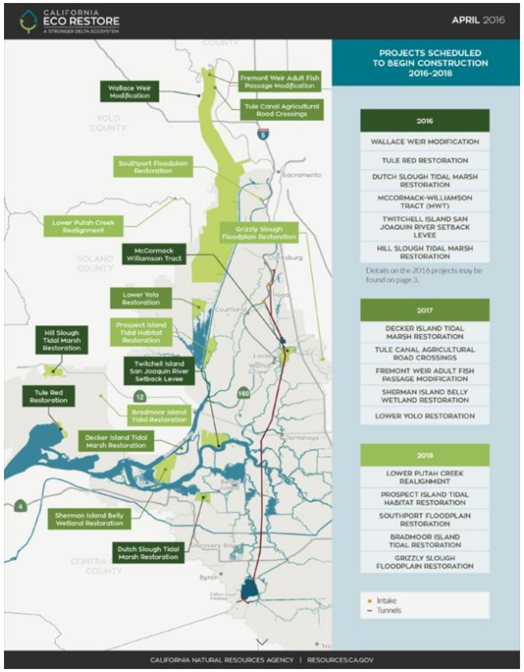
Assessing Ecosystem Restoration Effects on Fish and Shellfish

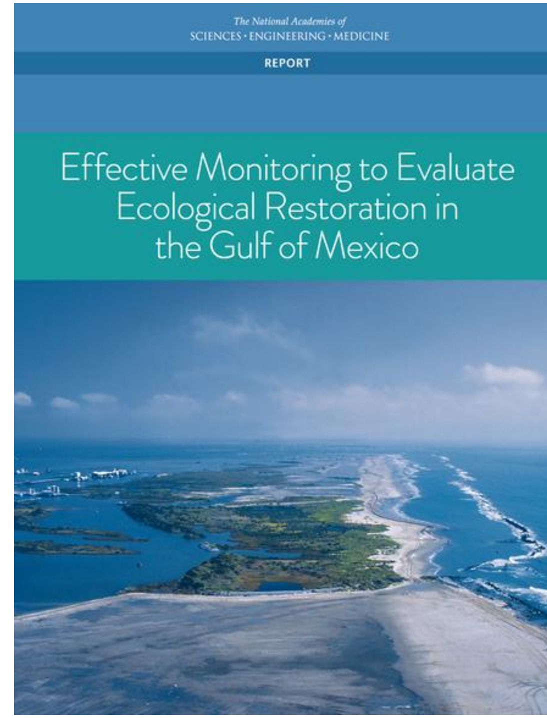
Necessary, Messy, Doable

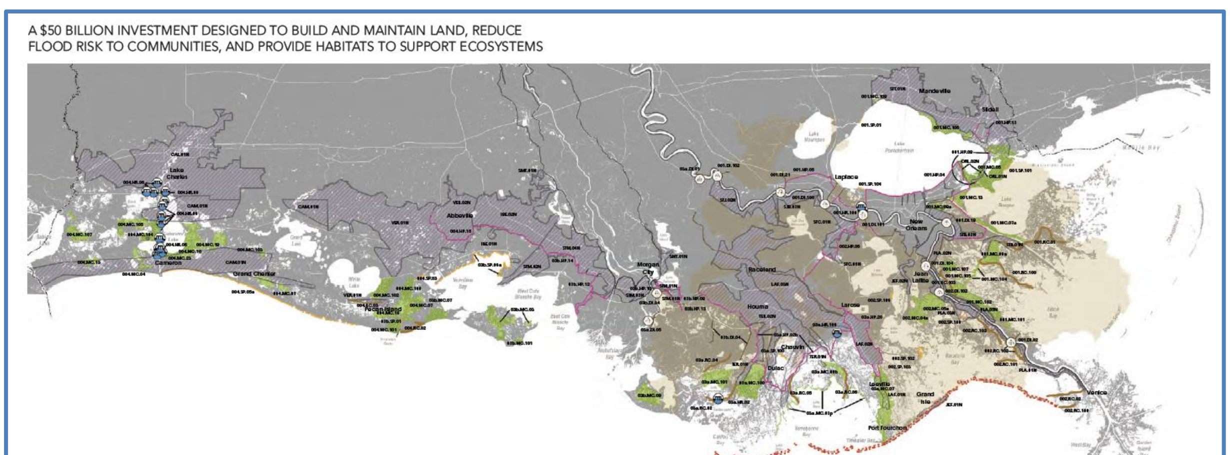
Kenneth Rose
University of Maryland Center for Environmental Science
Horn Point Laboratory

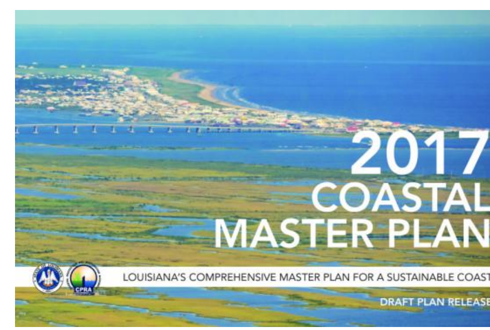
University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Chesapeake Bay is not alone!









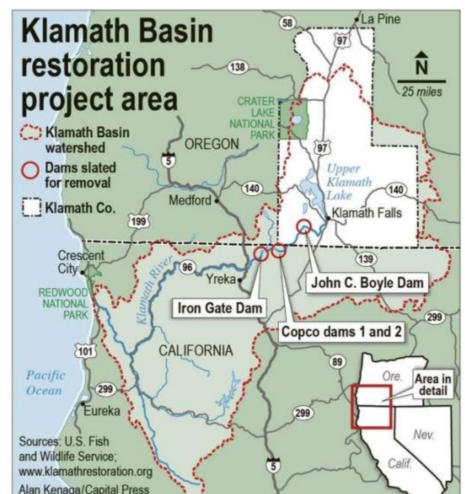
Evaluation of the Predictive Ecological Model for the Edwards Aquifer Habitat Conservation Plan: An Interim Report as Part of Phase 2

Committee to Review the Edwards Aquifer Habitat Conservation Plan

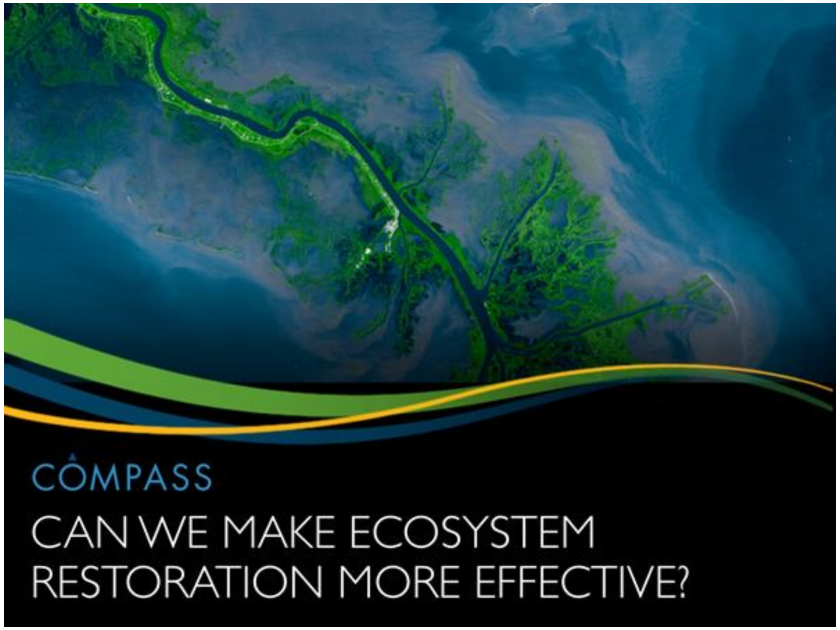
Water Science and Technology Board

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

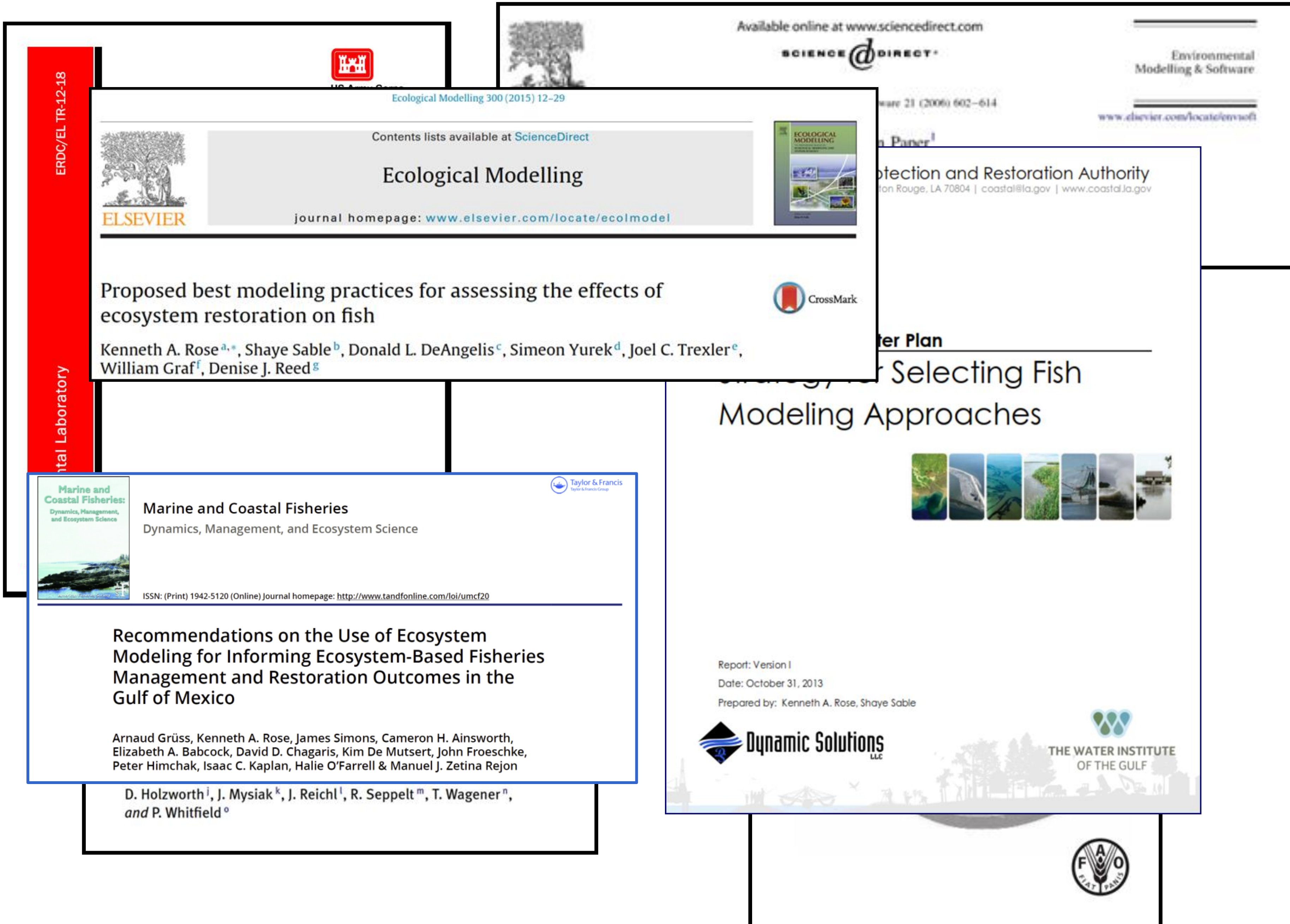
- Increasing demands for linkage to living resources (“fish”)
  - Title: State of the Science → Gap Analysis → Assessment?

Chesapeake Bay

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

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)


ERDC/EL TR-12-18
tal Laboratory
Ecological Modelling 300 (2015) 12–29
Contents lists available at ScienceDirect
Ecological Modelling
journal homepage: www.elsevier.com/locate/ecolmodel
ELSEVIER
Proposed best modeling practices for assessing the effects of ecosystem restoration on fish
Kenneth A. Rose, Shaye Sable, Donald L. DeAngelis, Simeon Yurek, Joel C. Trexler, William Graf, Denise J. Reed
CrossMark
Available online at www.sciencedirect.com
SCIENCE DIRECT
Environmental Modelling & Software
www.elsevier.com/locate/envsoft
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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
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, 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

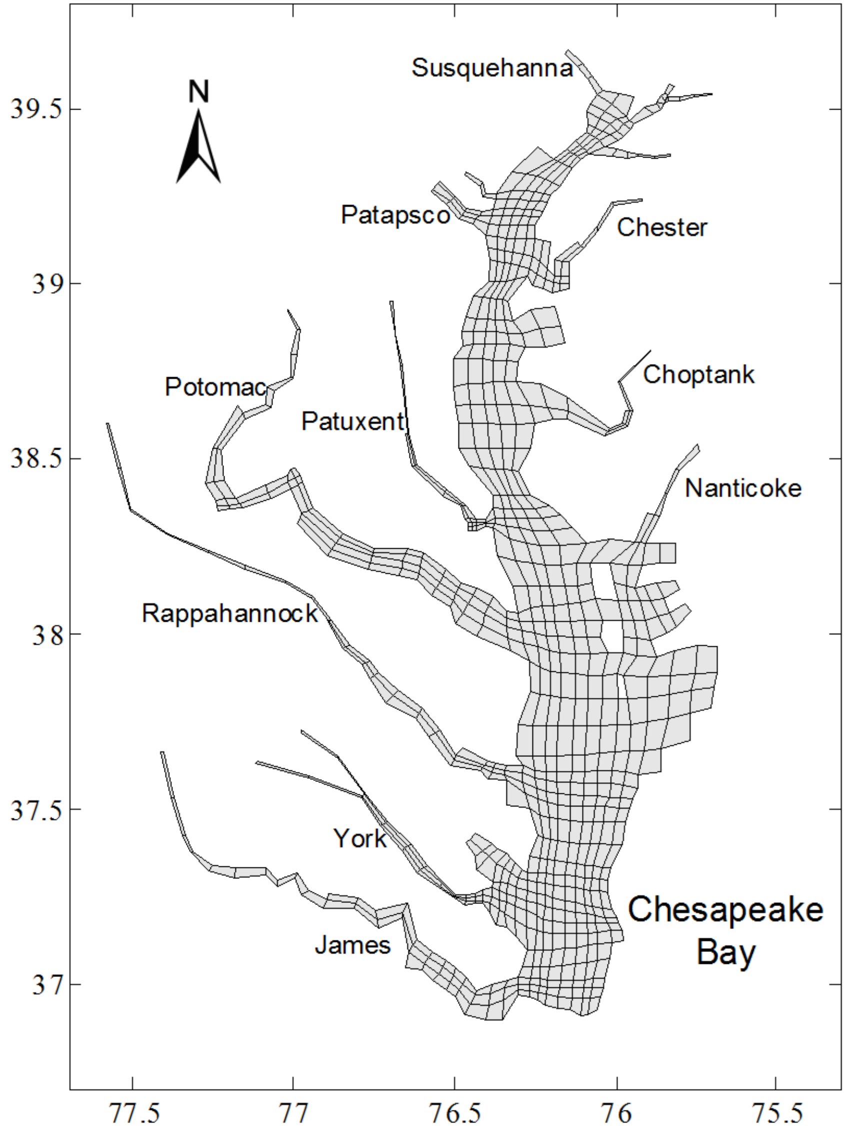
3. Atlantis model
   More complex

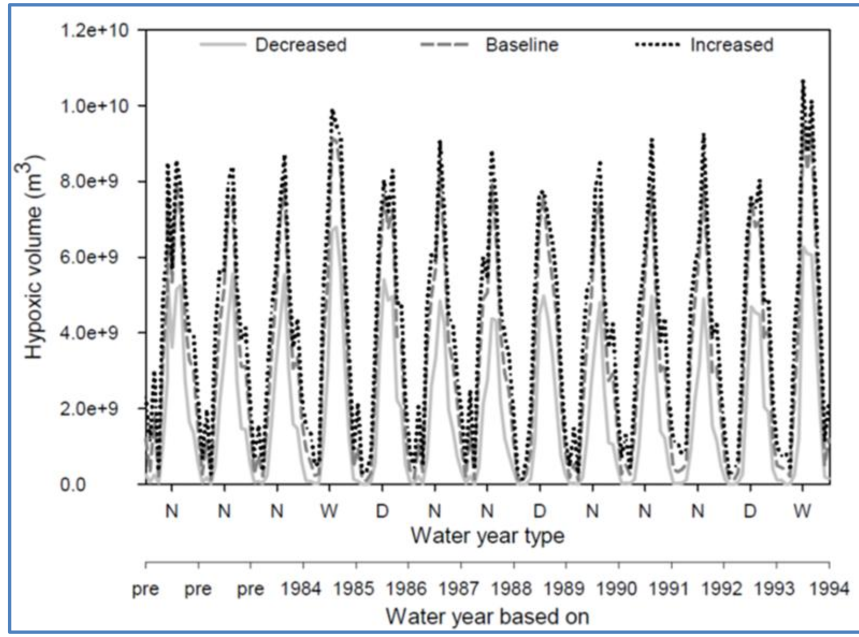
4. Bay anchovy larvae
   Much simpler – small part of life cycle

5. Habitat analyses
   Very simple

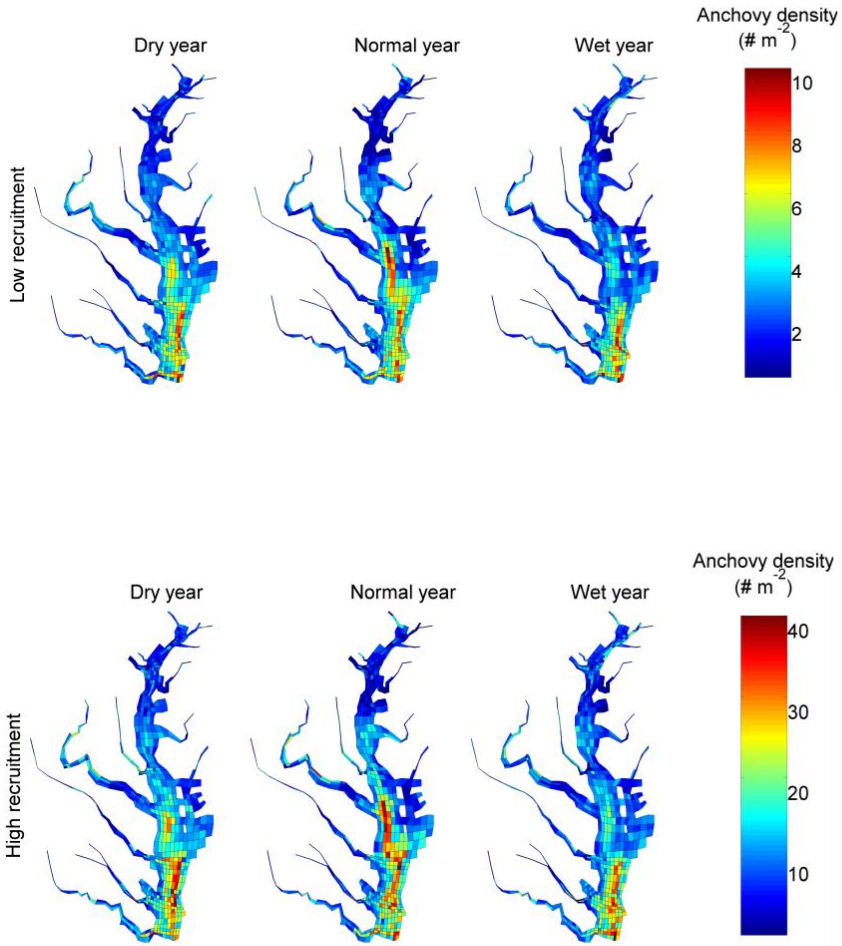
All involve linking water quality to fish and using coupled modeling

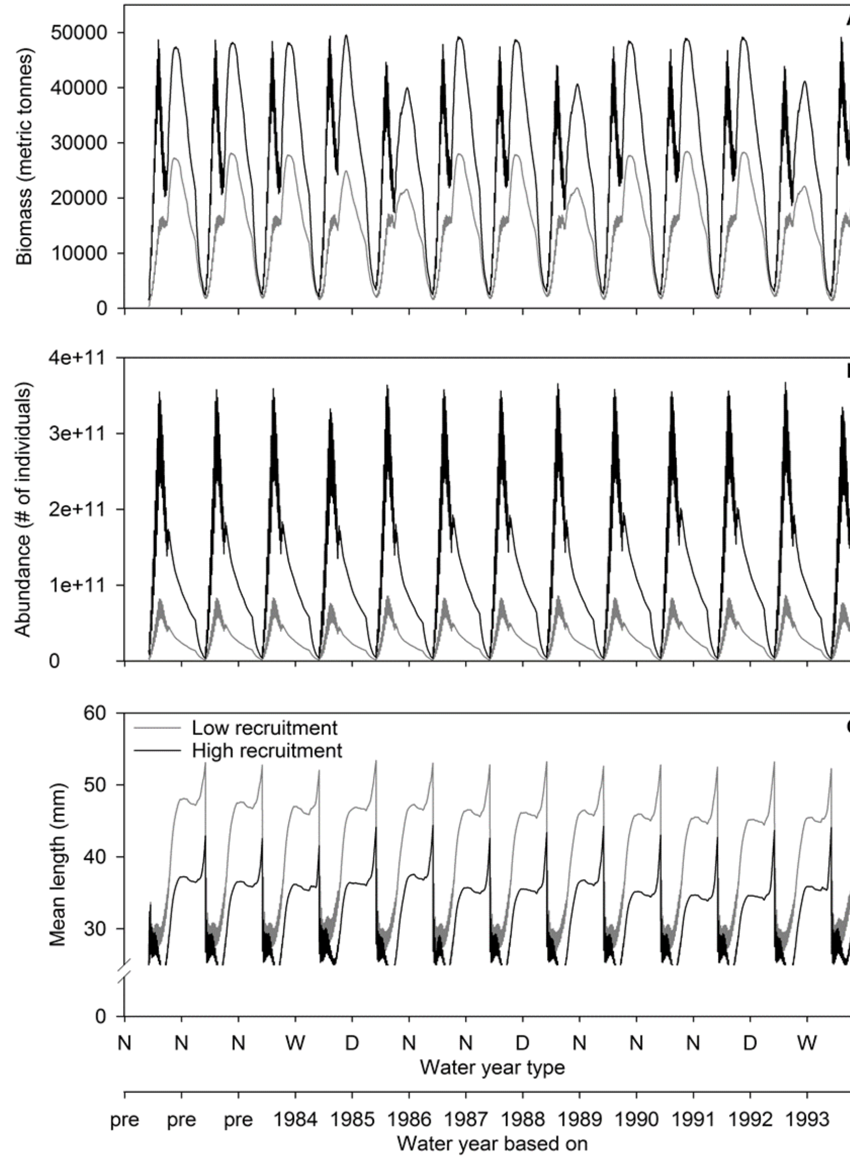
1. Bay Anchovy in Chesapeake Bay

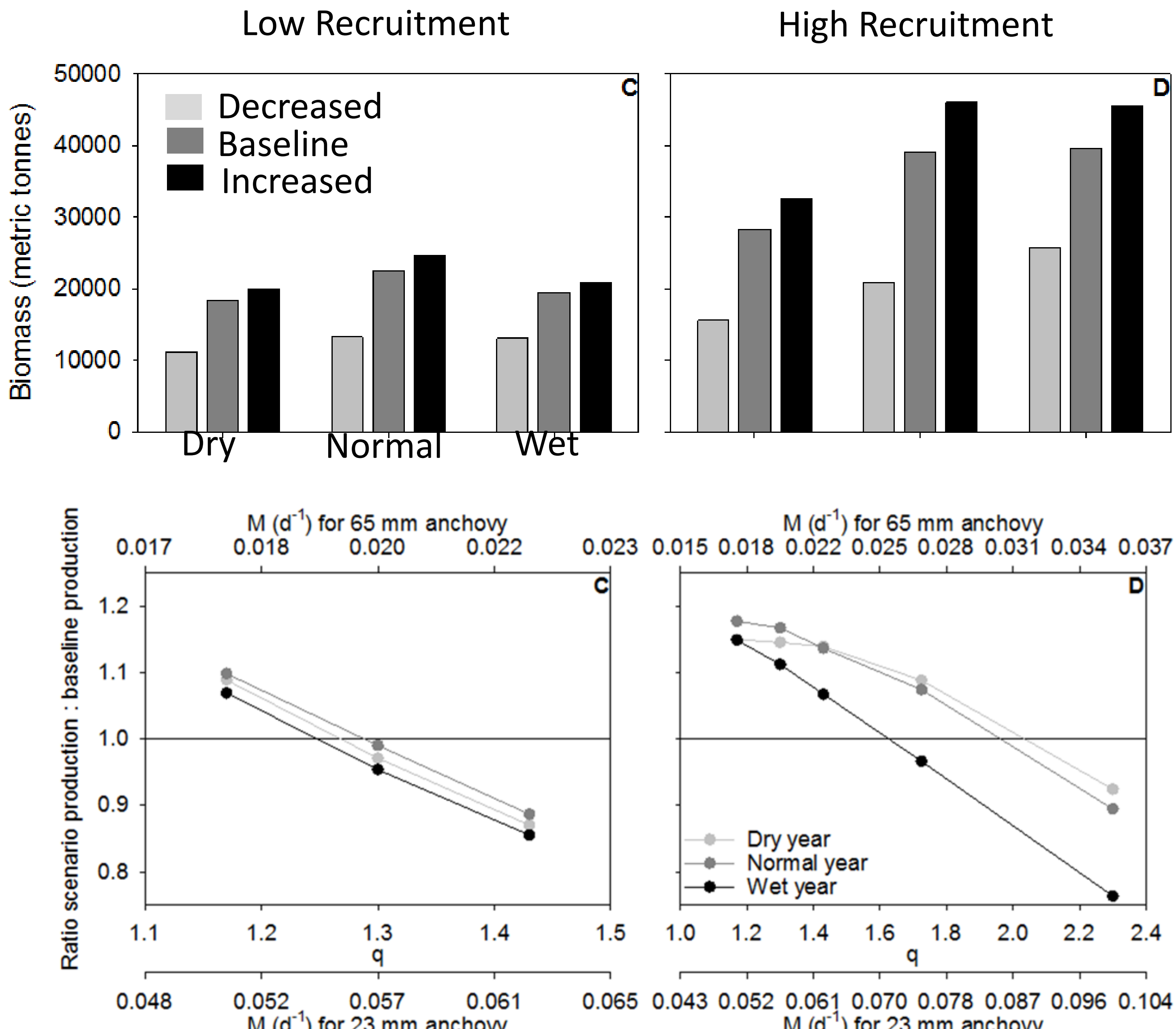




Adamack, A.A., K.A. Rose, and C. Cerco. 2017. Simulating the effects of hypoxia on bay anchovy in the Chesapeake Bay using coupled hydrodynamic, water quality, and individual-based fish models. In: *Modeling Coastal Hypoxia*, Springer, New York, NY

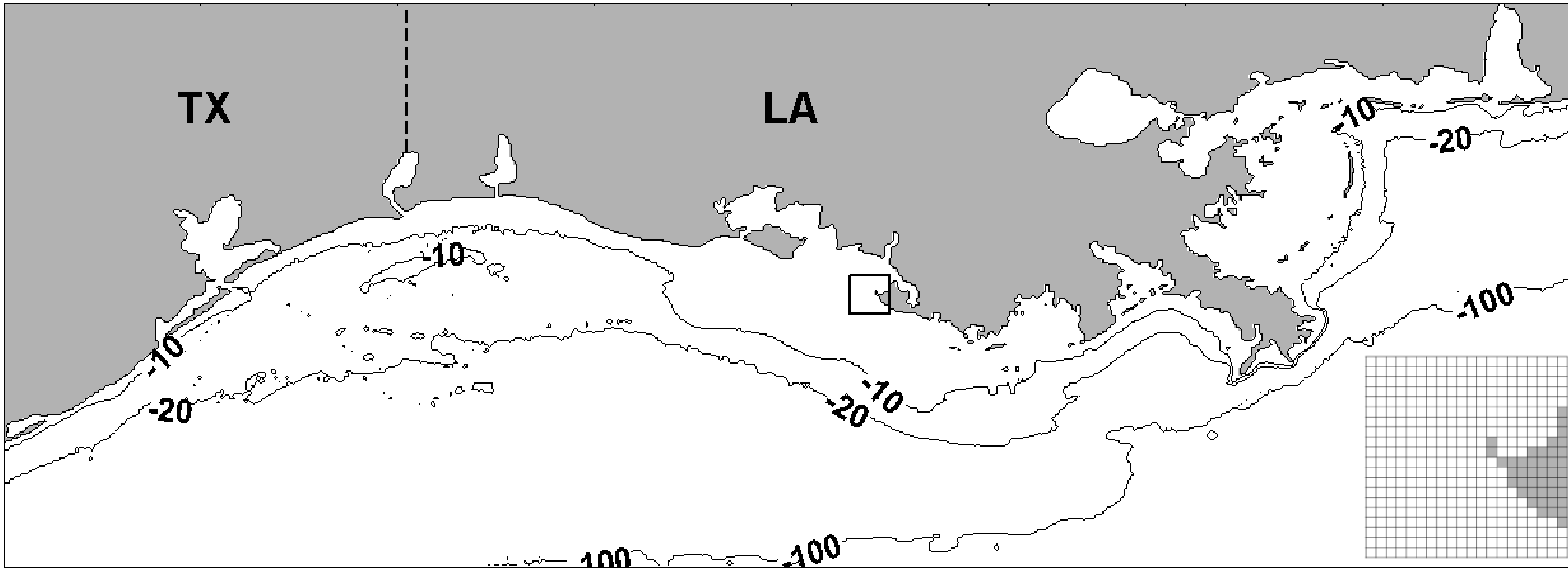

Anchovy density
(# m^{-2})
Dry year
Normal year
Wet year
Low recruitment
10
8
6
4
2
Anchovy density
(# m^{-2})
Dry year
Normal year
Wet year
High recruitment
40
30
20
10


A
Biomass (metric tonnes)
50000
40000
30000
20000
10000
0
B
Abundance (# of individuals)
4e+11
3e+11
2e+11
1e+11
0
C
Low recruitment
High recruitment
Mean length (mm)
60
50
40
30
0
N N N W D N N D N N N D W
Water year type
pre pre pre 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993
Water year based on



Low Recruitment
High Recruitment
Biomass (metric tonnes)
50000
40000
30000
20000
10000
0
C
D
Decreased
Baseline
Increased
Dry
Normal
Wet
M (d-1) for 65 mm anchovy
0.017
0.018
0.020
0.022
0.023
0.015
0.018
0.022
0.025
0.028
0.031
0.034
0.037
Ratio scenario production : baseline production
1.2
1.1
1.0
0.9
0.8
1.1
1.2
1.3
1.4
1.5
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
q
Dry year
Normal year
Wet year
M (d-1) for 23 mm anchovy
0.048
0.052
0.057
0.061
0.065
0.043
0.052
0.061
0.070
0.078
0.087
0.096
0.104

2. Croaker in GOM



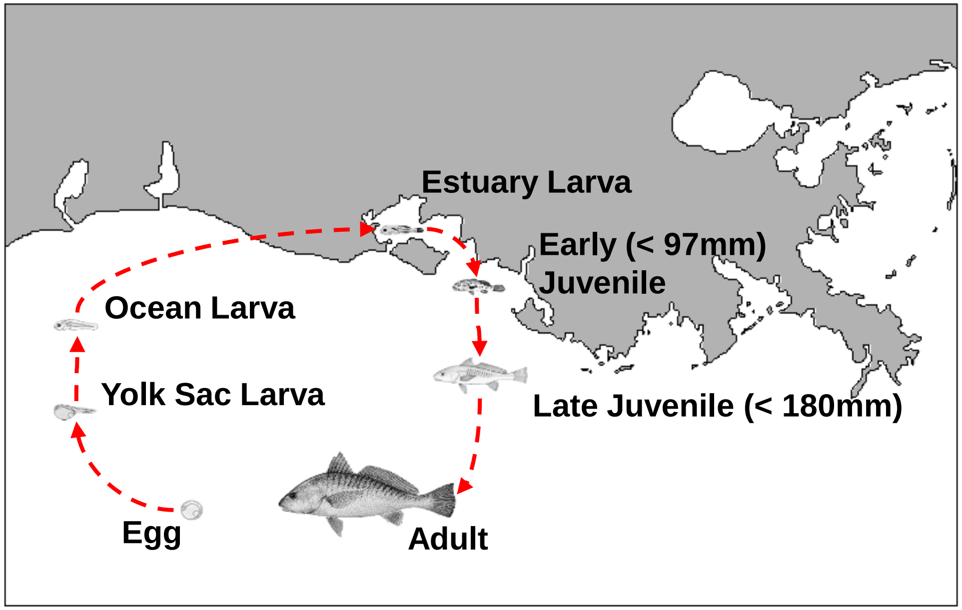
- Idealized 300 x 800 cell grid (1 km resolution)
- Bottom elevation for each cell is truncated beyond 100 m

Rose, K.A., Creekmore, S., Justić, D., Thomas, P., Craig, J.K., Neilan, R.M., Wang, L., Rahman, M.S. and Kidwell, D., 2018. Modeling the population effects of hypoxia on Atlantic croaker (*Micropogonias undulatus*) in the northwestern Gulf of Mexico: part 2—realistic hypoxia and eutrophication. *Estuaries and Coasts* 41: 255-279.

Model Overview

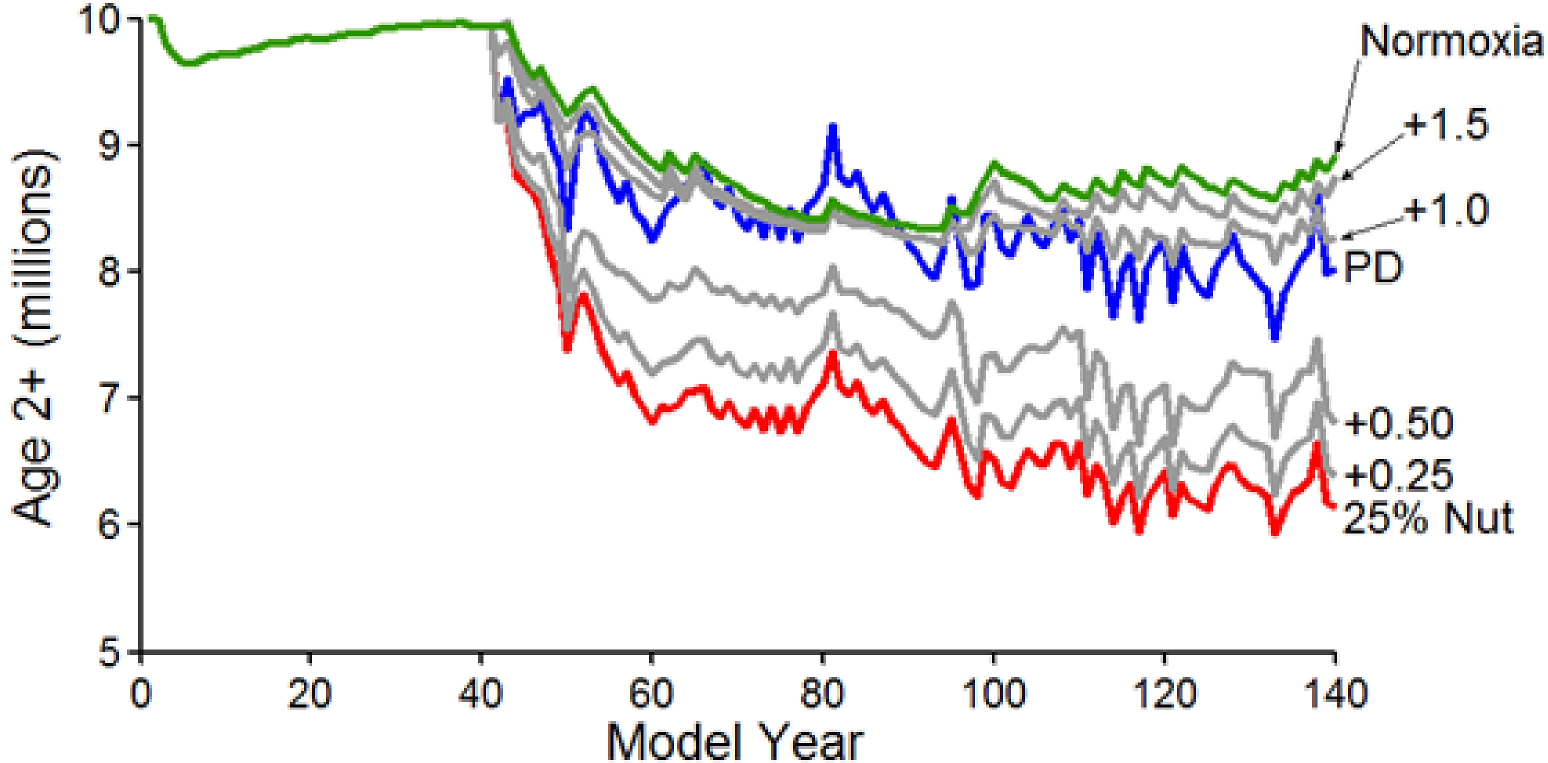
- Spatially explicit, IBM
  - Follows 7 stages to age 8
  - September 1 birthday
  - Model year begins Sept. 1
  - Each year 365 days long

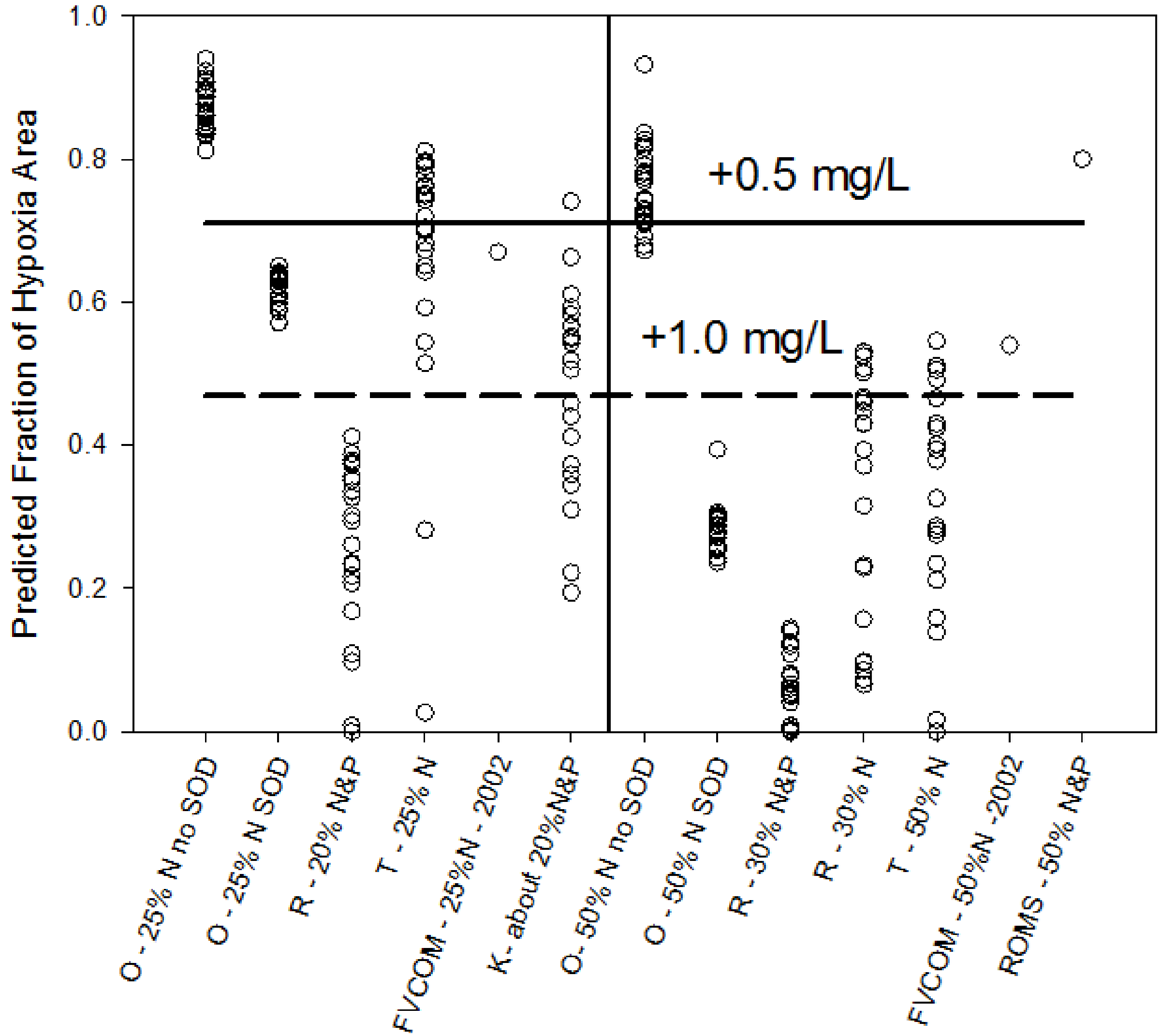
- Hourly processes
  - Growth
  - Mortality
  - Reproduction
  - Movement



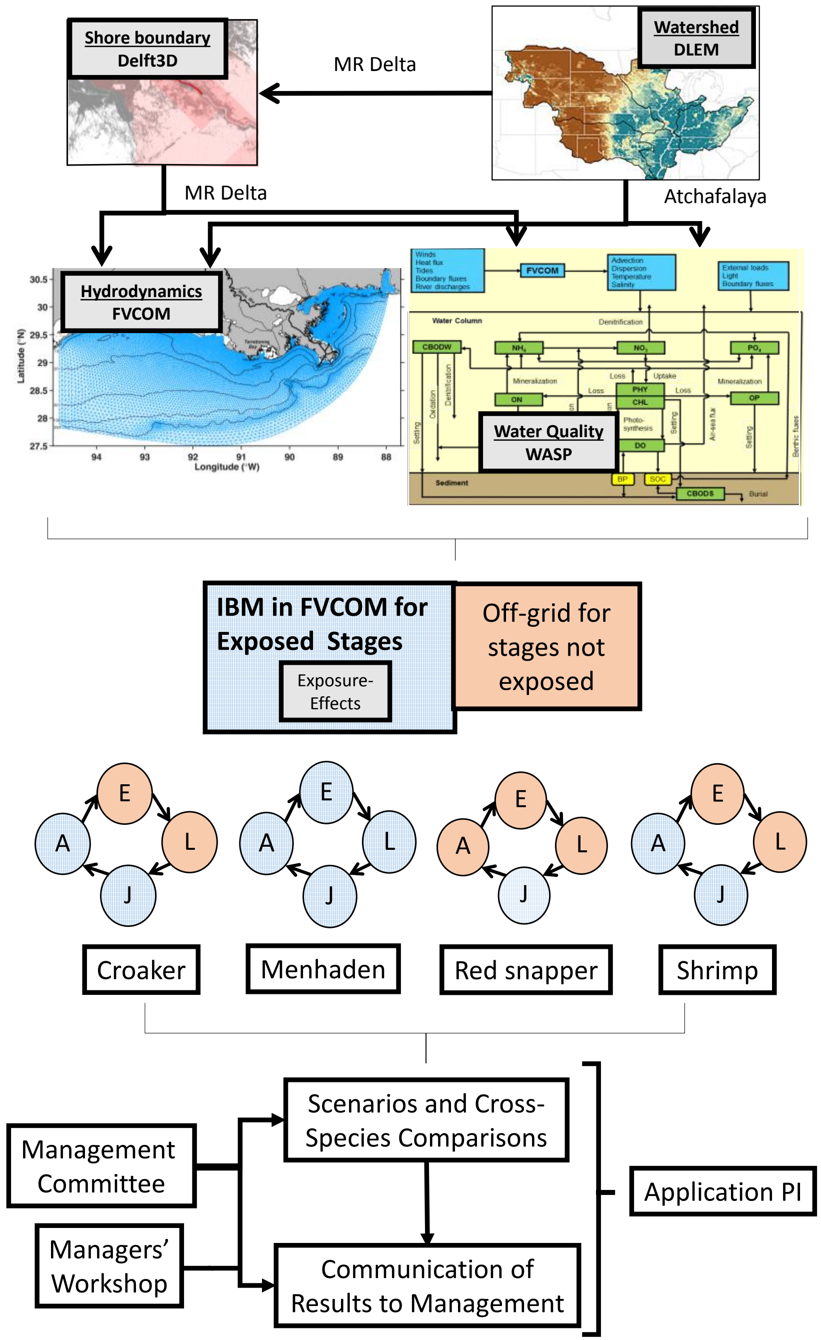
25% Reduction in Nutrients

PD: benefit?; Normoxia: best can be expected

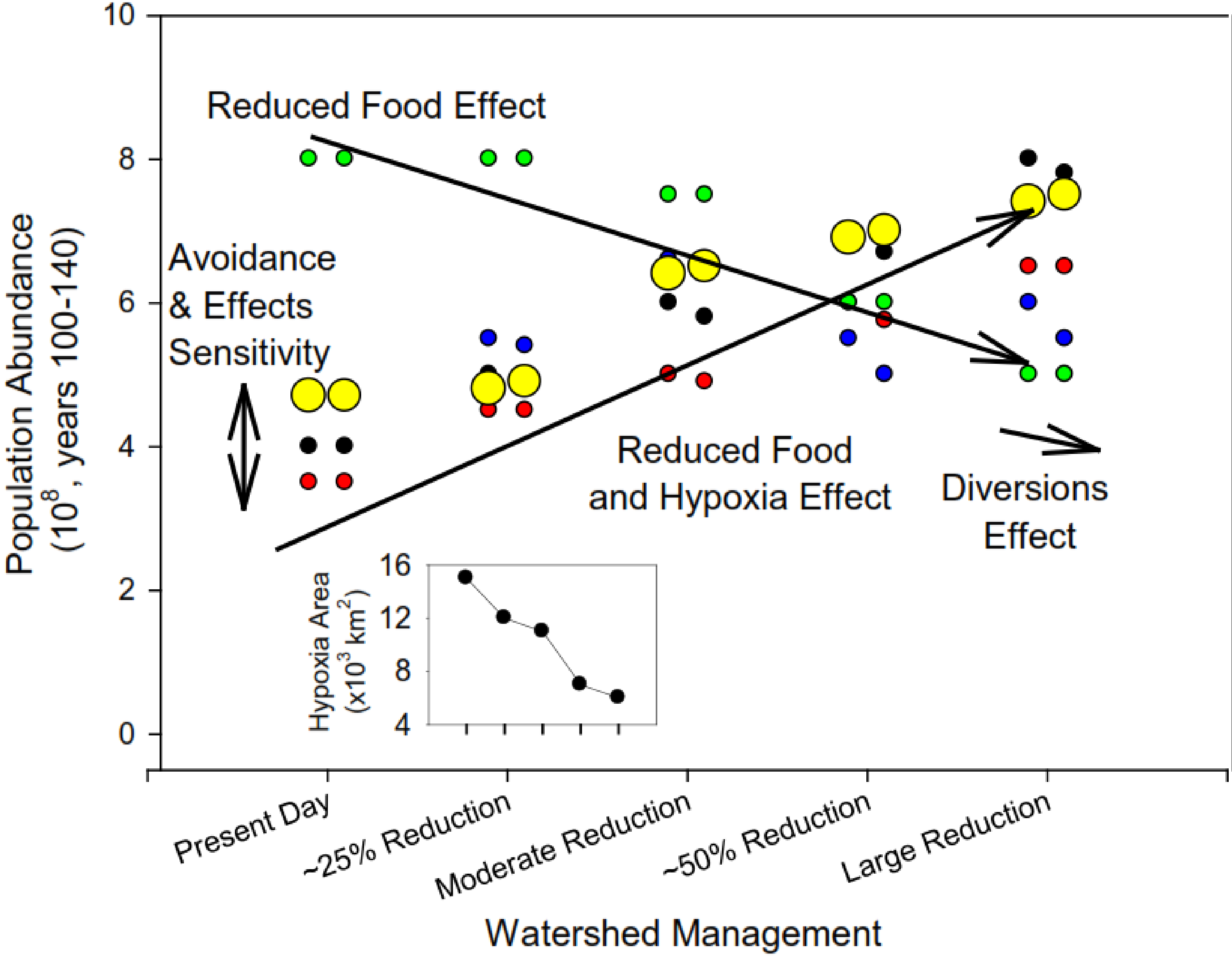




O = Obenour et al. (2012); R = Rabotyagov et al. (2014); T = Turner et al. (2012); K = Kling et al. (2014); ROMS = Laurent and Fennel (2014)


Shore boundary
Delft3D
MR Delta
Watershed
DLEM
MR Delta
Atchafalaya
Hydrodynamics
FVCOM
Water Quality
WASP
IBM in FVCOM for Exposed Stages
Exposure-Effects
Off-grid for stages not exposed
E
A
L
J
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?



3. Atlantis – Food Web

Design and Parameterization of the Chesapeake Bay Atlantis Model: A Spatially Explicit End-to-End Ecosystem Model

Thomas F. Ihde[1], Isaac C. Kaplan[2], Elizabeth A. Fulton[3], Iris A. Gray[2], Mejs Hasan[4], David Bruce[4], Ward Slacum[5], and Howard M. Townsend[4]

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

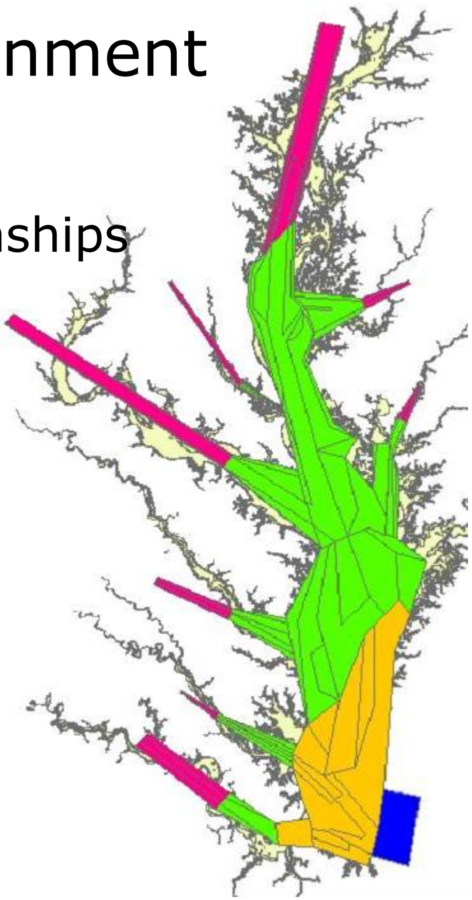
NOAA Technical Memorandum NMFS-F/SPO-166
September 2016

The Atlantis Model

Provided by Tom Ihde

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

Fisheries
- ✓Multiple sectors
- ✓Gears
- ✓Seasons
- ✓Spatially explicit

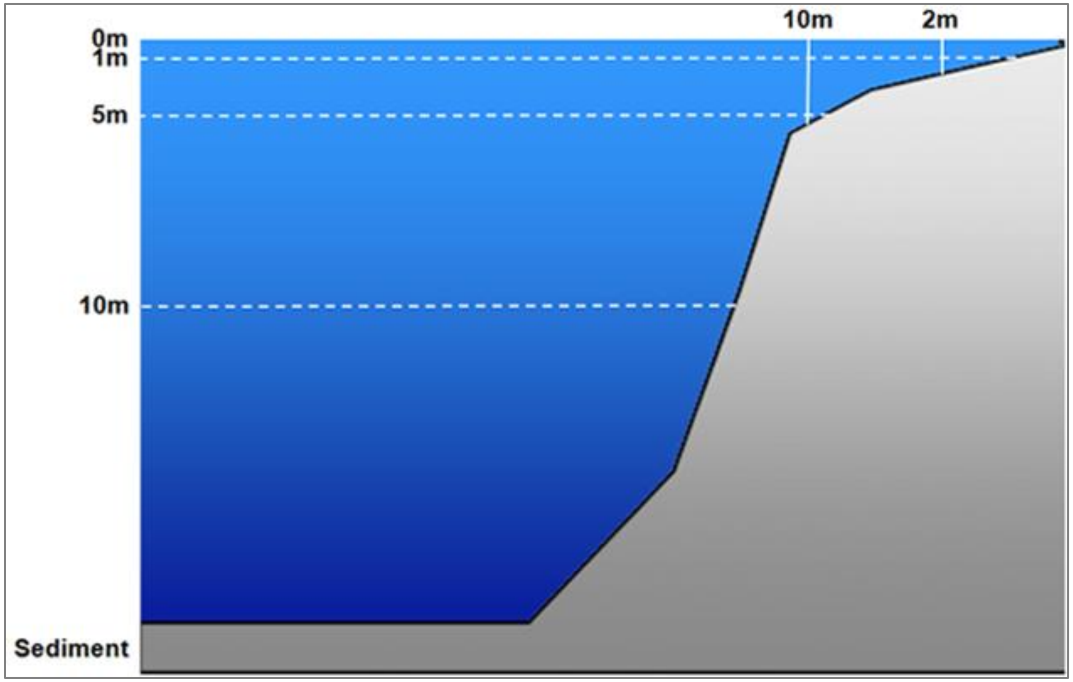


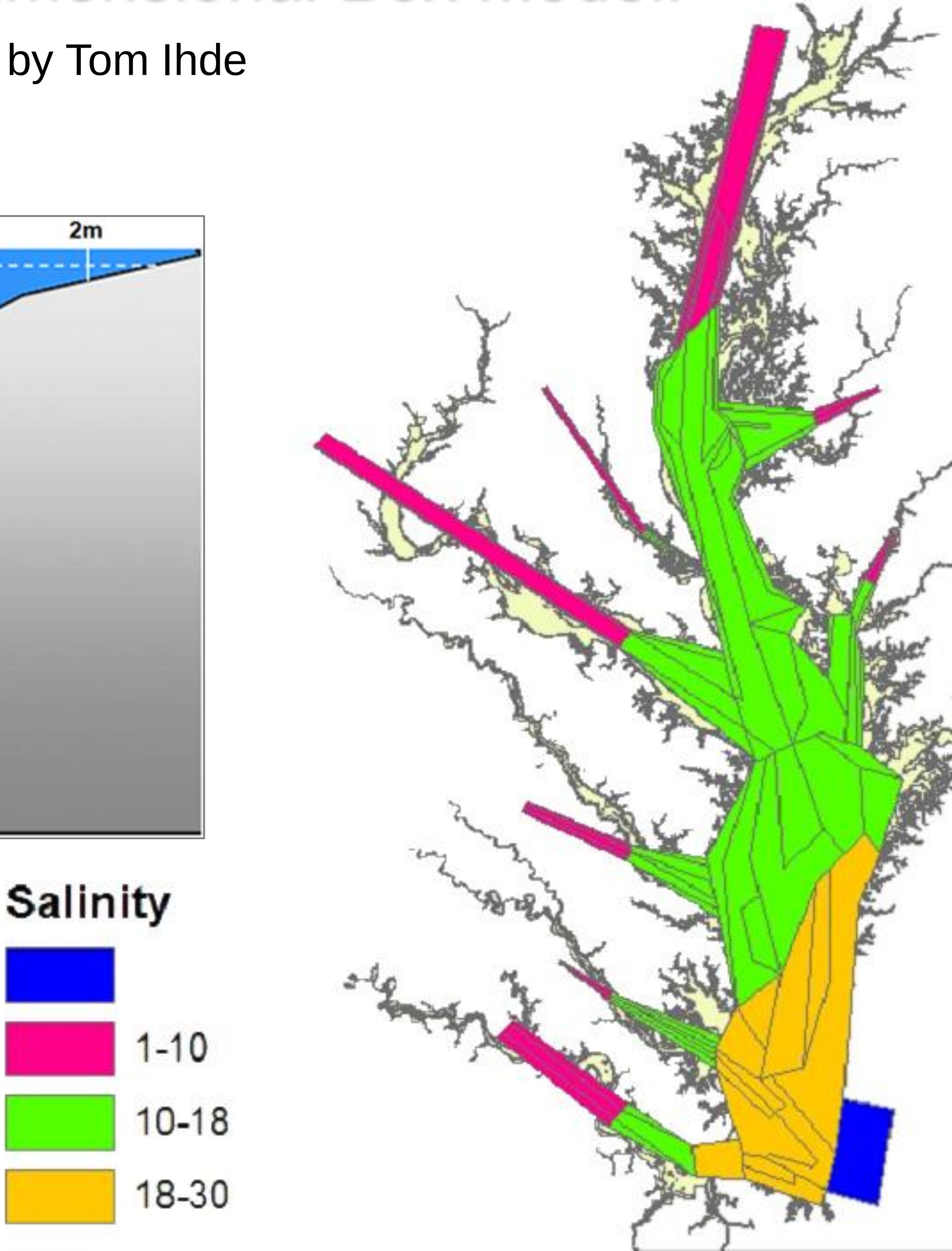
Physical environment
- ✓Geology
- ✓Chemistry
- ✓Circulation & currents
- ✓Temperature
- ✓Salinity
- ✓Water clarity
- ✓Climate variability

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**

Provided by Tom Ihde

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: nannoplankton, 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.

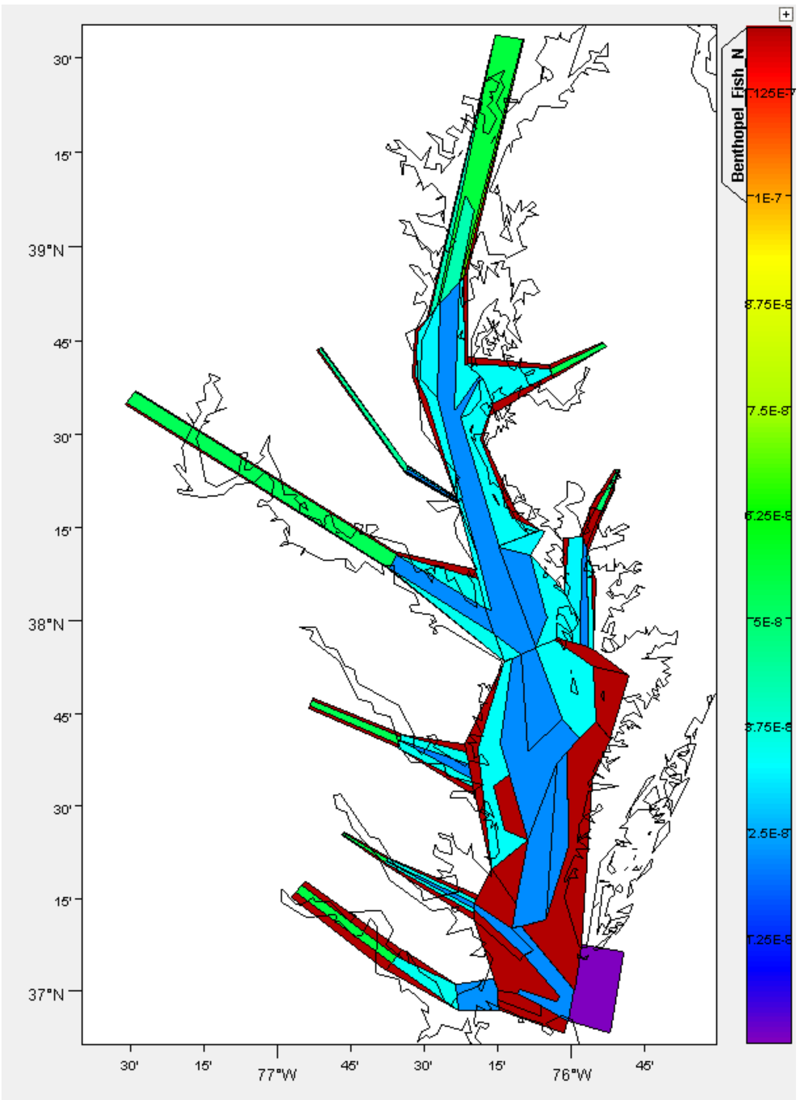
Detritus
- Carrion
- Carrion (sediment)
- Labile
- Labile (sediment)
- Refractory
- Refractory (sediment)

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

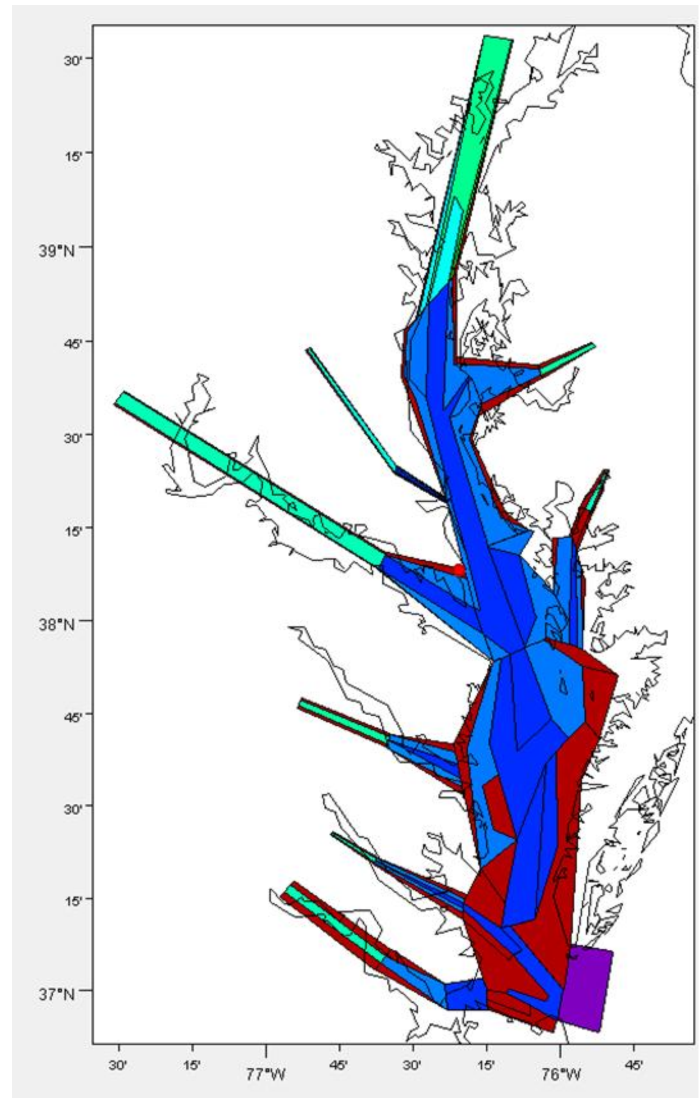
Striped Bass

Provided by Tom Ihde

Current Conditions

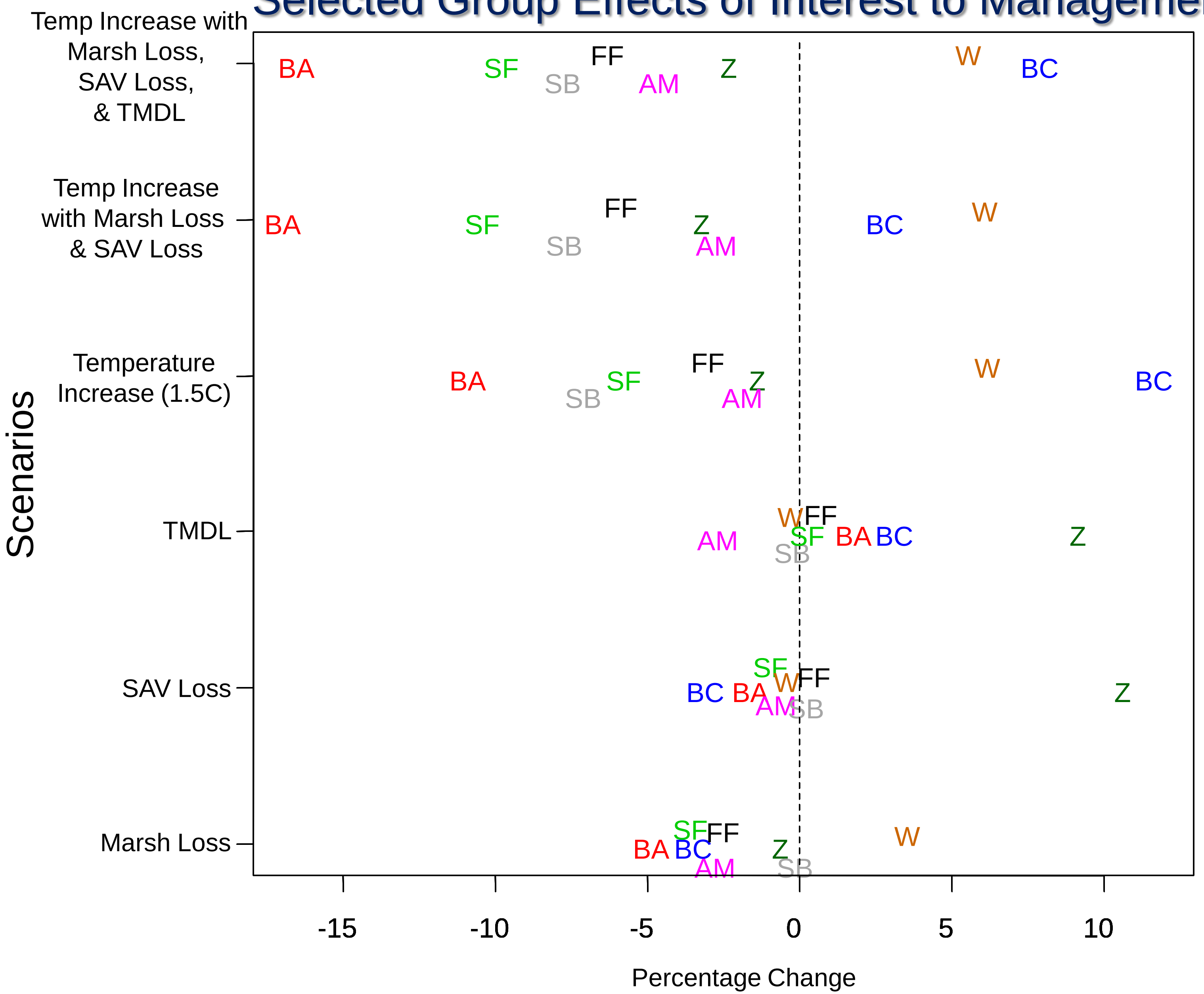


Temperature increase
& Habitat Loss



Sensitivity To Environmental Factors

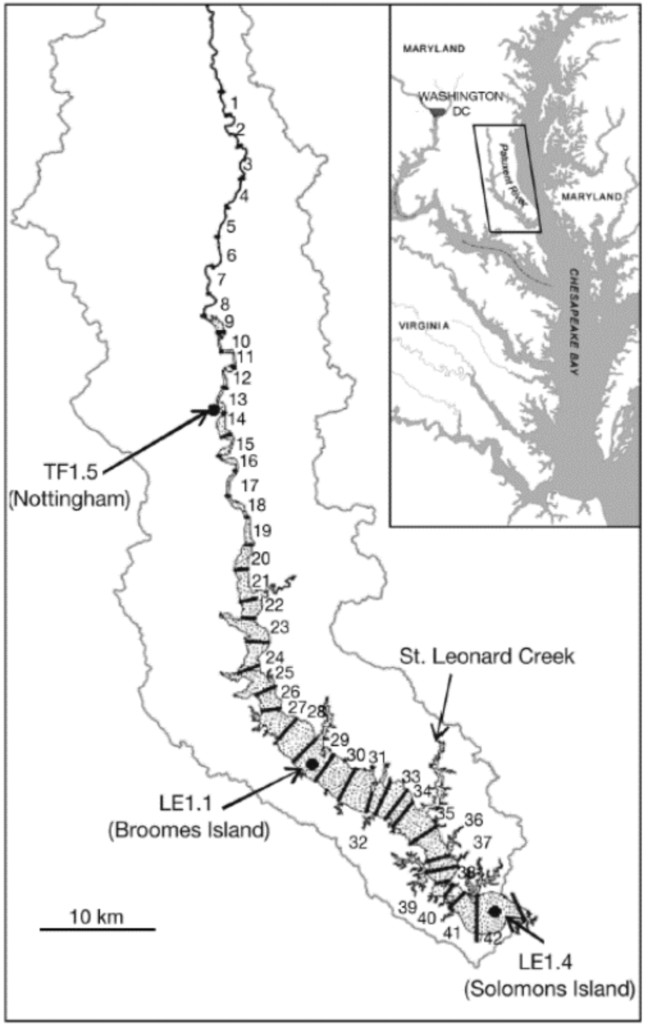
Selected Group Effects of Interest to Management

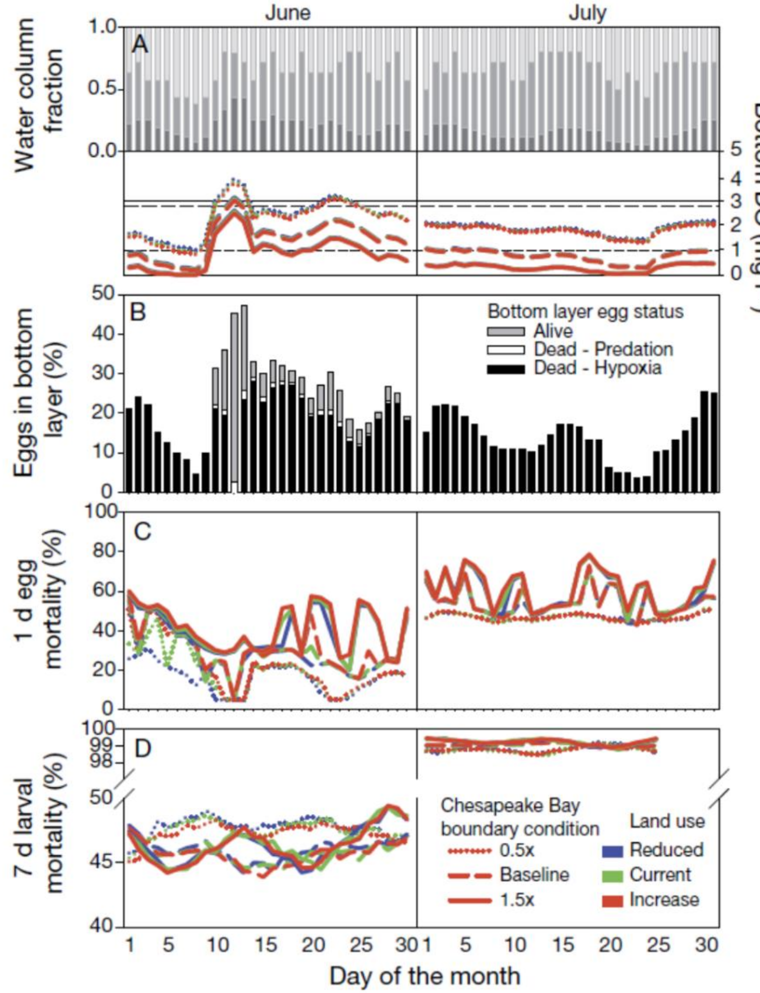


Z – Zooplankton
BA – Bay Anchovy
W – Worms *(and other benthic invert. prey)*
BC – Blue Crab
AM – Atlantic Menhade
SB – Striped Bass
SF – Summer Flounde
FF – All Finfish

Provided by Tom Ihde

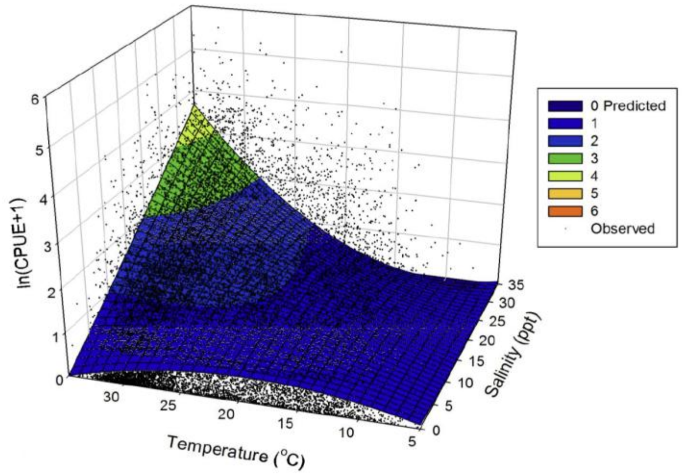
4. Larvae

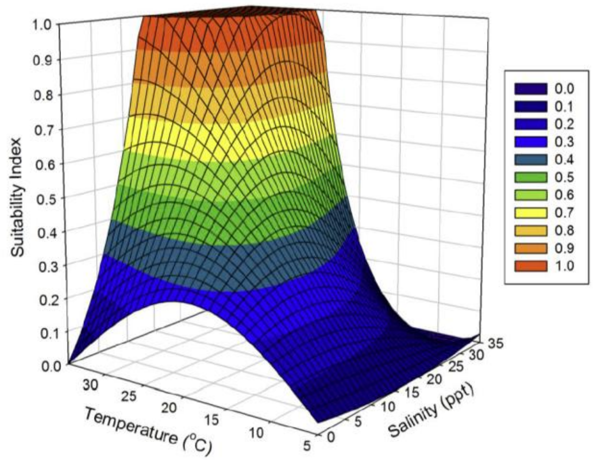


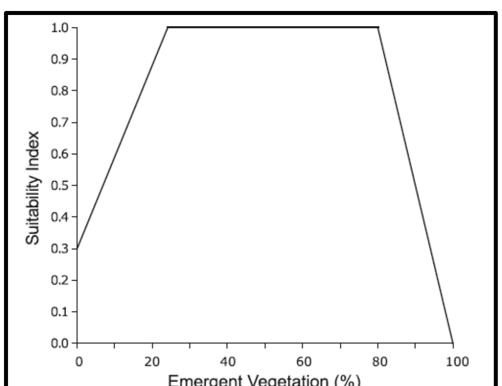


Adamack, A.T., K.A. Rose, D.L. Breitburg, A.J. Nice, and W.S. Lung. 2012. Simulating the effect of hypoxia on bay anchovy egg and larval mortality using coupled watershed, water quality, and individual-based predation models. *Marine Ecology Progress Series* 155: 141-160.

5. Habitat







2017 Coastal Master Plan: Modeling

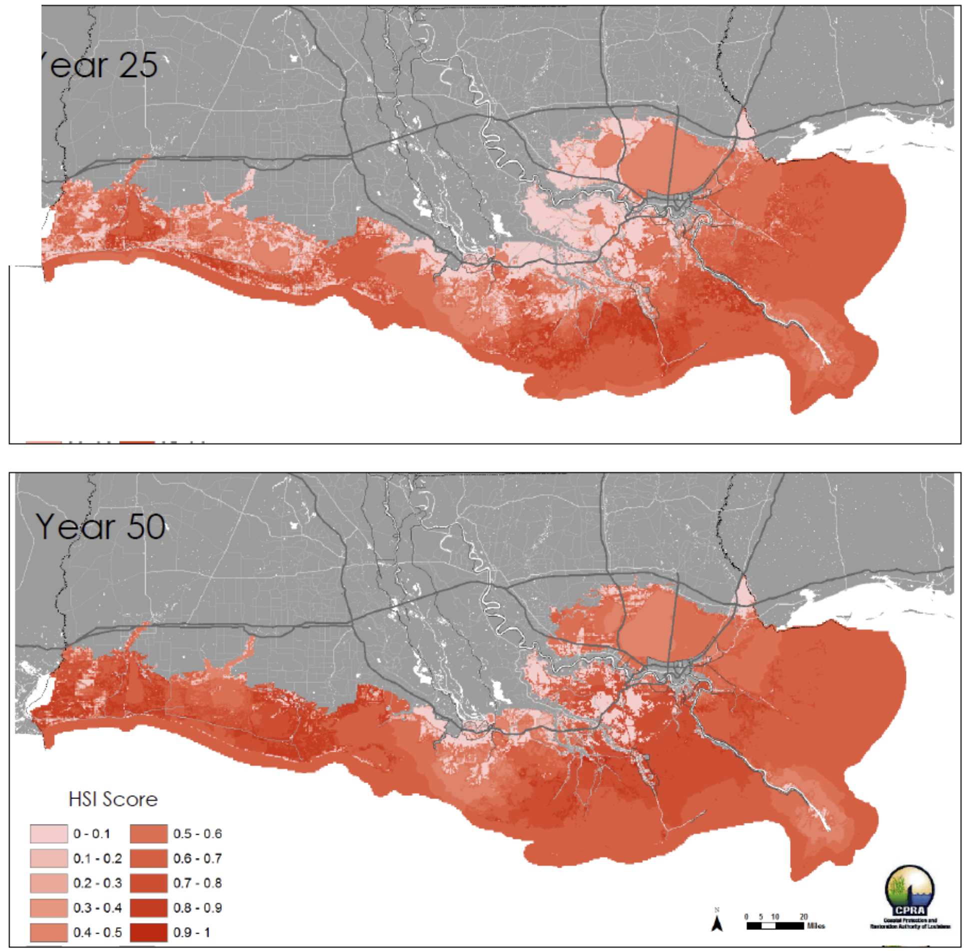


Figure 120: Coast Wide Habitat Suitability for Adult Spotted Seatrout at Years 25 and 50 of the Medium FWOA Scenario. Dark red indicates areas of highest suitability.

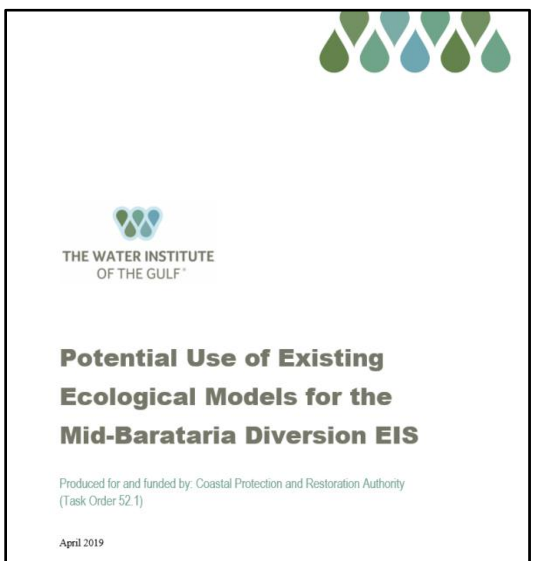
Sable et al. *2017 Coastal Master Plan: Attachment C3-16: Spotted Seatrout Habitat Suitability Index Model*. CPRA.

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

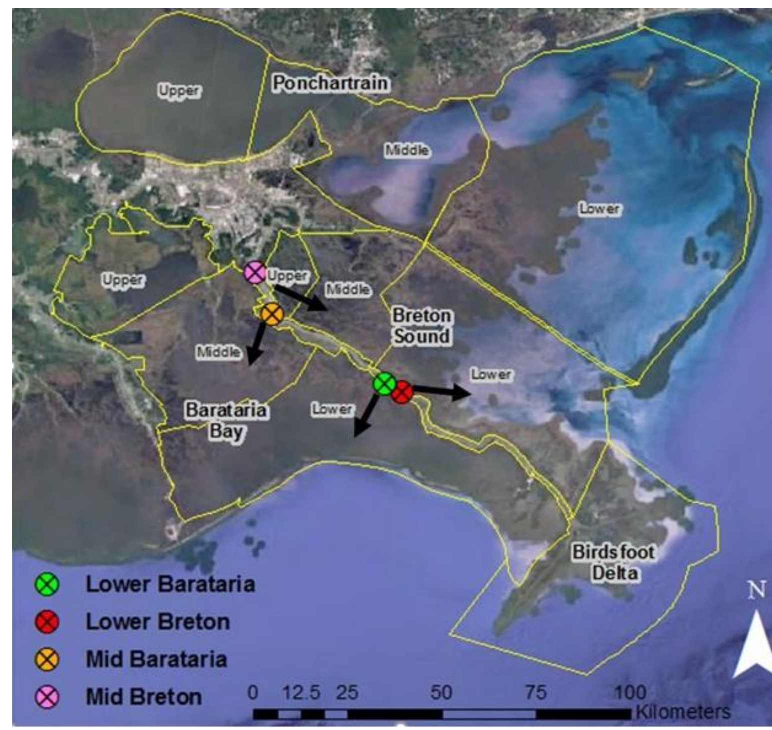


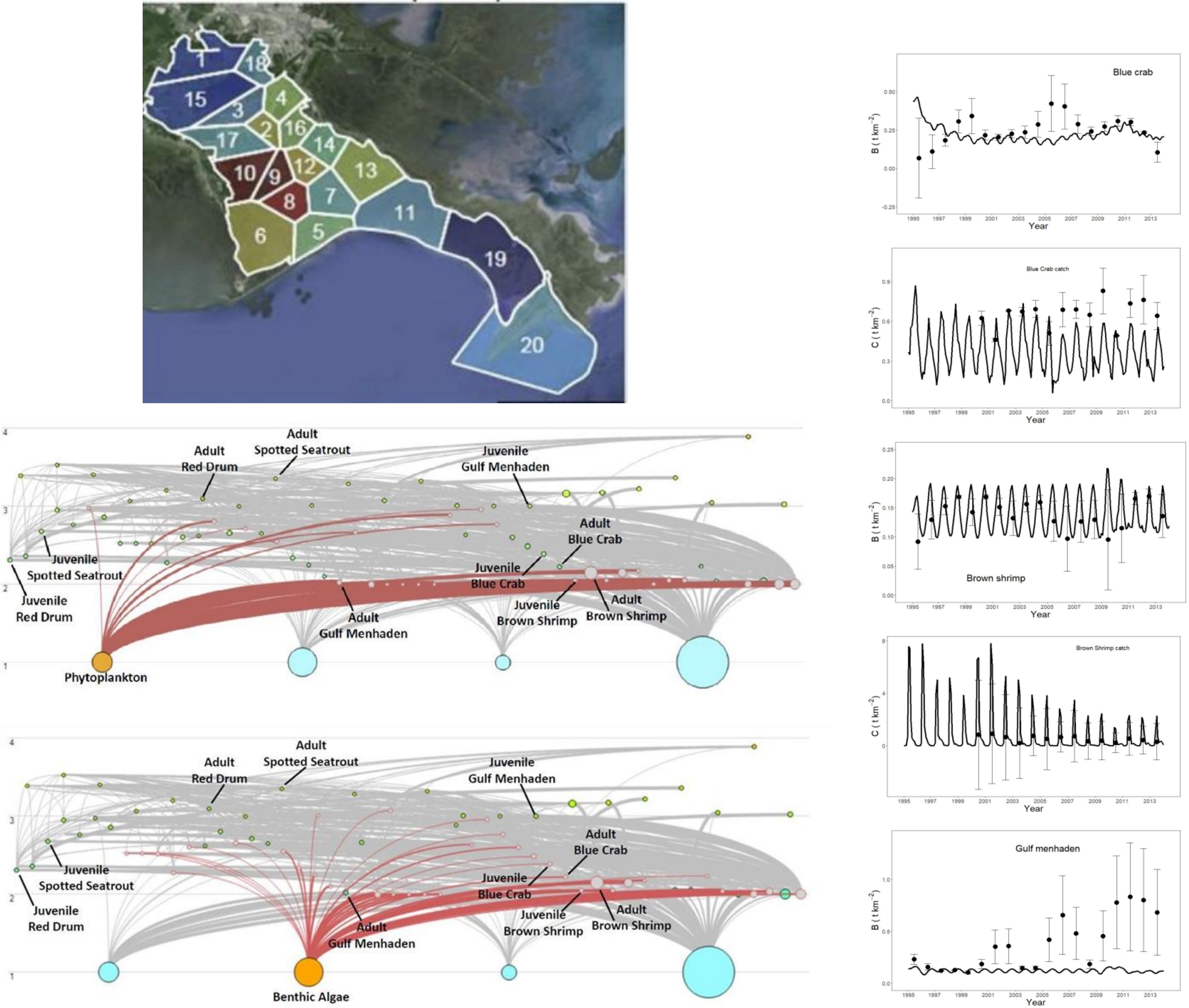
THE WATER INSTITUTE OF THE GULF

Potential Use of Existing Ecological Models for the Mid-Barataria Diversion EIS

Produced for and funded by: Coastal Protection and Restoration Authority (Task Order 52.1)

April 2019





1
18
15
3
4
2
16
17
14
13
10
9
12
8
7
11
6
5
19
20
Adult
Red Drum
Adult
Spotted Seatrout
Juvenile
Gulf Menhaden
Adult
Blue Crab
Juvenile
Spotted Seatrout
Juvenile
Red Drum
Juvenile
Blue Crab
Juvenile
Brown Shrimp
Adult
Brown Shrimp
Adult
Gulf Menhaden
Phytoplankton
Adult
Red Drum
Adult
Spotted Seatrout
Juvenile
Gulf Menhaden
Adult
Blue Crab
Juvenile
Spotted Seatrout
Juvenile
Red Drum
Juvenile
Blue Crab
Juvenile
Brown Shrimp
Adult
Brown Shrimp
Adult
Gulf Menhaden
Benthic Algae
Blue crab
B (t km^{-2})
Year
Blue Crab catch
C (t km^{-2})
Year
Brown shrimp
B (t km^{-2})
Year
Brown Shrimp catch
C (t km^{-2})
Year
Gulf menhaden
B (t km^{-2})
Year

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

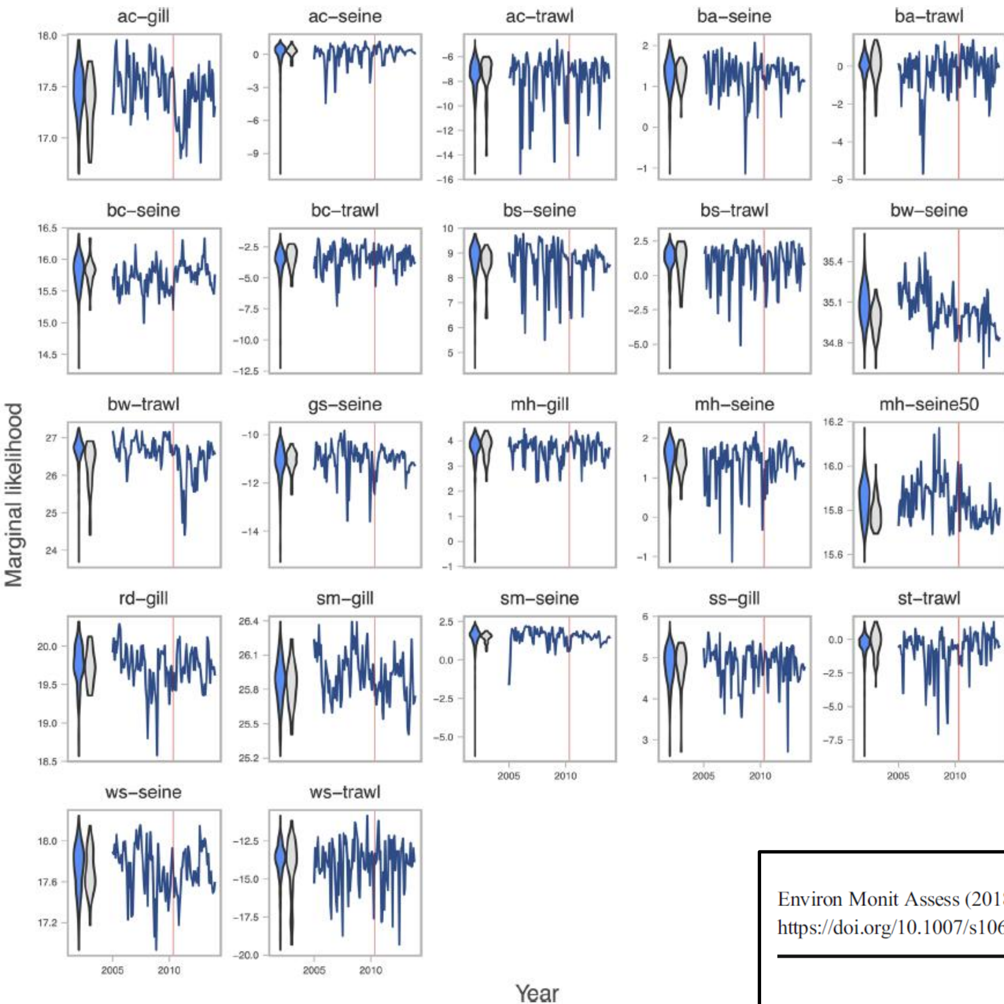
- Ultimately, trust

SESYNC NATIONAL SOCIO-ENVIRONMENTAL SYNTHESIS CENTER

Oct 22 Dr. Kenneth Rose
Multidisciplinary team science and engaged {-raged} stakeholders: Two often neglected aspects of coupled human-natural systems

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

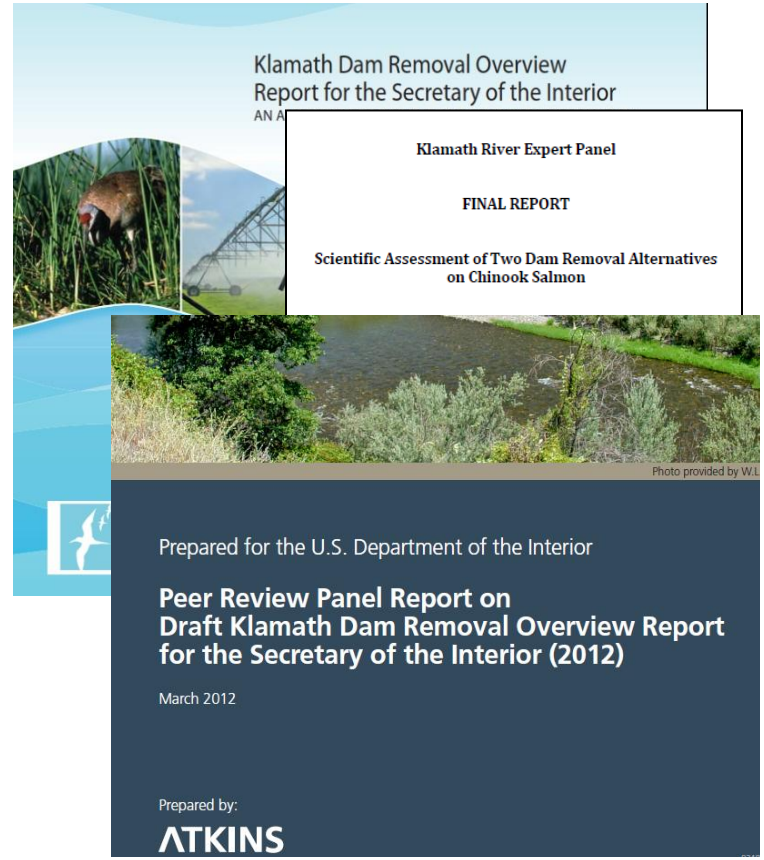
Managing Expectations

- 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

Todd Trumbull / The Chronicle

Klamath controversy continues

An agreement to remove four dams has been reached, but barriers remain

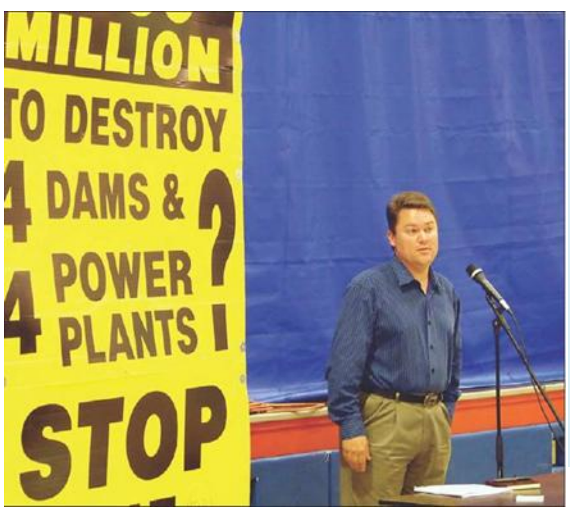


Klamath Propaganda: Who do you believe?

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

Coastal Protection and Restoration Authority
450 Laurel Street, Baton Rouge, LA 70804 | coastal@la.gov | www.coastal.la.gov

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Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

ELSEVIER

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

CrossMark

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]

Dynamic Solutions LLC

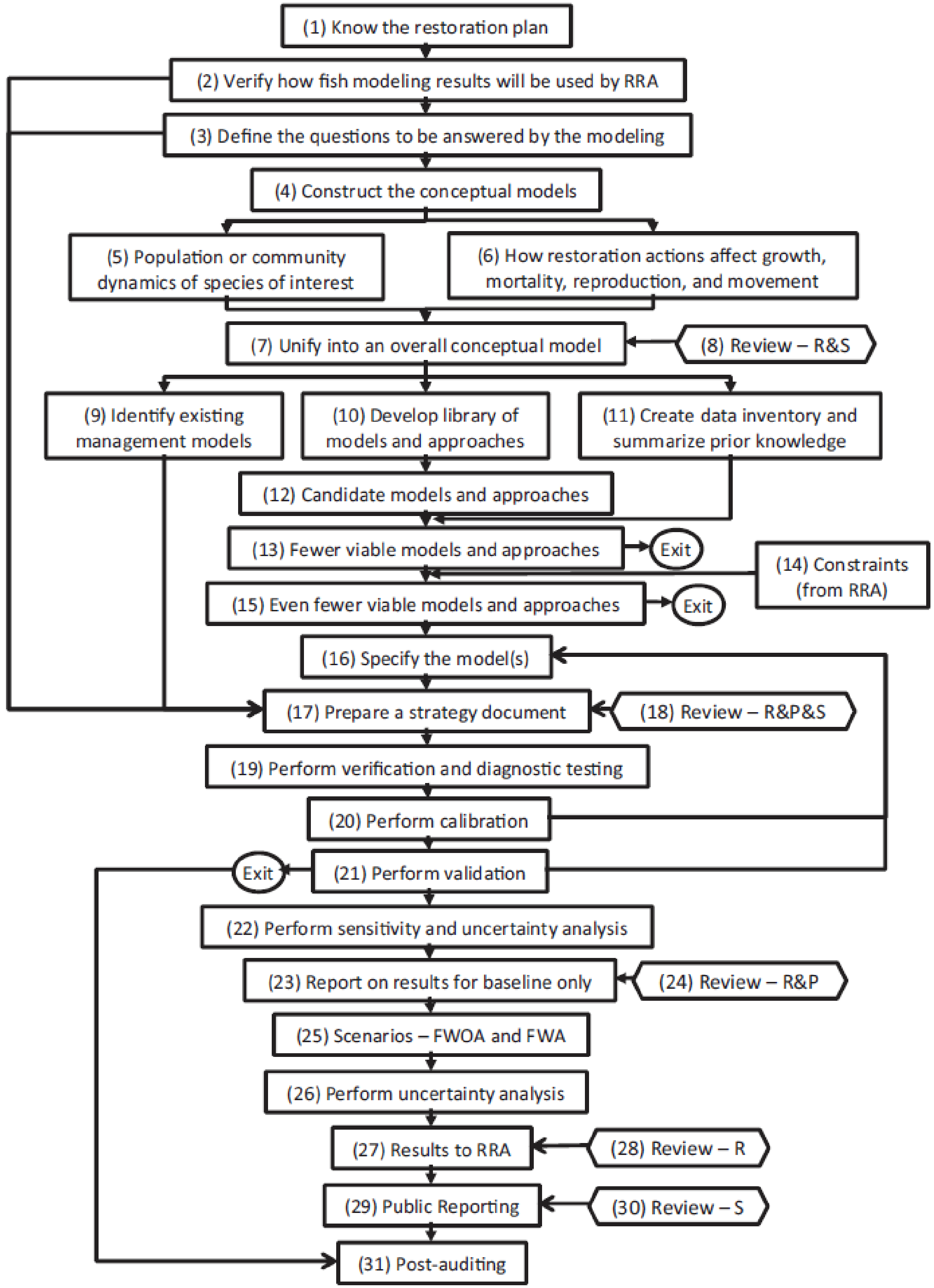
THE WATER INSTITUTE OF THE GULF

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"

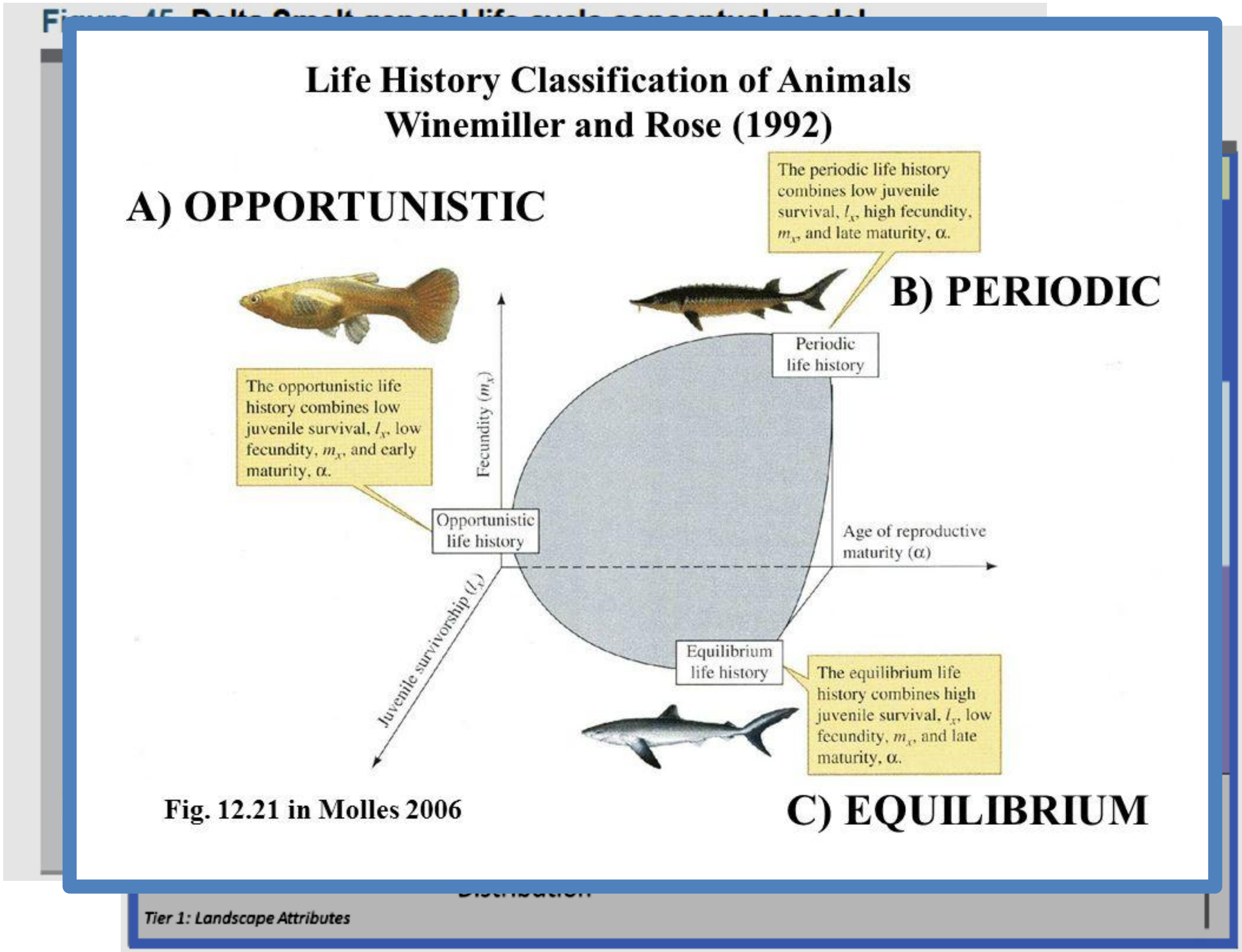
13 Concepts

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



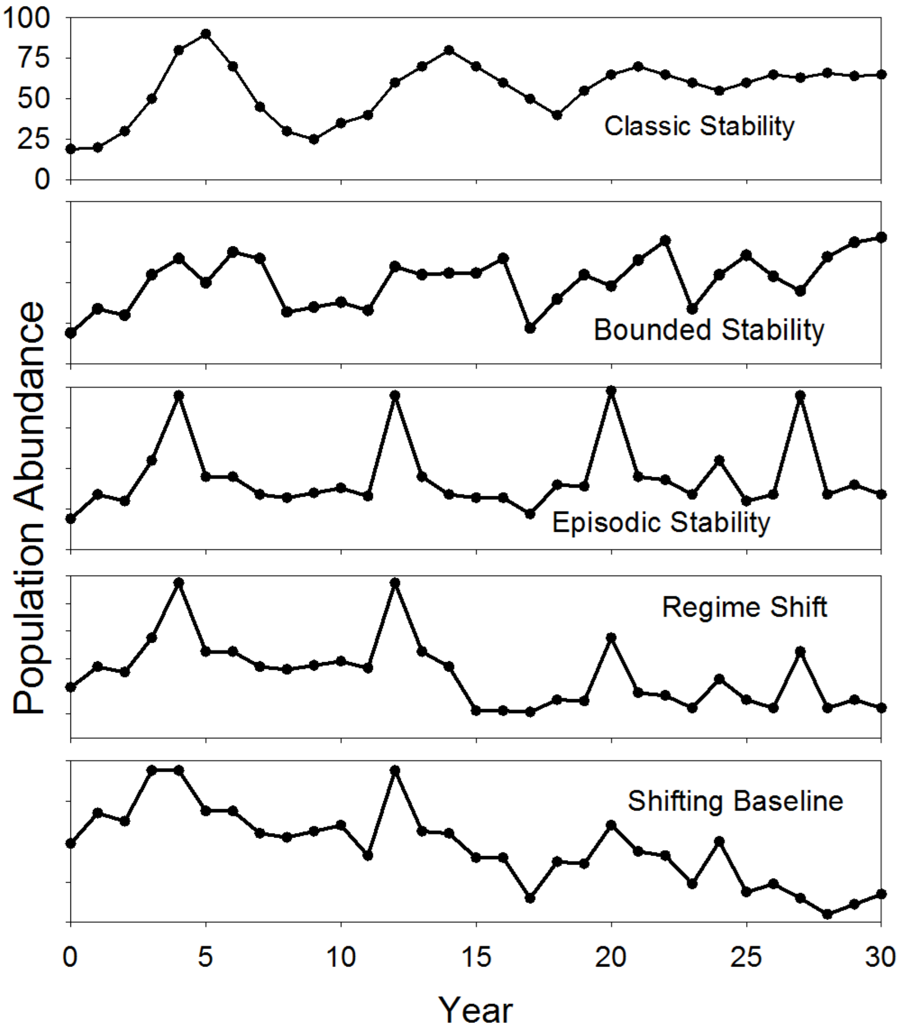
(1) Know the restoration plan
(2) Verify how fish modeling results will be used by RRA
(3) Define the questions to be answered by the modeling
(4) Construct the conceptual models
(5) Population or community dynamics of species of interest
(6) How restoration actions affect growth, mortality, reproduction, and movement
(7) Unify into an overall conceptual model
(8) Review – R&S
(9) Identify existing management models
(10) Develop library of models and approaches
(11) Create data inventory and summarize prior knowledge
(12) Candidate models and approaches
(13) Fewer viable models and approaches
Exit
(14) Constraints (from RRA)
(15) Even fewer viable models and approaches
Exit
(16) Specify the model(s)
(17) Prepare a strategy document
(18) Review – R&P&S
(19) Perform verification and diagnostic testing
(20) Perform calibration
Exit
(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 RRA
(28) Review – R
(29) Public Reporting
(30) Review – S
(31) Post-auditing

13 Concepts – (1) Life Cycles

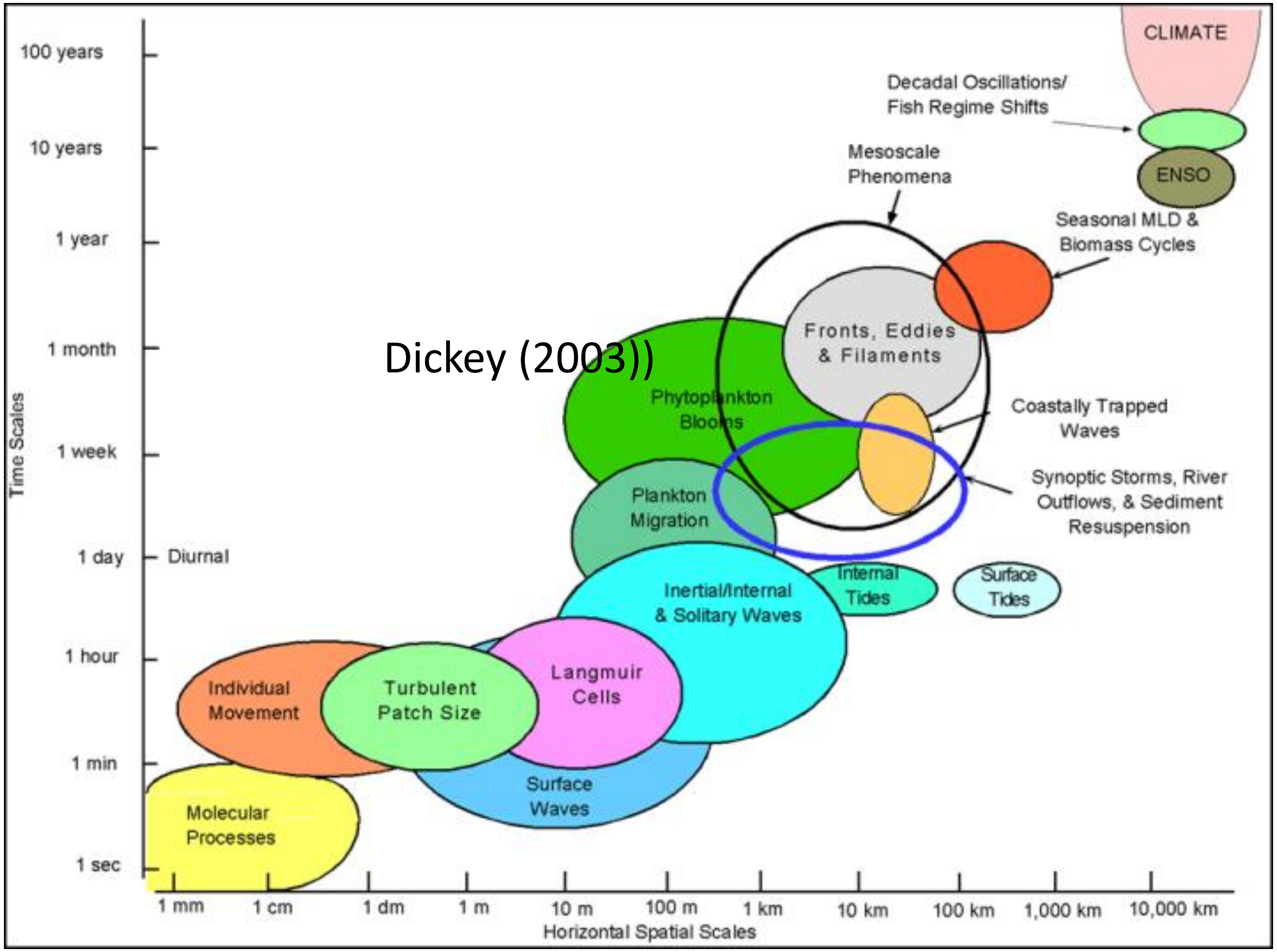


Delta Smelt Resiliency Strategy. California Natural Resources Agency, July 2016.

13 Concepts – (4) Nonequilibrium Theory



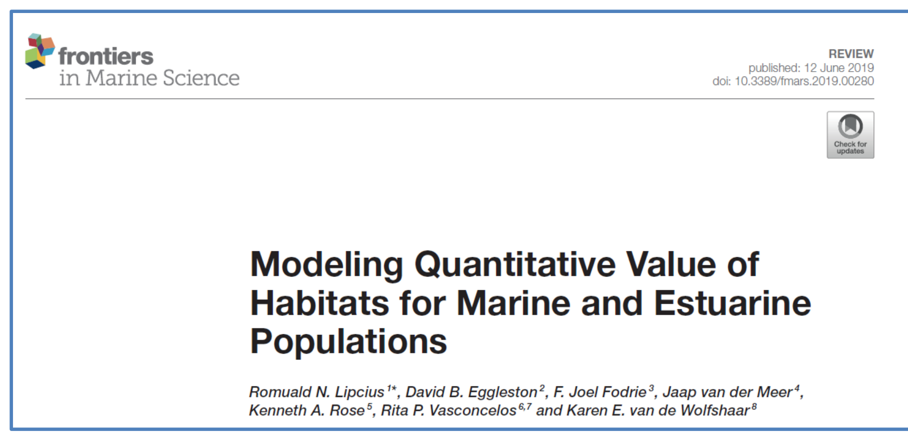
13 Concepts – (5) Scaling



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


frontiers in Marine Science

REVIEW
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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]*

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