Assessing Ecosystem Restoration Effects on Fish and Shellfish

Necessary, Messy, Doable

Kenneth Rose
University of Maryland Center for Environmental Science
Horn Point Laboratory
Chesapeake Bay is not alone!
Evaluation of the Predictive Ecological Model for the Edwards Aquifer Habitat Conservation Plan:
An Interim Report as Part of Phase 2

Committee to Review the Edwards Aquifer Habitat Conservation Plan
Water Science and Technology Board
Division on Earth and Life Studies

The National Academies of
SCIENCES • ENGINEERING • MEDICINE
Question: Spending billions but everyone is unhappy
Emergent Patterns

• Tightening resources ("bang for the buck") and tradeoffs

• Convolution of hypoxia, warming, acidification, coastal development, agriculture, and habitat

• Increasing knowledge and savvy of stakeholders

• Critical (controversial) role of increasingly complex and complicated coupled models

• Increasing demands for linkage to living resources ("fish")
  – Title: State of the Science → Gap Analysis → Assessment?
# Chesapeake Bay

<table>
<thead>
<tr>
<th>Good News</th>
<th>Bad News</th>
</tr>
</thead>
<tbody>
<tr>
<td>• You are not alone</td>
<td>• Some have gone sour</td>
</tr>
<tr>
<td>• We know how to do this</td>
<td>• Answers may not satisfying; false negatives</td>
</tr>
<tr>
<td>• Chesapeake is well studied</td>
<td>• Major effort</td>
</tr>
<tr>
<td>• Long history of monitoring, modeling, and process studies</td>
<td>• Other management occurring to promote stability</td>
</tr>
</tbody>
</table>
Technical Issues (cautions)

• Which models to use (looks arbitrary or convenient)
• A lot of work on coupling models (loss of information)
• Validation (physics people need to relax)
• Uncertainty (I prefer certainty)
• Multiple and ensemble modeling (confusion)
• Domain of application (not defined)
• {Active/passive} Adaptive Management (delay difficult decisions)
• Coupled human-natural systems (disappointing in fisheries)
Proposed best modeling practices for assessing the effects of ecosystem restoration on fish

Kenneth A. Rose, Shay Sable, Donald L. DeAngelis, Simeon Yurek, Joel C. Trexler, William Graf, Denise J. Reed

Recommendations on the Use of Ecosystem Modeling for Informing Ecosystem-Based Fisheries Management and Restoration Outcomes in the Gulf of Mexico


D. Holzworth, J. Mysiak, J. Reichl, R. Seppelt, T. Wagener, and P. Whitfield
Some Examples (Doable)

1. Bay anchovy in Chesapeake Bay  
   Shows it can be done

2. Croaker in Gulf of Mexico (ongoing)  
   Specific to reducing nutrients and effects of water quality

3. Atlantis model  
   More complex

4. Bay anchovy larvae  
   Much simpler – small part of life cycle

5. Habitat analyses  
   Very simple

All involve linking water quality to fish and using coupled modeling
1. Bay Anchovy in Chesapeake Bay

2. Croaker in GOM

- Idealized 300 x 800 cell grid (1 km resolution)
- Bottom elevation for each cell is truncated beyond 100 m

Model Overview

• Spatially explicit, IBM
  – Follows 7 stages to age 8
  – September 1 birthday
  – Model year begins Sept. 1
  – Each year 365 days long

• Hourly processes
  – Growth
  – Mortality
  – Reproduction
  – Movement
25% Reduction in Nutrients
PD: benefit?; Normoxia: best can be expected
O = Obenour et al. (2012); R = Rabotyagov et al. (2014); T = Turner et al. (2012); K = Kling et al. (2014); ROMS = Laurent and Fennel (2014)
IBM in FVCOM for Exposed Stages

Off-grid for stages not exposed

Croaker
Menhaden
Red snapper
Shrimp

Management Committee
Managers’ Workshop

Scenarios and Cross-Species Comparisons
Communication of Results to Management

Application PI
Is the GOM ahead of CB?
Design and Parameterization of the Chesapeake Bay Atlantis Model: A Spatially Explicit End-to-End Ecosystem Model

Thomas F. Ihde¹, Isaac C. Kaplan², Elizabeth A. Fulton³, Iris A. Gray³, Mejs Hasan⁴, David Bruce⁵, Ward Slacum⁶, and Howard M. Townsend⁷

¹NOAA Chesapeake Bay Office, 410 Severn Avenue, Suite 207A, Annapolis, MD 21403; Tom.Ihde@noaa.gov
²Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd E, Seattle, WA 98112
³Commonwealth Scientific and Industrial Research Organization, Marine and Atmospheric Research, GPO Box 1538, Hobart, Tasmania 7001, Australia
⁴NOAA Chesapeake Bay Office/Cooperative Oxford Laboratory, 904 South Morris Street, Oxford, MD 21654
⁵Oyster Recovery Partnership, 1805A Virginia Street, Annapolis, MD 21401

NOAA Technical Memorandum NMFS-F/SPO-166
September 2016
The Atlantis Model
Provided by Tom Ihde

Biological environment
✓ Primary production
✓ Trophic interactions
✓ Recruitment relationships
✓ Age structure
✓ Size structure
✓ Life History
✓ Refuge Habitat

Physical environment
✓ Geology
✓ Chemistry
✓ Circulation & currents
✓ Temperature
✓ Salinity
✓ Water clarity
✓ Climate variability

Fisheries
✓ Multiple sectors
✓ Gears
✓ Seasons
✓ Spatially explicit

Nutrient Inputs
✓ Currency is Nitrogen
✓ Oxygen
✓ Silica
✓ 3 forms of detritus
✓ Bacteria-mediated recycling
CAM Design: 3-Dimensional Box Model:

Provided by Tom Ihde
Ecological Groups: Federal fisheries, Forage, Protected, Habitat

Finfish
- **Alosines** (Amer.Shad, Hickory Shad, Alewife & Herring)
- Atlantic Croaker
- **Bay anchovy**
- Black drum
- **Bluefish**
- **Butterfish**, harvestfish (“Jellivores”)
- Catfish
- Gizzard shad
- **Littoral forage fish**: silversides, mummichog
- **Menhaden**
- Striped bass
- **Summer flounder**
- Other flatfish (hogchoker, tonguefish, window pane, winter flounder)
- **Panfish**
  - Euryhaline: Spot, silver perch; FW to 10ppt: yellow perch, bluegill
- **Reef assoc. fish**: spadefish, tautog, **black seabass**, toadfish
- Spotted hake, lizard fish, northern searobin
- Weakfish
- White perch

Elasmobranchs
- Cownose ray
- Dogfish, smooth
- **Dogfish, spiny**
- Sandbar shark

Birds
- **Bald Eagle**
- Piscivorous birds (osprey, great blue heron, brown pelican, cormorant)
- Benthic predators (diving ducks)
- Herbivorous seabirds (mallard, redhead, Canada goose, & swans)

Mammals
- **Bottlenose dolphin**

Reptiles
- **Diamond-back Terrapin**
- **Seaturtles**

Invertebrates
- **Benthic feeders**: (B-IBI “CO”+“IN”) …,
- **Benthic predators**: (B-IBI “P”) …,
- **Benthic suspension feeders**: (B-IBI “SU”)
- Blue crab YOY
- Blue crab adult
- **Brief squid**
- **Macoma clams**: (B-IBI)
- **Meiofauna**: copepods, nematodes, …,
- **Oysters**

Primary Producers
- Benthic microalgae (“microphytobenthos” benthic diatoms, benthic cyanobacteria, & flagellates)
- “Grasses:”
  - **SAV** – type varies with salinity
- **Marsh grass**
  - Phytoplankton – Large: diatoms & silicoflagellates (2-200um)
  - Phytoplankton – Small: nanoplankton, ultraplankton, aka “picoplankton” or “picoalgae” (0.2-2um), cyanobacteria included (2um)
- Dinoflagellates (mixotrophs) (5-2,000um)

ZooPlankton
- Ctenophores
- Sea nettles
- Microzooplankton (.02-.2mm): rotifers, ciliates, copepod nauplii
- Mesozooplankton (.2-20mm): copepods, etc.

Detritus
- Carrion
- Carrion (sediment)
- Labile
- Labile (sediment)
- Refractory
- Refractory (sediment)

Bacteria (.2-2 um [.002 mm] - feed microzooplankton food chain)
- Benthic Bacteria (sediment)
- Pelagic Bacteria: (free-living)

Provided by Tom Ihde
Striped Bass

Current Conditions

Temperature increase & Habitat Loss

Provided by Tom Ihde
Sensitivity To Environmental Factors
Selected Group Effects of Interest to Management

Scenarios:
- Temp Increase with Marsh Loss, SAV Loss, & TMDL
- Temp Increase with Marsh Loss & SAV Loss
- Temperature Increase (1.5C)
- TMDL
- SAV Loss
- Marsh Loss

Graph:
- Percentage Change
- marsh loss
- SAV Loss
- Temperature Increase (1.5C)
- TMDL

Legend:
- Z – Zooplankton
- BA – Bay Anchovy
- W – Worms (and other benthic invert. prey)
- BC – Blue Crab
- AM – Atlantic Menhaden
- SB – Striped Bass
- SF – Summer Flounder
- FF – All Finfish

Provided by Tom Ihde
5. Habitat

Sable et al. 2017 Coastal Master Plan: Attachment C3-16: Spotted Seatrout Habitat Suitability Index Model. CPRA.
Habitat

• Data-based so some people hate it less than others

• Long history – started with hydro-licensing

• Sum over spatial cells to get WUA

• New maps under management scenarios

• Not abundance but capacity

• Interpretation is tricky
“Familiar Situation in Louisiana”

- Two food web models and habitat suitability
- Did not know how to use them - stalemate
- Asked us (Rose, Ainsworth, and Brady) to help them
Non-technical Issues

- Terms: fish, fisheries, habitat
  hindcast, forecast, prediction, projection, relative vs absolute
  sustainable, resilience
  uncertainty, sensitivity, validation

- Answers to simple questions

- Managing expectations

- Role of stakeholders

- Unified voice

- Communication of models, uncertainty, risk

- Ultimately, trust
Terms

• Fishing or fisheries is “the industry or occupation devoted to the catching, processing, or selling of fish, shellfish, or other aquatic animals”

• Habitat – always say what aspects and processes you mean

• Prediction, projection, forecasting
  – Look at the x-axis and y-axis

• Sustainable, etc.
  – Always give units and scales

• Uncertainty
  – We love the methods
  – Issue is proper interpretation of the “error bars”
Simple Questions

Environ Monit Assess (2018) 190: 530
https://doi.org/10.1007/s10661-018-6912-z

Applying spatiotemporal models to monitoring data to quantify fish population responses to the Deepwater Horizon oil spill in the Gulf of Mexico

Eric J. Ward • Kiva L. Oken • Kenneth A. Rose • Shaye Sable • Katherine Watkins • Elizabeth E. Holmes • Mark D. Scheuerell
Managing Expectations

• Lags in water quality, LAGS in living resources

• Costs a lot of money, 4-year political cycle

• Detection challenge within the variation caused by other factors

• Interpreting modeling products

• False negatives
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.
Preparation documents sent to review panel members for the Gulf of Mexico Red Snapper stock assessment
Technical & Non-technical Issues + Lessons Learned

Proposed best modeling practices for assessing the effects of ecosystem restoration on fish

Kenneth A. Rose\textsuperscript{a,c}, Shaye Sable\textsuperscript{b}, Donald L. DeAngelis\textsuperscript{c}, Simeon Yurek\textsuperscript{d}, Joel C. Trexler\textsuperscript{e}, William Graf\textsuperscript{f}, Denise J. Reed\textsuperscript{g}
Scheme for Fish and Restoration

• 31 steps
  – Specific situation
  – Some not relevant, others done already

• 13 concepts
  – “framework”

• Proposed best practices
  – Tried to call it “Pretty Good Practices”
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 – (1) Life Cycles

Life History Classification of Animals
Winemiller and Rose (1992)

A) OPPORTUNISTIC

B) PERIODIC

C) EQUILIBRIUM

Fig. 12.21 in Molles 2006

13 Concepts – (4) Nonequilibrium Theory

![Graphs of different stability types]

- Classic Stability
- Bounded Stability
- Episodic Stability
- Regime Shift
- Shifting Baseline

Year
13 Concepts – (5) Scaling

Dickey (2003)
13 Concepts – (6) Explicit vs Implicit

- Process rates depend on a variable
- Formulations
  - Relationship within the model
  - Implied in the model so can still answer questions
  - Limited domain for further variation
  - Bridge calculations

- Do not believe labels
Going Forward – Checklist

• We know the question(s) pretty well

• Extensive data and database

• Process-level knowledge
  – Physics to water quality
  – Water quality to fish

• Complex life cycles with multiple factors

• Existing models

• Conclusion: Necessary, Messy, and Doable