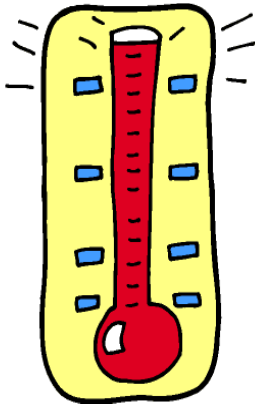
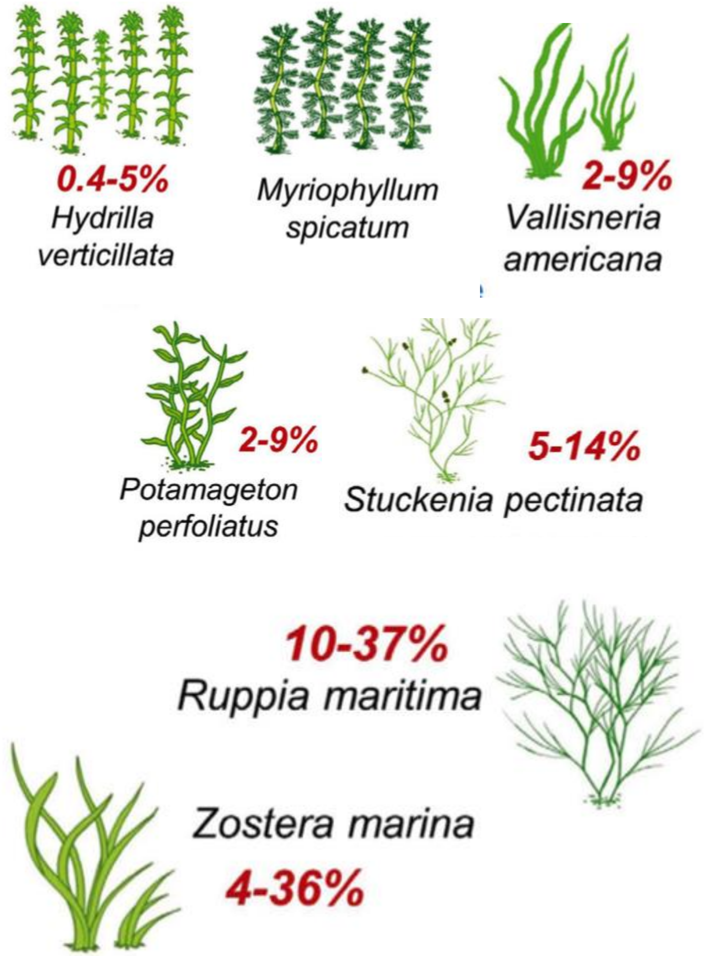
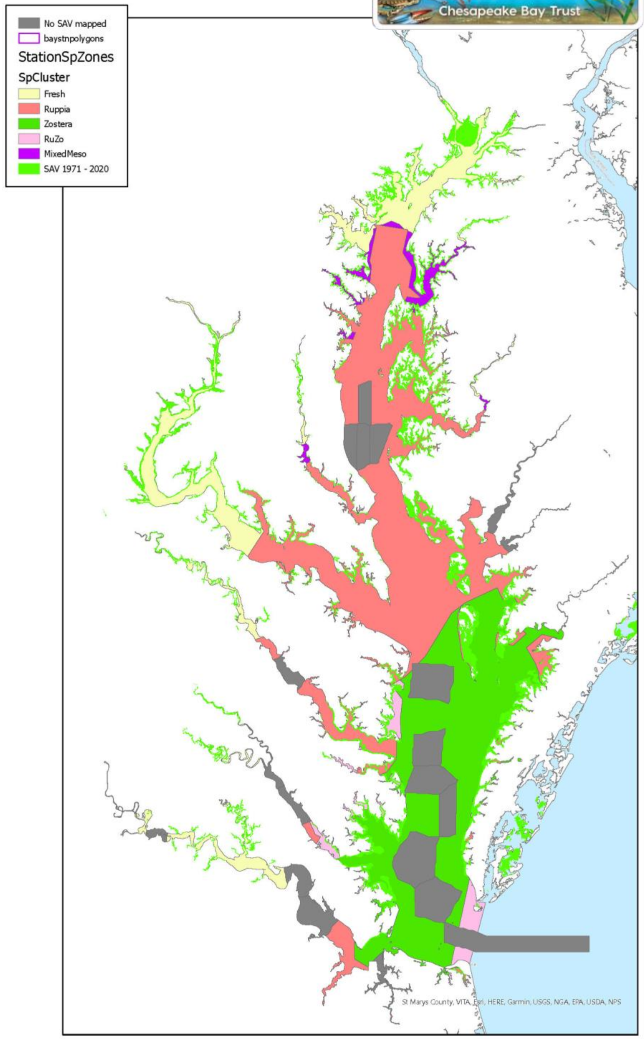
Envisioning the future for Chesapeake Bay SAV under climate change



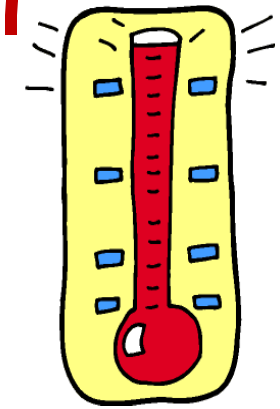
Marc Hensel
Chris Patrick
Dave Wilcox
Jon Lefcheck





How will climate change and human activities affect the major communities of seagrass and aquatic vegetation in the Chesapeake Bay?

Climate change



&

Temperature rise

Rainfall variability

Human activities

No further nutrient reductions

OR

More nutrient reductions

Predicting the future in three steps

Step 1 — How have past environmental conditions affected seagrass and aquatic plant communities?

Step 2 — How will environmental conditions shift with climate change & with human activities?

Step 3 — How will shifting conditions and shifting species affect SAV meadow coverage into the future?

Predicting the future in three steps

Step 1 — **How have past environmental conditions affected seagrass and aquatic plant communities?**

Step 2 — How will environmental conditions shift with climate change & with human activities?

Step 3 — How will shifting conditions and shifting species affect SAV meadow coverage into the future?

Predicting the future in three steps

Step 1

How have past environmental conditions affected seagrass and aquatic plant communities?

VIMS aerial SAV survey data (1984-2020)

Vegetation cover

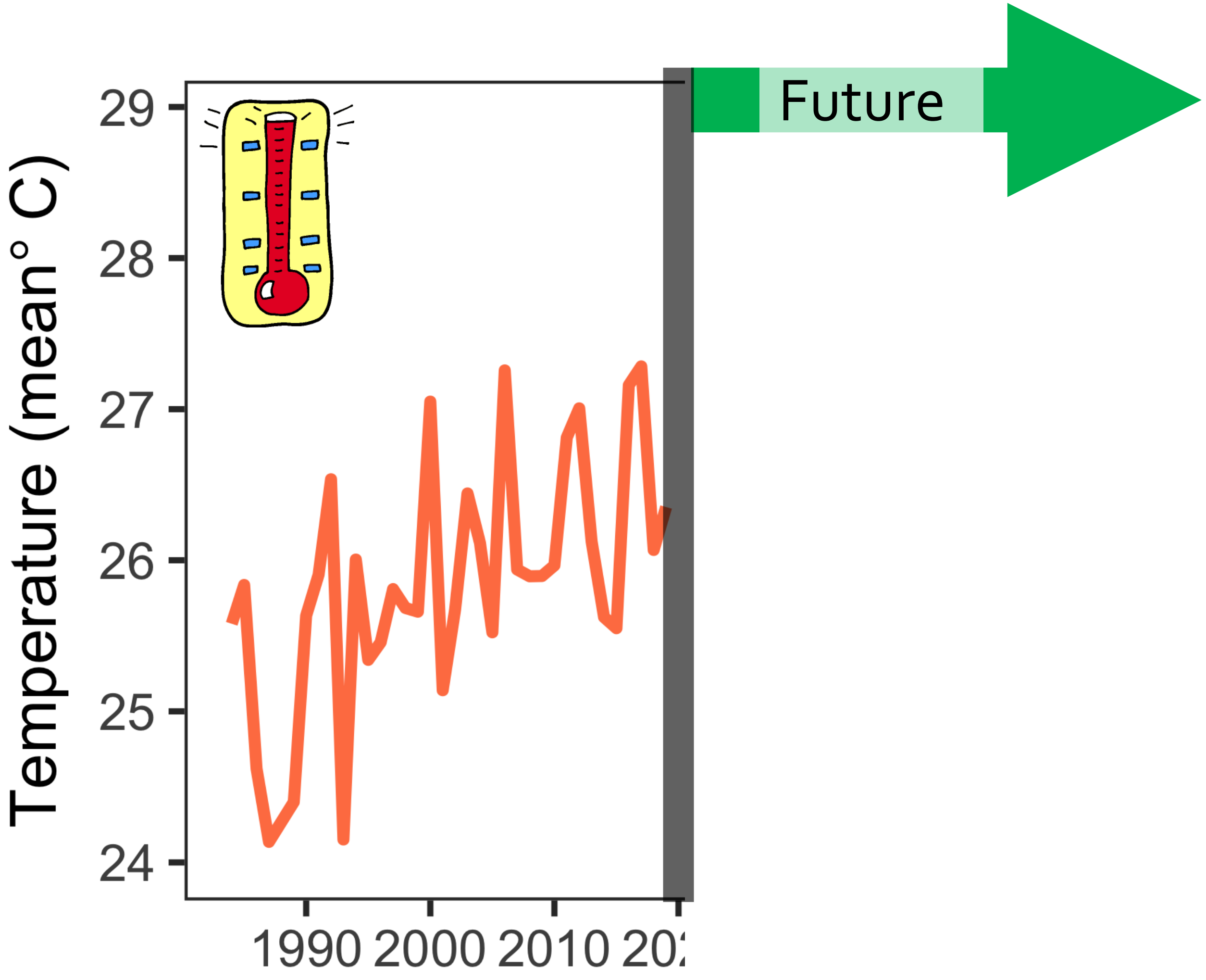
VIMS SAV Observation data (1984-2020)

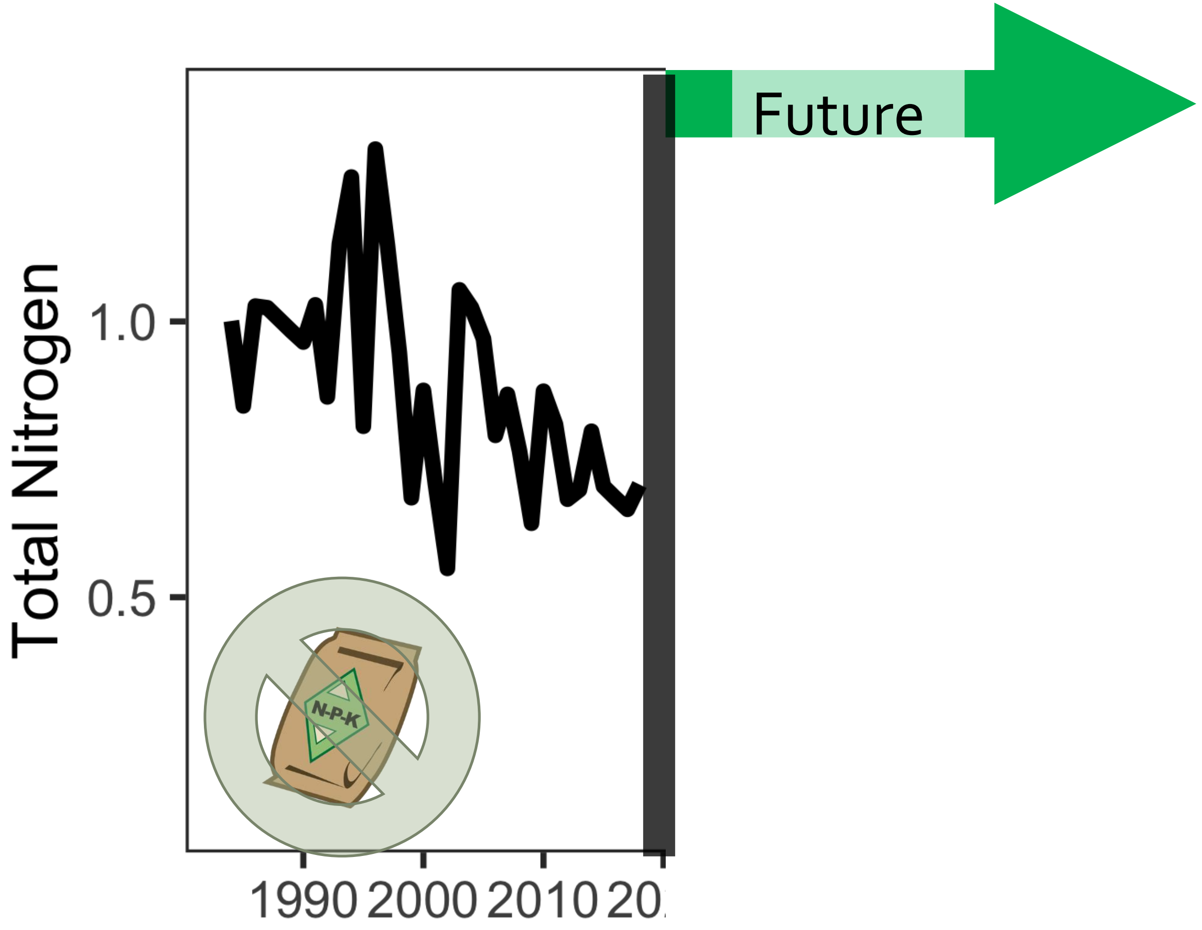
Species presence/absence

Chesapeake Bay Program water quality stations (1984-2020)

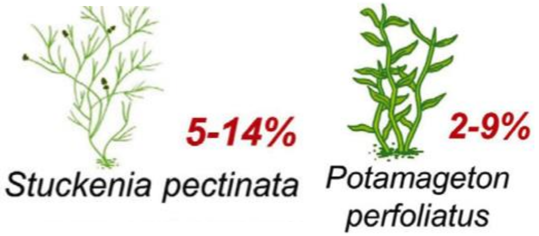
Temperature, Salinity, Nitrogen, Phosphorus, Water Clarity, Chlorophyll-a 1984-2020

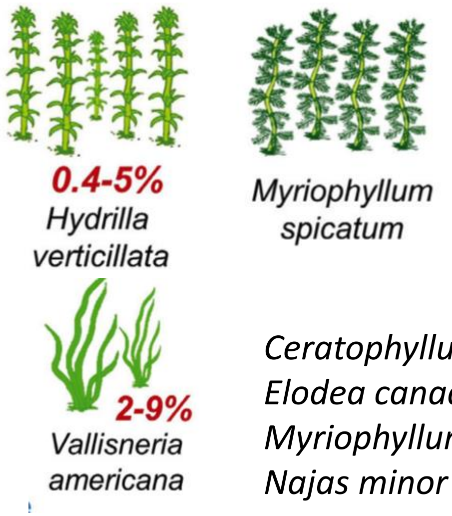
Step 1: Environmental conditions have changed from climate change and human activities



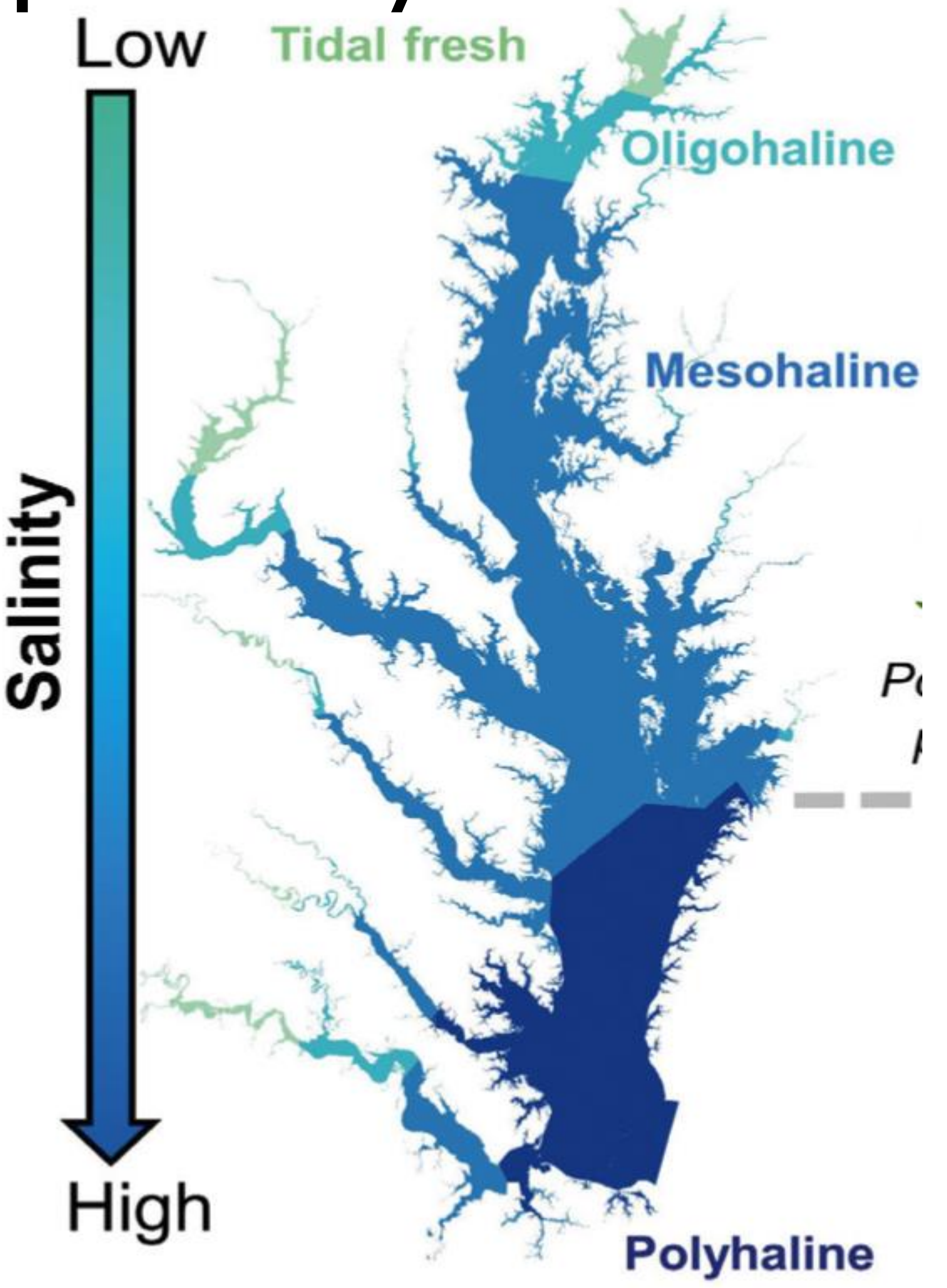


Step 1: ID major communities of Chesapeake Bay seagrass and vegetation



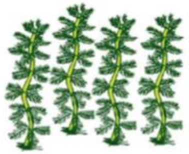


Ceratophyllum demersum
Elodea canadensis
Myriophyllum spicatum
Najas minor



Step 1: ID major communities of Chesapeake Bay seagrass and vegetation

0.4-5%
Hydrilla verticillata



Myriophyllum spicatum

Oligohaline/Tidal Fresh community

2-9%
Vallisneria americana

Ceratophyllum demersum
Elodea canadensis
Myriophyllum spicatum
Najas minor

Mixed Mesohaline

5-14%
Stuckenia pectinata

2-9%
Potamageton perfoliatus

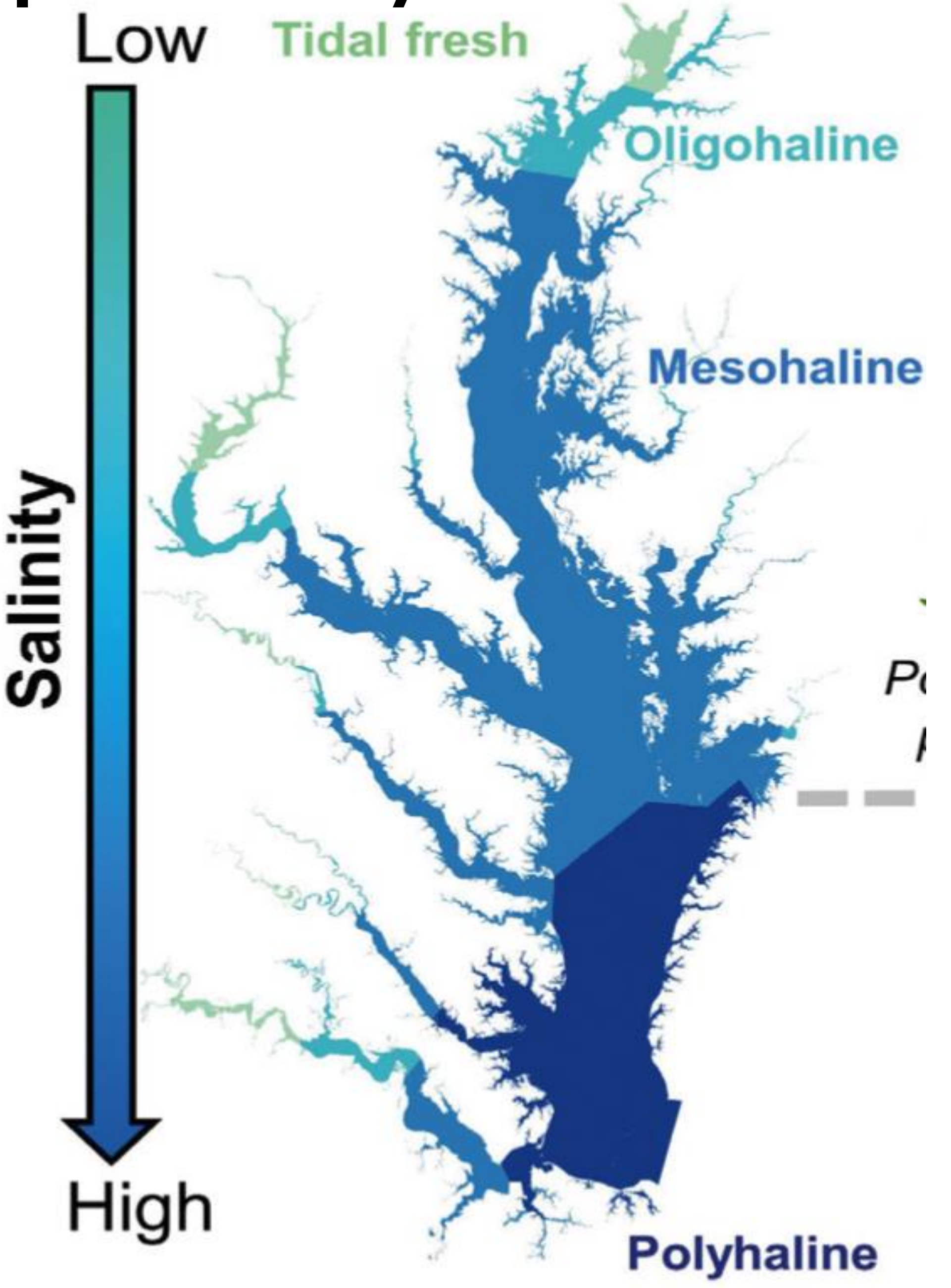
10-37%
Ruppia maritima

10-37%
Ruppia maritima

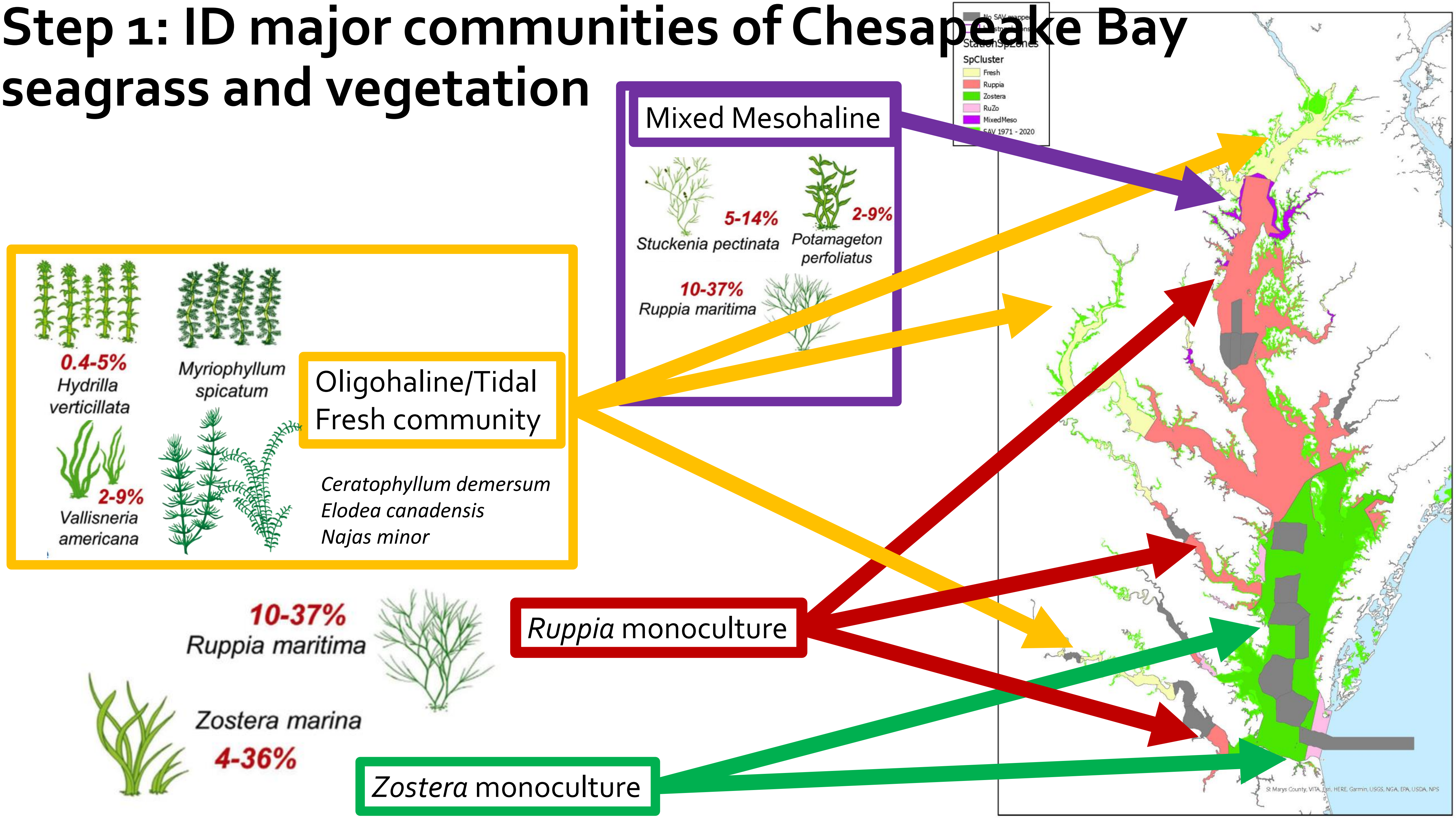
Ruppia monoculture

Zostera marina
4-36%

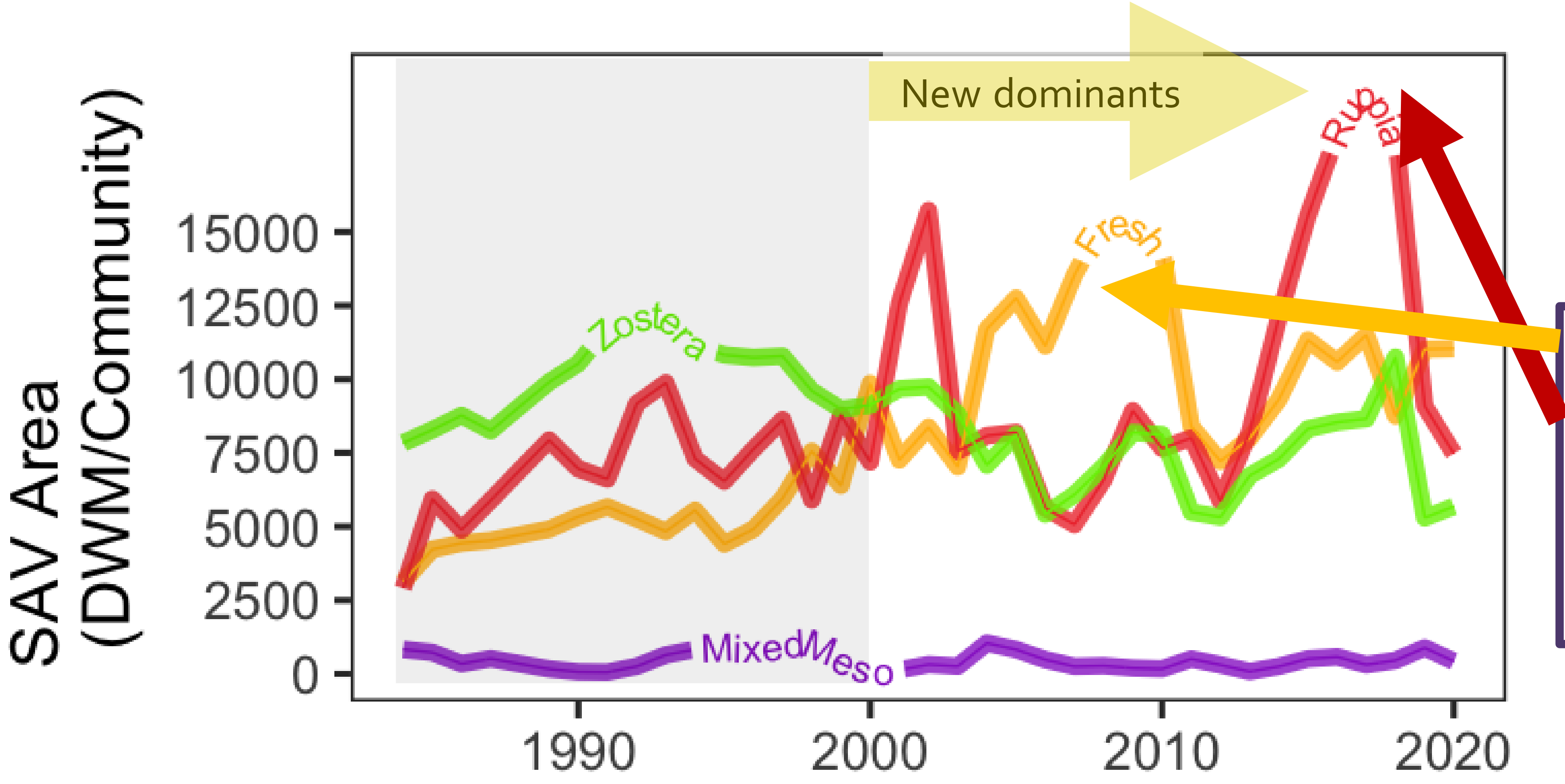
Zostera monoculture



Step 1: ID major communities of Chesapeake Bay seagrass and vegetation



Step 1: Dominant communities have changed over time in response to climate and management



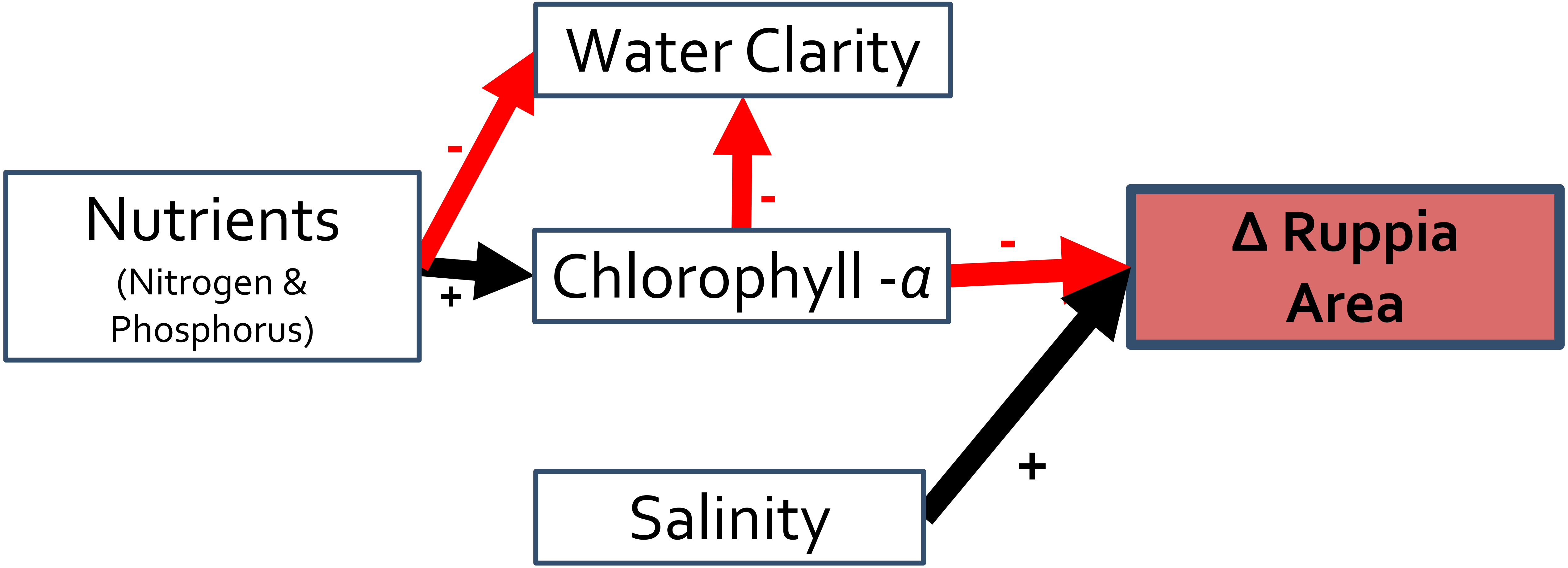
Tidal fresh and **widgeongrass** are the dominant communities now

Predicting the future in three steps

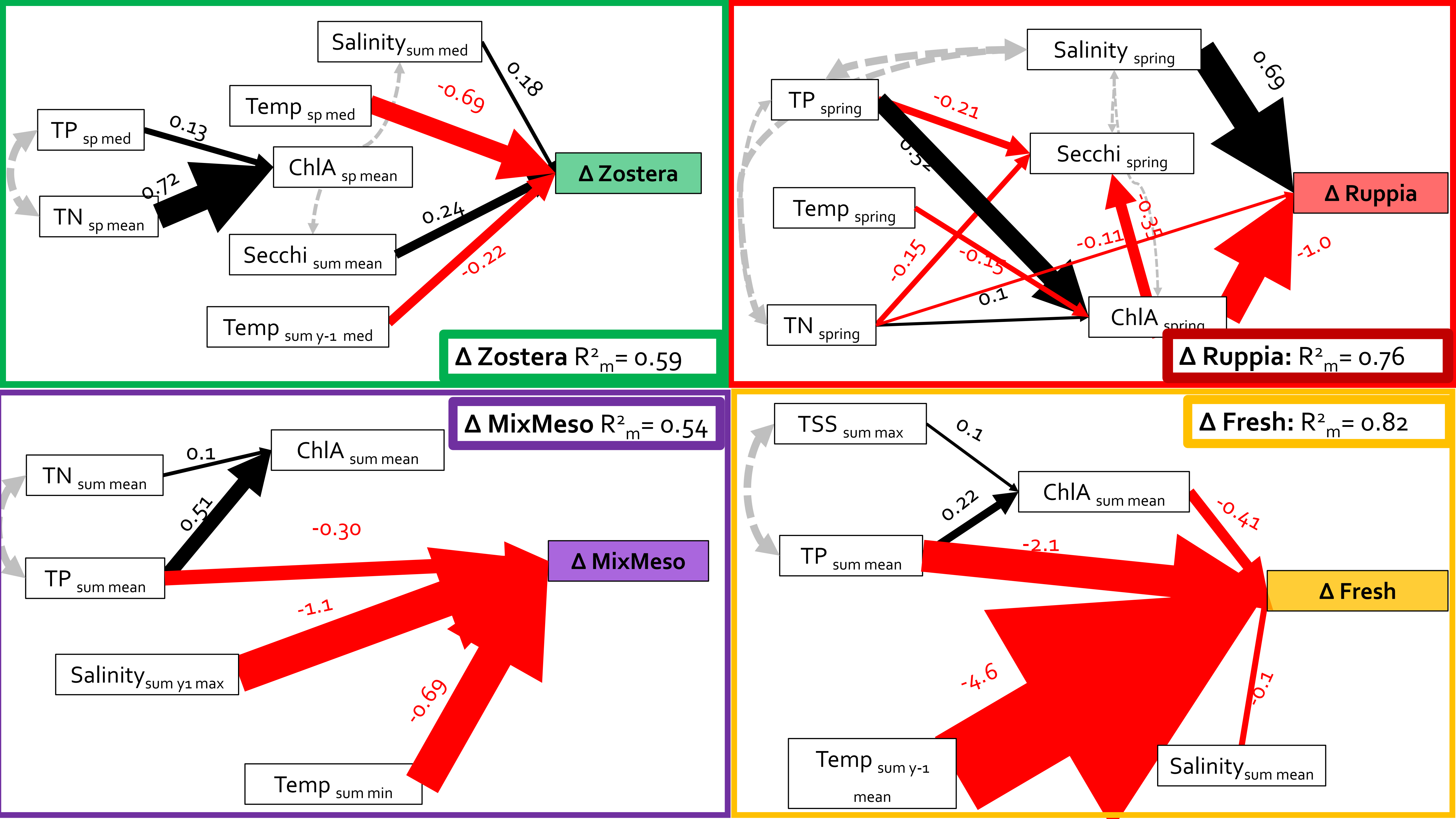
Step 1	**How have past environmental conditions affected seagrass and aquatic plant communities?**

Build structural equation models to explain how past environmental changes have affected each dominant community

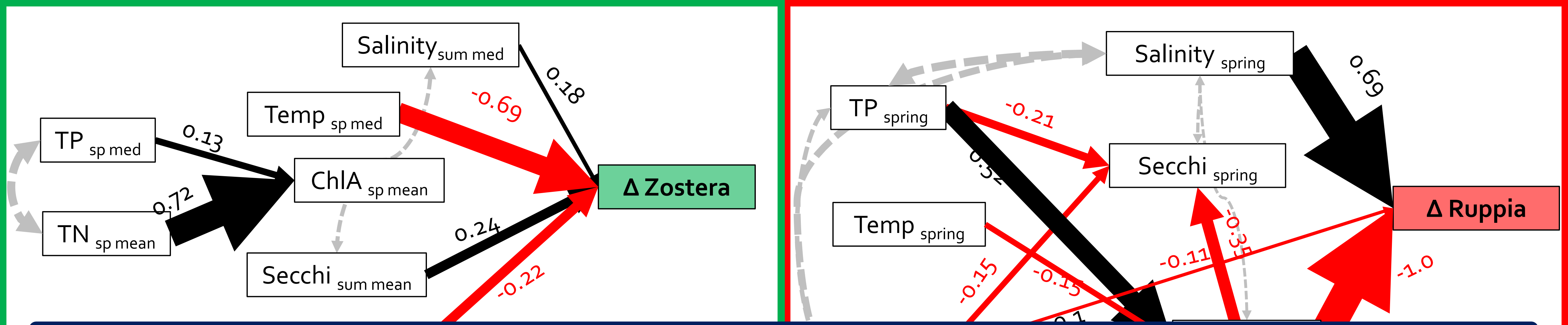
Structural Equation Modelling
example from *Ruppia*

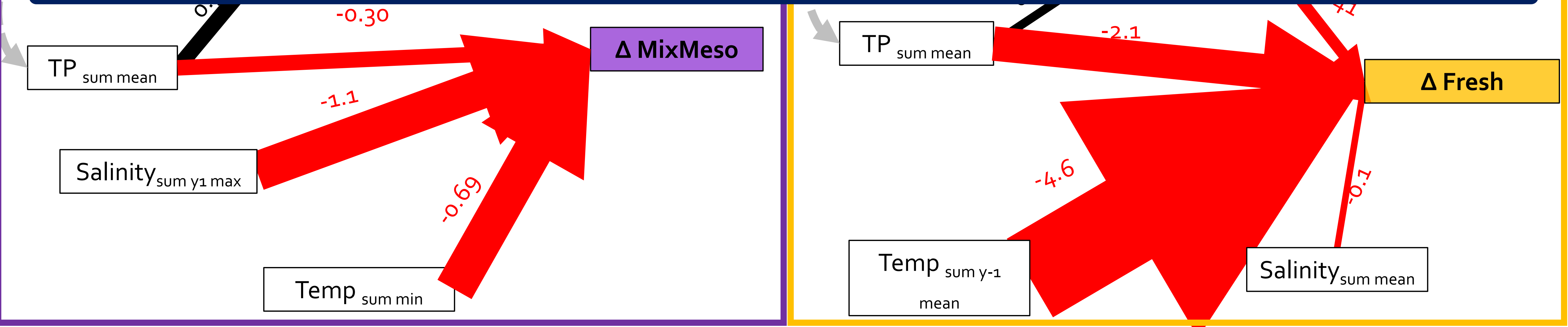


Δ Widg: $R^2_c = 0.59$


Salinity sum med
Temp sp med
TP sp med
ChlA sp mean
TN sp mean
Secchi sum mean
Temp sum y-1 med
Δ Zostera
0.18
-0.69
0.13
0.72
0.24
-0.22
Δ Zostera R²m= 0.59
Salinity spring
TP spring
Secchi spring
Temp spring
TN spring
ChlA spring
Δ Ruppia
0.69
-0.21
0.52
-0.35
-0.11
-0.15
-0.15
0.1
-1.0
Δ Ruppia: R²m= 0.76
Δ MixMeso R²m= 0.54
ChlA sum mean
TN sum mean
TP sum mean
Salinity sum y1 max
Temp sum min
Δ MixMeso
0.1
0.51
-0.30
-1.1
-0.69
Δ Fresh: R²m= 0.82
TSS sum max
ChlA sum mean
TP sum mean
Temp sum y-1 mean
Salinity sum mean
Δ Fresh
0.1
0.22
-0.41
-2.1
-4.6
-0.1

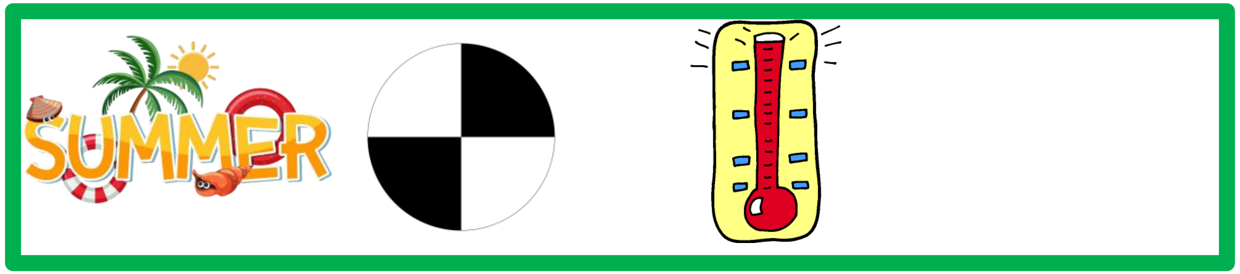
Step 1 RESULTS:
Different communities controlled by different seasonal variables, according to SEM from 1984-2020





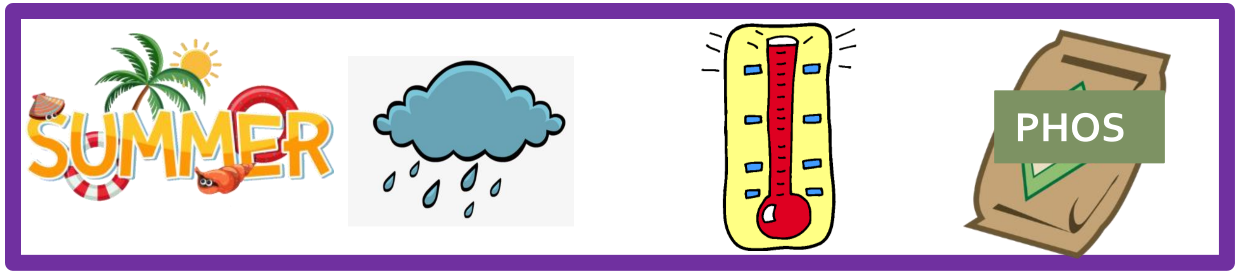
Seasonal climate and anthropogenic drivers

Zostera monoculture

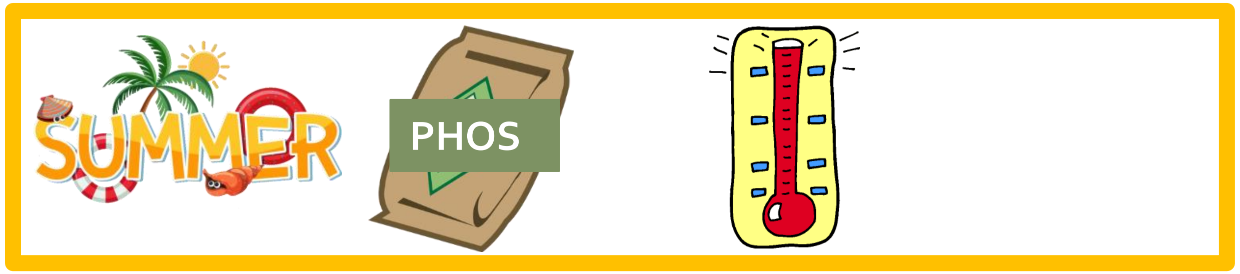


Ruppia monoculture

Mixed Mesohaline



Oligohaline/Tidal fresh



Predicting the future in three steps

Step 1	Climate (temperature, precipitation) and human activities (nutrients) have reshaped species dominance in CB
Step 2	How will environmental conditions shift with climate change & with human activities?
Step 3	How will shifting conditions and shifting species affect SAV meadow coverage into the future?

Predicting the future in three steps

Step 1

Climate (temperature, precipitation) and human activities (nutrients) have reshaped species dominance in CB

Step 2

How will environmental conditions shift with climate change & with human activities?

Step 3

How will shifting conditions and shifting species affect SAV meadow coverage into the future?

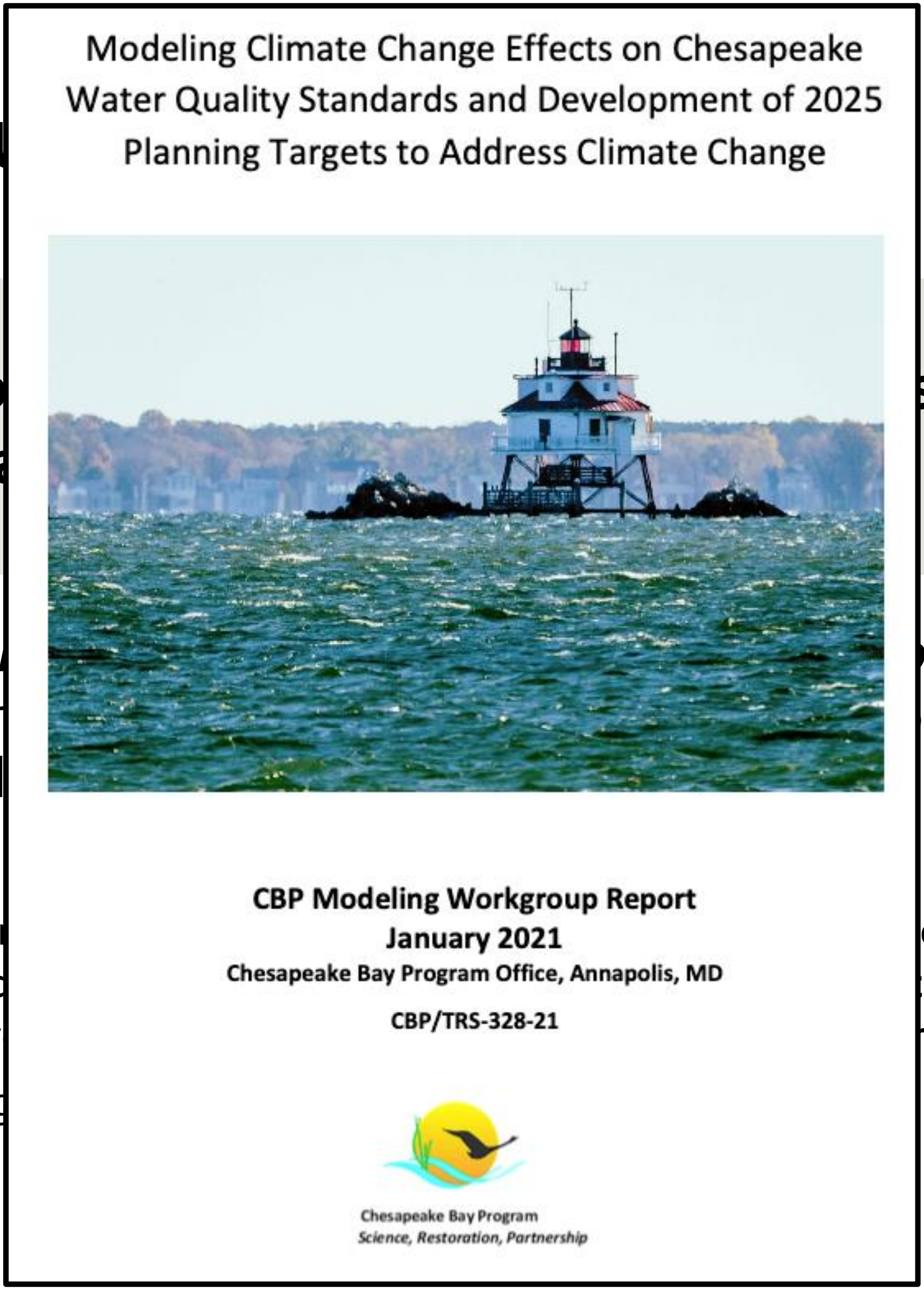
Predicting the fu

Step 2

Ho s shift with climate
cha

CB 60)
Ter rus, Water Clarity,
Chl

She d L. C. Linker. 2021.
Moc er Quality Standards and
Dev mate Change. Chesapeake Bay
Prog


Modeling Climate Change Effects on Chesapeake Water Quality Standards and Development of 2025 Planning Targets to Address Climate Change

CBP Modeling Workgroup Report
January 2021
Chesapeake Bay Program Office, Annapolis, MD

CBP/TRS-328-21

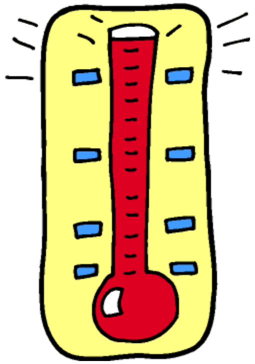
Chesapeake Bay Program
Science, Restoration, Partnership

Step 2: Two future scenarios from CBP Modeling data

No Further Action

No further nutrient reductions

Climate change accelerates



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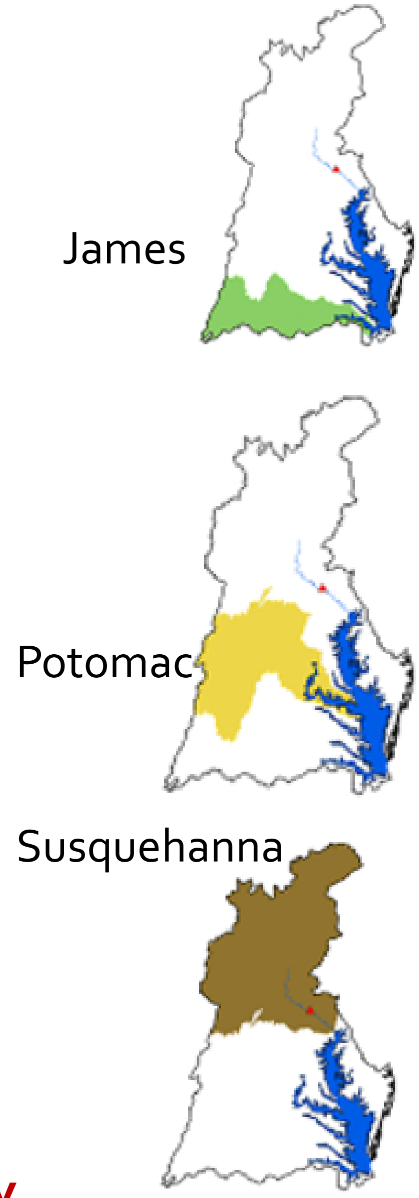
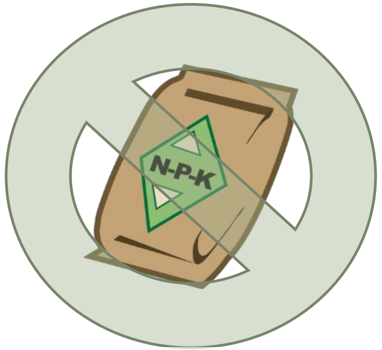
Temperature rise

Rainfall variability

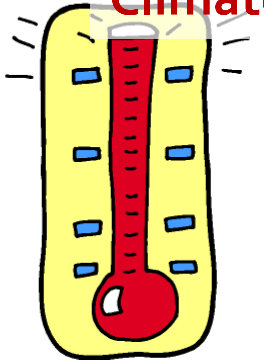


Nutrient Reductions



Agreed nutrient reductions (TMDLs)

Climate change accelerates

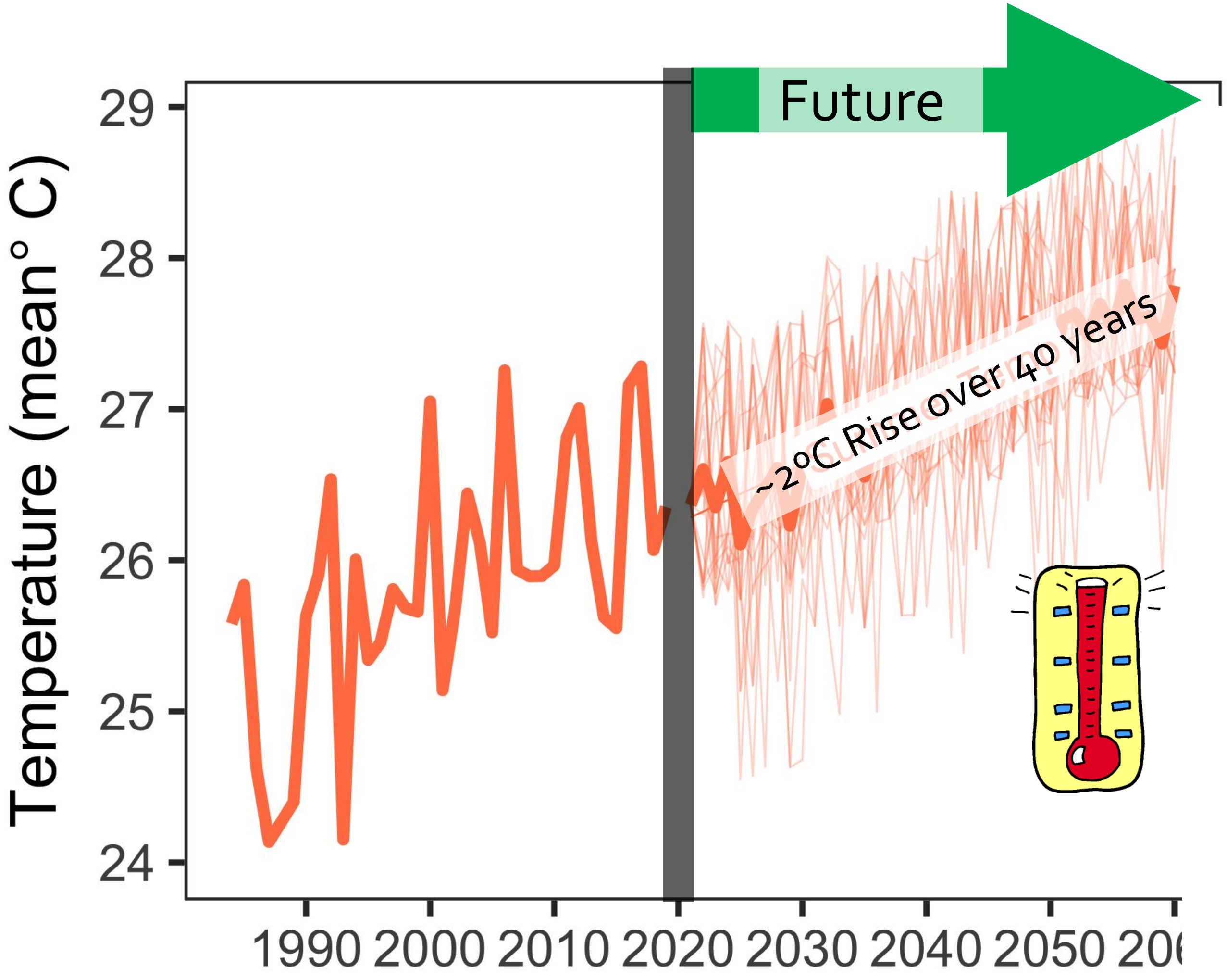


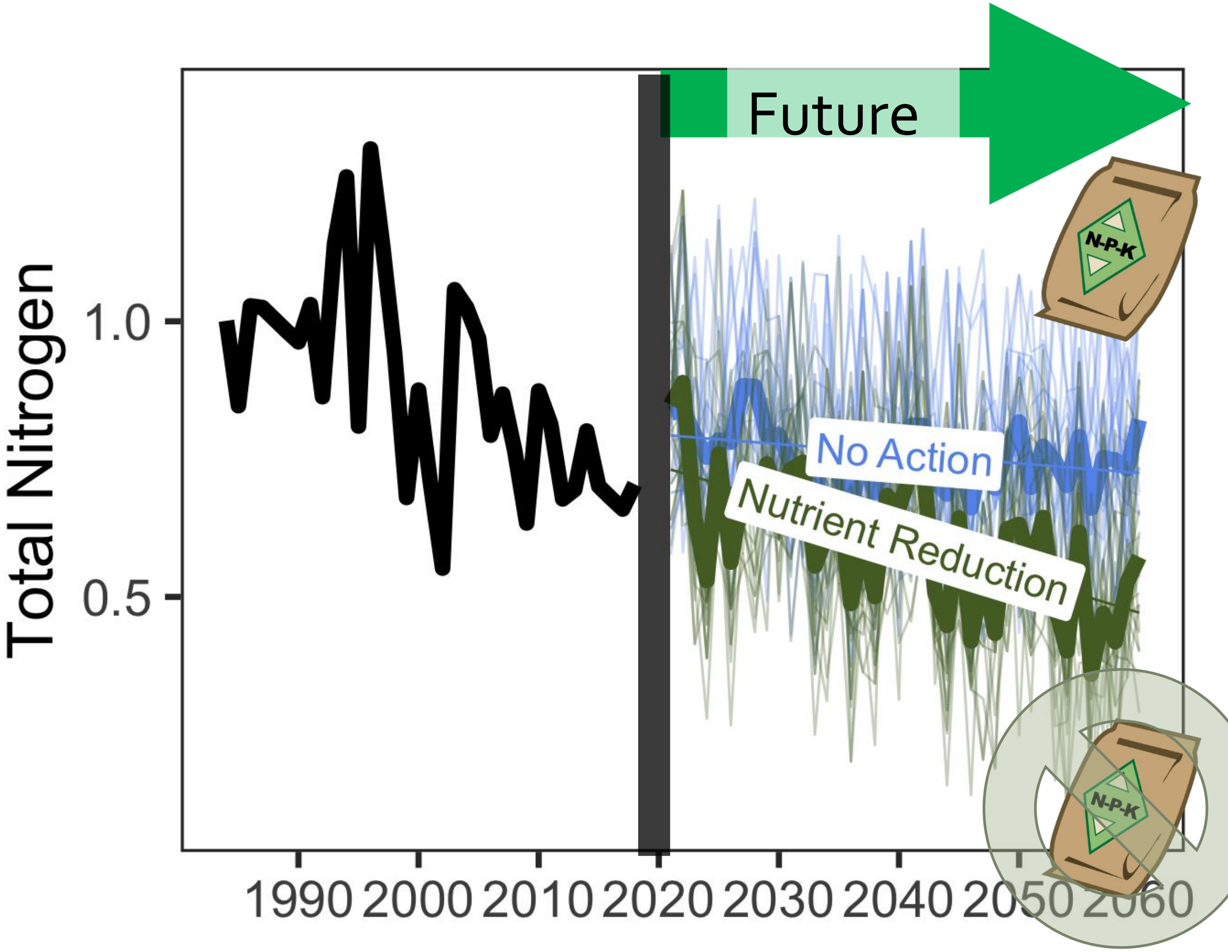
&

Temperature rise

Rainfall variability

Step 2: Temperature increase & rainfall variation in both, nutrient reductions vs no action





Predicting the future in three steps

Step 1 — Climate (temperature, precipitation) and human activities (nutrients) have reshaped species dominance in CB

Step 2 — **Temperature rise, precipitation variation are inevitable. Nutrient reductions may dictate future Bay conditions**

Step 3 — How will shifting conditions and shifting species affect SAV meadow coverage into the future?

Predicting the future in three steps

Step 1

Climate (temperature, precipitation) and human activities (nutrients) have reshaped species dominance in CB

Step 2

Temperature rise, precipitation variation are inevitable. Nutrient reductions may dictate future Bay conditions

Step 3

How will shifting conditions and shifting species affect SAV meadow coverage into the future?

Predicting the future in three steps

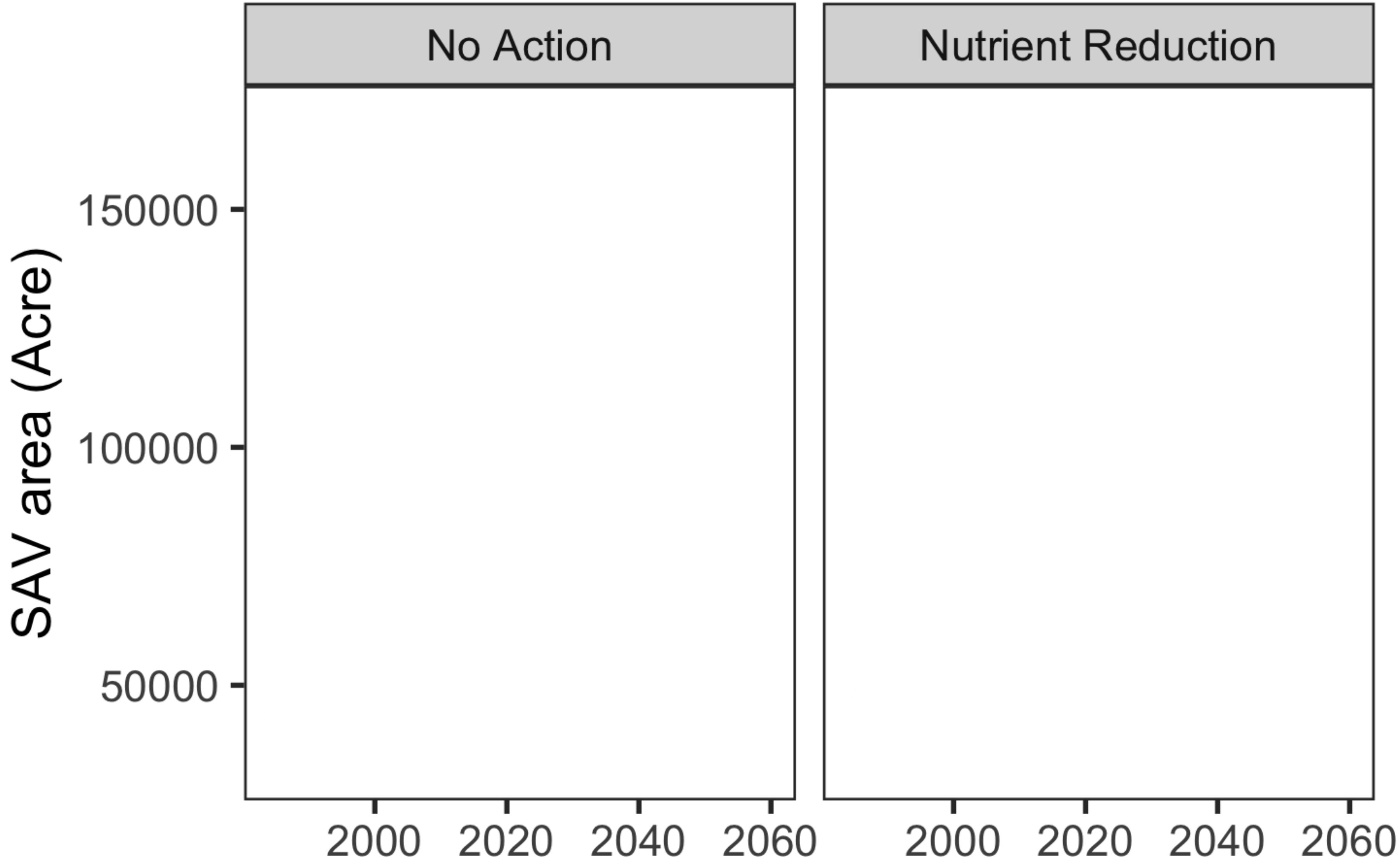
Step 3

How will shifting conditions and shifting species affect SAV meadow coverage into the future?

Predictive mixed effects models under two future scenarios (2021-2060)

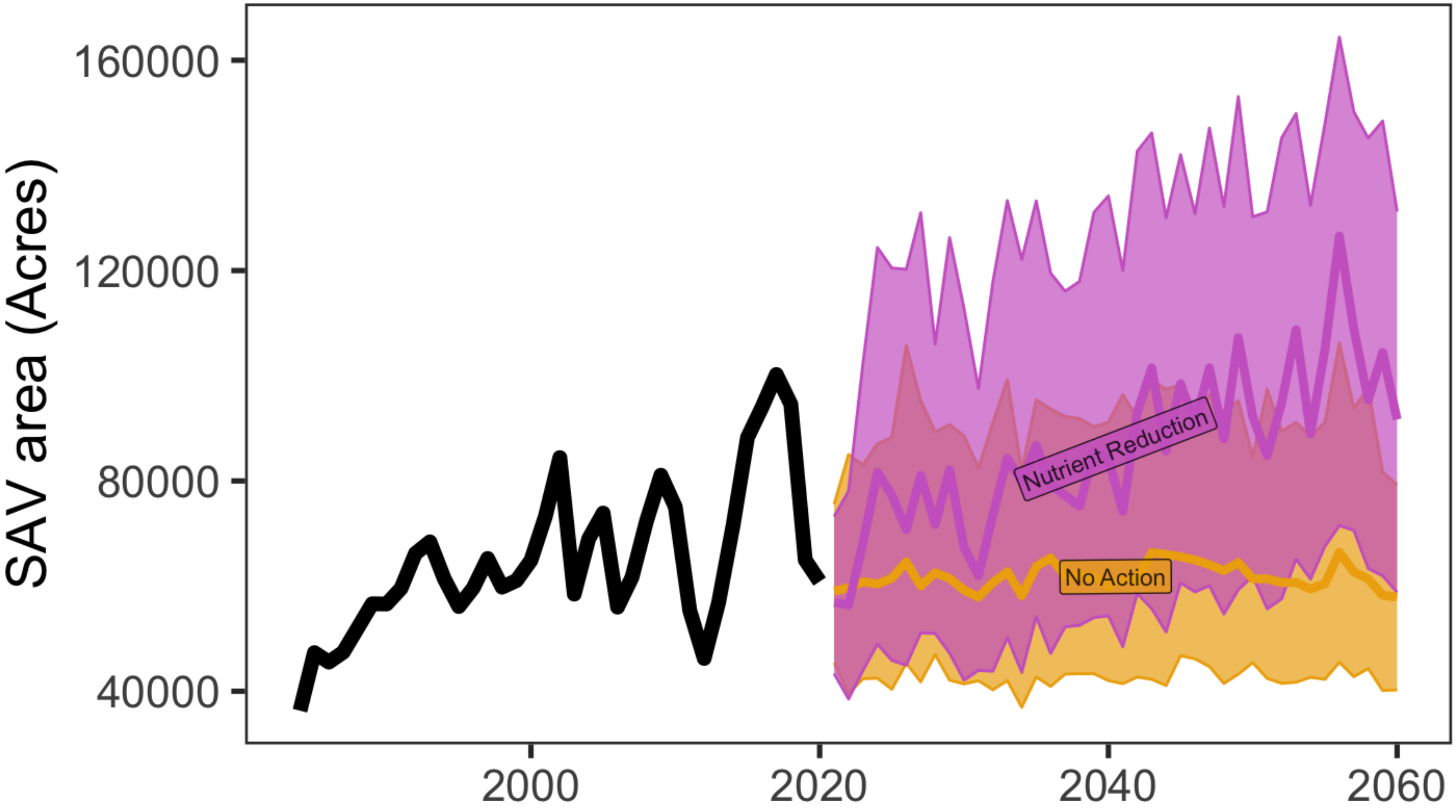
1000 simulations for each community

Climate change predictions|
Into the SAV Multiverse!!



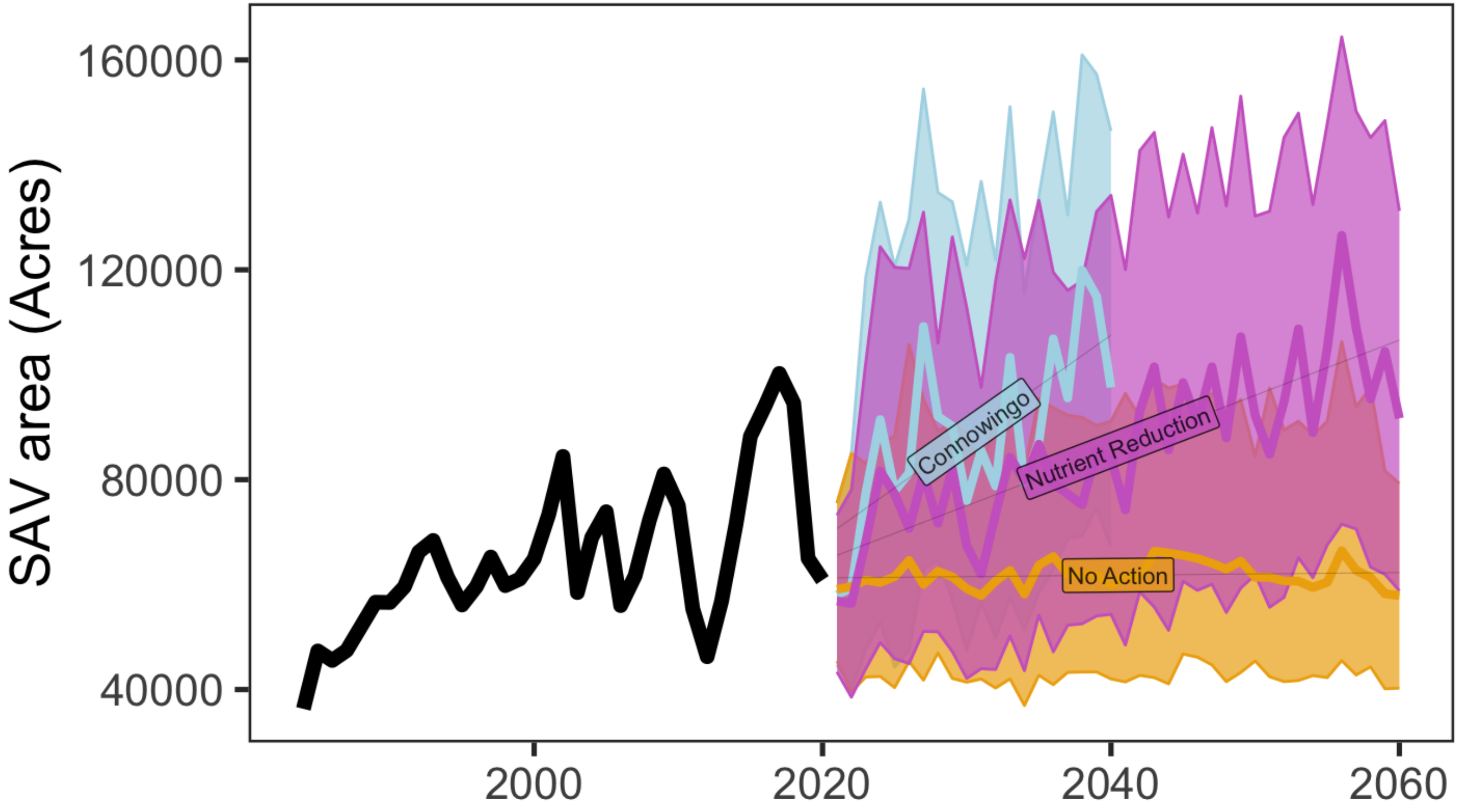
Climate change predictions|

95% envelopes show +50,000 acres by 2040 if nutrient reductions continue

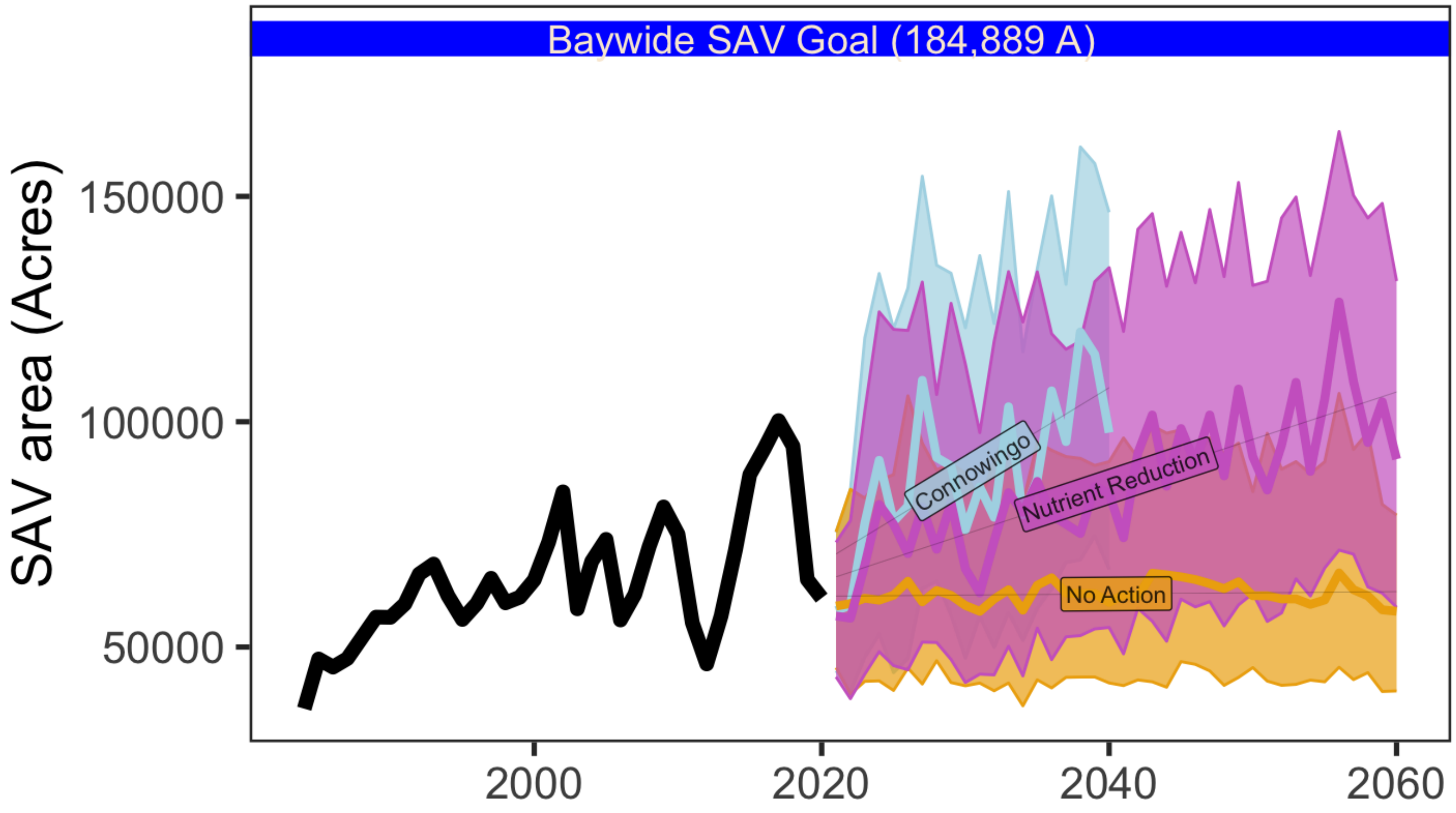


But they were deceived, for another simulation was made. In the land of the CBP Modeling Workgroup, the man Richard Tian forged in secret, the Connowingo Dam infill scenario that reduces another 10 million lbs of nitrogen and 1 million lb of phosporus

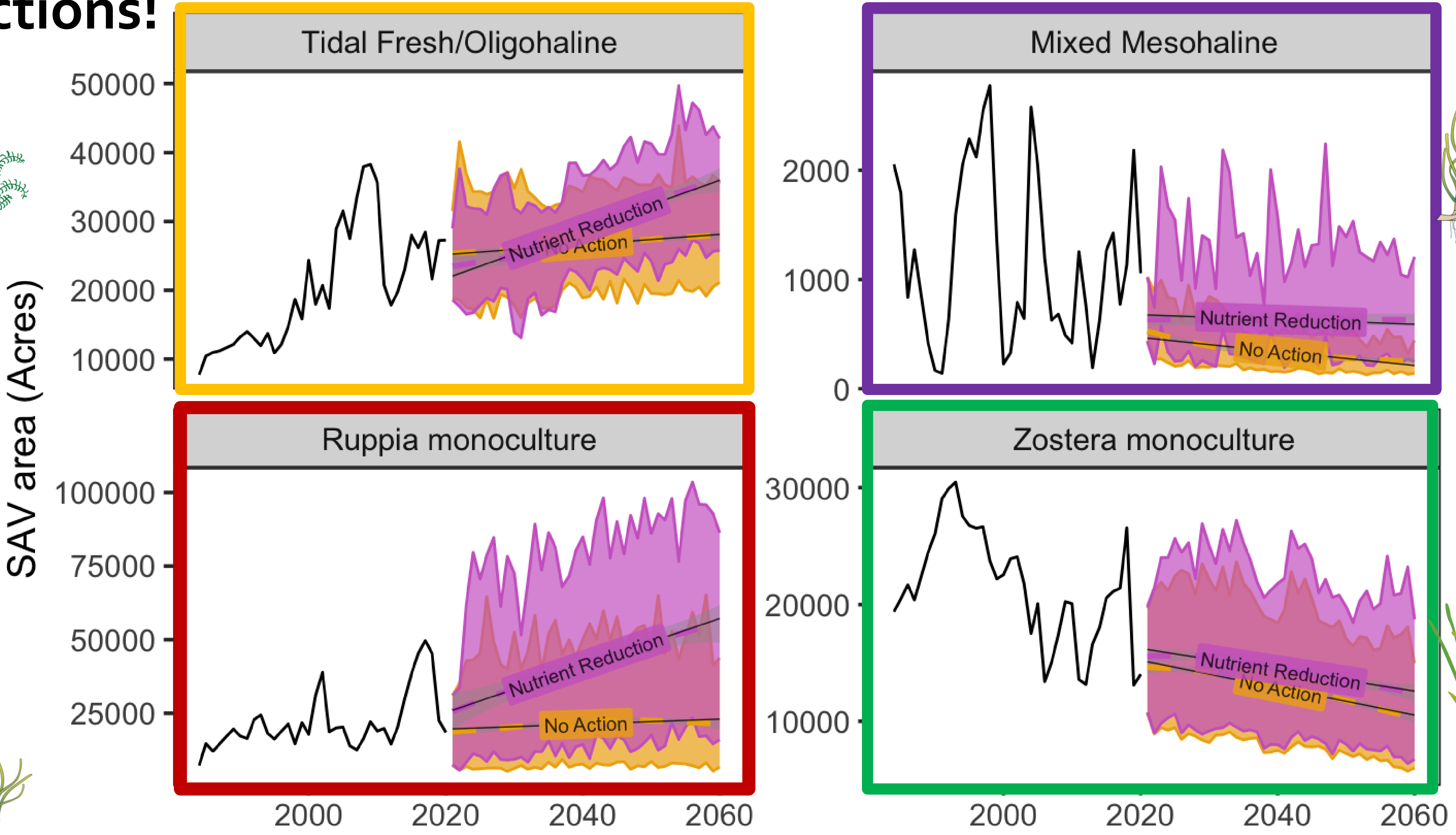
Climate change predictions|
Even further nutrient reductions from Connowingo scenario



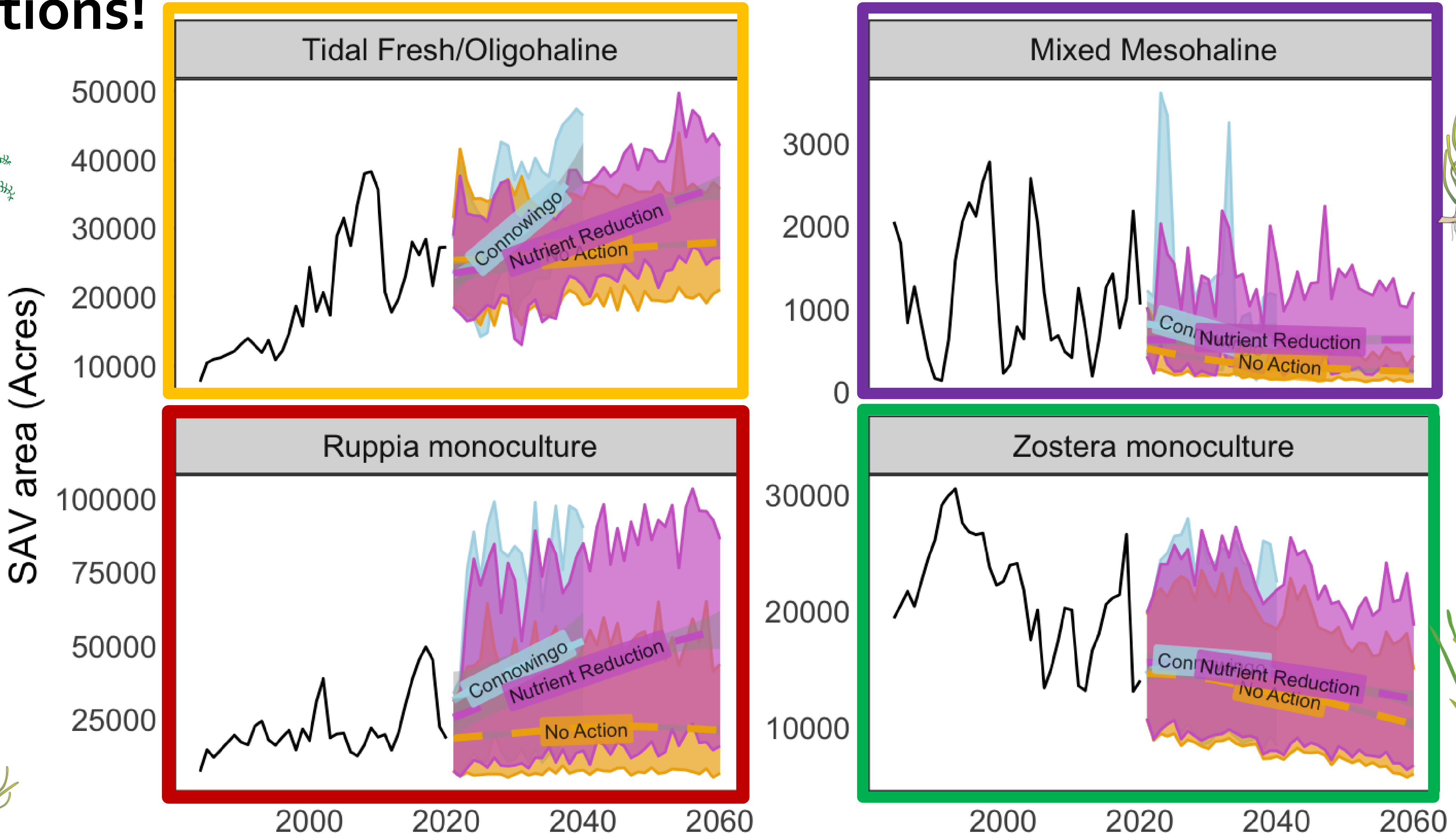
Climate change predictions|
0% of Nutrient reduction simulations reach Baywide goals..but get much closer by 2060!



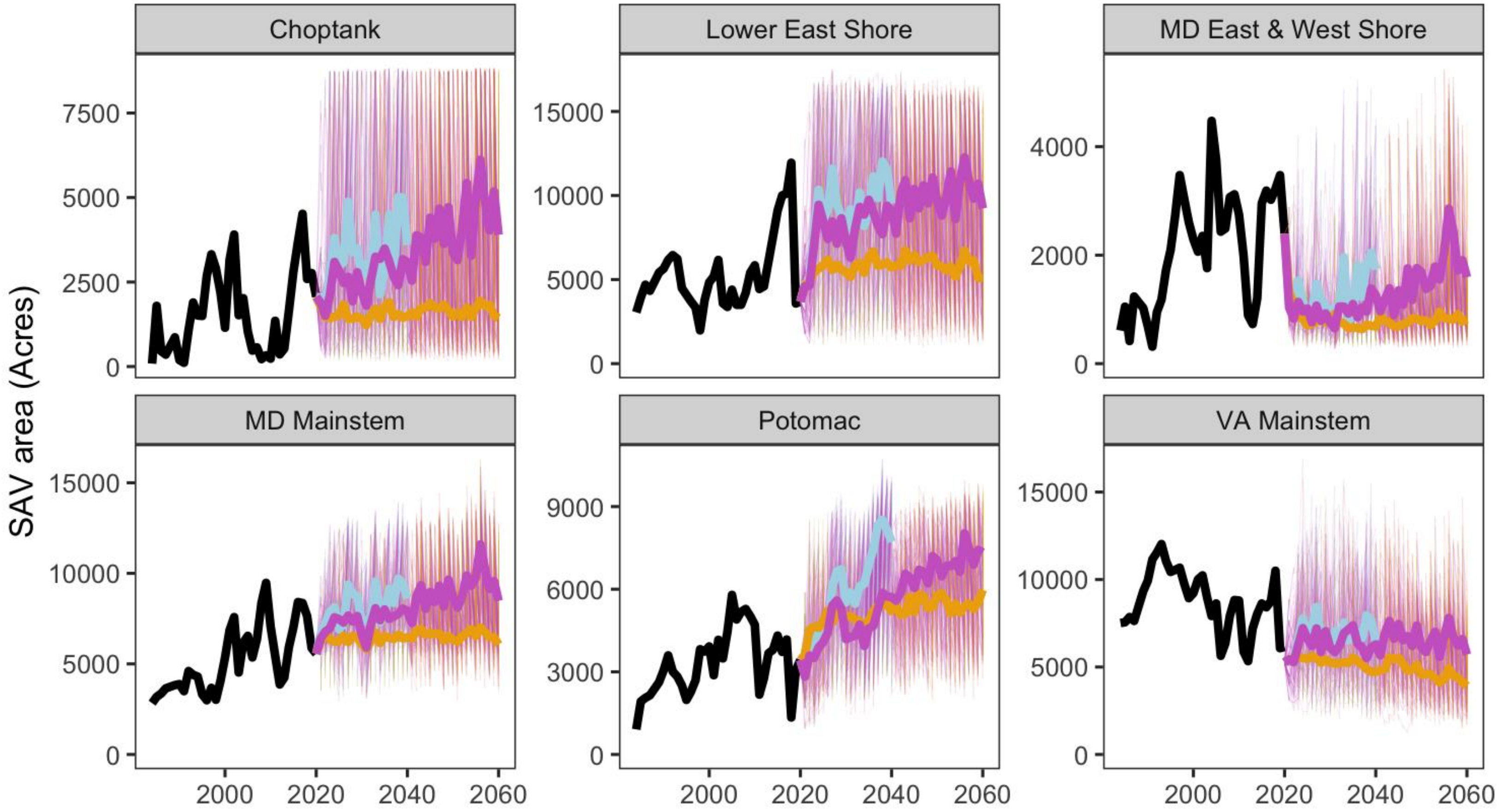
Climate change predictions| New dominants respond most positively to nutrient reductions!



Climate change predictions|
New dominants respond most positively to nutrient reductions!



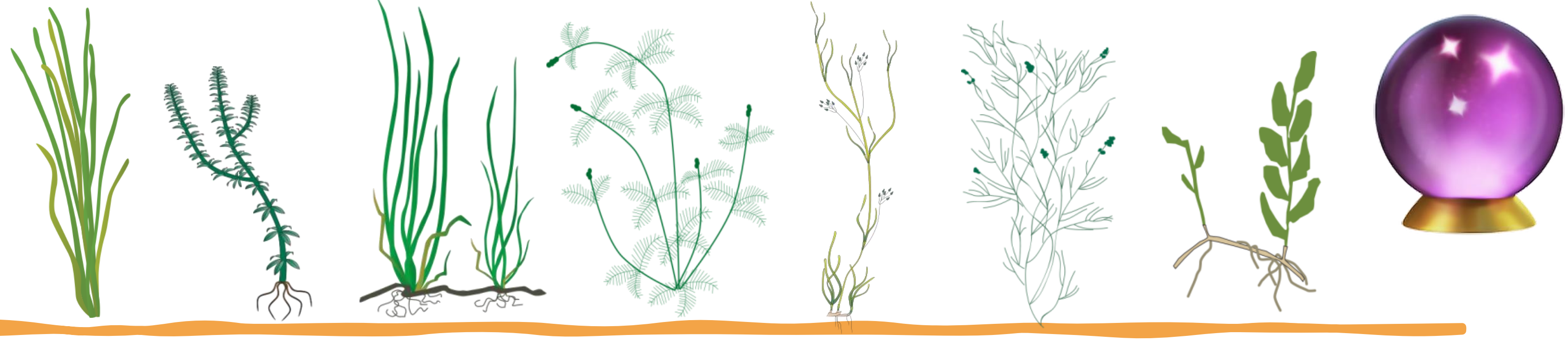
Climate change predictions|
Gains in Choptank, Lower E Shore, MD mainstem offset losses in York/James, VA



Predicting the future in three steps

Step 1	Climate (temperature, precipitation) and human activities (nutrients) have reshaped species dominance in CB
Step 2	Temperature rise, precipitation variation are inevitable. Nutrient reductions may dictate future Bay conditions
Step 3	**Widgeongrass and freshwater dominance elevates the importance of future, further nutrient reductions for a vegetated Chesapeake Bay**

SUMMARY



- **Temperature increases will widen the shift in dominant species, and management must adjust accordingly.**

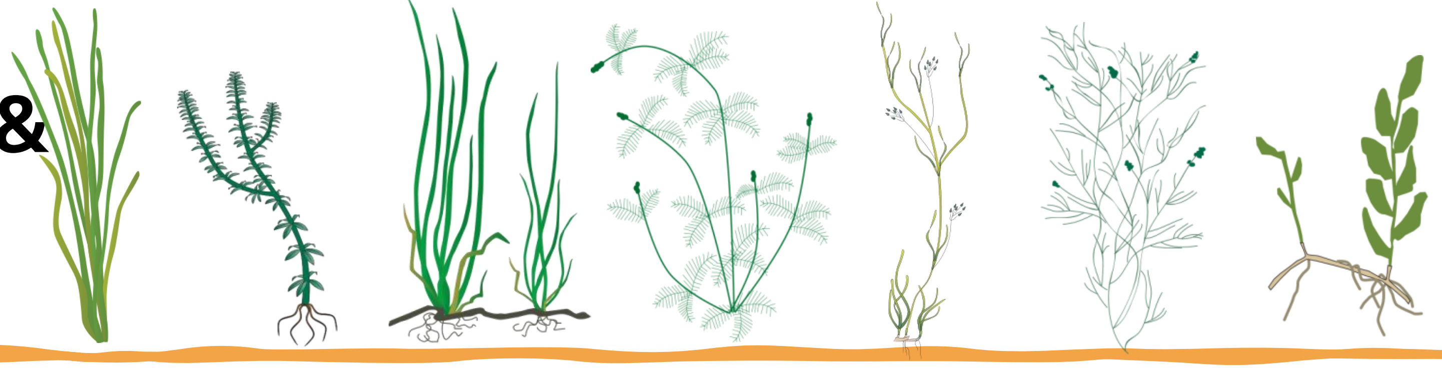
- **Nutrient reductions in the tidal fresh/oligohaline & *Ruppia* zones are essential, especially because the new dominants respond best to nutrient management**
    - **Further reductions in XXXX basins**

- **Local/regional action offsets and prevents the effects of global climate change (!!)**
    - targeted nutrient management that benefits climate-tolerant species encourages continued recovery

LESSONS LEARNED & WHAT WE DO NEXT

- Segment goals, baywide goals… now we need community goals
- We must start modeling and predicting species shifts, food web shifts, and changes in fisheries
- Local/regional action offsets and prevents the effects of global climate change (!!)
- Even further nutrient reductions look very promising

LESSONS LEARNED & WHAT WE DO NEXT



- What would other regions need to do predictions like this, as more conditions and species change? Can we build a roadmap for data poor regions to get on track for climate change

- We must start modeling and predicting species shifts, food web shifts, and changes in fisheries

- Local/regional action offsets and prevents the effects of global climate change (!!)

- Even further nutrient reductions look very promising

THANKS to our steering committee!

J.J. Orth, Bill Dennison, Rebecca Murphy, Jeremy Testa, Matt Fitzpatrick, Katia Engelhardt, Cassie Gurbisz, Karen McGlathery, Aaron Kornbluth, Joel Carr, Lewis Linker, Kathrynlynn Theuerkauf, **Becky Golden & Brooke Landry**

Richard Tian
IAN media library

VIMS William & Mary
Virginia Institute of Marine Science

University of Maryland
Center for Environmental Science

NOAA
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Smithsonian

USGS
science for a changing world

Chesapeake Bay Program
A Watershed Partnership

United States Environmental Protection Agency

Maryland Department of Natural Resources