IMPROVING ECOLOGICAL MODELING PRACTICES

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Ecosystem Restoration PCX

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OVERVIEW

• Ecological models and SMART Planning
  • Model development and certification is not mutually exclusive from planning timelines!

• Mediated model development
  • Model building with friends!

• Tools for rapid model development and application
  • We’ve got a model for that (maybe)!

• Case study
  • Environmental effects of large-scale, coastal storm risk management studies in New York and New Jersey
ARE YOU A “MODELER”? 

- Yes, definitely!
- Maybe-ish
- No way
ECOLOGICAL MODELS AND SMART PLANNING

AN ECOLOGICAL MODEL IS USED TO REPRESENT A SYSTEM FOR A PURPOSE
UNDERSTANDING THE SYSTEM, INFORMING PLAN FORMULATION, AND IDENTIFICATION OF KEY UNCERTAINTIES IS CRITICAL.
MODELS HAVE A ROLE IN FORECASTING, BENEFIT ANALYSIS, SCENARIO ANALYSIS, AND DECISION-MAKING

TSP Milestone

- Inefficient Alternatives
- Efficient Alternatives

Cost of Restoration vs. Environmental Benefits of Restoration

Best Buy Plan Alternatives

- Incremental Cost Per Unit vs. Output
- Output range: 0 to 14,000
SENSITIVITY OF DECISIONS TO UNCERTAINTY, FEASIBILITY LEVEL DESIGN, AND ADAPTIVE MANAGEMENT & MONITORING BENEFIT FROM ECOLOGICAL MODELS.
Advancing the state of ecological model development in the Corps.

- **Expertise** - Ecological model training
- **Technology** - Statistical and programming platforms
- **Best practices** - Guidelines for all phases of model development

Efficient and effective model certification

- Average = 3 to 6 months, $15-20k total
- Delegated approval
- Best Practices
- Experience!

Understanding and best use of model complexity and decision-making.
BUILDING EXPERTISE AND APPLYING BEST PRACTICES

COLLABORATIVE MODEL DEVELOPMENT

• Model development, application, and certification can overwhelm project teams

• Coupling ERDC tech and District expertise reduces model development time while introducing new tech

• Developed a short course (1.5 days) to work through models
  • USACE and agency partners can attend
  • Series of lectures and labs on good modeling practice in USACE
  • Hands-on, problem-specific curriculum for a district to work through from concept to application
  • Model development is interactive and in real-time
  • Best of both worlds

• Our objectives are to:
  • Empower district-led modeling through ERDC tools and collaboration
  • Increase stakeholder buy-in through transparent, scientifically defensible model development.
  • Create a collaborative modeling culture.
Collaborative modeling streamlines project life cycle by:

1. being a natural mechanism to facilitate interagency interactions and buy-in,
2. providing a framework for documentation and transparency,
3. reducing risk by providing more details upon which to base decisions, and
4. introducing emerging ERDC tools and models for project planning and operations while introducing ERDC to district needs and issues.
The Math

Modeling is viewed as a complex task that can only be completed by engineers & mathematicians.
TOOLKIT FOR INTERACTIVE MODELING (TAM)

- Facilitated modeling develops model in real time (certified for national use)
- Increases transparency by demystifying modeling
- Catalyzes PDT, so they can focus on integrating relevant input data and models
- Increases critical thinking

TECHNOLOGY TO FACILITATE MODEL DEVELOPMENT
DIVERSE ECOLOGICAL MODELING TOOLS

Approach

Conceptual
Statistical
Index-based
Mass Balance

Outcome

Physical
Population
Habitat
Ecosystem

DIAGRAMS AND GRAPHS
HABITAT MODELS IN THEORY

Future Without Restoration

Restoration “Benefits”

Existing Habitat

Target Habitat

NOW

TIME (YR)

+50
Ad hoc spreadsheet models for:
- a single taxa
- one location
- one restoration alternative
- one point in time

NO PROBLEM!

Ad hoc spreadsheet models for:
- a single taxa
- one location
- multiple restoration alternatives
- multiple points in time

WELL…
## WHY BUILD AN R PACKAGE?

<table>
<thead>
<tr>
<th>Problem for Restoration Practitioners</th>
<th>Why an R package would help</th>
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<tbody>
<tr>
<td>Lots of habitat models with complex structure</td>
<td>Compile existing USFWS habitat models in one place</td>
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<tr>
<td>Ad hoc spreadsheet models commonly contain errors</td>
<td>Error-checking and code review are part of package approval (and certification)</td>
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<tr>
<td>Spreadsheet models are not widely available</td>
<td>R packages are publicly available (and free)</td>
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<tr>
<td>Habitat is spatially distributed</td>
<td>R has loads of geospatial functions</td>
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<td>Spreadsheets many have limited visualization capability</td>
<td>Functions can be developed for high-end, rapid data viz</td>
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<td>Habitat analysis are often separate from decision tools and require sequential analyses in multiple platforms</td>
<td>One-stop-shopping for integrated habitat and decision modeling</td>
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<td>Some practitioners may not be comfortable with code-based modeling</td>
<td>R packages can be accessed through user-friendly web applications</td>
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<td>Model documentation can be laborious</td>
<td>Connectivity to real-time model documentation through Rmarkdown</td>
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[https://trout.shinyapps.io/lahontan/](https://trout.shinyapps.io/lahontan/)
ECOREST R PACKAGE: HABITAT DATA

- Compiled 100+ habitat suitability models from USFWS (with 500+ sub-models)

- All models and metadata loaded into the package

- Generic data structure for user-defined models

ECOREST R PACKAGE: HABITAT MODELING

Key Functions:

• View habitat suitability index curves

• Compute suitability relative to multiple variables

• Compute overall patch quality by combining variables via:
  • USFWS equations
  • Arithmetic mean
  • Weighted arithmetic mean
  • Geometric mean
  • Minimum

• Compute habitat units
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SO YOU DON’T WANT TO USE R? NO PROBLEM!

- Different tools for different user communities!
- All tools build from the USFWS habitat data set

- ArcGIS Toolbox
- Raster data focused
- POC: Christina Saltus
CASE STUDY:
NEW YORK BIGHT ECOLOGICAL MODEL
WHY BUILD A MODEL?

Regional Coastal Storm Risk Management (CSRM) Studies

Compliance with the National Environmental Policy Act (NEPA)

- Regional Ecosystems
- Air Quality
- Water Quality
- Navigation
- Cultural Resources
- Occupational Safety and Health
- Special Status Species
- HTRW Sites
- Community Uses

- State Boundaries
- New Jersey Back Bays (NJBB)
- NY/NJ Harbor and Tributaries Study (HATS)
- Nassau County Back Bays (NCBB)
A series of workshops to iteratively develop models with research and synthesis between meetings.

- Preliminary workshop with Philadelphia District (Jan 2019)
- USACE workshop with two Districts (Mar 2019)
- Interagency conceptual modeling workshop (Jun 2019)
- Interagency numerical modeling update (Nov 2019)
- Phase-1 Model application to NJBB (Feb 2019)
- …

Ecological Model Development Process
(Herman et al. 2019)
MODEL QUANTIFICATION

Conceptual Models
("How the system works")

Quantitative Model
("Suitability Index")

Key data, models, studies, and resources
- ESPS (Hed) models, North America (1990), global biodiversity dataset (loot and Chapter 2006), climate (NLCD 2011), Ecosystem Models (FAMOUS 2005), habitat models (FAMOUS 2005)
- Other habitat suitability models: nyma (Gunnarsson et al. 2017), mangroves (Cao 2003), flood (2003), flood models (2003), habitat (2003)
- Habitation mitigation functional assessment model (USACE 2000)

Transitional impacts and construction issues
- Environmental windows for native Everglades
- Construction-related and elevation
- Construction disturbance and sediment release

Critical uncertainties and data gaps
- Water quality processes
- Relative composition of habitat types (e.g., SAD, open water)

Model Application
(parameterized with hydro models and available data)
MODEL EVALUATION (UNDERWAY)

- Technical Quality
  - Drawing from existing models and regional literature
  - Agency feedback *during* development
  - Comparison with known habitats (e.g., oyster, SAV, National Wetlands Inventory)
  - USACE certification

- System Quality
  - Code-sharing and inspection
  - Testing plan

- Usability
  - Transparent documentation
  - Data and code sharing
  - No GUI planned
• Application for screening environmental impacts as part of a programmatic EIS (i.e., “tiered” EIS)

• Primary model outputs:
  • Direct impacts
  • Indirect effects
  • Cumulative, regional effects

• Benefits of process:
  • Agency involvement
  • Transparency
  • Regional gap analysis
  • Custom tools for unique planning challenges

ALL VALUES ARE FICTIONAL AND PURELY REPRESENTATIVE OF THE TYPES OF ANALYTICAL OUTCOMES
TAKE-HOME POINTS
Salton Sea, California (R&D)

Invasive seagrass, Oregon (R&D)

Oyster Habitat Suitability (Gulf and Atlantic Coast)

Proctor Creek, Georgia (Regional Use)

Environmental Flows, Georgia (R&D)

East San Pedro Bay (Regional Use)

Meramac River (Single Use)

Fish Passage Prioritization (National Use)

Oyster Population Dynamics, Virginia (R&D)
FUTURE DIRECTIONS

• Implementing ERDC technology and models across USACE
• The field of modeling has come a long way, ERDC is actively moving the needle, but there's more to be done

• Developing new tools
  – Multi-platform TAM
  – Model selection tool
  – Interactive spatial toolkits
  – Refining integrated modeling packages
  – Guidance for good modeling practices
WHAT ARE YOUR MAJOR MODELING CHALLENGES? WHAT TOOLS DO YOU NEED?
QUESTIONS AND COMMENTS

Acknowledgements
• Ecosystem Management and Restoration Research Program (EMRRP)
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• Water Operations Technical Support (WOTS) Program
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• Todd Swannack, Todd.M.Swannack@usace.army.mil, 601-415-3509
POTENTIALLY USEFUL RESOURCES

- Toolkit for interActive Modeling (TAM), Certified for National Use.
- ERDC Technical Note – Ecological model development: Toolkit for interActive Modeling (Forthcoming)
- Habitat Suitability Modeling Tools
  - Library of 500+ USFWS Habitat Suitability Models
  - EcoRest R package + Vignette / User Manual (Spring 2020)
  - EcoRest Shiny App (Summer 2020)
  - ArcGIS Toolbox + User Manual
- Best Practices in Model Development:
  - Book Chapter – Encyclopedia of Ecology – Systems ecology
  - Book Chapter – Encyclopedia of Ecology – Model Types: Overview
  - Book Chapter – Encyclopedia of Ecology – Visualization as a tool for ecological analysis
  - ERDC Technical Note – Evaluation of system quality (Summer 2020)
  - ERDC Technical Note – Best practices for coding ecological models (Summer 2020)
  - ERDC Technical Note – Model application using scenario analysis (Spring 2020)
  - ERDC Technical Note – Conceptual modeling for large-scale regional projects (Spring 2020)
- Webinars: Models and SMART Planning (Proctor Creek), environmental flow modeling (Minnesota River), Incorporating secondary objectives to restoration planning (Hudson-Raritan Estuary), Data visualization,…
- Conferences: Ecological Society of America, Society for Freshwater Science, Symposium on Urban Stream Ecology
- Video series on key aspects of the model development process (Summer 2020)
- Facilitated modeling workshops: East San Pedro Bay, Cypress Valley, New York Bight, Swan Island, San Francisco Bay