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

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2020 CHESAPEAKE COMMUNITY RESEARCH SYMPOSIUM

Chesapeake Bay Research and Management: Progress and Future Challenges

A VIRTUAL SYMPOSIUM

JUNE 8-10, 2020

The TMDL faces several challenges as we enter the third decade of the 21st century:

Nutrient Reductions

What magnitude of additional nutrient reductions, beyond those specified in the 2017 mid-point assessment, will be needed to compensate for impacts of climate change and population growth in 2025 and beyond?

Effort

What is the current status of efforts to account for these impacts and what new observations and models are needed to improve future predictions?

Living Resources

How will we look beyond the TMDL to restoration of living resources?

Management

What is the state of the art in our ability to predict how management of nutrient and sediment loads will impact higher trophic levels in the Bay and its watershed?

Observation & Modeling

What additional observations and models are needed?

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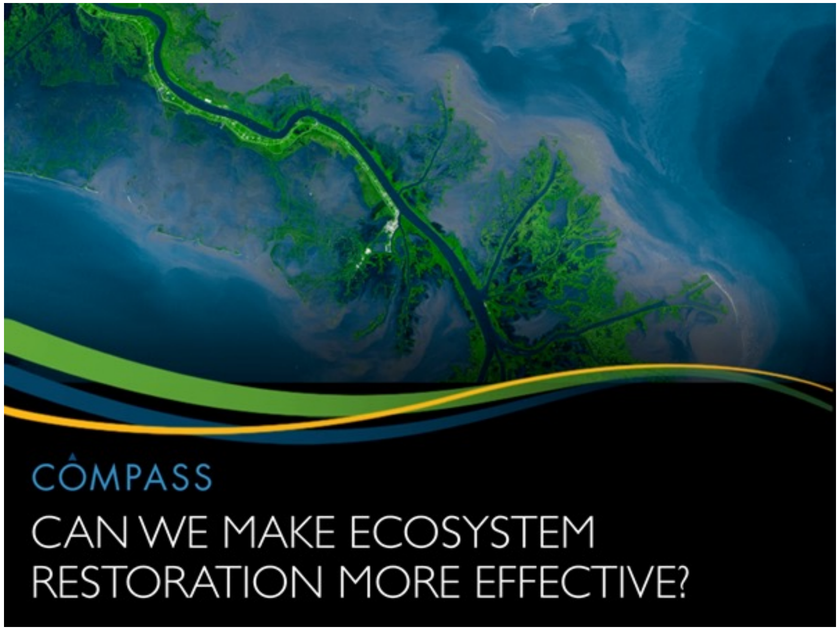
Context

- 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

Question: Spending billions so why are some unhappy



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Fish were so abundant in the bay when John Smith arrived in 1607 that his crew tried to scoop them into a frying pan and the men could walk on enormous oyster reefs that breached the surface.

Now, wild oyster populations are about 1 percent of their historic numbers, crab populations have reached historic lows…

Under the 2011 cleanup plan, the bay, a major source of recreation, tourism and commerce for Maryland and Virginia, was returning to life. “POPULATIONS OF SPECIES THAT WERE IN RAPID DECLINE ARE NOW COMING BACK AT INCREDIBLE RATES: BLUE CRABS, CLAMS, OYSTERS AND MANY OTHERS ARE STARTING TO FLOURISH,” Herring [VA AG] said. “THE WATERS ARE HEALTHIER TODAY THAN THEY HAVE BEEN IN DECADES. BUT WE STILL HAVE A LOT OF WORK TO DO BEFORE WE CAN DECLARE VICTORY.”

The Washington Post

May 18, 2020 - Darryl Fears and Brady Dennis

Two states, D.C. plan to sue EPA for failing to enforce Chesapeake Bay cleanup plan

Nutrient reductions → Effort → Living Resources → Management → Obs & modeling

Ike Irby, Plenary Talk

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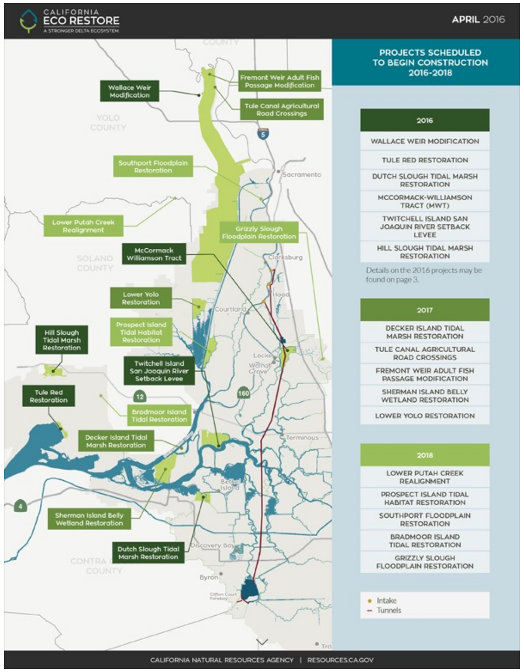
Feasibility – Chesapeake Bay

- 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?

Chesapeake Bay is not alone!



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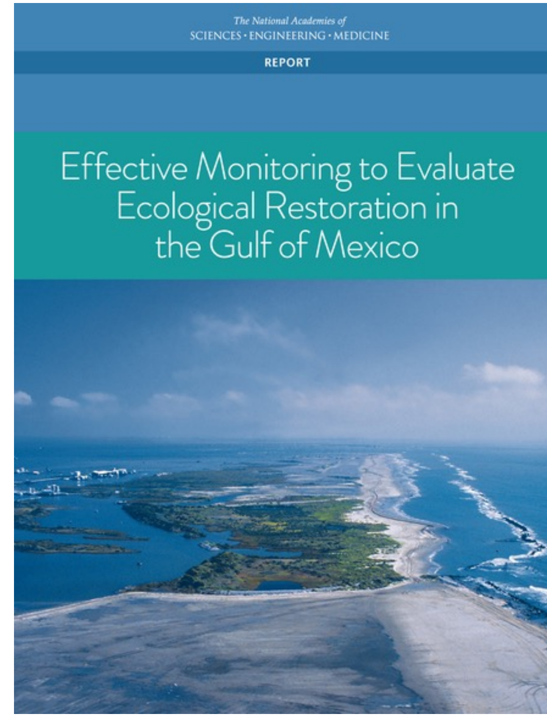

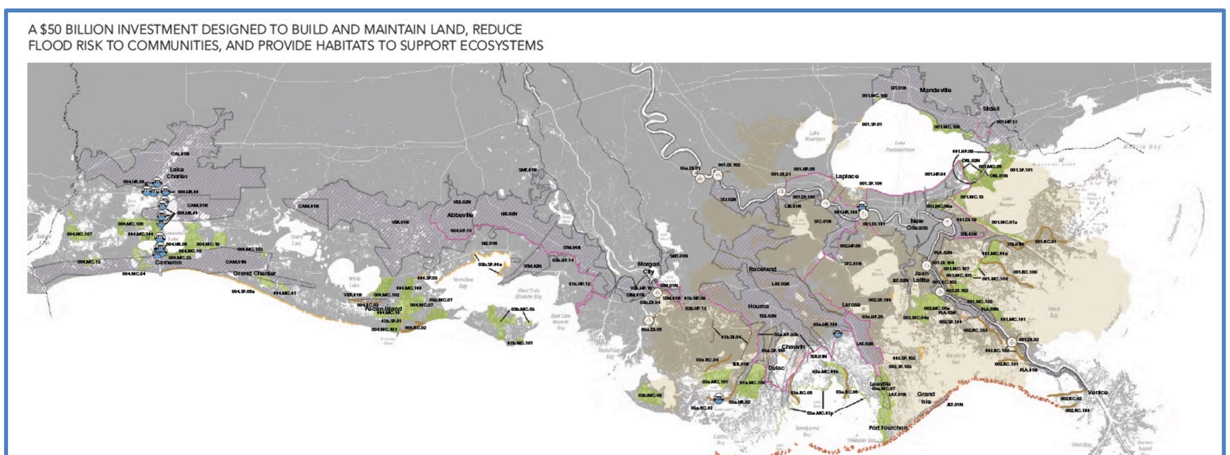

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Evaluation of the Predictive Ecological Model for the Edwards Aquifer Habitat Conservation Plan: An Interim Report as Part of Phase 2

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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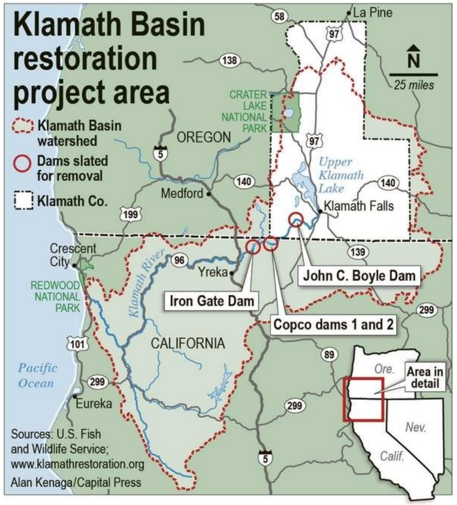

Emergent Patterns

- Tightening resources (“bang for 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 link to living resources (“fish”)

Chesapeake Bay

Good News	Bad News
• You are not alone • We know how to do this • Chesapeake is well studied • Long history of monitoring, modeling, and process studies	• A few have gone sour • Answers may not satisfying; false negatives • Major effort • Other management occurring to promote stability

ERDC/EL TR-12-18

US Army Corps

...ntal Laboratory

Ecological Modelling 300 (2015) 12–29

Contents lists available at ScienceDirect

Ecological Modelling

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

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Environmental Modelling & Software

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...n Paper[1]

...otection and Restoration Authority

...ton Rouge, LA 70804 | coastal@la.gov | www.coastal.la.gov

...ter Plan

...r 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

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[i], J. Mysiak[k], J. Reichl[l], R. Seppelt[m], T. Wagener[n], and P. Whitfield[o]

FAO

STAC

- Scientific and Technical Advisory Committee
- Living Resources is one part of a broader effort
- Watershed → Estuary → Living resources

Very Different Situation to "WQ"

- Questions change
- Not specific targets for living resources
- Not an established set of data or models
- Greater uncertainties

Very Different Situation to “WQ”

- Many critters move
- Affected by many factors in a complex life cycle
- Responses are on longer time scales
- Ability to isolate responses to actions decreases

Framework

- Uses the results of the gap analysis for WQ
  - 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 TMDLS
- Realistic expectations
- Interpretative guide
  - Generally
  - Case-by-case basis
- Someone could actually implement the framework
  - Step-wise

Living Resources: Framework

1. <u>Foundational concepts</u>
2. Available and needed tools
3. <u>Logical workflow</u>
4. Shovel-ready examples
5. Likely types of results and their interpretation
6. Implementation
7. Path forward

- Foundational concepts – these are the theories and ideas from ecology and ecological modeling that need to be considered in the design of an analysis scheme and provide the theoretical and conceptual basis of the steps in the scheme.

- Available and needed tools – these are the "pieces" such as statistical modeling (local effects and long-term spatial and temporal trends), correlative approaches, state-space, and simulation models for recruitment, population, multi-species, and food web.

- Logical workflow – a series of steps (flowchart) to show the logic and rationale (transparency) for the analyses of monitoring data and development and use of the models.

Note: must link to watershed and estuary groups outputs

- Shovel-ready examples – combinations of species and management actions that have sufficient data and models (“data-rich”) available to perform analyses to illustrate key steps in the workflow.

- Likely types of results and their interpretation – preview of the types of results expected using the shovel-ready (Chesapeake Bay) examples and examples from other systems and general guidelines in interpreting anticipated results.

- Implementation— preparatory activities and how the proposed scheme can be implemented (personnel, team science) in phases.

Foundational Concepts: Examples

- Vital rates (growth, mortality, reproduction, and movement)
- Habitat suitability and capacity – what is habitat? How does it relate to abundance?
- Temporal and spatial scales
- Biological organization – life stages (recruitment), population, multi-species, food web

Foundational Concepts: Examples

- Multiple Stressors and Influencing Factors – including climate change
- Tradeoffs (win-lose), Win-win, and Lose-lose
- Population and Food web bottlenecks
- Non-linear relationships and responses

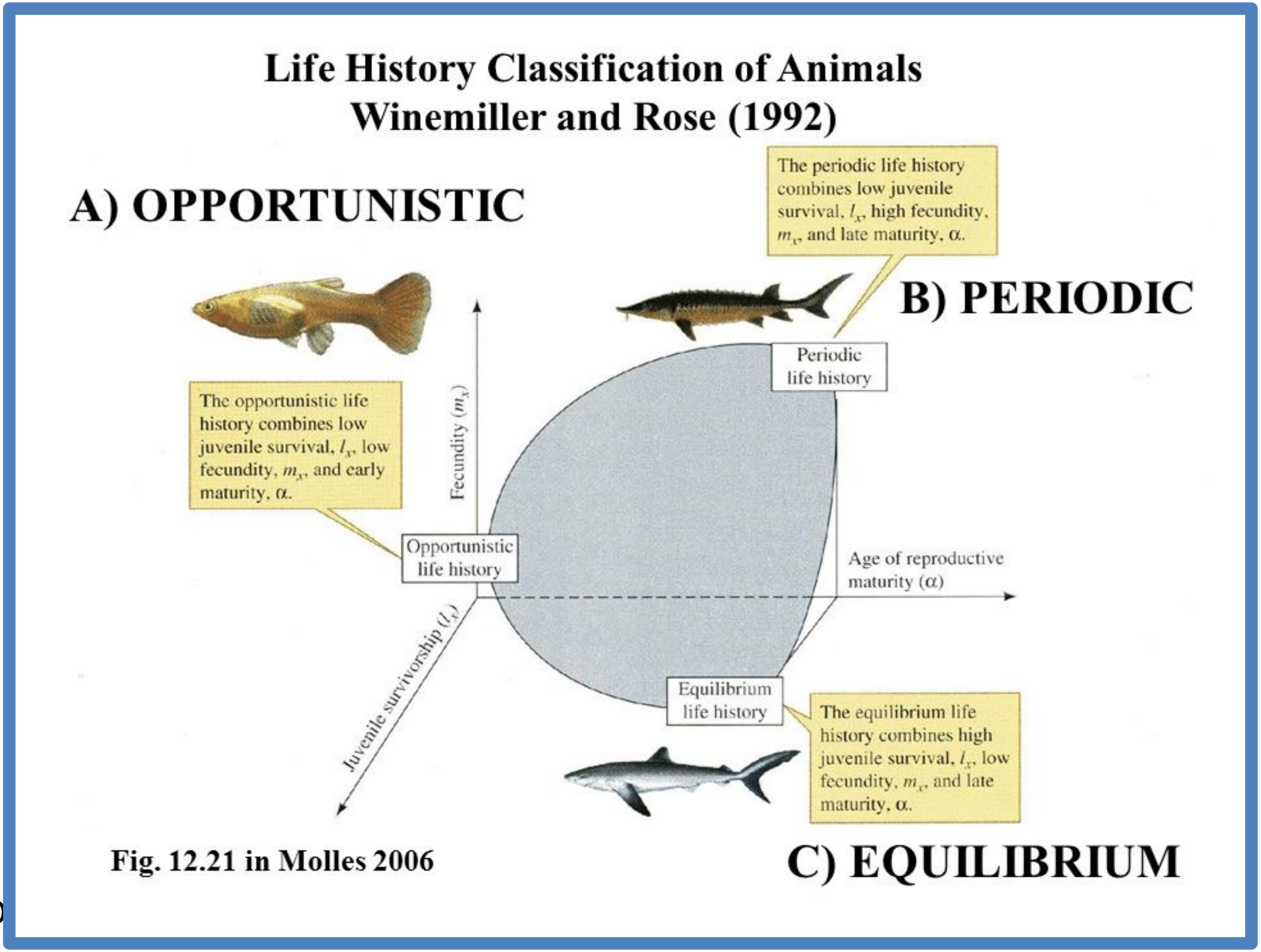
Foundational Concepts: Examples

- Production versus attraction
- Managing expectations and some caveats
- Signal to noise, managed populations
- Calibration and validation
- Power – ability to truly distinguish differences

Foundational Concepts: Examples

- Explicit and implicit representations
- Relative versus absolute predictions
- Projections, predictions, forecasts, scenarios
- Conceptual models like California delta example
- Analysis approaches: comparative, limiting factor, correlation, semi-empirical, and mechanistic

Foundational Concepts – Life Cycles



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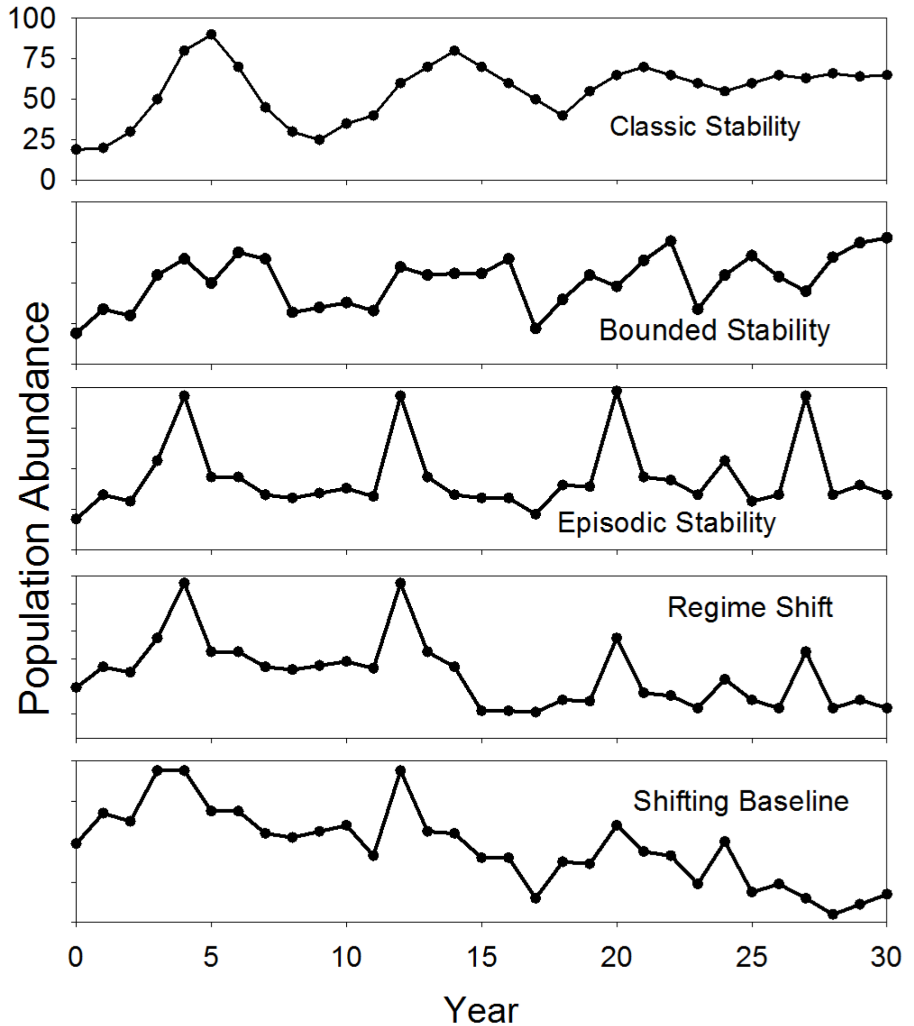
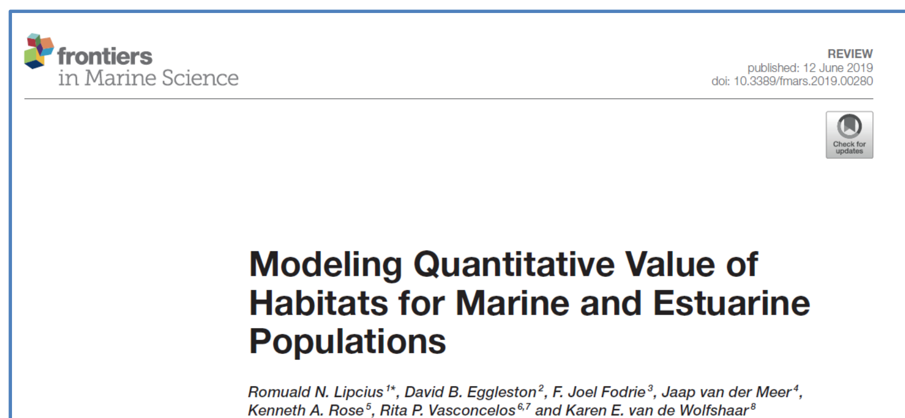
Foundational Concepts – Nonequilibrium Theory



Foundational Concepts –Explicit vs Implicit Representations

- 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


frontiers in Marine Science
REVIEW
published: 12 June 2019
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Check for updates

Modeling Quantitative Value of Habitats for Marine and Estuarine Populations

Romuald N. Lipcius[1], David B. Eggleston[2], F. Joel Fodrie[3], Jaap van der Meer[4], Kenneth A. Rose[5], Rita P. Vasconcelos[6,7] and Karen E. van de Wolfshaar[8]*

Technical & Non-technical Issues: Lessons Learned

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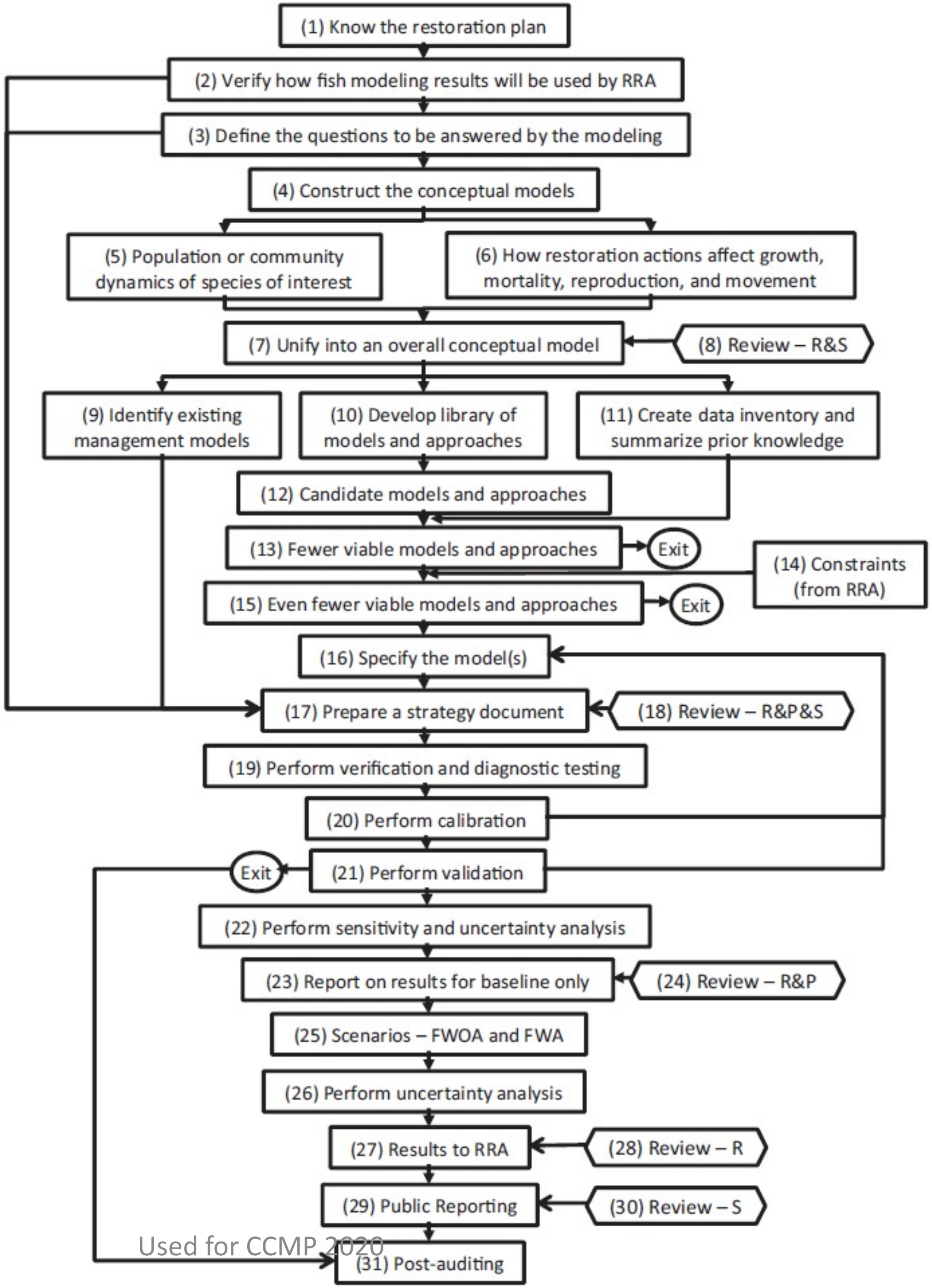
Workflow



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Details about the steps in the best practices scheme for the development and application of fish models for evaluation of large-scale restoration plans. The steps are also shown in Fig. 1.

Step	Description
(1) Know the restoration plan (Concepts 1 and 4)	Understand the details of the various proposed restoration actions and the past and current status of key species *(Concepts 1 and 4)* and general ecosystem health and issues. Often overlooked, it is also important to know the history of the restoration efforts and the historical development that lead to the current plan under evaluation. Be familiar with the various stakeholder groups, regulatory and resource agencies (RRA), permitting process, and any legal issues (e.g., Endangered Species Act; Clean Water Act).
(2) Verify how fish modeling results will be used by the RRA (Concept 5)	Modeling results can be used in a variety of ways and at a range of levels of specificity. Results can be limited to informing decision-making about general trends and ecosystem health, but more likely, the modeling results will be viewed as highly precise and accurate predictions of future conditions. Clarity is needed in whether the modeling results are to be viewed as forecasts of absolute abundances and biomass or as predictions of relative changes (e.g., between without and with the restoration actions) *(Concept 5)*. Also important is clarifying to what degree mechanistic understanding of the model predictions is needed. This will affect how easily and directly empirical relationships (e.g., regression results) are used in the modeling.
(3) Define the questions to be answered by the modeling (Concepts 2, 3, and 11)	Defining the questions is a critical step that ensures the modeling results that will be reported months to years from their initial generation will be relevant *(Concept 3)* and will meet people's expectations. Often, modeling is considered unsuccessful because of the lack of specification of the questions to be answered, coupled with people having overly high expectations of what the modeling can do. Explaining the certainties and uncertainties is vital *(Concept 2)*. The more specific the questions, the more likely a model can be configured that will answer that particular question. Trying to have a single model answer many questions is another way the power of the modeling gets diluted. Sometimes the appropriate approach is to develop different models to address different subsets of the overarching questions *(Concept 11)*. A hypothetical illustration of a poorly and well-stated questions would be: (1) What are the effects of wetland creation on shrimp, versus (2) How does the wetland-related habitat created by projects A, B, and C (i.e., acreages, land-water configuration, inundation frequency) in region X combine to affect annual shrimp summertime growth and abundance in September over the next 20 years.
(4)–(6) Create the conceptual models (Concepts 1, 5, 6, 7, and 12)	Conceptual models will provide an important communication tool for explaining how the model works. Most everyone (except the modelers) will not understand the heavy mathematics and the computer codes that are actually the model. The conceptual models help in explaining the models. Simply showing a box and arrow diagram is not sufficient. Conceptual models require specification of what factors are being considered important (and unimportant by omission) and the cause and effect relationships. Three separate conceptual models should be specified: an overview model of the major food web dynamics in the system *(Concept 12)*, a second model for the factors affecting the population or community dynamics of species of focus, and a third model for how the various restoration actions affect the vital rates of growth, reproduction, mortality, and movement of the species of focus *(Concepts 1, 5, 7)*. The overview conceptual model allows the other two models to be viewed in the broader context of the food web and ecosystem. The second model is about what is needed for realistic simulation of the population or community of interest, and the third model is about what is needed for realistic simulation of the effects of the restoration action. It is important to keep these three conceptual models separate so that later steps of model development can be traced back to either being motivated by needing to add food web complexity, needing to better simulate the population dynamics, or needed to better simulate the restoration actions. The conceptual models should define the system in terms of the boundaries and the inputs to the model, and describe the levels of aggregation across time (yearly, monthly, daily) and space (domain, resolution) for the system *(Concept 5)*. The overview model can be less specific than the other two models, as there will not be a numerical model that matches the overview conceptual model. The models of the populations of interest and restoration action effects should be very specific and detailed and will change as the numerical model is developed. These conceptual models involve specifying the key species and their life cycles *(Concept 1)*, and the key factors (e.g., temperature, predation) that affect the fish (life stage) vital rates and the effects of the restoration actions on the vital rates (i.e., the cause-effect relationships) *(Concept 5)*. Care must be taken to describe whether representation of these environmental and biological factors will be explicit or implicit in the model *(Concept 6)*. Also important is defining the scales for modeling environmental and biological processes including the

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Organism	Listed in Outcomes (O) or Management Plan (P)	Permanent (P) / Migratory (M)	Life cycle sensitivity to WQ (H, M, L)
Adult Female Blue Crab	O	P	H
Male blue crab	P	P	H
Black Duck	O	M	M/L
Brook Trout	O	P	H
Migratory Fish Populations (alewife, blueback herring, American shad, hickory shad, American eel	O	M	H
Oysters	O	P	H
Forage Species *	P		
SAV	O		
Forest Buffers	O		
Wetland Habitats	O		
Urban Trees	O		

Key Forage Groups	Additional Important Forage Groups (alphabetical)
Bay Anchovy	American Shad & River Herrings
Polychaetes	Atlantic Rock Crab
Mysids	Atlantic Silverside
Amphipods and Isopods	Blackcheek Tonguefish
Mantis Shrimp	Blue Crab
Spot	Flounders
Weakfish	Gizzard Shad
Sand Shrimp	Kingfish
Atlantic Croaker	Lady Crab
Razor Clams	Macoma Clams
Atlantic Menhaden	Mud Crab
	Mummichog & Killifishes
	Small Bivalves*
*other than Macoma spp. or Razor clams	

Going Forward

- We know the question(s) pretty well
- Incentive (demand?) and ingredients are available
- Leverage existing analyses; identify new analyses
  - CA Delta, Everglades, Coastal LA, NCEAS, NAS, Columbia River
- Follow the framework, we can add analyses:
  - “meta-methods”
  - “meta-results”
- Rigorous and robust assessment
- We present this in early stage and welcome comments, criticisms, and suggestions (krose@umces.edu)