Drivers of fish and invertebrate forage in Chesapeake Bay

Integrating space, time and the environment

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Role of forage in ecosystem-based fisheries management

- critical consideration of EBFM
- Chesapeake Bay → legacy of forage fish research

Bigford 2014, Ihde et al. 2015, Buchheister et al. 2016

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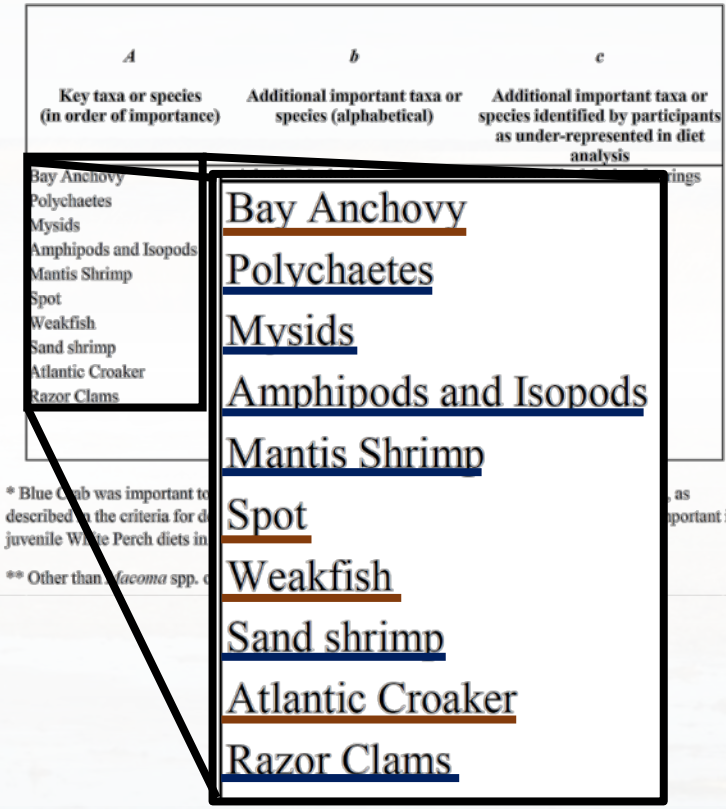
- importance of invertebrate forage and YOY of fisheries species
- temporal patterns in forage abundance



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Role of forage in ecosystem-based fisheries management

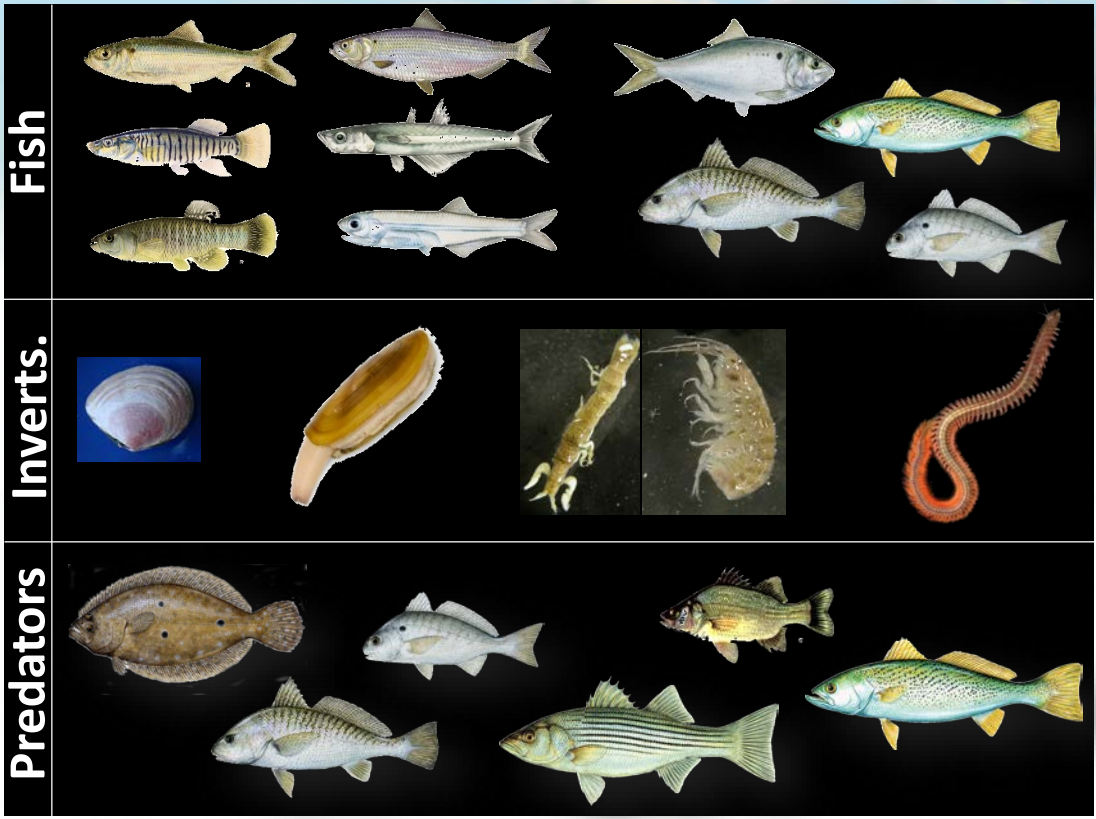
Current Project

- **Objective 1** – *Identify environmental factors associated with spatial and temporal patterns in relative abundance of forage taxa in Chesapeake Bay*

- **Objective 2** – *Explain how spatial and temporal factors in environmental variables influence consumption of forage taxa, and quantify the effect of forage abundance on consumer populations*

Methods: data

- Dominant forage and representative predators



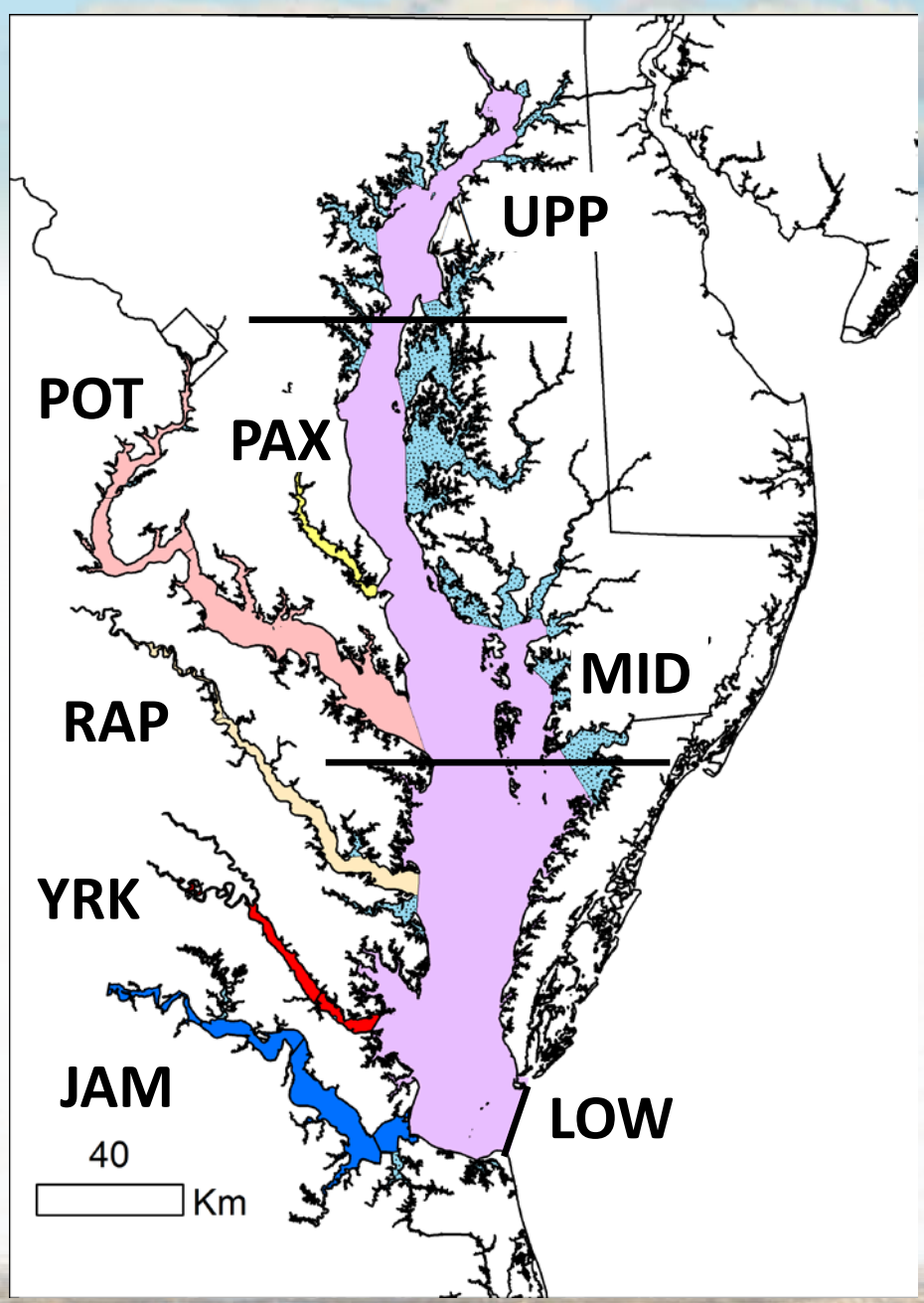
Data type	Group	Source	Area
Forage	**Fish**	ChesFIMS/TIES historical data	Mainstem
		MDDNR/VIMS seine surveys	Tributaries
	Invertebrates	Chesapeake Bay Program/Versar	Main/Trib
Predators	**Fish**	ChesMMAP survey	Mainstem

Methods: data

- Dominant forage and representative predators

Response variables

- Regional scale
- Forage: relative abundance or biomass per unit area
- Predators: diet, per capita consumption

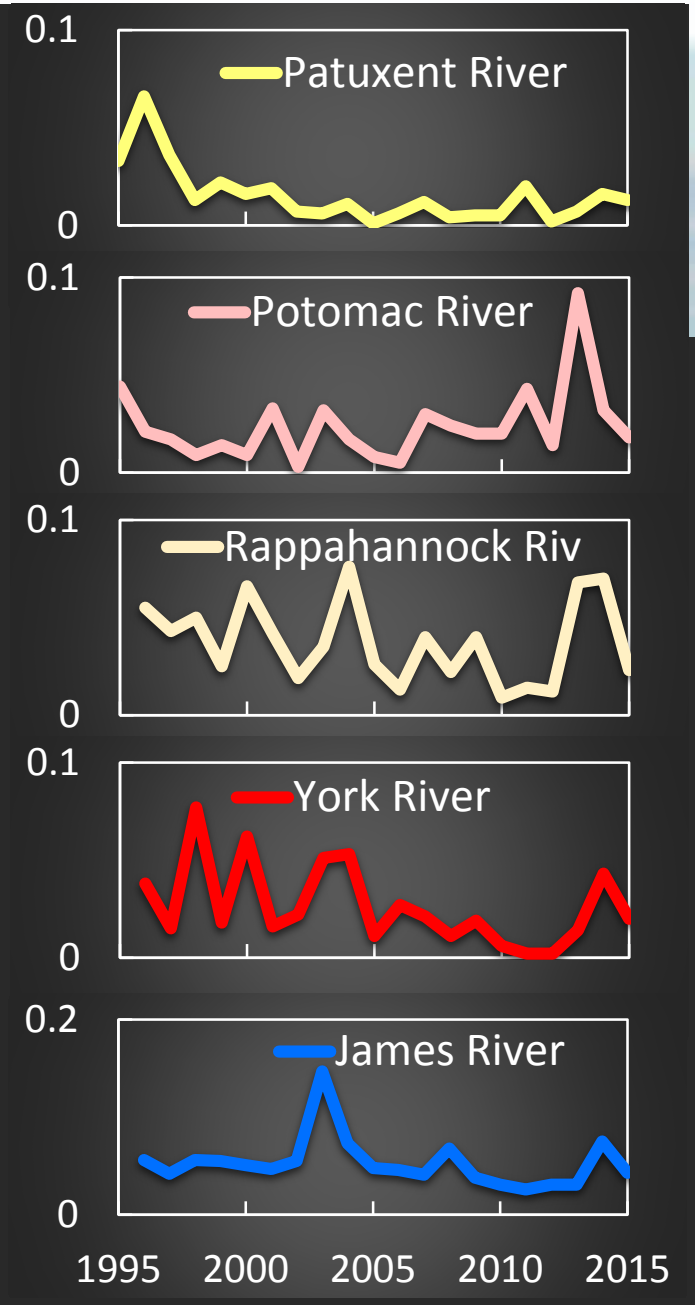


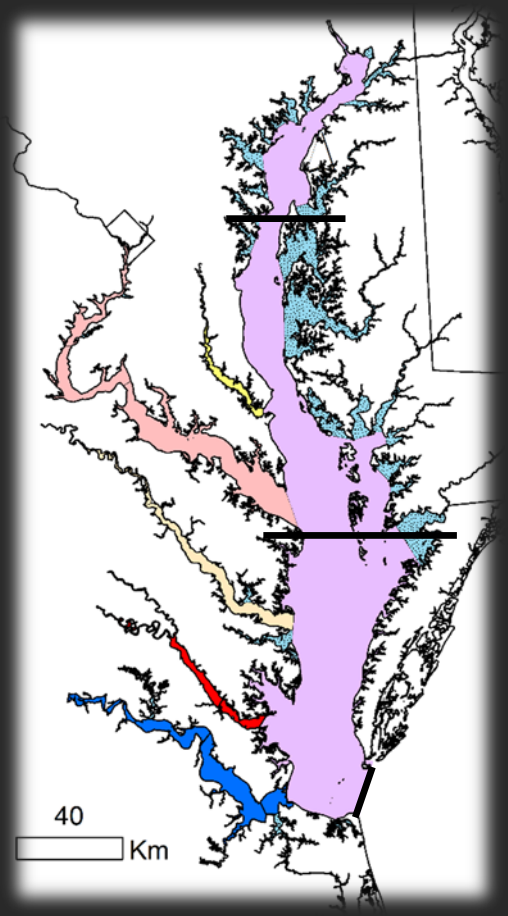
Forage-environment analysis

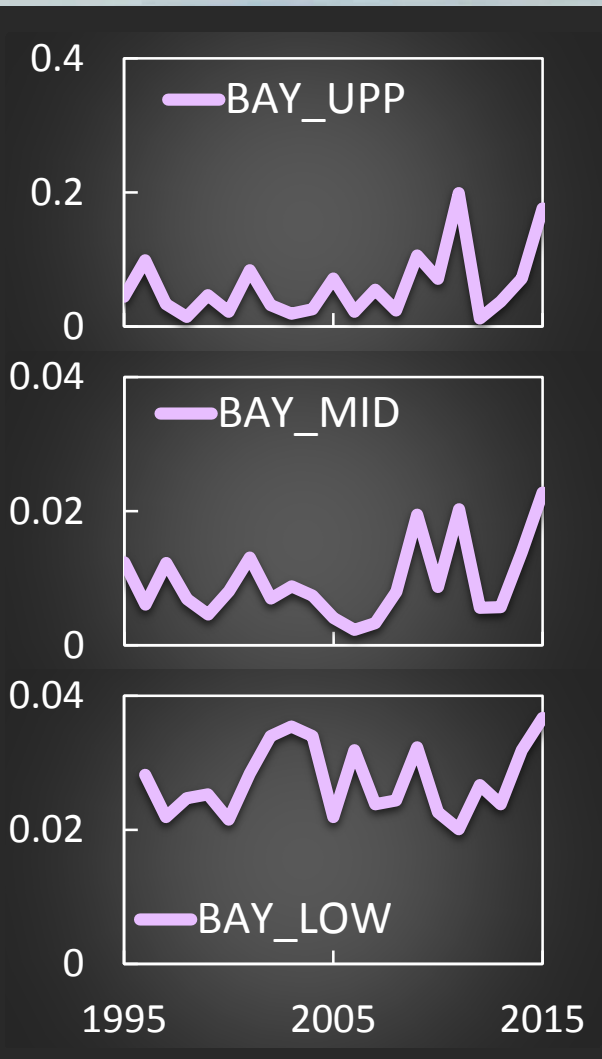
- Methodology
  - explore literature for potential environmental factors
  - download/obtain environmental data
- Analyses
  - temporal patterns in forage composition and spatial variability
  - environmental factors associated with forage indices

Spatially explicit index estimates

Example:
Amphipods/Isopods







Spatially explicit index estimates

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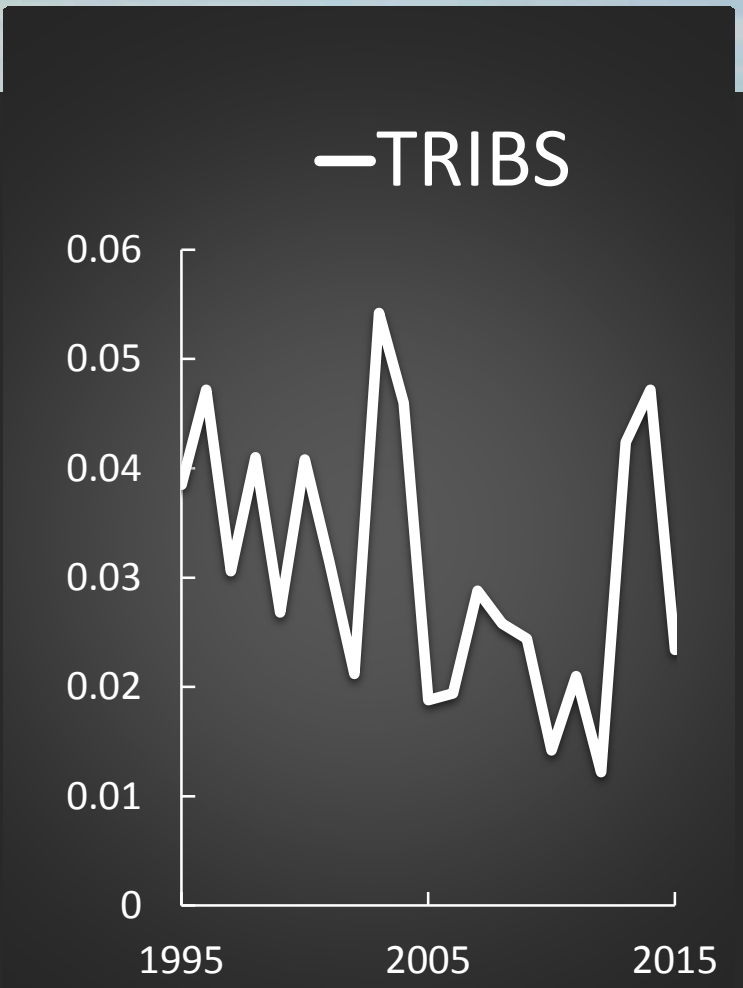
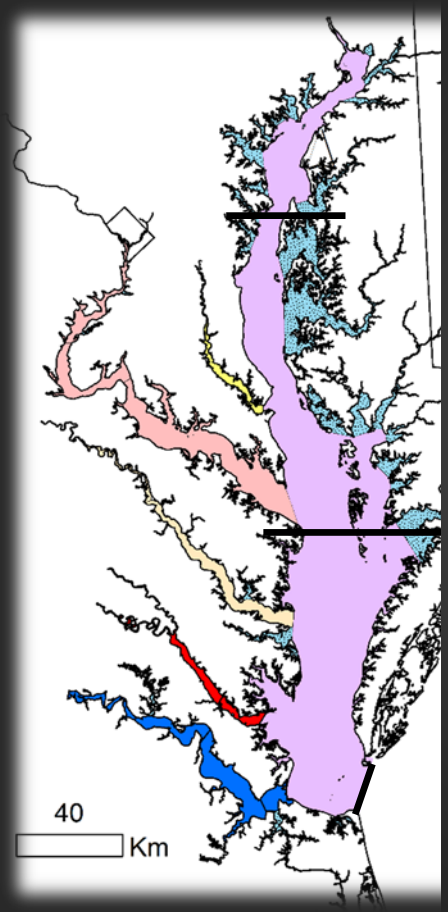
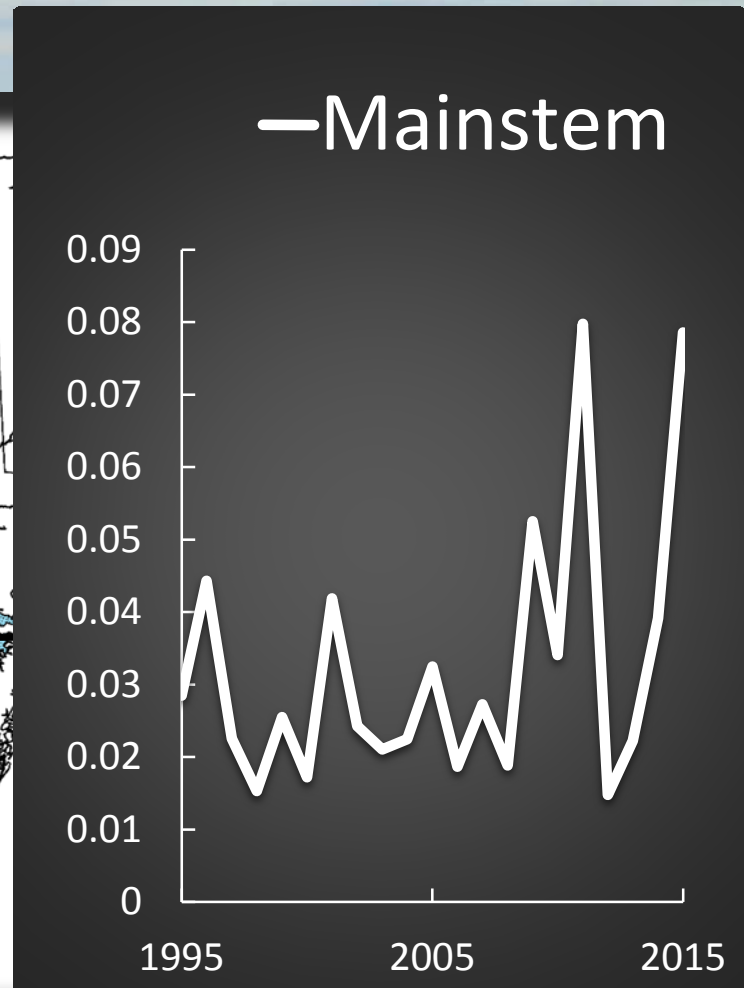
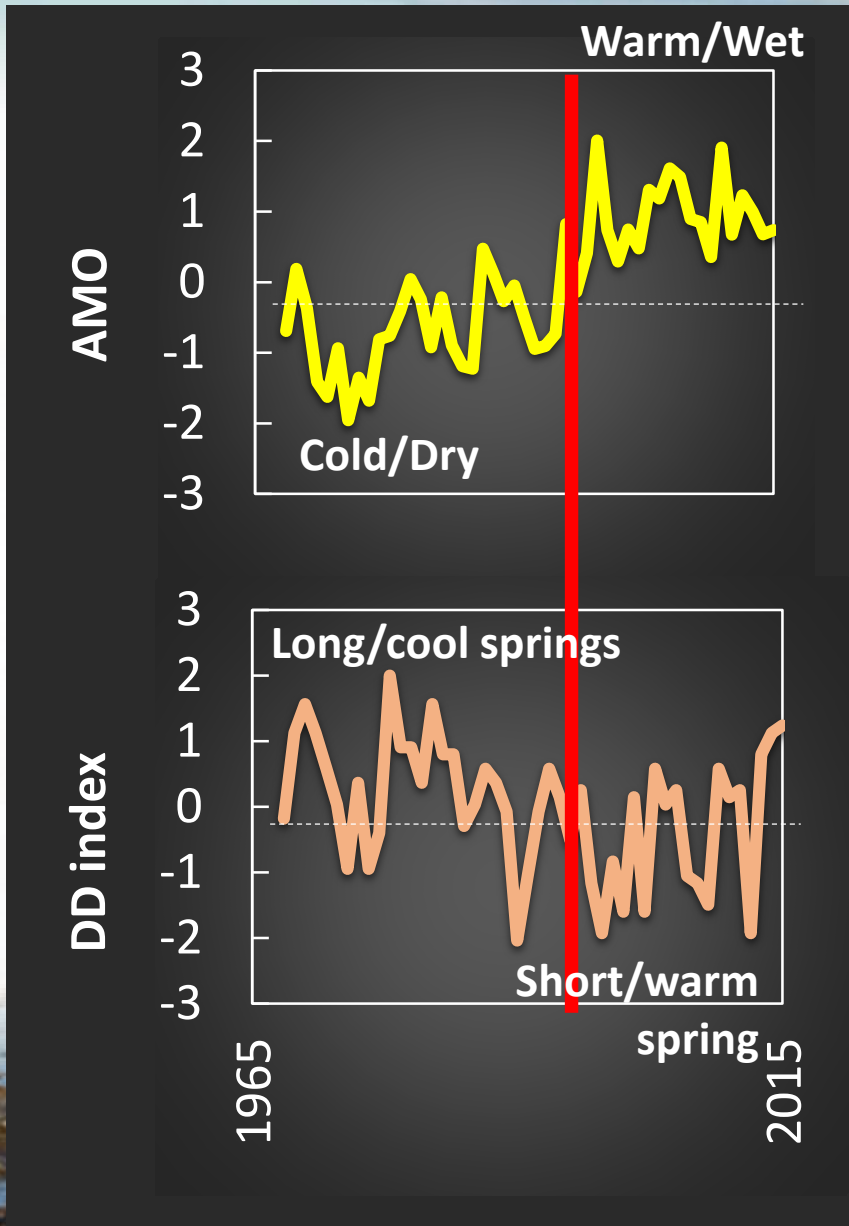






Forage-environment analysis

- Explanatory variables
  - Atlantic Multidecadal Oscillation (AMO)
  - Degree-Day (DD) warming index (DOY 500 5°C degree days)
  - winter-spring discharge (Jan-June)
  - spring chl-*a* conc. (Feb-May)
  - hypoxic volume



Forage-environment model results

Taxon	Mainstem AMO	Mainstem CHL	Mainstem DD	Mainstem Flow	Mainstem HYP	Tributaries AMO	Tributaries CHL	Tributaries DD	Tributaries Flow	Tributaries HYP
Alewife										
Anchovy										
Blueback herring										
Atl. croaker										
Killifish										
Atl. menhaden										
Mummichog										
Silverside										
Spot										
Weakfish										
Amphipods/Isopods										
Macoma spp.										
Other bivalves										
Polychaetes										

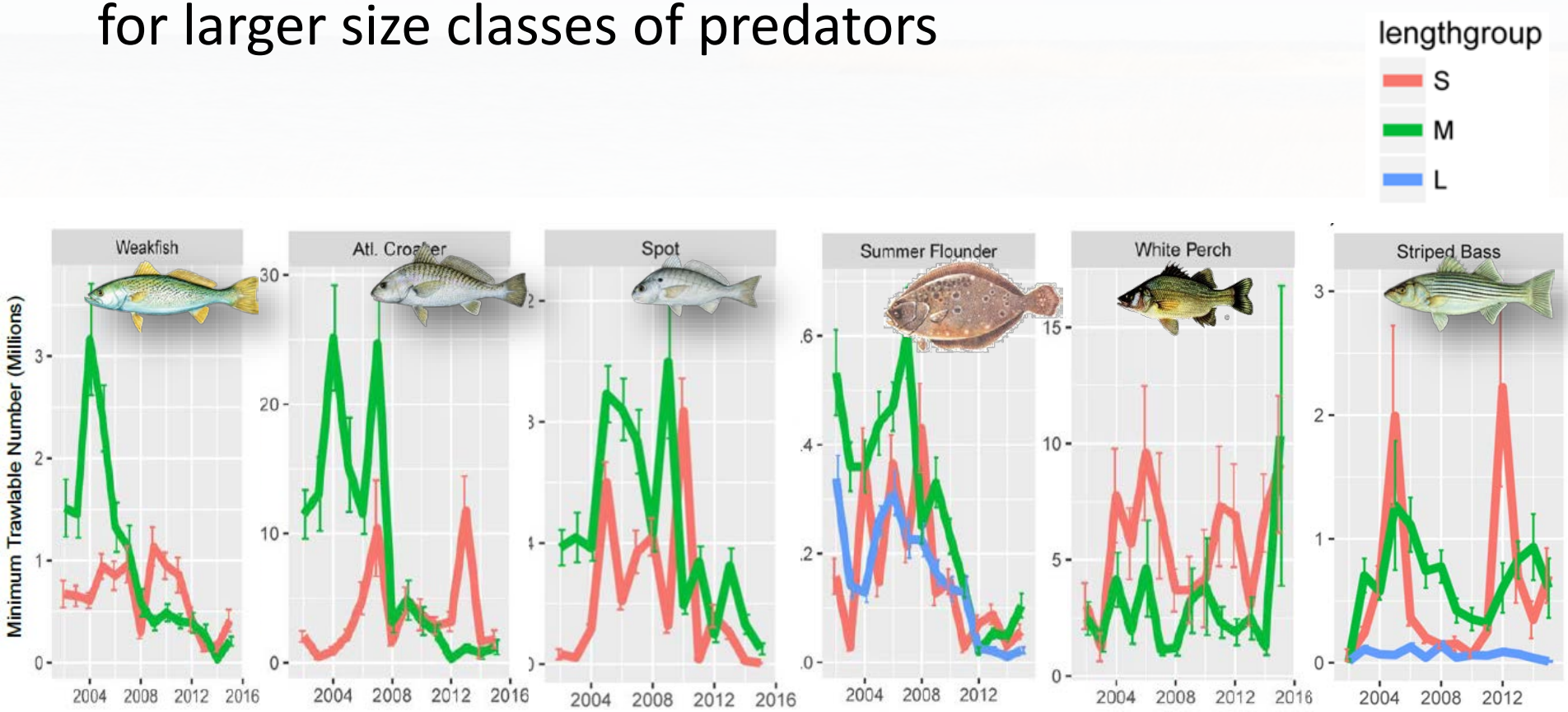
P-value	Parameter direction
<0.05	↑ Positive
<0.10	↑ Positive
<0.10	↓ Negative
<0.05	↓ Negative

Predator consumption analysis

- Methodology
  - six predator fish species with multiple size-classes
  - bioenergetic-based consumption estimates
- Analyses
  - spatial analysis of predator diets
  - environmental & biological factors associated with per capita consumption
  - long-term trends in per capita consumption

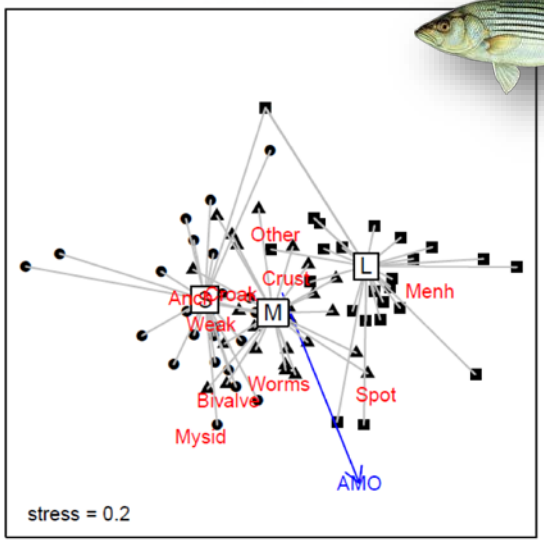
Temporal trends – predator abundance

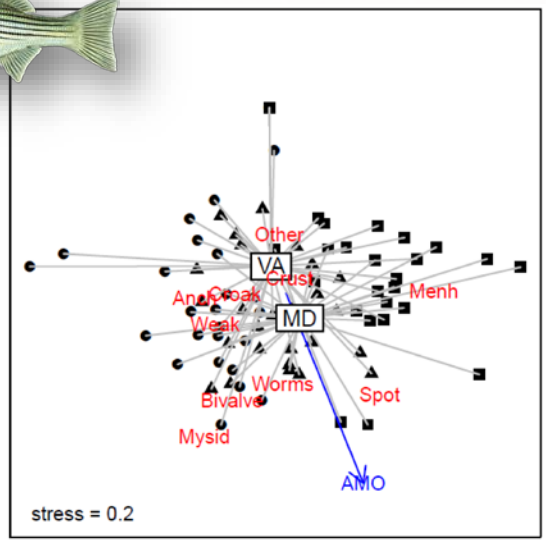
- Long-term declines in indices of abundance for larger size classes of predators



Spatial patterns – predator diet

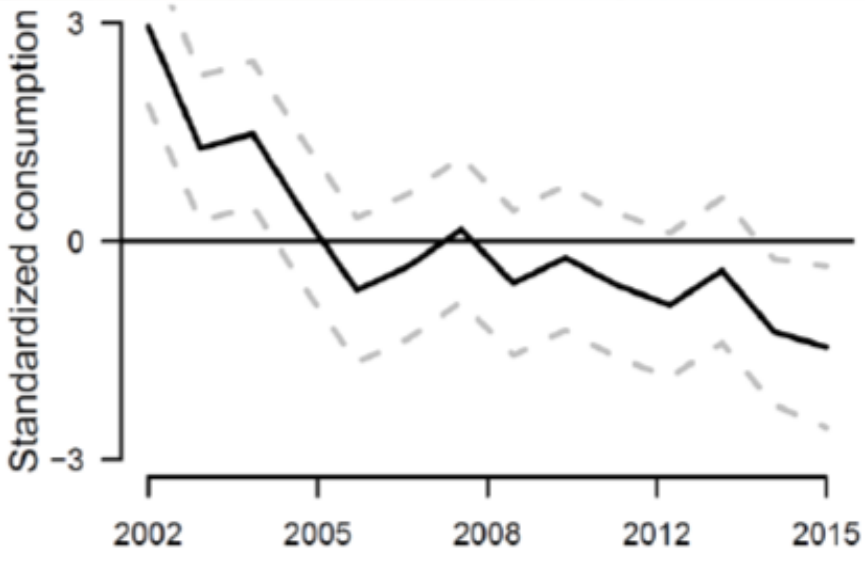
- Spatial resolution: state-level (MD and VA)
  - sufficient data for 4 of 6 predators
- Spatial differences present for summer flounder, weakfish, striped bass
- Environmental correlates with predator diet
  - AMO (striped bass/weakfish)
  - NAO, chl-*a* (weakfish)

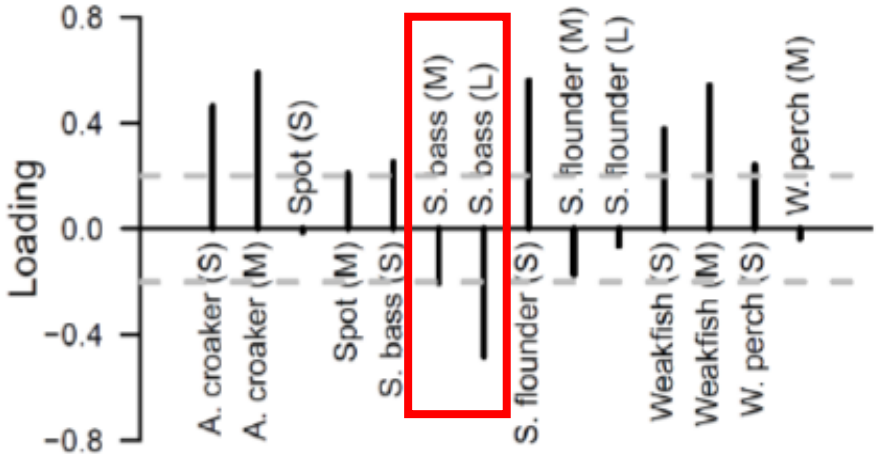




Temporal trends – predator consumption

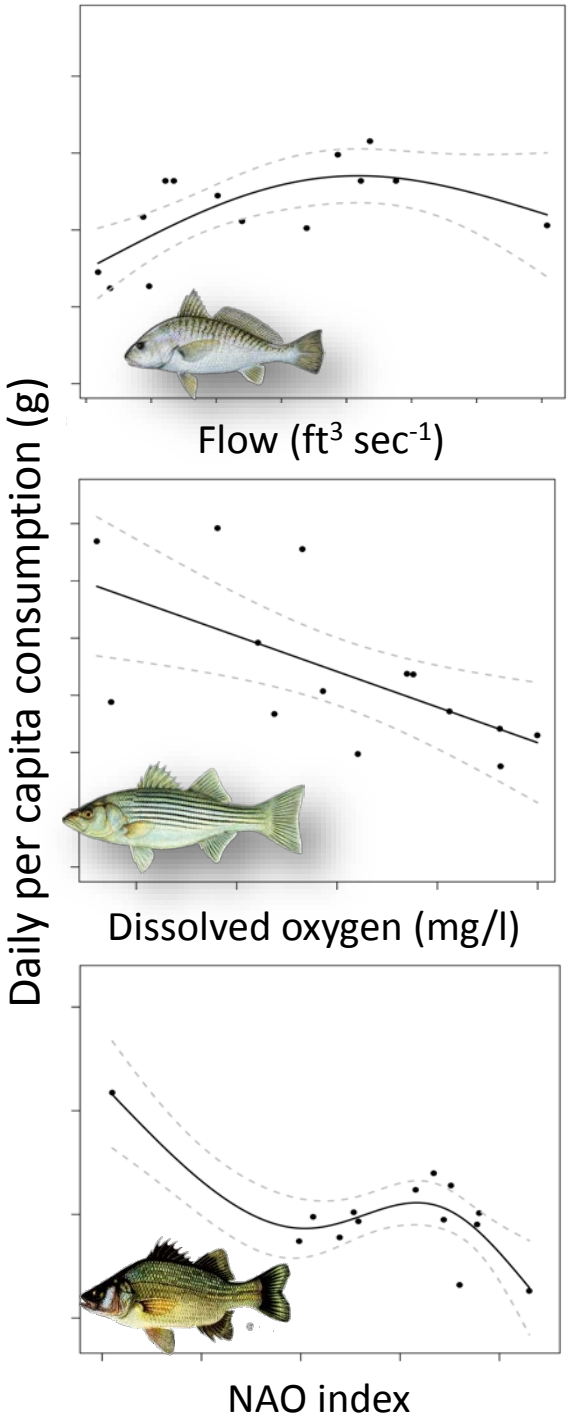
- Dynamic Factor Analysis
- Negative multispecies trend in per capita consumption
  - most predator size-classes show trend
  - medium-to-large striped bass show positive trend
  - no significant covariates





Environmental factors – predator consumption

- Generalized additive models
- Salinity-associated factors
  - sm/med. Atl. croaker, sm. weakfish & spot
- Dissolved oxygen
  - small/med. striped bass, white perch: ↓
  - summer flounder: ↑
- NAO – climate index
  - small white perch, spot (complex)



Key findings – forage and predators

Forage

- Climate-forcing linked to temperature and precipitation
  - AMO and winter-spring flow volume
- Rapid vernal warming negatively associated w/forage
  - match-mismatch of prey available to forage groups
  - altered predator demand on forage

Predators

- Spatial differences in diet between MD and VA portions of the Bay
- Consumption correlated with environmental conditions
  - availability of forage or suitable foraging habitat
  - unrelated to forage indices (as calculated)
- Long-term declines in per capita consumption

Management implications

Forage

- Findings have utility for understanding and predicting forage conditions under long term climate regimes
  - strategic planning and preparedness rather than year-to-year decisions
  - results useful for ecosystem-based model simulations and forecasting
  - consistent monitoring to identify trends toward critical levels

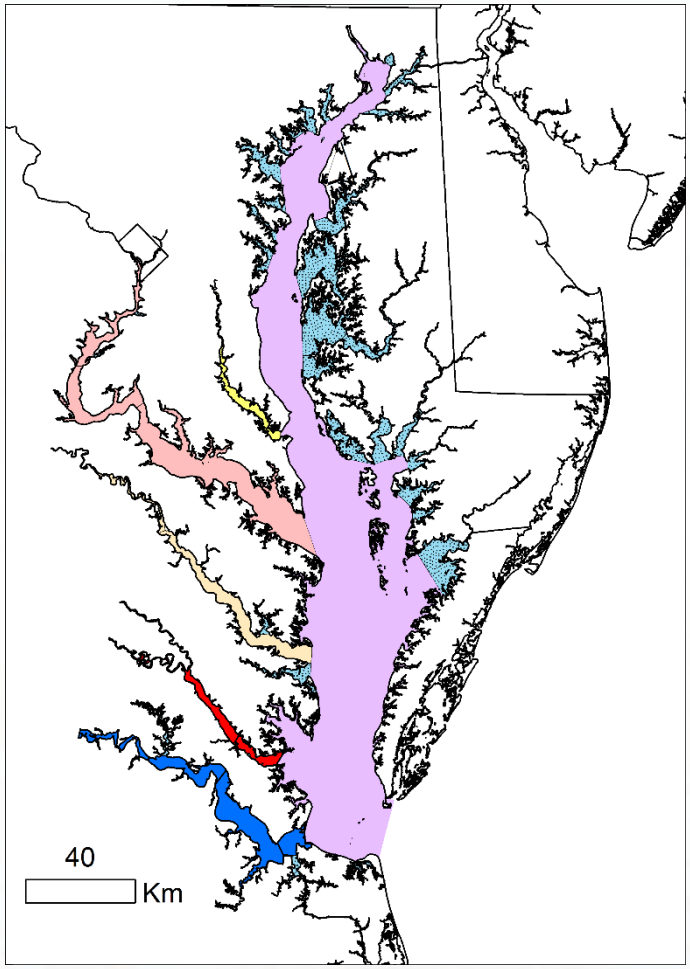
Predators

- Reduced predator consumption at individual level
  - decreased per capita consumption may indicate decline in habitat conditions for predators (biological or environmental)
- Changes in relative composition of predator assemblage
  - altered trophic demand on different components of forage base

Recommendations

- Expanded monitoring capacity
  1. Mainstem forage fish survey
  2. Zooplankton survey
  3. Tributary / shallow water predator survey

- Future research
  - Increasing temporal, spatial, taxonomic resolution
  - Integrating habitat considerations (e.g., SAV, shoreline type)
  - Ecosystem-based modeling to explore effects of climate forcing on forage abundance and predator consumption
  - Spatial analysis of per capita consumption – requires finer scale data




Thank you!

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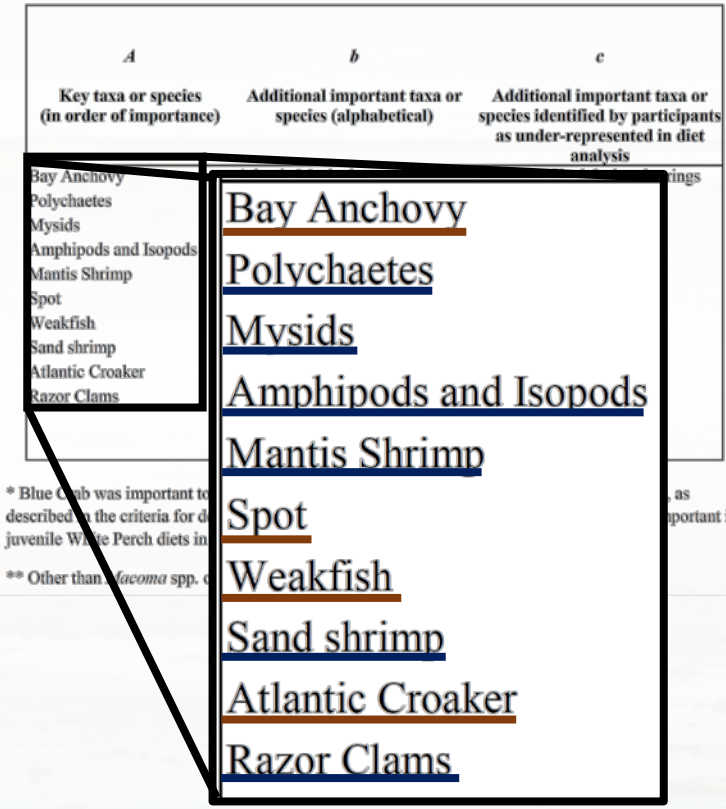

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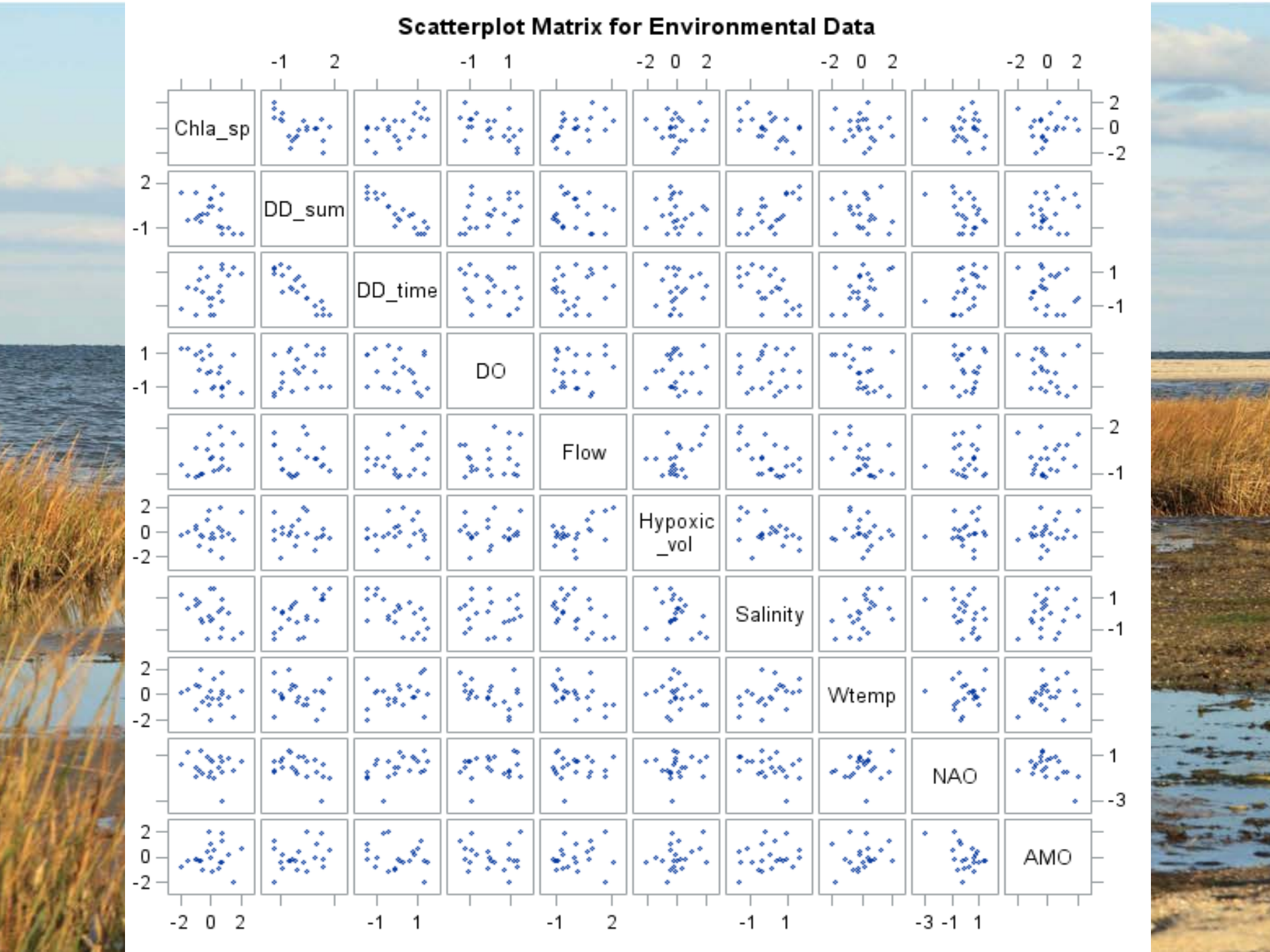
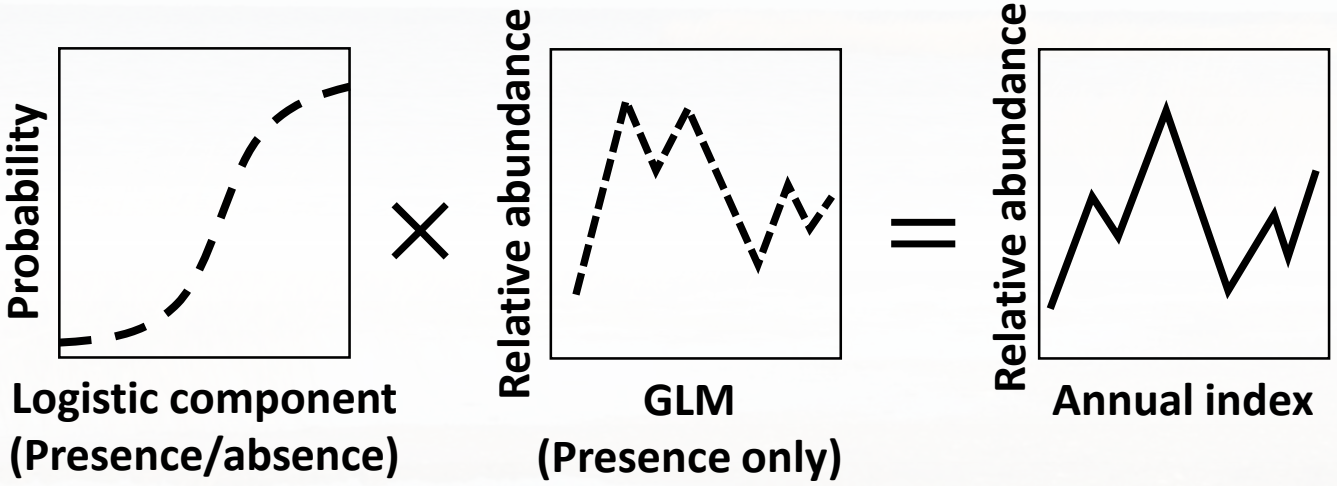

Scatterplot Matrix for Environmental Data
Chla_sp
DD_sum
DD_time
DO
Flow
Hypoxic_vol
Salinity
Wtemp
NAO
AMO

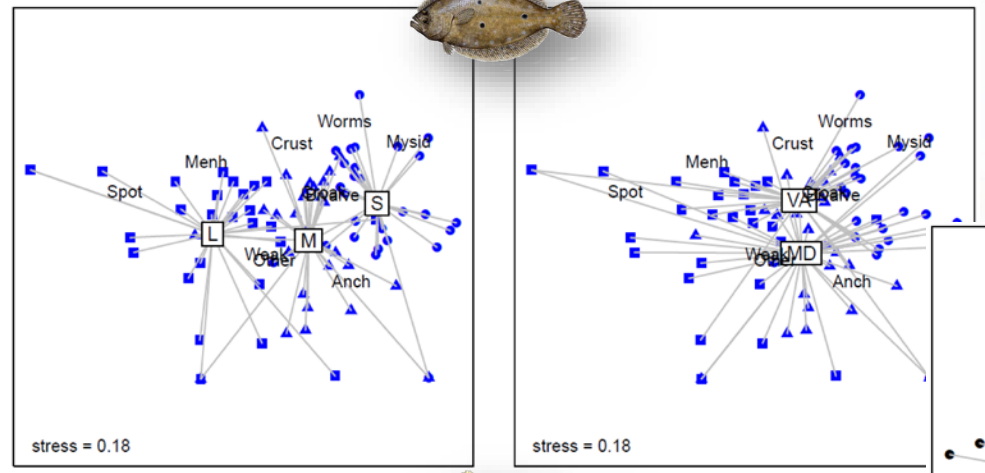
Methods: statistical models

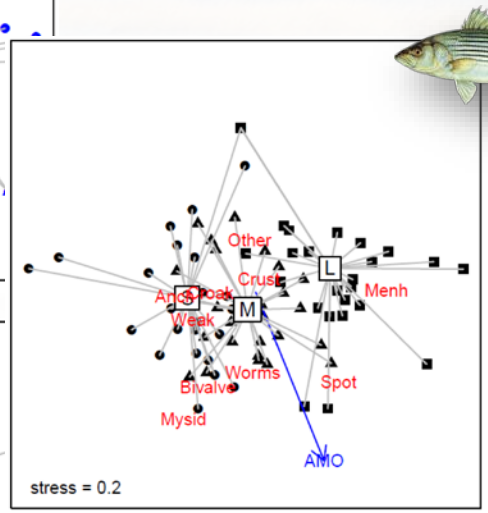
Annual indices: delta-generalized linear models (Delta-GLMs)

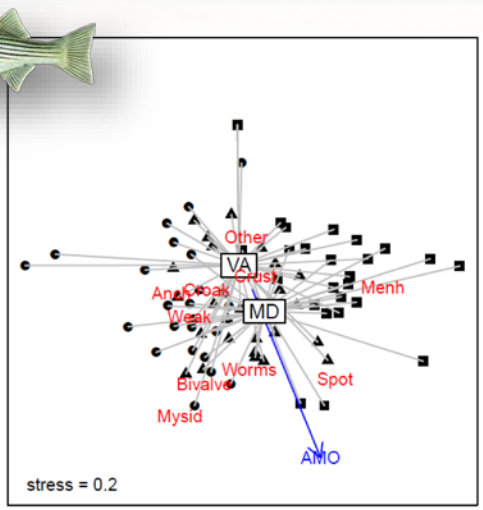


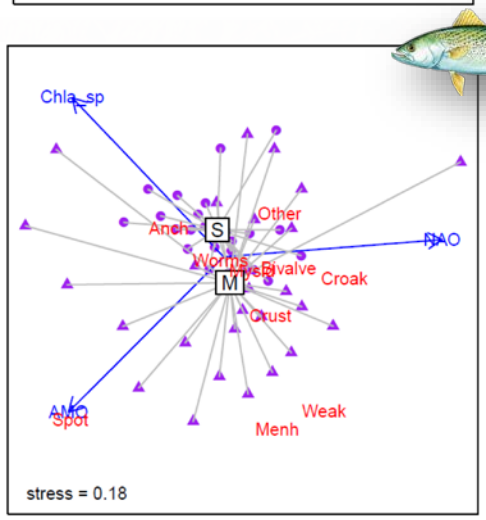
$$\hat{y} = \text{Section} + \text{Year} + \text{Section} \times \text{Year} + \text{Depth}$$

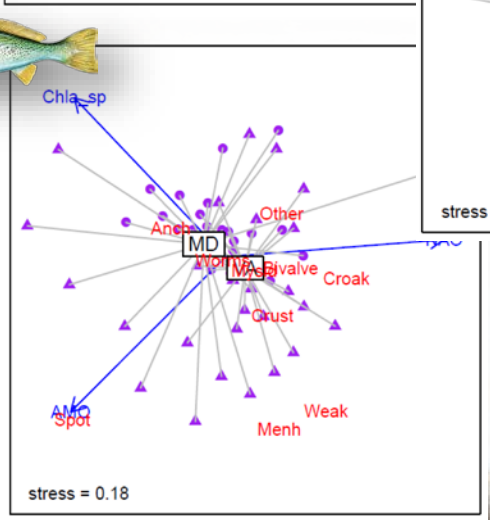
Spatial patterns in predator diet











Temporal trends – predator size