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Forage Indicator Development – Using Environmental Drivers to Assess Forage Status

Sustainable Fisheries Goal Implementation Team Summer meeting

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

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

Funder: Chesapeake Bay Trust/EPA

7/20/2022

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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*)

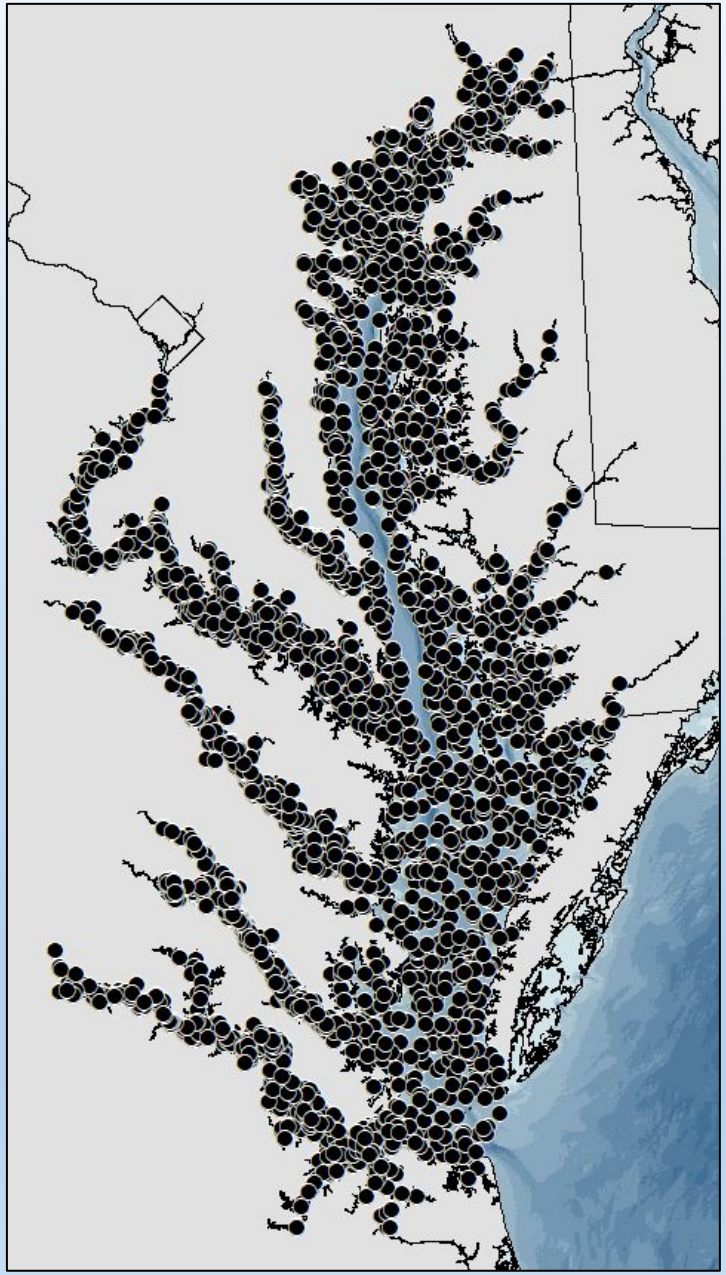
Images: https://www.inaturalist.org/guide_taxa/829795, https://en.wikipedia.org/wiki/Nereididae

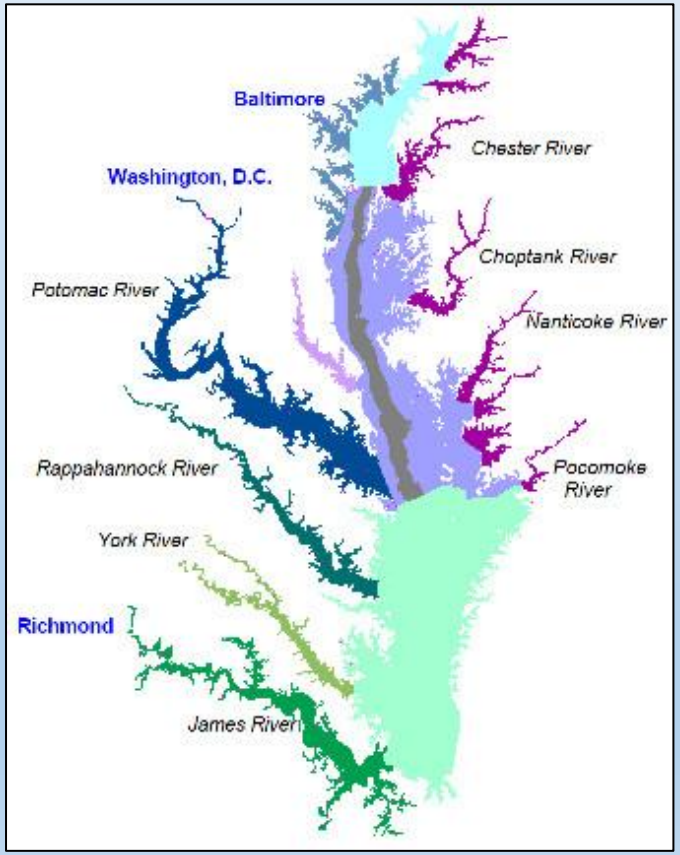
Data sources

- Biota data sources
  - Chesapeake Bay Program
  - TIES/ChesFIMS
  - MD DNR/VIMS Seine survey
  - Juvenile fish & blue crab trawl survey (VIMS)
- Climatological 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

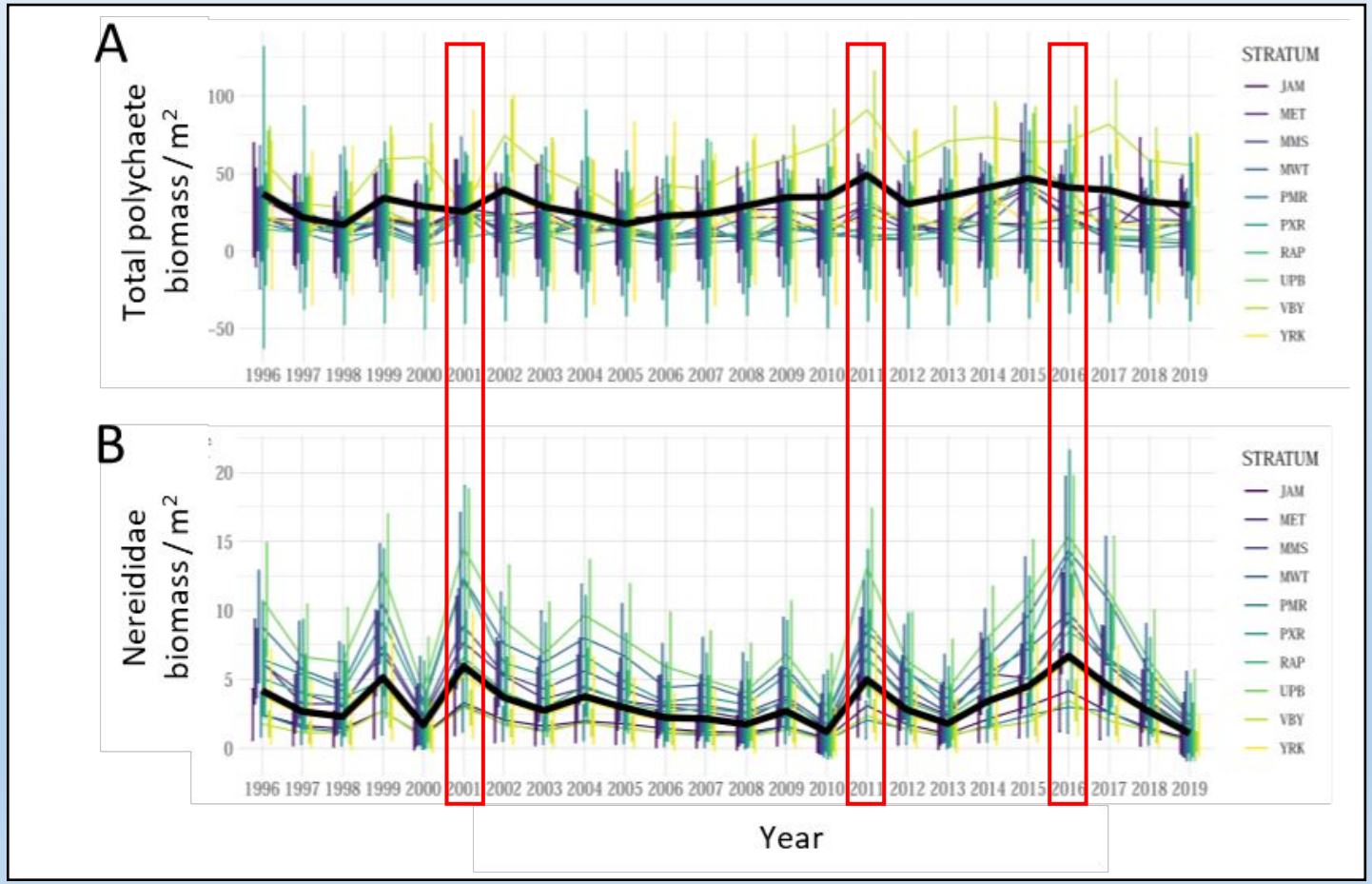
- Spatial domain
  - CBP Benthic Survey random sampling component
- Temporal range
  - 1996-2019
  - July-Oct





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



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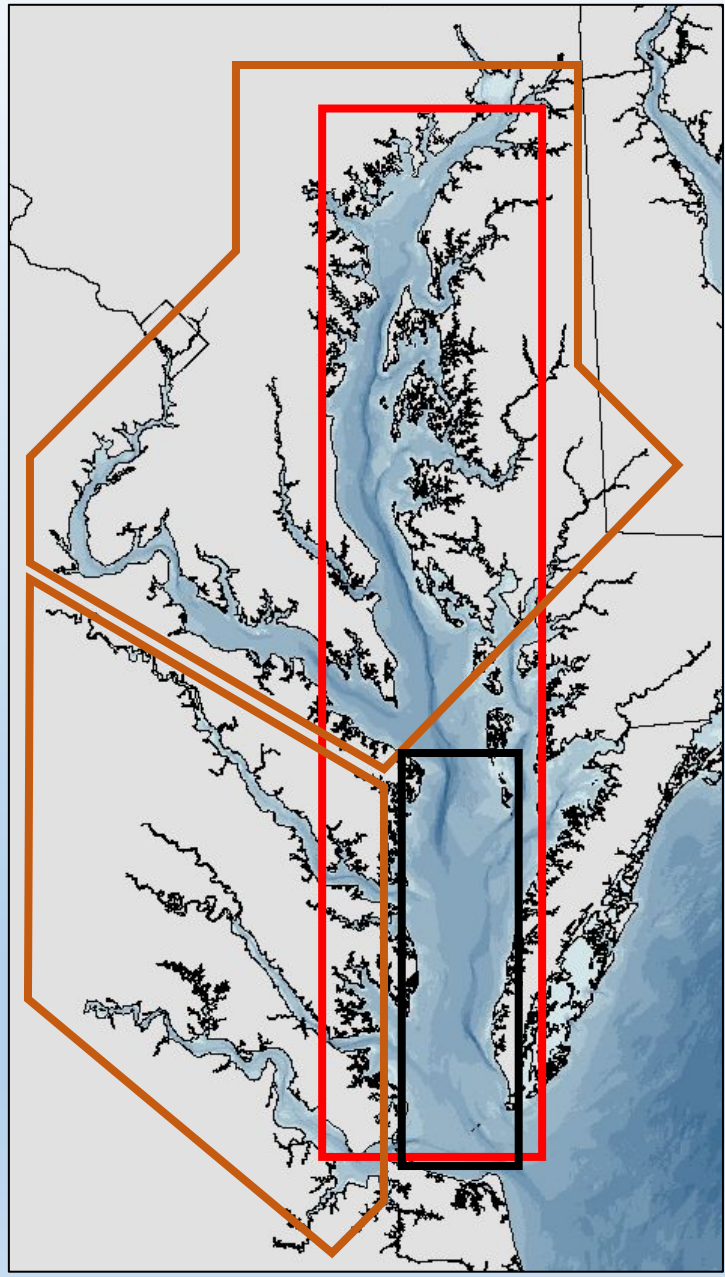
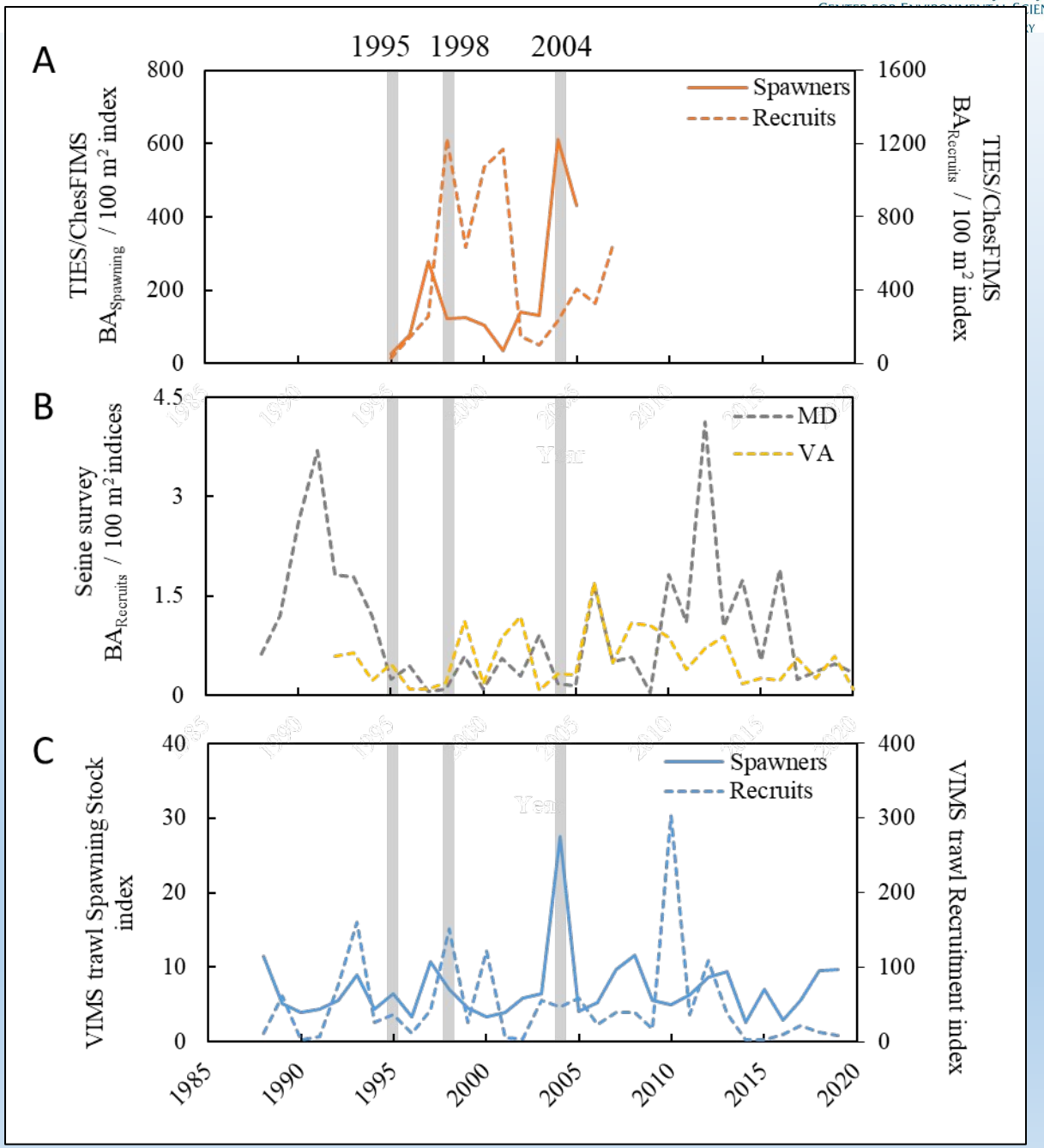
Bay Anchovy Surveys: Spatiotemporal extent

- 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



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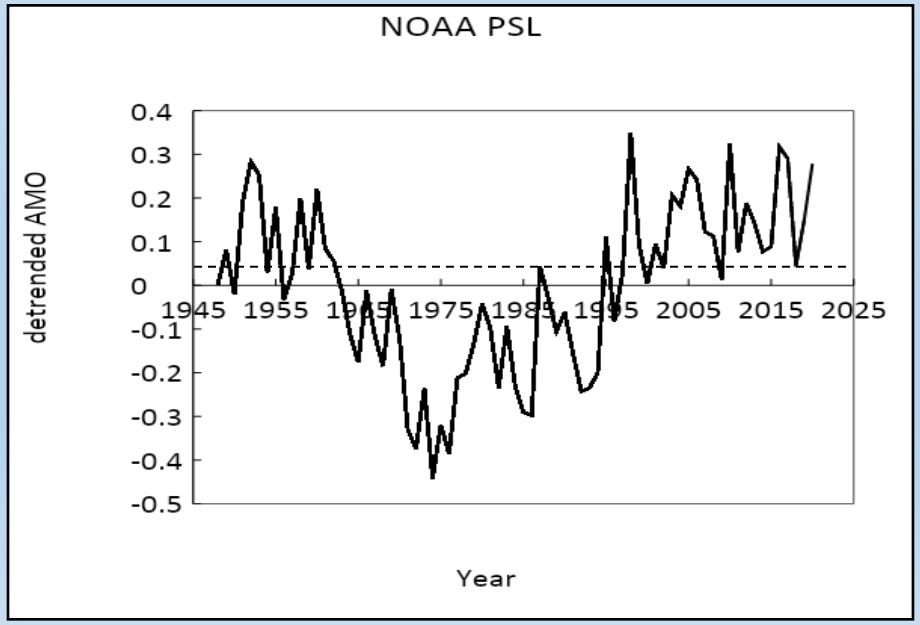
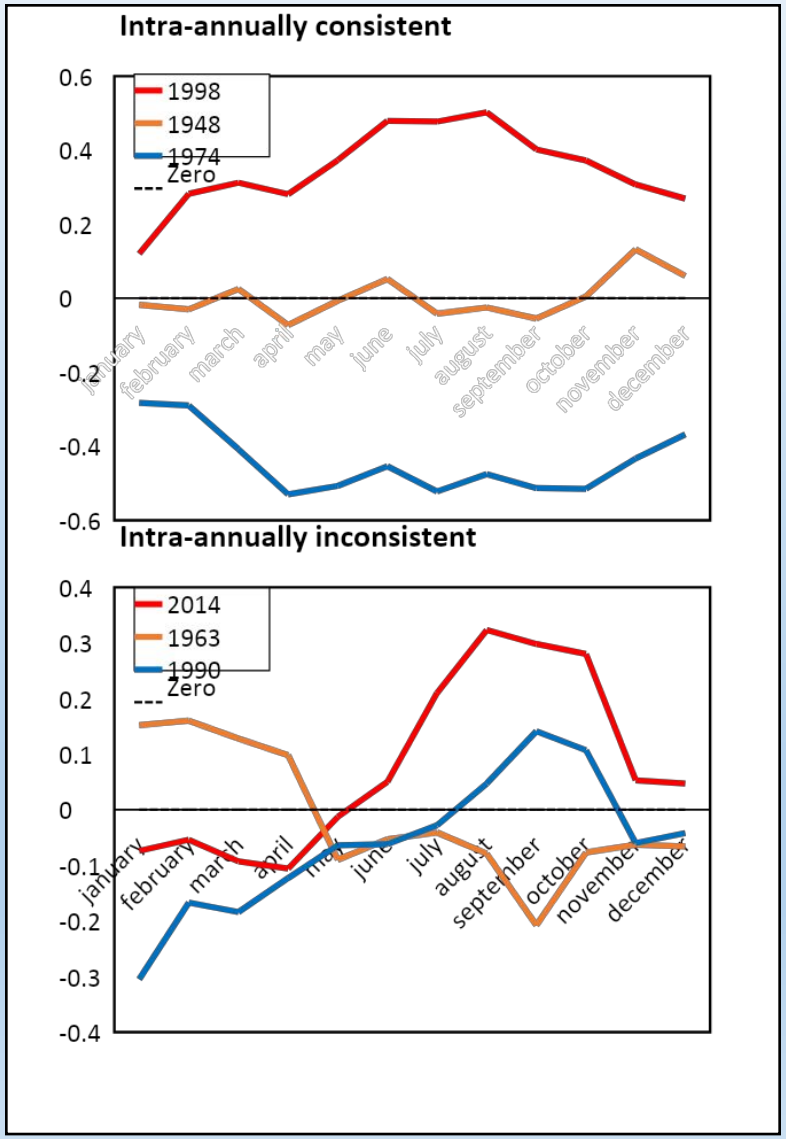
Climate indices

- 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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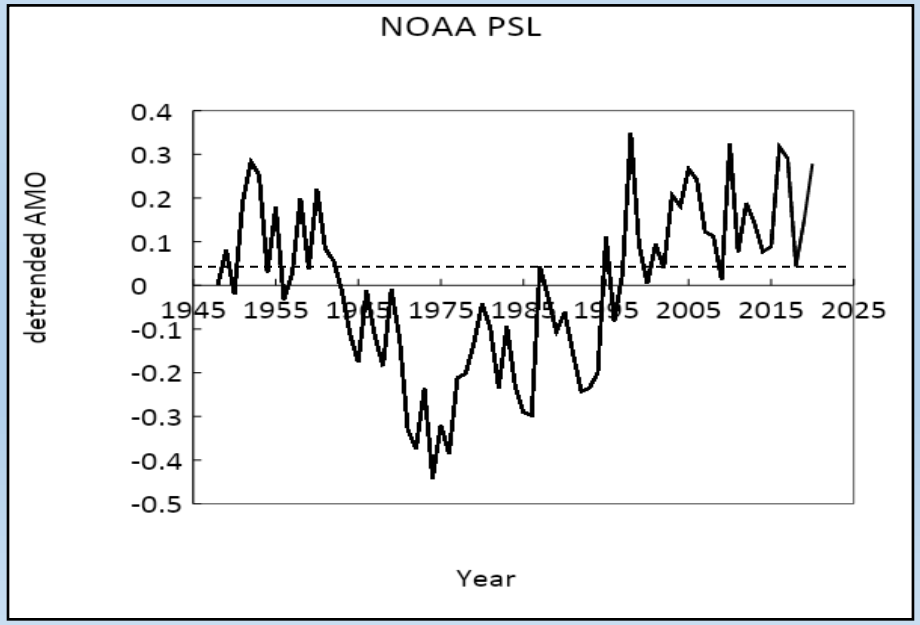
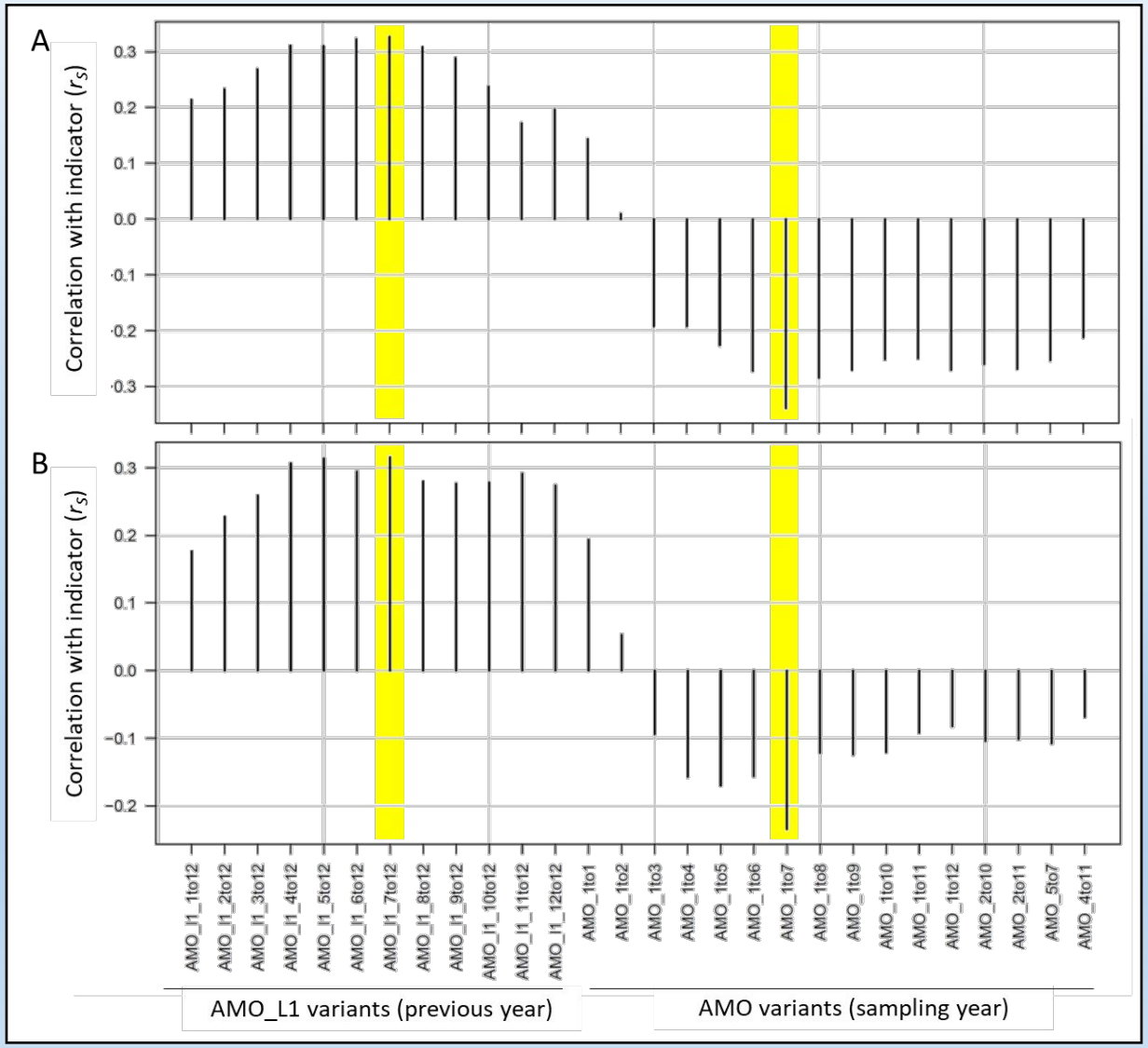


Varying monthly average AMO correlations w/Total and Nereididae Polychaete



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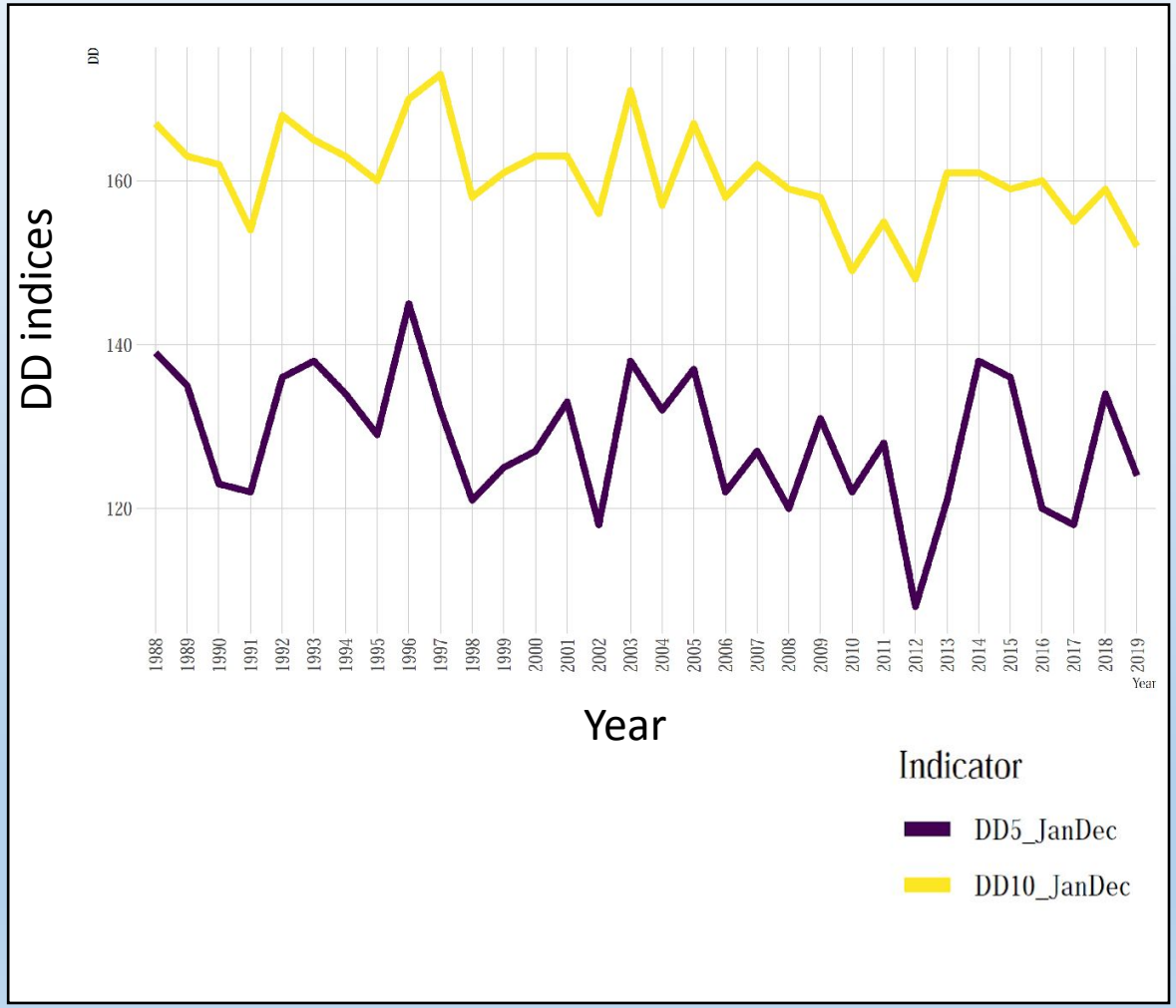
Climate indices

- 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
  - *Forage ~ DD index + AMO + AMO_{Lagged}*

*also considered detrended versions of DD indices

- Model comparisons
  - 10-fold cross-validation
  - Model performance indicators (MAE, RMSE, R^2)
  - Visual assessment

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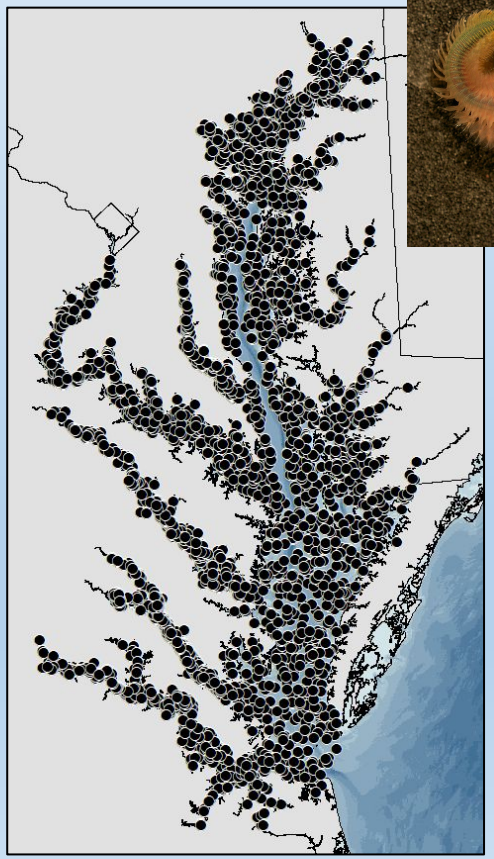
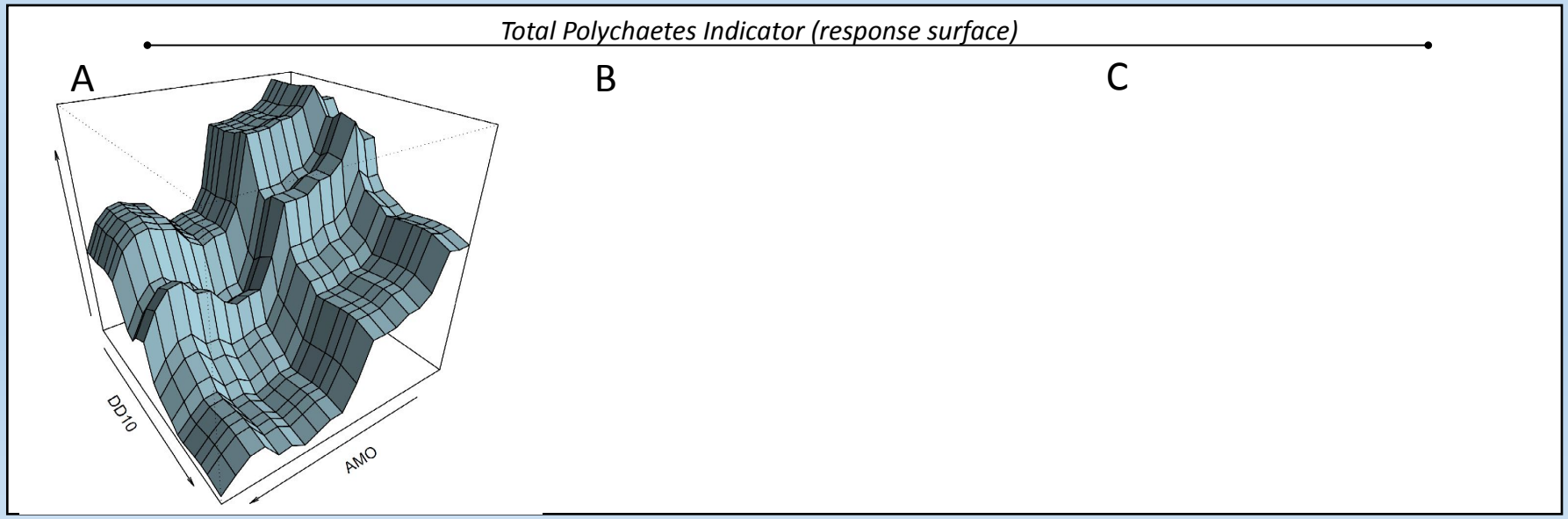
Relating Forage & Climate indices

Polychaete-Climate models



Taxon	Habitat	Group	*DD*	*AMO*	AMO_{Lag}
Polychaete	Baywide	Total	–	–	+
		Nereididae			



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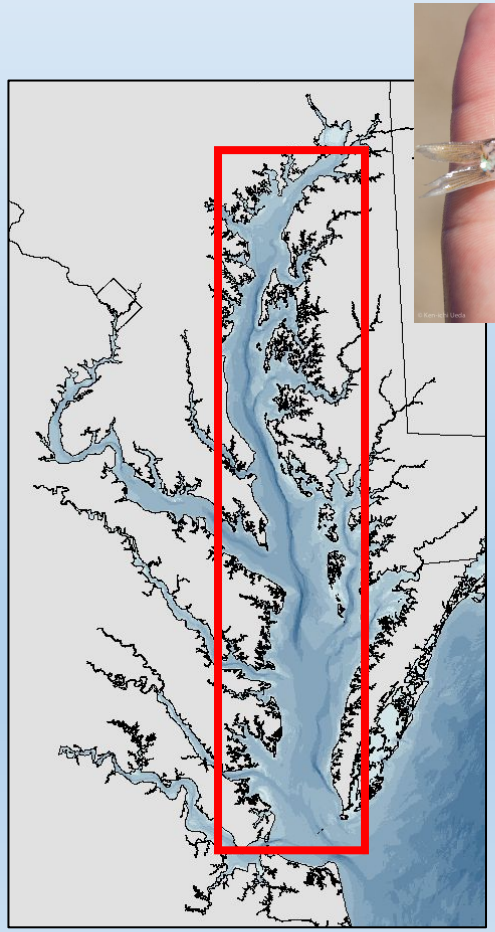
Relating Forage & Climate indices

Bay Anchovy-Climate models



Taxon	Habitat	Group	*DD*	*AMO*	AMO_{Lag}
Polychaete	Baywide	Total	–	–	+
		Nereididae			
Bay Anchovy	Mainstem	Spawning stock	–	+	+
		Recruits	–	∪	–
		Total	∩	Var.	–

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Relating Forage & Climate indices

Bay Anchovy-Climate models

Taxon	Habitat	Group	*DD*	*AMO*	AMO_{Lag}
Polychaete	Baywide	Total	–	–	+
		Nereididae			
Bay Anchovy	Mainstem	Spawning stock	–	+	+
		Recruits	–	⌒	–
		Total	⌒	Var.	–
	Tributaries	Recruits	–	–	
		Total	–	–	

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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_{Lag}
Polychaete	Baywide	Total	–	–	+
		Nereididae			
Bay Anchovy	Mainstem	Spawning stock	–	+	+
		Recruits	–	∪	–
		Total	∩	Var.	–
	Tributaries	Recruits	–	–	
		Total	–	–	

St. Laurent et al. 2021

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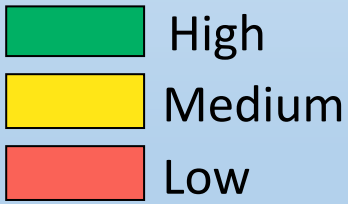
Classifying Forage and Climate indices

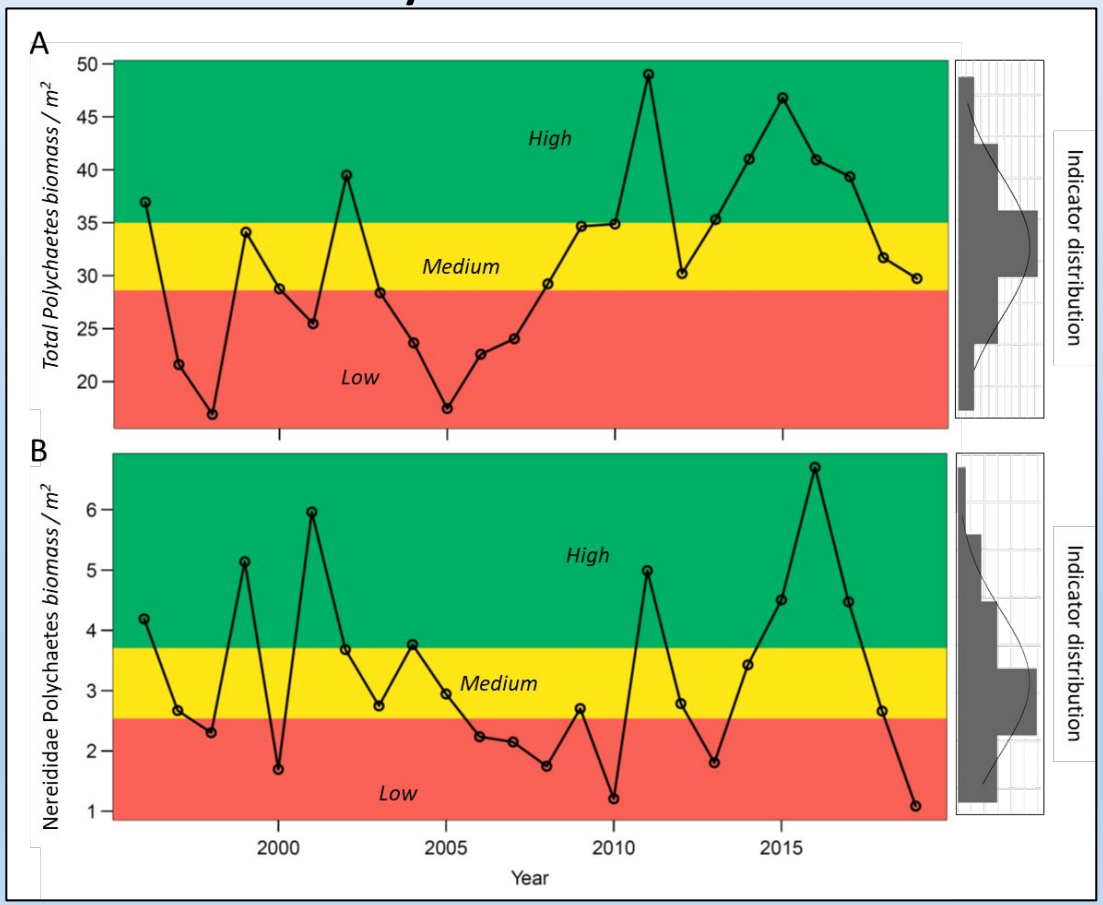
- Summarize forage indices
  - Developed numeric classifications based on:
    - Terciles (~ normal distribution)
    - *k*-means clustering (non-normal)
  - Assigned colorimetic scheme



Classifying Forage and Climate indices

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

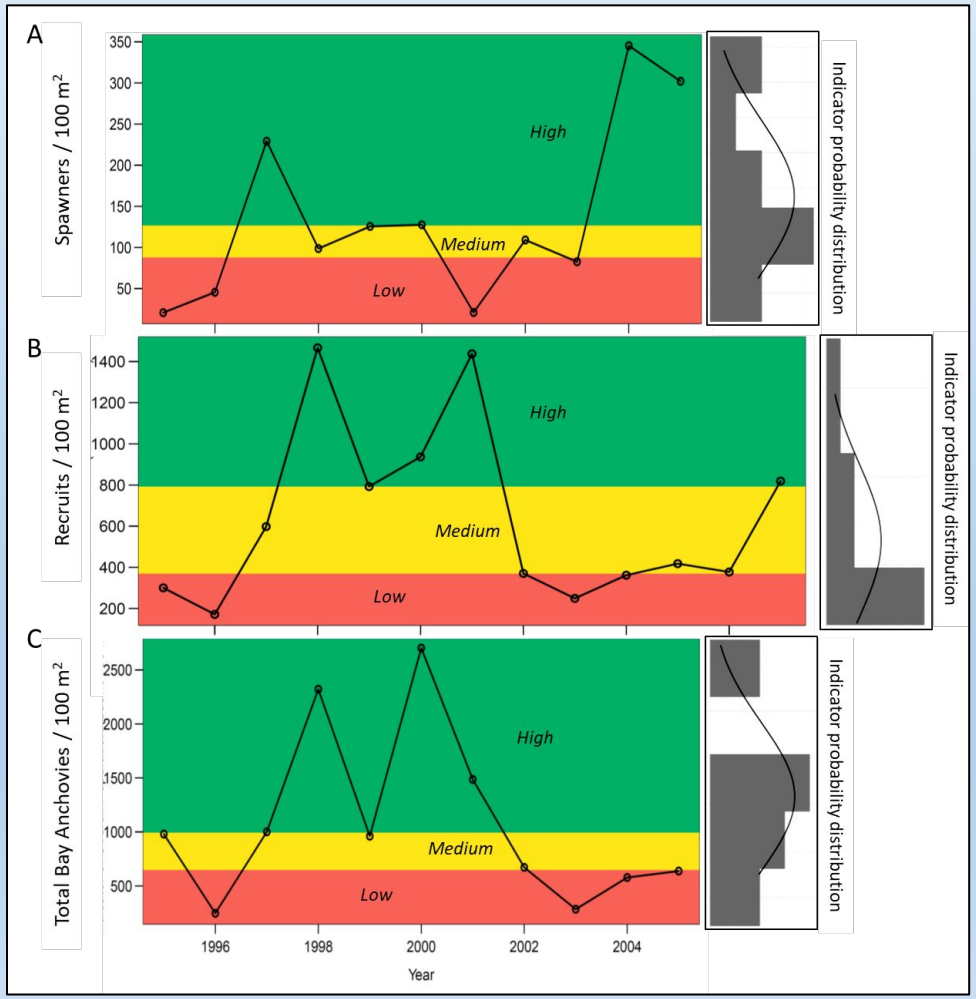
Polychaete indices



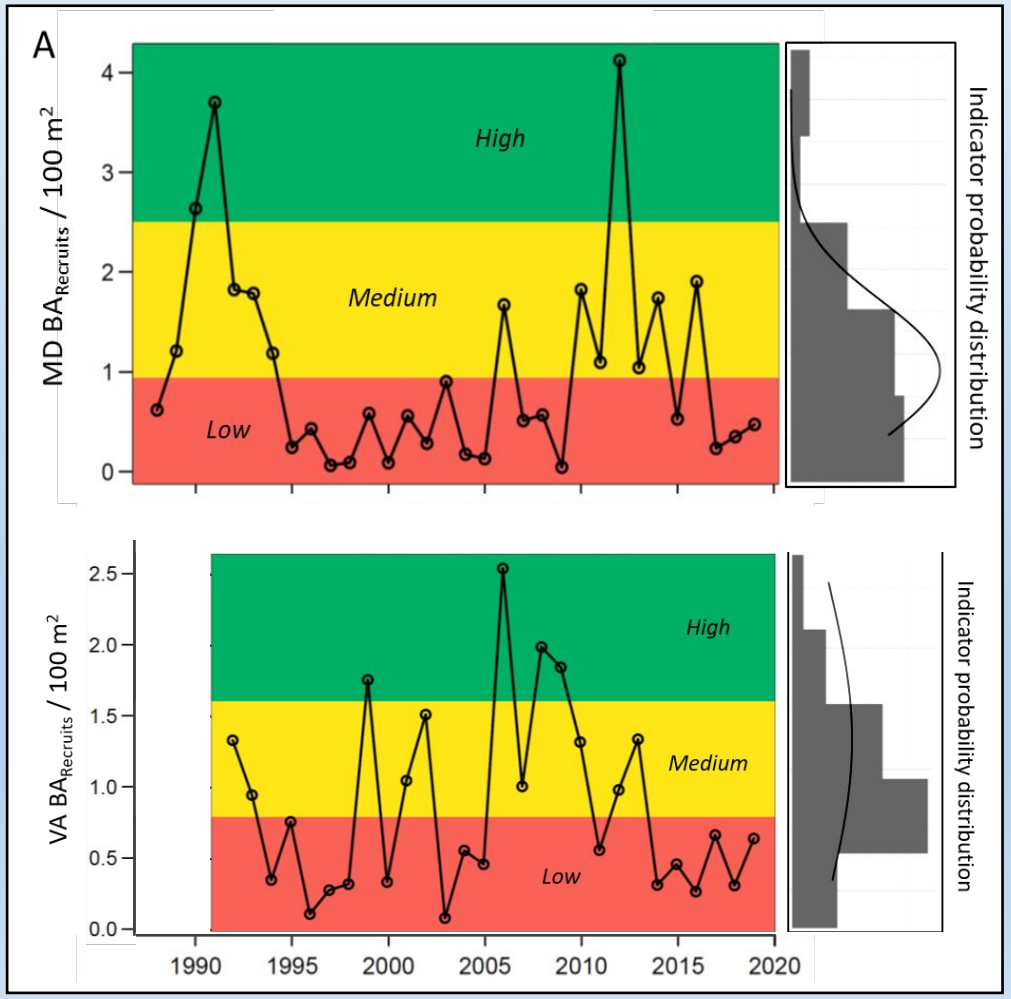
Classifying Forage and Climate indices

Bay Anchovy indices

Mainstem



Tributaries



<u>Note</u>: difference in tercile thresholds between states

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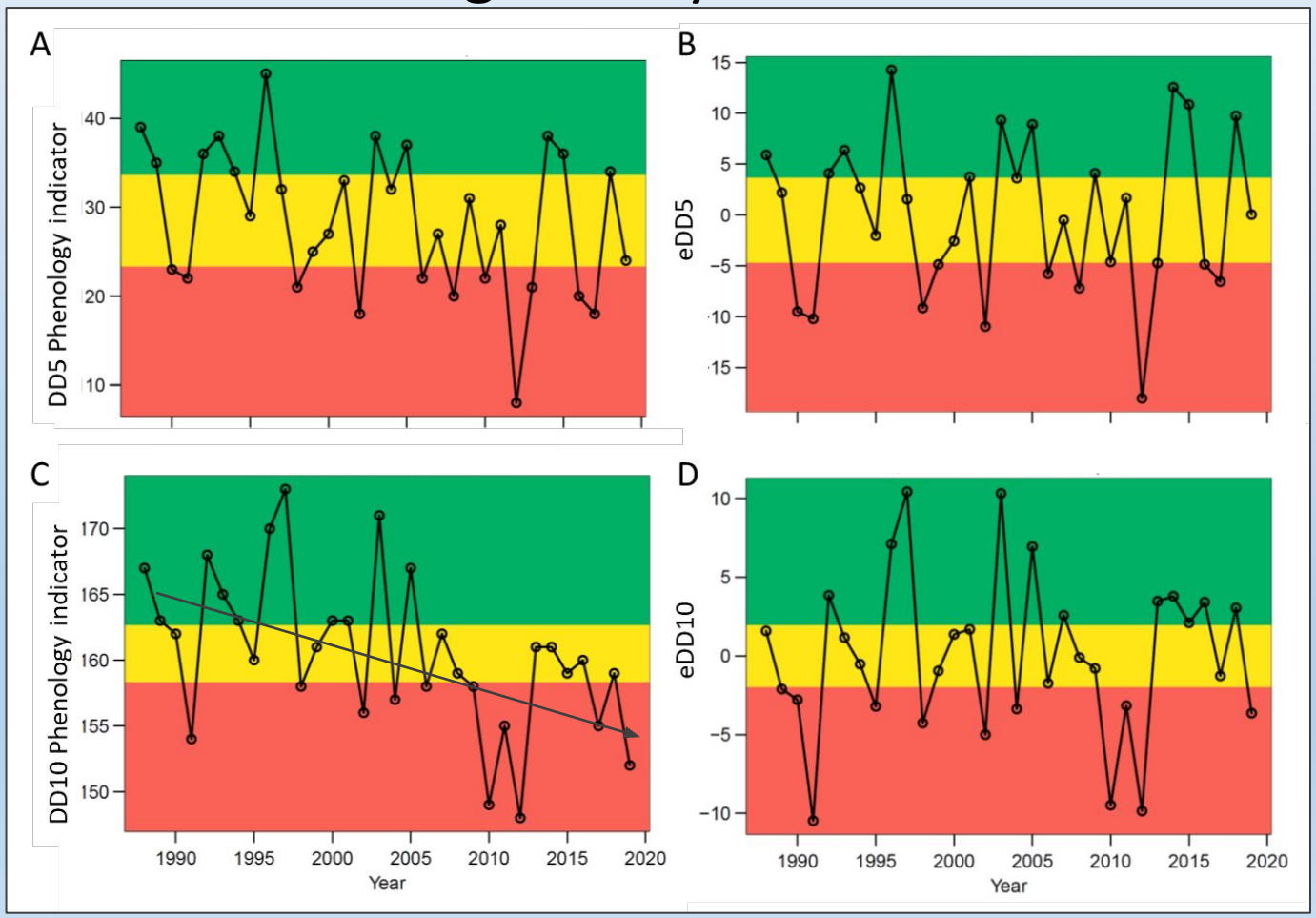
Classifying Forage and Climate indices

Degree Day indices

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



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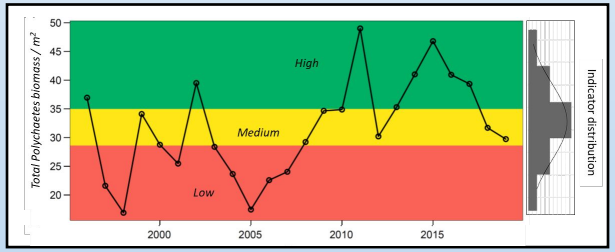
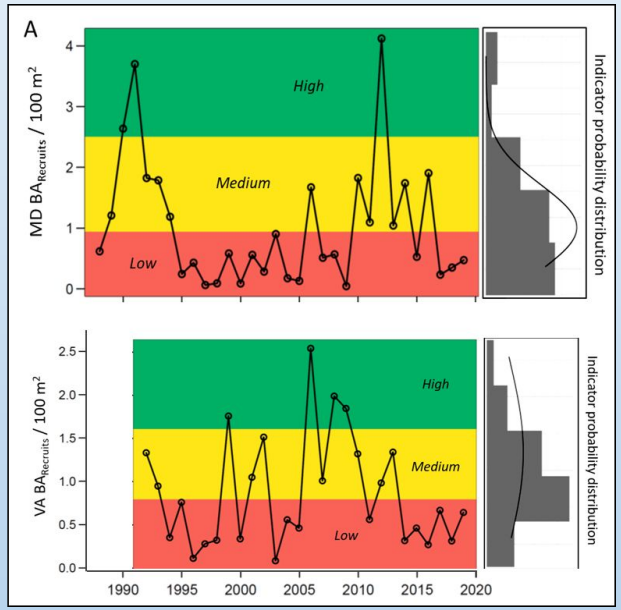
Toward Forage and Climate indicators

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



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



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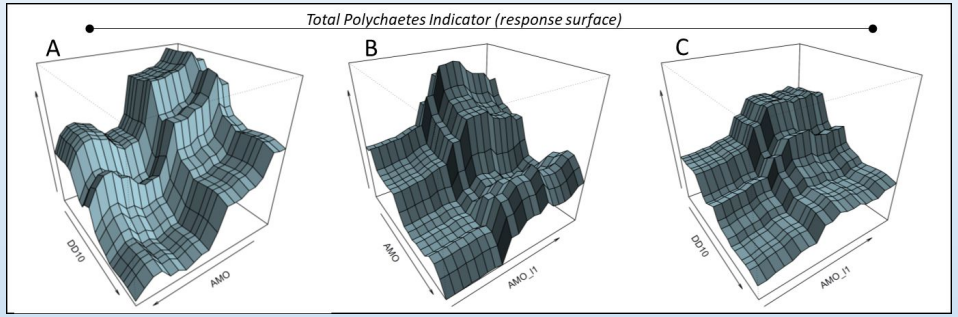
Toward Forage and Climate indicators

- 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) for Low, Medium, or High, then average
  - Similar approach could be used to combine forage taxa



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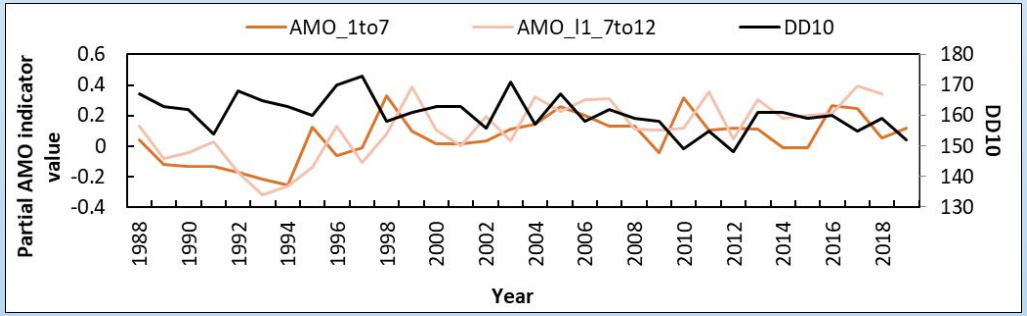
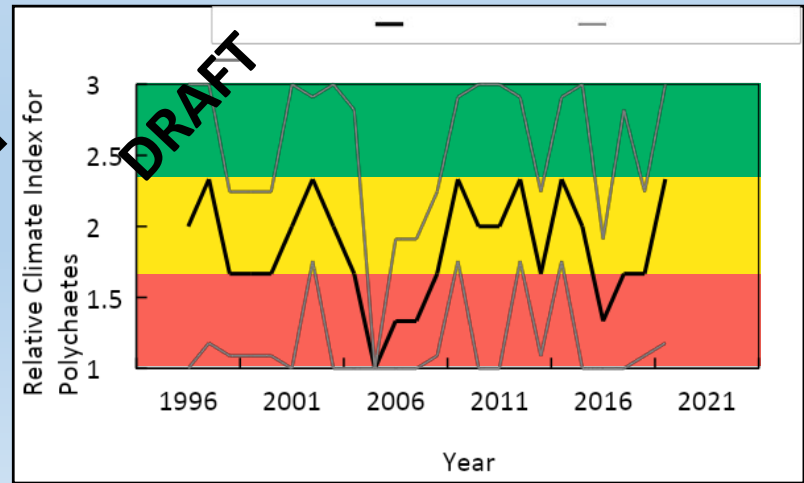


Example of what this **could** look like



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Thank you

Questions?

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

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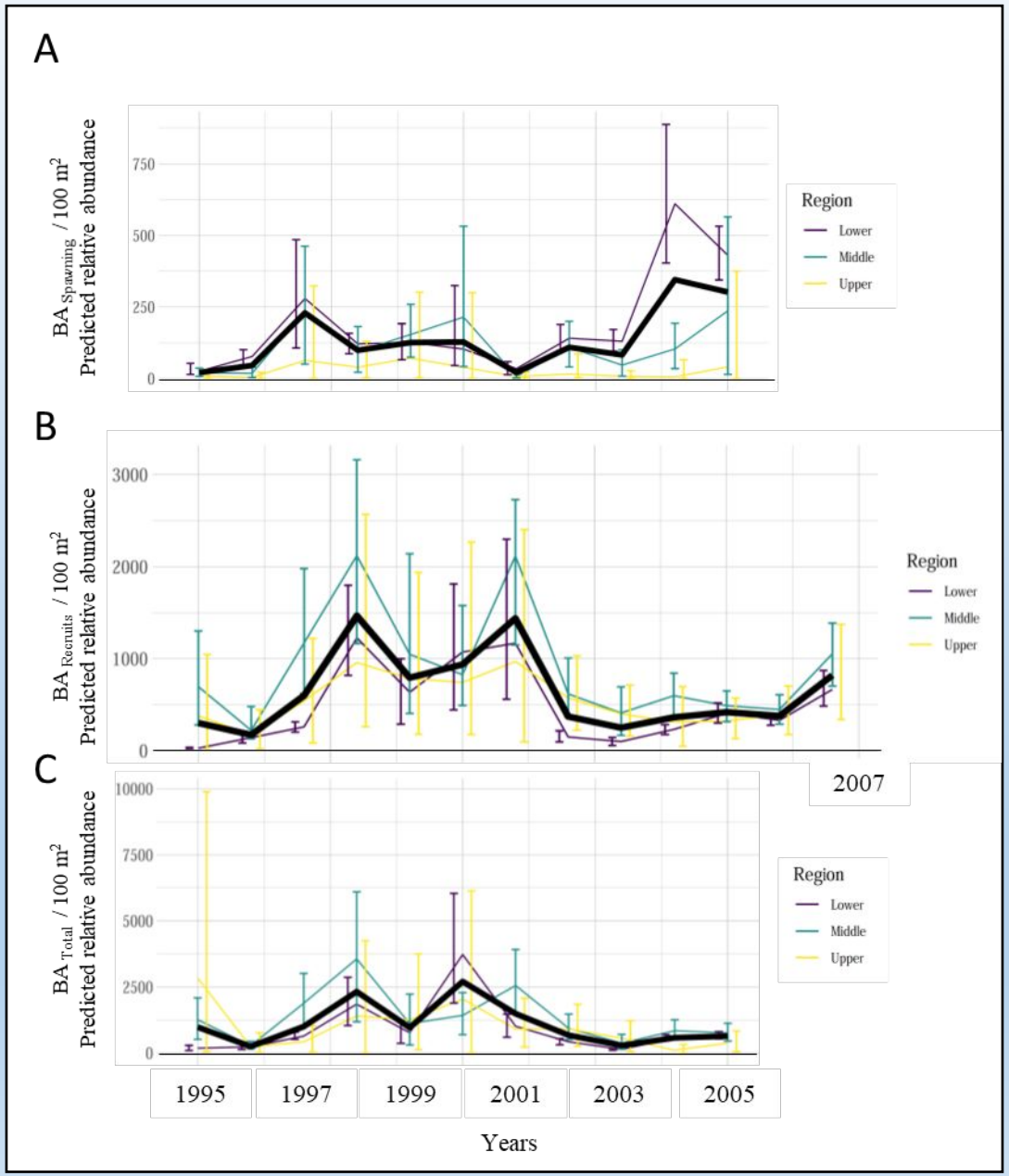
Results: Forage indices

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



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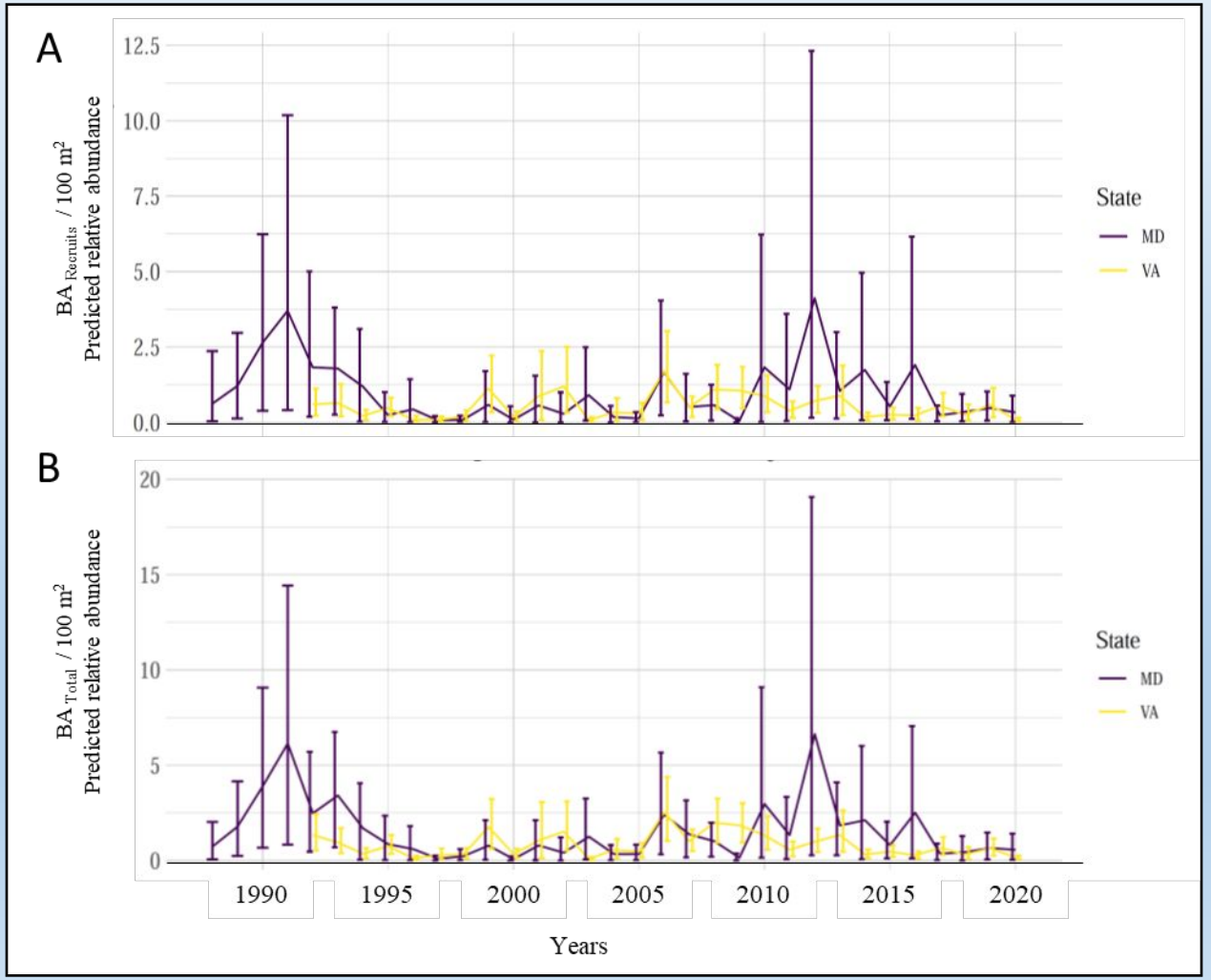
Results: Forage indices

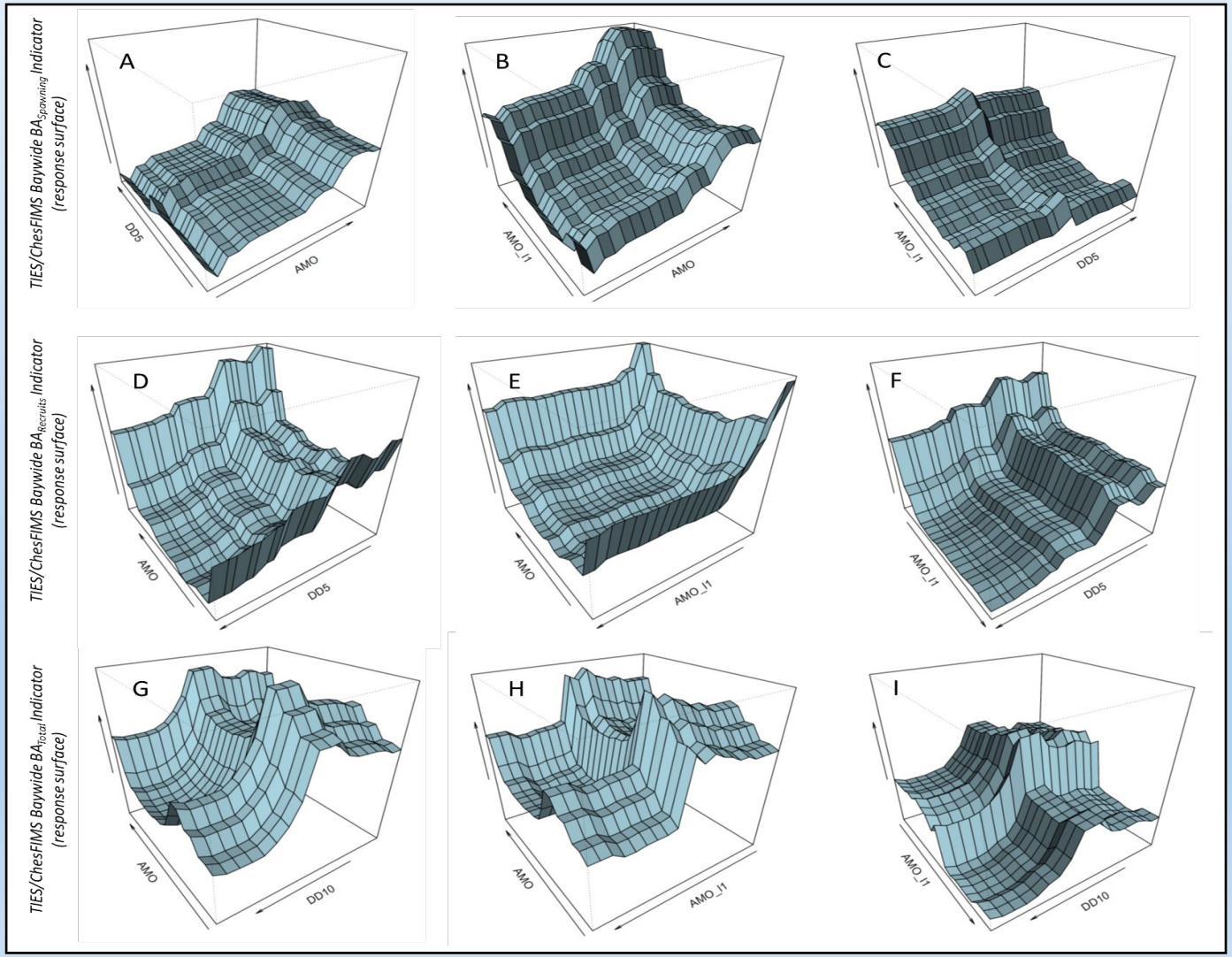
- Polychaete group results
  - Total polychaetes
  - Nereididae
- Bay Anchovy group results
  - TIES/ChesFIMS
    - Spawning stock
    - Recruits
    - Total
  - MD Seine
    - Recruits
    - Total
  - VA Seine
    - Recruits
    - Total



Relating Forage & Climate indices

Mainstem (TIES/ChesFIMS)

- Spawning stock
  - DD5 – weak (possibly negative)
  - AMO – positive
  - AMO_{Lagged} – positive
- Recruits
  - DD5 – negative
  - AMO – modal
  - AMO_{Lagged} – negative
- Total
  - DD10 – modal
  - AMO – variable/multi-model
  - AMO_{Lagged} – negative



Relating Forage & Climate indices

<u>Tributaries (MD/VA seine sureys)</u>

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