STAC Workshop
Climate Change Modeling 3.0

Arlington VA, May 7-9, 2024

Gary Shenk - CBPO

STAC Meeting 6/4/2024

Total Maximum Daily Load (TMDL)

What management practices…

…. will reduce nitrogen, phosphorus, and sediment to levels …

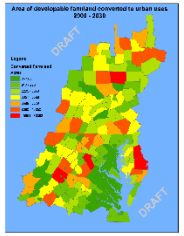
…. that will achieve levels of dissolved oxygen, clarity, and chlorophyll in the Bay…

… that are supportive of living resources?

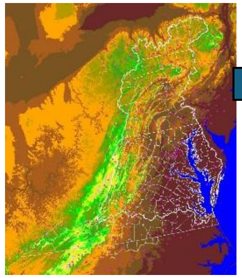
Photo credit: CBP

CBP Decision Support System

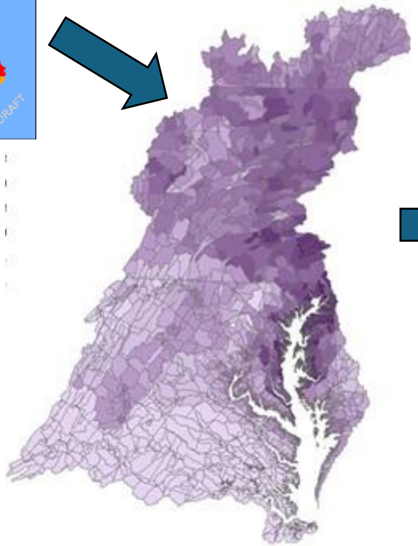
Land Use
Change Model



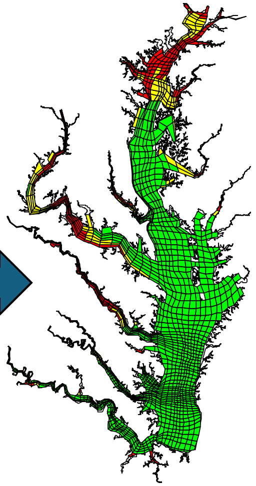
Atmospheric
Model



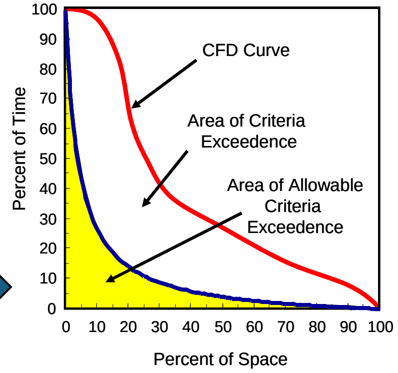
Watershed
Model
(CAST)



Estuary
Model



Criteria
Assessment
Procedures



What management practices…

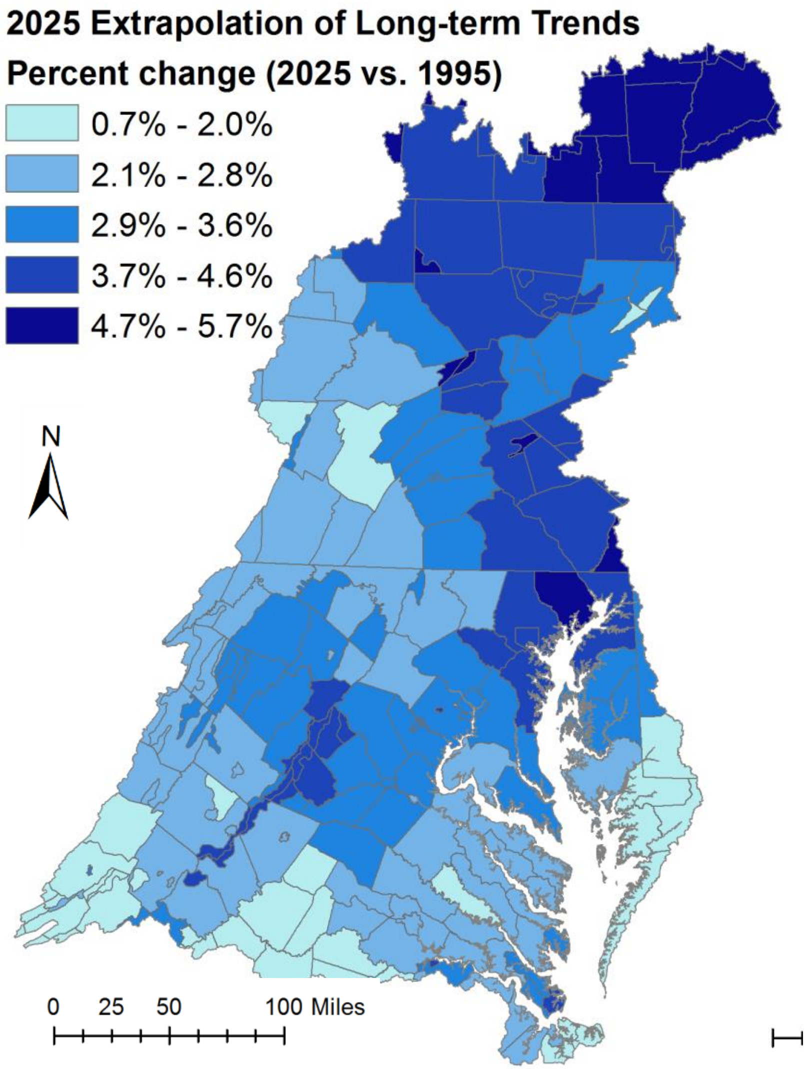
…. will reduce nitrogen and phosphorus to levels …

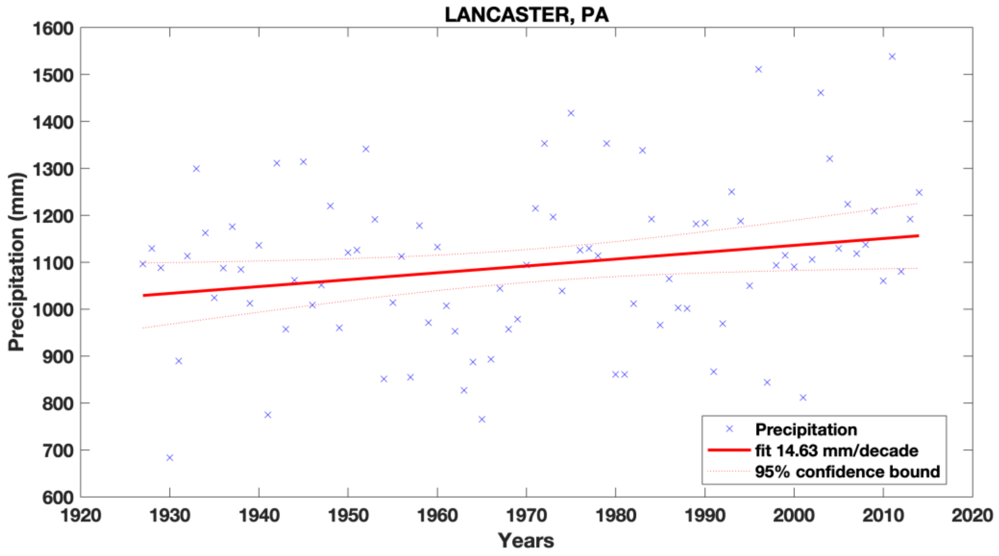
…. that will achieve appropriate dissolved oxygen, clarity, and chlorophyll in the Bay?

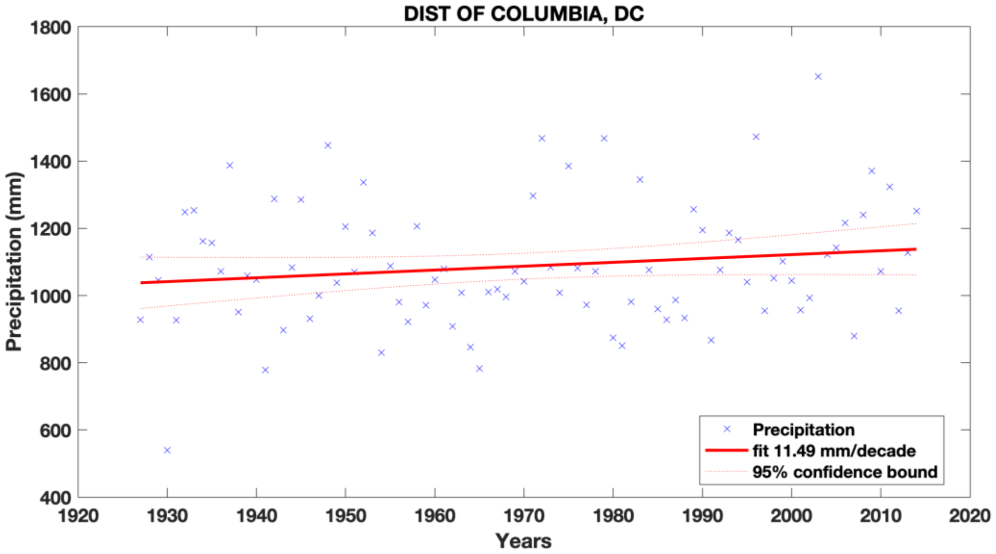
TMDL Incorporation of Climate Change

- 2010 TMDL – climate change mentioned, but not incorporated
- 2017 re-evaluation
  - Intention to incorporate climate change
  - 2016 STAC climate modeling workshop informed climate projections

Long-term trends in historical observations

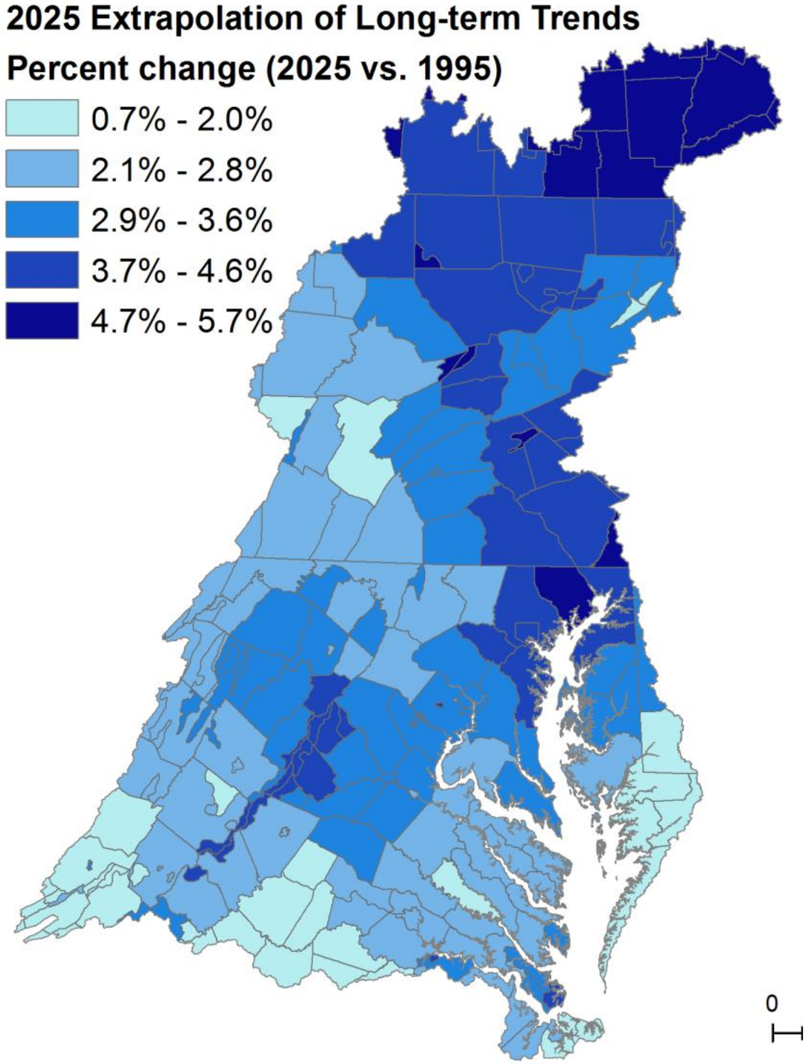




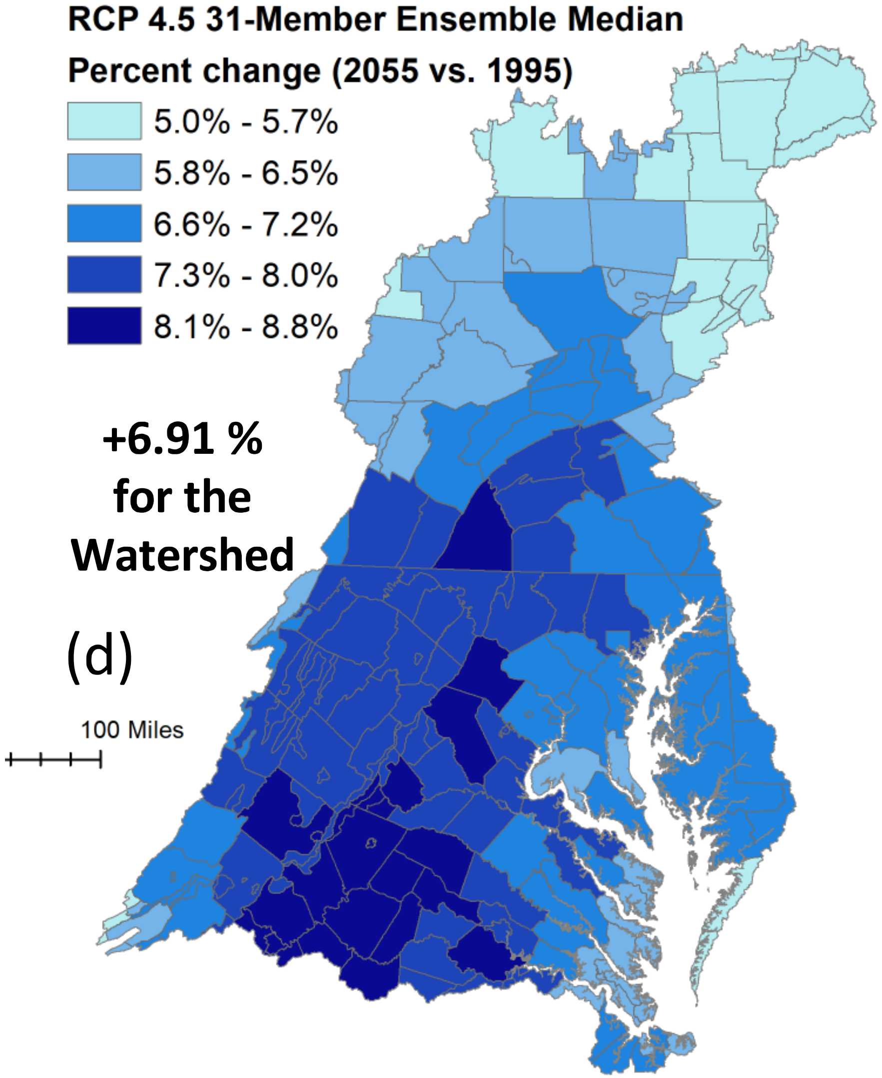


Long-term trends in historical observations

2025

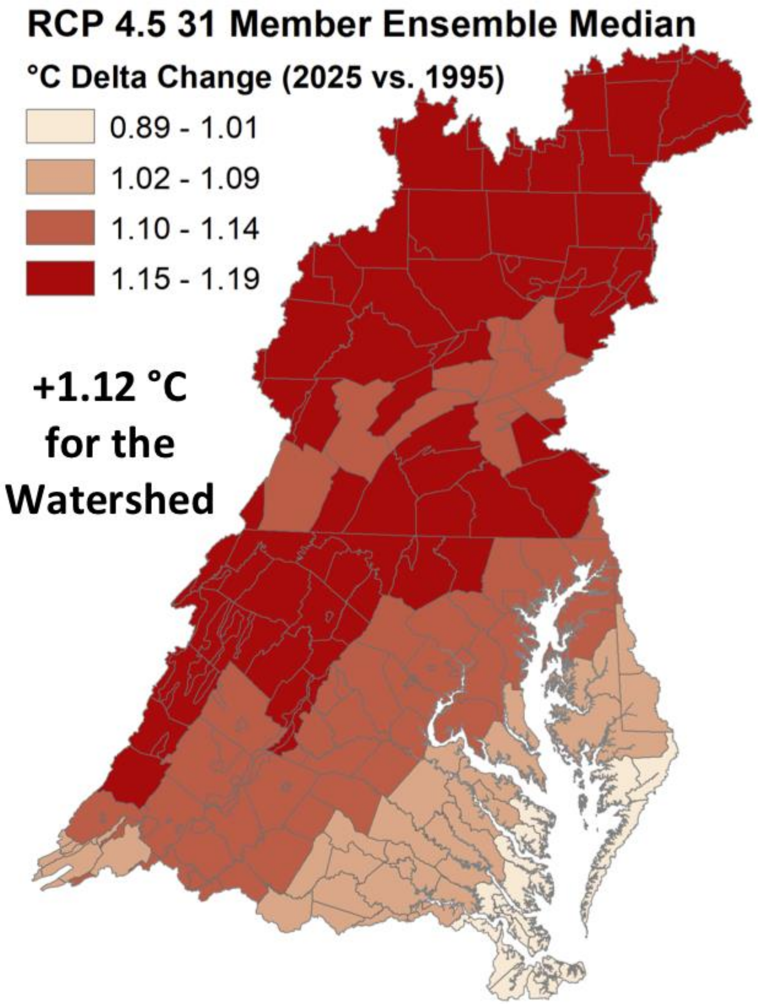


2055

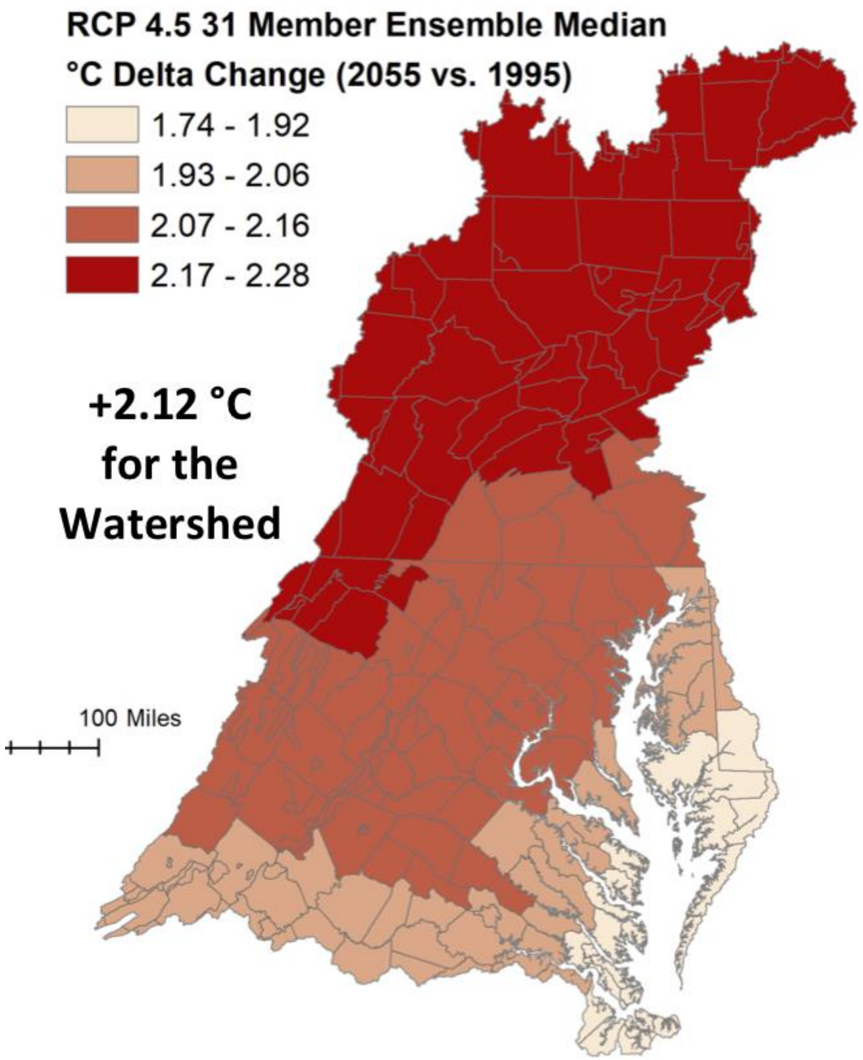


Estimated change in mean annual temperature

2025



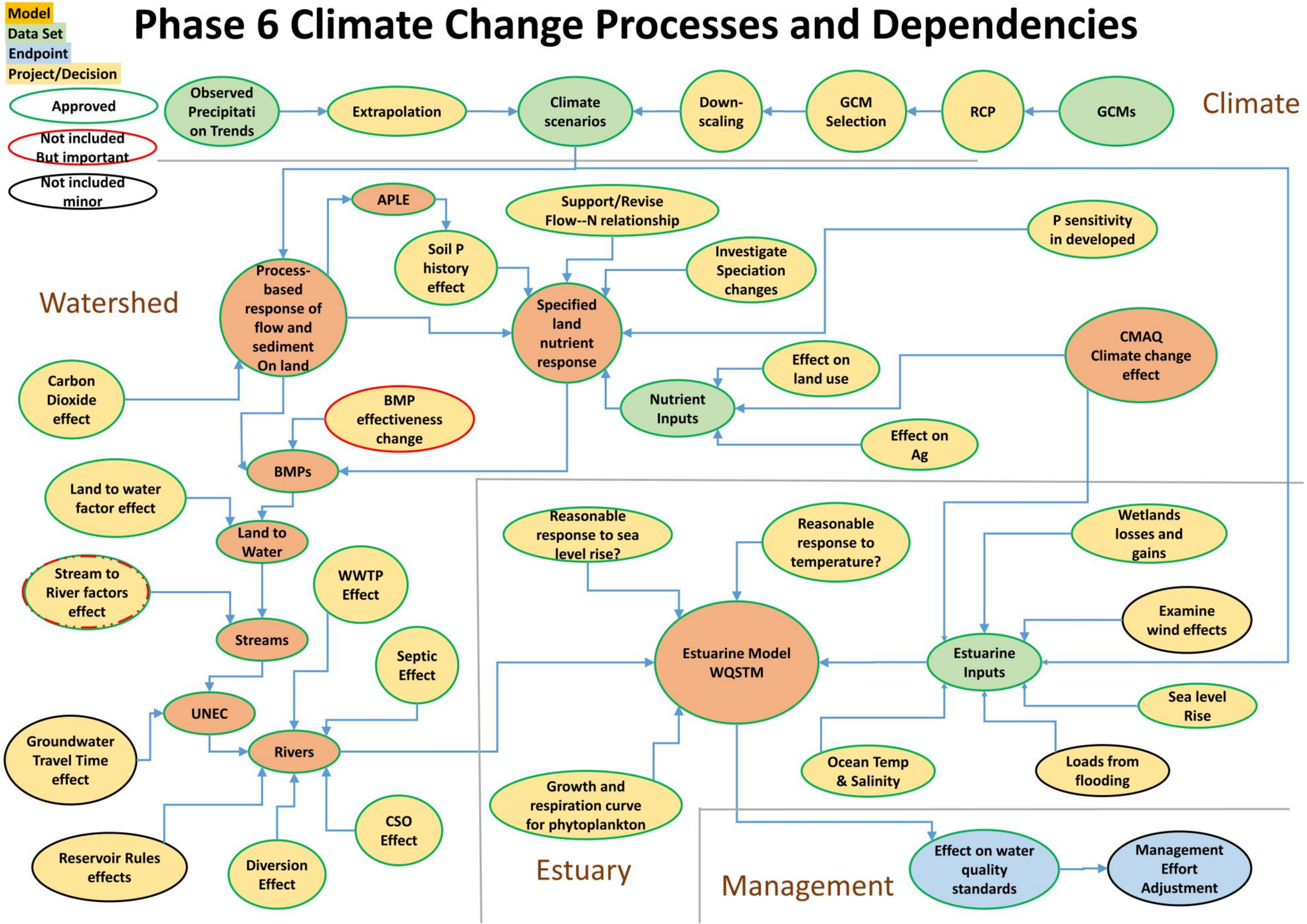
2055



TMDL Incorporation of Climate Change

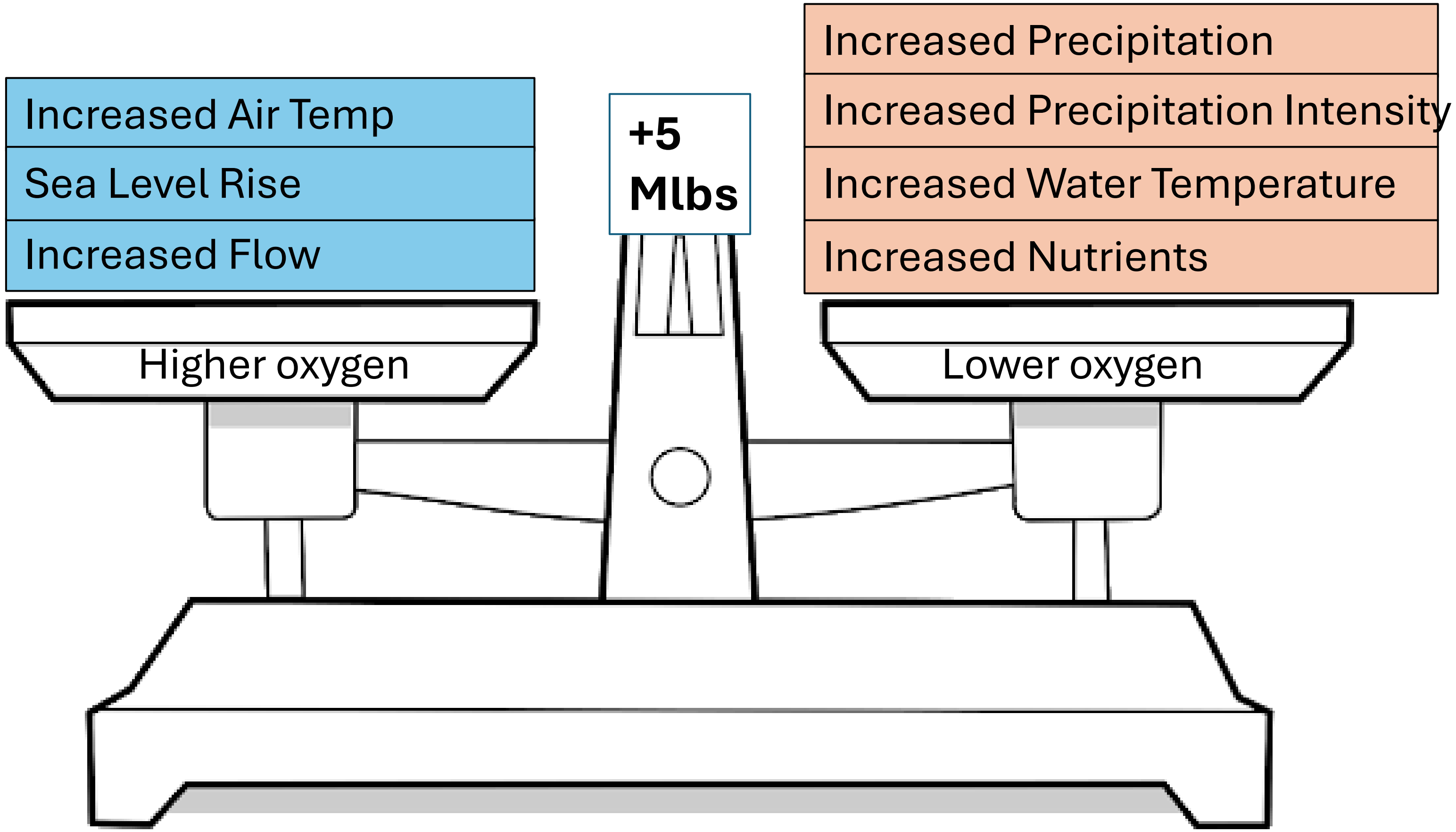
- 2017 re-evaluation
  - Too much uncertainty in response – pushed to 2020
- 2021 climate effects incorporation
  - 2018 STAC climate modeling 2.0 workshop – list of improvements
  - Improvements made in 2019

Phase 6 Climate Change Processes and Dependencies



- Checklist of 21 activities for the CBP modeling team

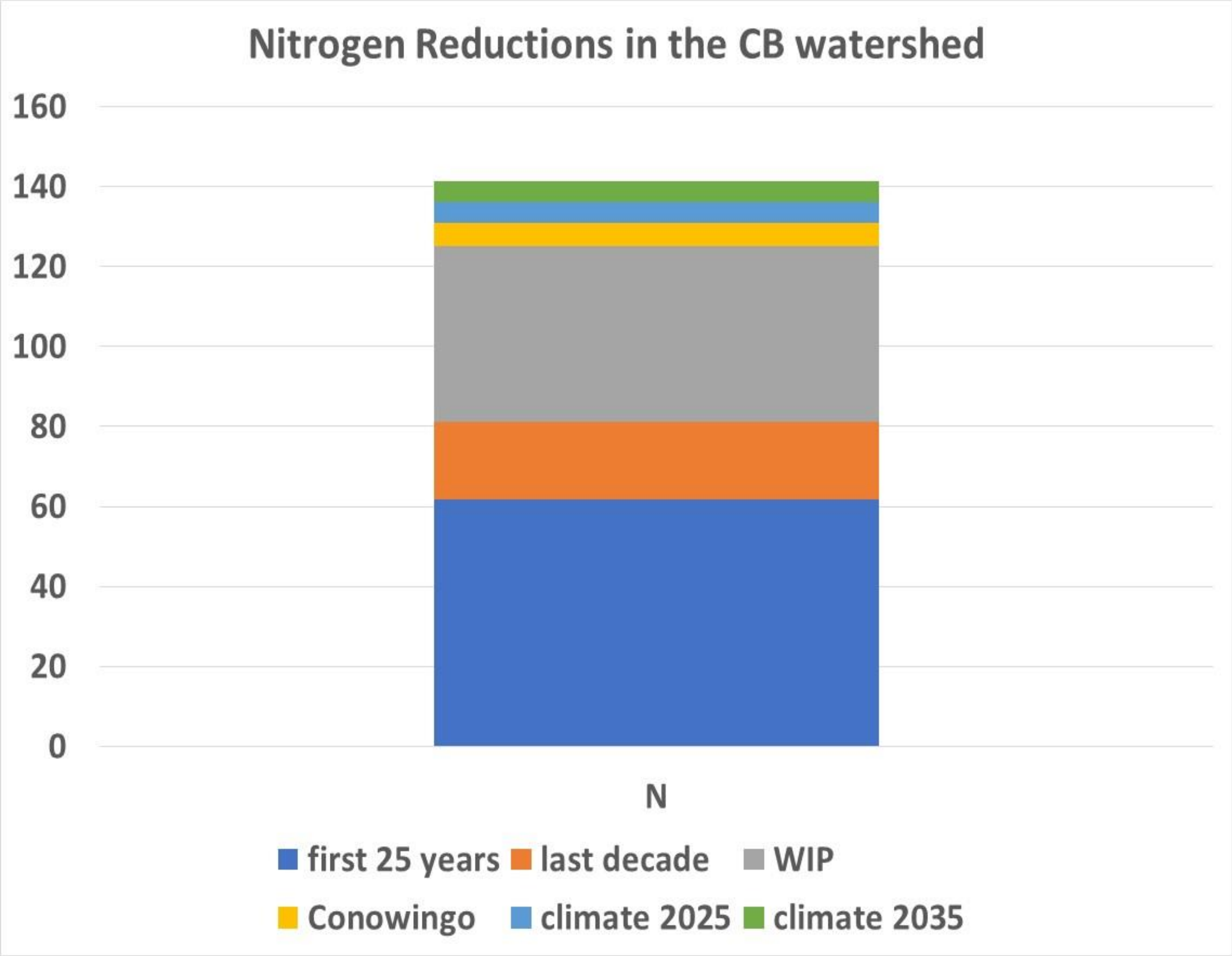
Balance of effects – Science Question

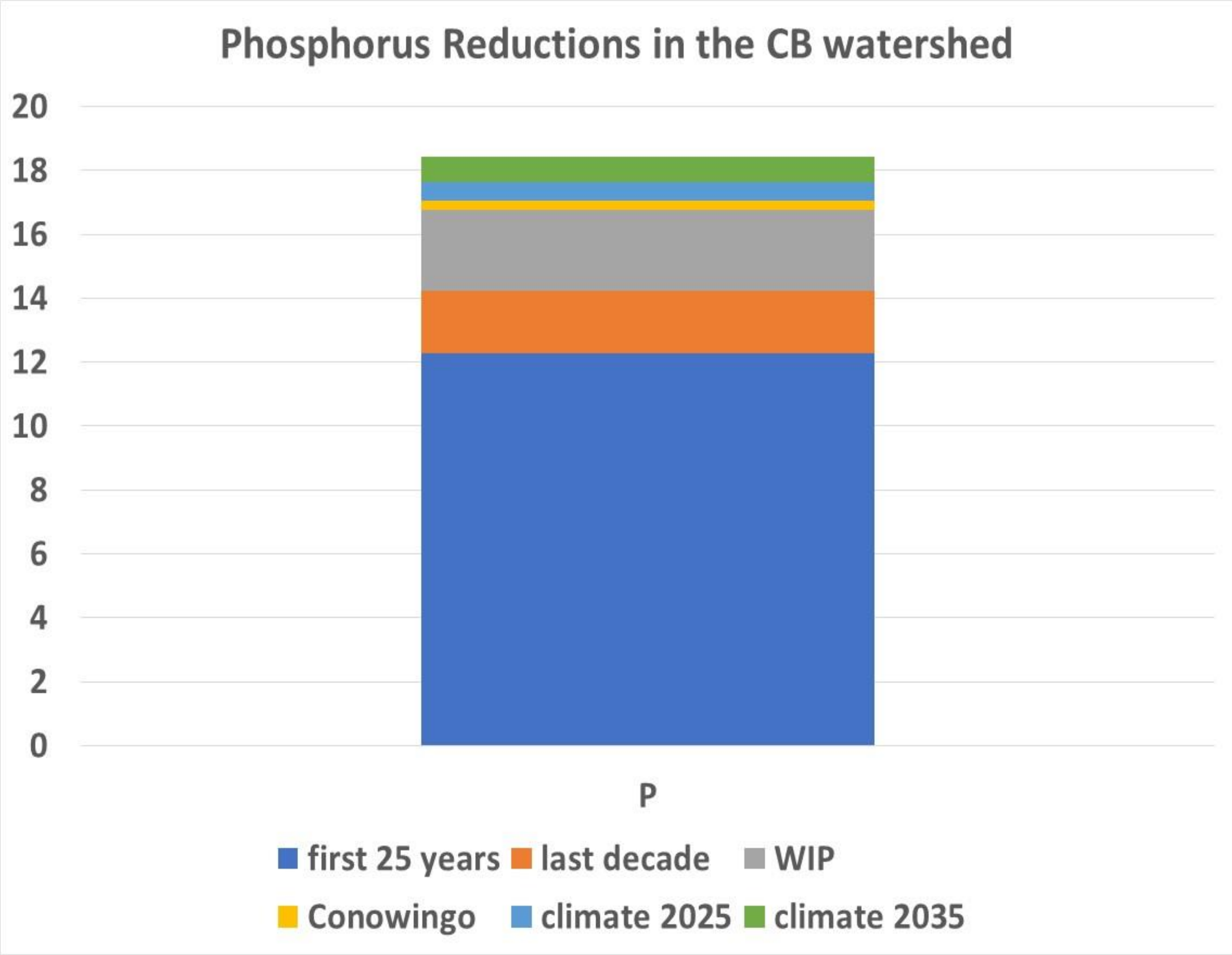


CBP studied 21 different effects producing an overall lower level of oxygen

Modeled load reductions from CAST-2019

Climate effects in perspective





2021 Climate Decision – Principals' Staff Committee

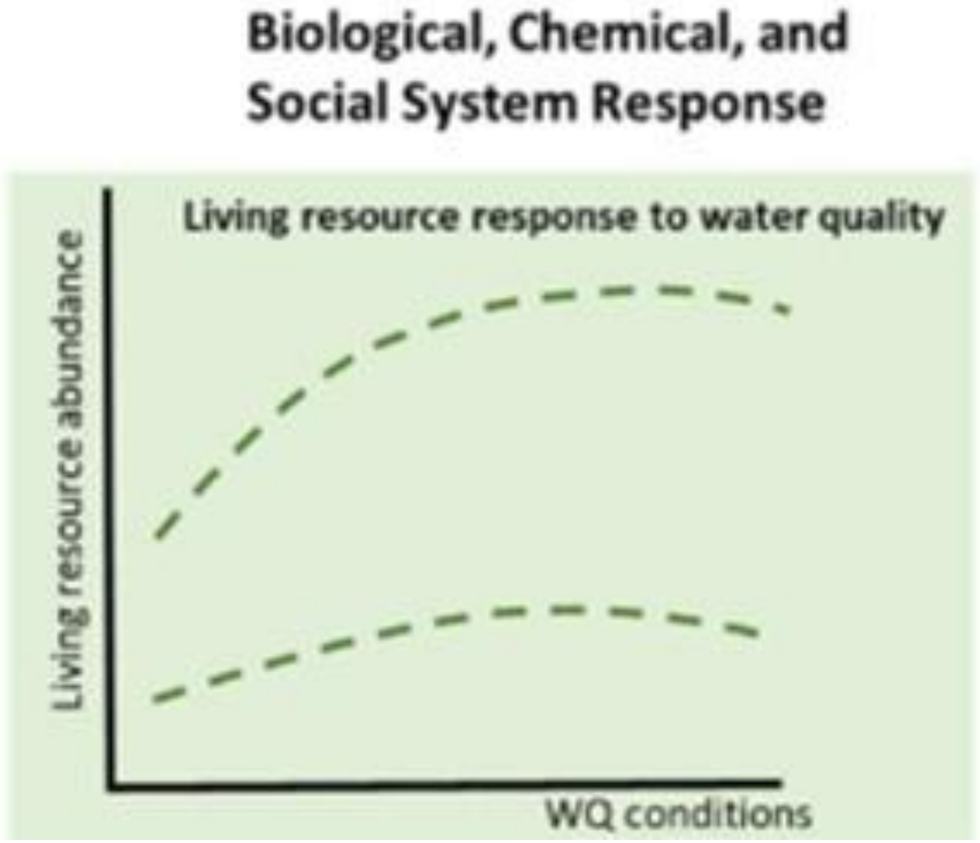
- Accept updated models
- Accept recommended adjustments to TMDL planning targets, increasing the level of effort toward nutrient reduction
- Develop new models and methods for shallow water
- Reassess in 2025 for 2035 climate

CBP Climate Work Plan

2021-2025	2026	2027	2028+
Develop Phase 7 models ***STAC Climate Modeling 3.0 Workshop***	STAC and CBP partnership Review Models Begin climate application	CBP's policy workgroups decide how to ***allocate additional effort*** necessary to counteract the effects of climate change through 2035	Phase 7 models in use

STAC-
Comprehensive Evaluation of System Response

- Living Resource focus
  - Water quality criteria were developed according to living resource needs
  - However –
    Expected living resource response is unknown
- Better incorporate shallow water
  - Important for living resources
  - Where people interact with the Bay



STAC Climate Modeling 3.0 Workshop

Steering Committee

- Mark Bennett
- Zach Easton
- Marjy Friedrichs
- Jeni Keisman
- Lewis Linker
- Ray Najjar
- Robert Sabo
- Gary Shenk
- Charlie Stock

Purpose

- Develop recommendations to guide the Chesapeake Bay Program in developing models and methods to estimate the effects of climate change on the Bay TMDL and on living resources.

Workshop Agenda

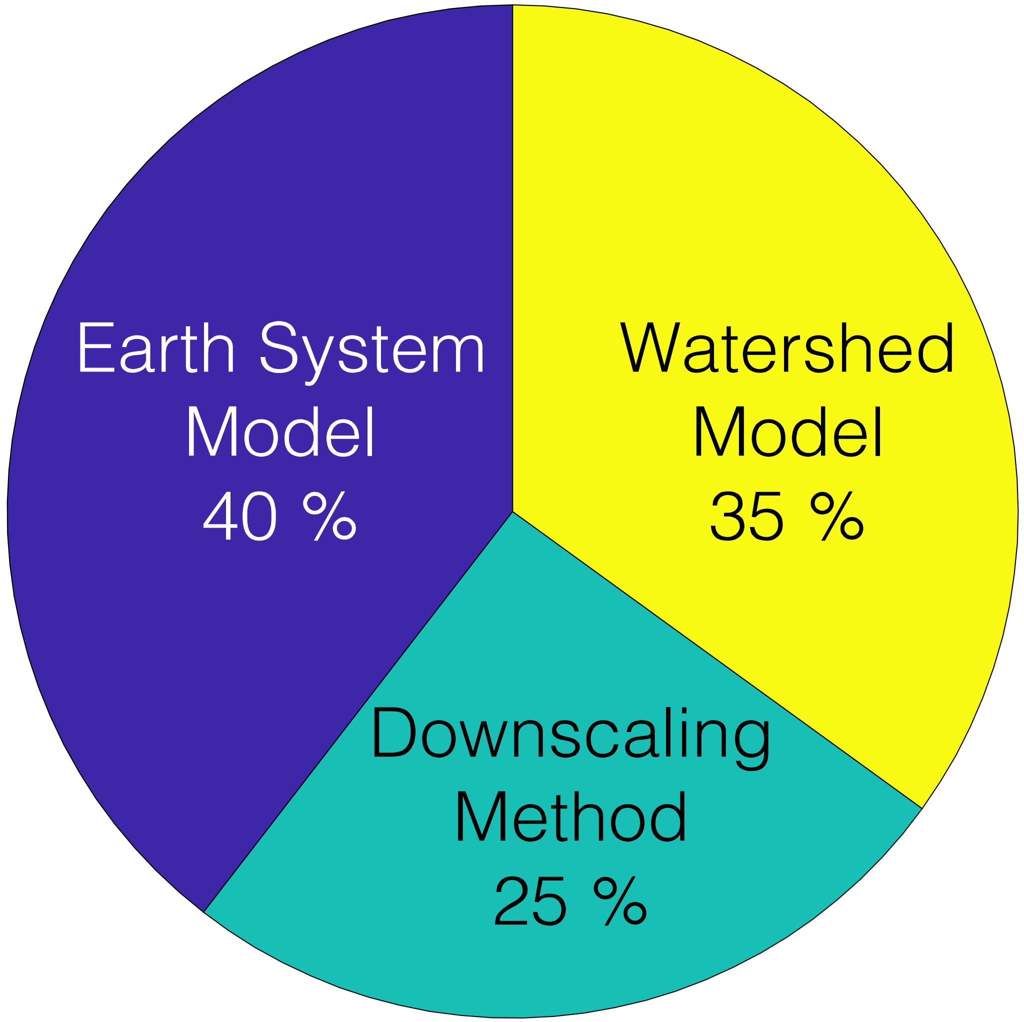
- CBPO Presented:
  - Management Context
  - Existing and planned models relating management, nutrients, and oxygen
- Research Community Presented:
  - Prior STAC advice
  - New climate science
  - New science around management, nutrients, and oxygen
  - Incorporating shallow water and living resources
- Breakouts
  - Vertical – Cross-Sector
  - Horizontal – Within-Sector

Challenge Presentations

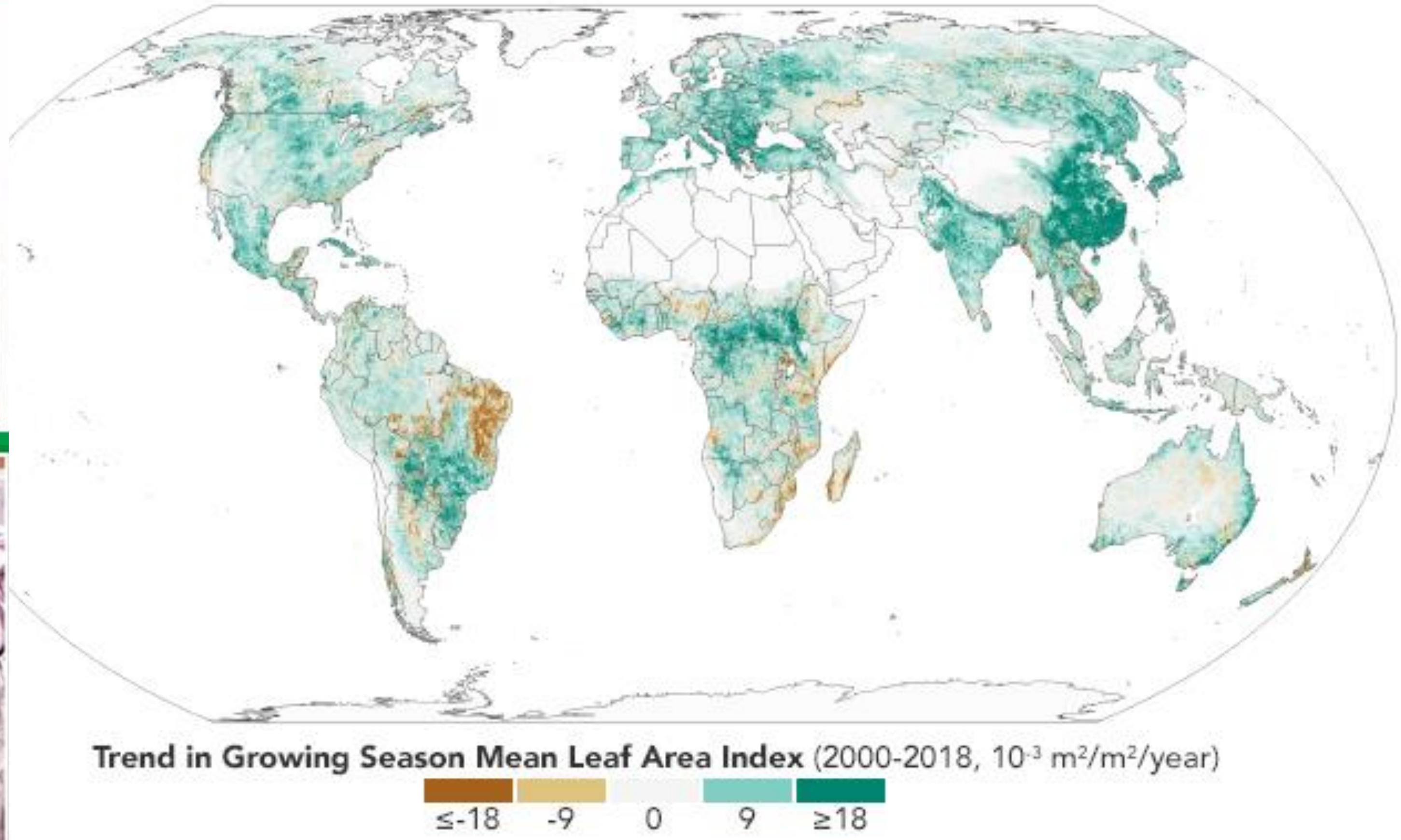
• STAC Activities	Zach Easton, Jeni Keisman
• Climate Projections	Paul Ullrich
• Watershed Processes	Robert Sabo, Andrew Elmore
• Parallel TMDL	Marjy Friedrichs, Kyle Hinson
• Seasonal Bay Processes	Ray Najjar
• Ecosystem Management	Kenny Rose, Bruce Vogt

Hypoxia Cumulative Uncertainty

- All factors in the setup of a climate scenario are important for projecting future hypoxia
- Selecting a single ESM, downscaling method, or WSM may substantially limit range of outcomes.
- *How do these results compare to uncertainties in management actions?*



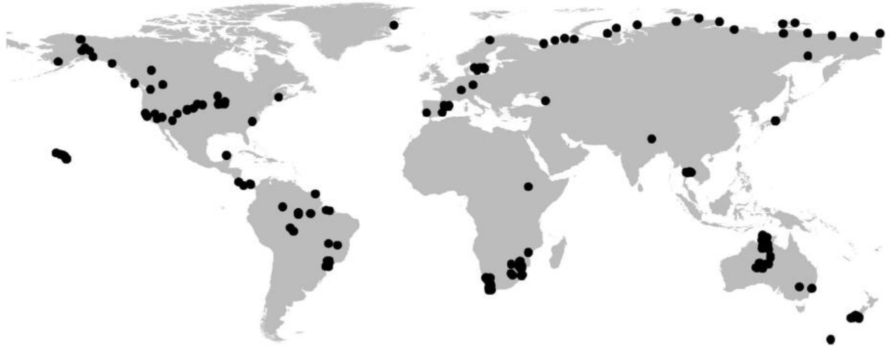
eCO_2 and Longer Growing Seasons

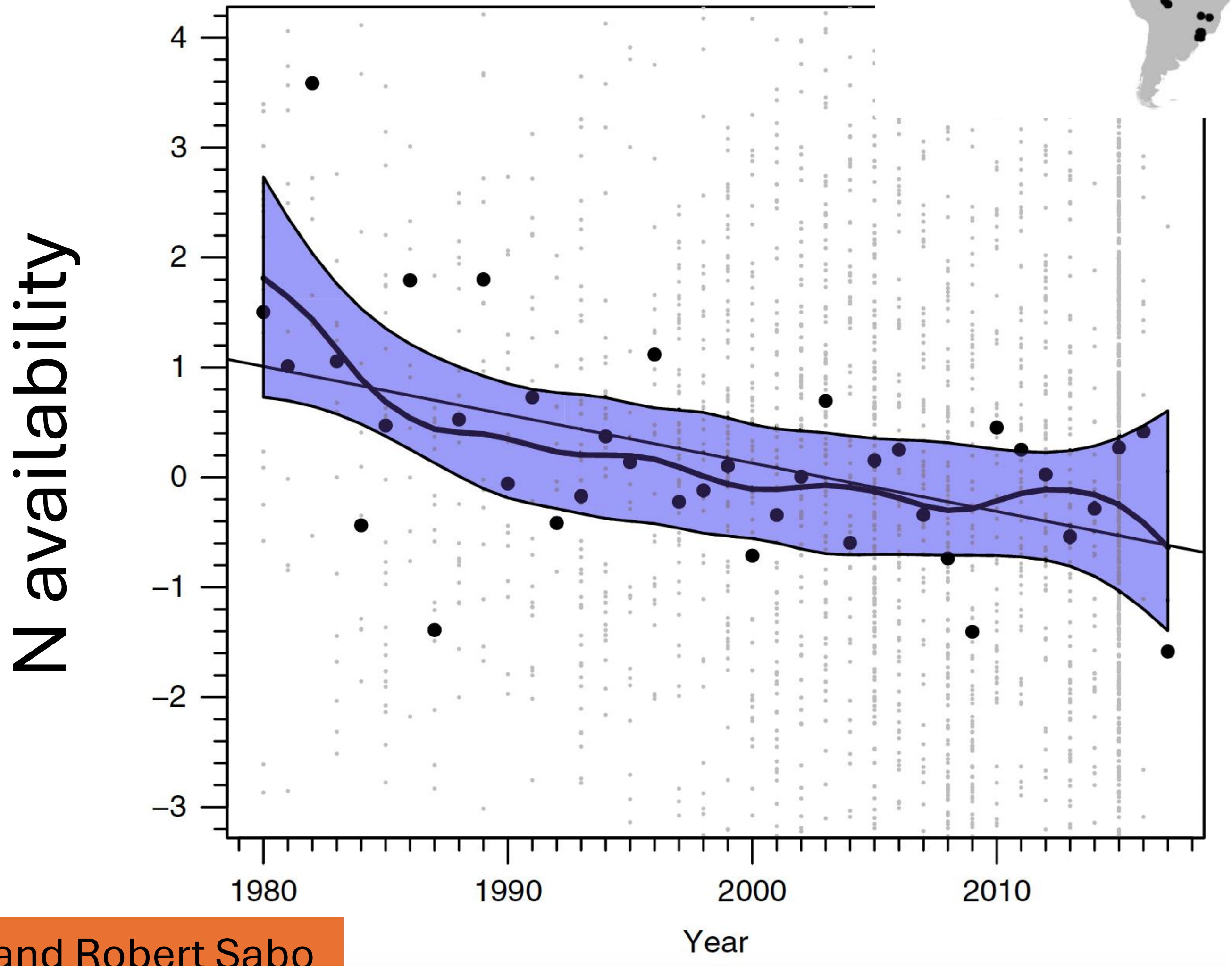


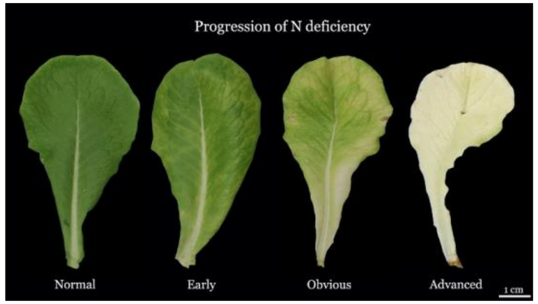
Piao, S., Wang, X., Park, T. et al. Characteristics, drivers and feedbacks of global greening. Nat Rev
…27 (2020). https://doi.org/10.1038/s43017-019-0001-x

Andrew Elmore and Robert Sabo

Global observations of N availability



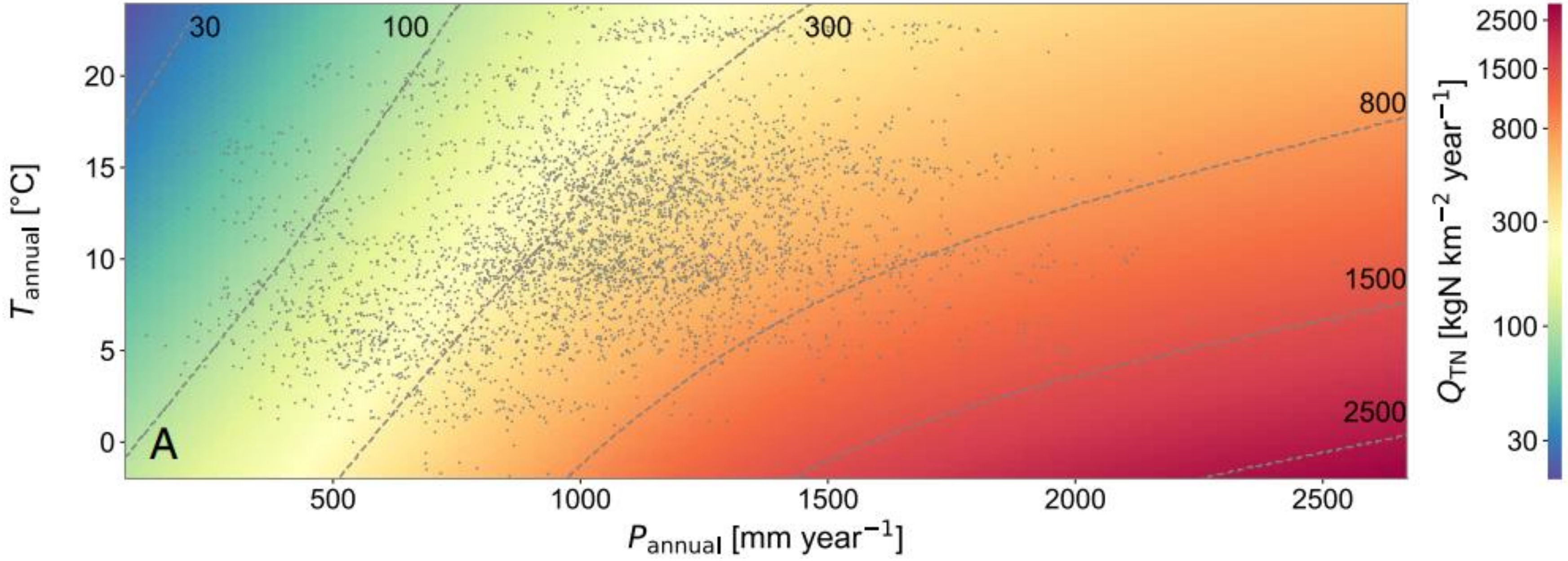




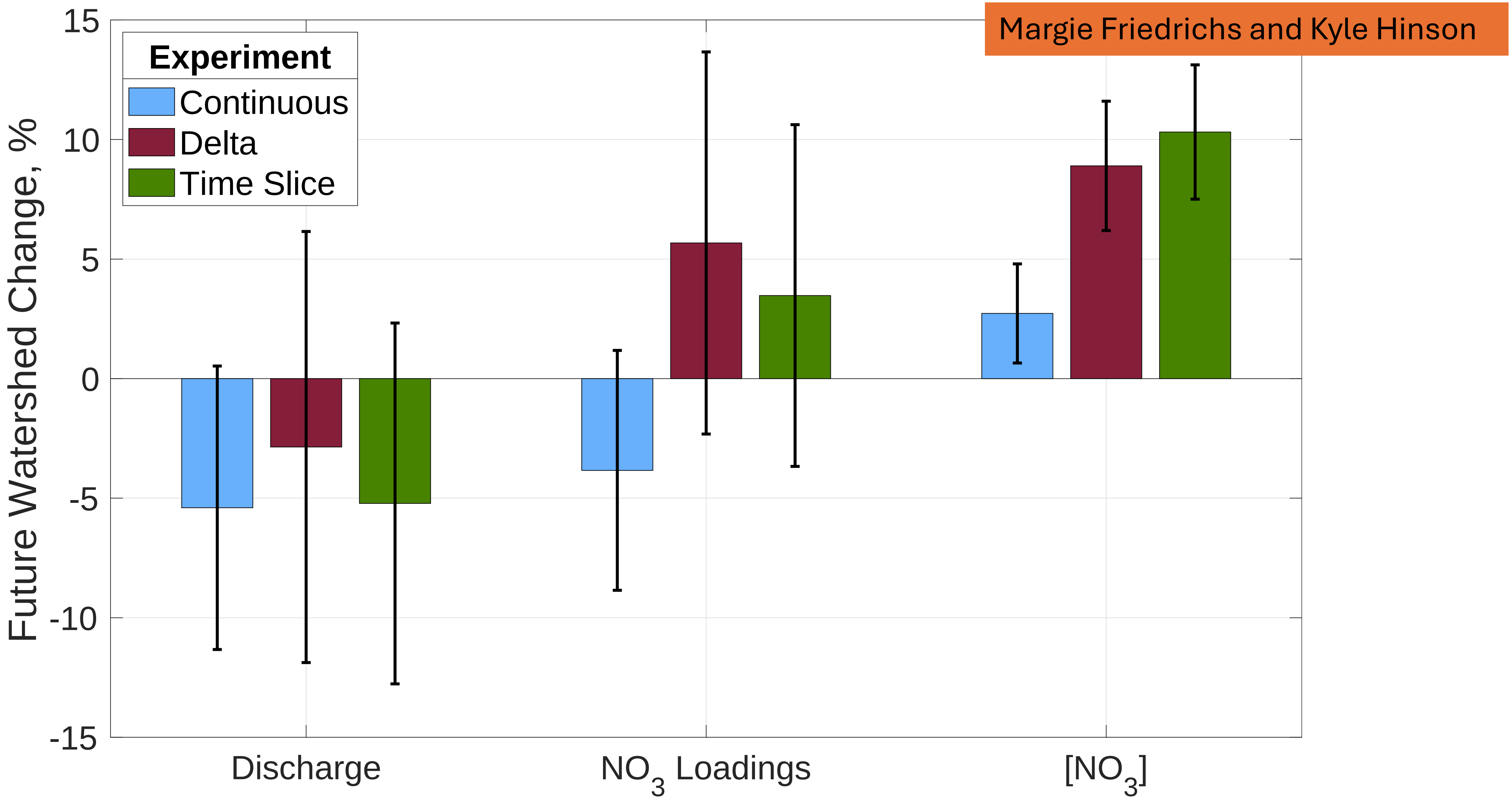
Craine JM, Elmore AJ, et al. Isotopic evidence for oligotrophication of terrestrial ecosystems. Nat Ecol Evol. 2018 Nov;2(11):1735-1744.

Andrew Elmore and Robert Sabo

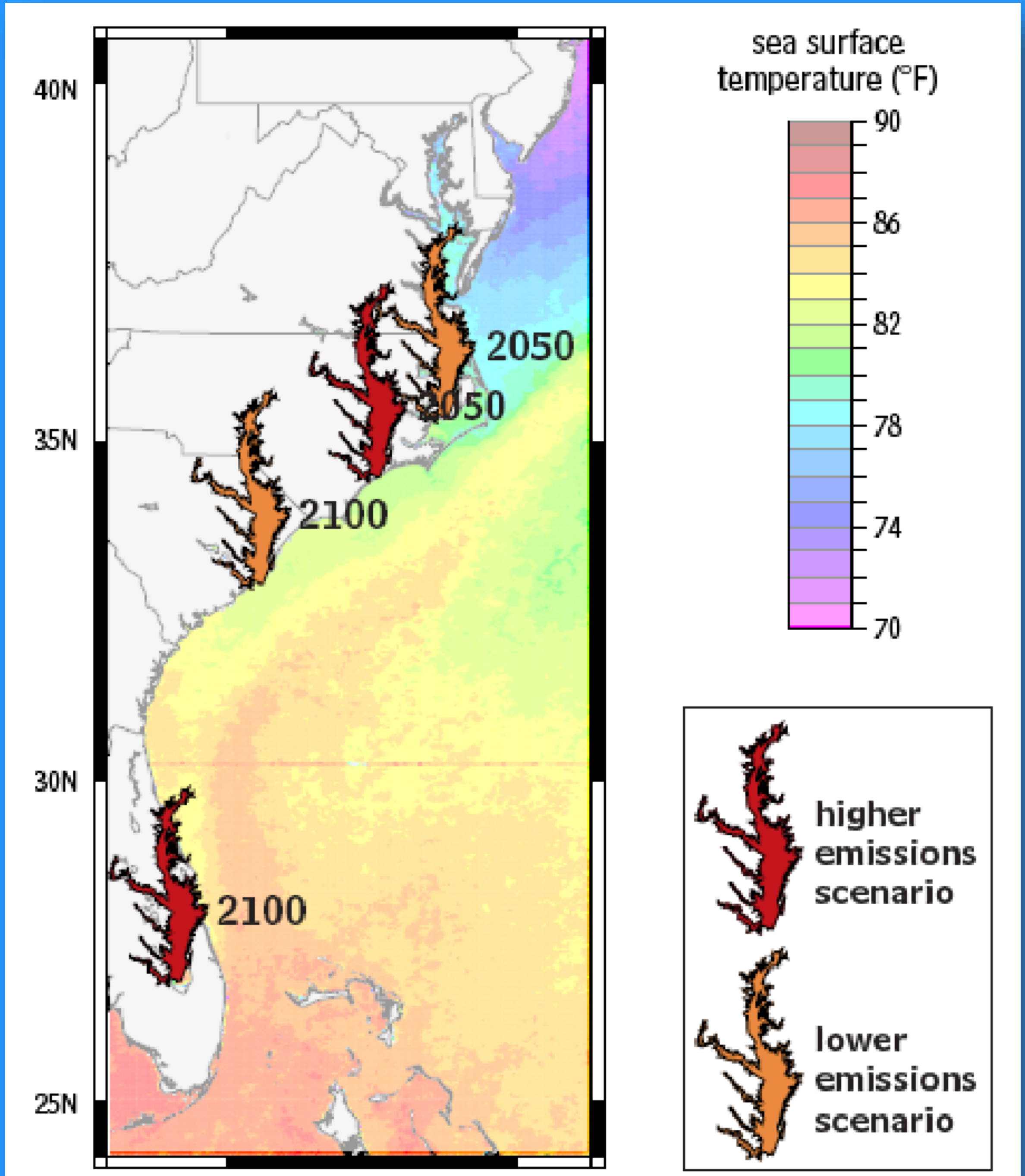
Warming may offset impact of precipitation changes on riverine nitrogen loading



Zhao, Merder, Ballard, and Michalak (2023) Warming may offset impact of precipitation changes on riverine nitrogen loading. *PNAS* 120:33, e2220616120



- NO_3 loadings *increase* in Delta and Time Slice, but *decrease* in Continuous
- Difference due to changing discharge and nitrate concentrations

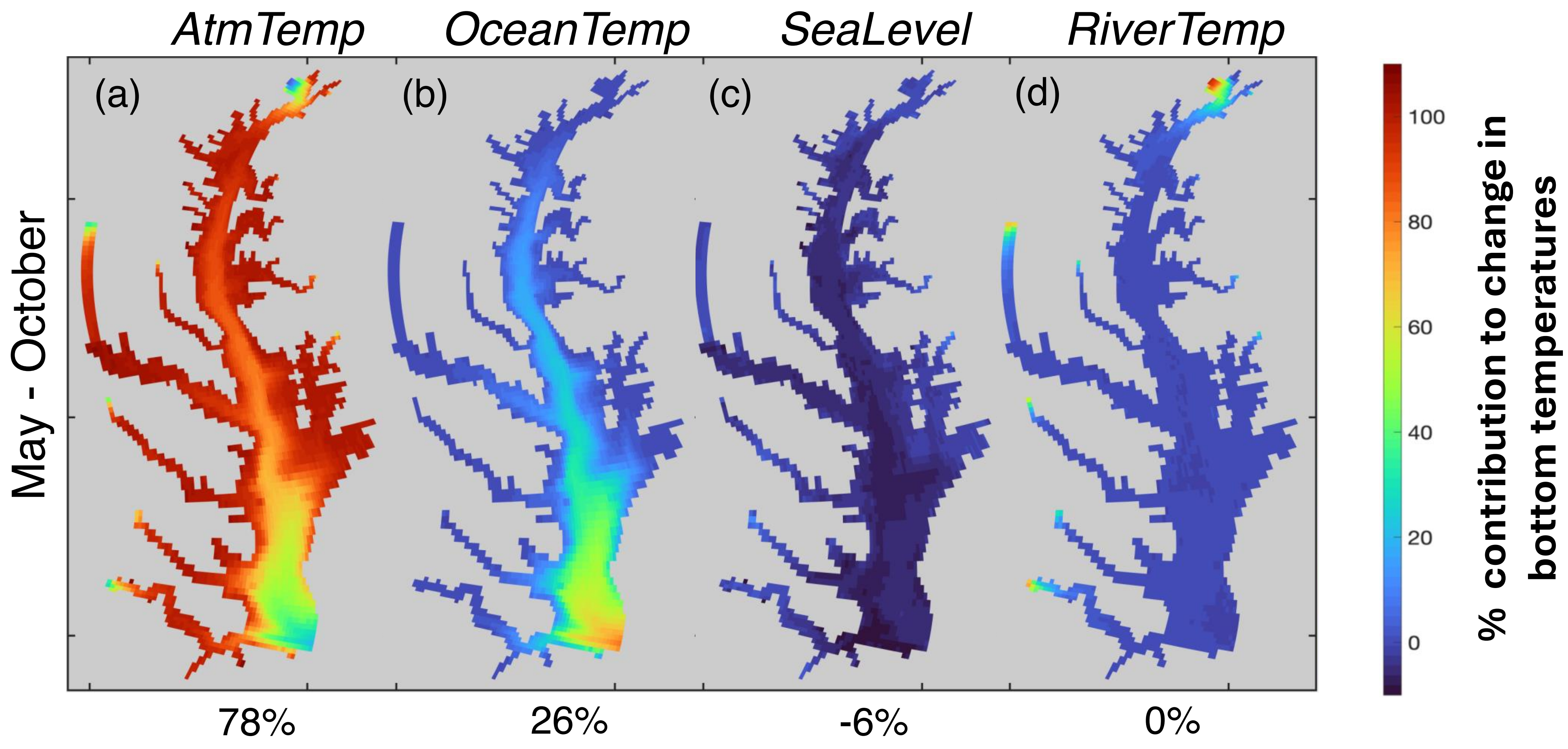


Boesch (2008)

A range of possibilities!

Bruce Vogt

Bay is warming due to atmospheric and oceanic warming

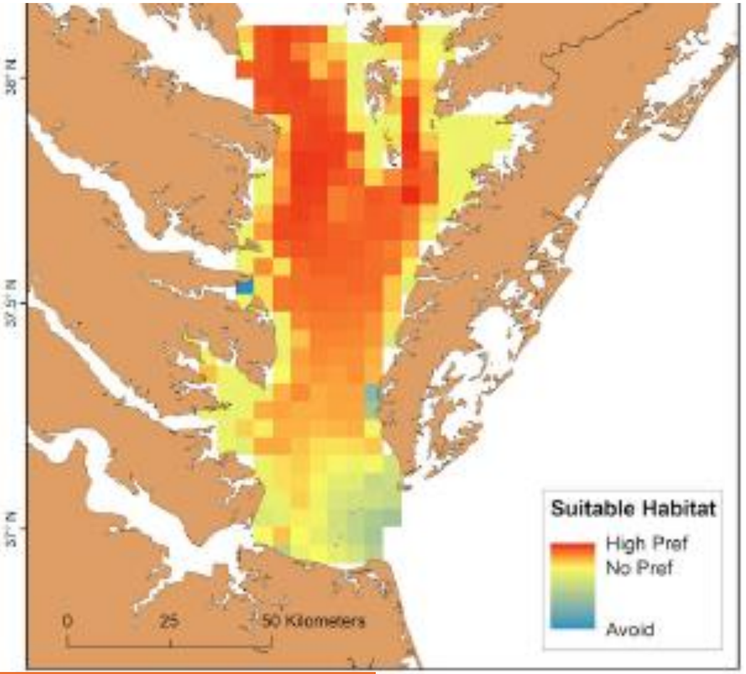


- Atmospheric warming dominates
- Ocean warming is important in VA waters
- Sea level rise cools Bay everywhere
- Rivers only important at heads of tributaries

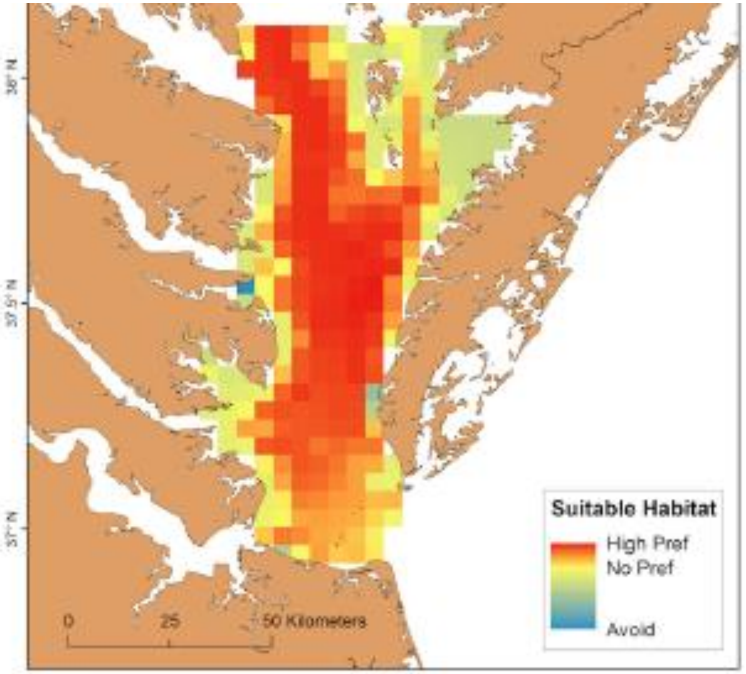
Margie Friedrichs and Kyle Hinson

Simulated Cobia suitable habitat (May 15 – Sep 30) response to climate is nonlinear

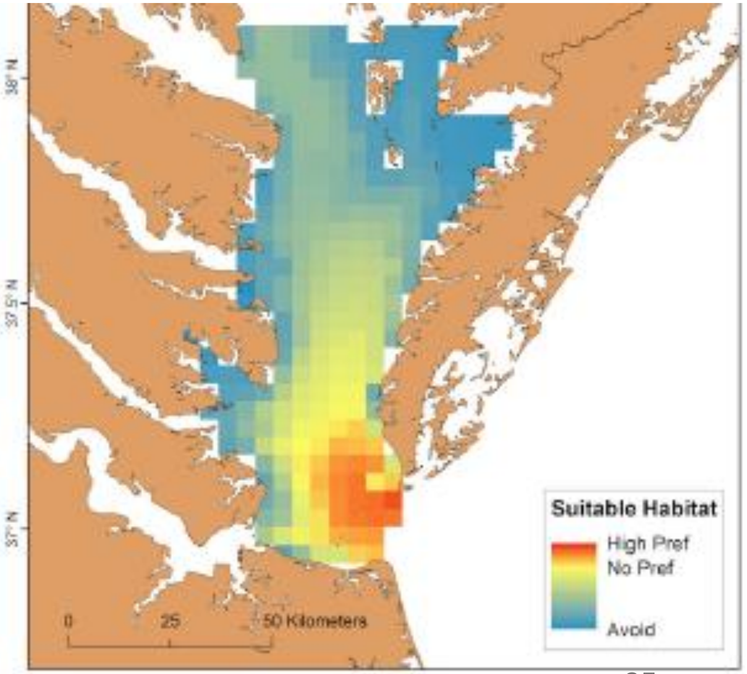
Contemporary



Mid-century



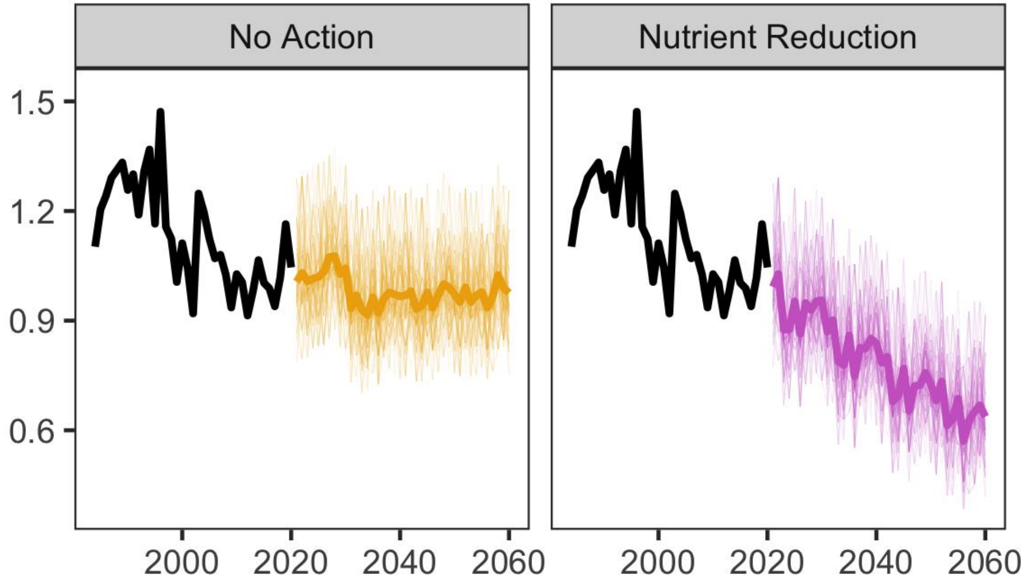
End-of-century



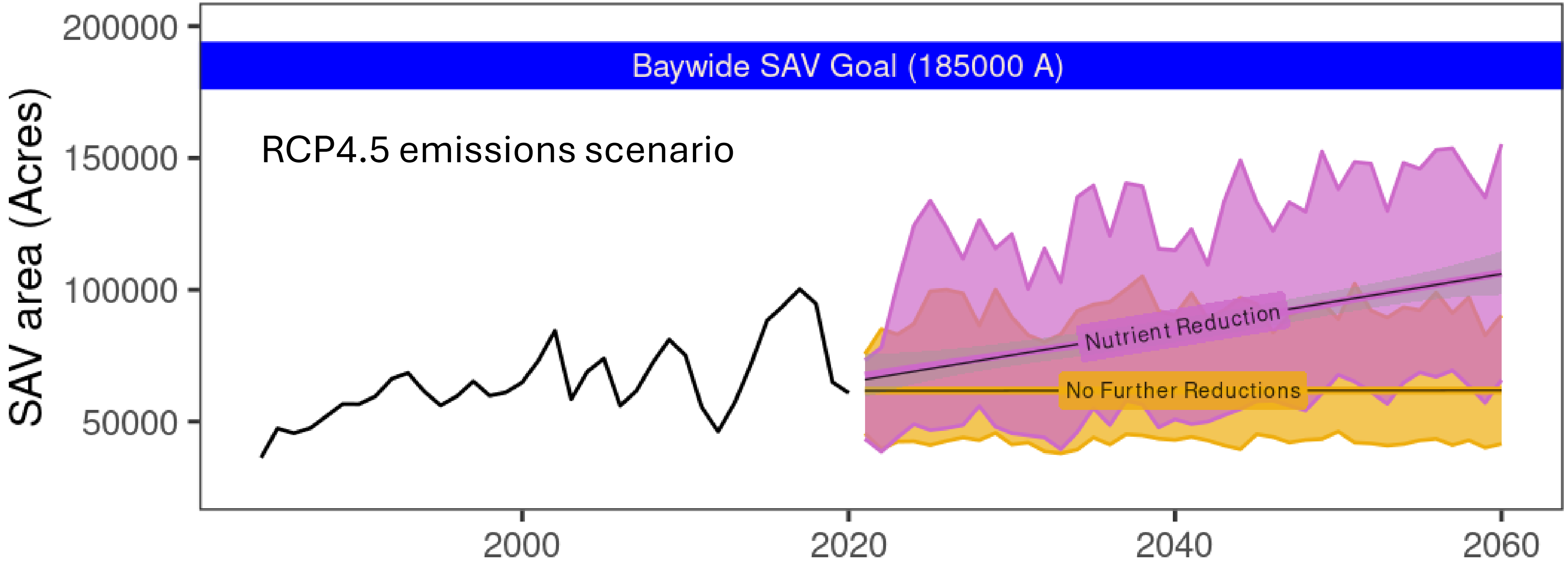
Ray Najjar

Total SAV projections show large impact of nutrient management

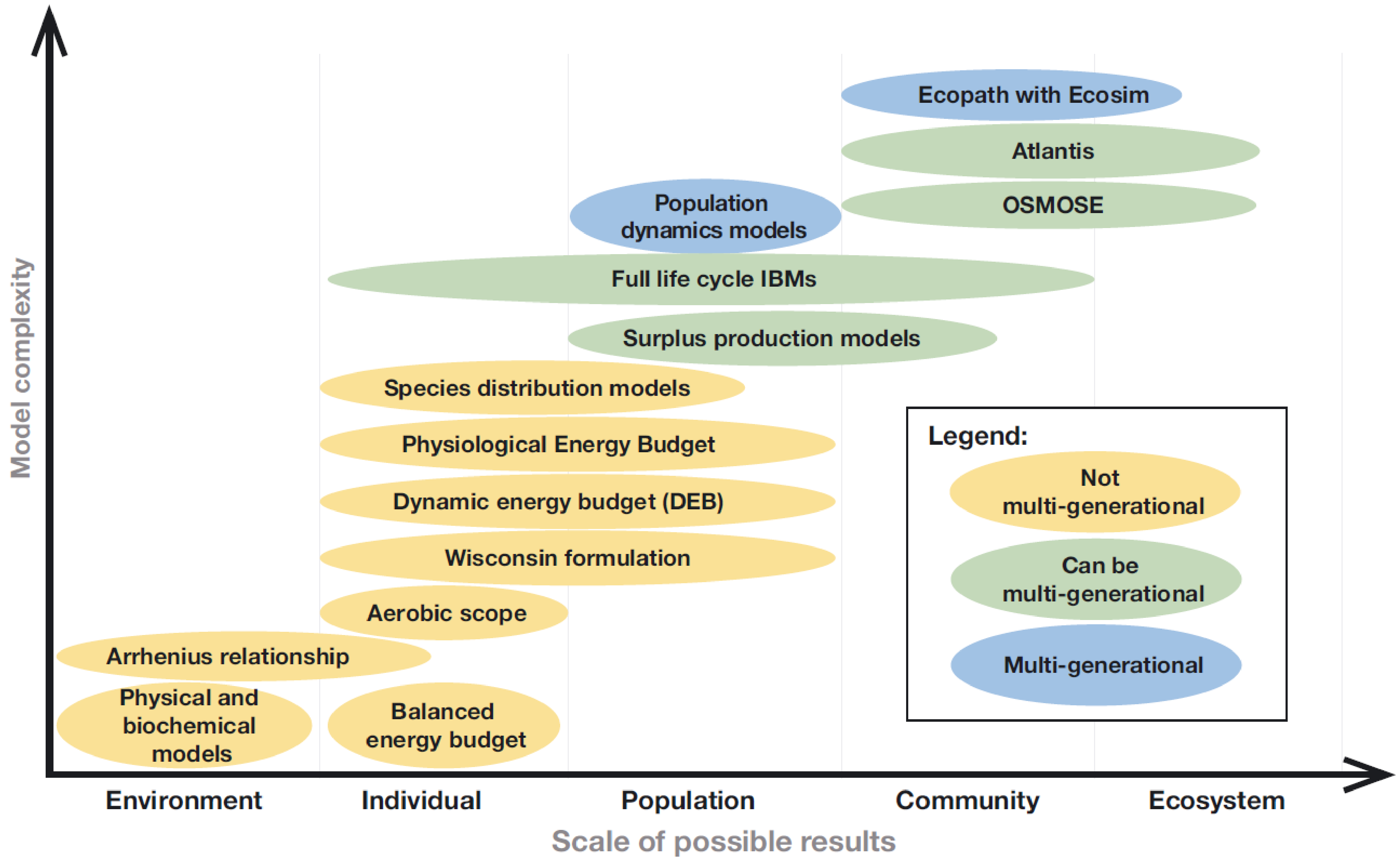
Mean springtime total nitrogen (mg/L)



From CBP modeling suite

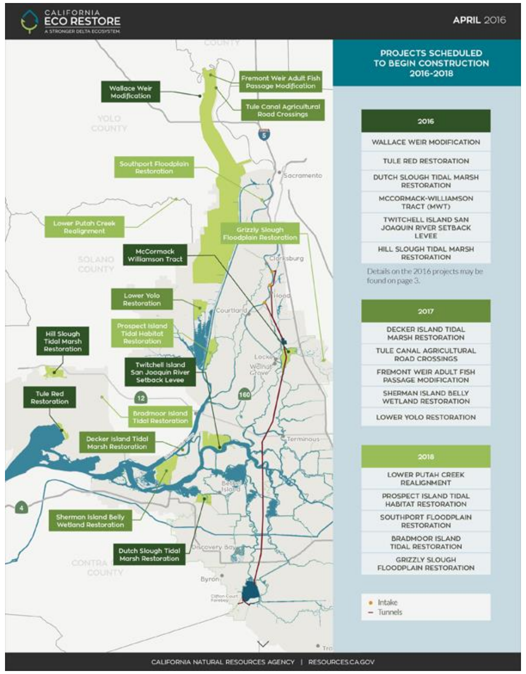


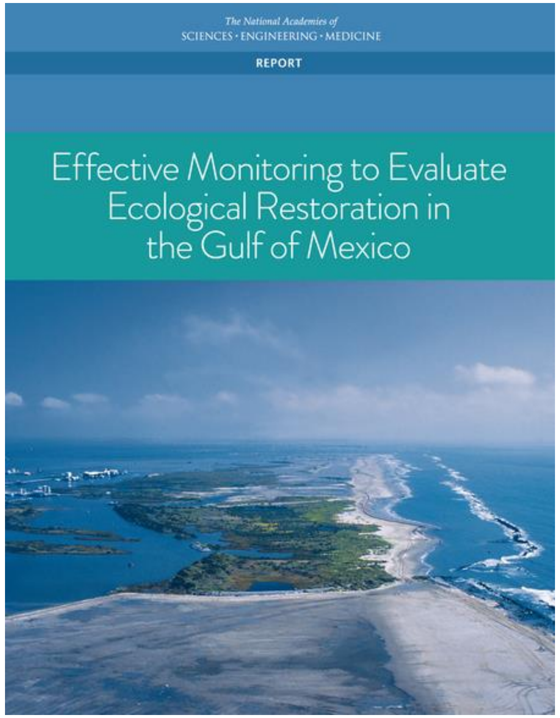
Community-specific statistical models using water quality inputs

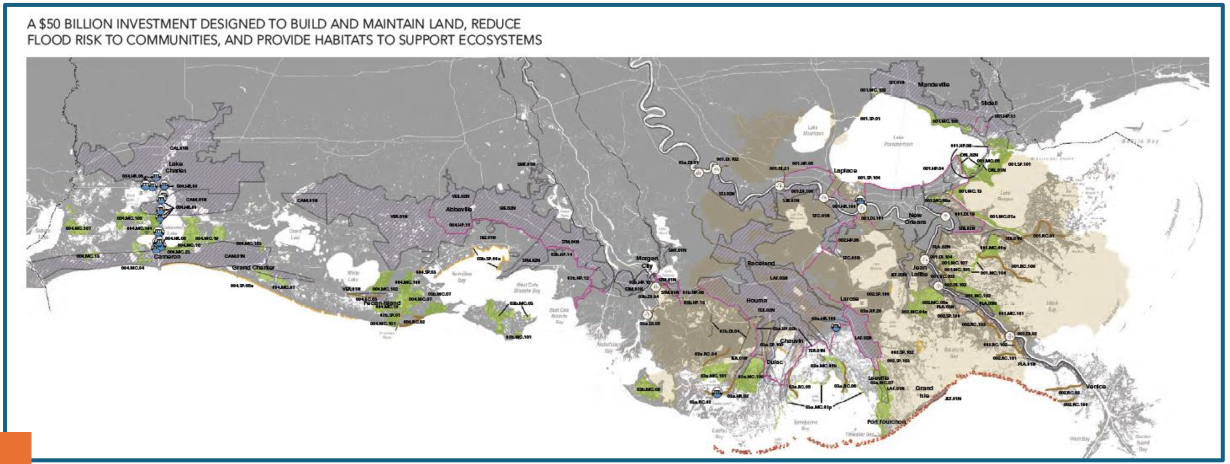

Ecopath with Ecosim
Atlantis
OSMOSE
Population dynamics models
Full life cycle IBMs
Surplus production models
Species distribution models
Physiological Energy Budget
Dynamic energy budget (DEB)
Wisconsin formulation
Aerobic scope
Arrhenius relationship
Physical and biochemical models
Balanced energy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

Kenny Rose

(4) Chesapeake Bay is unique! False

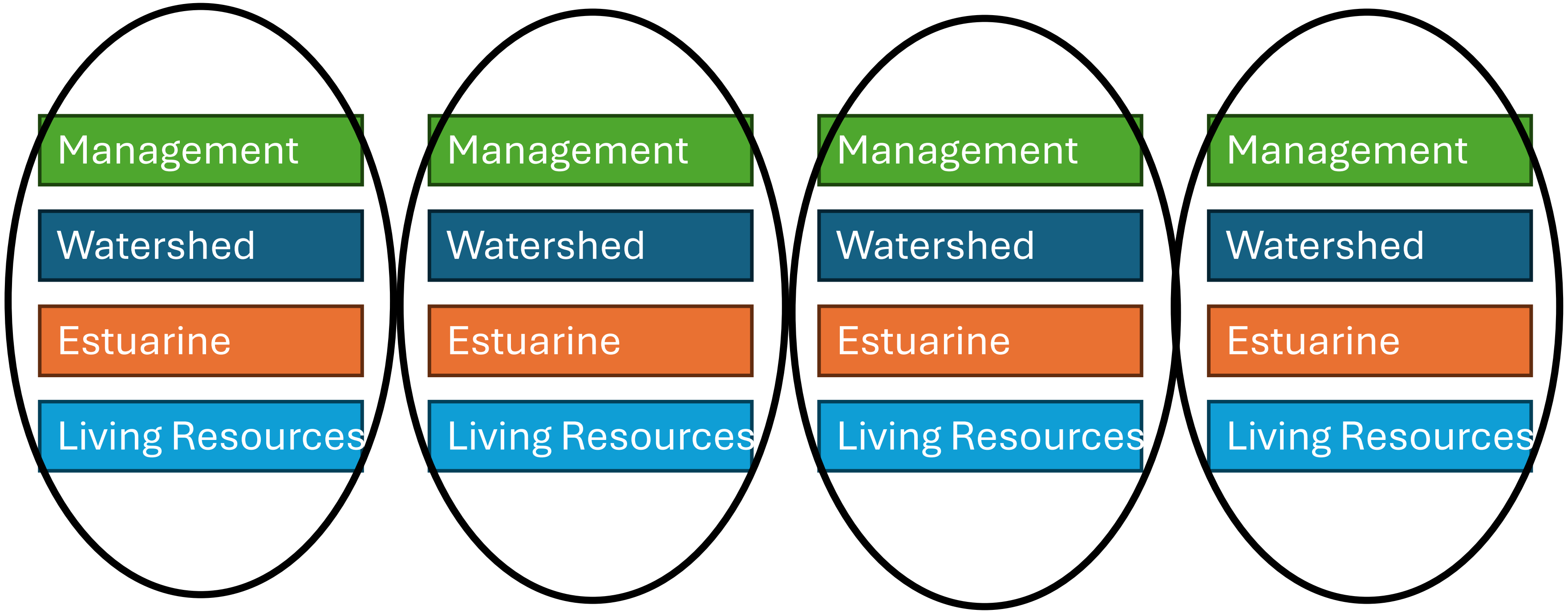






Kenny Rose

Vertical (Multi-sector) Breakouts



The CBP should prioritize the development and use of new and existing living resource models.

- The existence of the water quality outputs and living resource models provides the partnership with an easy path to quick progress in this area.
- Development should start with existing living resource models at broad spatial scales and work toward location-specific responses and goals.
- Initial development should focus on selected individual species and life stages.
- Linkages should be sequential rather than coupled to simplify the work and lower computing time.

Re-examine the TMDL accountability Framework

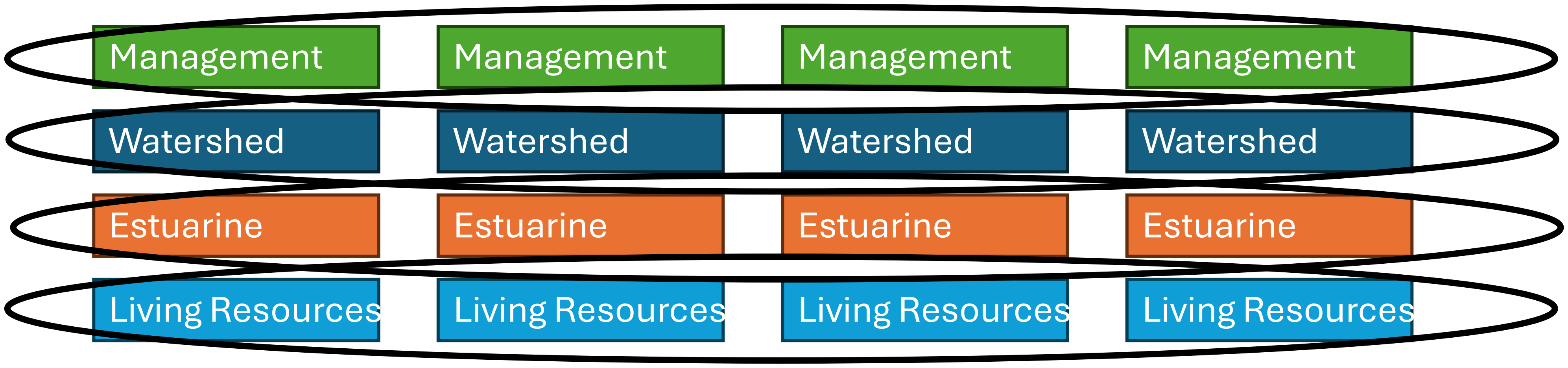
- The TMDL baseline is the 1990s. The modeling question is: How would loads have to change from 1990's such that water quality standards are met.
  - Would this make sense to our successors in 2050?

- Prioritize restoration of areas where living resource responses could be seen more quickly. (Tiered TMDL Implementation)

Model evaluation should be tailored to answer questions relevant to management

- Uncertainty quantification for its own sake does not advance management.
- The response gap framework of CESR is a useful method of prioritizing effort.
- Long, continuous runs of the modeling suite
  - Suitably capture tipping points.
    - Estuarine benthic-pelagic shifts, changes in SAV spatial distribution
    - Watershed trends from climate, weather, anthropogenic effects, and time lags.
  - Climate change evaluation methods other than the delta method.
- Assessing variability rather than just mean

Horizontal (Single-sector) Breakouts



Watershed

- Incorporate climate-related change in transport, storage, and loss,
  - Denitrification, soil moisture effects, etc.
  - Validate predictions relevant to climate for flow, N, P, and S - difficult task
- Identify hot spots, moments, and actors and how they change for climate
  - Sub-field to watershed; hourly to annual.
  - Climate change could make the ordering of hot spots dynamic.
  - Investigate targeted theory-based synoptic sampling.
- Advice for analysis climate effects on BMP performance
  - Separate into structural, hydrologic, biochemical transformation, and buffers
  - Look for more refined process-based small-footprint models
    - SWMM, SWAT, and HSPF are not ideal as they do not have the processes represented

Management

- Tiered TMDL Implementation
  - Shallow water
  - Include Co-benefits
  - Give managers more flexibility
- Modeling
  - A good central tendency is more important than an uncertainty-based range.
  - Beyond phase 7, consider more precipitation events, and more extremes of drought and flood.
  - Excited about living resource modeling.

Estuarine

- *Hydrodynamics working! Now need to focus on WQ model –*
  - Make use of new data
    - southern ecosystems, shallow water, NSF/NOAA projects, satellite data
  - Still concern about temperature control functions in WQ model, both for autotrophic and heterotrophic processes
  - pH and acidification – Key for living resources

- Explore use of ML/AI techniques
- Need to account for extreme events and tipping points
  - storms (rain and wind)
  - droughts
- Uncertainty quantification still important

Living Resources

- Start with strategic approach - see CESR for framework approach
  - table of living resource sensitivities to key climate drivers; include tradeoffs, include stakeholders, what can we manage around…
- The delta method of including climate change does not capture seasonal changes driving living resources.
- Add carbon module for acidification, provide max/min, variance, marine heat waves, include which spp & habitat distributions will change, etc.
- Develop/improve methods to identify geographic sources of water quality changes that impact living resources at scales relevant to restoration activities

Top Line Takeaways – extremely draft

- Models are in pretty good shape after prior 2 workshops
- Continuing uncertainty⇔validation⇔evaluation conversation.
- Tiered TMDL Implementation, which requires shallow water
- Living resource modeling – lets get started!