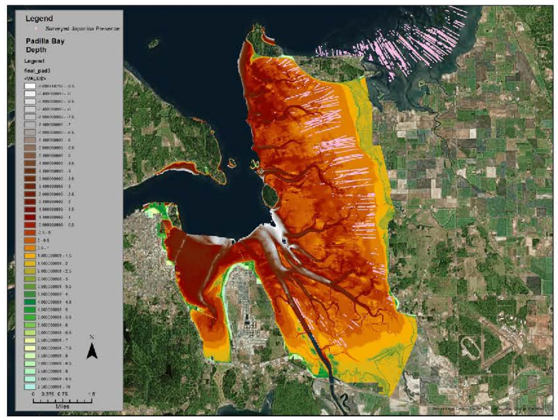


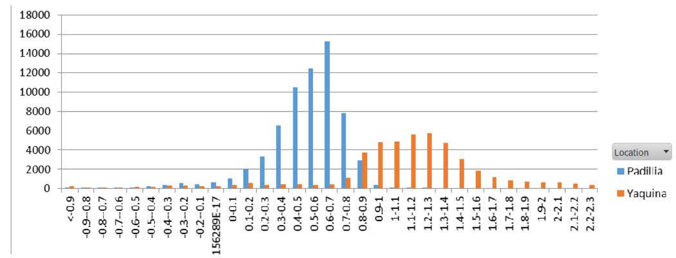
	Variable	Equation	Eq#
	Depth (m)		
	$Depth \leq 0.6$ or $Depth > 2.4$	$ZSI_{Depth} = 0$	(1)
	$0.6 < Depth \leq 0.7$	$ZSI_{Depth} = -3 + (5 * Depth)$	(2)
	$0.7 < Depth \leq 0.9$	$ZSI_{Depth} = -0.2 + (Depth)$	(3)
	$0.9 < Depth \leq 1.0$	$ZSI_{Depth} = -2 + (3 * Depth)$	(4)
A	$1.0 < Depth \leq 1.9$	$ZSI_{Depth} = 1$	(5)
	$1.9 < Depth \leq 2.0$	$ZSI_{Depth} = 6.7 - (3 * Depth)$	(6)
	$2.0 < Depth \leq 2.3$	$ZSI_{Depth} = 2.033 - (0.67 * Depth)$	(7)
	$2.3 < Depth \leq 2.4$	$ZSI_{Depth} = 12 - (5 * Depth)$	(8)
	Slope		
	$Slope \leq 0.5\%$	$ZSI_{\%\ Slope} = 1$	(9)
B	$0.5\% < Slope \leq 1\%$	$ZSI_{\%\ Slope} = 1.5 - Slope$	(10)
	$1\% < Slope \leq 2\%$	$ZSI_{\%\ Slope} = 1.5 - (0.25 * Slope)$	(11)
	$2.0\% < Slope$	$ZSI_{\%\ Slope} = 0.25$	(12)
	Salinity		
C	$0 \leq Salinity \leq 10$	$ZSI_{Salinity} = 0.1 * Salinity$	(13)
	$Salinity > 10$	$ZSI_{Salinity} = 1$	(14)

Conceptual **Functional** **Mathematical**

Re-quantifying model for new area







In first application (Yaquina Bayt), depth worked well. In second (Puget Sound), *Depth* relationship didn't capture the relationship as well. Have to re-quantify, or re-conceptualize functional form based on data.

Quantification for Kelp and Seagrass

Ideal conditions:
- clear water (light availability)
- nutrient-rich waters
- moderate water movement
- 20 C (68 F) temperatures
- typical depth range 25 – 90 feet

Ideal conditions:
- *Z. marina* near-shore, estuarine areas
- clear water (low turbidity and high PAR light)
- calmer waters
- optimal temperature 50-68 F
- typically 0-8 foot depths, max 20 feet
- 4 - 97% sand composition
- salinity 10-30 ppt

Missing data

There are often relationships that aren't defined quantitatively

- Have to rely on expert opinion
- Literature
- Interpolations

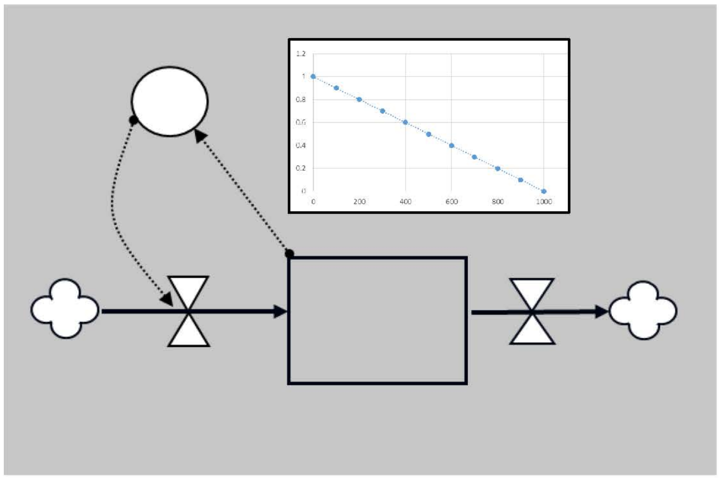
This is not less rigorous than quantitative data analysis, just less precise

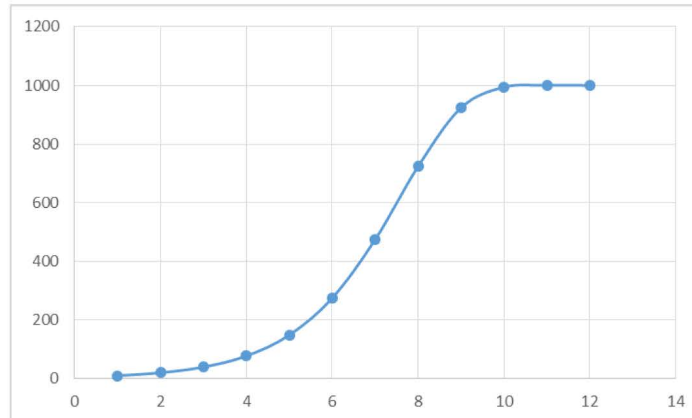
- Qualitative data requires increased attention in the documentation

Will make bigger mistake leaving out important relationships than hypothesizing about relationships

- Increased need for transparency

Quantifying feedbacks w/o data





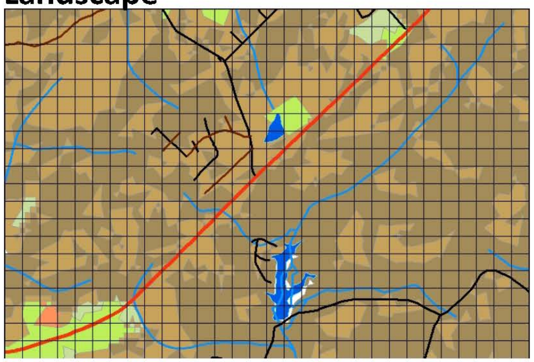
Tell the story!

In this case, negative feedback causes incremental decrease in growth

Quick way to generate patterns

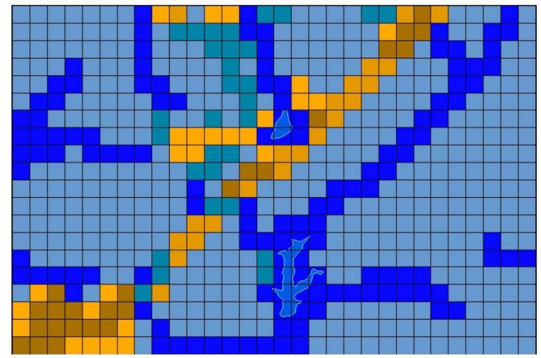
Quantifying expert opinion: Habitat

Landscape



Expert Opinion

Model



$$I_A + I_B - (I_A * I_B), \text{ if } I_A > 0, I_B > 0$$
$$I_A + I_B + (I_A * I_B), \text{ if } I_A < 0, I_B < 0$$
$$\frac{I_A + I_B}{1 - \min[|I_A|, |I_B|]}, \textit{ otherwise}$$

Modeling without data

Decisions will need to be made, regardless of data availability

Need for transparency

Simple functions can help identify magnitude and general trends in absence of data

Expert opinion can be used to parameterize equations until other datasets are available

Considering Scale

System properties emerge as scale changes

GoTeamEcoMod

Spatial Modeling

Incorporating topographic, geomorphic, and/or land use patterns into models to understand how changes in spatial configurations affect ecological dynamics

Space matters

- Configuration and composition of landscapes can affect ecological structure and function http://www.slideshare.net/gceyre/what-is-gis-9719692

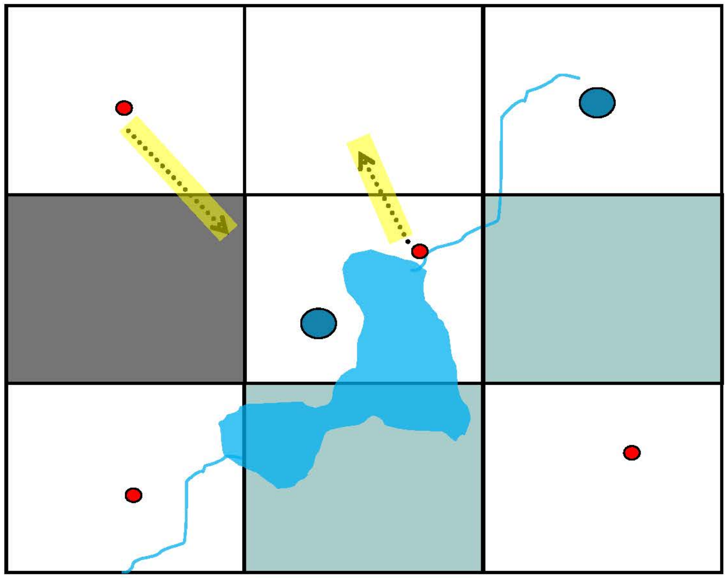
Considering Space

Working with spatial models

Considerations:

- Location-based differences across the project area

- What spatial scale is relevant?
  - Link ecological processes to a spatial scale (i.e., the grid/DEM/etc)



interactive Toolkit for Applied Modeling (TAM)

Platform developed for rapid model development

Quantifies threshold-based datasets

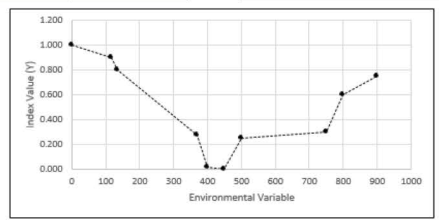
Certified for USACE

ENTER DATA INTO HIGHLIGHTED CELLS

Breakpoint #	Environmental Variable	Index Value (Y)
1	0	1.000
2	118	0.900
3	136	0.800
4	368.4	0.275
5	400	0.01
6	450	0
7	500	0.25
8	750	0.3
9	800	0.6
10	900	0.75

Values	Intercept	Slope	Equation
0 -118	1.00	-0.0008	Y= 1 + (-0.0008 * Environmental Variable)
118 -136	1.56	-0.0056	Y= 1.56 + (-0.0056 * Environmental Variable)
136 -368.4	1.11	-0.0023	Y= 1.11 + (-0.0023 * Environmental Variable)
368.4 -400	3.36	-0.0084	Y= 3.36 + (-0.0084 * Environmental Variable)
400 -450	0.09	-0.0002	Y= 0.09 + (-0.0002 * Environmental Variable)
450 -500	-2.25	0.0050	Y= -2.25 + (0.005 * Environmental Variable)
500 -750	0.15	0.0002	Y= 0.15 + (0.0002 * Environmental Variable)
750 -800	-4.20	0.0060	Y= -4.2 + (0.006 * Environmental Variable)
800 -900	-0.60	0.0015	Y= -0.6 + (0.0015 * Environmental Variable)
900 -			Y = 0.75

References



Pitfalls

Choosing inappropriate mathematics & software

- Not all formats lend themselves to a given problem
- Can get trapped by constraints of approach

Not choosing appropriate time step

- Too long: violate assumption that change is system is constant b/w time steps
- Too short: lose interpretability, longer simulation time

Pitfalls

Relying on automated parameterization techniques

- Processes that test every possible combination of parameter values can quickly turn the model into a black box

Using overly sophisticated equations

- It's easy to rely on fancy stats, but make sure they are appropriate for the objective of the model

Pitfalls

Uninterpretable functional relationships/coefficients without meaning

- Functional relationships should make sense (within your discipline)
- Coefficients should reflect magnitude of process occurring in nature

Not paying attention to units of measure

- Can violate assumptions and create nonsensical results

Pitfalls

No clear verbal description

- If you can't explain it clearly, you can't math it correctly
- Try to explain it in one minute – where you get hung up can help identify problem areas

Don't consider graphical relationships

- Intermediate step b/w verbal and mathematical model
- Can serve as proxy for formalized equations

Reluctance to use qualitative information

- Specific numbers can be difficult to find. Stories aren't.

Removing functional relationships due to lack of data

Appendix J: Model Evaluation/Application: Does Your Model Make Sense & to Anyone Else?

(Note: For an accessible version of appendix J, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-J.pdf.)

MODEL EVALUATION/ APPLICATION

DOES YOUR MODEL MAKE SENSE & TO SOMEONE ELSE?

1

OVERVIEW

What is evaluation?

Why is it useful?

How do you evaluate environmental models?

Dealing with uncertainty.

Practical Evaluation Techniques

Pitfalls

EVALUATION

- **Process of rigorously assessing model components, structure, parameter values, assumptions, but not scenario results**
- **Commonly called *model validation***
  - Models represent a point of view of a system. Validation probably not the best term b/c it indicates a model can be true. Are opinions true?
  - Evaluation captures the essence of validation without connoting that the model is true
- **Process needs to ensure scientific defensibility and transparency**

EVALUATION CON'T.

- **Is the model useful for its intended purpose?**
  - Given the assumptions, structure, and assumptions, can the model be used for what the developers intended.
- **What are its limits and weaknesses?**
  - Under what conditions does the model break?
  - Should you try to break it?
- **Is it re-creatable?**

4

EVALUATION IS OFTEN NOT RIGOROUS

Detailed evaluation is rare

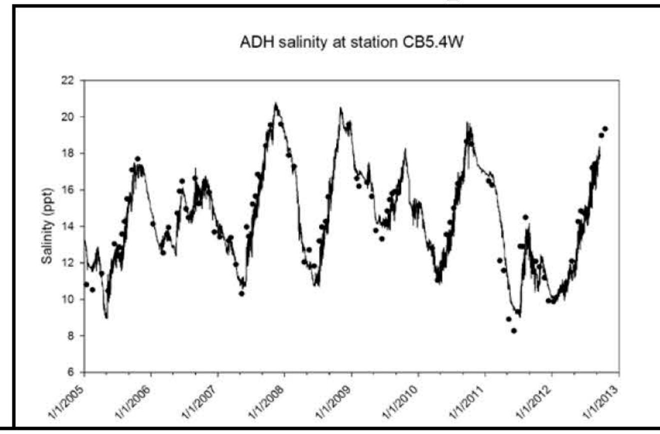
- Overly rely on software
- Don't have time
- Aren't concerned with recreatability
- Discipline hasn't required it
  - Small field & modeling was esoteric
  - But most agencies rely on models now
  - Increased need for scientifically-defensible and detailed documentation
  - TRACE (Transparent and comprehensive model evaluation)

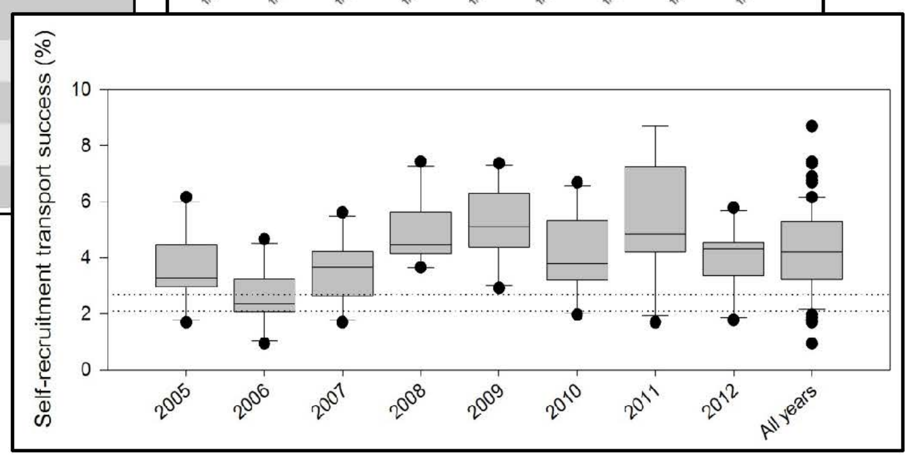
5

PROBLEMS WITH EVALUATION

Different disciplines have different expectations of model performance

	Hydrological Modeling	Ecological Modeling
Main Focus	Water	Persistence of species
Sub focus	Chemistry of water	Dynamic relationships
Environmental Hierarchy Target	Landscape	Molecular (Genetics) Organ systems / tissues Individuals Populations Landscape Ecosystem Biome
First principles?	Sometimes	Never
Model confidence	High	Low
Science/Art	99/1	25/75
Knowledge of dynamics	High	Low





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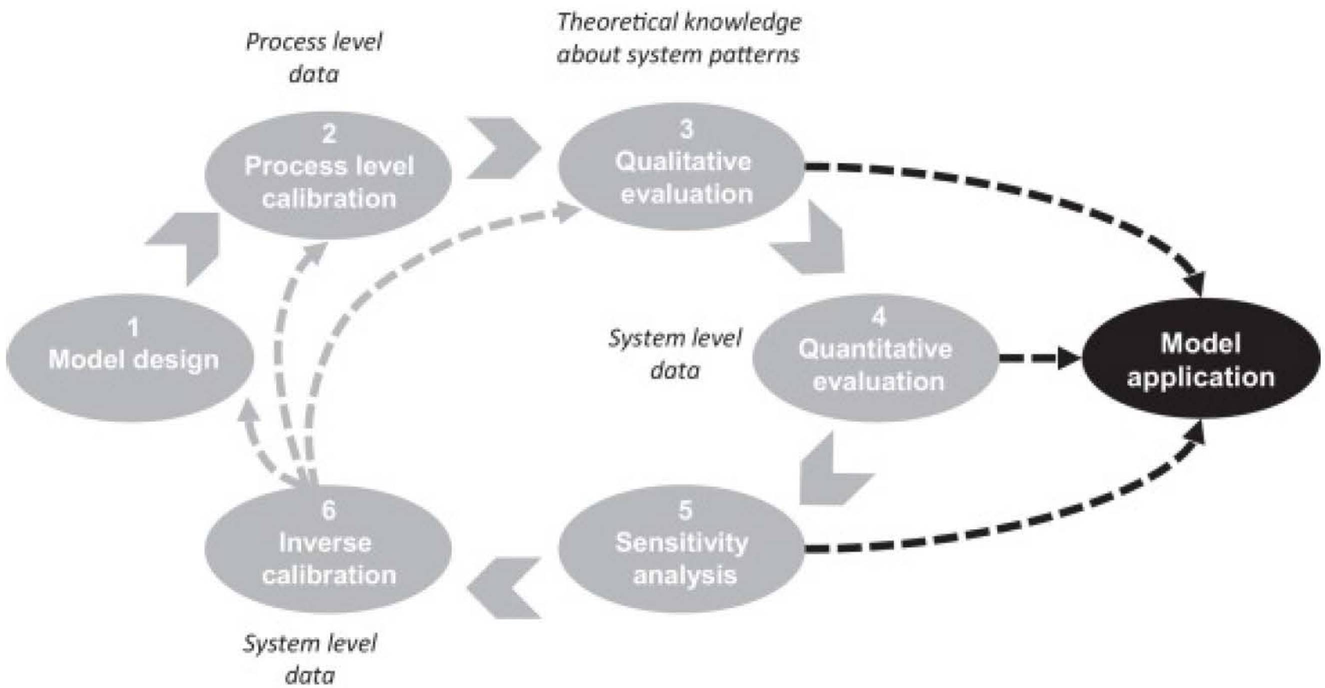
PROBLEMS WITH EVALUATION

Biggest issue is failure to document entire evaluation process

- Iterative approach
- Evaluation occurs throughout the modeling process, but is rarely documented thoroughly. Need to document each cycle.



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STEPS IN EVALUATING ENVIRONMENTAL MODELS

1) Assess reasonableness of model structure

2) Assess functional relationships & verify code

3) Evaluate model behavior vs expected patterns

4) Does model correspond well to data from real system?

5) Document uncertainty

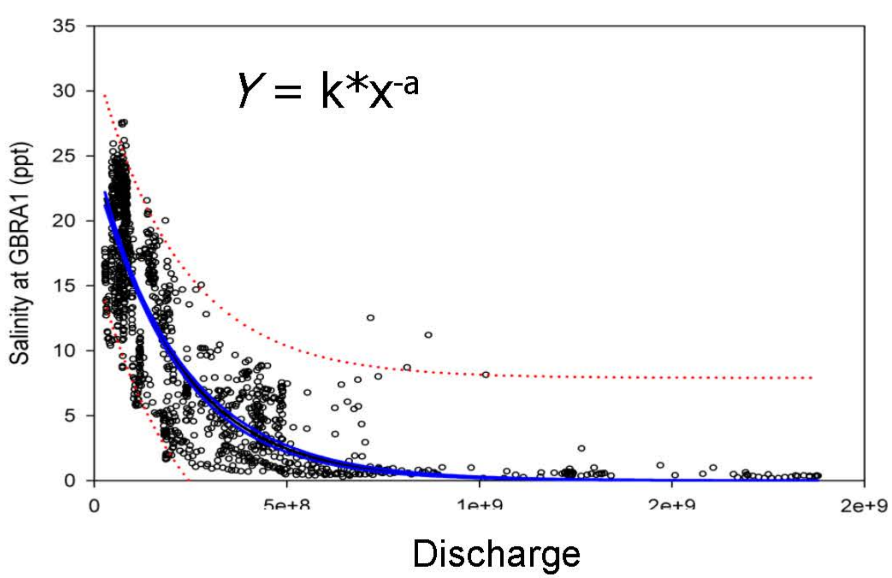
8

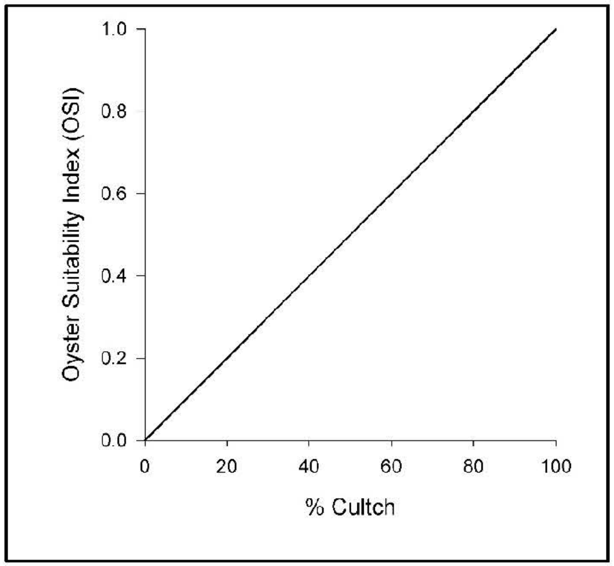
ASSESS REASONABLENESS OF MODEL STRUCTURE

- **Does the structure make sense?**
  - Absolutely required for explanatory models (most environmental models), but not really for correlative models, which are less focused on capturing relationships b/w variables
- **Somewhat subjective**
  - Requires a priori hypotheses to test functional relationships
  - There are always simpler and more complex models

DO THE FUNCTIONAL FORMS MAKE SENSE?

- Do the functional forms of the equations generate reasonable output given the other components in the model?
- Equations may not stand up after they're coupled with other model components





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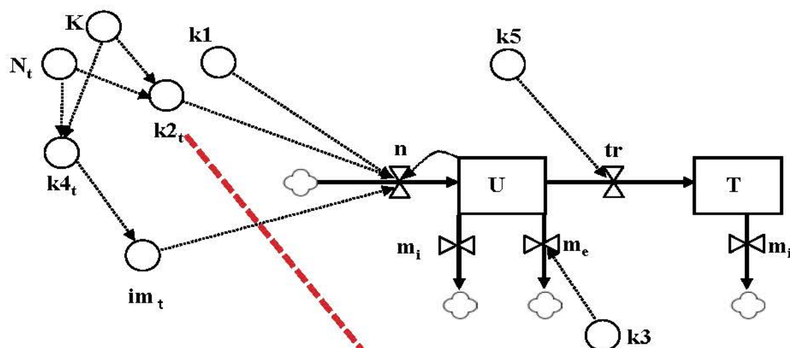
EVALUATING FUNCTIONS

Each function must be evaluated separately, then again when coupled to other components. Document each step!



$$k2_t = 1 - (1 / \mathrm{K})N_t$$

$$n_{i,\,t} = (U_{f,\,t})\,(k1)(k2_{\mathrm{t}})$$

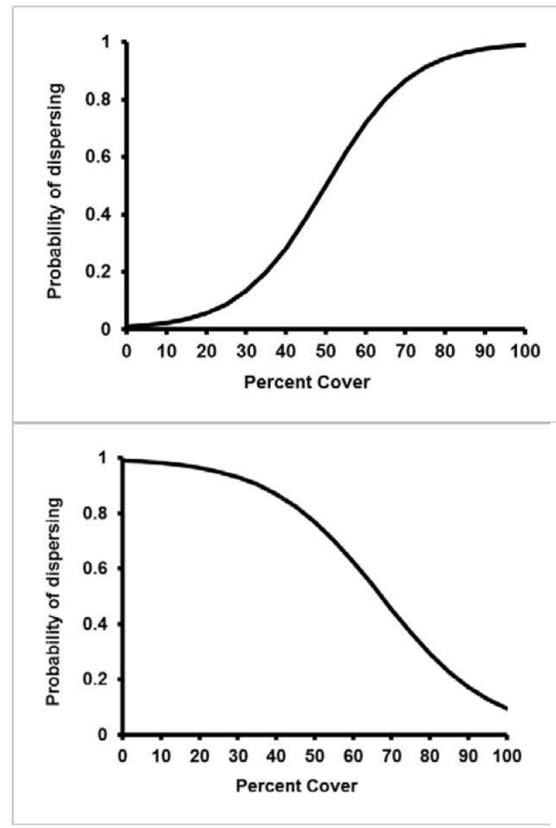
$$U_{i,\,t+1} = U_{i,\,t} + (n_{i,\,t} + i_{i,\,t} - m_{i,\,t} - me_{i,\,t} - tr_{i,\,t})$$

11

DOES MODEL ACT LIKE YOU THOUGHT IT WOULD?

A priori expectations are critical for thorough evaluation

- Without documenting expected patterns of behavior, it becomes difficult to ascertain whether the model is producing the correct values
- Evaluate code and each function to make sure everything is being calculated correctly
- Practice iterative evaluation



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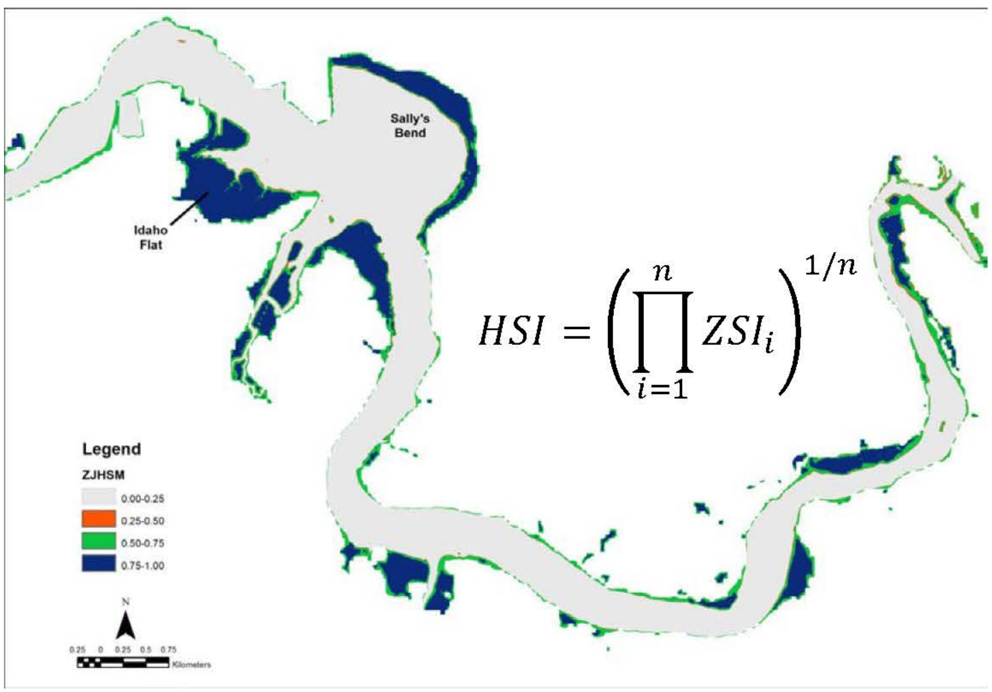
SEAGRASS EXAMPLE

- **In general, environmental models are used to project system dynamics, so some understanding of how output compares to real data can be useful.**



$$HSI = \left(\prod_{i=1}^{n} ZSI_i \right)^{1/n}$$

- **Model does a good job of predicting presence of *Z. japonica,* as well as predicting its absence.**

13

MODEL SENSITIVITY

Determines degree of response of model behavior to changes in various components.

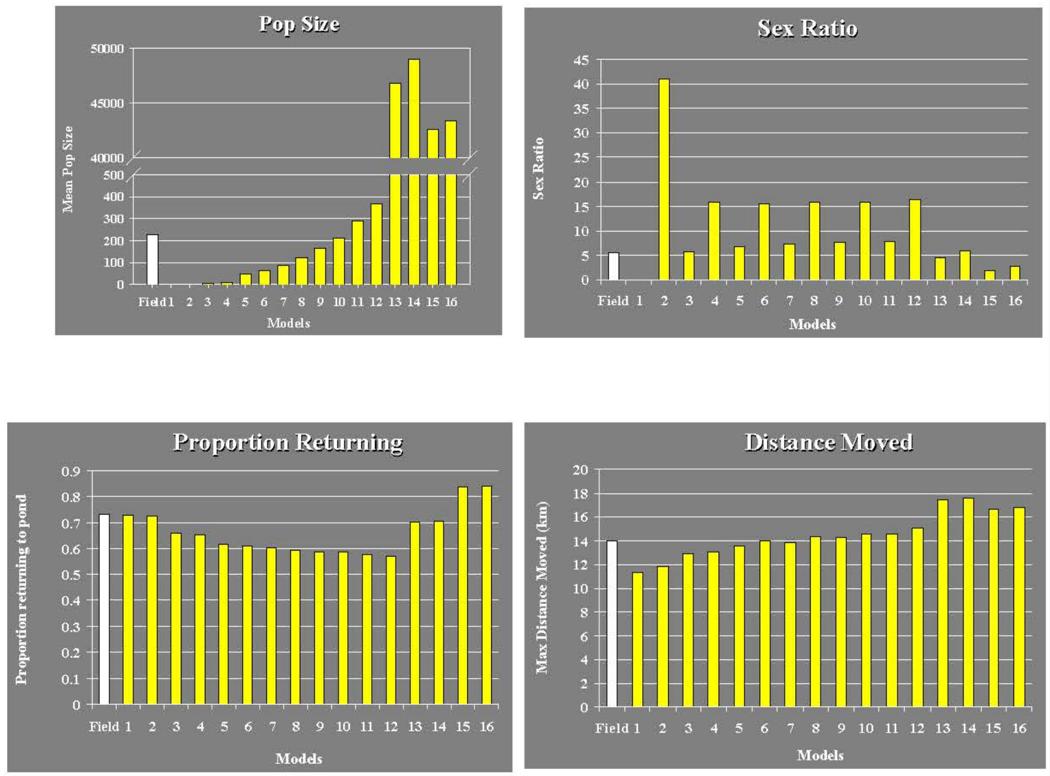
- Provides indication of relative accuracy of each parameter
- Run model over range of values representing degree of uncertainty
- Indicates level of confidence we have with model's ability to address question

14

WHAT ABOUT MODELS WITH HIGH UNCERTAINTY/MISSING DATA?

Pattern-oriented modeling

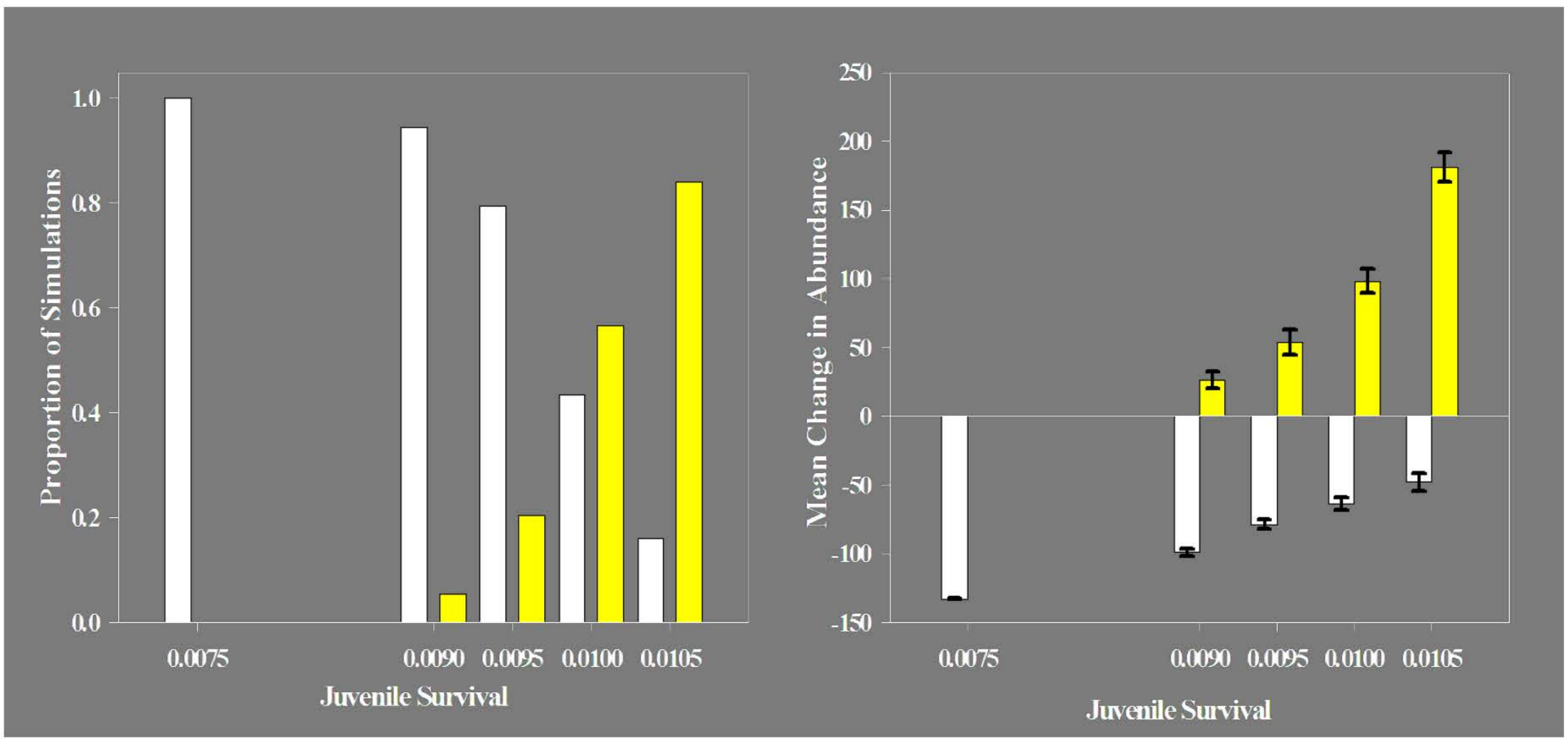
- Parameterize different versions of model that represent range of uncertainty
- Compare results to observed or hypothesized patterns
- Discard models that don't match multiple patterns



15

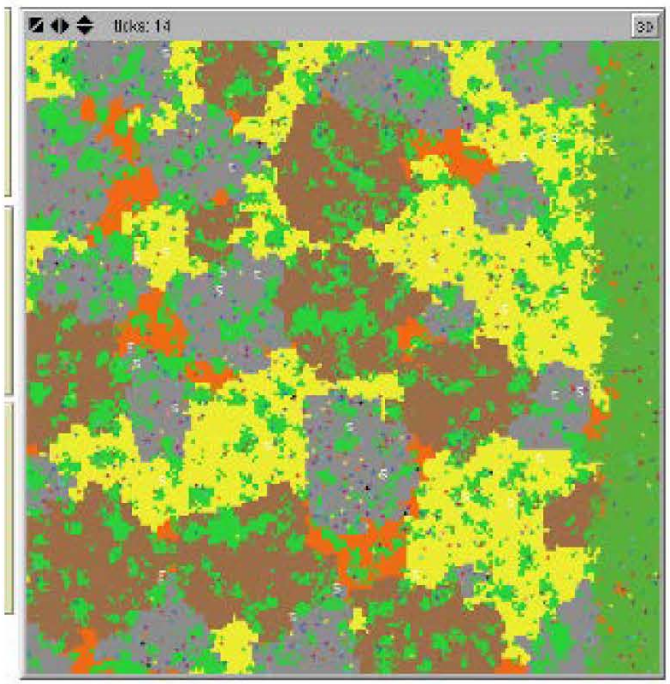
PATTERN ORIENTED MODELING, CON'T.

Carry the analysis forward with models that weren't removed



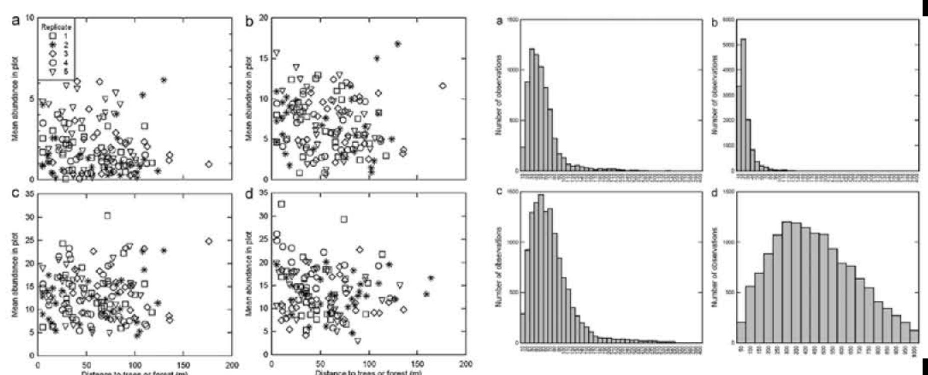
16

PATTERN ORIENTED MODELING



9 Patterns analyzed

- Infestation rates
- Bird densities in shade
- Foraging patterns (3)
- Vegetation characteristics & bird densities
- Bird movement patterns
- Bird consumption of beetles



How land use and habitat diversity affect migratory bird populations and their ability to suppress an insect pest on Jamaican coffee farms

DISCOVERING THE MODEL'S LIMITS

How does the model perform under extreme circumstances?

- Run model across wide range of values outside of range

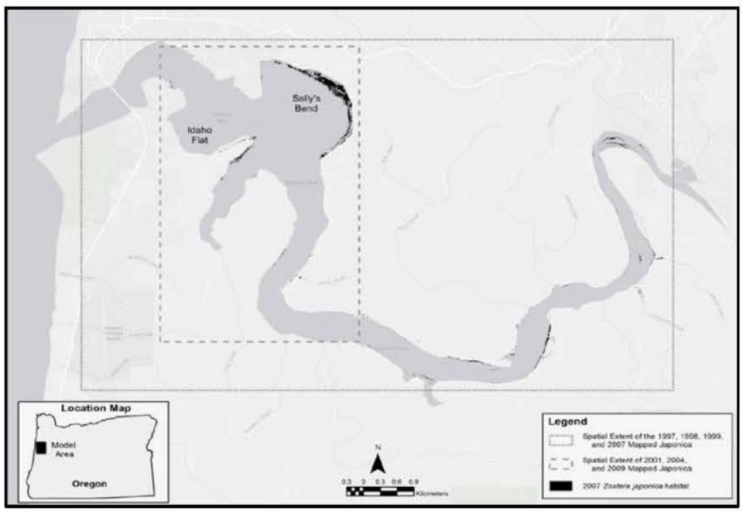
Break the model!

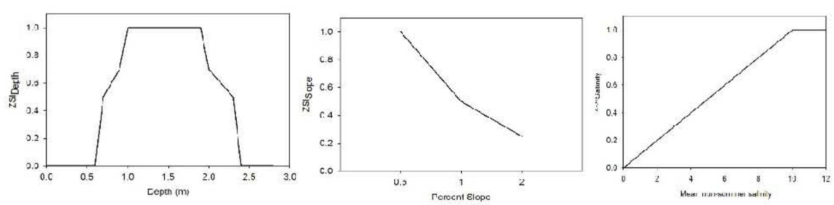
Critical for understanding how model functions across a wide range of conditions.

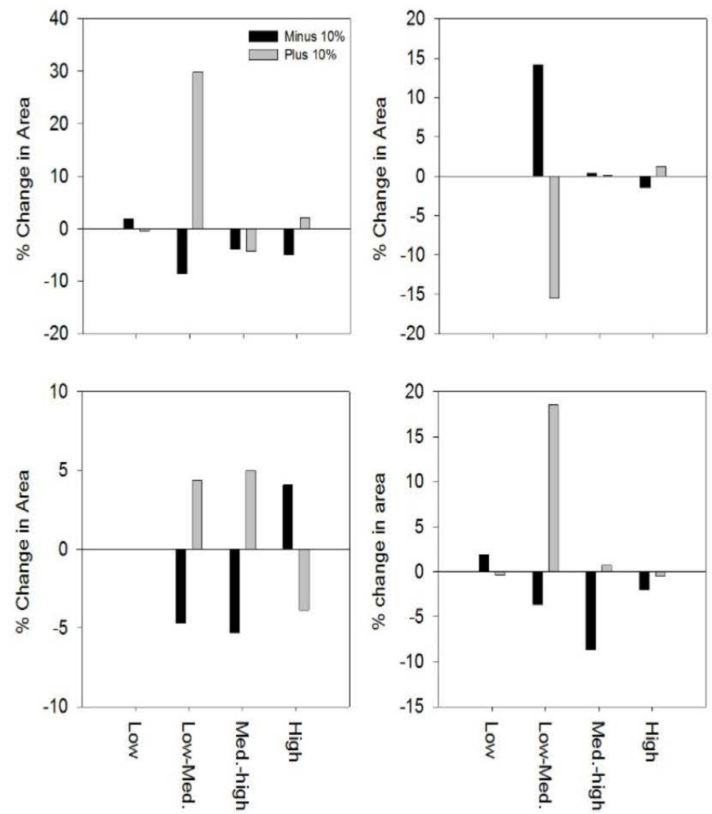
SEAGRASS EXAMPLE

Developed model for *Zostera japonica* (invasive seagrass in PNW)

- Used sensitivity analysis and contingency tables to evaluate model equations

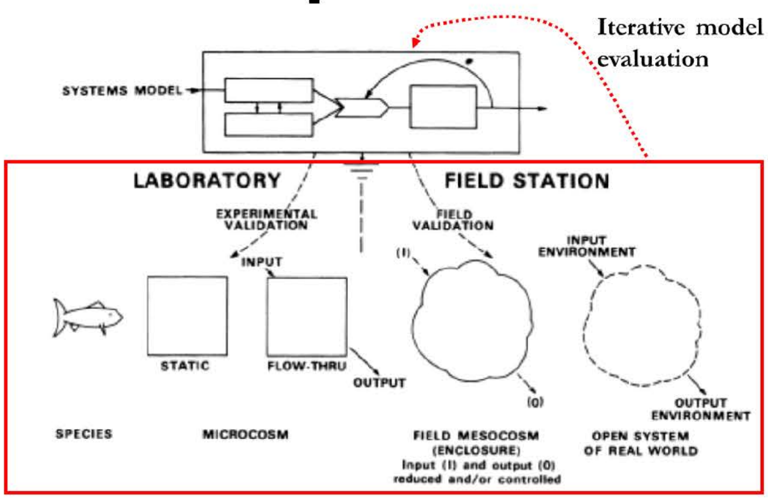






PITFALLS

Failure to iteratively evaluate and document each step



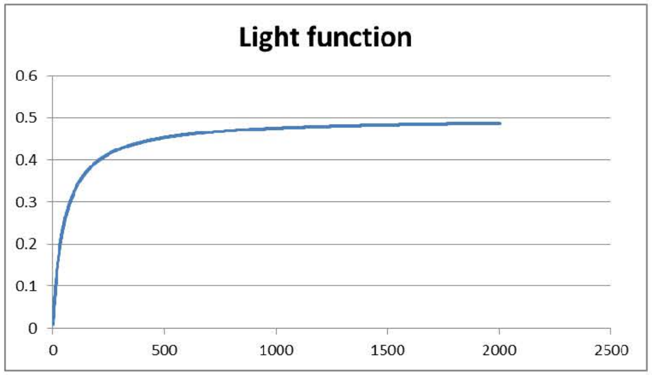
$$\Delta W = W_s P - W(R_m + M) \quad (1)$$

$$R_m = r_{20} * Q_{10}^{((T-20)/10)} \quad (2)$$

$$P = P_{max} * \frac{I}{I+H_I} * \frac{S*T^{pt}}{T^{pt}+H_T^{pt}} * \frac{H_D}{D+H_D} \quad (3)$$

$$I_{z,t} = I_0 * e^{-K_d - K_p * b_z} \quad (4)$$

$$I_{z,t} = I_0 * e^{-K_d} \quad (5)$$



PITFALLS

Underestimating importance of qualitative components of model

- Does it look right?

Accepting conceptually flawed functional relationships

- Immediately places you in position to defend

21

PITFALLS

Acceptance of surprising model results

- "Hmmm…that seems weird. Oh well."
- Need to figure it out and document it!
  - Could be coding issue, flawed conceptualization, quantification, etc..

Interpreting initial results without letting model burn-in

- Initial behavior might not represent model patterns
- Resulting from initial conditions and parameter values

22

PITFALLS

Over-reliance on automated evaluation techniques

- Canned software cannot provide level of rigor needed for complex models

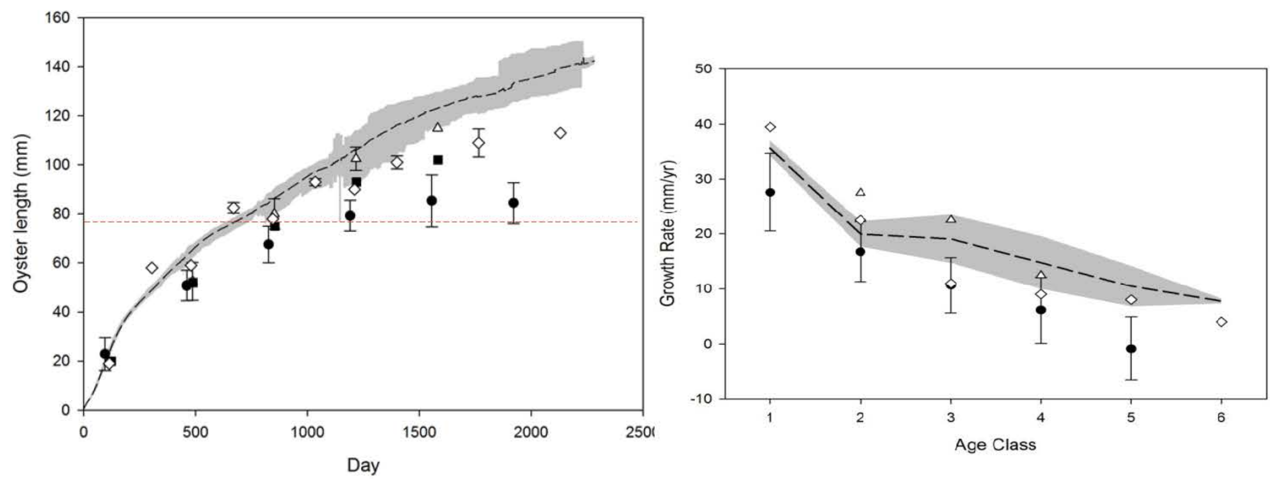
Over-reliance on statistics

- Statistical and practical significance aren't always the same thing

PITFALLS

Believing data from real system are correct

- Field data were collected over a specific period of time, under a particular set of environmental conditions.
- May not necessarily correlate with model projections



PITFALLS

Careless design of sensitivity analysis

- What parameters actually make sense for a sensitivity analysis?

Tendency to equate model sensitivity with model failure

25

TAKEAWAYS

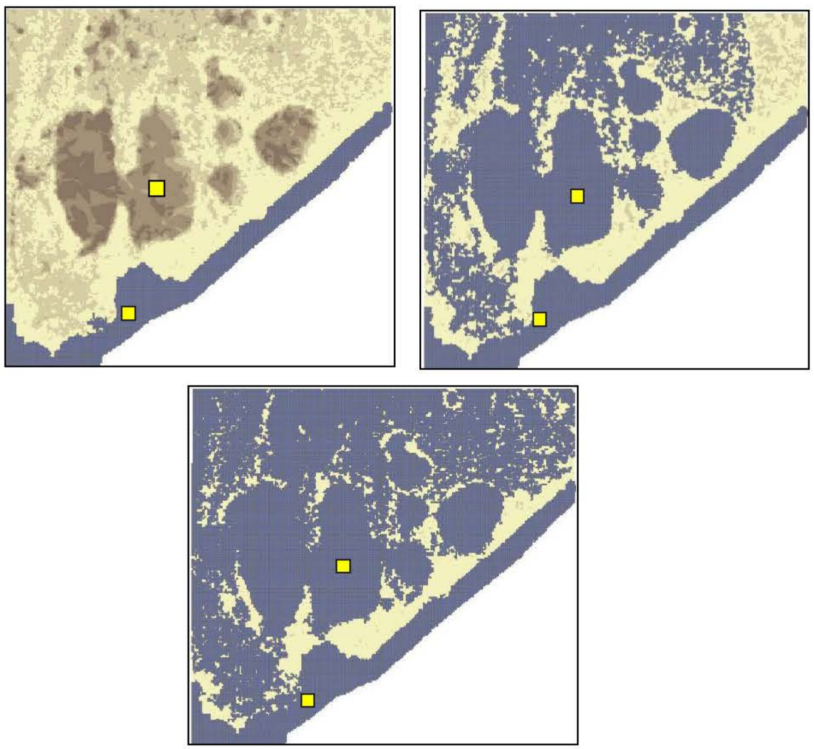
Iterative process…

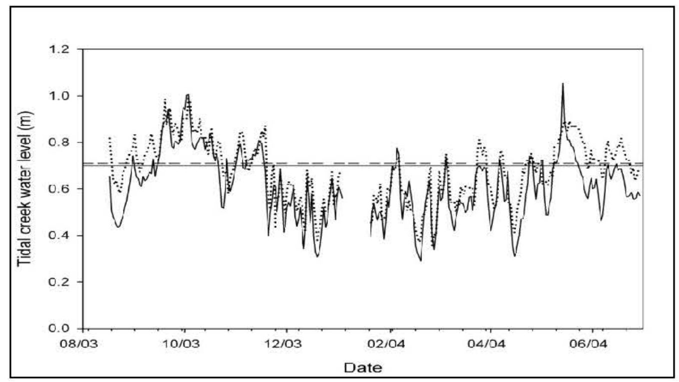
Keep learning about your model and about your system.

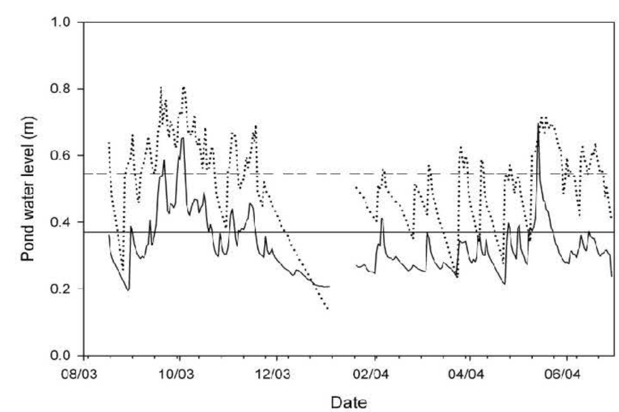
Be patient with yourself and the process.

EXAMPLE OF MODEL STRUCTURE

SLOSH: the does water run uphill model



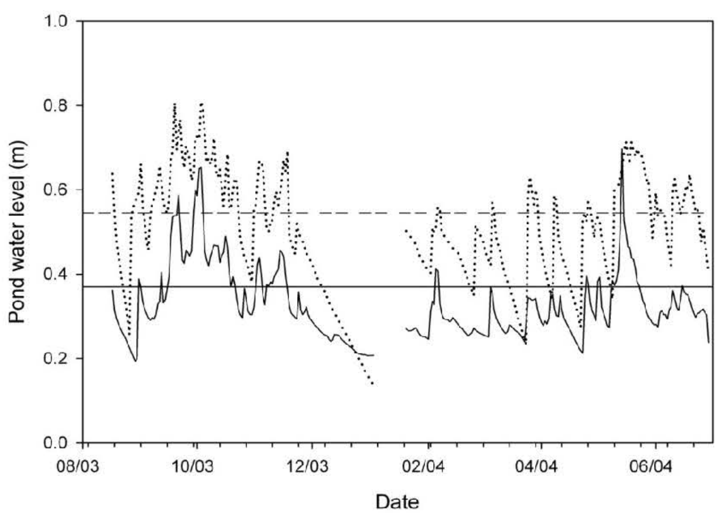


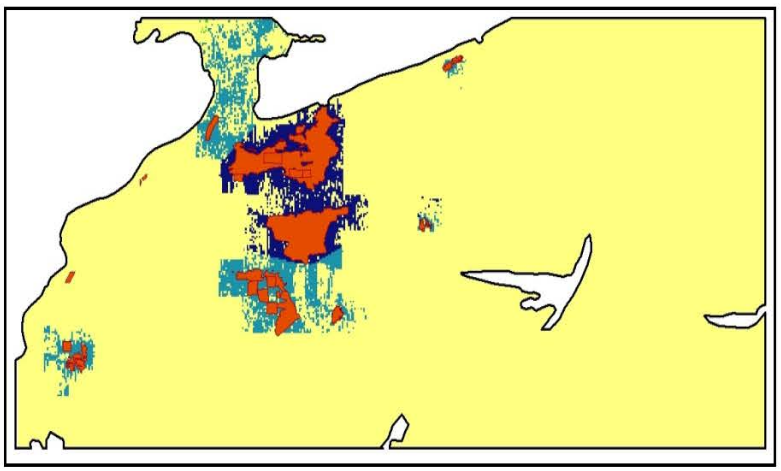


27

HOW DOES THE MODEL OUTPUT COMPARE TO REAL DATA?

- In general, environmental models are used to project system dynamics, so some understanding of how output compares to real data can be useful.





28

Appendix K: Monitoring and Management Plan

(Note: For an accessible version of appendix K, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-K.pdf.)

Monitoring and Adaptive Management (MAMP)

April 12, 2019

Swan Island Model Workshop

Monitoring Objectives

- Determine Success
- Adaptive Management Decisions
- Advance the Science – Pool and Compare Results
- Refine Restoration Techniques
- Reduce Restoration Costs
- Communication to Agencies/Public

Monitoring Challenges

- Time/Budget
- Site Specifics (All Projects are Different)
- None/Few Standard Protocols
- Personal Biases
- Differences Spatial/Temporal scales

Monitoring and Adaptive Management Plan - Living Document

TABLE of CONTENTS

Northerly Island
Section 506 Great Lakes Fishery & Ecosystem Restoration

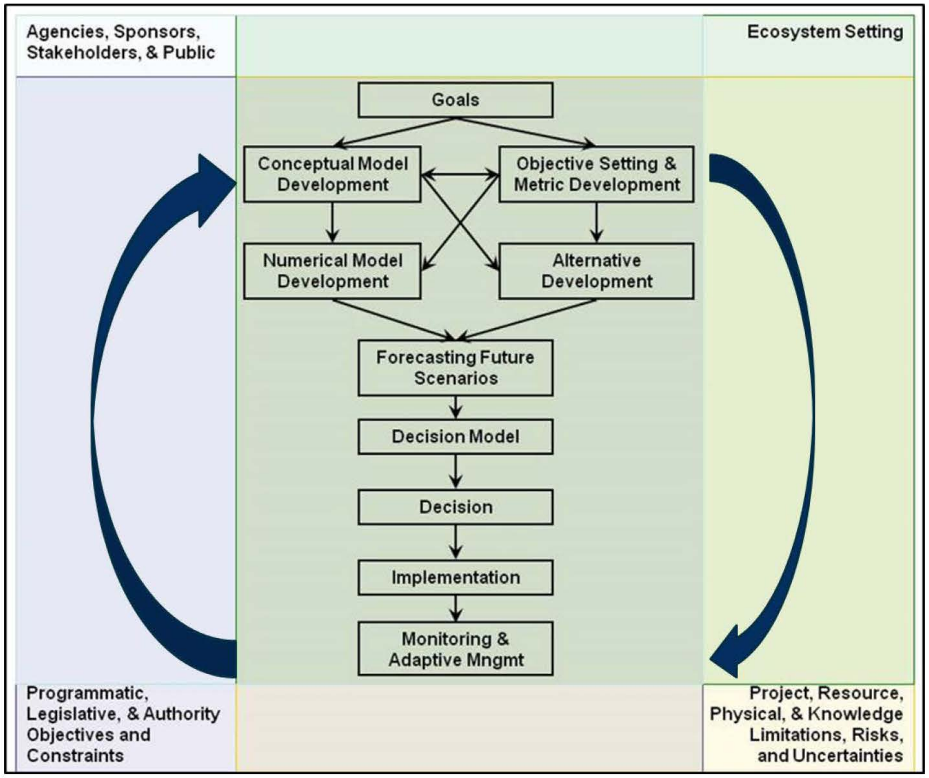
Appendix E - Monitoring & Adaptive Management Plan

Chicago District, GL-ECO-CX

1

What do you want out of the monitoring data?

Set Monitoring Objectives.

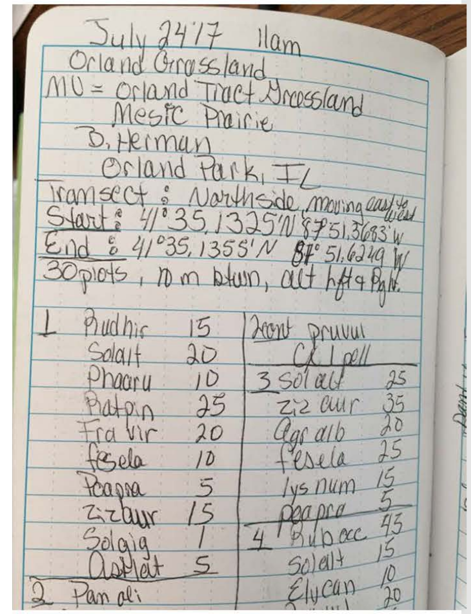


Protocols:

- Detailed enough that someone could pick up plan and collect data for project (personnel turnover)
- Seasonality (timing) and Frequency (1x yr)

Data Records

Information	Notes
Date	day, month, year
Name(s) of Monitor	Even though it may be your notebook, and you will know who recorded the data, the person that takes over for you once you leave or retire from the position may need to know this information.
Site	Project name.
Management Unit or Locale	Specific type of vegetation or unique management unit name.
Transect Number and Description	Unique name or label of transect, start location of the transect (GPS coordinates), how far the start is from the edge of management unit, compass bearing/direction toward end, length of transect, location of end (GPS coordinates), rules of plot placement, etc.
No. of Plots	Expected number of plots to be sampled from transect.



Data Management/

Roles & Responsibilities

- Electronic Files (e.g., Excel spreadsheet)
- Manage Folders/Files

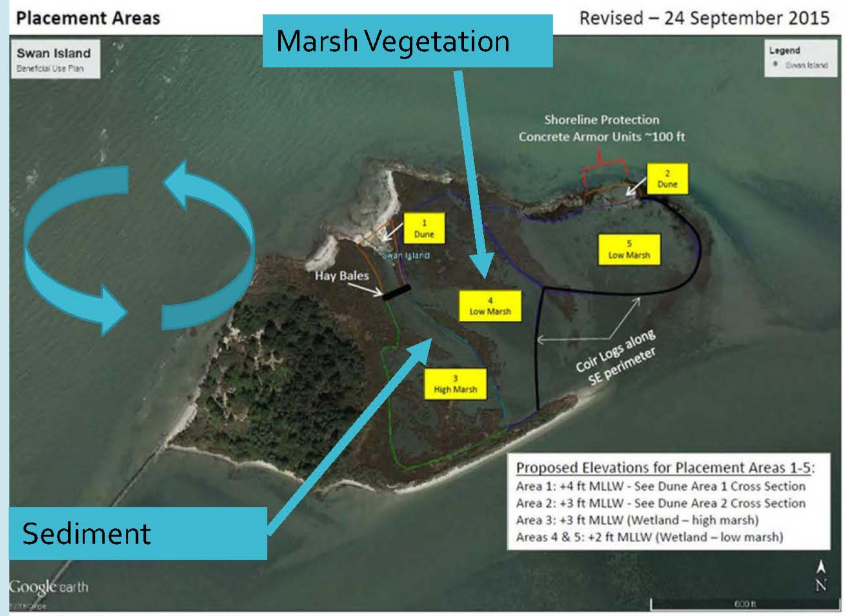
A. Orland Tract Grassland sect 206
    a. Monitoring
        i. 2010
            1. Wet Prairie
                a. Transects
                    i. Orland_WetPraire_2010_T2.exl

- Data collection, per parameter
- Data management/storage
- Reporting – factsheets, rare data, journal articles

Interpret the Data

Marsh Vegetation Restoration Project

1. a)To track establishment of marsh vegetation b)To test the role of sediment marsh vegetation establishment
2. Critical Drivers: biomass, sediment transport
3. Metrics:
   1. a) stem density: number of stems per plot
   2. b) depth: average depth of plot at low tide
4. Predictions:
   1. Stem density will increase over time (Years 1-5) to reach a maximum of 50 stems (over predefined area)
   2. Depth will be maintained at an average of 0.05 meters after sediment placement (Years 1-5)



Appendix L: Communicating Models: Explaining Complex Systems to Diverse Audience

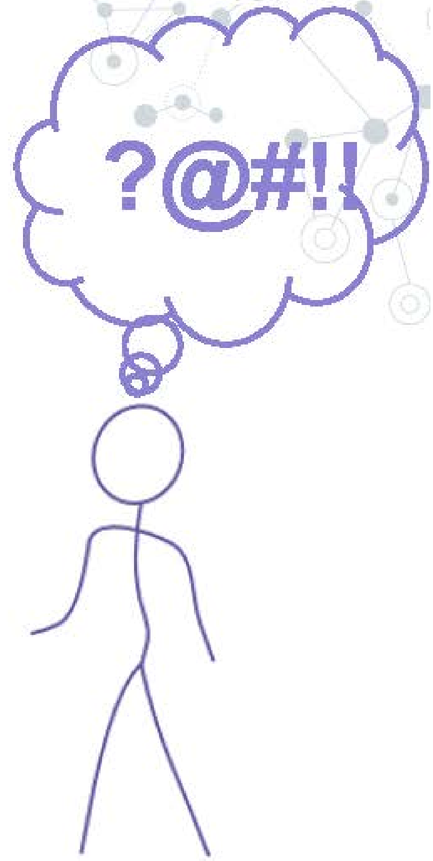
(Note: For an accessible version of appendix L, please visit https://ewn.el.erdc.dren.mil/projects/products_19-15/Ecological-Habitat-Modeling-Workshop-Appendix-L.pdf.)

Communicating Models

Explaining complex systems to diverse audience

This model is a Black Box

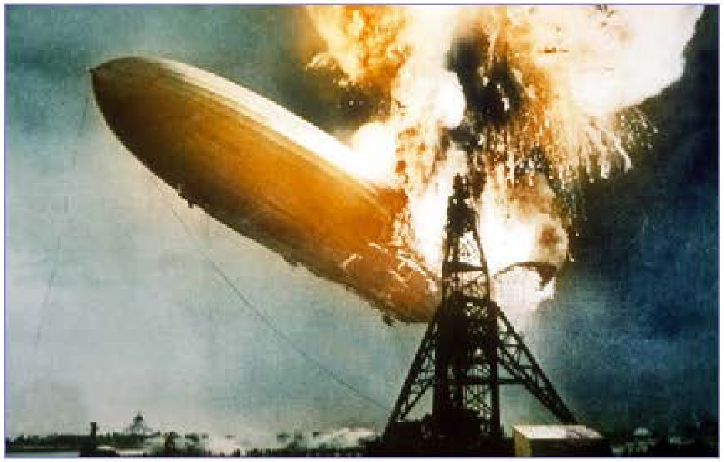
All models are wrong,
but some are useful



Communicating Models

- Two levels required
  - Technical documentation
    - Each stage of model development should be thoroughly documented, including equations and assumptions
  - Communicating to non-technical audiences
    - How do we communicate to non-modelers, stakeholders, general public, etc…

Model Communication … a Disaster!



- Most ignored aspect of modeling
- Confusionover the meaning ofmodel”
- Preexisting notionsprevent audiencefrom understanding objective

- Very rarely do we
  - Analyze audience
  - Anticipatepotential obstacles

Three Common Obstacles in Communicating Models

1. Audience fails to understand meaning & use of a key concept or term
2. Audience struggles to represent mentally some phenomenon, structure, or process
3. Audience may have a preexisting understanding preventing them from believing (therefore understanding) the model

1. Audience fails to understand meaning of a key concept

Elucidating Explanation:

- Lists a concept's critical features
- Provide an array of varied examples & nonexamples
- Provides opportunities to practice distinguishing examples from nonexamples by looking for critical features

2. Audience struggles to represent mentally some phenomenon, structure, or process

A General Impression of the System

- Develop a summary image identifying critical components
- Structure-suggesting titles & organizing analogies
- Strong main points & connections
- Easily discernible points with clear connections between them that create a narrative form
- Clear conceptual models can really help with this

3. Audience's preexisting notions prevent understanding

Transformative Explanation

- States existing "lay" or "implicit" description of the system
- Acknowledge the apparent plausibility
- Using examples familiar to the audience, point out where existing description falls short
- Present an alternative explanation
- Demonstrate how alternative more effectively represents the system

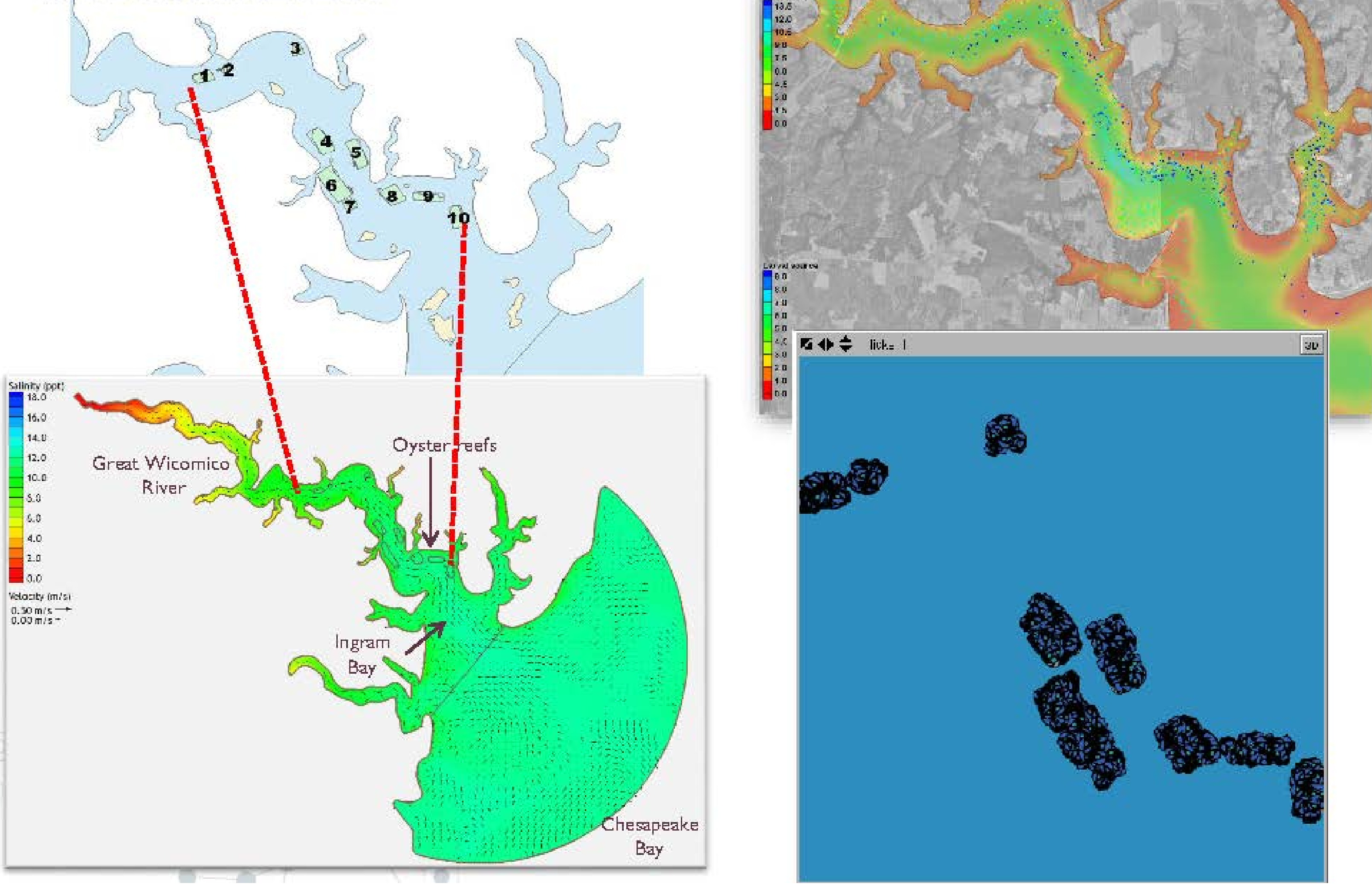
Model Communication 2.0

Case study: Oyster modeling in Chesapeake Bay

- Oyster abundance at all time low
- Federal and state agencies disagree on how to bes manage species (fishery vs. environmental benefits
- Developed an integrated hydrodynamiecological model to address management questions
    - Multi-disciplinary team developed hydrodynamic, particle tracking, and agentbased models

Communication challenge

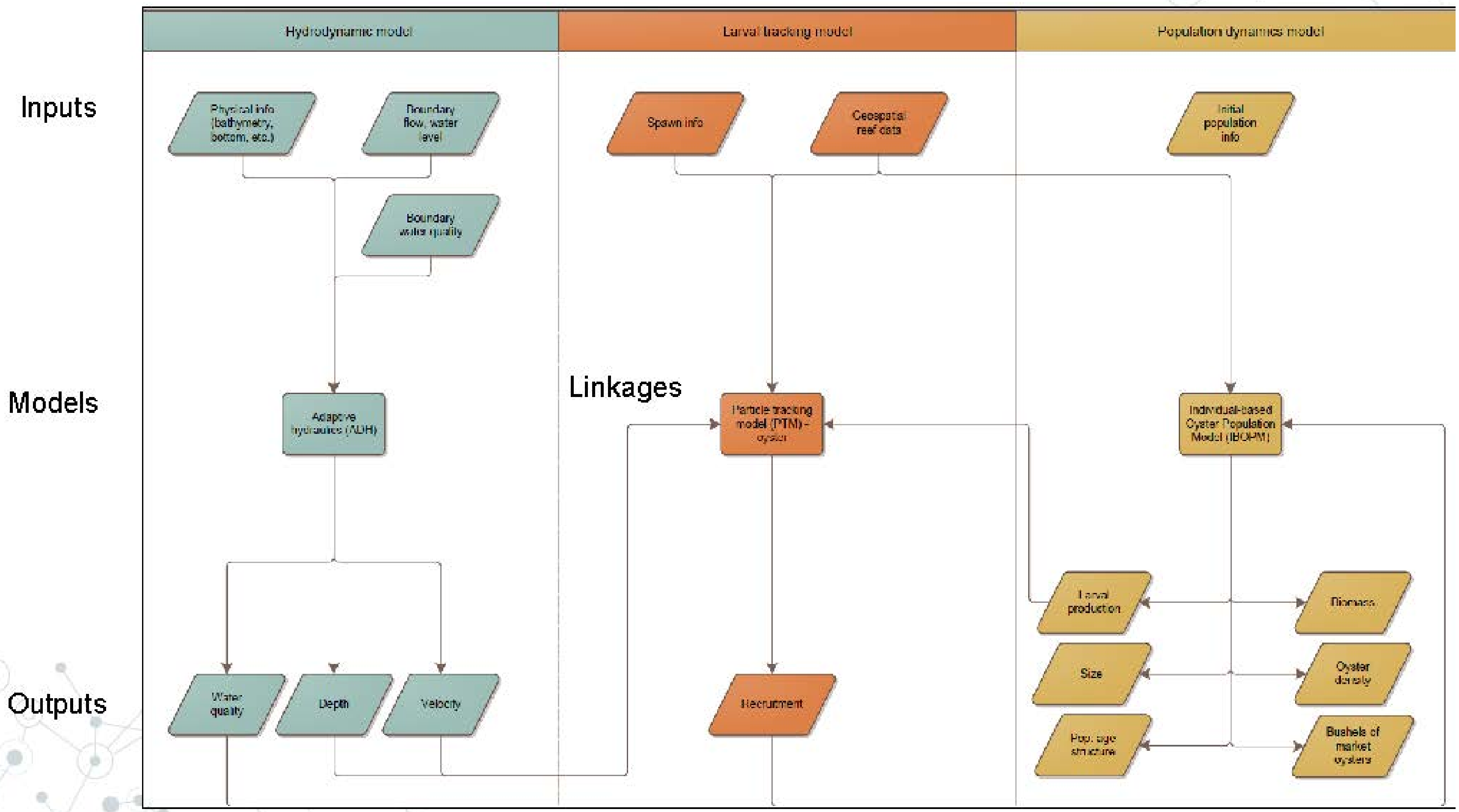
How to make this understandable & meaningful?



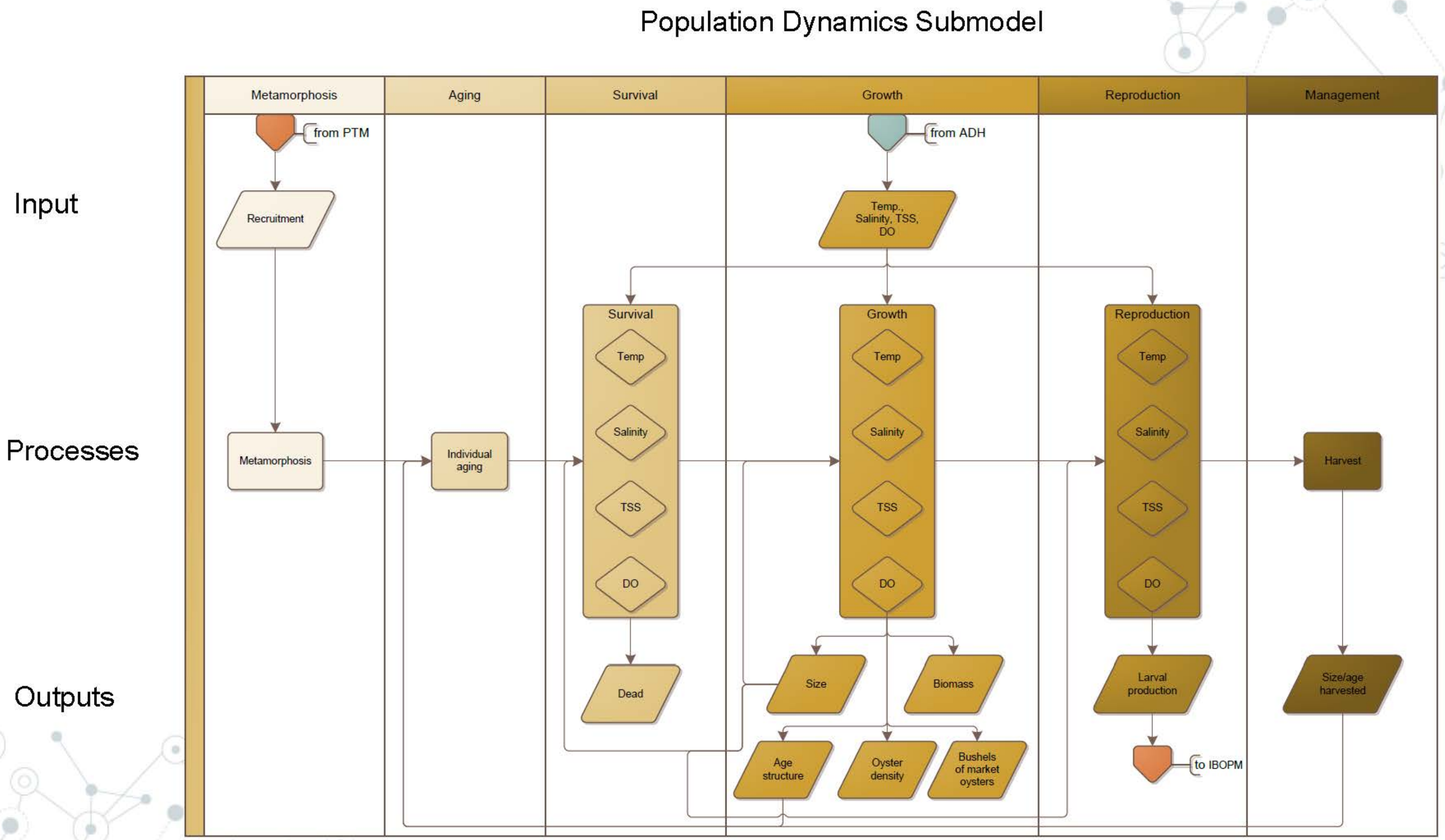
- Federal & State stakeholders
  - Planners, project managers, fisheries managers, oyster biologists
  - No engineers or modelers in stakeholder group, but they had general understanding of models
- We decided on a mediated-modeling approach

- <u>Audience Analysis</u>: Series of meetings prior to, during, and after model development
  - Preliminary meeting: discussion of modeling approach
    - identified background knowledge and experience of stakeholders
  - Second meeting: we convened with stakeholders to evaluate model and develop scenarios

Obstacle 2: Understanding big picture

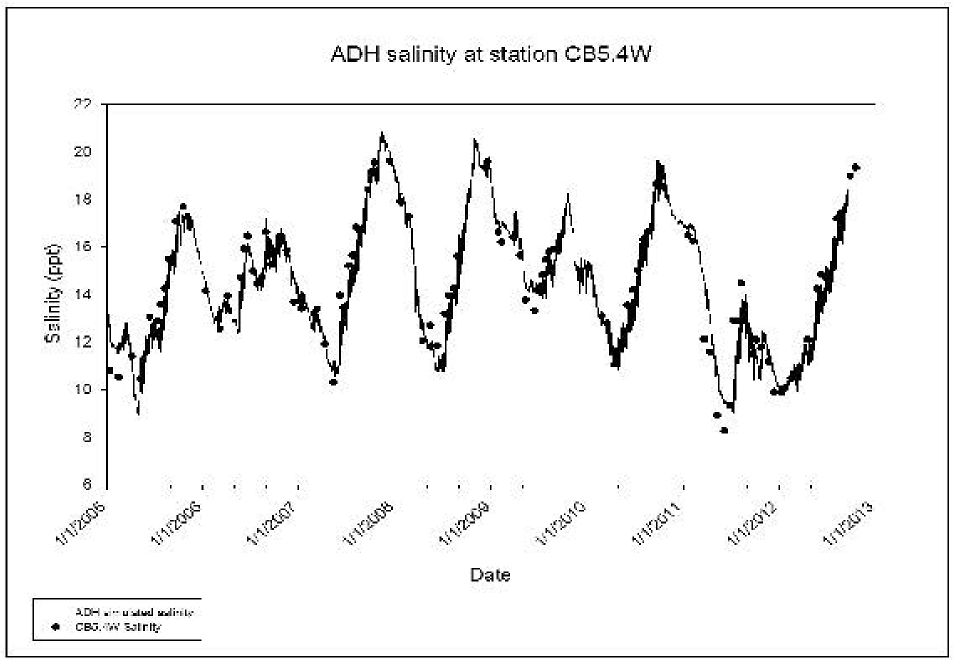


Drilling down to points of interest



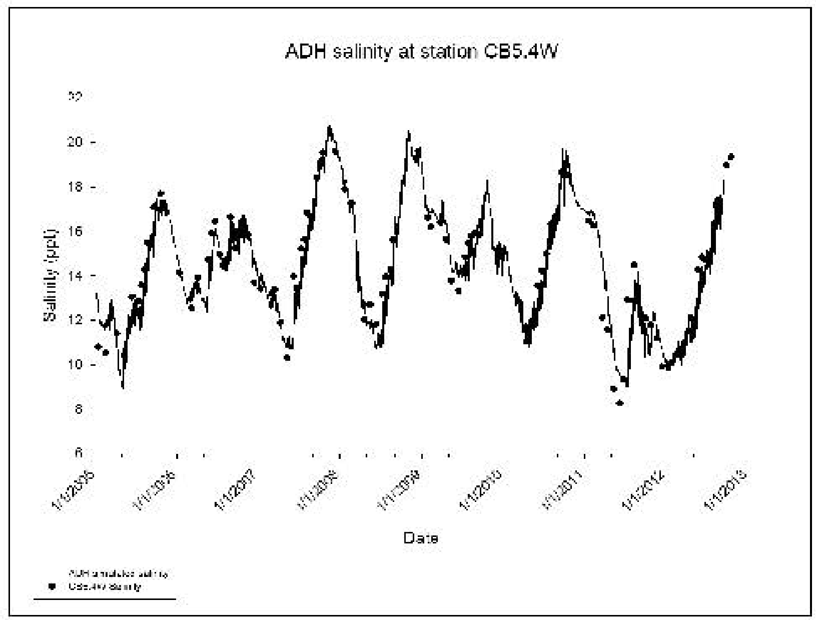
Obstacle 2 confirmed

- Audience was interested in big picture of oyster dynamics and not underlying hydrodynamic & particle tracking models
  - For example:



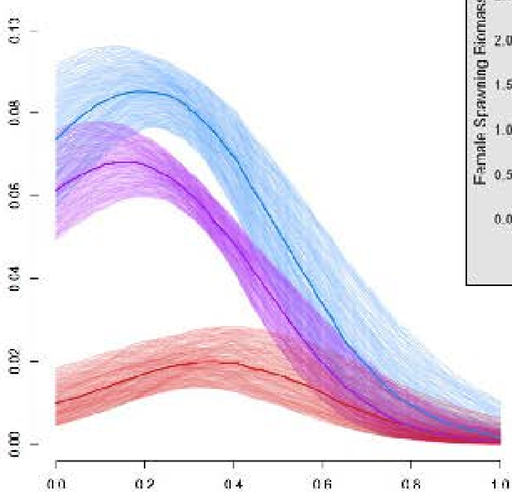
Additional Model Communication Pitfalls Observed

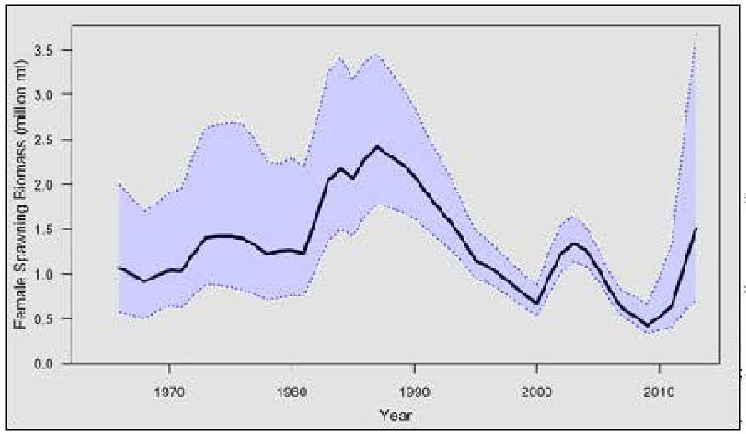
- Eachteam memberwantsto talk about how cool their stuffis
  - Audienceanalysis defines interests (i.e., what to talk about, what to omit)

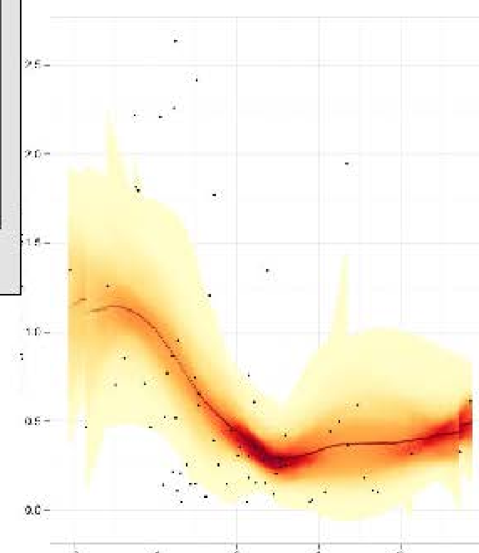


Potential Pitfalls

- Discussing, rather than just documenting, uncertainty is crucial
  - Without describing limitations, it hurts modeler's credibility

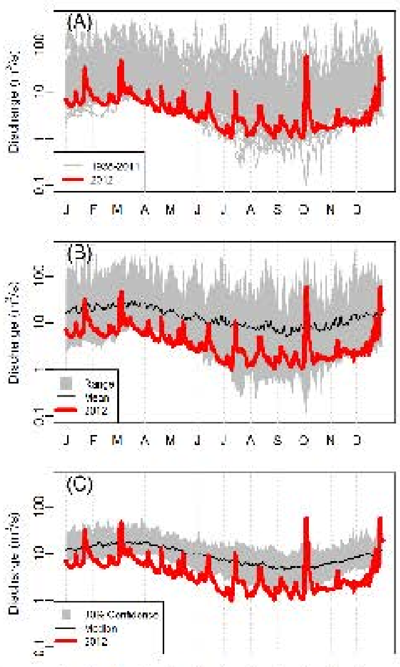


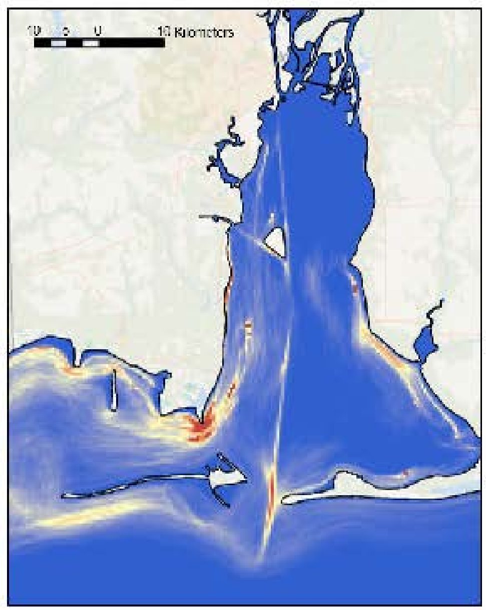


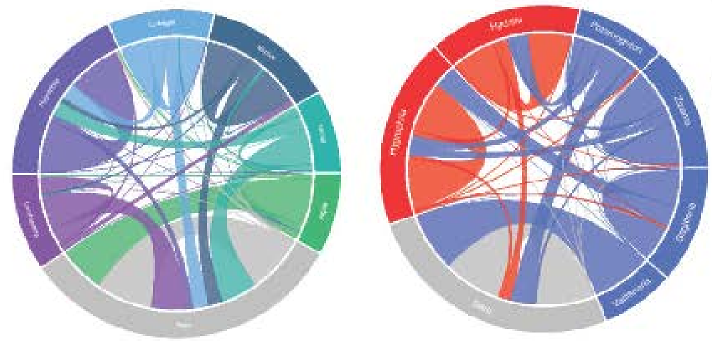


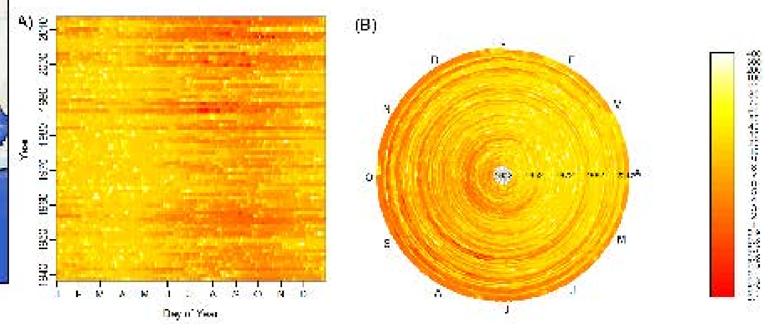
Novel Visualizations

- Visualexploration takes advantage of the capacity of the human eye to rapidly detect anpdatterns



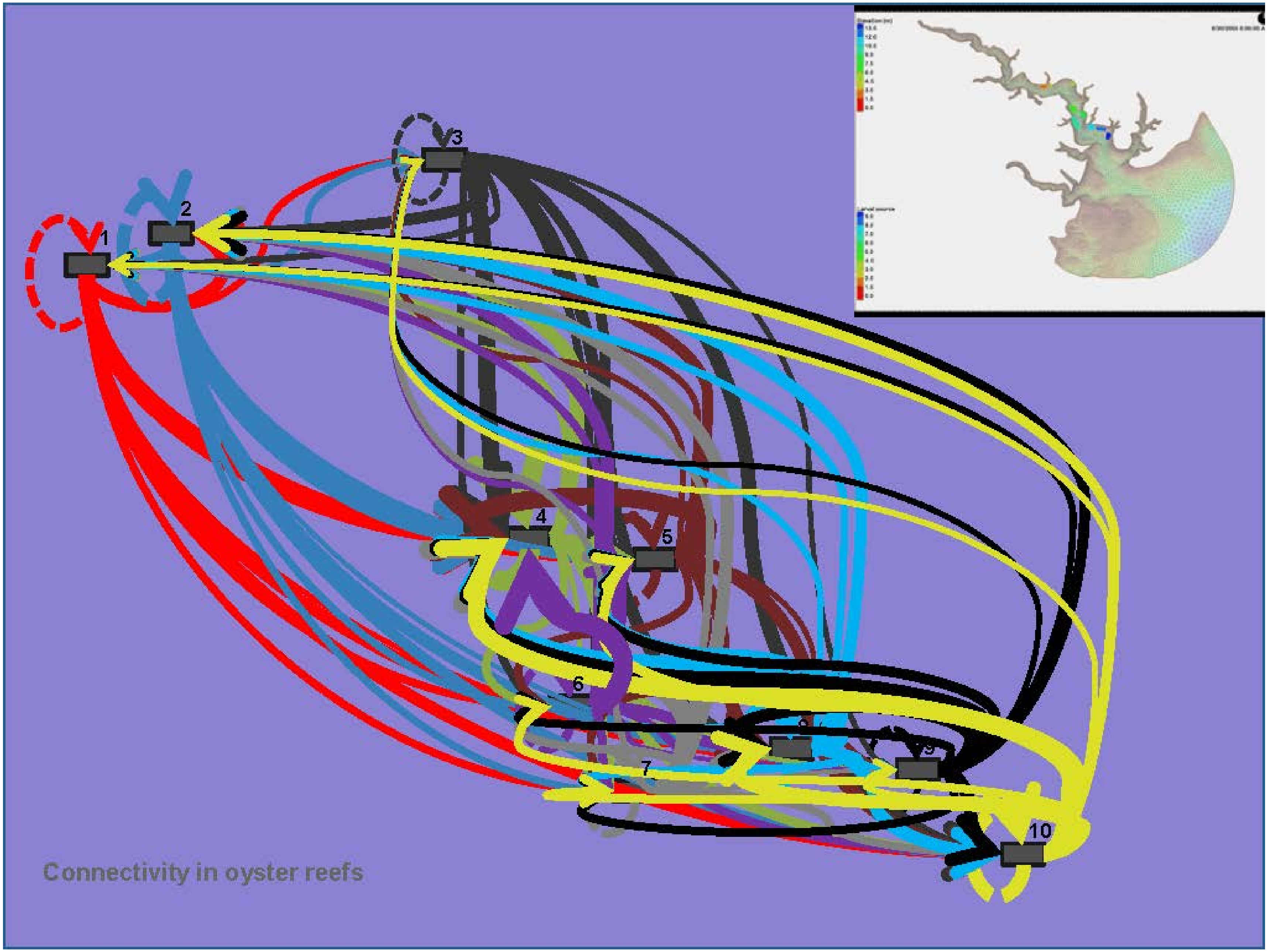






Interesting to certain audiences

Colors draw eye and audience tends to pay attention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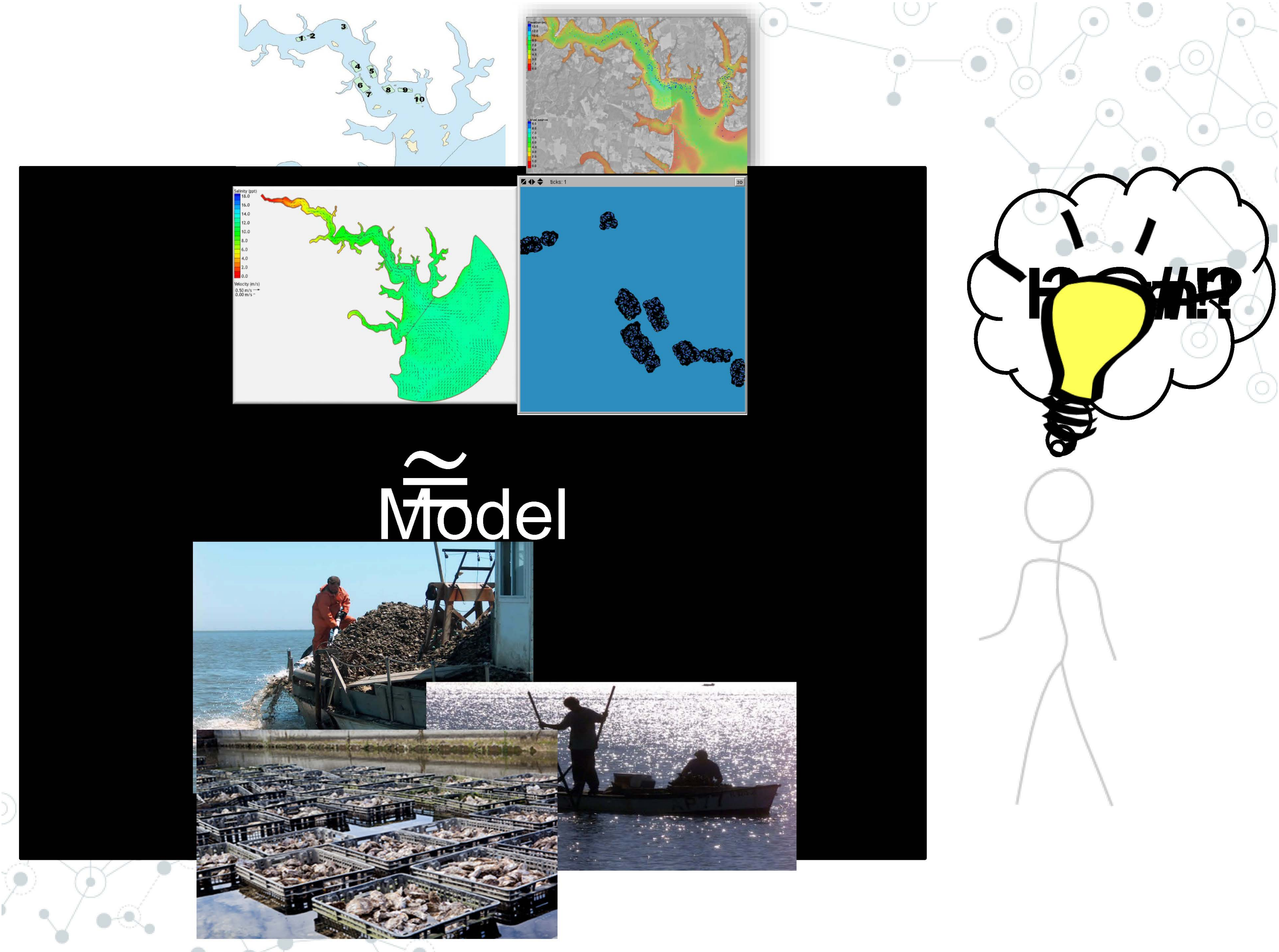
Connectivity in oyster reefs


Model

1. REPORT DOCUMENTATION PAGE

1. *Form Approved*
2. *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
4. TITLE AND SUBTITLE		**5a. CONTRACT NUMBER**
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		**5d. PROJECT NUMBER**
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)		**8. PERFORMING ORGANIZATION REPORT**
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12. DISTRIBUTION / AVAILABILITY STATEMENT

13. SUPPLEMENTARY NOTES

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14. ABSTRACT

15. SUBJECT TERMS

1. 2.

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION** 1. **OF**	**18. NUMBER**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT 1.	**b. ABSTRACT** 1.	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*

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