

# CBT Forage Indicator Project

## Final presentation

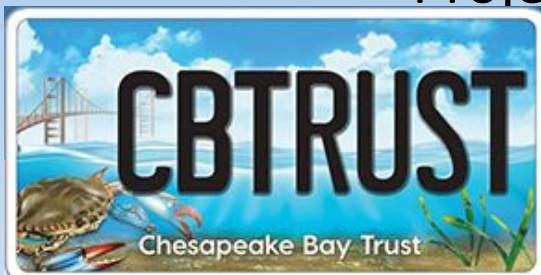
### *Forage Action Team Spring meeting*

UMCES Team: Ryan Woodland, Edward Houde, Vyacheslav (Slava) Lyubchich

Project Admin Team: Bruce Vogt, Mandy Bromilow, Justin Shapiro

Funder: Chesapeake Bay Trust/EPA

6/9/2022



# Project Goals

- Address stated needs of Chesapeake Bay Program:
  - Calculate and provide updated forage population indices
  - Explore new variants of the forage population indices
  - Relate forage population indices to forage climate indices
- Focal forage taxa
  - Polychaetes (marine annelids)
  - Bay Anchovy (*Anchoa mitchilli*)

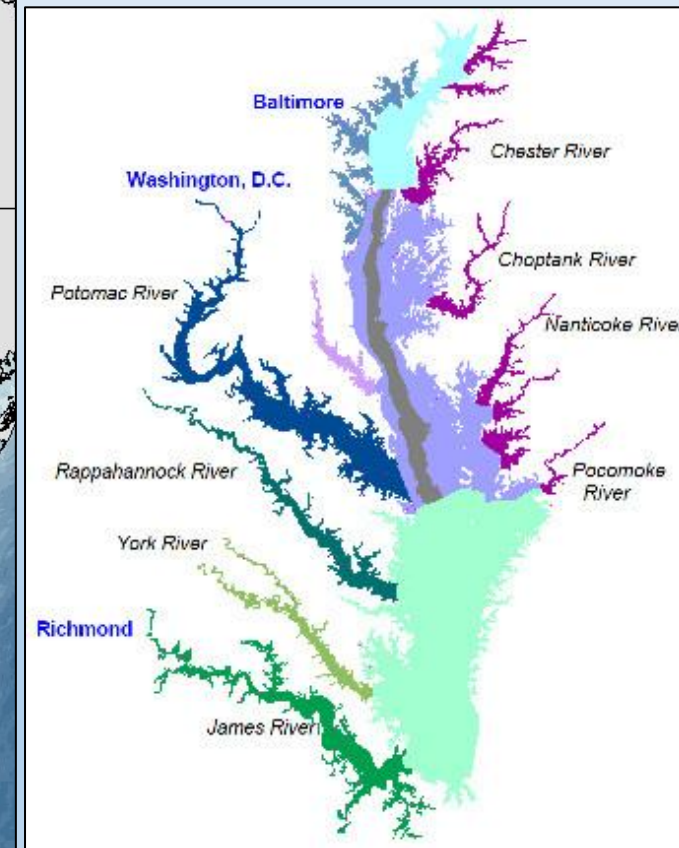
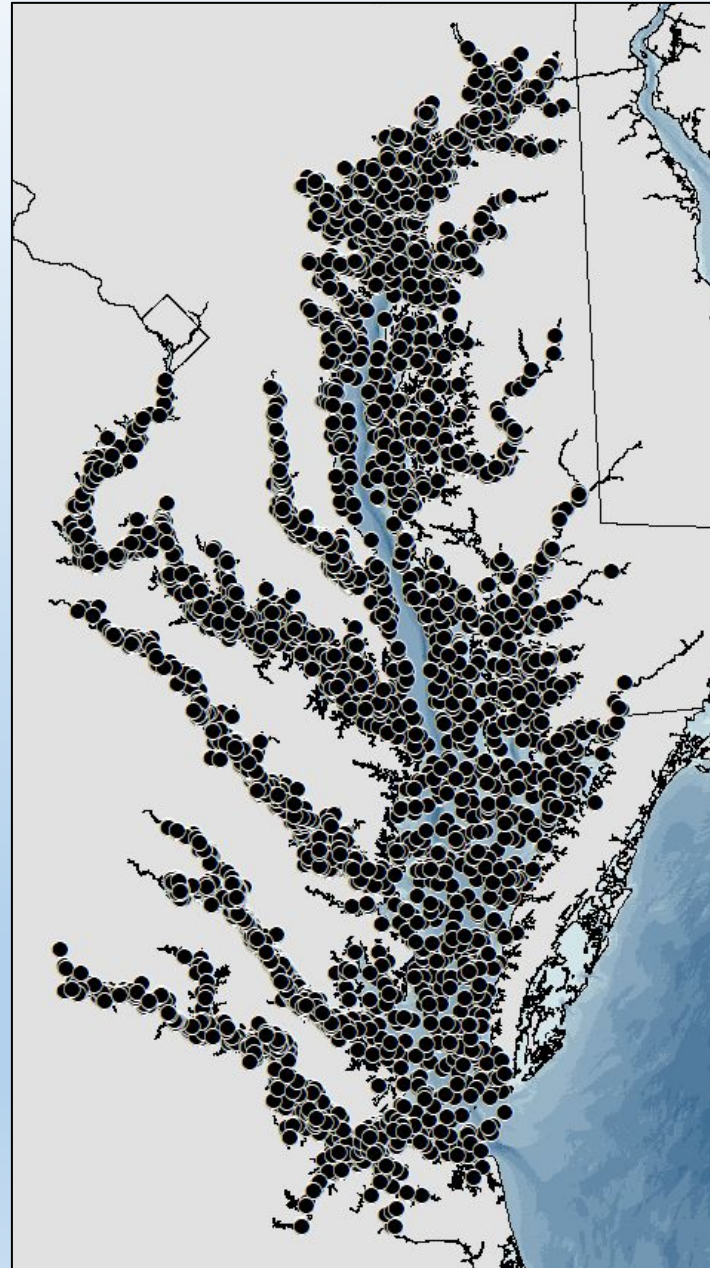


# Data sources

- Biota data sources
  - Chesapeake Bay Program
  - TIES/ChesFIMS
  - MD DNR/VIMS Seine survey
  - Juvenile fish & blue crab trawl survey (VIMS)
- Environmental data sources
  - Chesapeake Bay Program
  - VIMS Ferry Pier/Goodwin Is. CBNERR
  - CBL Pier time-series
  - NOAA National Data Buoy Center
  - NOAA Physical Sciences Laboratory
- Taxon index variants
  - Polychaetes
    - Nereididae
    - Total (all taxa)
  - Bay Anchovy
    - Age-1+ spawning stock index (Spring-ES)
    - Age-0 recruit index (LS-Autumn)
    - Total (annual index)

# Polychaete Survey: Spatiotemporal extent

- Spatial domain
  - CBP Benthic Survey random sampling component
- Temporal range
  - 1996-2019
  - July-Oct

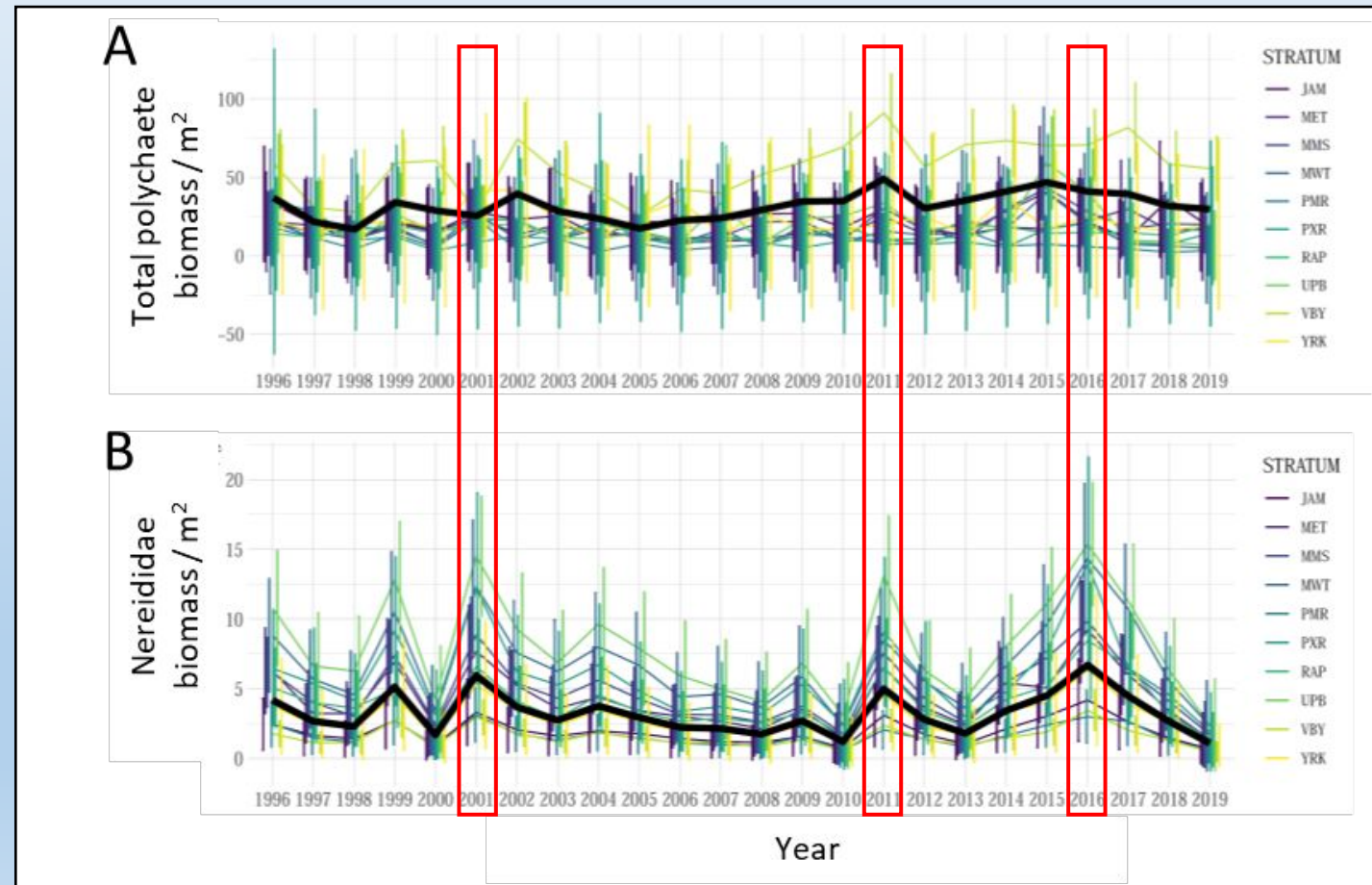






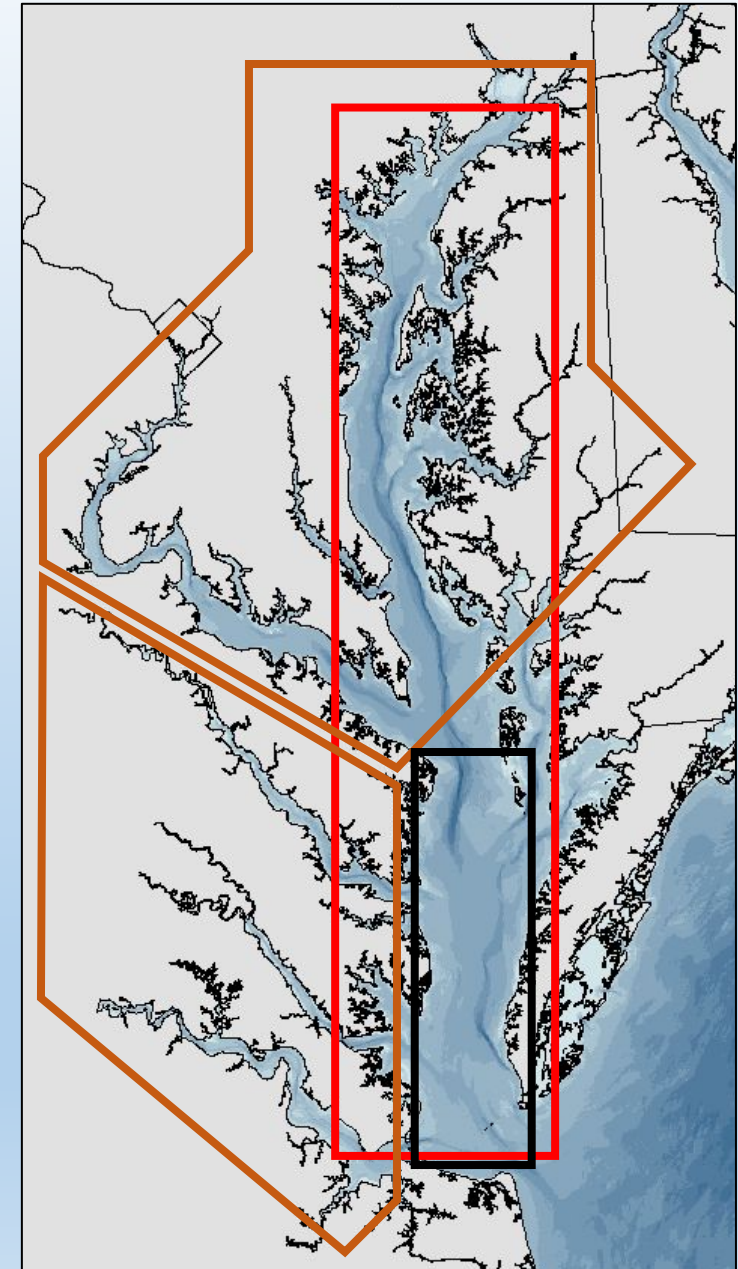
# Polychaete Survey: Spatiotemporal patterns

- Interannual patterns differ
- Regional rank order
  - Variable for Total
  - Consistent for Nereididae
- Regional hotspots
  - Total: Lower Bay, James River
  - Nereididae: Upper Bay, Patuxent River



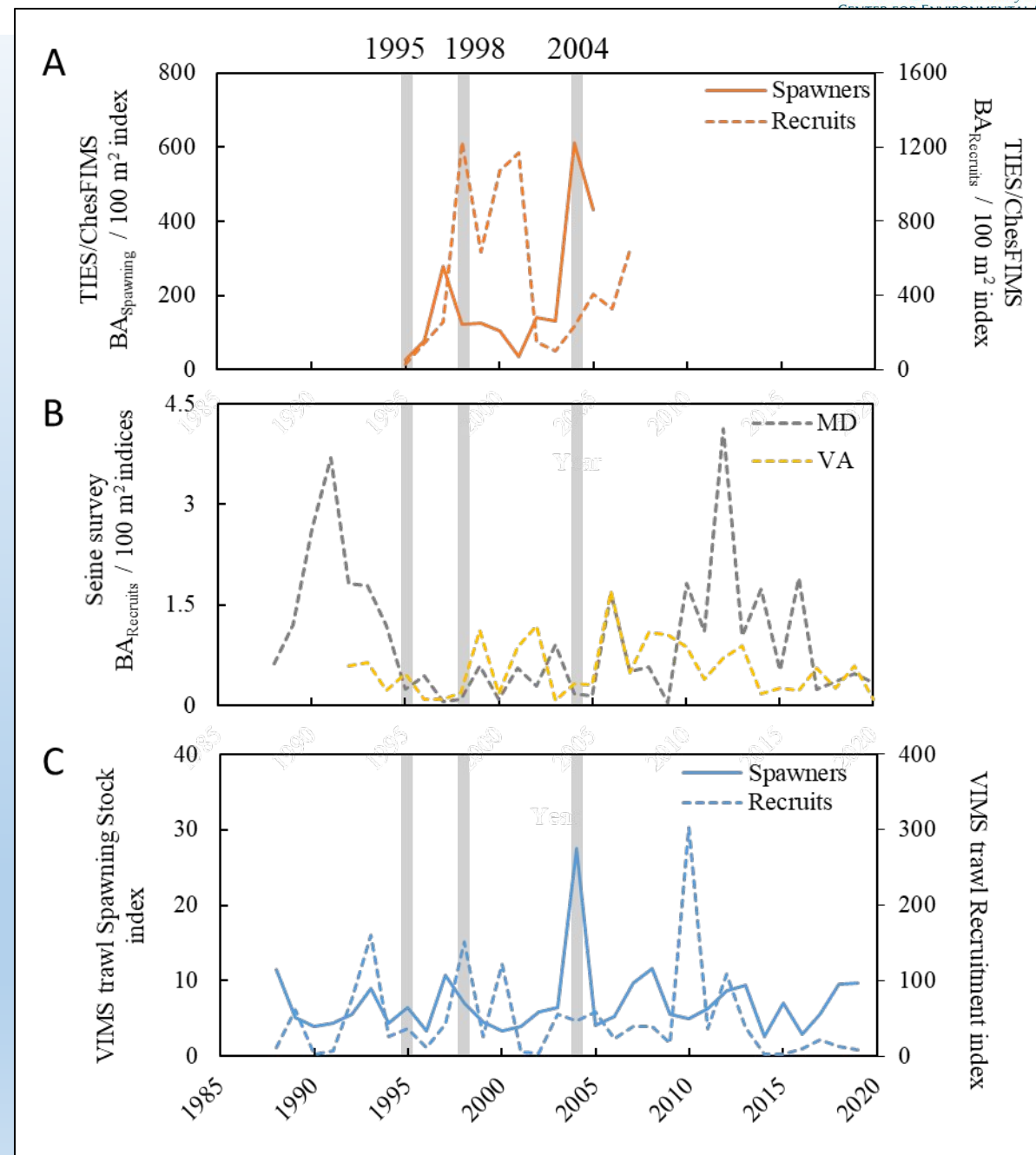
# Bay Anchovy Surveys: Spatiotemporal extent

- Spatial domain
  - Mainstem – TIES/ChesFIMS (red)
  - Mainstem – VIMS trawl (black)
  - Tributaries – MD/VIMS seines (Orange)
- Temporal range
  - TIES/ChesFIMS – 1995-2007
  - MD seine – 1988-2019
  - VIMS seine – 1992-2019
  - VIMS trawl – 1988-2019



# Bay Anchovy Surveys: Spatiotemporal patterns

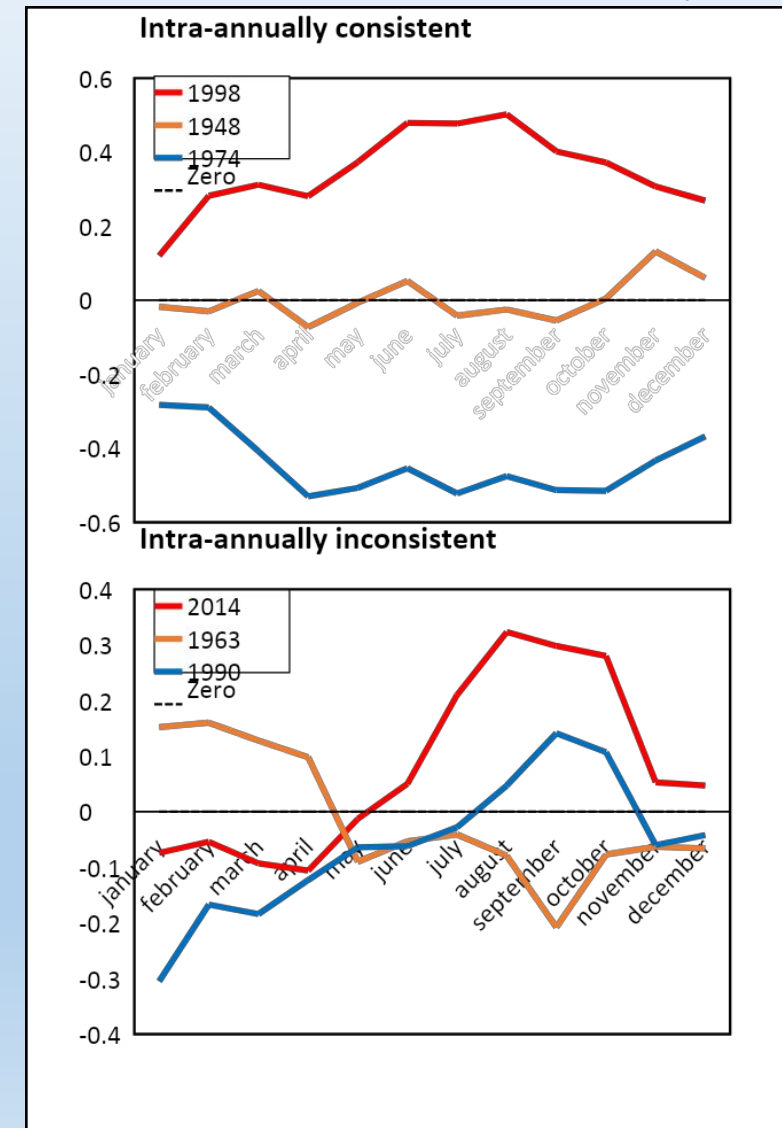
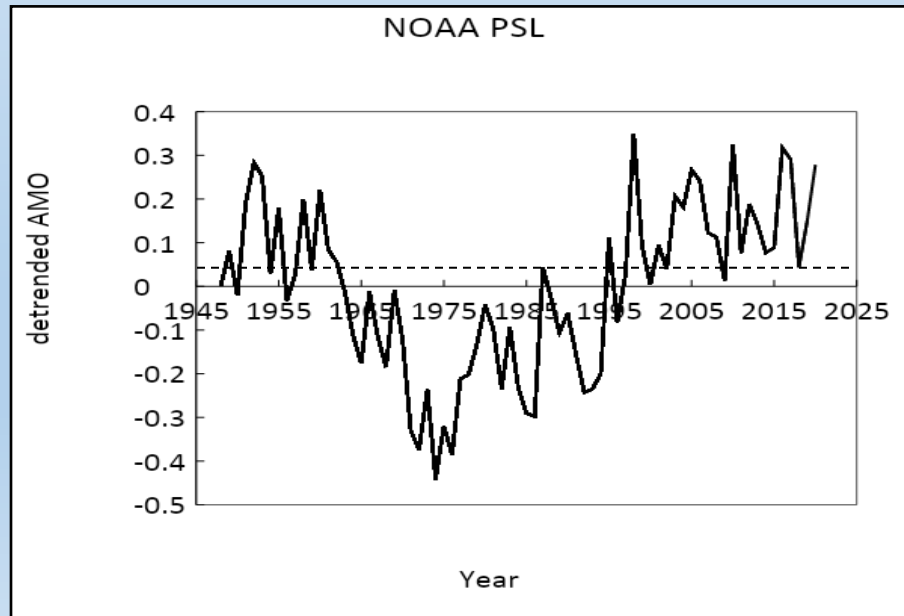
- Bay Anchovy (BA) indices
  - Stage dependent patterns
- Correlation between surveys within habitat types
- No correlation between surveys across habitat types



# Climate indices

- Focus on two climate indices
  - Atlantic Multidecadal Oscillation (AMO)
    - 1948-2020 annual indices available
    - AMO conditions vary intra-annually

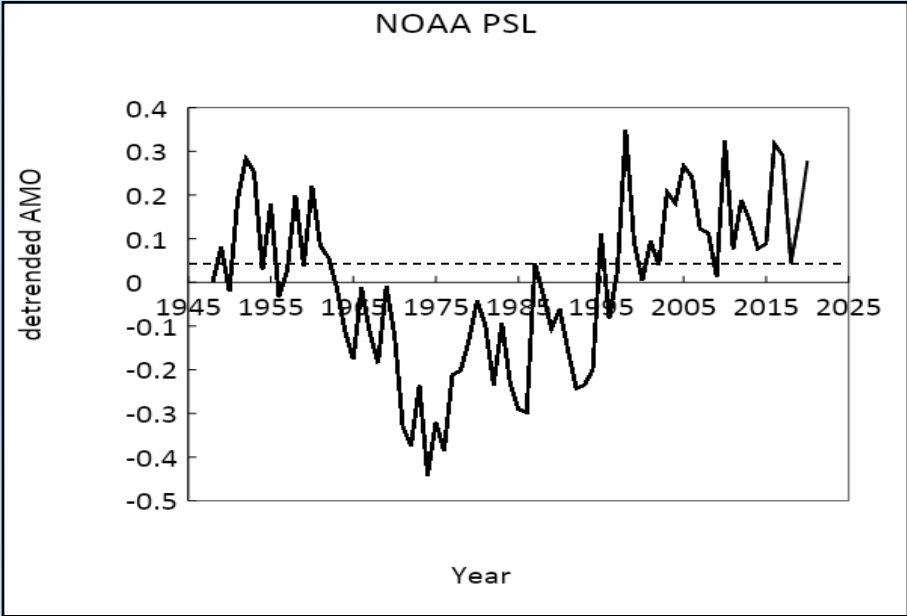
Examples of years with consistent AMO conditions (top)  
and inconsistent AMO conditions (bottom)



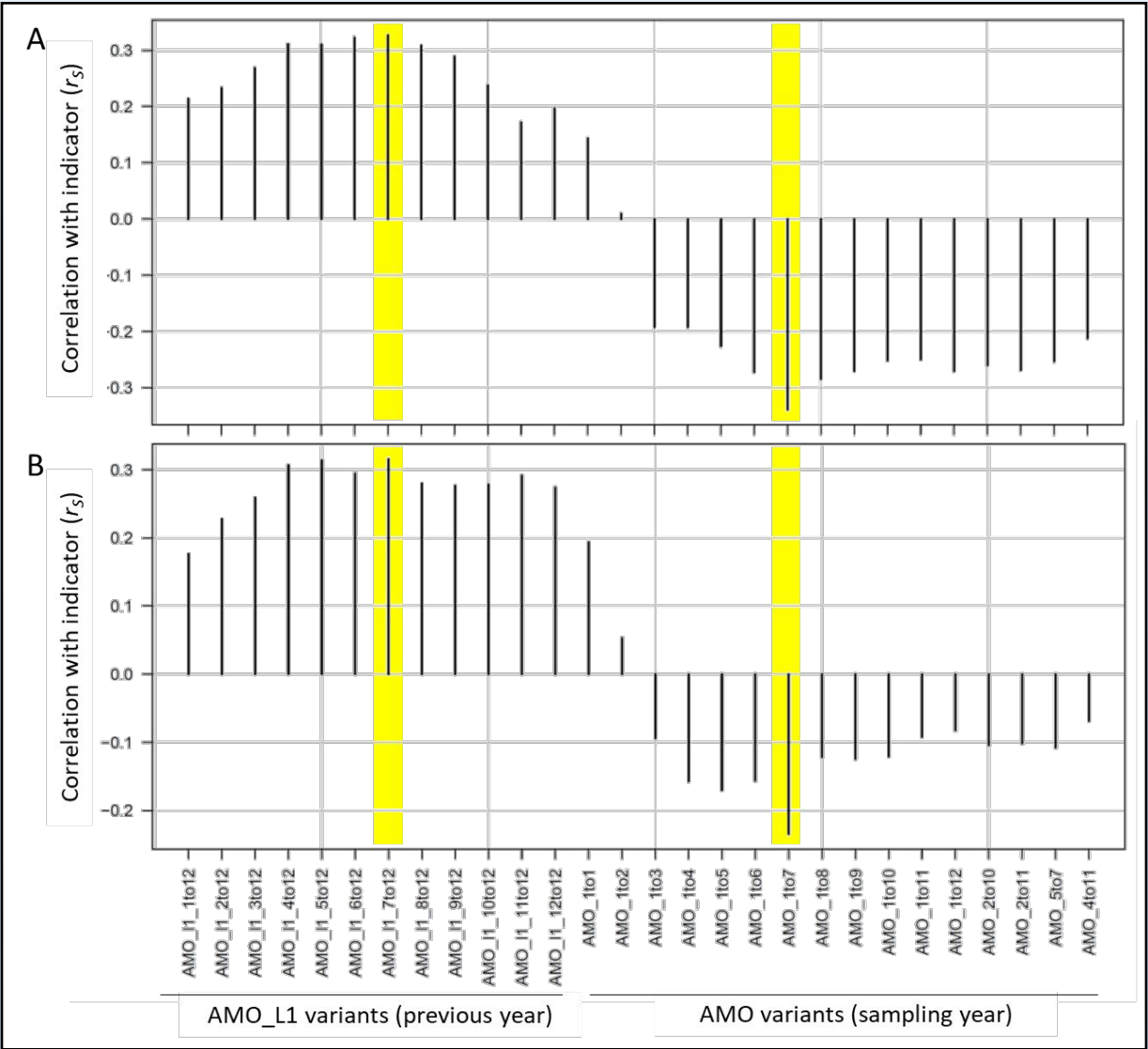


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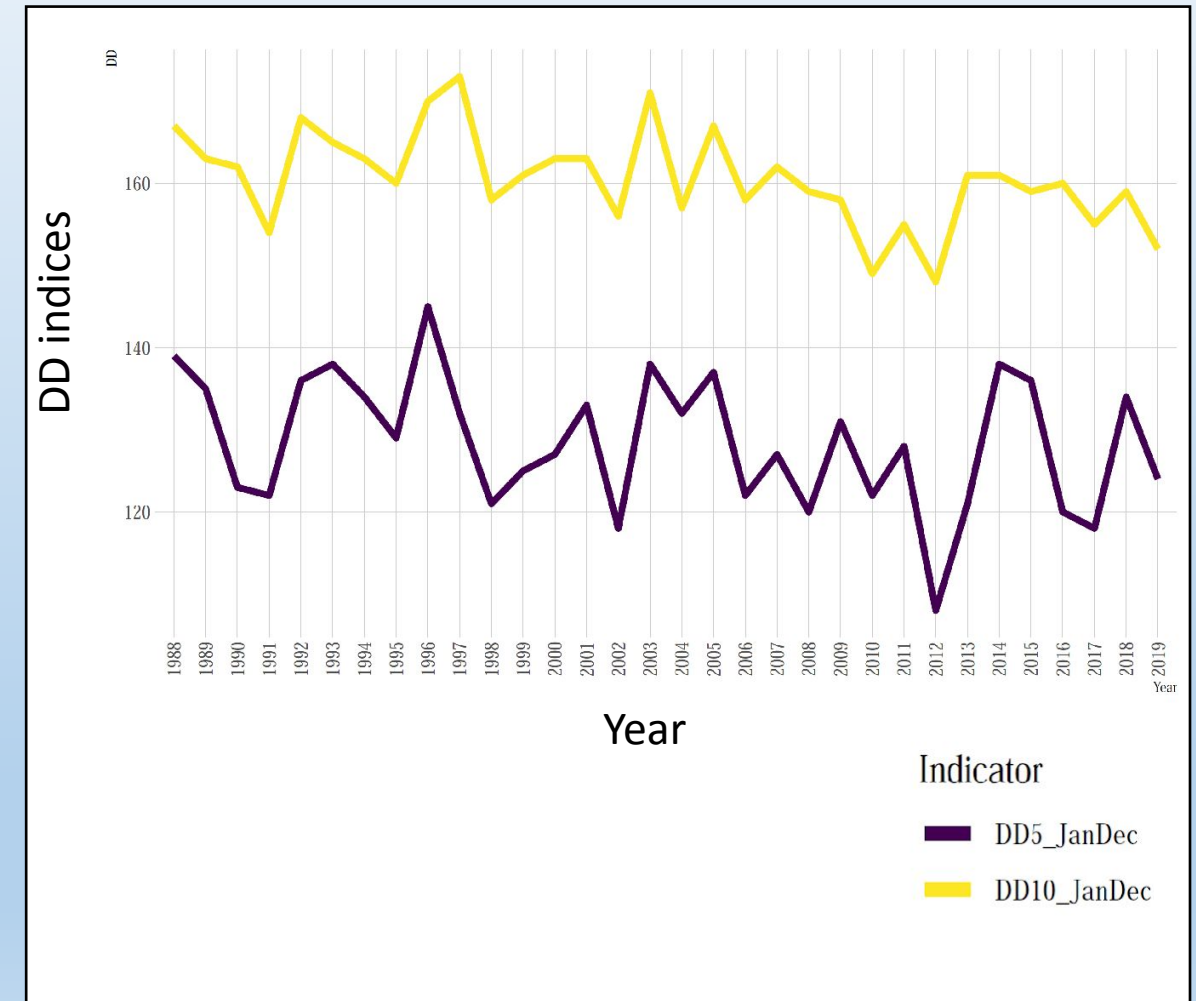


Varying monthly average AMO correlations w/Total and Nereididae Polychaete



# Climate indices

- Focus on two climate indices
  - Atlantic Multidecadal Oscillation (AMO)
    - 1948-2020 annual indices available
    - Partial year index values
  - Degree-Day Index (DD)
    - Mean daily water temperature: 1988-2019
    - Integer day each year at which the cumulative threshold of 500 5°C (DD5) or 10°C (DD10) is achieved



# Relating Forage & Climate indices

- Modeling approaches
  - General linear model (GLM)
  - General additive model (GAM)
  - Random forest (RF)
- Forage-Climate model variables
  - $\text{Forage} \sim \text{DD index} + \text{AMO} + \text{AMO}_{\text{Lagged}}$
- Model comparisons
  - 10-fold cross-validation
  - Model performance indicators (MAE, RMSE,  $R^2$ )
  - Visual assessment

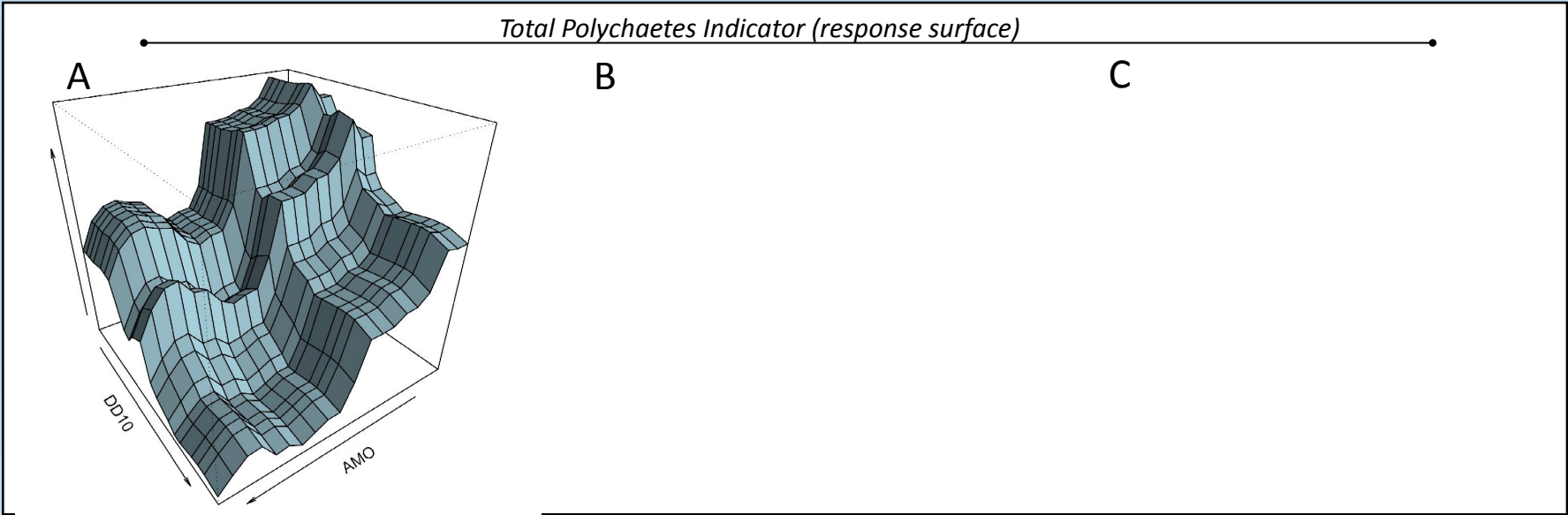
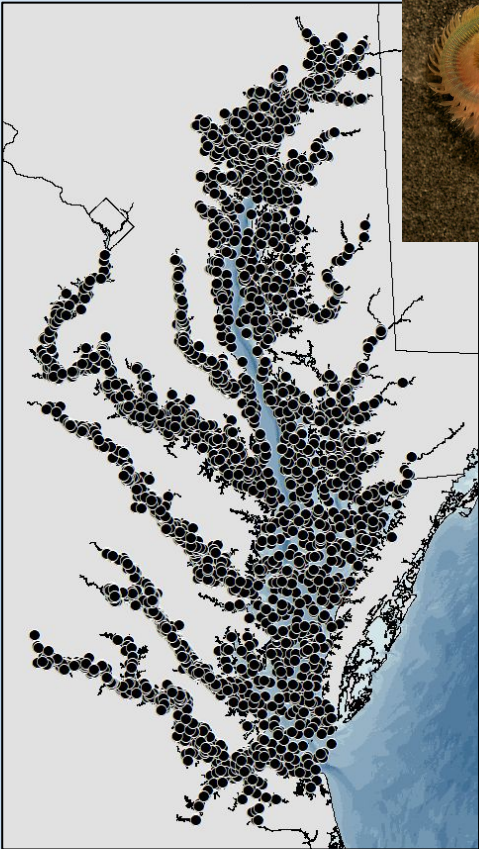
\*also considered detrended versions of DD indices

# Relating Forage & Climate indices

## Polychaete-Climate models



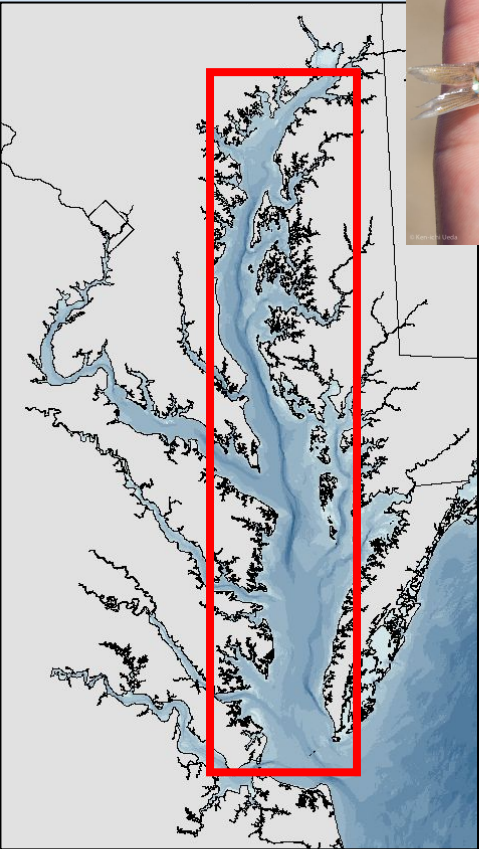
Taxon	Habitat	Group	DD	AMO	AMO <sub>Lag</sub>
Polychaete	Baywide	Total	-	-	+
		Nereididae			





# Relating Forage & Climate indices

## Bay Anchovy-Climate models



Taxon	Habitat	Group	DD	AMO	AMO <sub>Lag</sub>
Polychaete	Baywide	Total	–	–	+
		Nereididae			
Bay Anchovy	Mainstem	Spawning stock	–	+	+
		Recruits	–		–
		Total		Var.	–

# Relating Forage & Climate indices

## Bay Anchovy-Climate models





Taxon	Habitat	Group	DD	AMO	AMO <sub>Lag</sub>
Polychaete	Baywide	Total	–	–	+
		Nereididae			
Bay Anchovy	Mainstem	Spawning stock	–	+	+
		Recruits	–	∩	–
		Total	∩	Var.	–
	Tributaries	Recruits	–	–	
		Total	–	–	

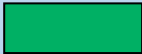


# Relating Forage & Climate indices

## Forage-Climate modeling results and discussion

- Degree days
  - Rapid vernal warming associated with ↑ indices
  - Covariates likely important (e.g., DO, river discharge)
- AMO
  - Positive AMO – warm conditions, precipitation intensity in summer/fall
  - Negative AMO – cooler conditions, lower winter daily minimums/longer durations
  - Recent work suggests AMO associated with annual extreme climate indices
  - ‘Good’ climate conditions differ among life history stages

Taxon	Habitat	Group	DD	AMO	AMO <sub>Lag</sub>
Polychaete	Baywide	Total	–	–	+
		Nereididae			
Bay Anchovy	Mainstem	Spawning stock	–	+	+
		Recruits	–		–
		Total		Var.	–
	Tributaries	Recruits	–	–	
		Total	–	–	

# Classifying Forage and Climate indices

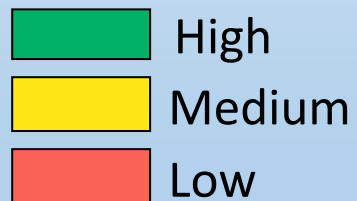
- Summarize forage indices
  - Developed numeric classifications based on:
    - Terciles ( $\sim$  normal distribution)
    - $k$ -means clustering (non-normal)
  - Assigned colorimetric scheme
    -  High
    -  Medium
    -  Low



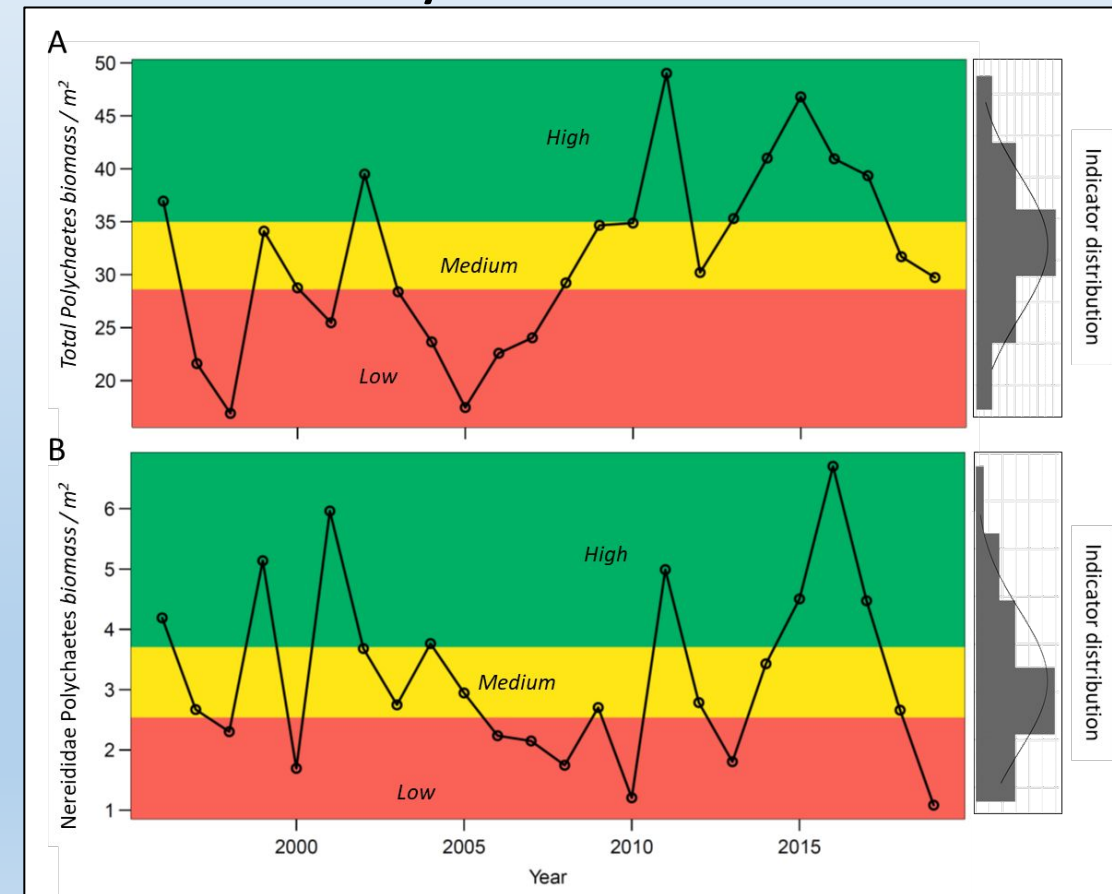


# Classifying Forage and Climate indices

- Summarize forage indices
  - Developed numeric classifications based on:
    - Terciles (~ normal distribution)
    - *k*-means clustering (non-normal)
- Assigned colorimetric scheme



## Polychaete indices

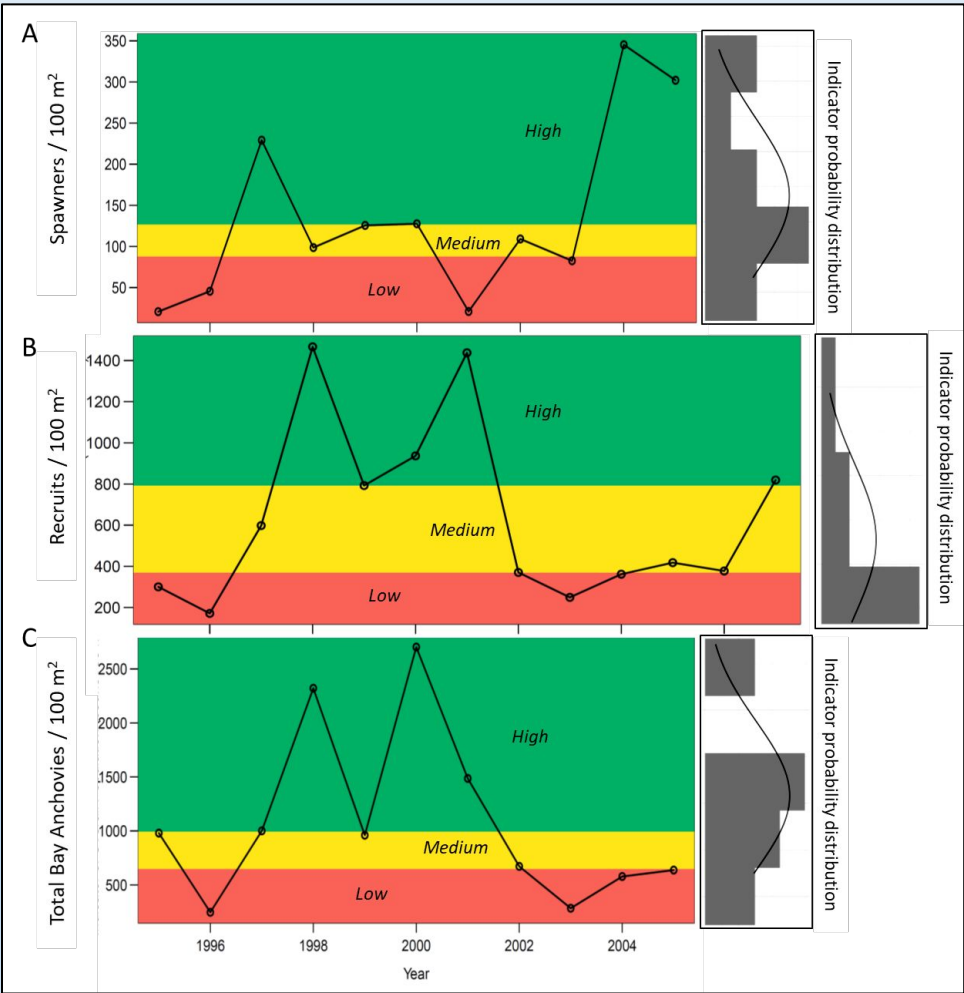




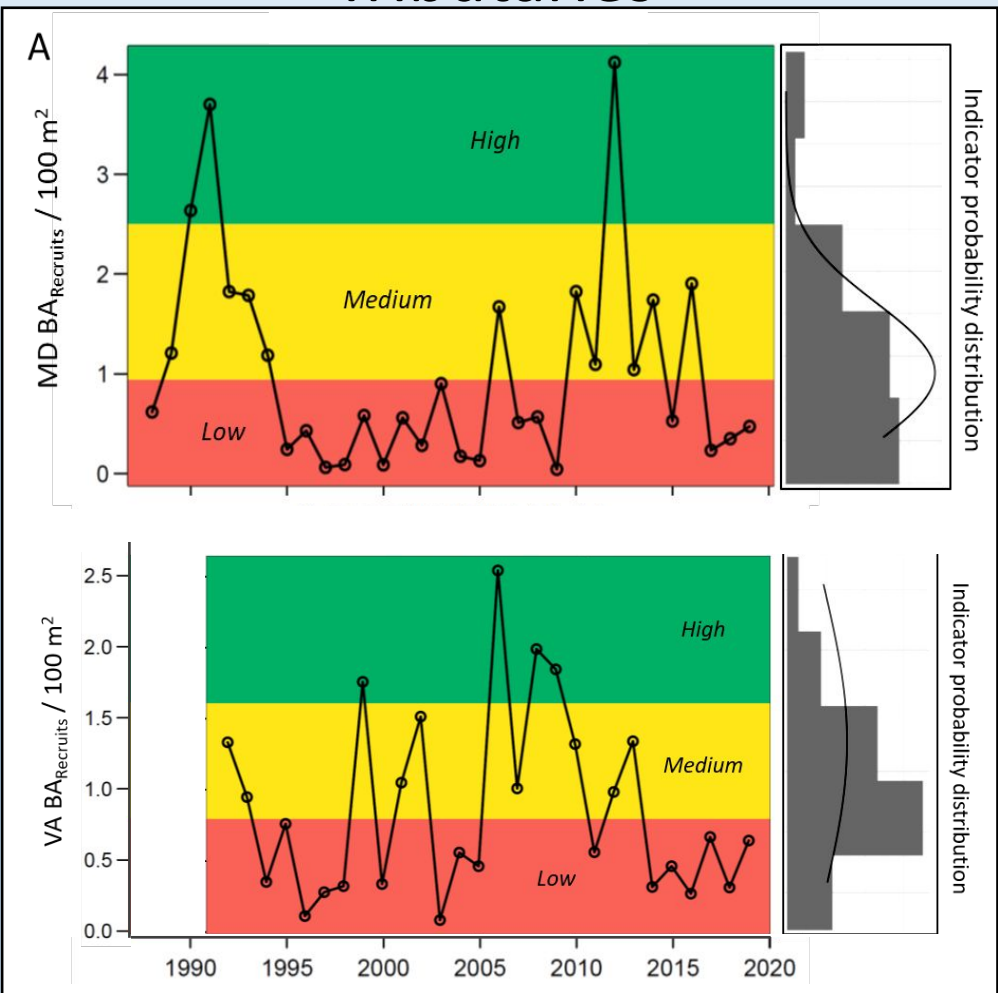
Bay Anchovy indices

# Classifying Forage and Climate indices

## Mainstem



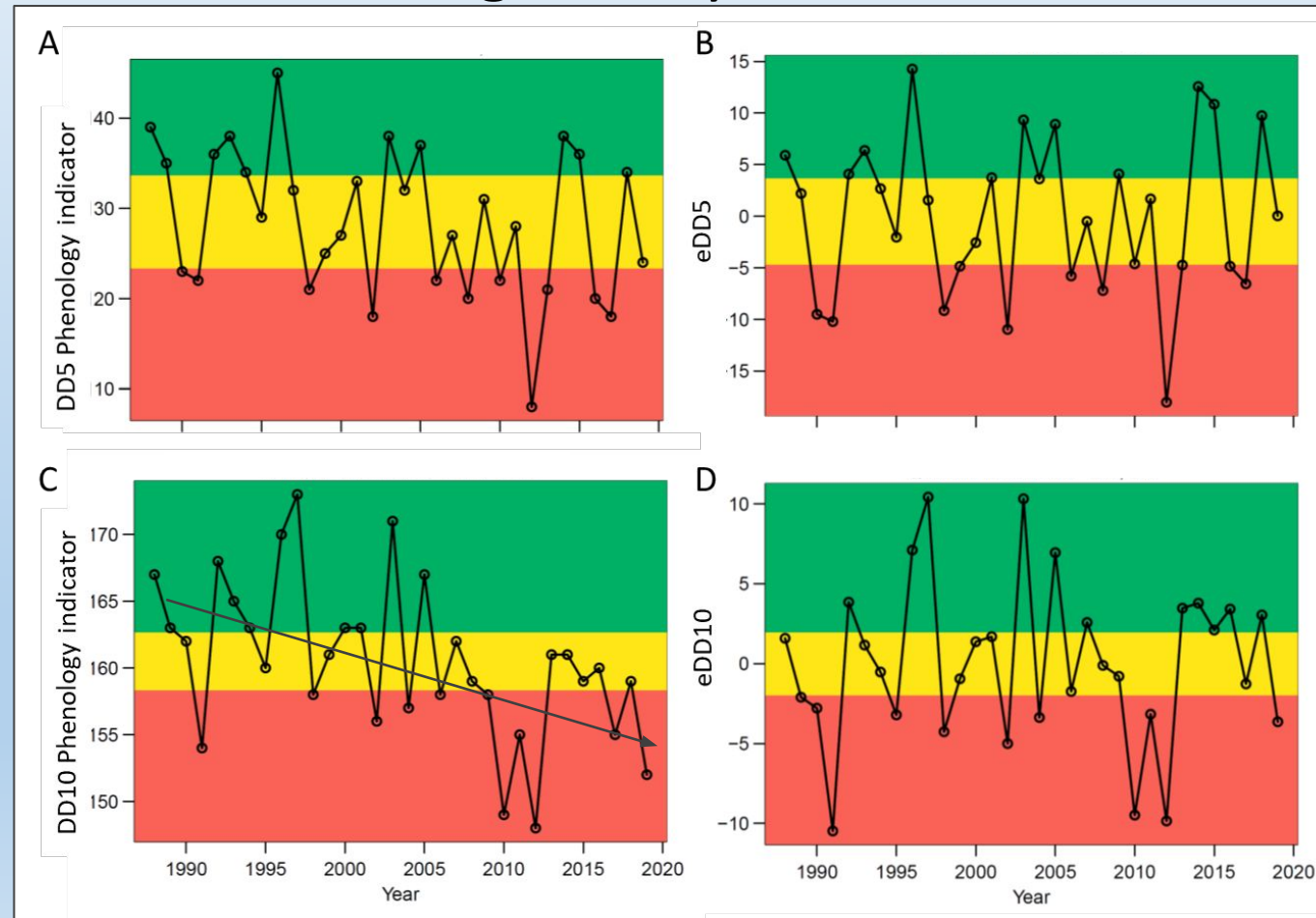
## Tributaries



Note: difference in tercile thresholds between states

# Classifying Forage and Climate indices

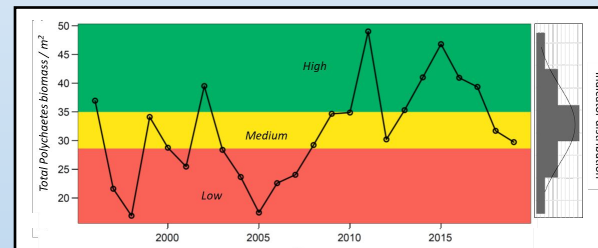
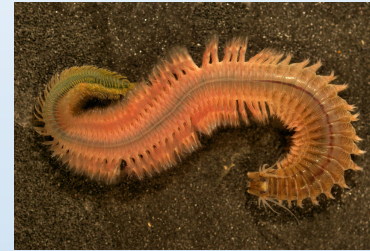
## Degree Day indices



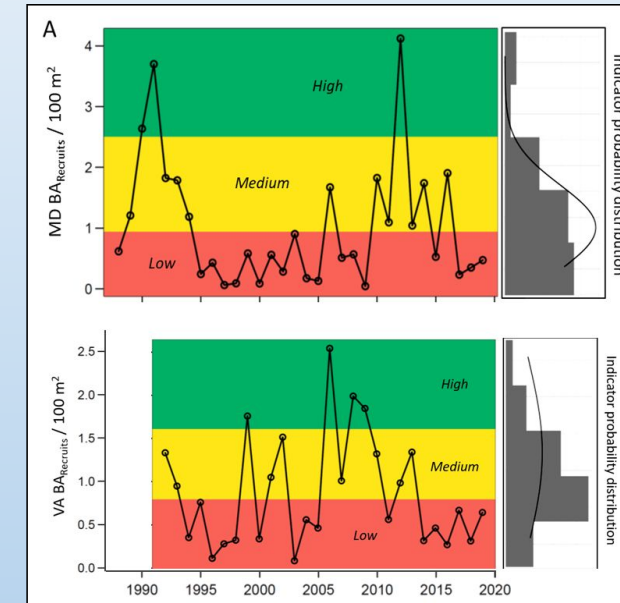
Trend is n.s.  
from  
1988-2019,  
but  
consistent  
long-term

# Toward Forage and Climate indicators

- Translating individual indices to indicators
  - Mainstem vs tributaries – continuity
  - Taxonomic group or life stage
  - Climate indices – directionality



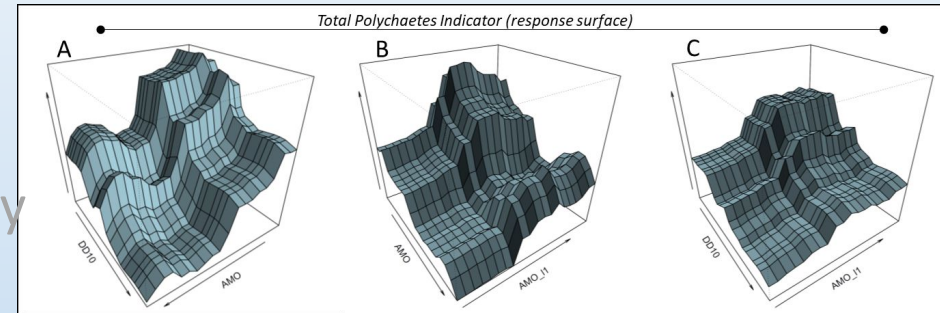
***Value in a 'non-Nereid'  
polychaete indicator??***



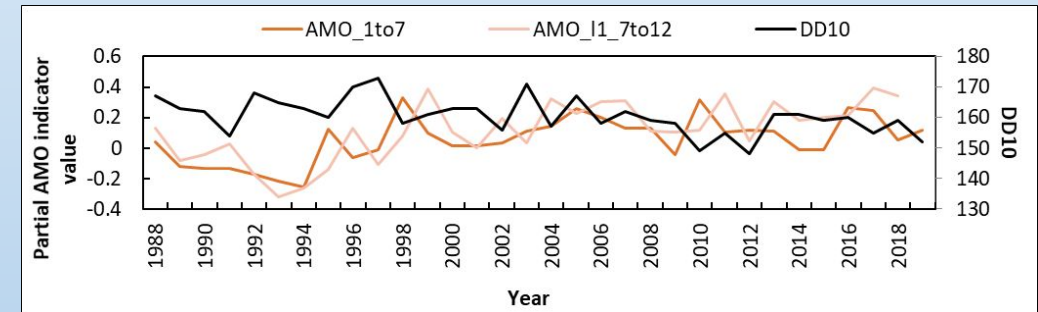


# Toward Forage and Climate indicators

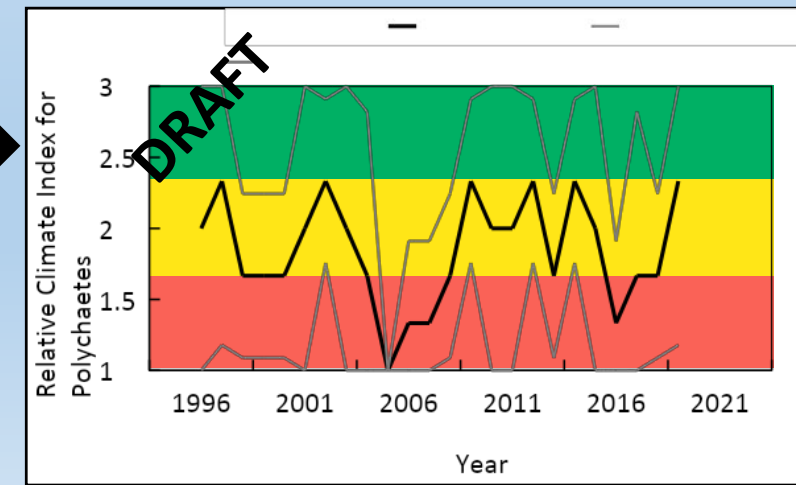
- Translating individual indices to indicators
  - Mainstem vs tributaries – continuity
  - Taxonomic group or life stage
  - Climate indices – directionality
- Toward integrated indicators
  - Across climate indices
    - Use forage-climate model results
    - Use variable ranking or effect size to combine variables into a single index
    - E.g., assign ordinal values (1, 2, 3) associated with Low, Medium, or High
      - Average ordinal values across indices
      - Ranges 1 (all indicators = 'Low') to 3 (all indicators = 'High')
  - Similar approach could be used to combine forage taxa



+



Example of what this could look like



Thank you

Questions?



# Thoughts from email chain

- Ryan: A couple of thoughts in response to your questions, which are good ones. The management folks will want to know what, if any, recommended actions could come from our project.
- 1. The DD outcomes will be of interest, especially for long-term forecasting (perhaps speculative at this point). The 'partial year' AMO analysis may be new to the Chesapeake Bay Program community. It has broader potential to investigate climate effects than those particular to our analyses. Our terciles approach to categorizing forage abundances also will be of interest. It could form the basis for future management actions (or considerations) if a forage indicator fell below the boundary for the mid-level abundance or fell below it for "x" consecutive years, etc. I don't believe we have to speculate about what management actions an agency might take if the indicator were below the threshold for "x" years but the concept seems good for management consideration.
- 2. Yes, the project was narrowly focused. We followed the directive in our research but broader, more inclusive analysis and modeling are needed. Your thoughts on the consequences and implications are good and should be a part of your presentation, probably in a discussive conclusion. Are polychaetes and bay anchovy the best indicator forage species? Are total polychaetes (that includes nereids) really a good indicator group or would Total minus nereids and nereids be better groups to evaluate for indicator development?  
I suspect that some on the FAT would like to know if other taxa than those we analyzed, e.g., zooplankton (either as an indicator or as a predicting variable), could be evaluated by our approach.
- While we did consider spatial aspects of forage occurrence and abundances, we did not do a detailed analysis of the spatial scale of forage occurrences and distributions, which also could be addressed in a future project. What is a minimum scale for analysis and what areas, habitats, regions should be considered? Presumably, these would differ among forage taxa. This might be a really difficult question to answer.
- I'm of two minds about it:
  - 1 - I think that the FAT will want to understand the details of the forage-climate model results and will want to better understand what inferences, if any, we can draw from them. Given that, it seems that highlighting the unexpected positive effect of DD on most forage indices will be of interest, as will a more nuanced discussion of forage relationships with partial year AMO conditions.
  - 2 - I'm concerned that the narrow nature of the project focus (as stipulated by CBT) didn't allow us to explore potentially important co-varying factors such as river discharge, bottom water DO, etc. All of those were important predictors from our previous project and I wonder if our modeling results from this project would have differed if we'd had the time and resources (i.e., funding) to explore those other variables? For example, are there dangers in saying that 'warmer springs' are indeed better for bay anchovy and polychaetes (as we found in this study but not the last study) when 'warmer springs' might only be good if subsequent summertime bottom water DO remains above the hypoxia threshold?
- What do you guys think about this? I want to make this discussion as useful as possible but I don't want to gloss over potentially important caveats.

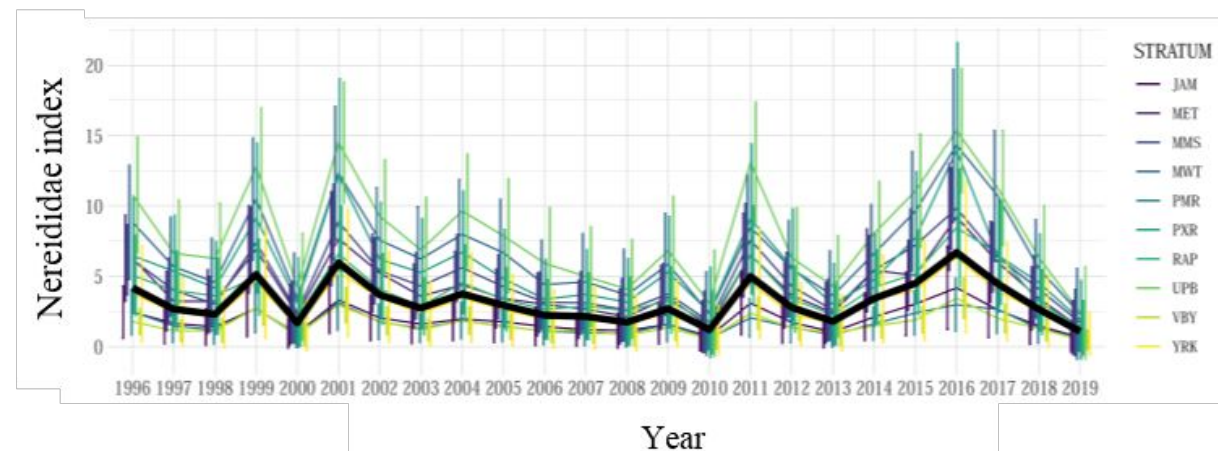
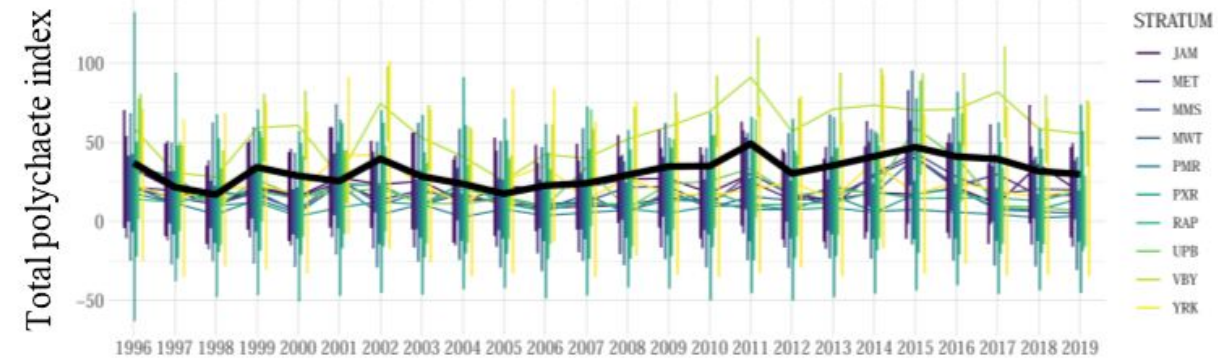
# Proposed Methods: Relating forage to climate

			Scale	
Tier	Variable	Indicator	Spatial	Temporal
1. Abundance	Bay Anchovy	Spawning stock	Mainstem	Spring-Early summer
		Recruits	Mainstem	Late summer-Fall
		Population	Mainstem/Tribs	Spring-Fall
	Polychaetes	Aggregate taxa	Mainstem/Tribs	Summer
		Family (Nereididae)	Mainstem/Tribs	Summer
2. Environmental Factors	Degree day (DD) spring warming index & Atlantic Multidecadal Oscillation (AMO)	Spawning stock	Mainstem	Spring-Early summer
		Recruits	Mainstem	Late summer-Fall
		Population	Mainstem/Tribs	Spring-Fall
		Aggregate taxa	Mainstem/Tribs	Summer
		Family (Nereididae)	Mainstem/Tribs	Summer



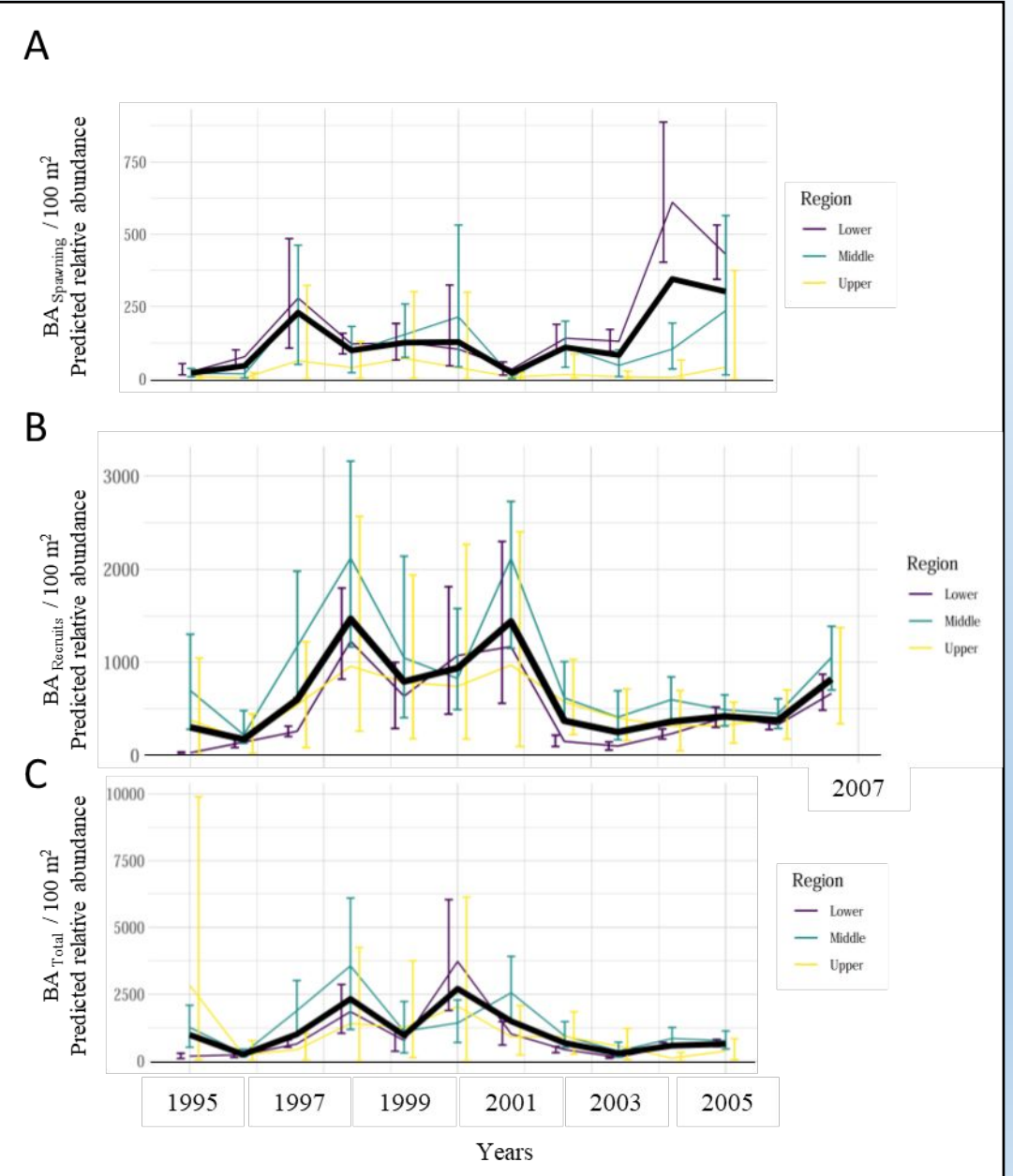
# Results: Forage indices

- Polychaete group results
  - Total polychaetes
  - Nereididae



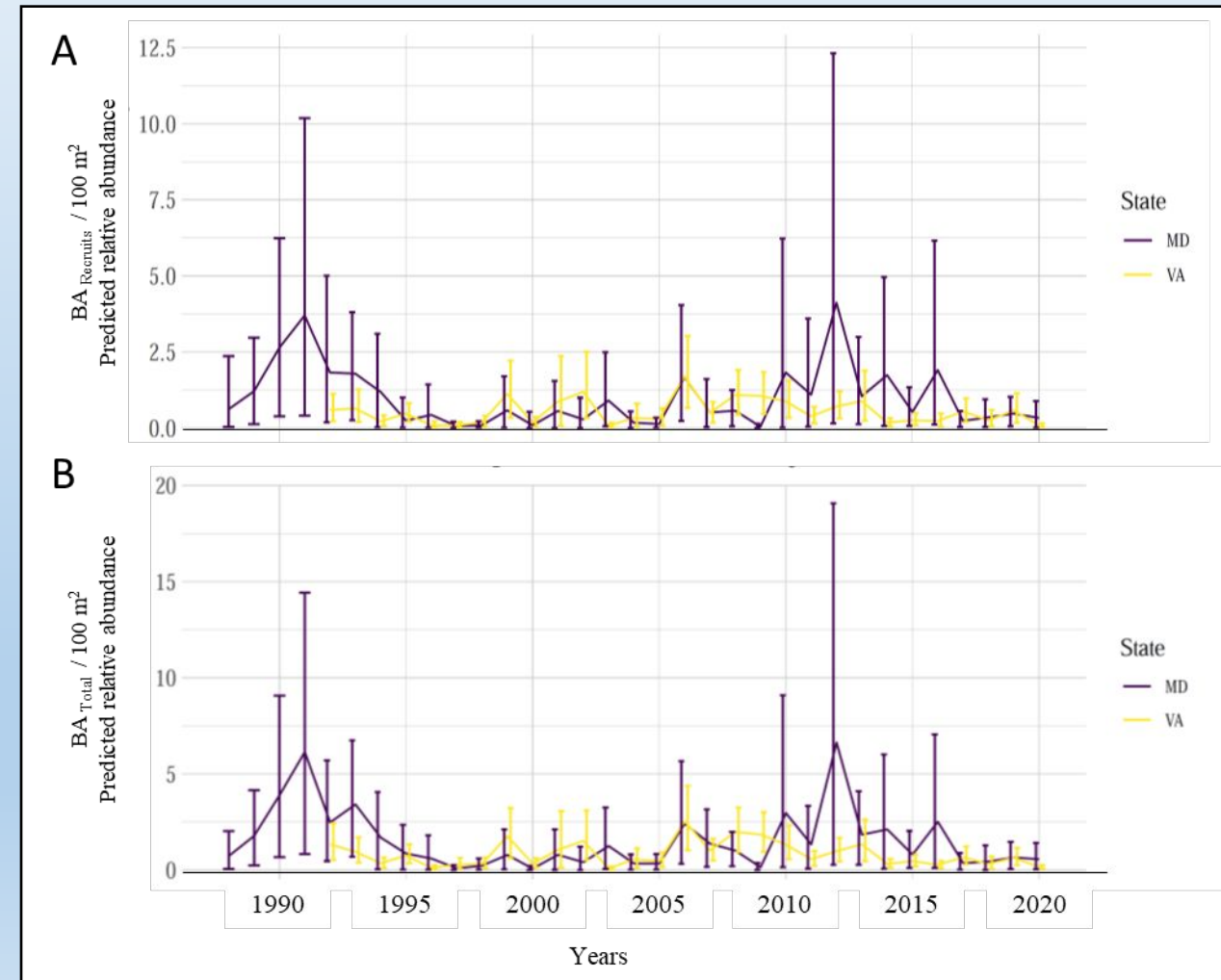
# Results: Forage indices

- Polychaete group results
  - Total polychaetes
  - Nereididae
- Bay Anchovy group results
  - TIES/ChesFIMS
    - Spawning stock
    - Recruits
    - Total



# Results: Forage indices

- Polychaete group results
  - Total polychaetes
  - Nereididae
- Bay Anchovy group results
  - TIES/ChesFIMS
    - Spawning stock
    - Recruits
    - Total
  - MD Seine
    - Recruits
    - Total
  - VA Seine
    - Recruits
    - Total





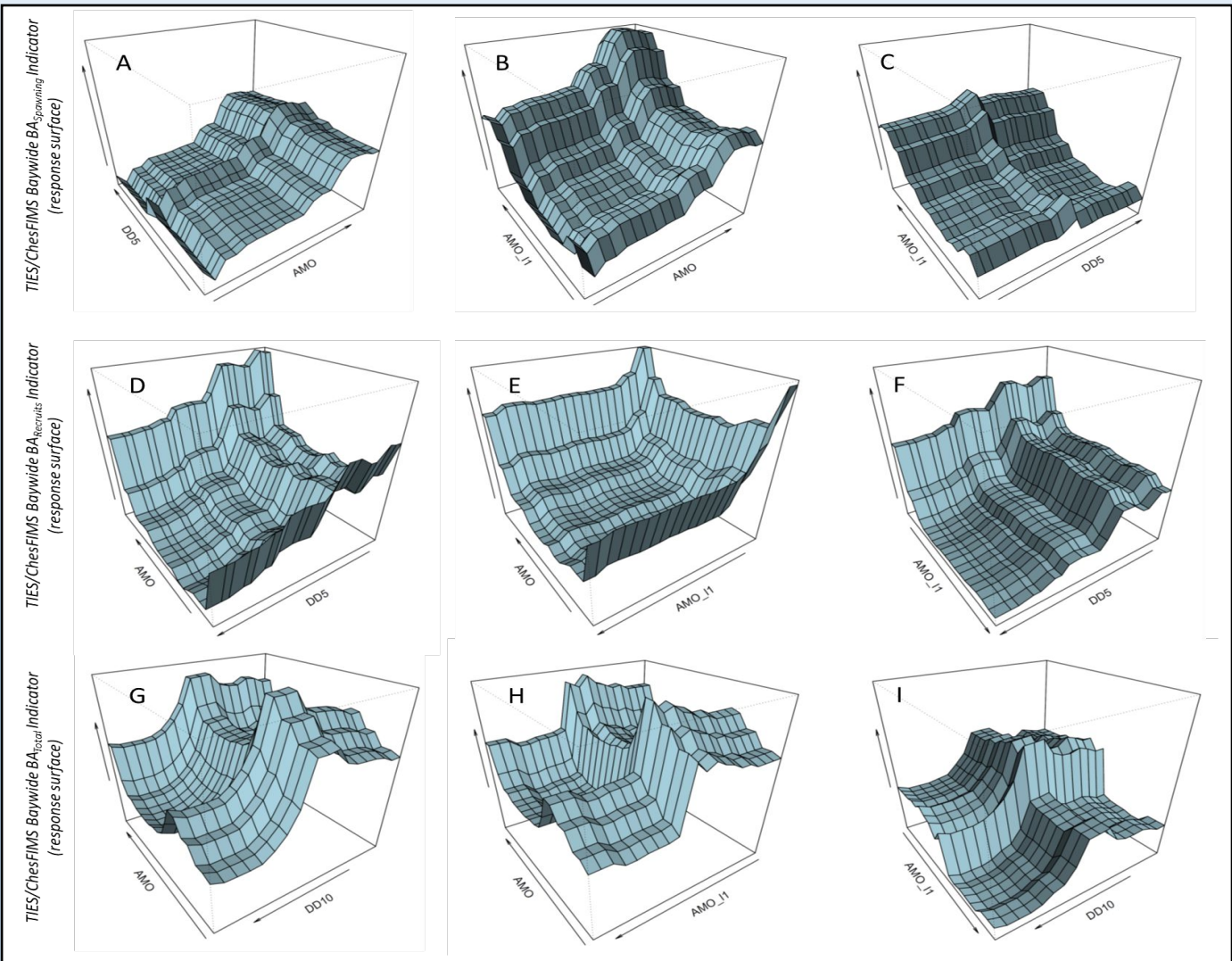


# Relating Forage & Climate indices

Category	Group	DD	AMO	AMO <sub>Lag</sub>
Species	Total	-	-	+
	Nereididae			
System	Spawning stock	-	+	+
	Recruits	-	∩	-
	Total	∩	Var.	-
Indices	Recruits	-	-	
	Total	-	-	

tive)

- AMO<sub>Lagged</sub> – negative
- Total
  - DD10 – modal
  - AMO – variable/multi-model
  - AMO<sub>Lagged</sub> – negative

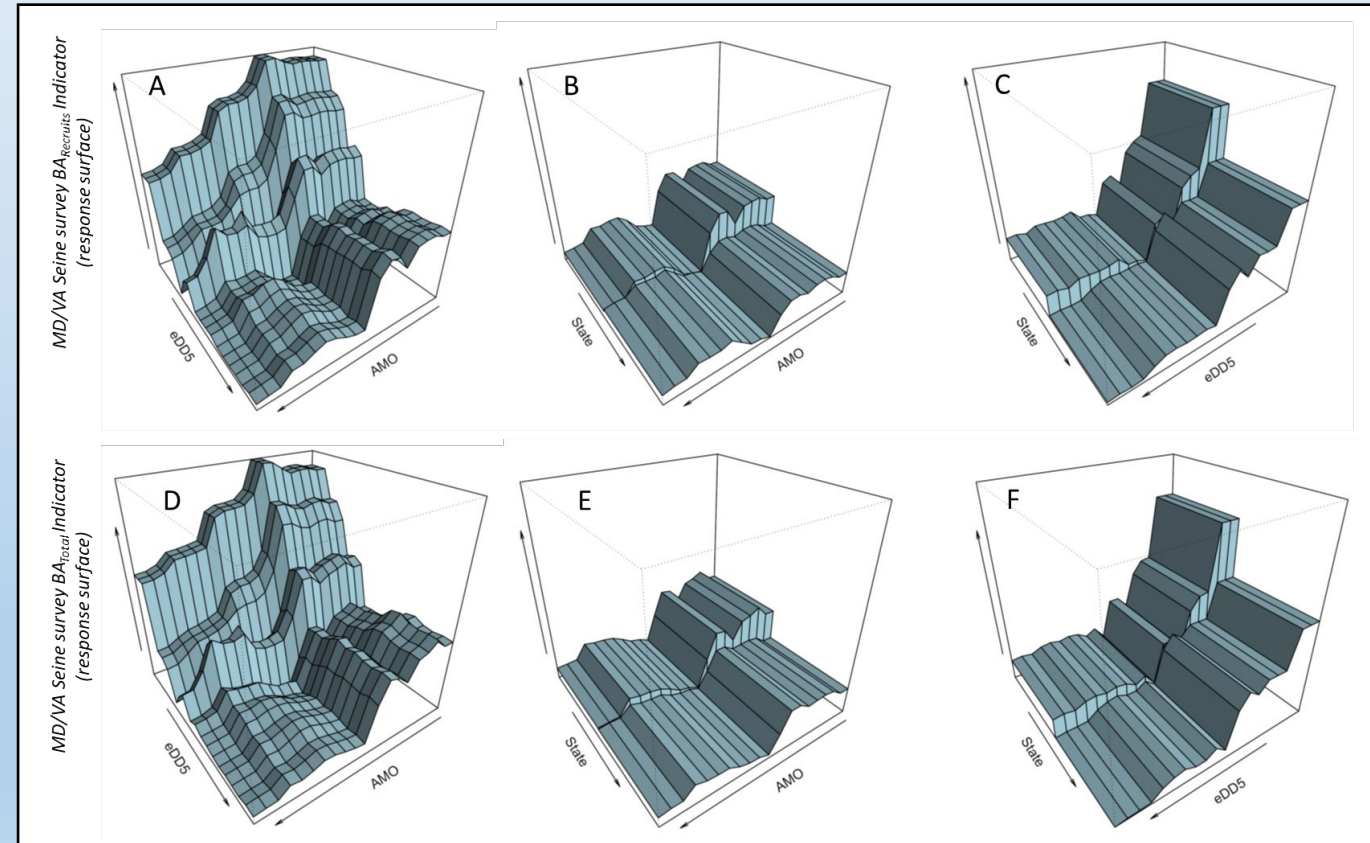




# Relating Forage & Climate indices

## Tributaries (MD/VA seine sureys)

- Recruits
  - Detrended DD5 – negative
  - AMO – negative
- Total
  - Detrended DD5 – negative
  - AMO – negative





# Toward Forage and Climate indicators

- Bay Anchovy

