# A Proposed Framework for Analyzing Water Quality and Habitat Effects on Aquatic Living Resources of Chesapeake Bay

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# CESR

- Achieving Water Quality Goals in the Chesapeake Bay: A Comprehensive Evaluation of System Response

- Independent report from STAC

- Three supporting documents

- Easton, Z., Stephenson, K., Benham, B., Böhlke, J. K., Brosch, C., Buda, A., Collick, A., Fowler, L., Gilinsky, E., Hershner, C., Miller, A., Noe, G., Palm-Forster, L., & Thompson, T. (2023). ***Evaluation of watershed system response to nutrient and sediment policy and management.***

- Testa, J. M., Dennison, W. C., Ball, W. P., Boomer, K., Gibson, D. M., Linker, L., Runge, M. C., & Sanford, L. (2023). ***Knowledge gaps, uncertainties, and opportunities regarding the response of the Chesapeake Bay estuary to proposed TMDLs.***

- Rose, K., Monaco, M. E., Ihde, T., Hubbart, J., Smith, E., Stauffer, J., & Havens, K. J. (2023). ***Proposed framework for analyzing water quality and habitat effects on the living resources of Chesapeake Bay.***

# Context

- Many reasons to relate water quality and habitat changes to living resources

  - Valued by stakeholders and society
  - Restoration is costly
  - Realistic and feasible targets and goals
  - Ecological and economic efficiency (“reckoning”)
  - Expectations
  - Adaptive management
  - Winner and losers

1 Introduction

2 Why now?

3 Management Questions that Could Be Answered

4 Existing Links Between WQ/Habitat & LR
- 4.1 Assessing Progress of Restoring LR of the CB
- 4.2 Example of Analyses for CB Living Resources
  - 4.2.1 Habitat-based Assessment
  - 4.2.2 Statistical Analysis of LR Monitoring Data
  - 4.2.3 Living Resource Models

5 LR and Other Large-scale Restoration Efforts

6 Going Forward

7 Proposed Framework

- 7.1 Complex Life cycles and life history strategies
- 7.2 Variability, uncertainty, and stochasticity
- 7.3 Model complexity
- 7.4 Vital rates
- 7.5 Habitat suitability and capacity
- 7.6 Biological organization
- 7.7 Nonequilibrium theory and baseline
- 7.8 Multiple Influencing Factors
- 7.9 Tradeoffs (win-lose), Win-win, and Lose-lose
- 7.10 Power to detect responses
- 7.11 Explicit and implicit representations
- 7.12 Relative versus absolute predictions

8 Strategic determination of an analysis plan
- 8.1 Selecting species
- 8.2 Available Data
- 8.3 Response and explanatory variables
- 8.4 Biological, temporal, & spatial scales
- 8.5 Analytical approaches
- 8.6 Coordination and combining results

9 Final comments

10 Acknowledgements

11 References

# Feasibility – Chesapeake Bay

- Historical focus on water quality
- Productivity and highly valued
- Information and data rich
- Many scientists = a lot of past and ongoing activities
- Done at other large-scale restoration efforts
- Q: How would we go about doing this (daunting) task?

# Context

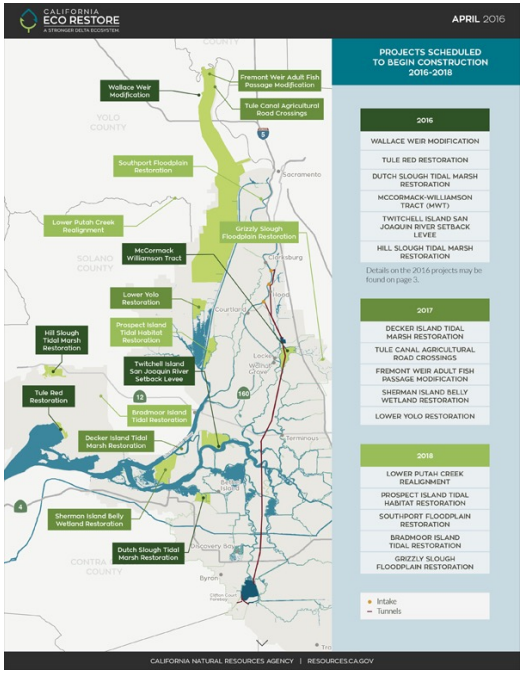
- TMDL
- 2025 assessment
- Not reaching some goals - why?
- Expectations

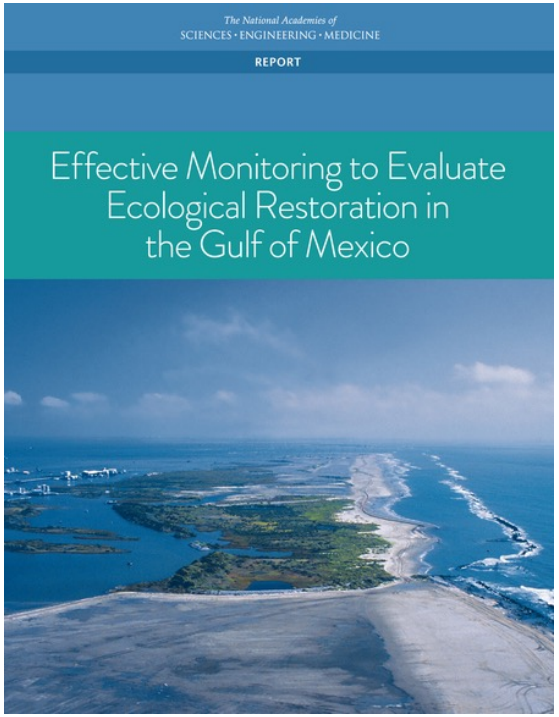
# Historically

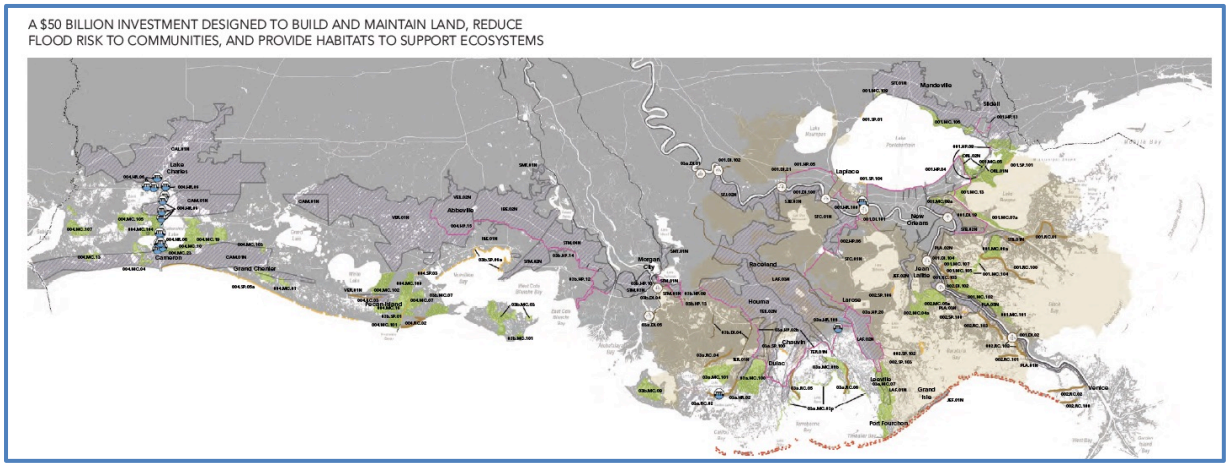
- Statuary lever is CWA
  - DO, nitrogen, chlorophyll
- Extensive analysis with lab data to derive WQS
  - Covered the entire Bay
- 2012 Agreement
  - Added many living resources goals
  - “in-situ” conditions

# Chesapeake Bay is not alone!

Used for CCMP 2020




***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*
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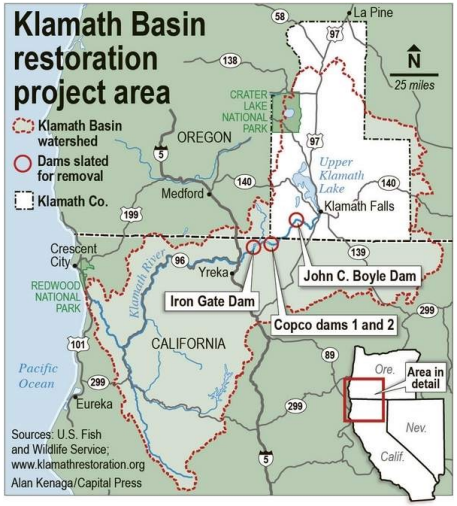
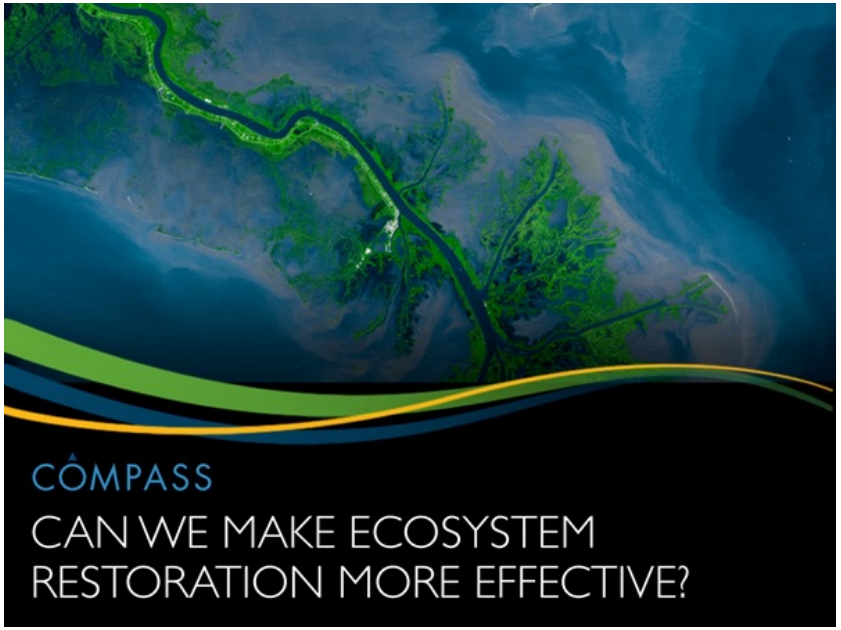


# Question: Spending billions on restoration in the US and yet so many are unhappy



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Ecological Modelling 300 (2015) 12–29

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

Kenneth A. Rose[a,*], Shaye Sable[b], Donald L. DeAngelis[c], Simeon Yurek[d], Joel C. Trexler[e], William Graf[f], Denise J. Reed[g]

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ter Plan

Selecting Fish Modeling Approaches

Report: Version I

Date: October 31, 2013

Prepared by: Kenneth A. Rose, Shaye Sable

Dynamic Solutions LLC

THE WATER INSTITUTE OF THE GULF

Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science

Taylor & Francis

Marine and Coastal Fisheries

Dynamics, Management, and Ecosystem Science

ISSN: (Print) 1942-5120 (Online) Journal homepage: http://www.tandfonline.com/loi/umcf20

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

Arnaud Grüss, Kenneth A. Rose, James Simons, Cameron H. Ainsworth, Elizabeth A. Babcock, David D. Chagaris, Kim De Mutsert, John Froeschke, Peter Himchak, Isaac C. Kaplan, Halie O'Farrell & Manuel J. Zetina Rejon

D. Holzworth[j], J. Mysiak[k], J. Reichl[l], R. Seppelt[m], T. Wagener[n], *and* P. Whitfield[o]

# Management Questions

- What is the expected (projected) response of living resources to water quality and habitat conditions in the Bay:

  (a) without the TMDL and habitat targets

  (b) present TMDL and habitat attainment continued

  (c) under full TMDL and habitat goals

# Management Questions

- Given the current state or condition, how can the analyses inform what types and magnitude of changes in water quality and habitat are needed to evoke an agreed-upon target set of the desired living resources' responses?

- What are the certainties and critical uncertainties of the analyses and how can they help guide future monitoring and modeling efforts?

# Continued Status-Quo

- Provides much useful information on progress
- Focused on the first question
  - WQ
  - Habitat goals reached
  - Simple population status indicators
- Comprehensive approach - answer all questions
- Status-quo → moderate → major → comprehensive
  - More relevant questions and answers
  - Tradeoff is effort and uncertainties

# Existing links WQ/Habitat to LR

- WQS
- Agreement indicators
- Report cards
- Others

# Existing links WQ/Habitat to LR

- Seitz et al. 2009
- Woodland et al. 2021
- Adamack et al. 2017
- Fulford et al. 2010
- Ihde et al. 2016

- Monitoring data
- WQ modeling system
- Habitat → population → food web

# Existing links WQ/Habitat to LR

- Many completed analyses
  - Excellent
  - Independent
- Species, methods, spatial/temporal coverage vary
- Addressed study-specific questions
  - Not “TMDL” and CBP habitat restoration

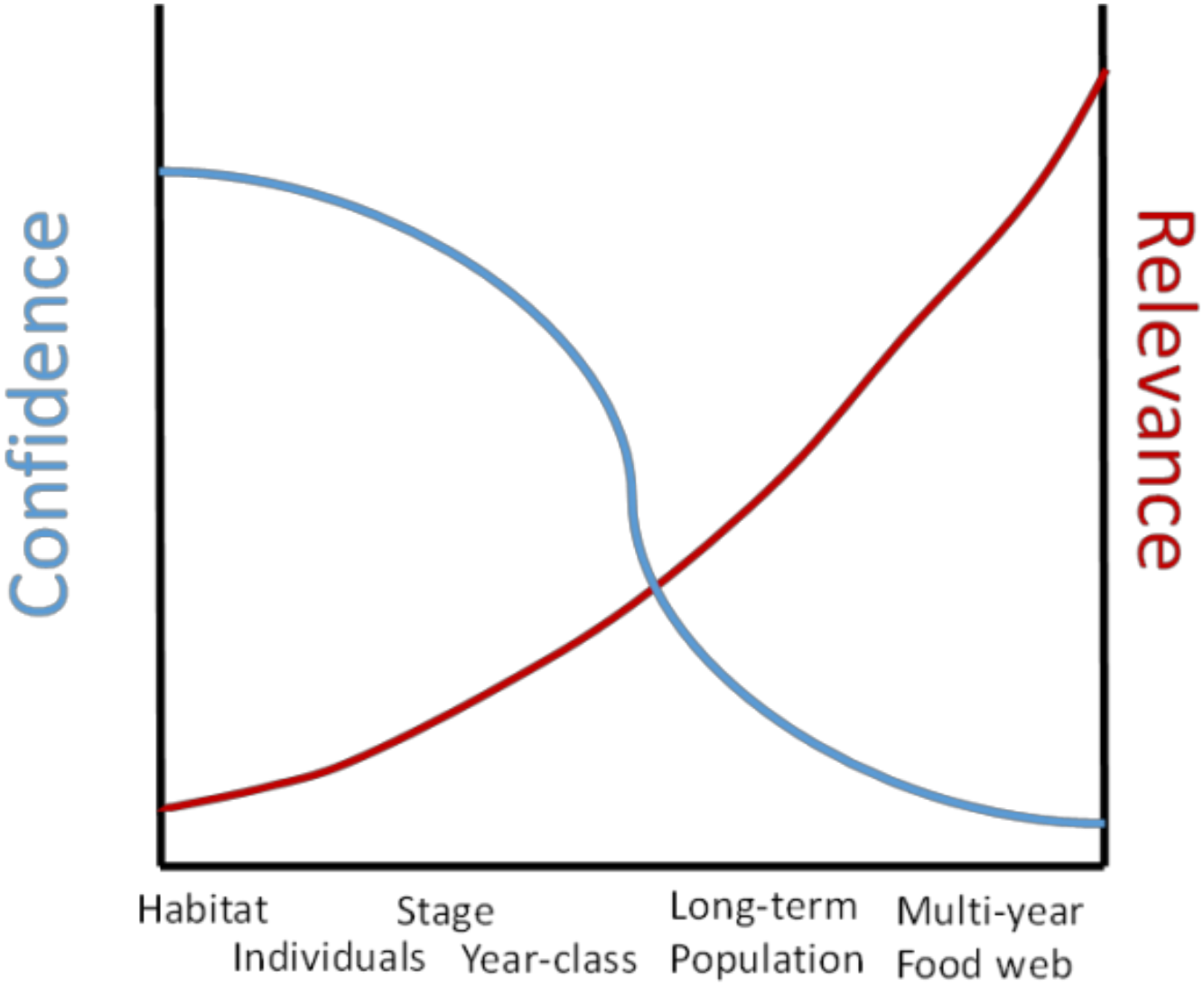
# Different Situation to “WQ”

- Many critters move
- Affected by many factors in complex life cycles
- Responses are on longer time scales
- Challenging to isolate responses

# Going Forward

# Foundational Concepts: Examples

- Variability, uncertainty, stochasticity
- Vital rates
  - Growth, mortality, reproduction
  - Movement
- Model complexity


Confidence
Relevance
Habitat
Individuals
Stage
Year-class
Long-term
Population
Multi-year
Food web

# Foundational Concepts: Examples

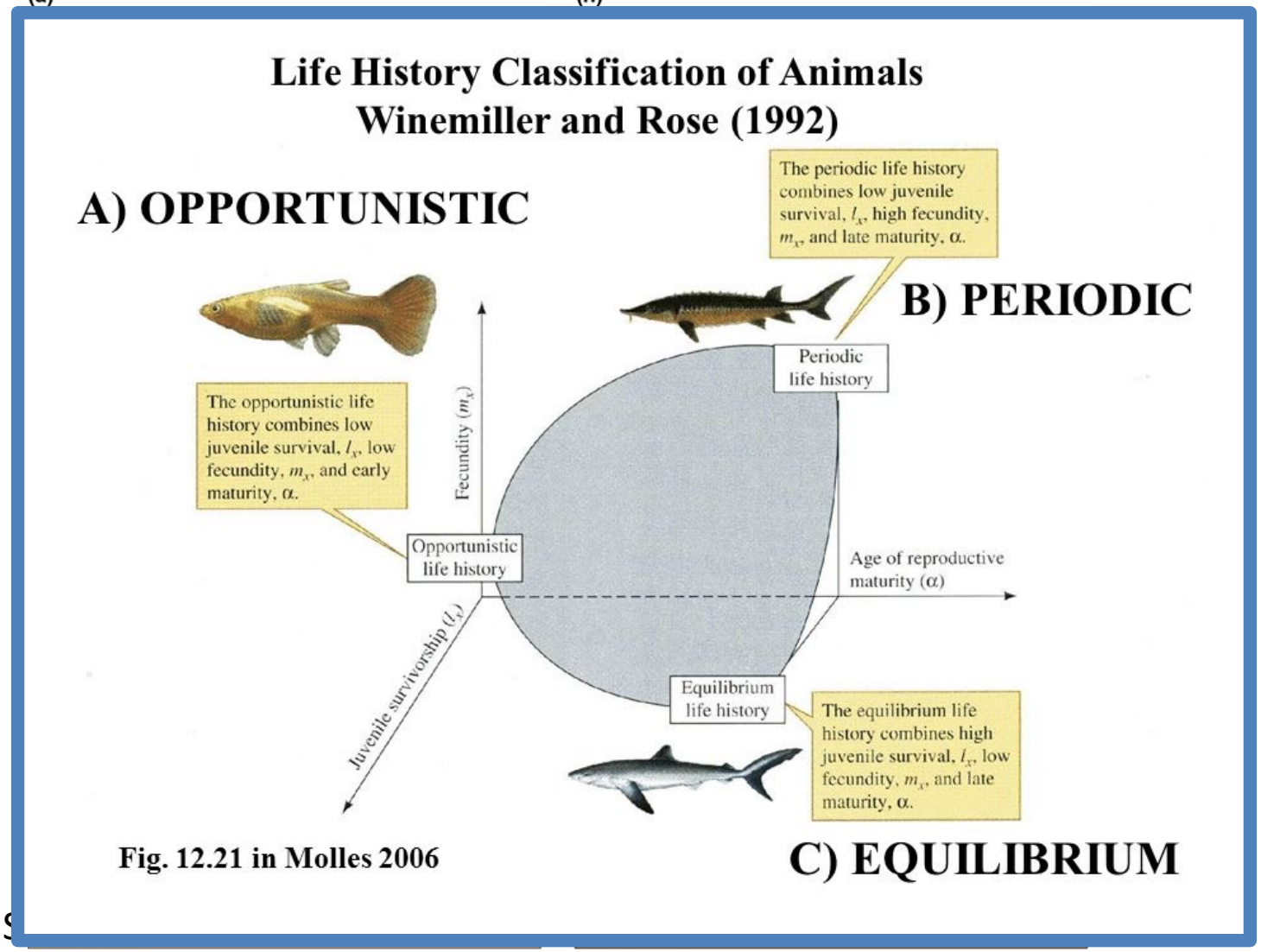
- Habitat suitability and capacity
  - What is habitat?
  - How does it relate to abundance?

- Biological organization
  - Life stages (recruitment)
  - Population
  - Multi-species and Food web

- Complex life cycles and strategies

# Foundational Concepts – Life Cycles

(a) (h)

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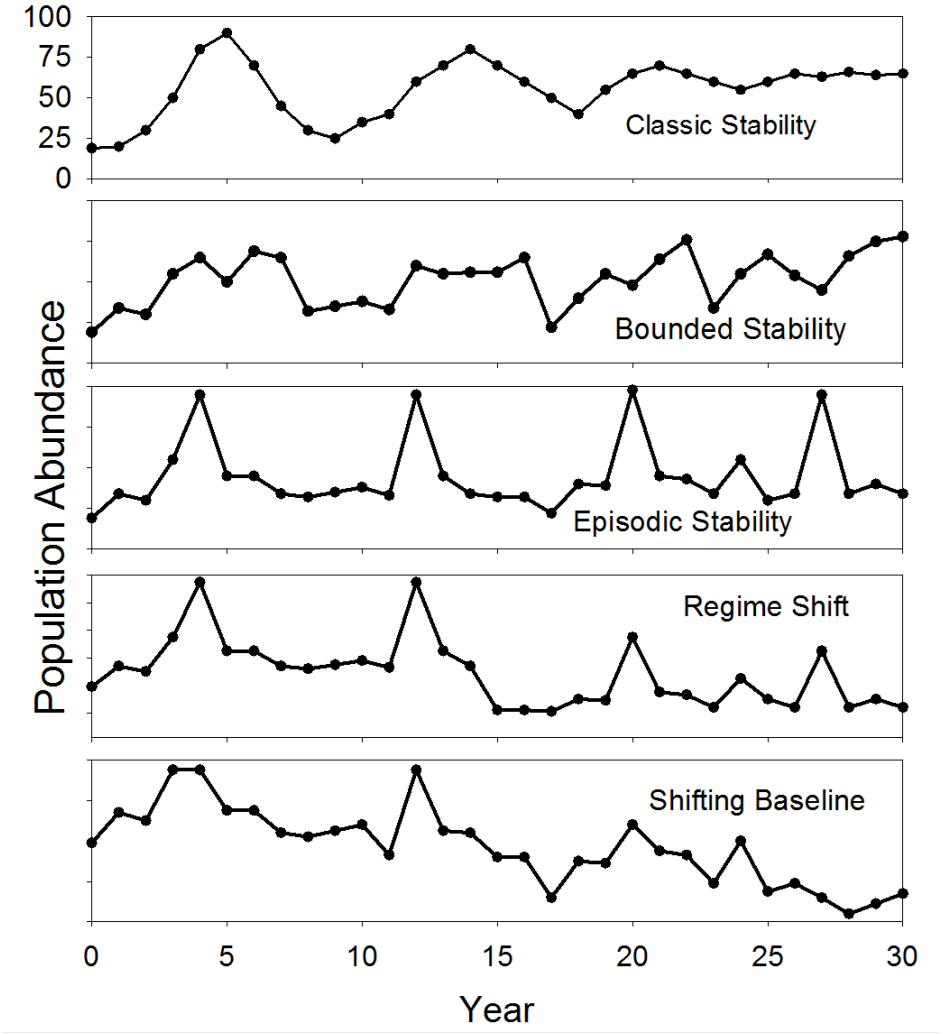
Potter et al. 2015

# Foundational Concepts: Examples

- Multiple Stressors and Influencing Factors
  - Ocean conditions
  - Fisheries management
  - Climate change
- Tradeoffs
  - Win-lose
  - Win-win
  - Lose-lose
- Nonequilibrium theory and baseline

# Foundational Concepts – Nonequilibrium Theory

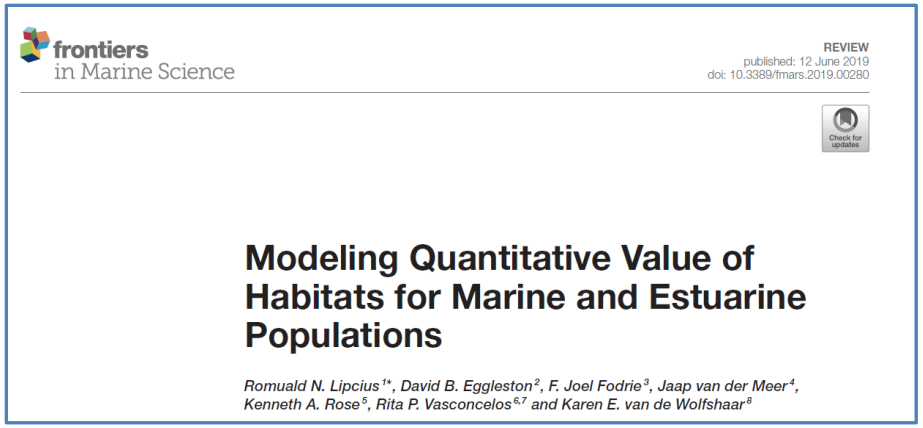


# Foundational Concepts: Examples

- Power – ability to truly distinguish differences
- Relative versus absolute predictions
- Explicit and implicit representations

# Foundational Concepts –Explicit vs Implicit Representations

- Turbidity not in model but can assess its effects
- Formulations
  - Implied in the model so can still answer questions
  - Bridge calculations
- Do not believe labels
- Aside: Define habitat



# Lessons Learned

Ecological Modelling 300 (2015) 12–29

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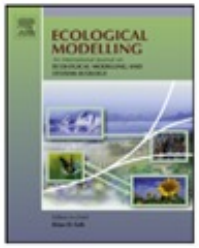


## Proposed best modeling practices for assessing the effects of ecosystem restoration on fish

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# Framework

- Uses the results of the watershed and estuary
  - Types, timing, locations, magnitude
  - WQ and habitat

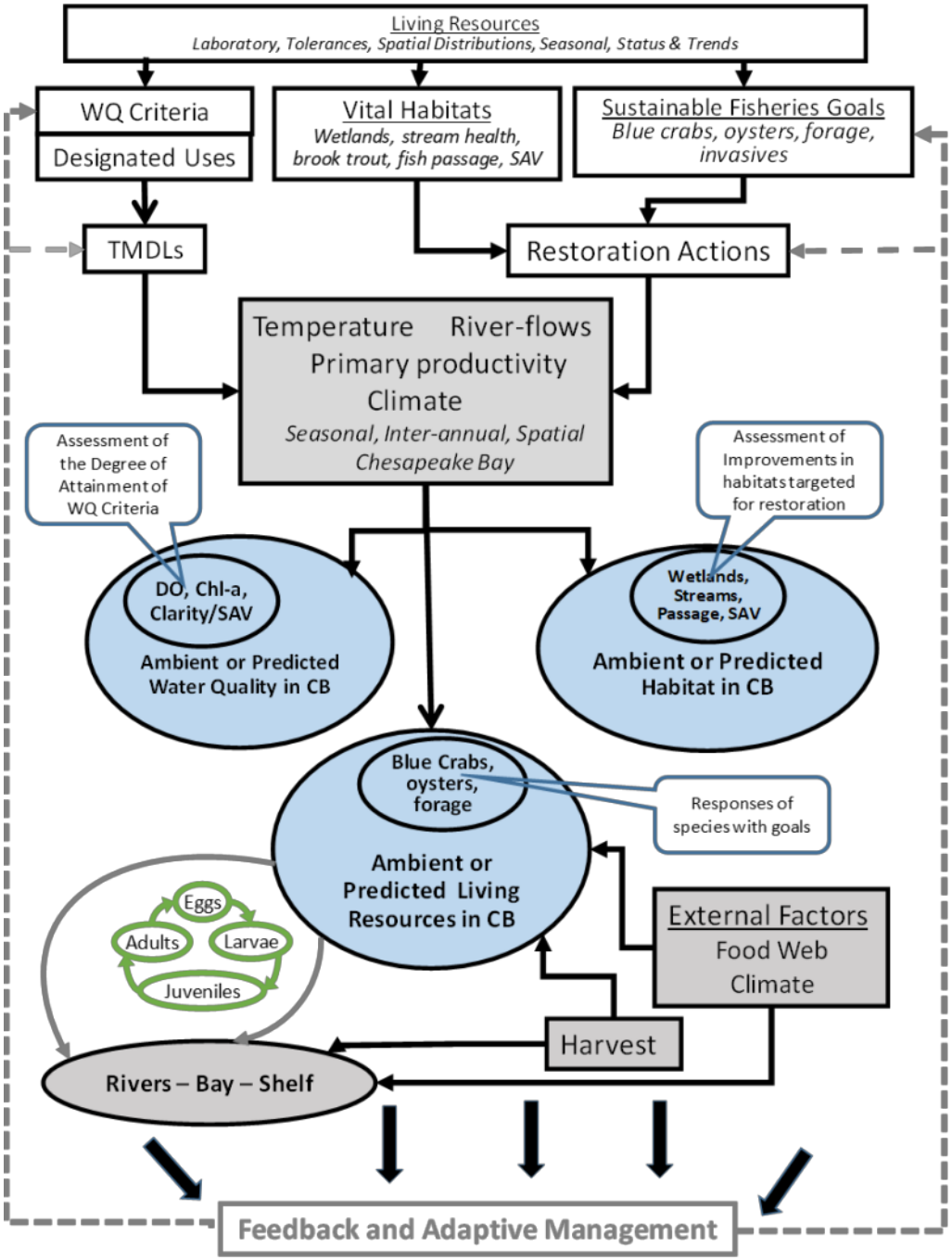
- Describes how to translate these changes into responses of living resources
  - Habitat suitability
  - Recruitment, population
  - Stages in subregions
  - Food web

# Framework

- Clearly show the linkages
  - Long-lived, complex life cycles
  - Affected by other factors than TMDL
- Realistic expectations
- Interpretative guide
  - Generally
  - Case-by-case basis
- Someone could actually implement the framework
  - Step-wise

# Living Resources: Framework

1. Selecting species
2. Available data
3. Response and explanatory variables
4. Biological, temporal, and spatial scales
5. Analytical approaches
6. Coordination and combining results


Living Resources
Laboratory, Tolerances, Spatial Distributions, Seasonal, Status & Trends
WQ Criteria
Designated Uses
Vital Habitats
Wetlands, stream health, brook trout, fish passage, SAV
Sustainable Fisheries Goals
Blue crabs, oysters, forage, invasives
TMDLs
Restoration Actions
Temperature River-flows
Primary productivity
Climate
Seasonal, Inter-annual, Spatial
Chesapeake Bay
Assessment of the Degree of Attainment of WQ Criteria
Assessment of Improvements in habitats targeted for restoration
DO, Chl-a, Clarity/SAV
Ambient or Predicted Water Quality in CB
Wetlands, Streams, Passage, SAV
Ambient or Predicted Habitat in CB
Blue Crabs, oysters, forage
Responses of species with goals
Ambient or Predicted Living Resources in CB
Eggs
Adults
Larvae
Juveniles
External Factors
Food Web
Climate
Harvest
Rivers – Bay – Shelf
Feedback and Adaptive Management

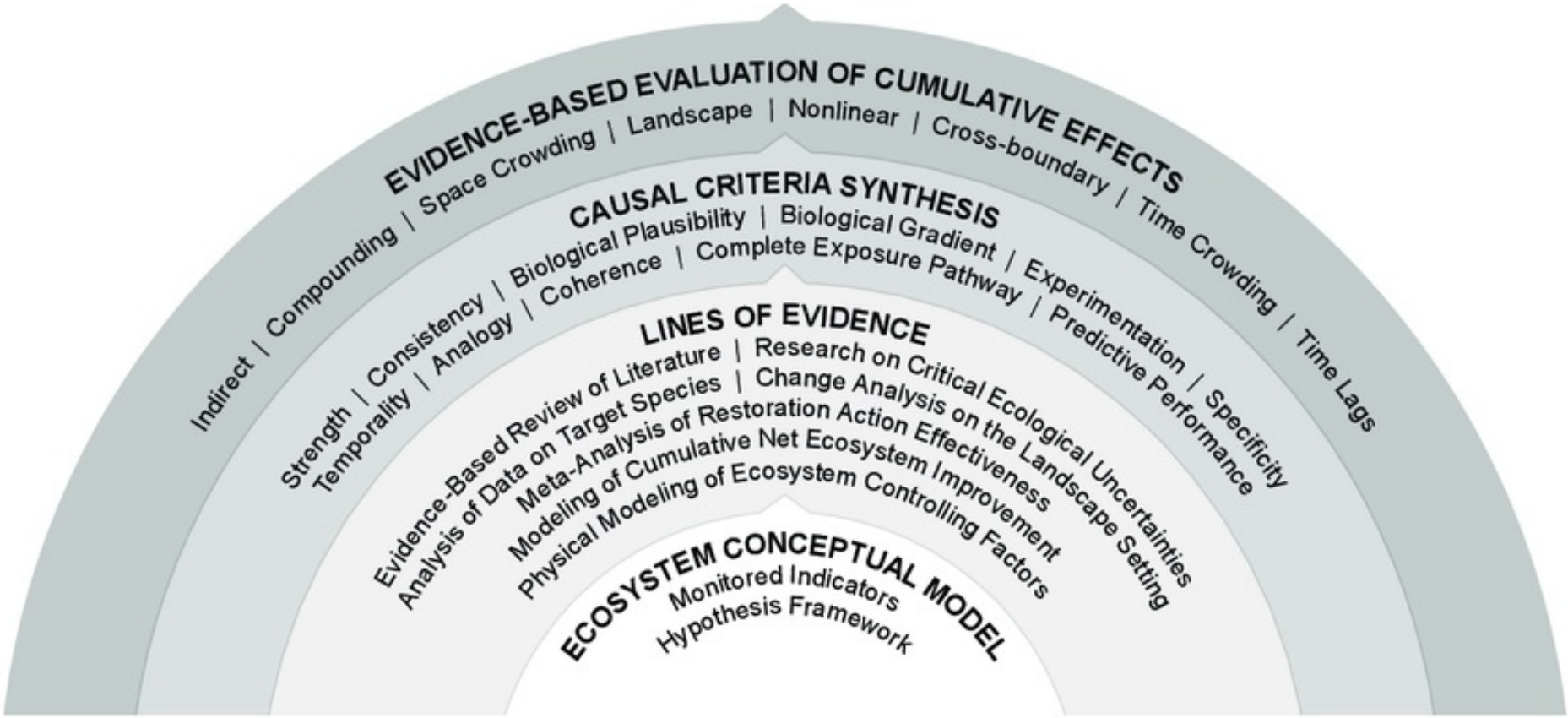



Figure 11. Example of a formal process for integrating and synthesizing information analysis results to assess the responses of the ecosystem to restoration. (from Diefenderfer et al. 2016).

# Final Comments

- We know the question(s)
- Incentive (demand?) and ingredients are available
  - "most studied estuary in the world"
  - Other restoration programs are assessing LR response
- Leverage existing analyses; identify new analyses
- Follow the framework, we can add analyses
  - "meta-methods"
  - "meta-results"

# Final Comments

- Living Resource Modeling & Assessment WG
- Assessment of LR responses and likely responses
  - “expectations”
- Use it to “optimize” WQ and habitat efforts
  - “inverse problem”
- Start with feasibility using low hanging fruit
  - “test the waters”