CESR, Living Resources, and Climate Change

CBP Climate Change Modeling III: Post-2025 decisions

Kenneth Rose

France-Merrick Professor in Sustainable Ecosystem Restoration

Horn Point Lab, UMCES

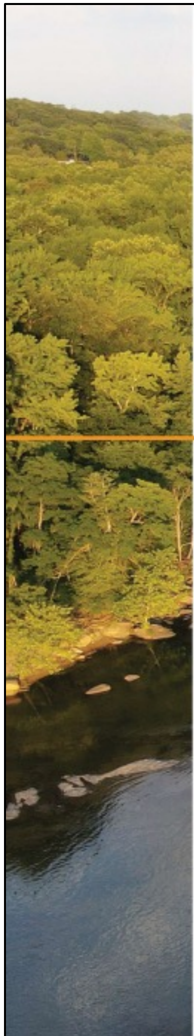
CESR

- Executive Summary, Policy Brief
- Main report
- Three supplemental reports
  - Watershed
  - Estuary
  - Living Resources

- 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.***



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

An Independent Report from the Scientific and Technical Advisory Committee (STAC)
Chesapeake Bay Program
Annapolis, MD

May 2023

Scientific and Technical Advisory Committee (STAC)

Scientific and Technical Advisory Committee: A Proposed Framework for Analyzing Water Quality and Habitat Effects on the Living Resources of Chesapeake Bay

Kenneth Rose[1], Mark E. Monaco[2], Tom Ihde[3], Jason Hubbart[4], Eric Smith[5], Jay Stauffer[6], Kirk Havens[7]

[1]University of Maryland Center for Environmental Science, [2]National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, [3]Morgan State University, Patuxent Environmental and Aquatic Research Laboratory, [4]West Virginia University, [5]Virginia Tech, [6]Penn State University, [7]Virginia Institute of Marine Science

May 2023

STAC Publication 23-005

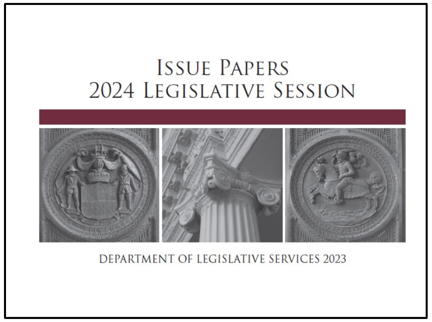
CESR

- **FINDING:** It might not be possible to meet the all TMDL and WQ goals **but** this may not be necessary to meet and support living resource goals.
- CWA diverts attention from consideration of LR responses
- Opportunities exist to adjust water quality goals to prioritize management actions that improve LR
- Water quality improvements in shallow water may have more of a benefit to living resources than elsewhere.
- Water quality alone does not guarantee improvements in Living Resources. There are other factors!


MENU BAY JOURNAL About Cont

Accepting leadership gavel, Maryland governor vows new approach toward Bay

eremy Cox Oct 23, 2023 1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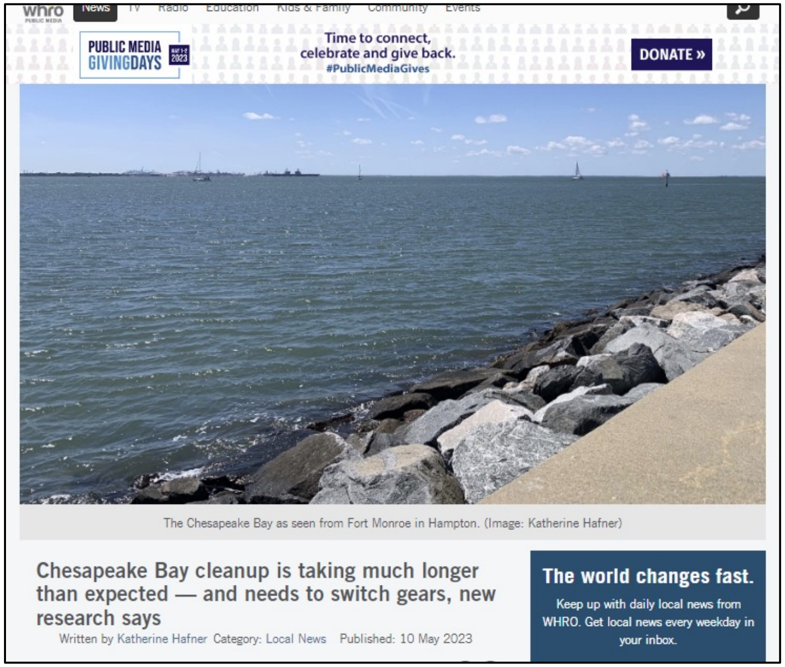
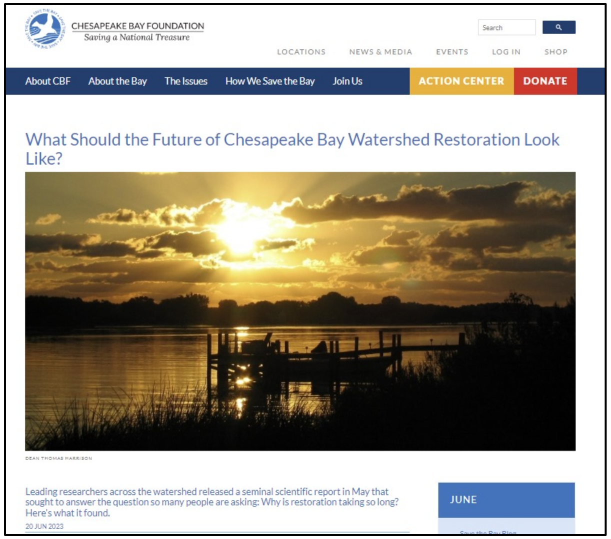
DEPARTMENT OF LEGISLATIVE SERVICES 2023



The Chesapeake Bay as seen from Fort Monroe in Hampton. (Image: Katherine Hafner)

Chesapeake Bay cleanup is taking much longer than expected — and needs to switch gears, new research says

Written by Katherine Hafner Category: Local News Published: 10 May 2023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Saving a National Treasure

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What Should the Future of Chesapeake Bay Watershed Restoration Look Like?

Leading researchers across the watershed released a seminal scientific report in May that sought to answer the question so many people are asking: Why is restoration taking so long? Here's what it found.

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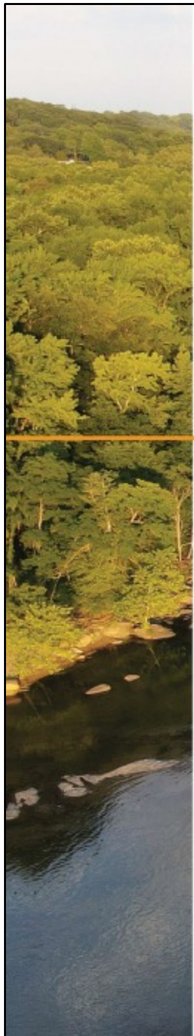
ENERGY + ENVIRONMENT

Report details why progress to clean up the Chesapeake Bay has been slow

Bay Program points to ineffective agricultural reductions, need to consider climate change

BY: **CHARLIE PAULLIN** - MAY 10, 2023 12:02 AM



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

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May 2023

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

Kenneth Rose[1], Mark E. Monaco[2], Tom Ihde[3], Jason Hubbart[4], Eric Smith[5], Jay Stauffer[6], Kirk Havens[7]

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May 2023

STAC Publication 23-005

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

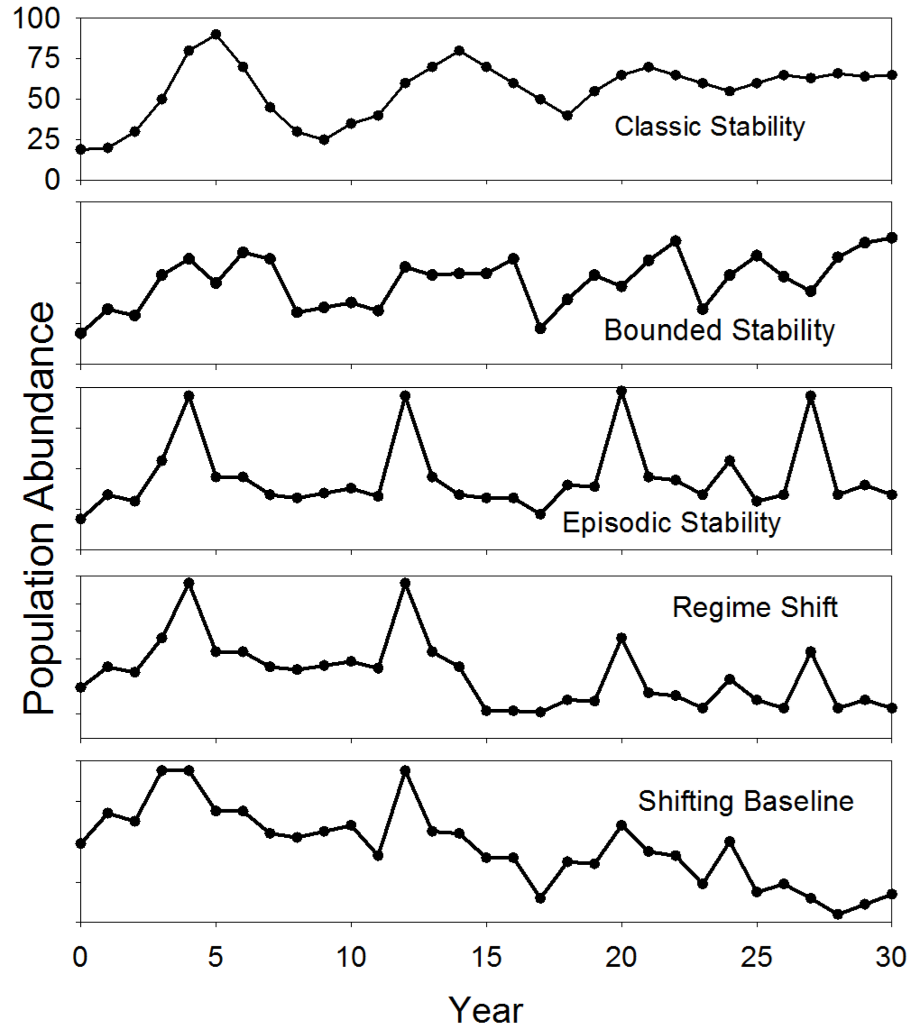
8 Strategic determination of an analysis plan
- 8.1 Selecting species
- 8.2 Available Data
- 8.3 Response and explanatory variables
- 8.4 Biological, temporal, & spatial scales
- 8.5 Analytical approaches
- 8.6 Coordination and combining results

9 Final comments

10 Acknowledgements

11 References

Foundational Concepts – Nonequilibrium Theory



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

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?

Feasibility – Chesapeake Bay

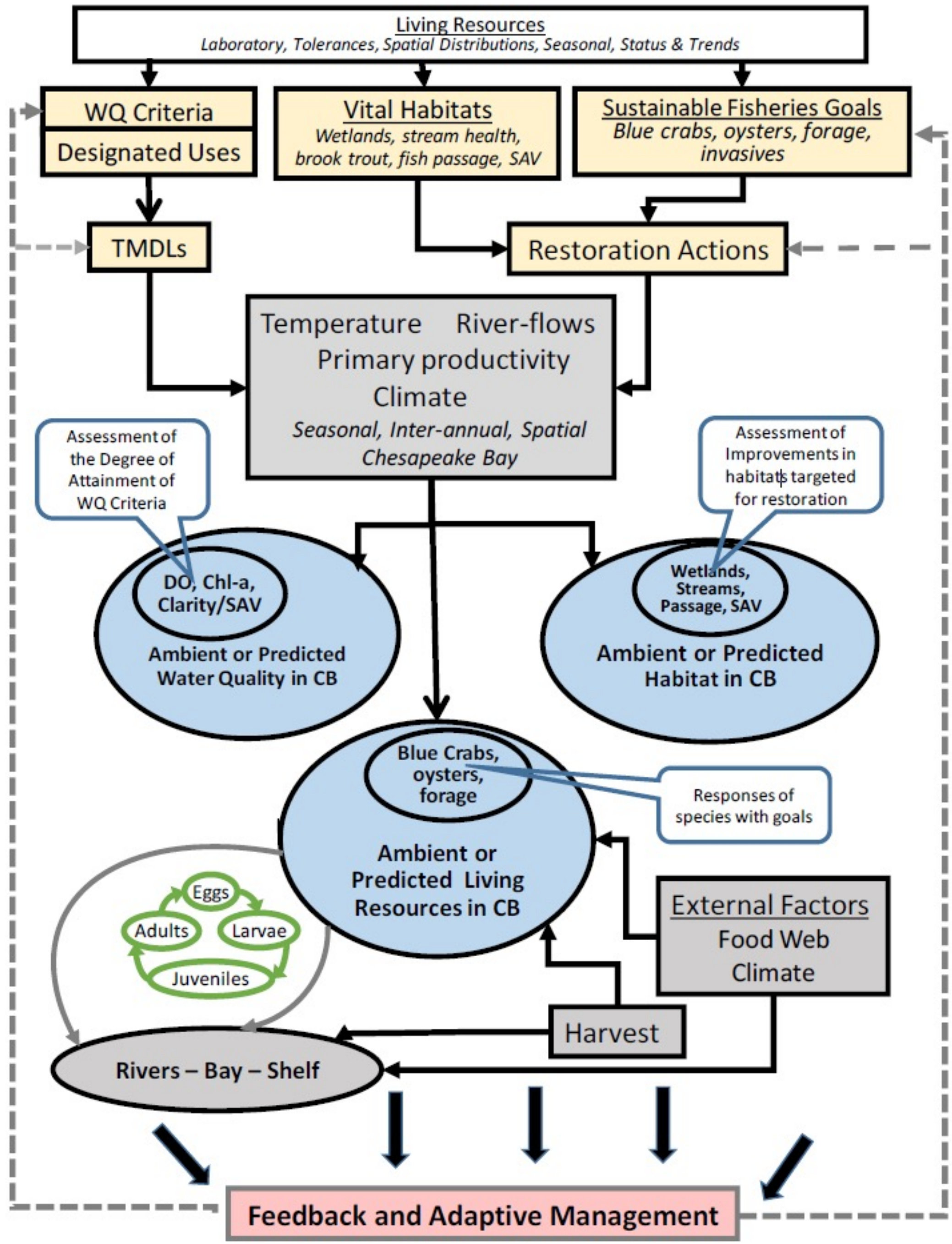
- Historical focus on water quality
- Productivity and highly valued
- Information and data rich
- Many scientists = a lot of past and ongoing activities
- Done at other large-scale restoration efforts
- Q: How would we go about doing this task?

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

Different Situation to "WQ"

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

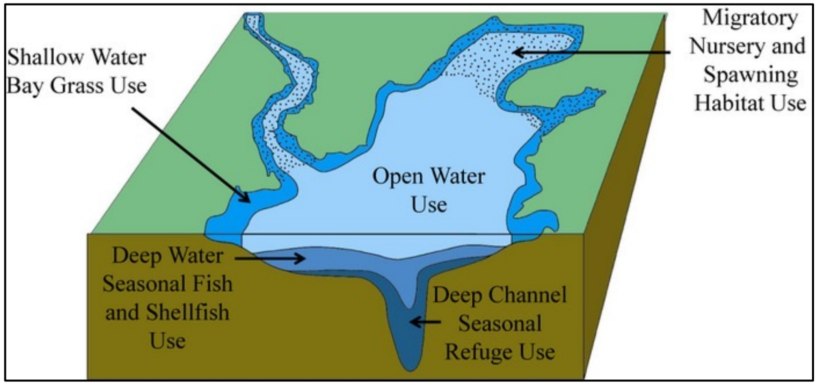


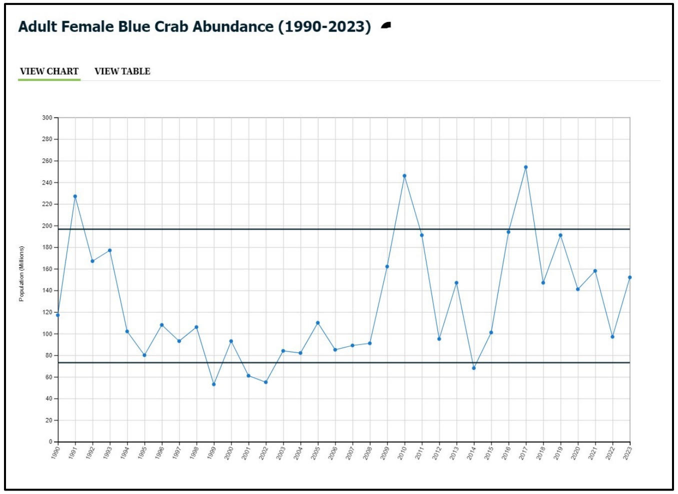
Living Resources
Laboratory, Tolerances, Spatial Distributions, Seasonal, Status & Trends
WQ Criteria
Designated Uses
Vital Habitats
Wetlands, stream health, brook trout, fish passage, SAV
Sustainable Fisheries Goals
Blue crabs, oysters, forage, invasives
TMDLs
Restoration Actions
Temperature River-flows
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


MYTHBUSTERS
WITH
EXPLOSIVES
Confederate
Rocket

(1) TMDL ignores fish! False

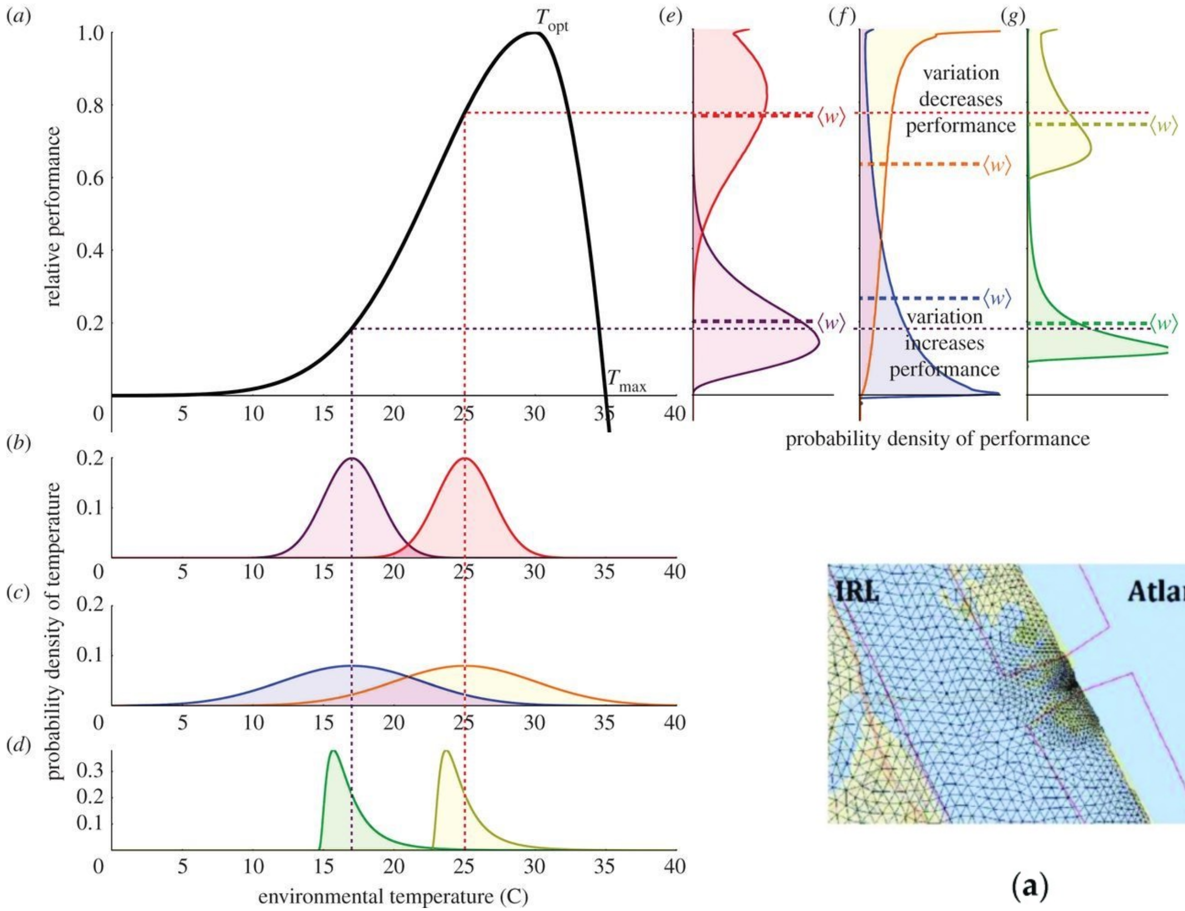
- Bottom up approach – very well done
- WQS
- Agreement indicators
- Report cards
- Others



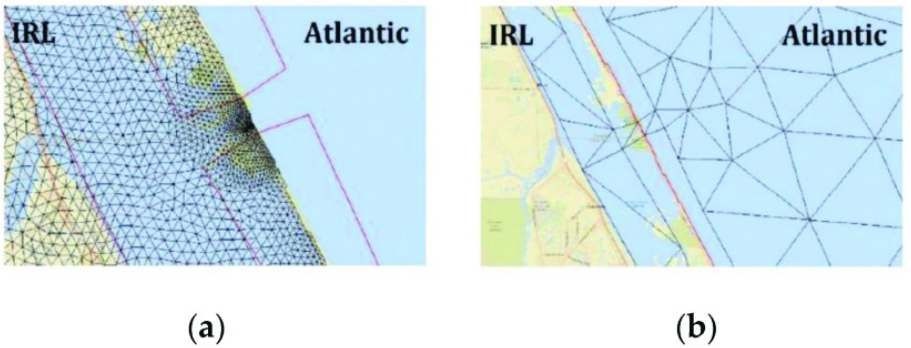


Tango, P.J. and R.A. Batiuk. 2013. Journal of the American Water Resources Association 49: 1007-1024
https://www.chesapeakeprogress.com/abundant-life/blue-crab-abundance

(2) WQ Predictions for TMDL are the same as for living resources! False



Vasseur et al. 2014. Increased temperature variation poses a greater risk to species than climate warming. *Proc. Royal Society B, 281*, p.20132612.



Lodge and Weaver (2022) Journal of Marine Science and Engineering 10(8):1117

(3) We cannot do this! False

Available online at www.sciencedirect.com
SCIENCE DIRECT
Environmental Modelling & Software
…l Modelling & Software 21 (2006) 602–614
www.elsevier.com/locate/envsoft

Ecological Modelling 300 (2015) 12–29
Contents lists available at ScienceDirect
Ecological Modelling
journal homepage: www.elsevier.com/locate/ecolmodel
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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]

Environmental Laboratory

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

…7 Coastal Master Plan
…ategy for Selecting Fish Modeling Approaches

Marine and Coastal Fisheries
Dynamics, Management, and Ecosystem Science
Taylor & Francis
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]

frontiers in Marine Science
REVIEW

Modeling Quantitative Value of Habitats for Marine and Estuarine Populations

Dynamic Solutions LLC
THE WATER INSTITUTE OF THE GULF

Vol. 732: 193–221, 2024
https://doi.org/10.3354/meps14535

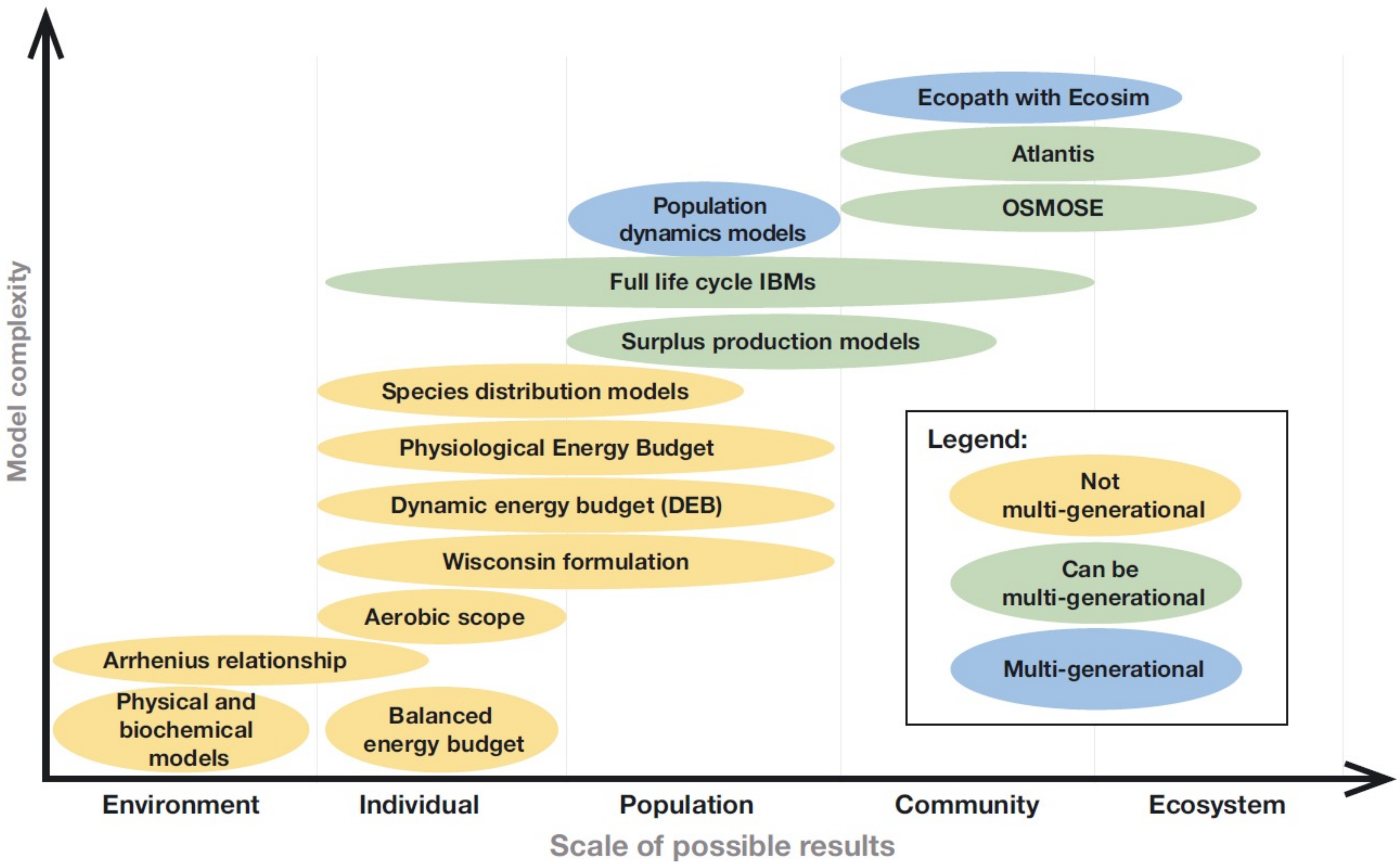
MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published March 20

REVIEW

Advancing bioenergetics-based modeling to improve climate change projections of marine ecosystems

Kenneth A. Rose[1,*], Kirstin Holsman[2], Janet A. Nye[3], Emily H. Markowitz[2], Thomás N. S. Banha[4], Nina Bednaršek[5,26], Juan Bueno-Pardo[6], David Deslauriers[7], Elizabeth A. Fulton[8], Klaus B. Huebert[9], Martin Huret[10], Shin-ichi Ito[11], Stefan Koenigstein[12,13], Lingbo Li[14], Hassan Moustahfid[15], Barbara A. Muhling[12,13], Philipp Neubauer[16], José Ricardo Paula[17,18,19], Elizabeth C. Siddon[20], Morten D. Skogen[21], Paul D. Spencer[2], P. Daniel van Denderen[22], Gro I. van der Meeren[23], Myron A. Peck[24,25]

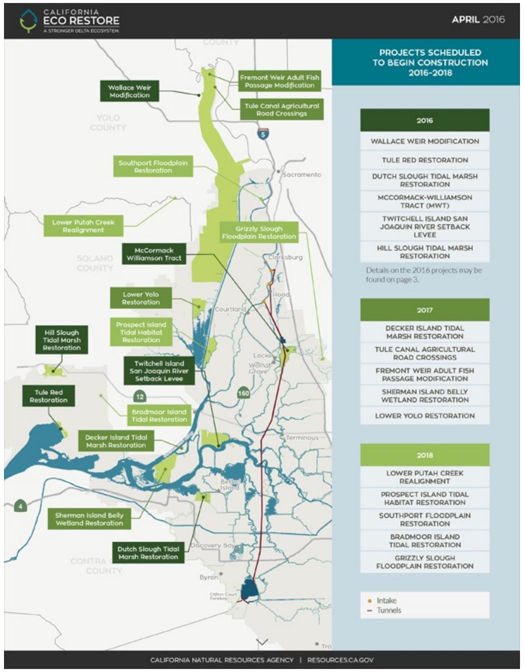


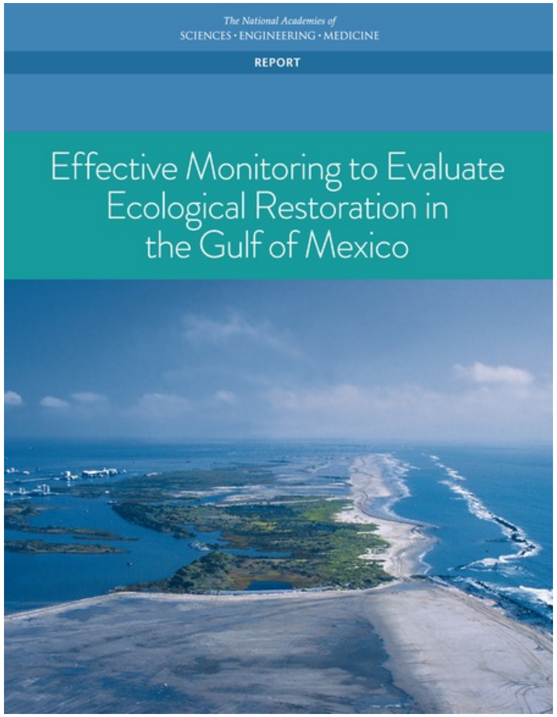
Ecopath with Ecosim
Atlantis
Population dynamics models
OSMOSE
Full life cycle IBMs
Surplus production models
Species distribution models
Physiological Energy Budget
Dynamic energy budget (DEB)
Wisconsin formulation
Aerobic scope
Arrhenius relationship
Physical and biochemical models
Balanced energy budget
Legend:
Not multi-generational
Can be multi-generational
Multi-generational
Model complexity
Environment
Individual
Population
Community
Ecosystem
Scale of possible results

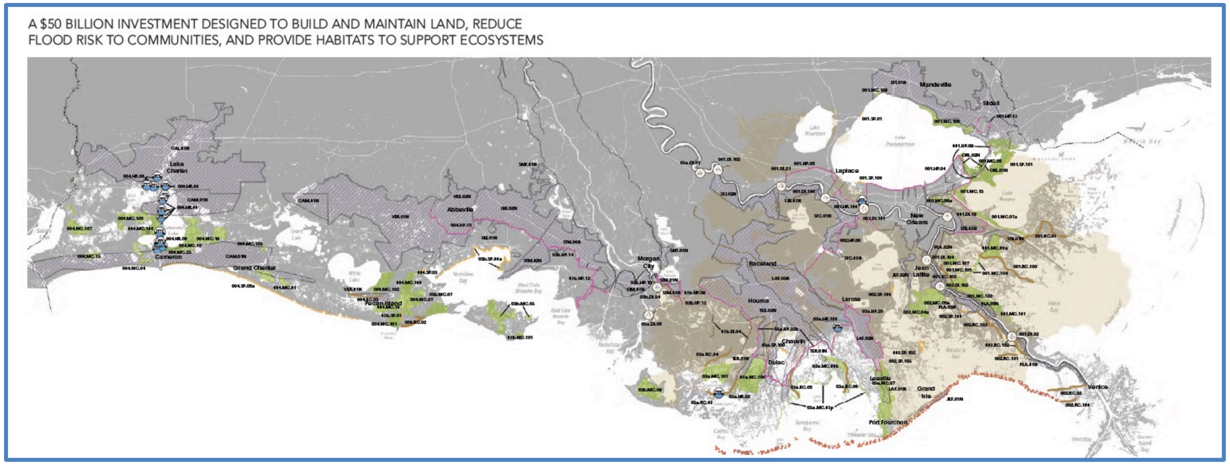
Existing links WQ/Habitat to LR

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

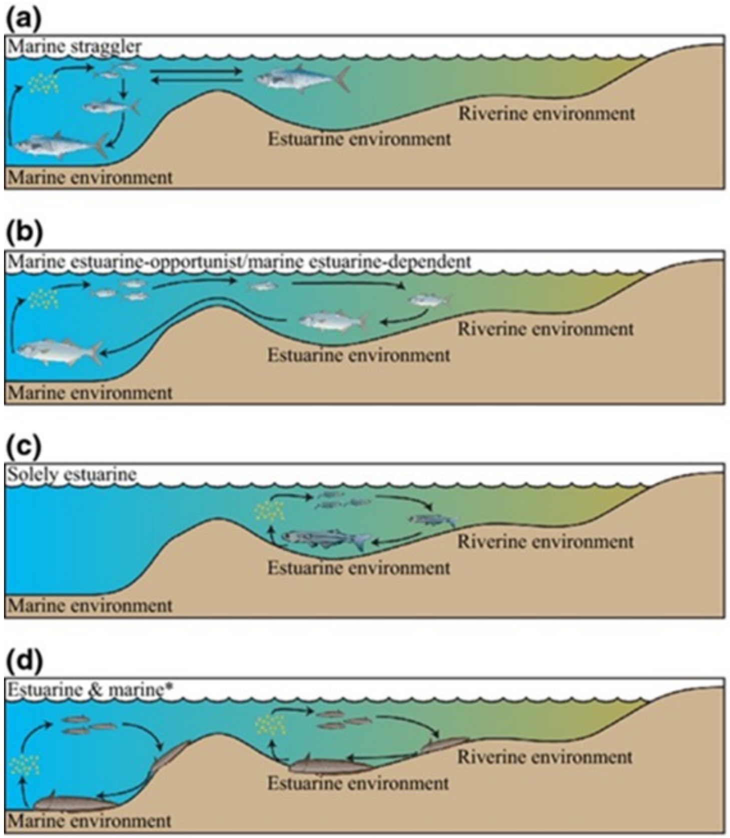
(4) Chesapeake Bay is unique! False

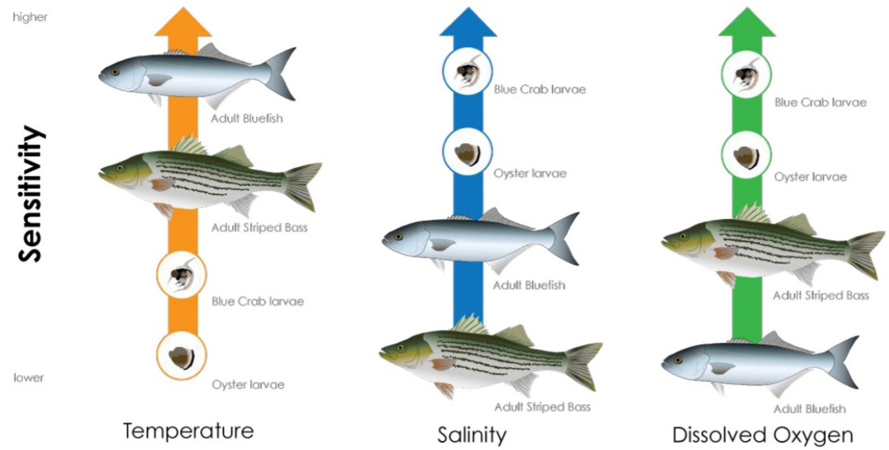


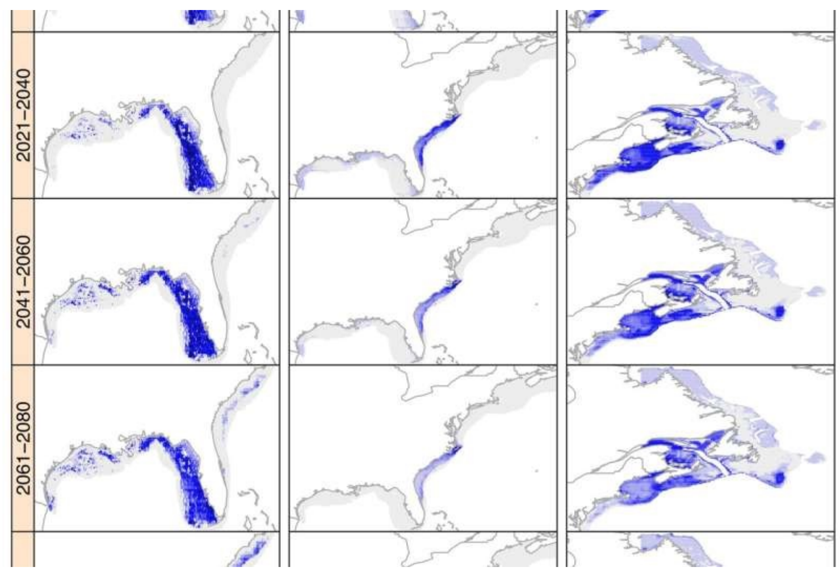




(5) A universal fish response! False

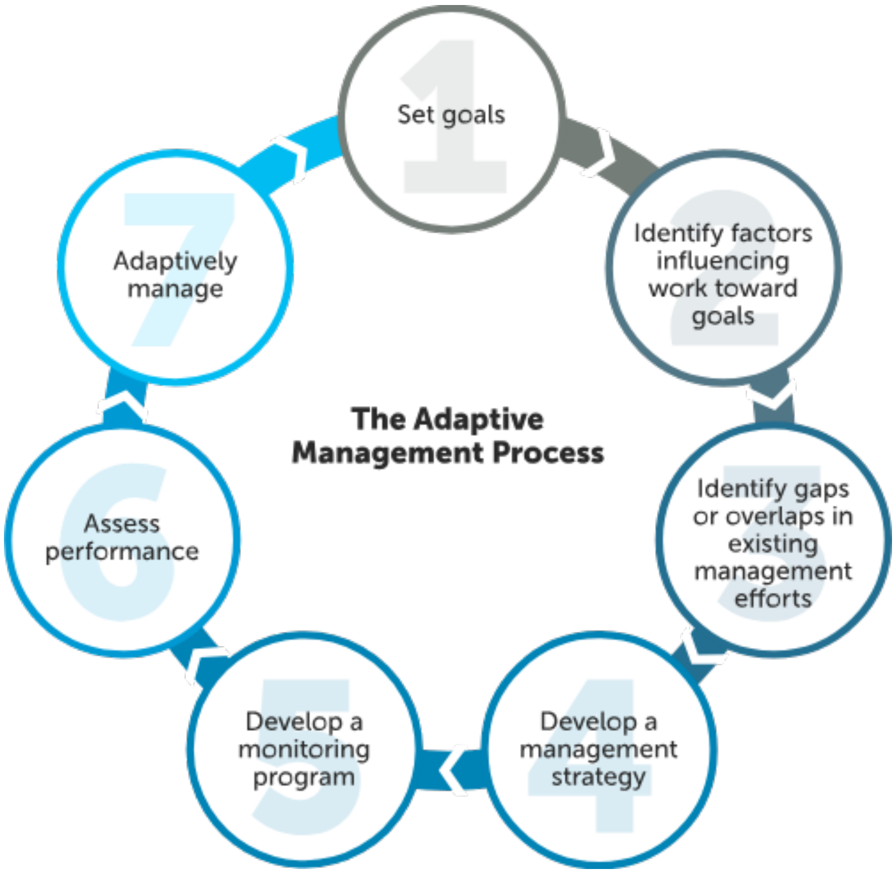


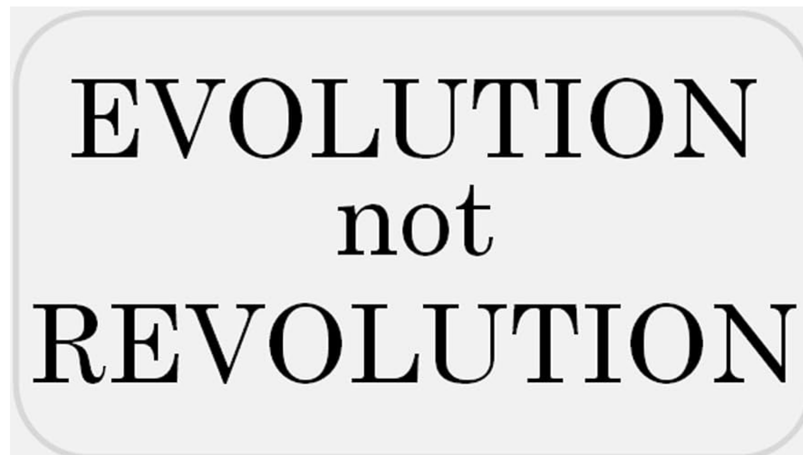




https://phys.org/news/2018-05-climate-shift-fish-species-north.html

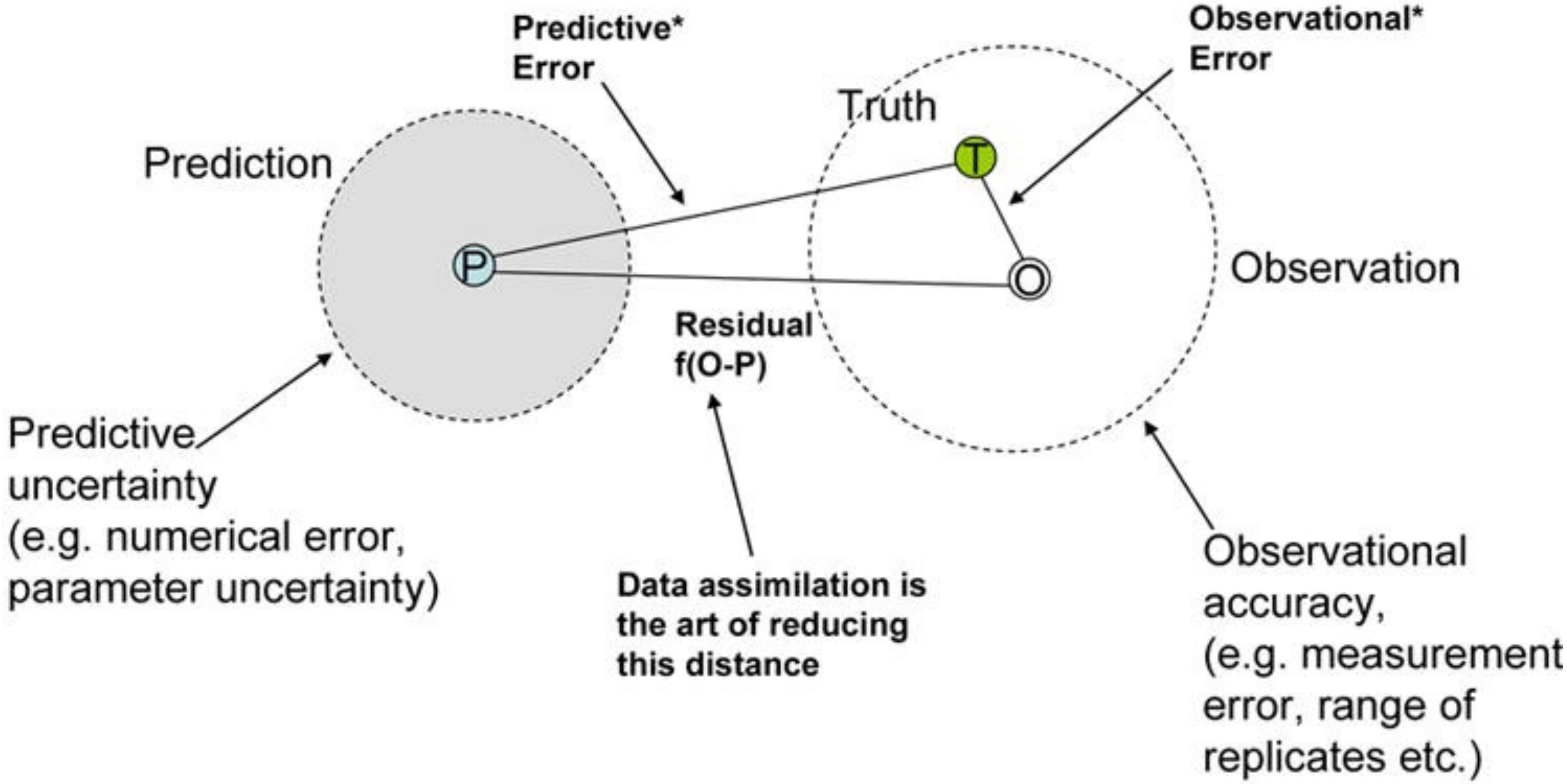
(6) CESR said to abandon the deep trench, TMDL, etc.! False





https://www.chesapeakebay.net/what/what-guides-us/decisions

(7) Data are truth! False



Stow et al. 2009

Ecological Modelling 264 (2013) 98–114

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Ecological Modelling

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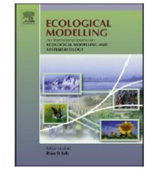
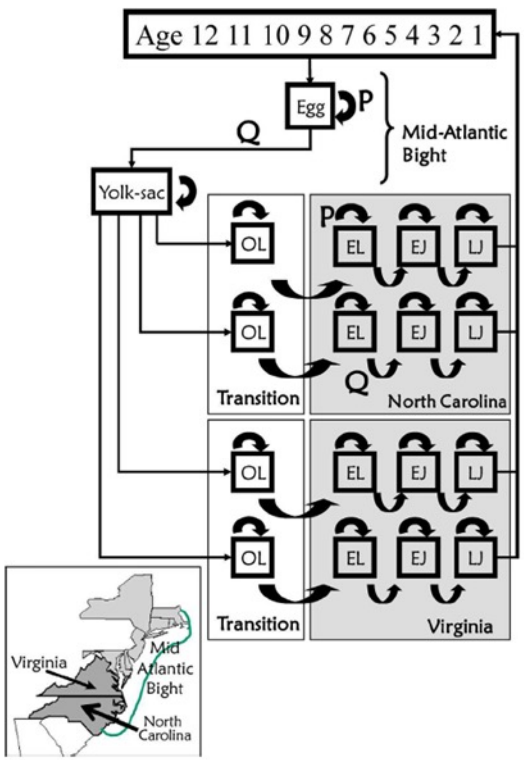
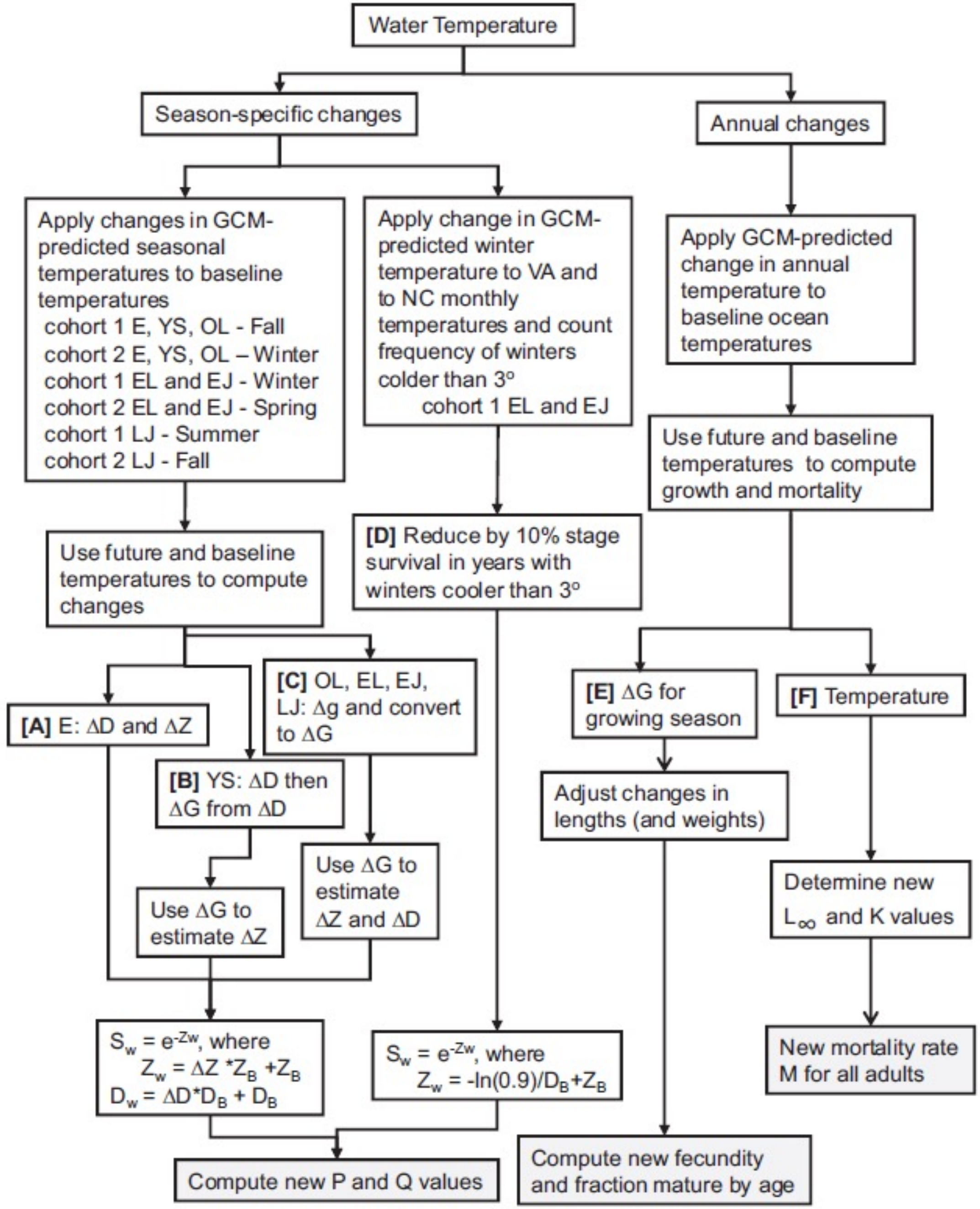


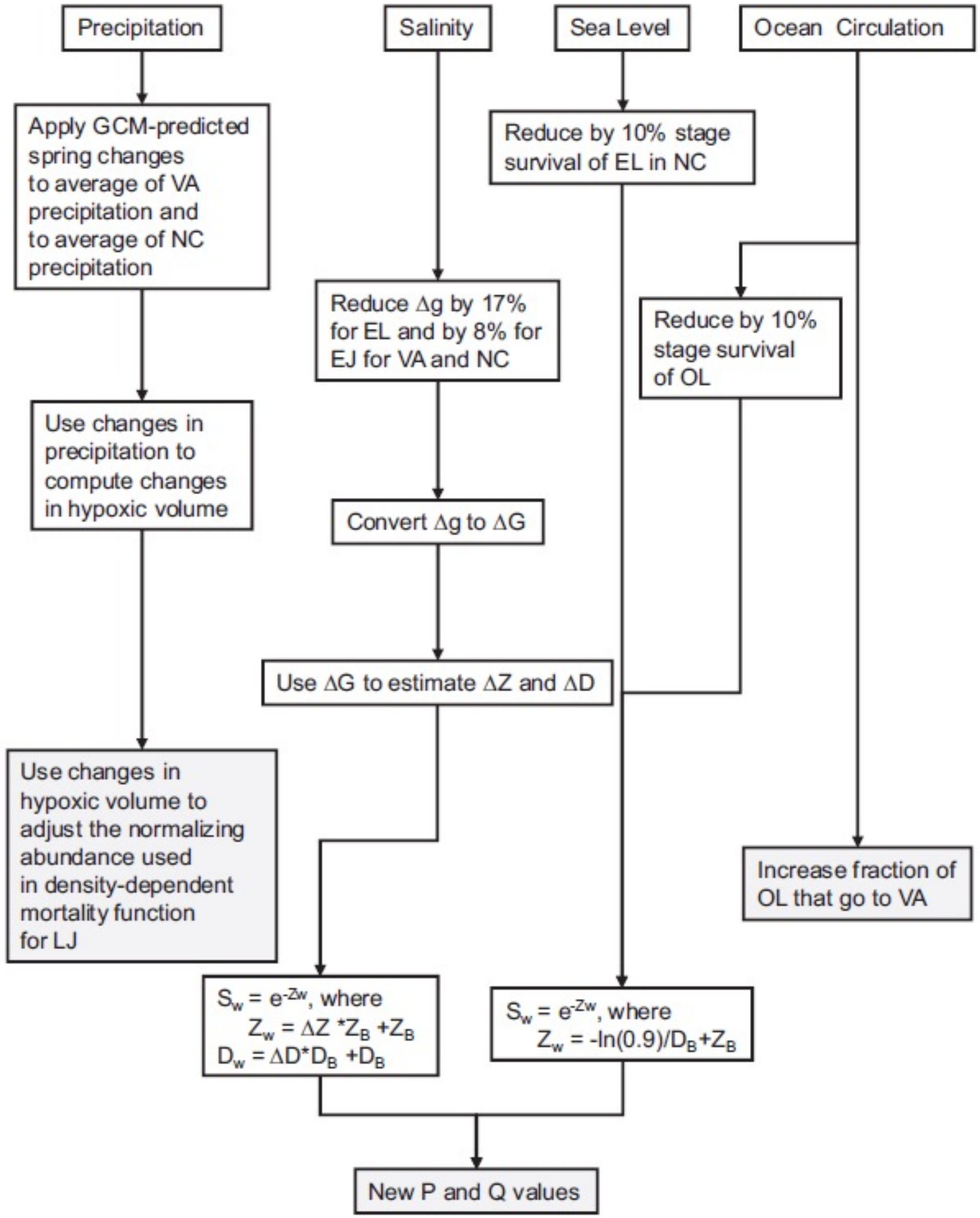
Simulating the effects of global climate change on Atlantic croaker population dynamics in the mid-Atlantic Region

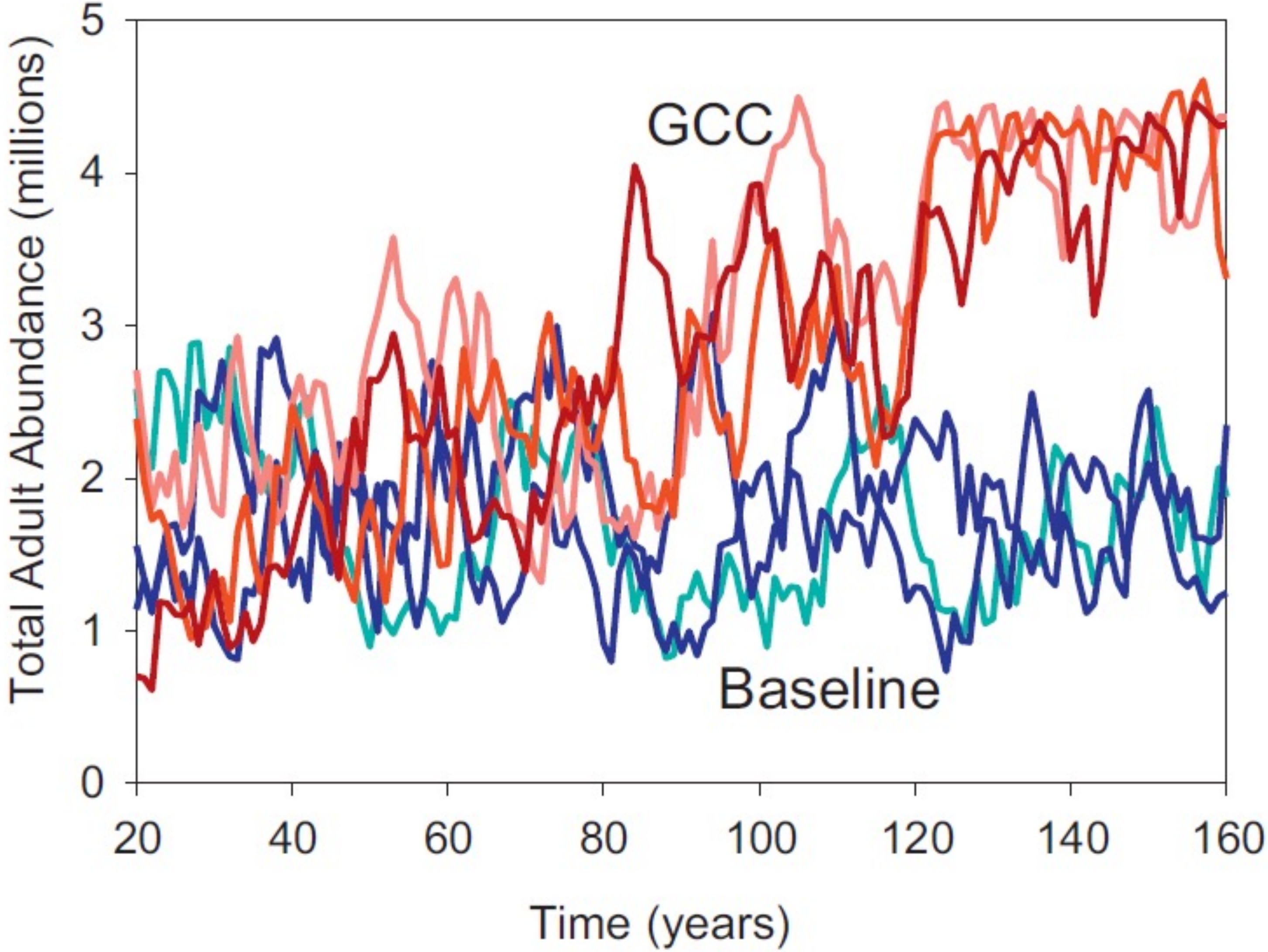
Sandra L. Diamond[a,*,1], Cheryl A. Murphy[b], Kenneth A. Rose[c]



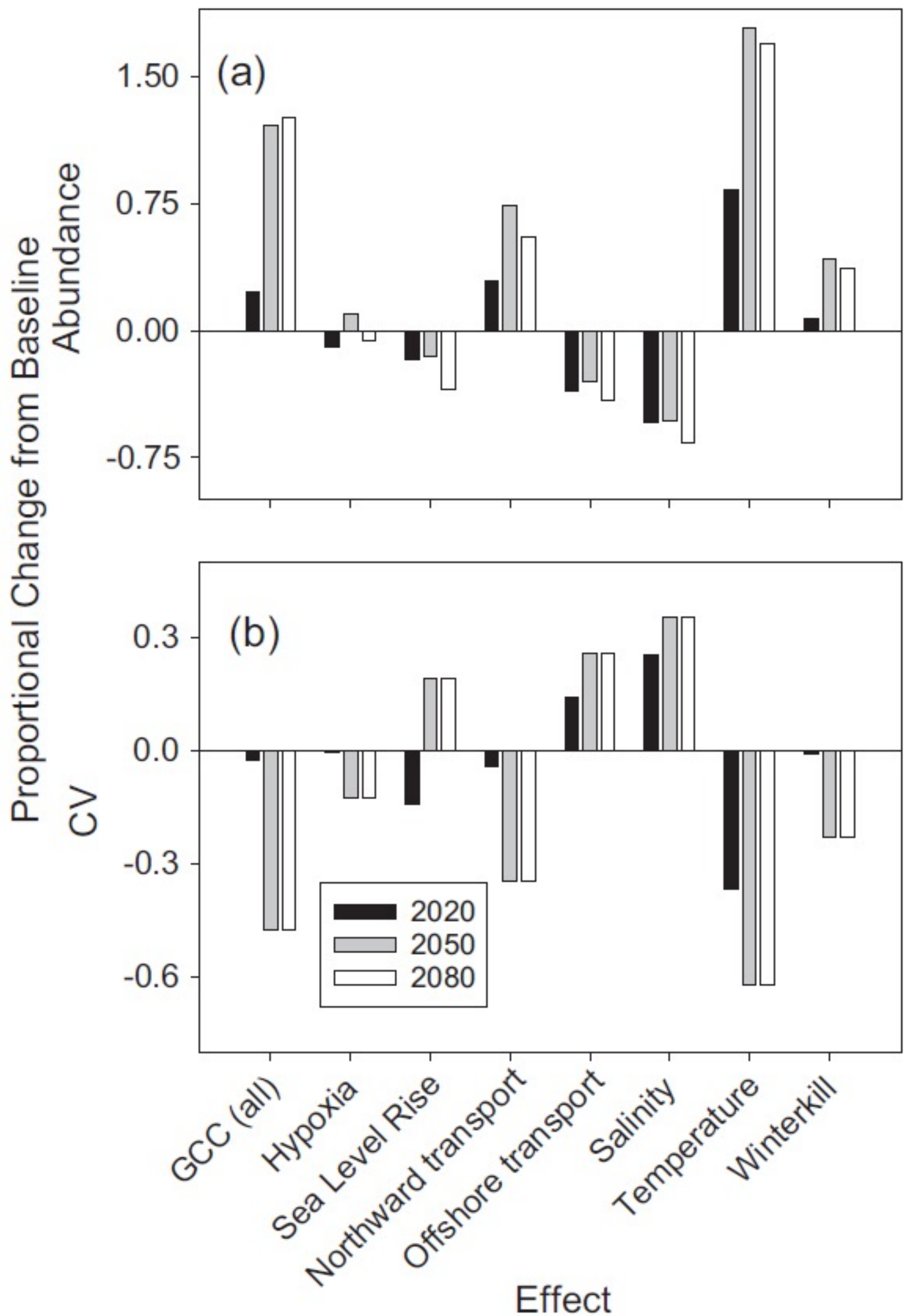
Stage	Baseline		2020		2050		2080	
	P	*Q*	*P*	*Q*	*P*	*Q*	*P*	*Q*
Virginia–Cohort 1								
Eggs	0.191	0.507	0.144	0.513	0.099	0.503	0.041	0.486
YS	0.748	0.116	0.733	0.123	0.715	0.131	0.689	0.143
OL	0.093	0.008	0.075	0.007	0.060	0.007	0.044	0.007
EL	0.204	0.142	0.246	0.121	0.217	0.125	0.183	0.131
EJ	0.581	0.049	0.582	0.046	0.579	0.054	0.575	0.066
Virginia–Cohort 2								
Eggs	0.390	0.308	0.370	0.284	0.340	0.266	0.303	0.242
YS	0.871	0.059	0.862	0.063	0.853	0.067	0.842	0.072
OL	0.191	0.007	0.163	0.006	0.144	0.007	0.122	0.007
EL	0.385	0.110	0.411	0.095	0.378	0.100	0.330	0.108
EJ	0.565	0.065	0.565	0.065	0.559	0.078	0.548	0.100
North Carolina–Cohort 1								
Eggs	0.0	0.728	0.0	0.705	0.0	0.685	0.0	0.658
YS	0.633	0.169	0.611	0.179	0.590	0.189	0.560	0.203
OL	0.125	0.008	0.102	0.007	0.081	0.007	0.070	0.007
EL	0.321	0.122	0.370	0.102	0.352	0.104	0.326	0.108
EJ	0.588	0.042	0.589	0.037	0.588	0.041	0.586	0.048
North Carolina–Cohort 2								
Eggs	0.236	0.462	0.192	0.475	0.169	0.469	0.137	0.459
YS	0.768	0.107	0.757	0.112	0.748	0.116	0.734	0.122
OL	0.141	0.007	0.122	0.007	0.111	0.007	0.097	0.007
EL	0.465	0.097	0.506	0.080	0.491	0.083	0.466	0.087
EJ	0.594	0.036	0.595	0.031	0.594	0.036	0.593	0.043


Water Temperature
Season-specific changes
Annual changes
Apply changes in GCM-predicted seasonal temperatures to baseline temperatures
cohort 1 E, YS, OL - Fall
cohort 2 E, YS, OL – Winter
cohort 1 EL and EJ - Winter
cohort 2 EL and EJ - Spring
cohort 1 LJ - Summer
cohort 2 LJ - Fall
Apply change in GCM-predicted winter temperature to VA and to NC monthly temperatures and count frequency of winters colder than 3°
cohort 1 EL and EJ
Apply GCM-predicted change in annual temperature to baseline ocean temperatures
Use future and baseline temperatures to compute growth and mortality
Use future and baseline temperatures to compute changes
[D] Reduce by 10% stage survival in years with winters cooler than 3°
[A] E: ΔD and ΔZ
[C] OL, EL, EJ, LJ: Δg and convert to ΔG
[B] YS: ΔD then ΔG from ΔD
[E] ΔG for growing season
[F] Temperature
Adjust changes in lengths (and weights)
Use ΔG to estimate ΔZ and ΔD
Use ΔG to estimate ΔZ
Determine new L∞ and K values
S_w = e^-Zw, where Z_w = ΔZ *Z_B +Z_B D_w = ΔD*D_B + D_B
S_w = e^-Zw, where Z_w = -ln(0.9)/D_B+Z_B
New mortality rate M for all adults
Compute new P and Q values
Compute new fecundity and fraction mature by age

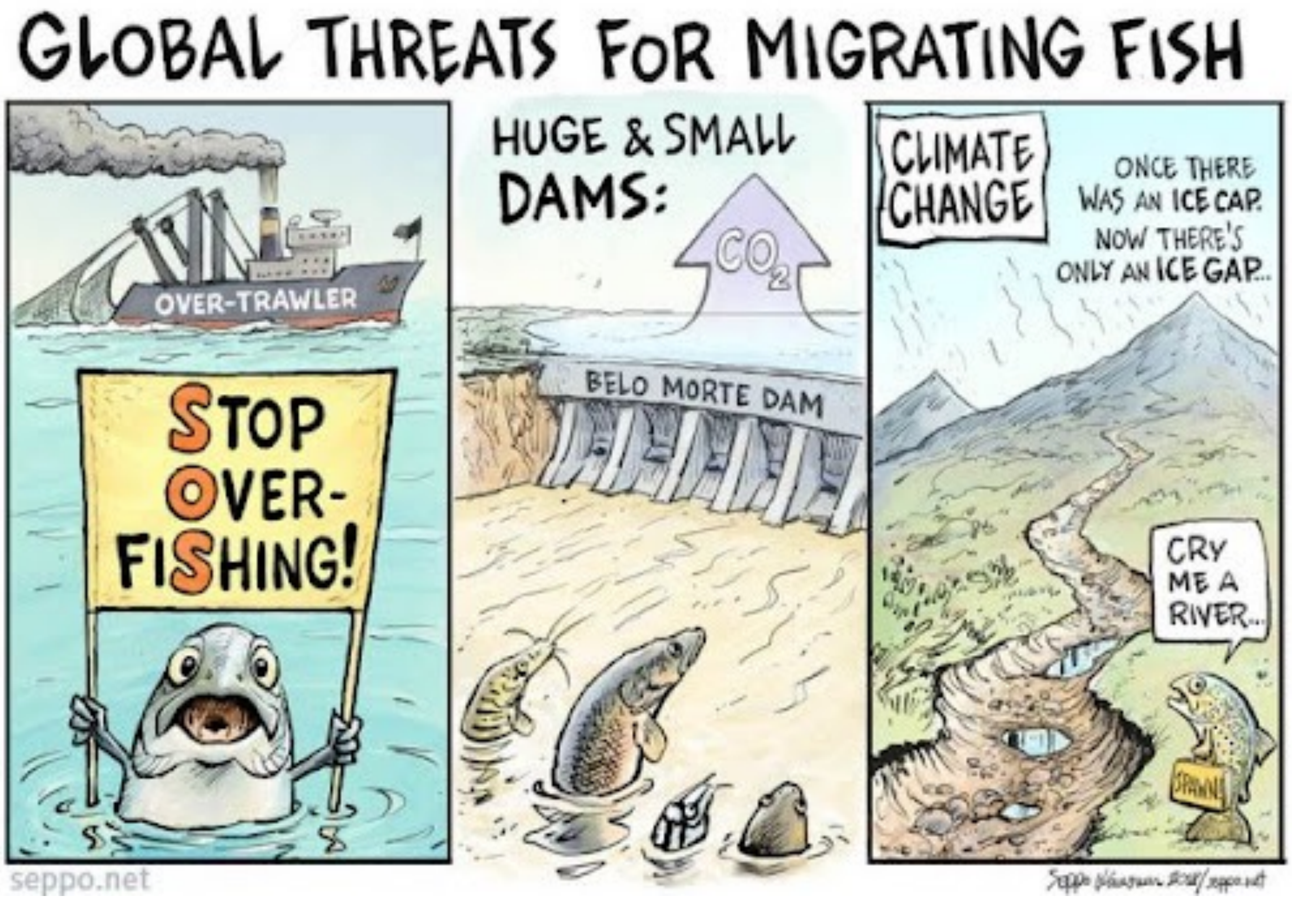

Precipitation
Salinity
Sea Level
Ocean Circulation
Apply GCM-predicted spring changes to average of VA precipitation and to average of NC precipitation
Reduce by 10% stage survival of EL in NC
Reduce Δg by 17% for EL and by 8% for EJ for VA and NC
Reduce by 10% stage survival of OL
Use changes in precipitation to compute changes in hypoxic volume
Convert Δg to ΔG
Use ΔG to estimate ΔZ and ΔD
Use changes in hypoxic volume to adjust the normalizing abundance used in density-dependent mortality function for LJ
Increase fraction of OL that go to VA
$S_w = e^{-Z_w}$, where $Z_w = \Delta Z * Z_B + Z_B$ $D_w = \Delta D * D_B + D_B$
$S_w = e^{-Z_w}$, where $Z_w = -\ln(0.9)/D_B + Z_B$
New P and Q values



Total Adult Abundance (millions)
5
4
3
2
1
0
GCC
Baseline
20
40
60
80
100
120
140
160
Time (years)



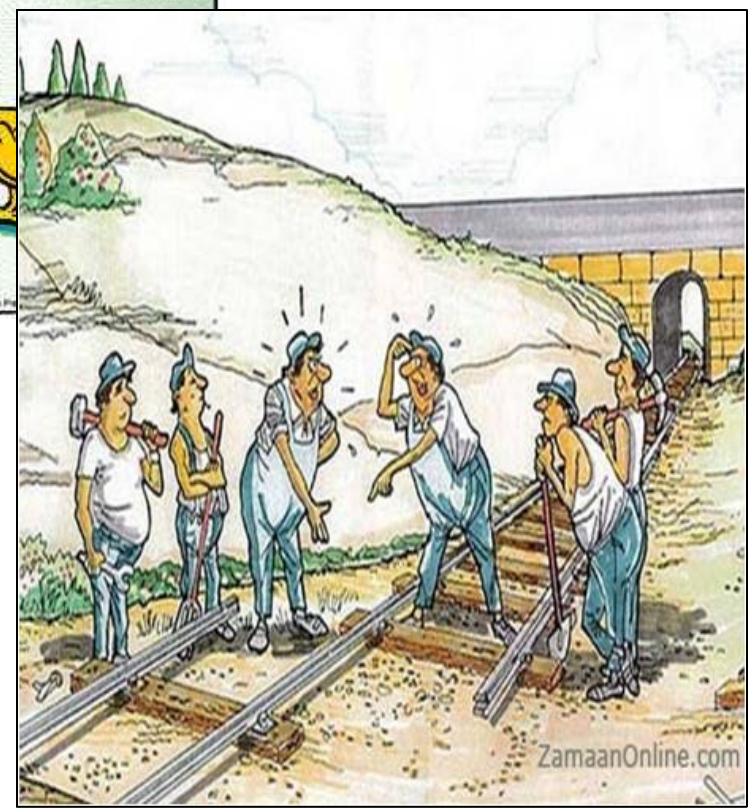
(a)
(b)
Proportional Change from Baseline
Abundance
CV
1.50
0.75
0.00
-0.75
0.3
0.0
-0.3
-0.6
2020
2050
2080
GCC (all)
Hypoxia
Sea Level Rise
Northward transport
Offshore transport
Salinity
Temperature
Winterkill
Effect


GLOBAL THREATS FOR MIGRATING FISH
OVER-TRAWLER
STOP OVER-FISHING!
HUGE & SMALL DAMS:
CO_2
BELO MORTE DAM
CLIMATE CHANGE
ONCE THERE WAS AN ICE CAP. NOW THERE'S ONLY AN ICE GAP...
CRY ME A RIVER...
SPAWN!
seppo.net

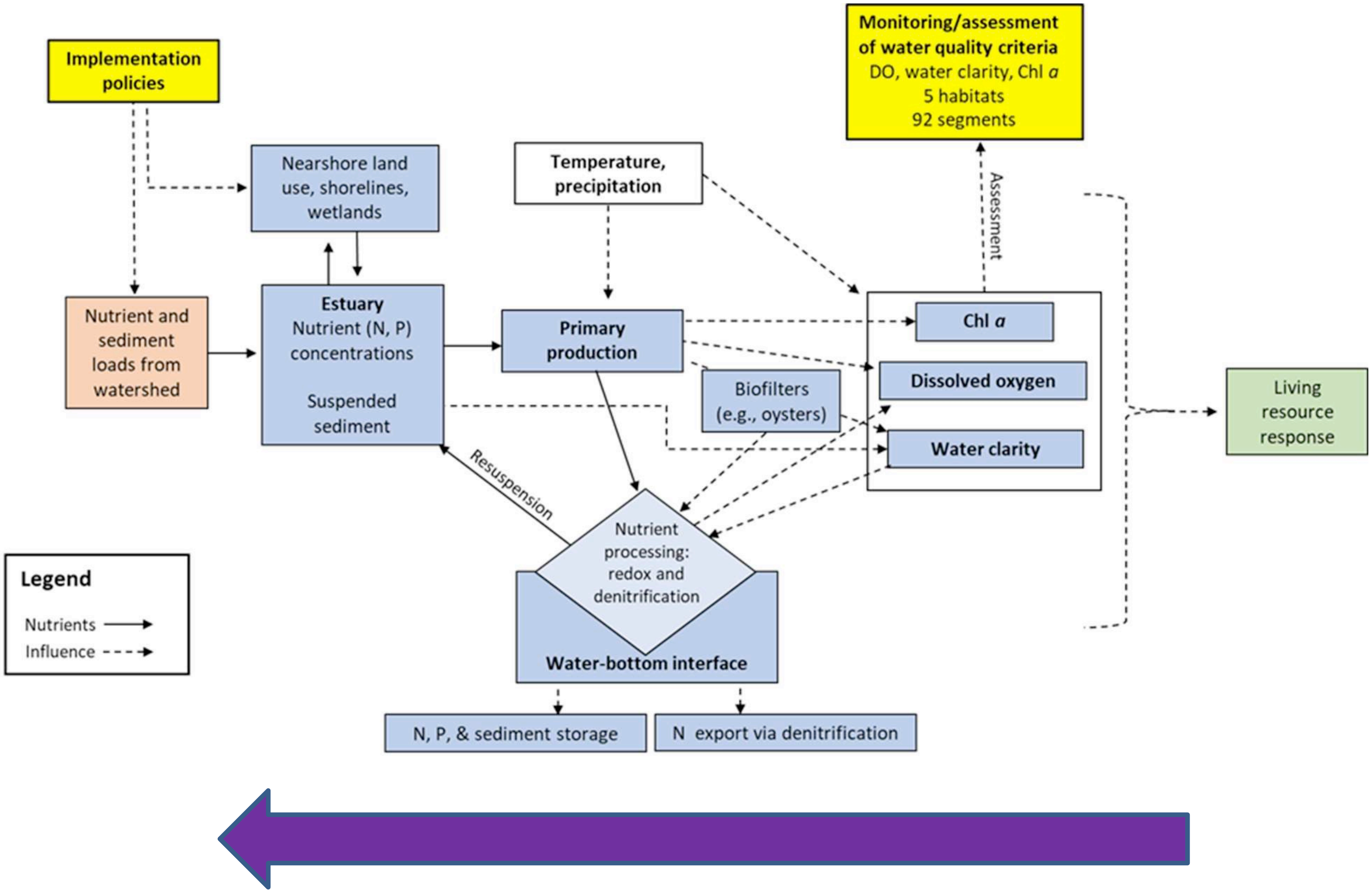
This Workshop: Reverse the Situation

https://drawception.com/game/CLL92bSp5m/batman-and-joker-swap-roles/

Challenge: Thought Experiment



http://be-sciencetaskcards.weebly.com/digital-task-card-3.html



Implementation policies
Monitoring/assessment of water quality criteria
DO, water clarity, Chl a
5 habitats
92 segments
Nearshore land use, shorelines, wetlands
Temperature, precipitation
Assessment
Nutrient and sediment loads from watershed
Estuary
Nutrient (N, P) concentrations
Suspended sediment
Primary production
Chl a
Dissolved oxygen
Biofilters (e.g., oysters)
Water clarity
Living resource response
Resuspension
Nutrient processing: redox and denitrification
Water-bottom interface
Legend
Nutrients
Influence
N, P, & sediment storage
N export via denitrification

https://stock.adobe.com/search?k=train+station+cartoon

(a) A typical thermal performance curve (TPC) for relative performance (fitness or a proximate
(b) biological rate; black line) as a function of environmental temperature (equation (2.1)). T_{opt} marks
(c) the temperature at which performance is greatest and T_{max} marks the critical transition to negative
(d) values at high temperatures. Owing to the nonlinearity of this curve, species that experience temporal
(e) variation in temperature will have a mean long-term performance $\langle w \rangle$ that differs from the value
(f) predicted by the mean of their environment (owing to Jensen's inequality). The distribution of instantaneous
(g) performance and long-term performance means are shown for nominal 'cold' and 'warm' temperature
(h) distributions (*b,e*), distributions with increased variance (*c,f*) and distributions with positive skewness (*d,g*).
(i) In 'cold' conditions, increasing the variance leads to an increase in long-term performance, whereas
(j) positive skewness has little effect. In 'warm' conditions, increasing variances and positive skewness both
(k) lead to reductions in long-term performance.
(l) The mean temperatures of 'cold' and 'warm' distributions are equal [**17,24**] across (*b*)–(*d*); variance is equal for (*b*) and