Ecosystem Modeling for Fish and Shellfish: What to Expect?

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Ecosystem Modeling

• Fish and shellfish

• Responses to actions

• Higher level than individuals

• Recruitment, population, community, multi-species, food web
Expectations

• Temporal and spatial scales of the predictions

• How much of the biomass is accounted for

• Relative versus absolute predictions

• Appropriate level of confidence in predictions
Best Practices

Proposed Best Modeling Practices for Assessing the Effects of Ecosystem Restoration on Fish

Kenneth Rose, LSU
Shaye Sable, Dynamic Solutions
Donald DeAngelis, USGS
Simeon Yurek, Univ of Miami
Joel Trexler, Florida International UNiv
William Graf, Univ of South Carolina
Denise Reed, Water Institute of the Gulf

• Evolved from a report done for CPRA
2017 Coastal Master Plan
Strategy for Selecting Fish Modeling Approaches

Report: Version 1
Date: October 31, 2013
Prepared by: Kenneth A. Rose, Shaye Sable
Why?

• Large-scale restoration
  – Increasing
  – Expensive
  – Controversial
  – Necessary

• Often, gravitates to fish and models

Toward an Era of Restoration in Ecology: Successes, Failures, and Opportunities Ahead
Katharine N. Suding
Department of Environmental Science, Policy, and Management, University of California, Berkeley, California 94720; email: suding@berkeley.edu

Keywords
resilience, ecosystem restoration, restoration ecology, recovery, degradation, ecosystem services, environmental change, novel ecosystems

Restoration of ecosystem services and biodiversity: conflicts and opportunities
James M. Bullock\textsuperscript{1}, James Aronson\textsuperscript{2,3}, Adrian C. Newton\textsuperscript{4}, Richard F. Pywell\textsuperscript{1} and Jose M. Rey-Benayas\textsuperscript{5}
Klamath controversy continues
An agreement to remove four dams has been reached, but barriers remain

Klamath Propaganda: Who do you believe?

Independent Peer Review Says Klamath Dam Removal Science “Sound” and “Reliable”
Klamath River: A Big Dam Controversy Finally Resolved

Whistleblower is taking his case to the public

Paul Houser, the Bureau of Reclamation’s former scientific integrity adviser, says he was fired for voicing concerns that the decision to remove four Klamath River dams is being based on politics and money not science. He spoke at a Tea Party meeting Sunday in Klamath Falls.
Environmental Economics, Volume 3, Issue 1, 2012

Andrew Schmitz (USA), P. Lynn Kennedy (USA), Julie Hill-Gabriel (USA)

Restoring the Florida Everglades through a sugar lan
benefits, costs, and legal challenges

The Great Lakes Restoration Initiative: Background and Issues

Pervaze A. Sheikh
Specialist in Natural Resources Policy

September 30, 2013
Schemes

• Many have been suggested

• FAO, ACOE, papers

• We focus on fish and restoration
  – Steps
  – Concepts
  – Case studies
ECOLOGICAL MODELING GUIDE FOR ECOSYSTEM RESTORATION AND MANAGEMENT

Todd M. Swanson, J. Craig Fischer, and David J. Taiz
August 2012

Environmental Benefits Analysis Program

Available online at www.sciencedirect.com


Position Paper

Ten iterative steps in development and evaluation of environmental models

A.J. Jakeman \textsuperscript{a,b,c}, R.A. Letcher \textsuperscript{a,c}, J.P. Norton \textsuperscript{a,c}

FAO TECHNICAL GUIDELINES FOR RESPONSIBLE FISHERIES

FISHERIES MANAGEMENT

2. The ecosystem approach to fisheries
2.1 Best practices in ecosystem modelling for informing an ecosystem approach to fisheries

N. Crout \textsuperscript{a}, T. Kokkonen \textsuperscript{b}, A.J. Jakeman \textsuperscript{a}, J.P. Norton \textsuperscript{a}, L.T.H. Newham \textsuperscript{a}, R. Anderson \textsuperscript{a}, H. Assaf \textsuperscript{b}, B.F.W. Croke \textsuperscript{b}, N. Gaber \textsuperscript{a}, J. Gibbons \textsuperscript{a}, D. Holzworth \textsuperscript{a}, J. Mysiak \textsuperscript{a}, J. Reichl \textsuperscript{a}, R. Seppelt \textsuperscript{a}, T. Wagener \textsuperscript{a}, and P. Whitfield \textsuperscript{a}
Scheme for Fish and Restoration

• 31 steps
  – 5 of the steps (model selection) were actually done in the CPRA report
  – Dr. Cam Ainsworth will discuss 3 more of the steps

• 13 concepts

• Proposed best practices
(17) Prepare a strategy document
(18) Review – R&P&S
(19) Perform verification and diagnostic testing
(20) Perform calibration
(21) Perform validation
(22) Perform sensitivity and uncertainty analysis
(23) Report on results for baseline only
(24) Review – R&P
(25) Scenarios – FWOA and FWA
(26) Perform uncertainty analysis
(27) Results to RAA
(28) Review – R
(29) Public Reporting
(30) Review – S
(31) Post-auditing
13 Concepts

1. Life cycles and strategies
2. Variability, uncertainty, stochasticity
3. Generality-precision-realism
4. Nonequilibrium theory
5. Scaling
6. Explicit versus implicit representations
7. Population definition
8. Density-dependence
9. Verification, calibration, validation
10. Sensitivity and uncertainty analysis
11. Multiple models
12. Food web dynamics
13. Hidden assumptions
13 Concepts

- Example: Scaling

Dickey (2003)
13 Concepts

- Example: Nonequilibrium Theory, Stability, and Recruitment
Our Strategy

• Combine steps with concepts

• Illustrate key steps and concepts:
  – Everglades
    • Steps 2, 3, 11, 15, and aspects of 17, 19, & 22
  – Colorado River (Glen Canyon Dam)
    • Steps 4 and 11
  – Planning for the Louisiana 2017 Master Plan
    • Step 3 (Define questions)
    • Steps 10-15 (Model selection incl Data inventory)
## Categorization Scheme

<table>
<thead>
<tr>
<th>Biological</th>
<th>Spatial</th>
<th>Temporal</th>
<th>Reproduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currency</td>
<td>Organization</td>
<td>Point</td>
<td>Seasonal</td>
</tr>
<tr>
<td>State variable</td>
<td>Single-species</td>
<td>Spatially-explicit</td>
<td>One year</td>
</tr>
<tr>
<td>Age-structured</td>
<td>Multispecies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage-structured</td>
<td>Community</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual-based</td>
<td>Foodweb Ecosystem</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Table 5. Example listing of the initial models considered for the Louisiana Master plan.
Six are shown from a total of more than 30.

Sources: aWhipple et al. (2000); bWest et al. (2013); cde Mutsert et al. (2012); dBartell et al. (2010); eRoth et al. (2008); fAult et al. (1999).

<table>
<thead>
<tr>
<th>Model</th>
<th>Location</th>
<th>Habitat</th>
<th>Currency</th>
<th>Biological Organization</th>
<th>Spatial</th>
<th>Temporal</th>
<th>Reproduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lotka-Volterraa</td>
<td>None</td>
<td>Not specific</td>
<td>State variable</td>
<td>Multispecies</td>
<td>Point</td>
<td>Multiple years</td>
<td>Implicitly represented</td>
</tr>
<tr>
<td>Reason Eliminated: Model is highly aggregated and does not allow for sufficient realism nor the representation of the many effects to hydrology and water quality.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Striped mullet stock assessmentb</td>
<td>Louisiana</td>
<td>Coastwide</td>
<td>Age-structured</td>
<td>Single species</td>
<td>Point</td>
<td>Multiple years</td>
<td>Full life cycle</td>
</tr>
<tr>
<td>Reason Eliminated: A statistical catch-at-age model does not permit easy simulation of the effects on hydrology and water quality.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>EwEc</td>
<td>Breton Sound, Louisiana</td>
<td>Estuary</td>
<td>Age-structured for some; State variable for others</td>
<td>Ecosystem</td>
<td>Point</td>
<td>Multiple years</td>
<td>Forced recruitment</td>
</tr>
<tr>
<td>Reason Eliminated: EwE was not eliminated and was used to illustrate an approach; Gulf of Mexico and Louisiana versions exist.</td>
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</tr>
<tr>
<td>CASMd</td>
<td>Pontchartrain Basin, Louisiana</td>
<td>Estuary</td>
<td>State variables</td>
<td>Ecosystem</td>
<td>Point</td>
<td>1989-2007</td>
<td>Forced recruitment</td>
</tr>
<tr>
<td>Reason Eliminated: CASM was not eliminated and was used to illustrate an approach; Louisiana versions exist.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Shrimp IBMe</td>
<td>Louisiana and Texas marshes</td>
<td>Vegetation and open water</td>
<td>Individual juvenile brown shrimp</td>
<td>Single species</td>
<td>Spatially explicit</td>
<td>One year</td>
<td></td>
</tr>
<tr>
<td>Reason Eliminated: Not eliminated and used to illustrate an approach. However, the fine spatial resolution (meters) limits the geographic scale of model predictions.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spatial dynamic multistock production modelf</td>
<td>Biscayne Bay, Florida</td>
<td>Coral, seagrass, hard and soft bottom</td>
<td>Age-structured</td>
<td>Multispecies</td>
<td>Spatially explicit</td>
<td>One year</td>
<td>Full life cycle</td>
</tr>
<tr>
<td>Reason Eliminated: Not eliminated and used to illustrate an approach.</td>
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</tbody>
</table>
### Step 15 – Recommended Approaches

Table 6. A subset of the features from the full list for three of nine modeling approaches identified as being candidate approaches for the 2017 Master Plan. The subset of features illustrate the types of information found in the full version of the Table used for model selection.

<table>
<thead>
<tr>
<th>Features</th>
<th>Ecopath with Ecosim (EwE)</th>
<th>CASM</th>
<th>Spatial Dynamic Multi-Stock Production Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of modeled species or groups</strong></td>
<td>BS: 39 groups including phytoplankton, zooplankton, SAV, benthos</td>
<td>BB: 30 groups including phytoplankton, zooplankton, periphyton, zoobenthos</td>
<td>Two-species predator-prey model</td>
</tr>
<tr>
<td></td>
<td>WFS: 60 groups including multiple plankton groups, seabirds, sharks</td>
<td>MRGO: 35 groups including phytoplankton, periphyton, zooplankton, zoobenthos, several aquatic vegetation groups</td>
<td></td>
</tr>
<tr>
<td><strong>Environmental inputs to existing models</strong></td>
<td>BS: Monthly and annual salinity</td>
<td>Daily surface light, water temperature, nutrients, depth, velocity, suspended sediments, Particulate organic carbon, salinity</td>
<td>Coral reef, seagrass, hard bottom, bare bottom habitats, salinity, temperature, velocity</td>
</tr>
<tr>
<td></td>
<td>WFS: Mississippi River nitrogen loads</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Calibration and parameter Uncertainty</strong></td>
<td>ECORANGER used to mass balance Ecopath model based on uncertainty, also to fit Ecosim to annual time series of abundance and catch data</td>
<td>Fitted to monthly biomass data for systematic calibration and parameter sensitivity using parameter estimation software called PEST (Dynamic Solutions, 2012)</td>
<td>Predicted growth of seatrout calibrated with sizes at age; seasonal abundance and densities of pink shrimp by habitat type validated with field data</td>
</tr>
<tr>
<td><strong>Model transparency and ease of use</strong></td>
<td>Free online software with a user interface makes it easy to use but difficult to customize the code; source code is now available but public version of source code continues to be developed</td>
<td>Input files and code customized for each project and source code must be obtained from model developer</td>
<td>Input files and code was customized for the project and source code must be obtained from the model developer</td>
</tr>
</tbody>
</table>
Final

• Repeat 2012 HSI analysis

• Improve HSI

• CASM (or TroSIM) and/or EwE
  – Cautions, e.g., movement
  – Suggestions

• Spatially-explicit IBM
  – Focus is movement
Concluding Remarks

• Best practices scheme offers a systematic way to evaluate a modeling effort
  – Steps were done
  – Results of the steps

• Good modelers do most of these but often they do not document them in this format
Acknowledgements

This paper evolved from a variety of workshops involving some of the authors on how to use ecological and fish models, a report for the California Delta Science Program on how to develop and implement salmon life cycle models (with James Anderson, Michelle McClure, and Greg Ruggerone), and a report prepared by KAR and SS to the Louisiana’s Coastal Protection and Restoration Authority on how to select fish models for evaluating restoration plans. KAR and SS want to thank CPRA and The Water Institute of the Gulf for their funding support to write this paper.

Contributions: KAR and SS developed the overall scheme; DLD, SY, and JCT provided the Everglades example; WG provided the Colorado River example; DJR worked with KAR and SS on the Coastal Louisiana example; all authors contributed to the final document.