

Drivers of forage population trends and consumption patterns:

*environmental, spatial and temporal patterns in
Chesapeake Bay forage population distributions and
predator consumption*

Update to the Forage Action Team – February 16th 2017

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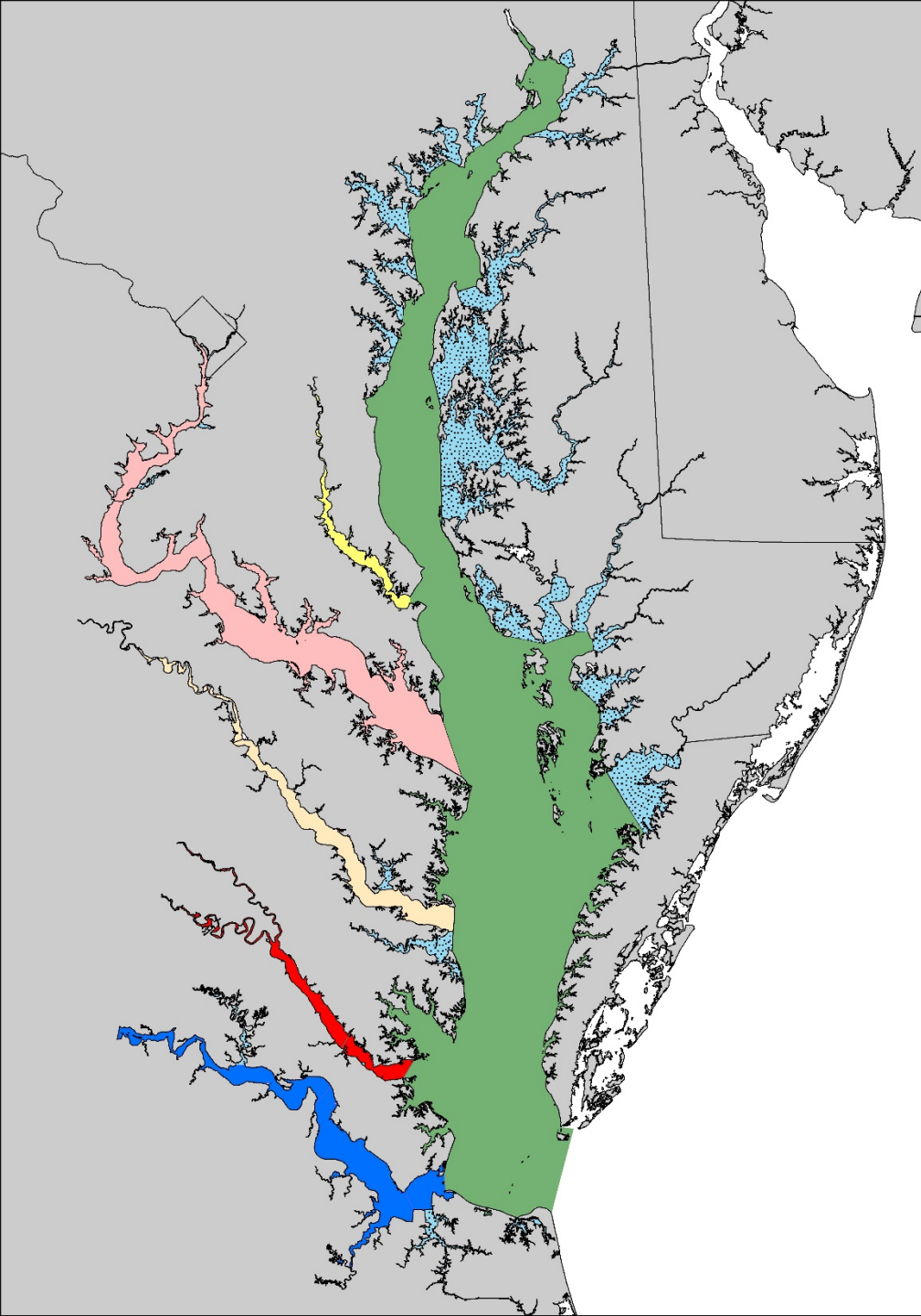
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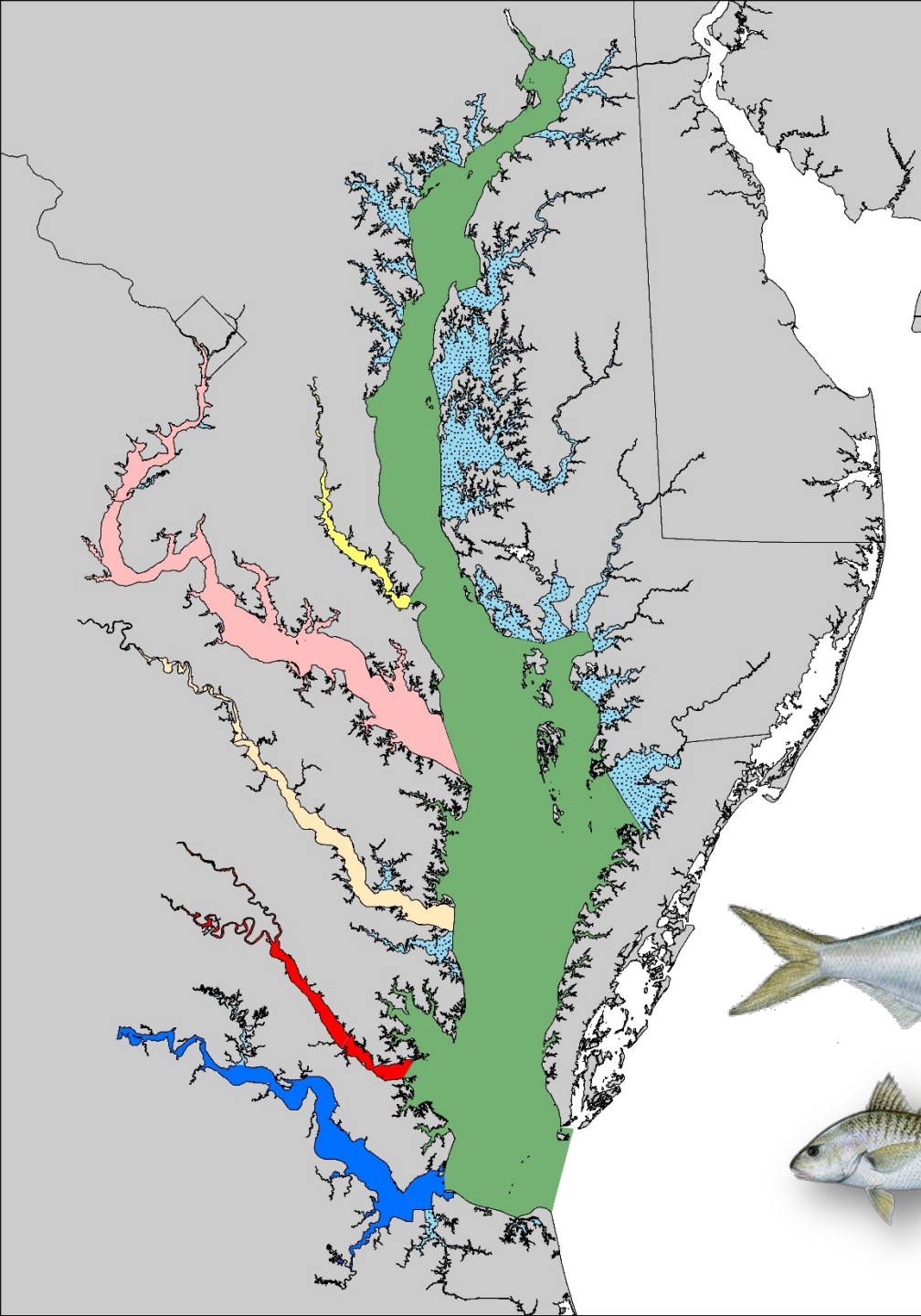
Project goals

- **Objective 1** – *Identify environmental gradients associated with spatial and temporal patterns in relative abundance of forage taxa in Chesapeake Bay*
- **Objective 2** – *Explain how spatial and temporal gradients in environmental variables control consumption of forage taxa, and quantify the effect of forage abundance on consumer populations*



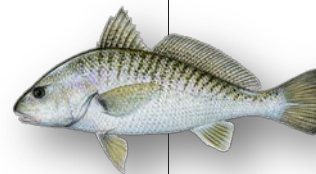
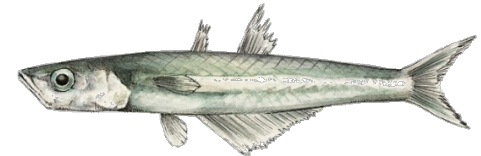
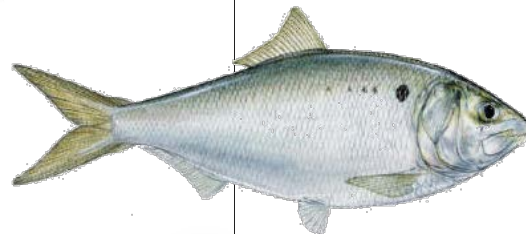
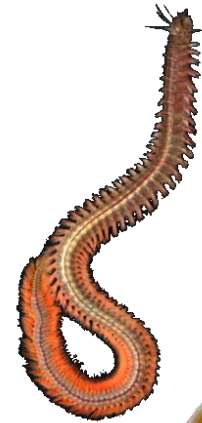
Spatial scales and areas of interest

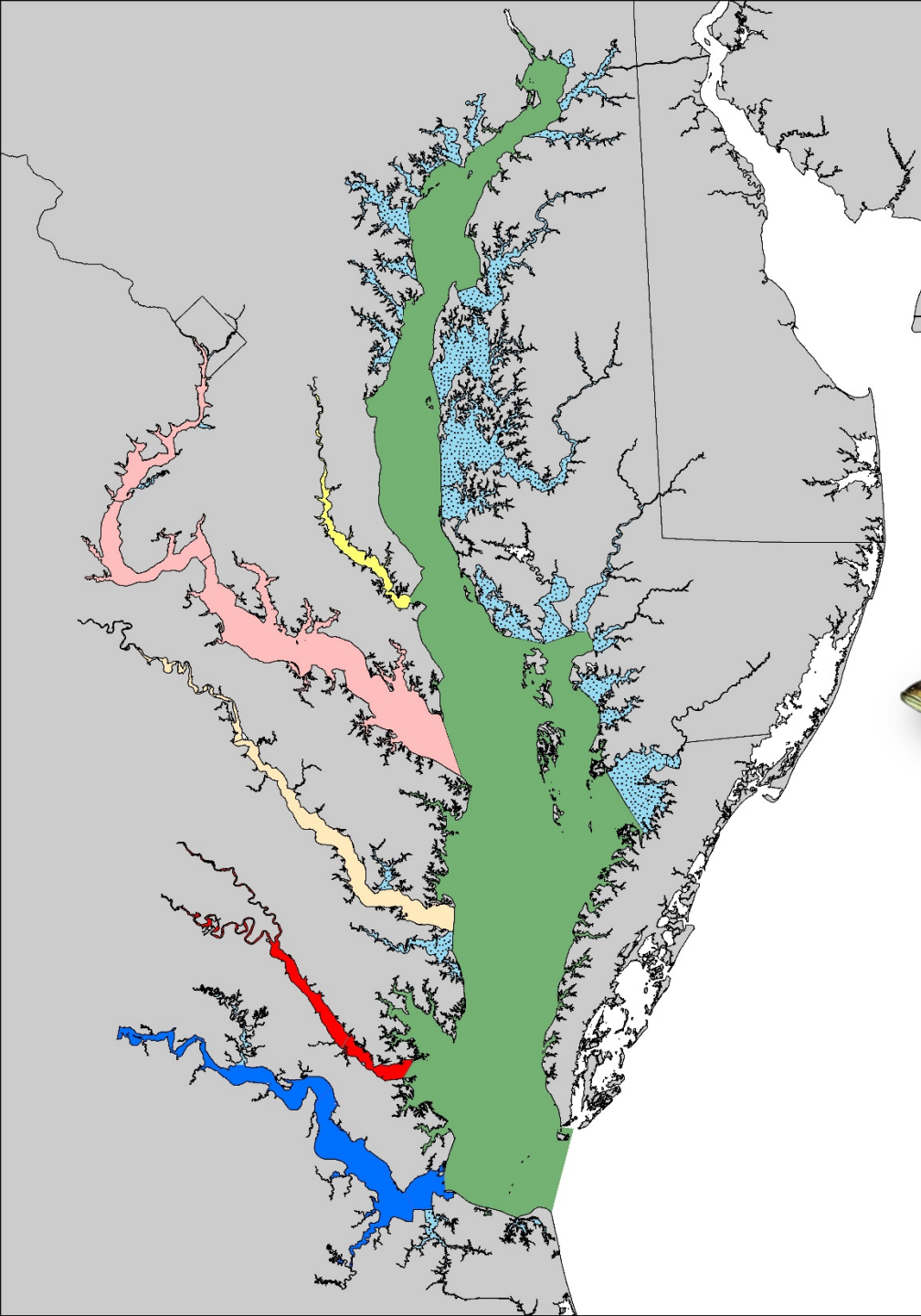
- Baywide
- Regional
 1. Mainstem
 2. Tributaries:
 - Patuxent River*
 - Potomac River*
 - Rappahannock River*
 - York River*
 - James River*



Species/taxa of interest

- Forage

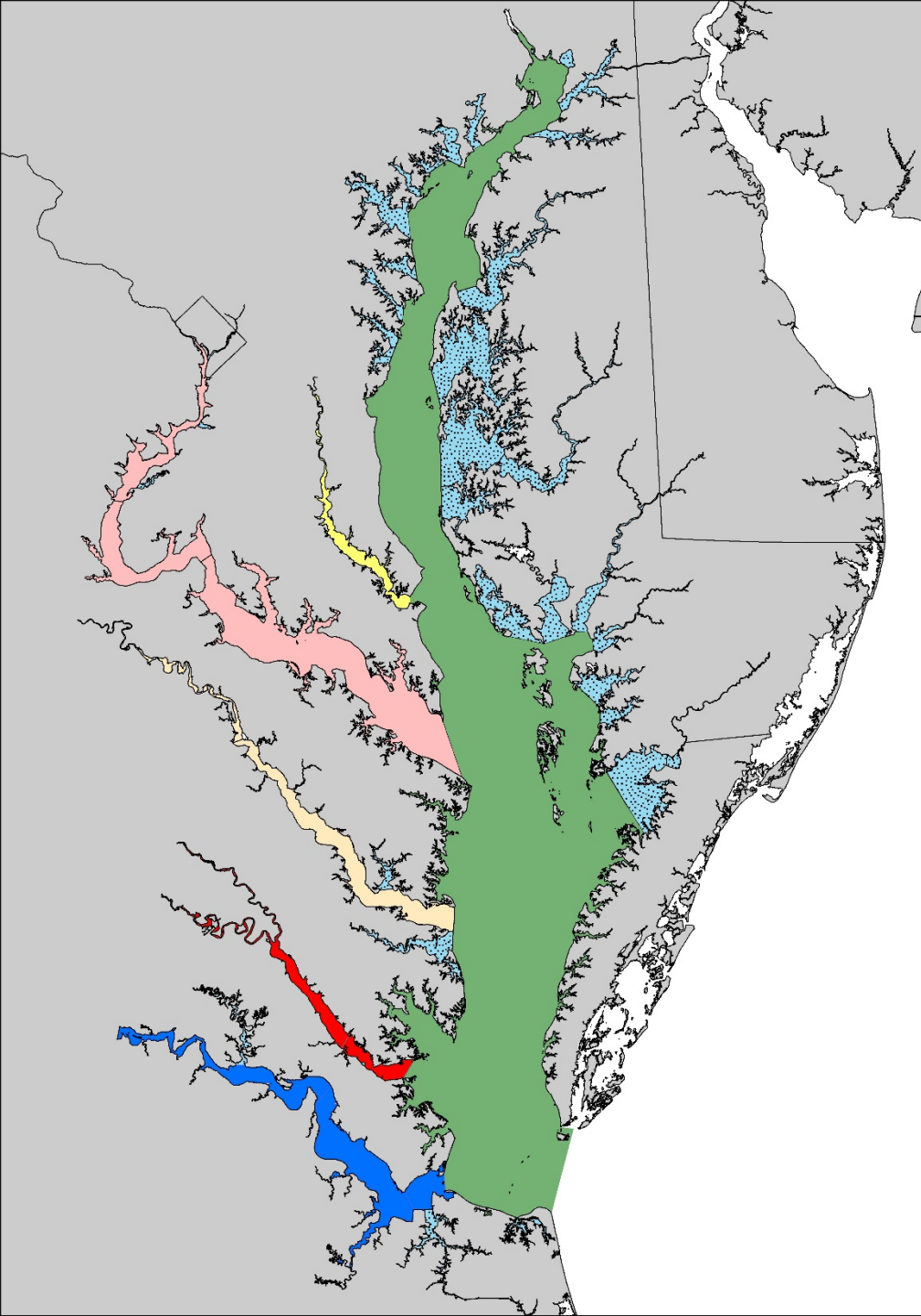




Species/taxa of interest

- Forage
- Consumers
 - Multiple size-classes





Species/taxa of interest

- Forage
- Consumers
 - Multiple size-classes

Multiple surveys

- Chesapeake Bay Program Benthic Survey/WQ monitoring survey
- MD DNR/VIMS juvenile striped bass index seine surveys
- MD DNR/VIMS trawl surveys
- CHESFIMS/TIES midwater trawl survey
- ChesMMaP trawl survey

Project methods

Project Objective	Indices	Patch-scale	Large-scale	Time-series
Forage				
<i>Environment</i>	Delta-GLM	GAM/GAMM	GLM/GLMM	DFA
Predators				
<i>Consumption-Environment</i>	Evacuation model		GLM	DFA
<i>Diet-Environment</i>		Delta-GAMM		
<i>Diet-density dependence</i>			GLM	

Models–

1. GLM: generalized linear model
2. GAM: generalized additive model
3. Delta-GLM: delta-generalized linear model
4. Delta-GAM(M): delta-generalized additive (mixed) model
5. DFA: dynamic factor analysis

Forage-environment analysis

GAMs: patch-scale patterns

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + s_1(x_1) + s_1(x_1) \dots \beta_n x_n + s_n(x_n)$$

- **Taxonomic resolution** – Species ($n=8$), Genus/Family ($n=5$), Functional ($n=5$)
- **Response variable** – $\ln(\text{biomass per square meter [AFDW]})$
- **Explanatory variables**
 - *Class*: region, year
 - *Continuous*: dissolved oxygen, salinity, temperature, depth (CBP survey)
 - *Interactions* (depth*DO, depth*salinity, temperature*DO)

GLMs: large-scale patterns

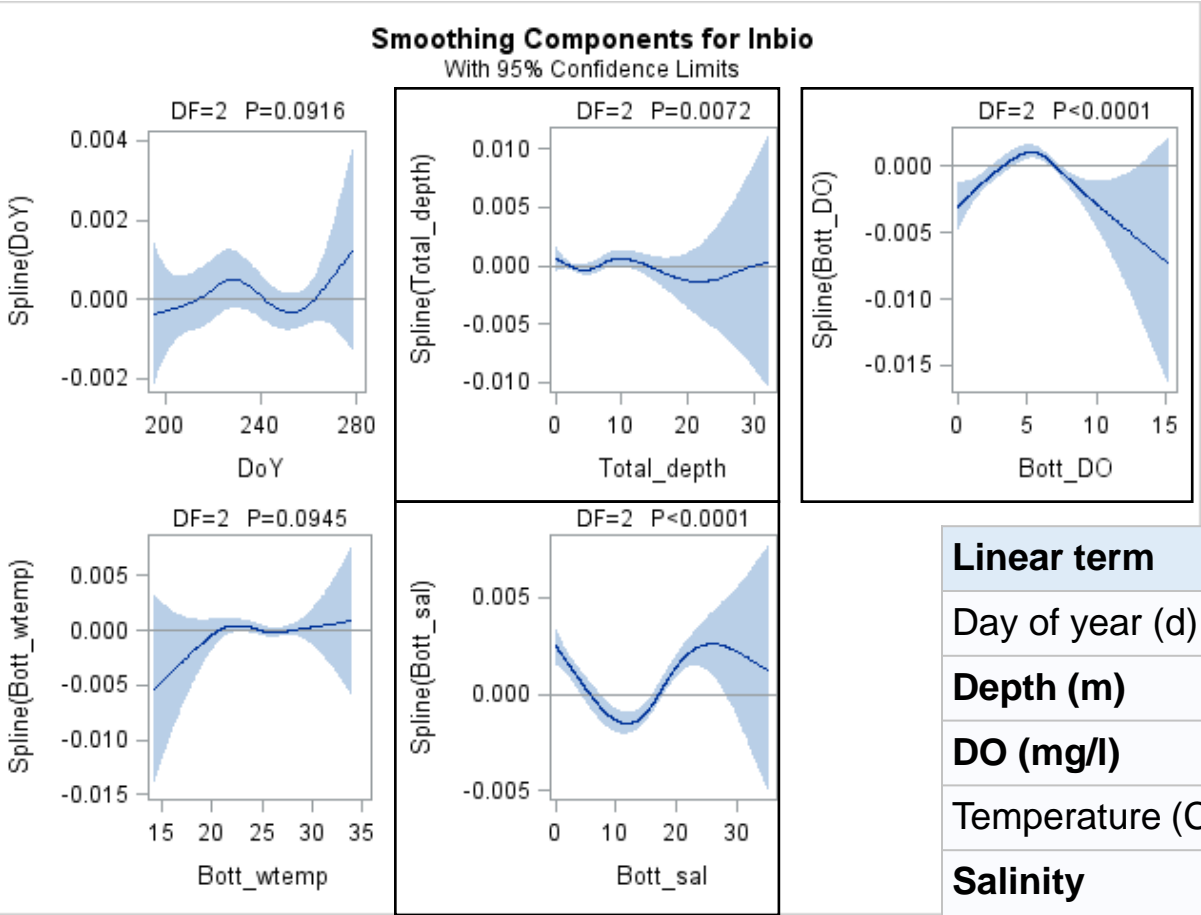
$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \dots \beta_n x_n$$

- **Response variable** – $\ln(\text{biomass per square meter [AFDW]})$
- **Explanatory variables (all continuous)**
 - Teleconnections/climate indices (NOAA)
 - Susquehanna River flow (USGS)
 - Cumulative 5°C water temperature degree (CBL/VIMS pier dataset)
 - Ordinate DoY at which cumulative 5°C DD > 500 (CBP survey)
 - Chlorophyll concentration (CBP WQ survey)
 - Hypoxic volume (UMichigan)

Example: trumpet worm (*Pectinaria gouldii*)

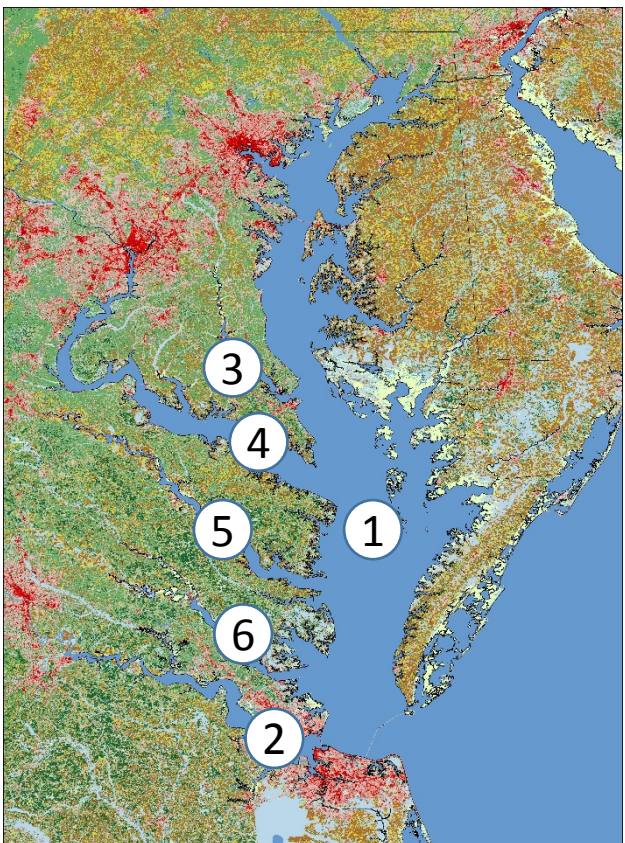


Sms.si.edu

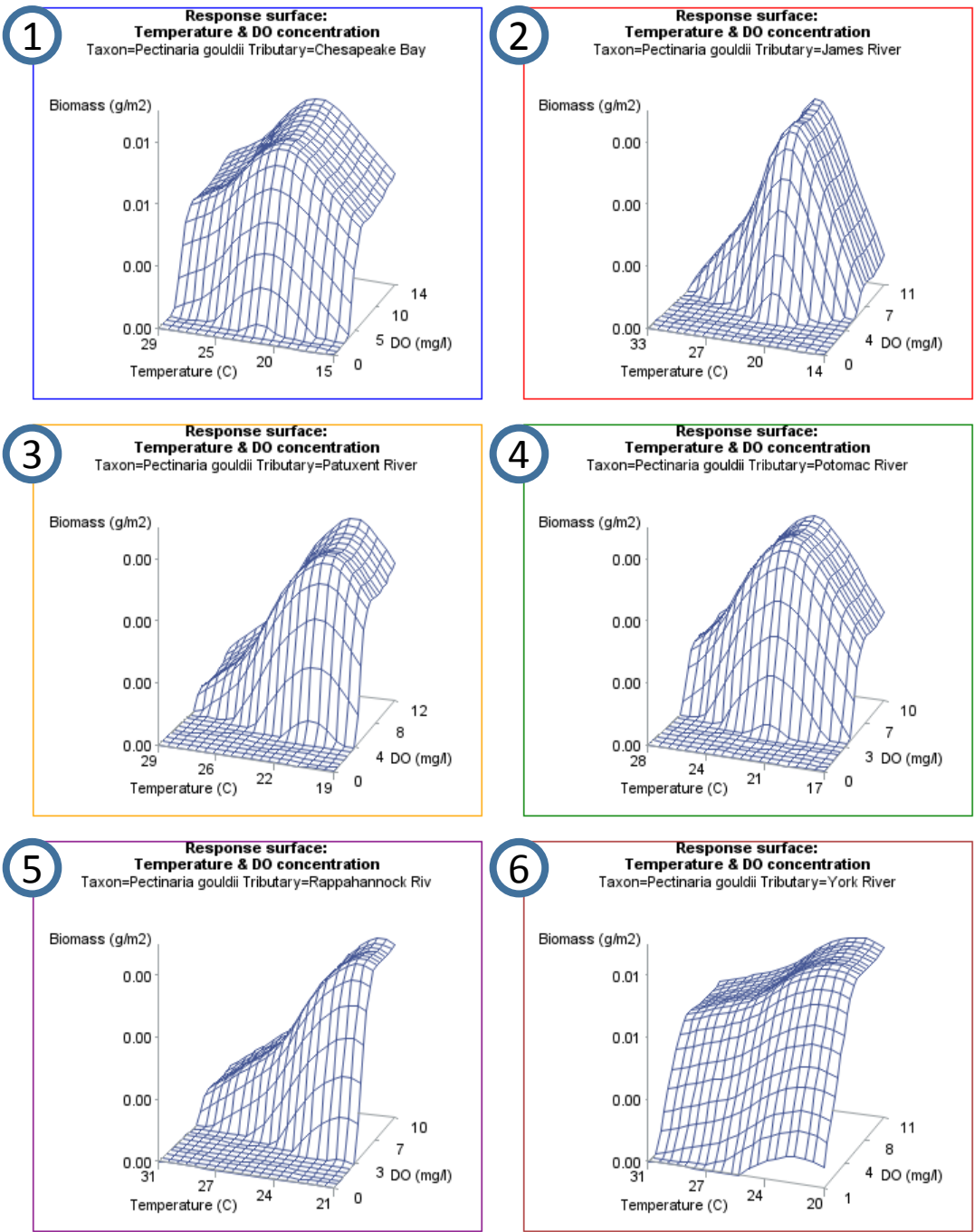


Linear term	Estimate	SE	t-value	p
Day of year (d)	-0.00003	0.00002	-1.55	0.12
Depth (m)	0.0007	0.00008	7.94	<.0001
DO (mg/l)	0.0009	0.0002	5.90	<.0001
Temperature (C)	-0.0003	0.0002	-1.79	0.07
Salinity	0.0006	0.00006	11.20	<.0001

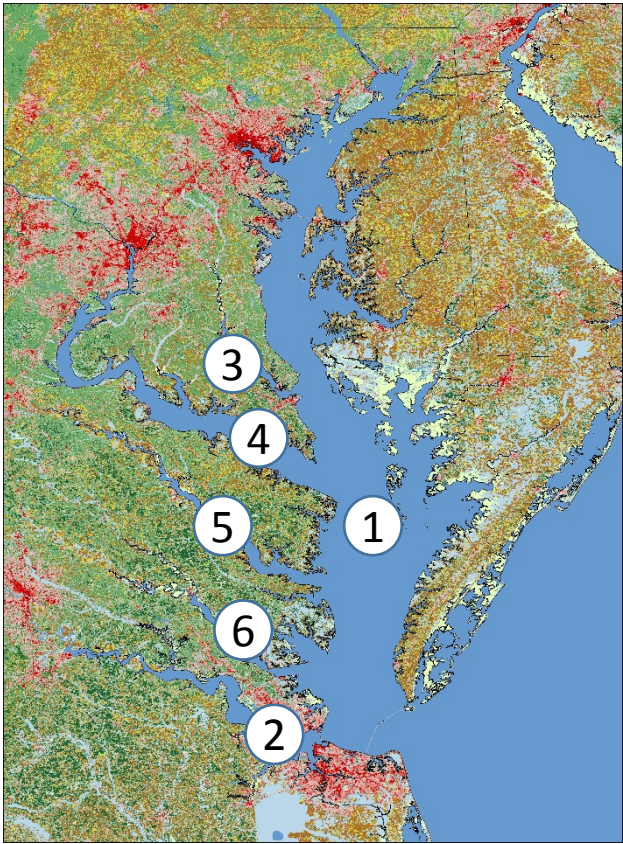
Pectinaria gouldii
(trumpet worm)



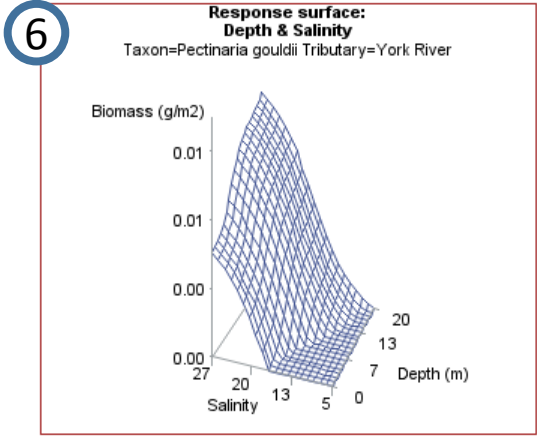
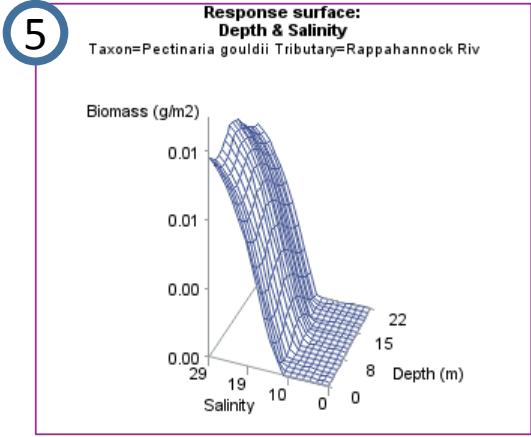
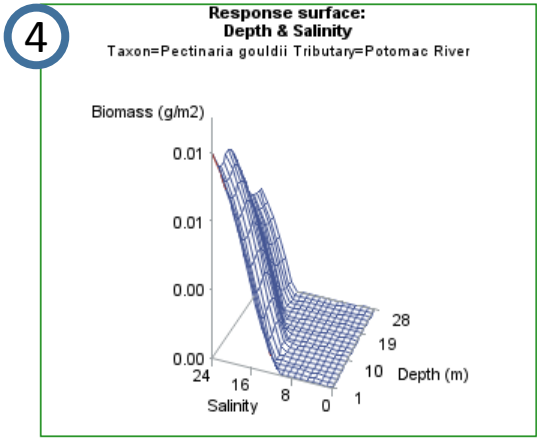
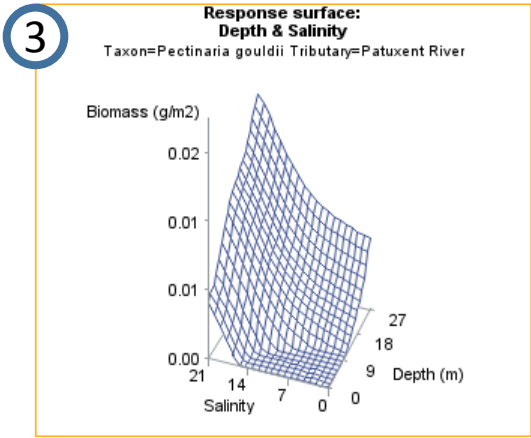
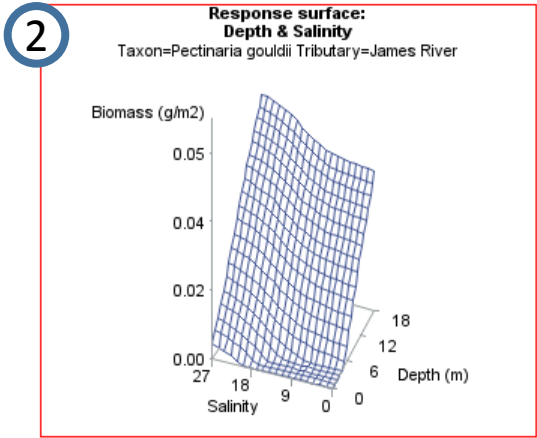
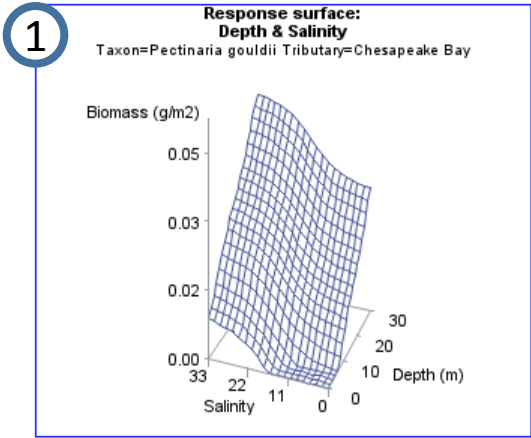
Response surface: temperature & DO



Pectinaria gouldii
(trumpet worm)

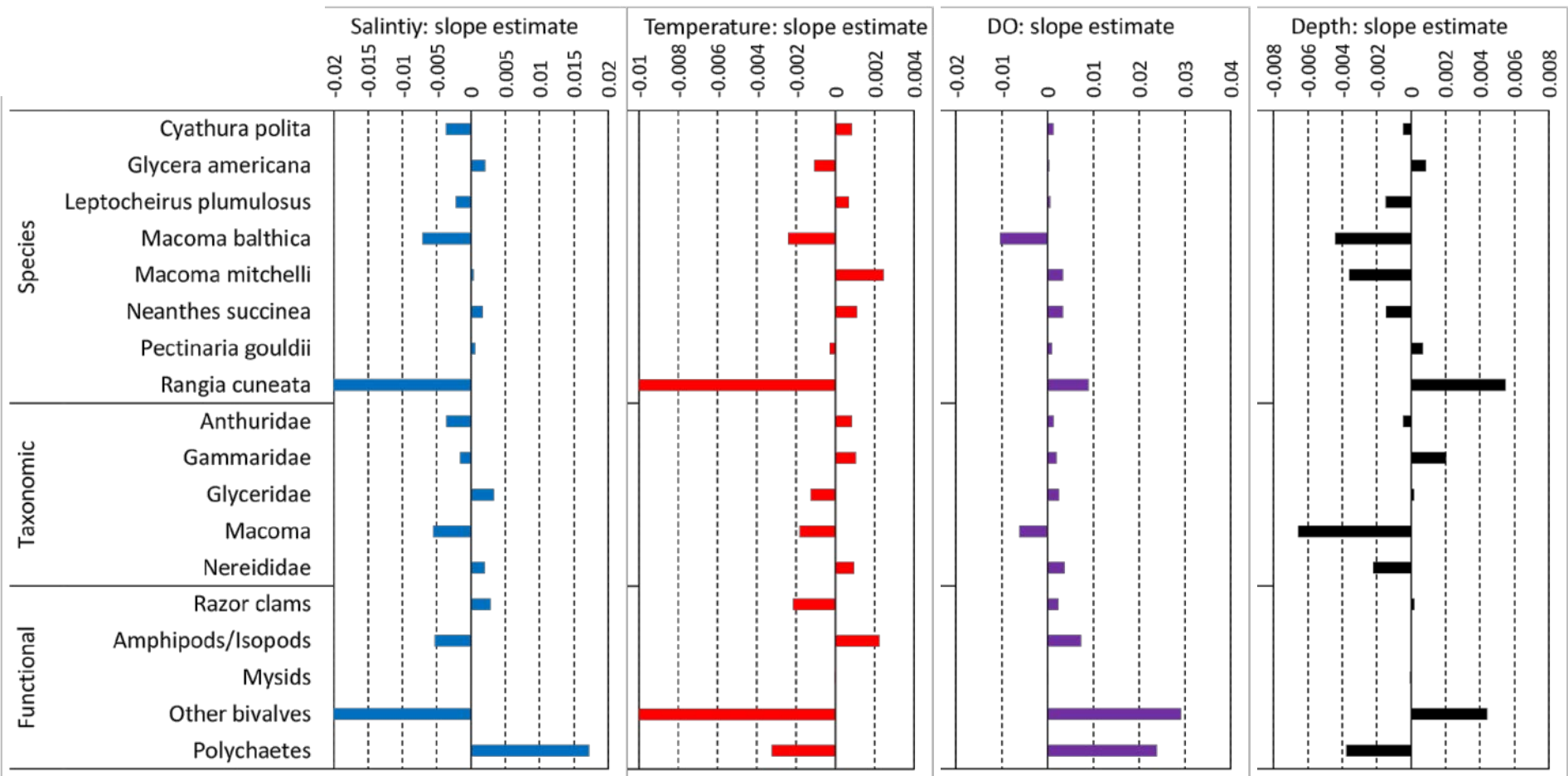


Response surface: depth & salinity



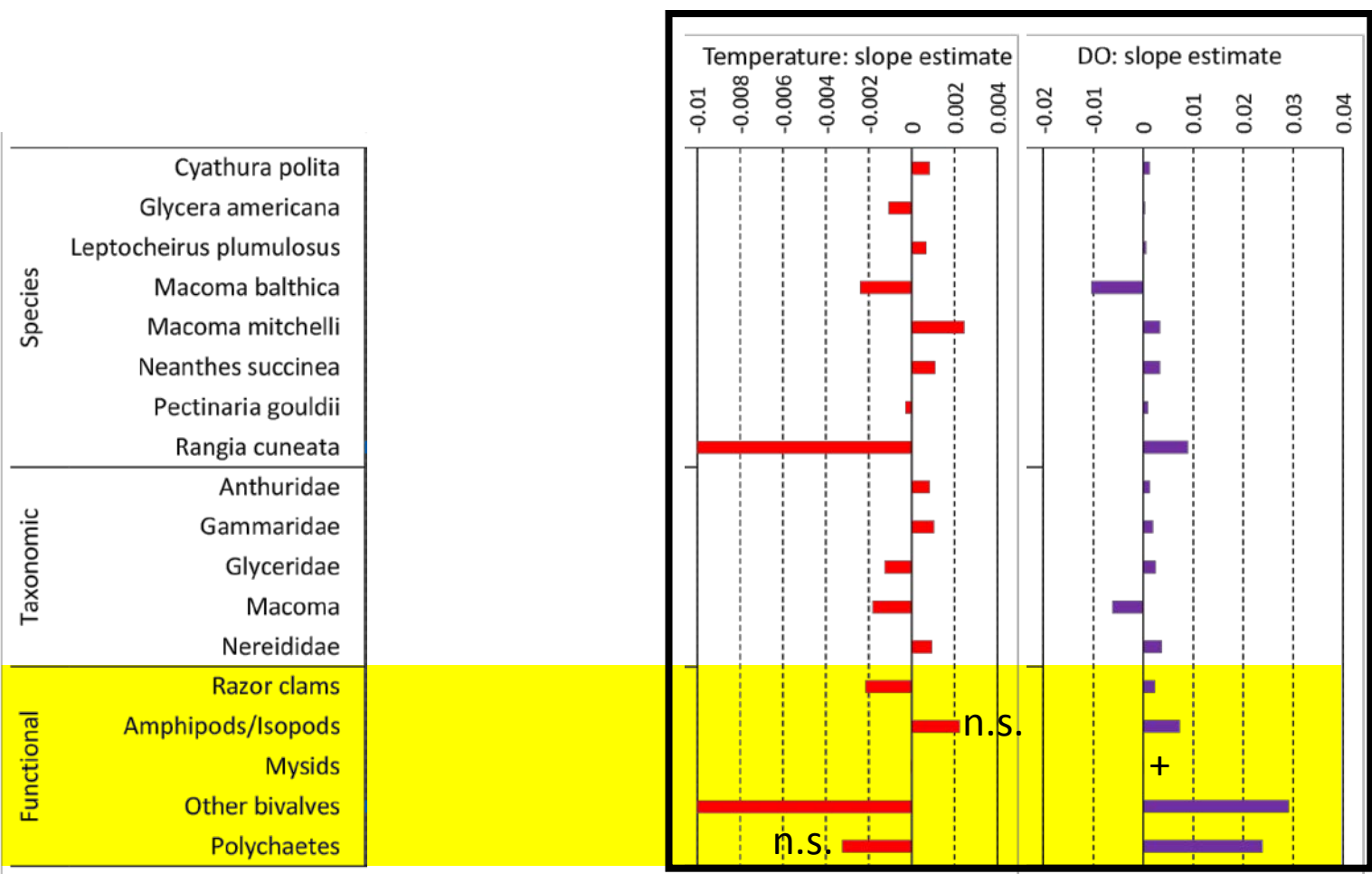
Forage-environment analysis

1. Strong differences among invertebrate groups, even within genera (e.g., *Macoma* spp.)



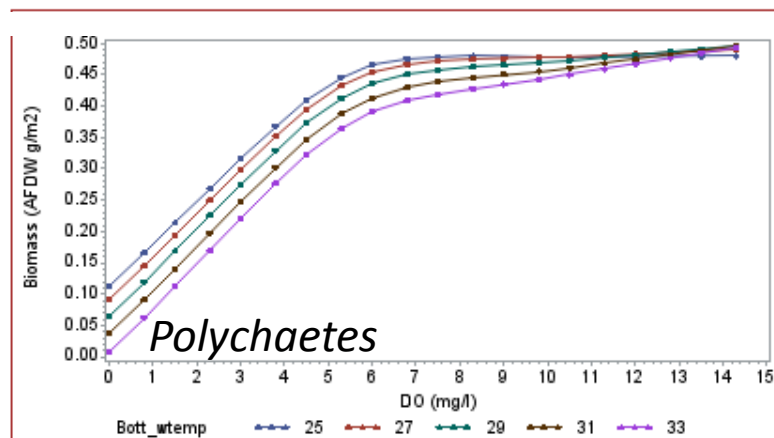
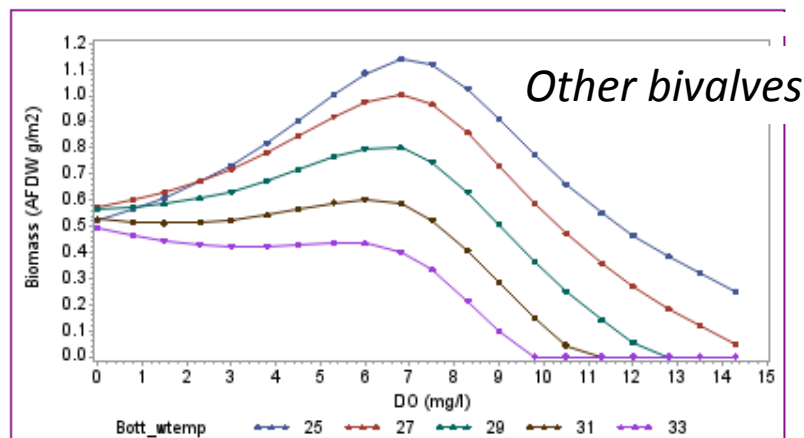
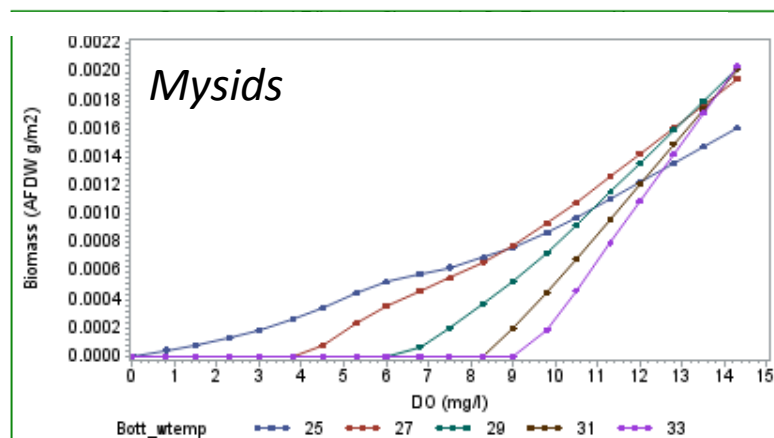
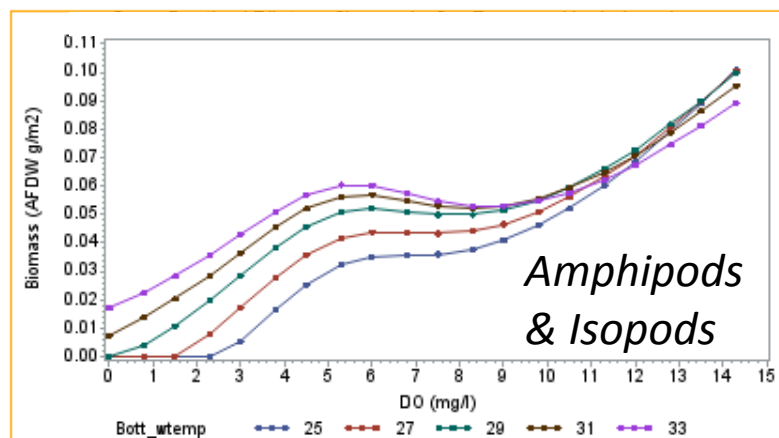
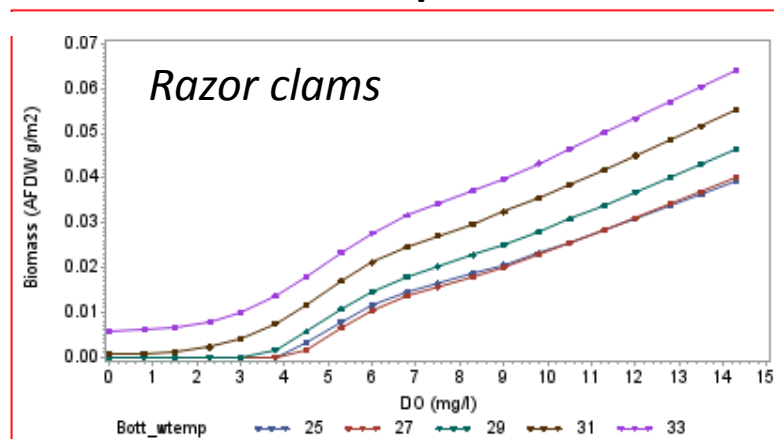
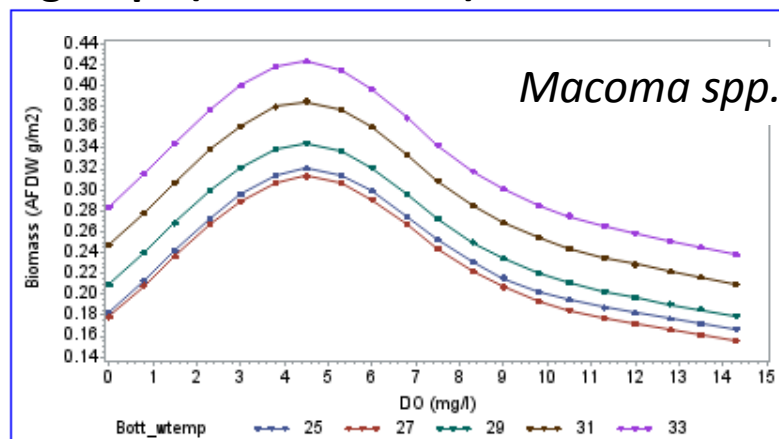
Forage-environment analysis

- 1. Strong differences among invertebrate groups, even within genera (e.g., Macoma spp.)
- 2. At level of 'Functional' group, significant linear effect of both Temperature and DO



Mainstem Chesapeake Bay

Functional groups (and *Macoma*): Modeled effect of DO at different Temperatures on biomass



Forage-environment analysis

- 1. Model performance evaluated using information criterion AICc
- 2. Variables most consistently occurring in best performing models: salinity, spring Chla, degree day ‘phenology’, large-scale climate patterns

Group	Taxon	Average water quality				Degree day variables				Climate patterns	
		Salinity	Temp	DO	Chla	Cumulative	Timing	Flow	Hypoxia	AMO	NAO
Species	<i>Leptocheirus plumulosus</i>	-0.58**									0.37*
	<i>Macoma balthica</i>					-0.42					
	<i>Macoma mitchelli</i>				0.21		0.26	0.71***			
	<i>Neanthes succinea</i>				0.34						0.41*
	<i>Pectinaria gouldii</i>						0.38*			-0.47*	
	<i>Rangia cuneata</i>	0.45*			-0.38						
Taxonomic	Anthuridae				0.49*	-0.29				-0.29	
	Glyceridae	-0.5*							-0.61**		
	<i>Macoma</i>					-0.59					
	Nereididae				0.33						0.42*
Functional	Amphipods & Isopods						0.6***			-0.47**	
	Polychaetes	0.38			0.35*		0.58**			-0.28	
	Other bivalves										

P-values provided for information – grey text: $p = 0.2-0.1$, black text, no asterisk: $p = 0.1-0.05$, *: $p = 0.05-0.01$, **: $p = 0.01-0.001$, ***: $p < 0.001$

Forage-environment preliminary results (*invertebrates*)

- Local densities major forage groups influenced by dissolved oxygen availability and temperature (some groups)
 - Groups such as *Macoma* spp., razor clams and polychaetes show negative relationships with temperature
 - A positive relationship with water column DO was observed in all functional groups
- Interannual patterns in density of several forage groups
 - timing of water temperature warming
 - spring phytoplankton production
 - Large-scale climate patterns (positive NAO, negative AMO)

Project timeline (updated to include extension)

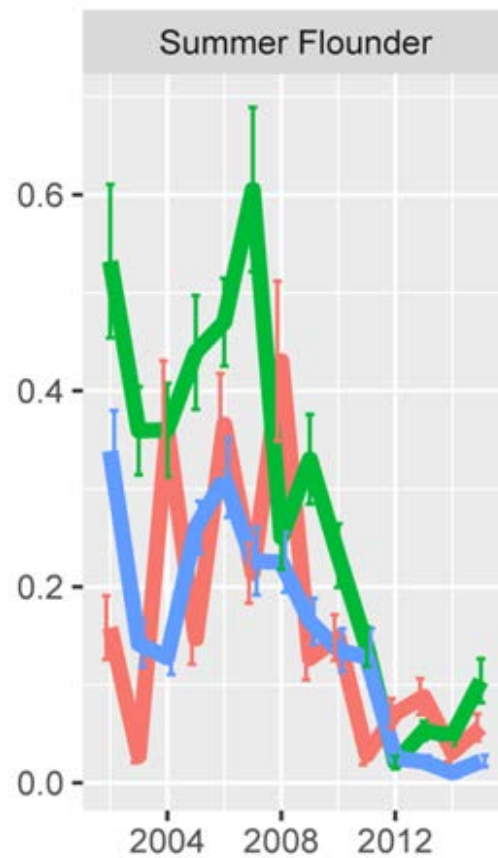
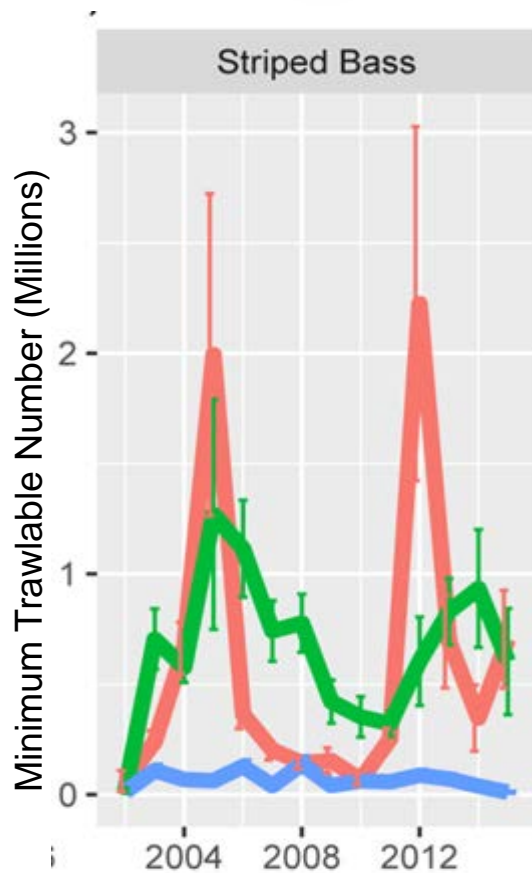
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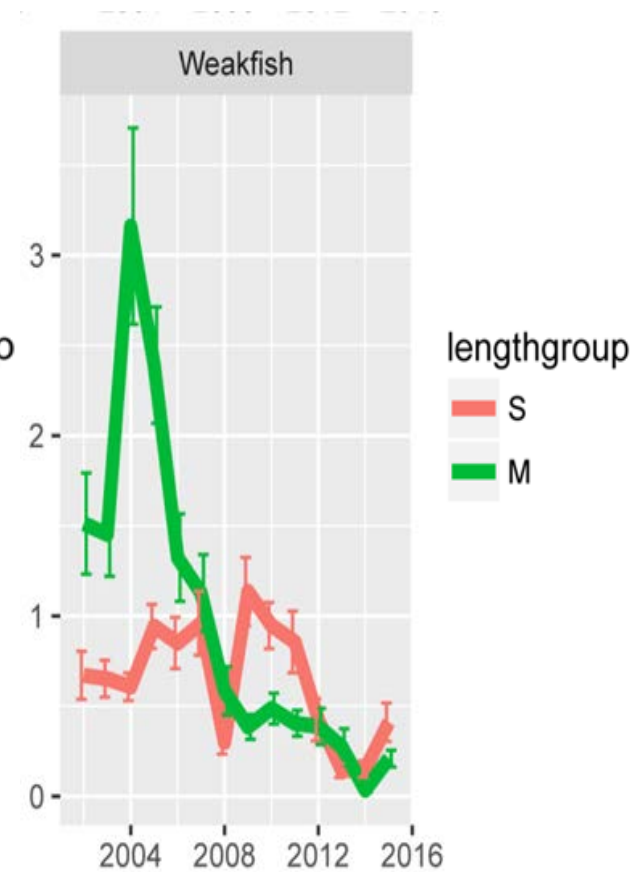
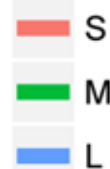
Questions?



Abundance Indices

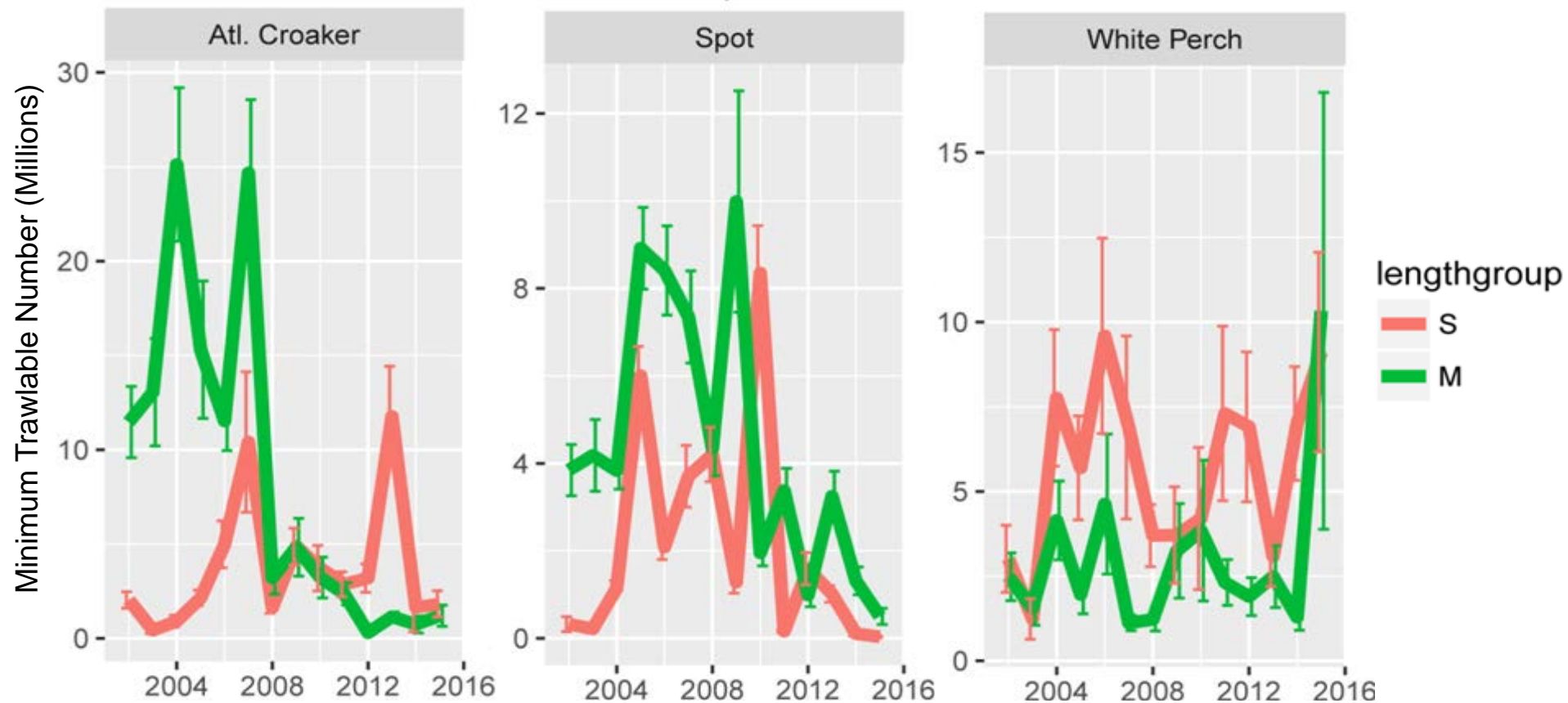
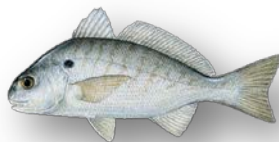


lengthgroup



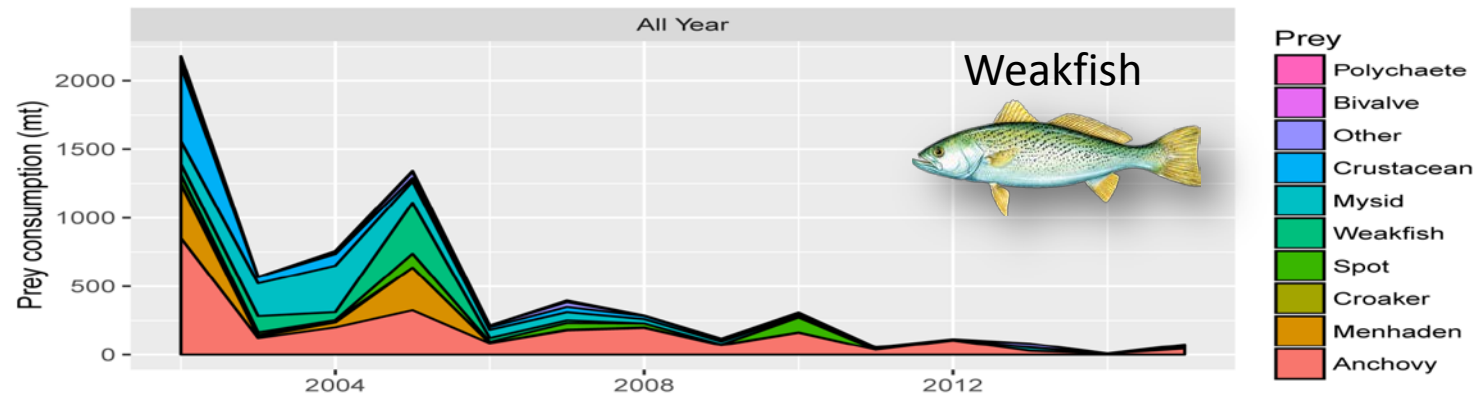
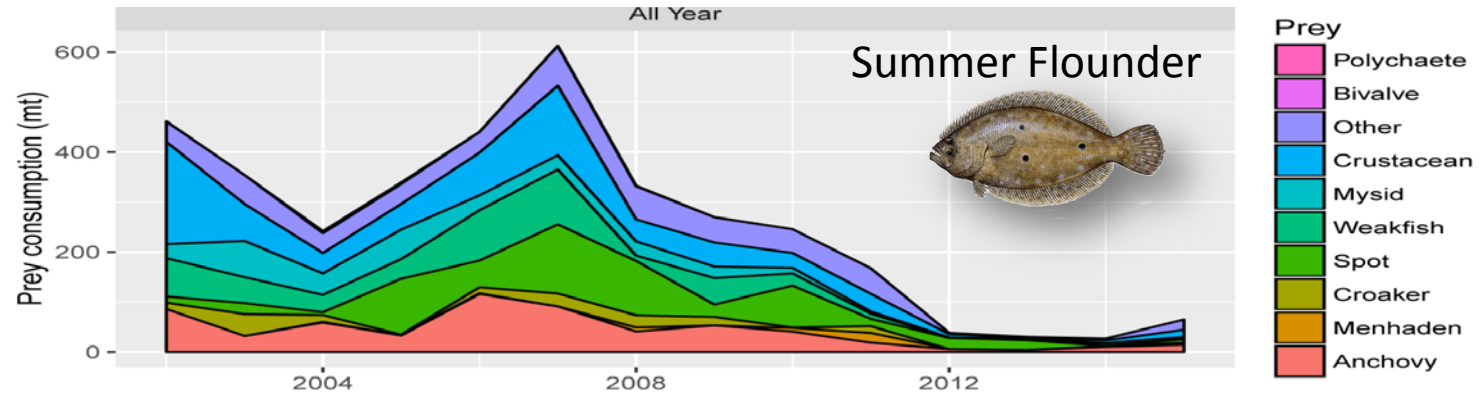
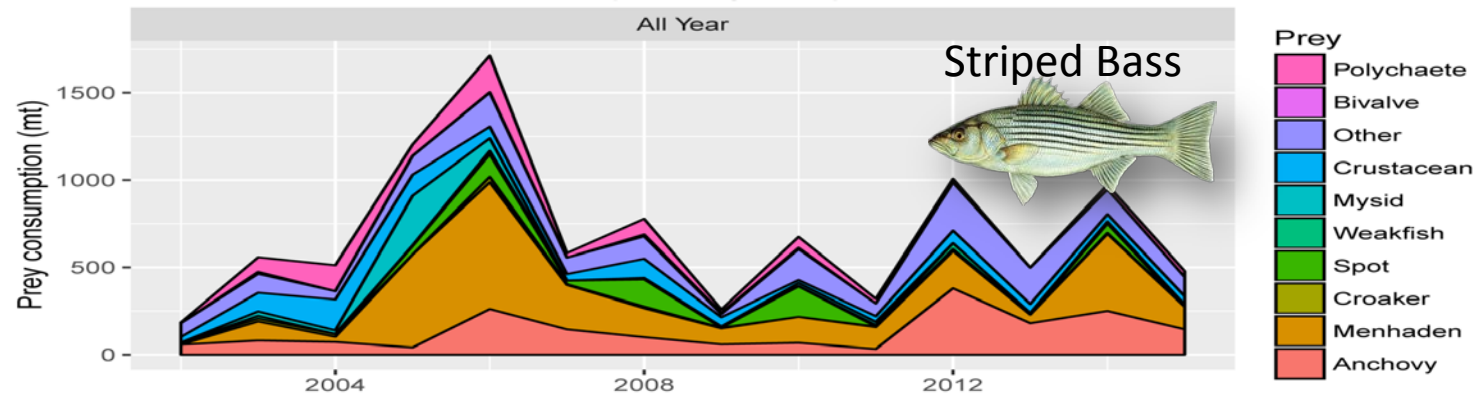


Abundance Indices



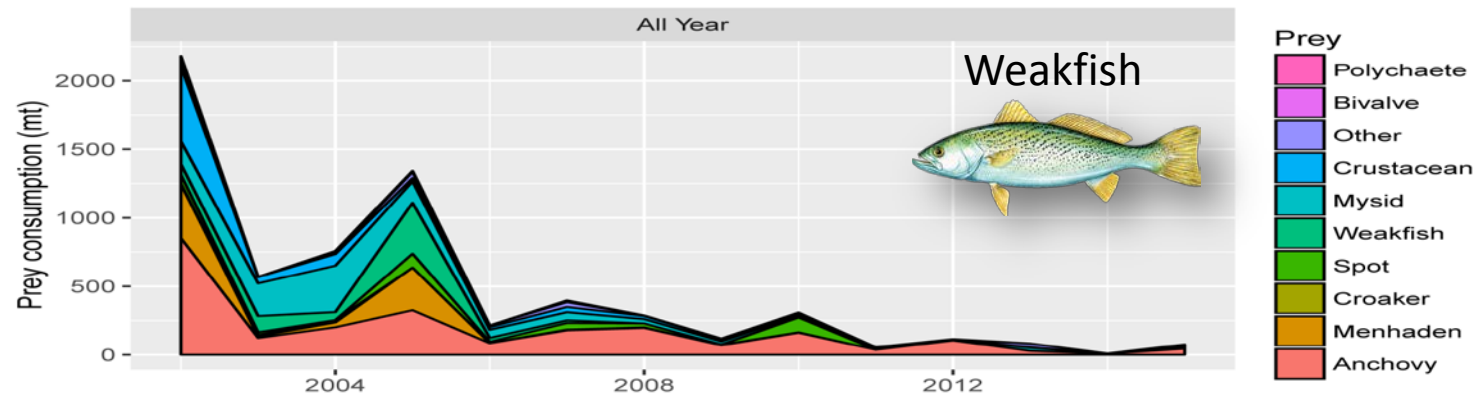
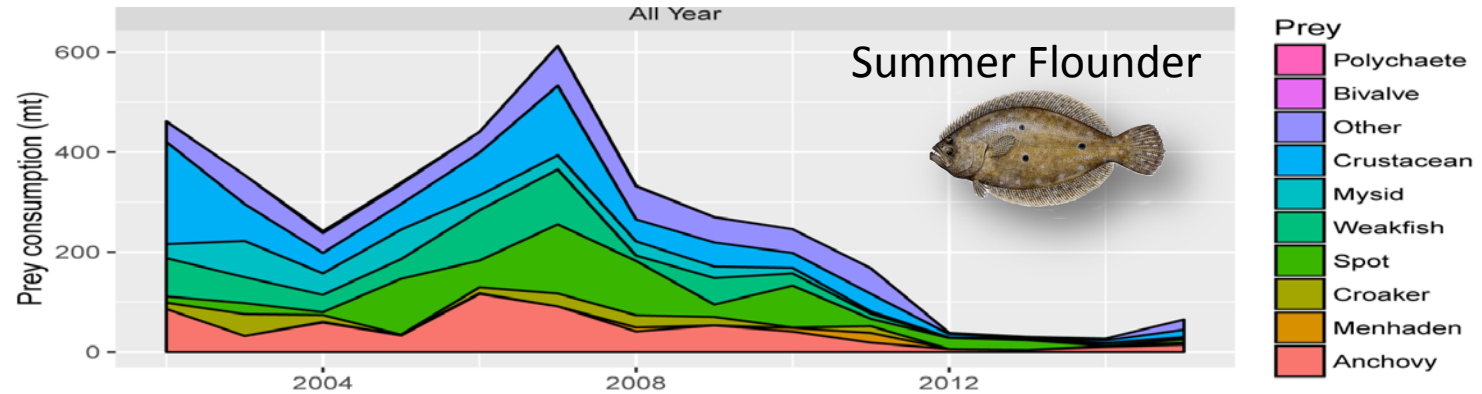
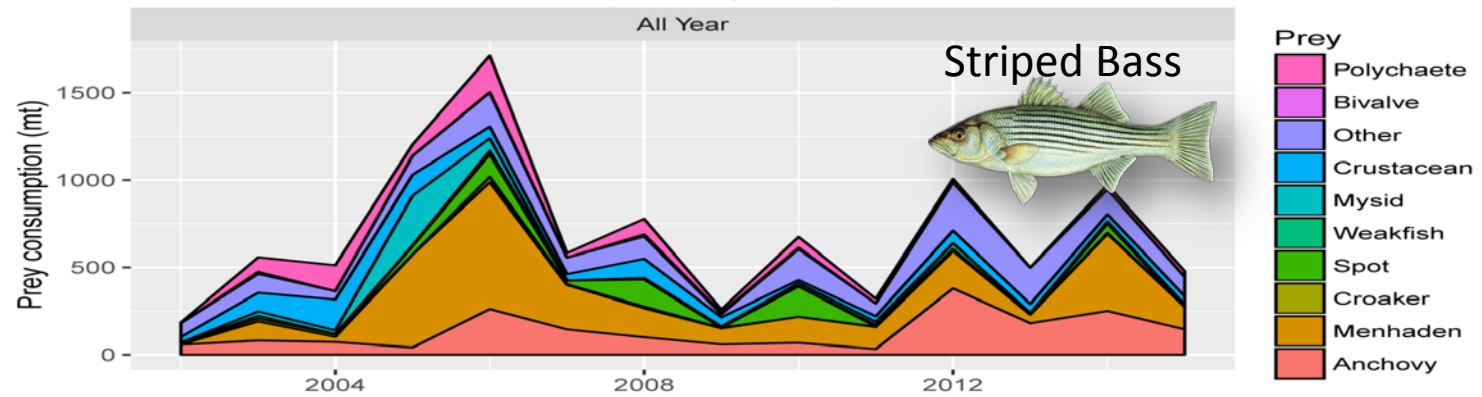


Population-level Consumption



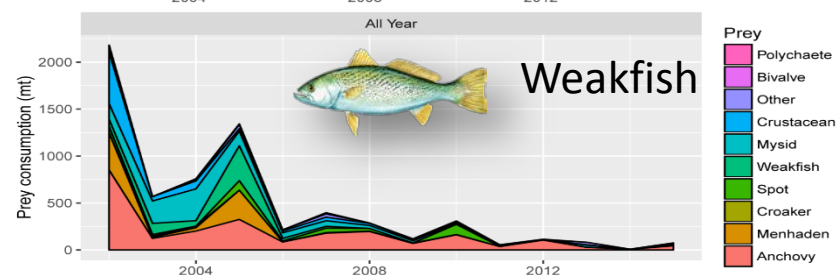
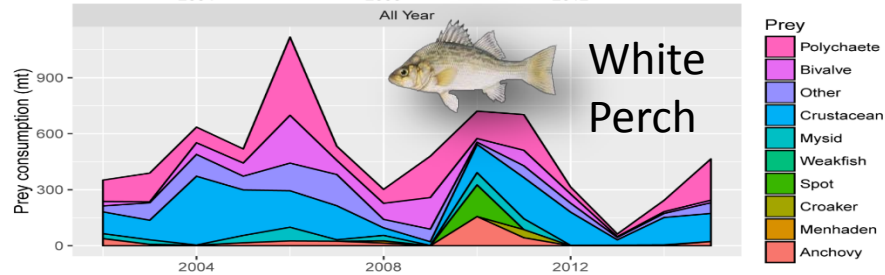
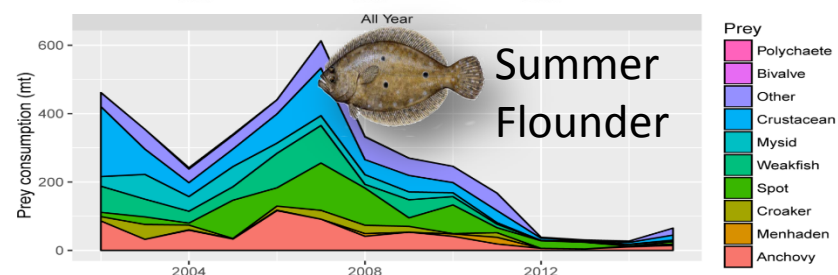
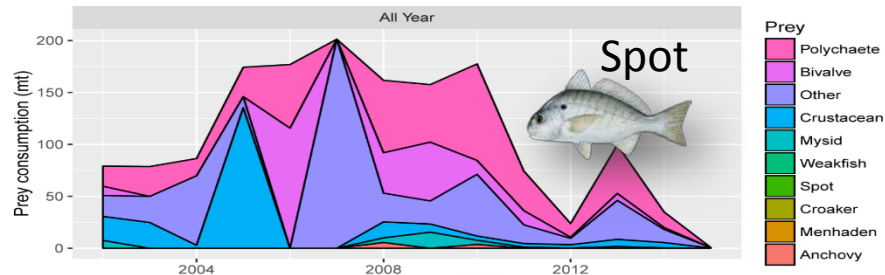
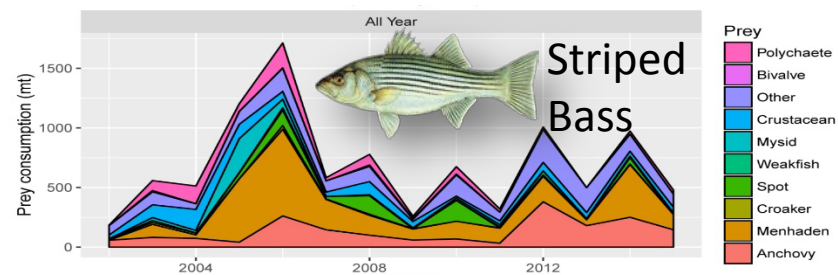
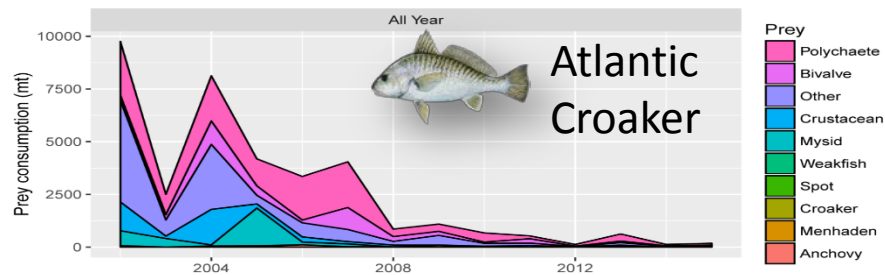


Population-level Consumption

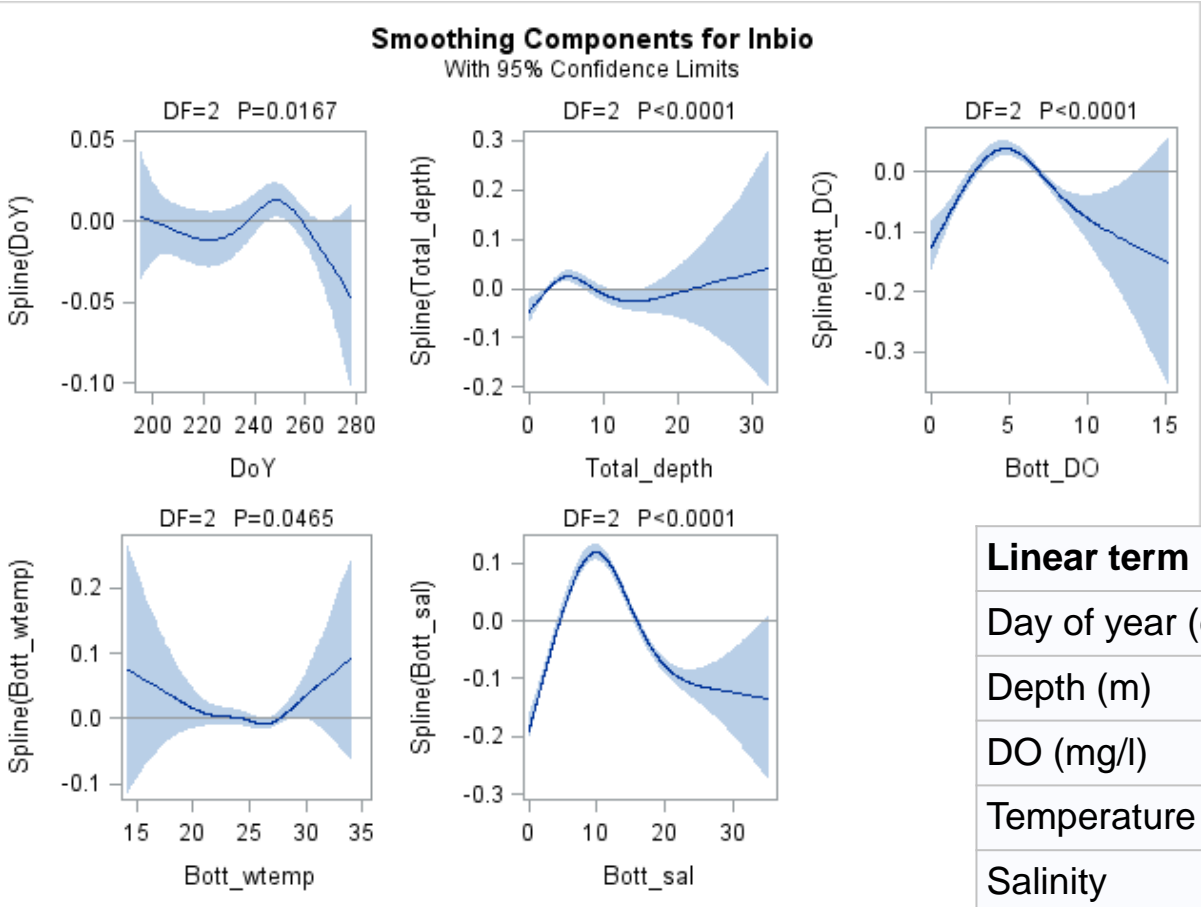


Predator-environment & -forage analysis

- Consumption indices have been updated to include most recent years in ChesMAPP survey
- Analysis of multivariate diet composition, diet-forage and consumption-environment underway
 - assessing potential for spatial analysis within mainstem of Chesapeake Bay



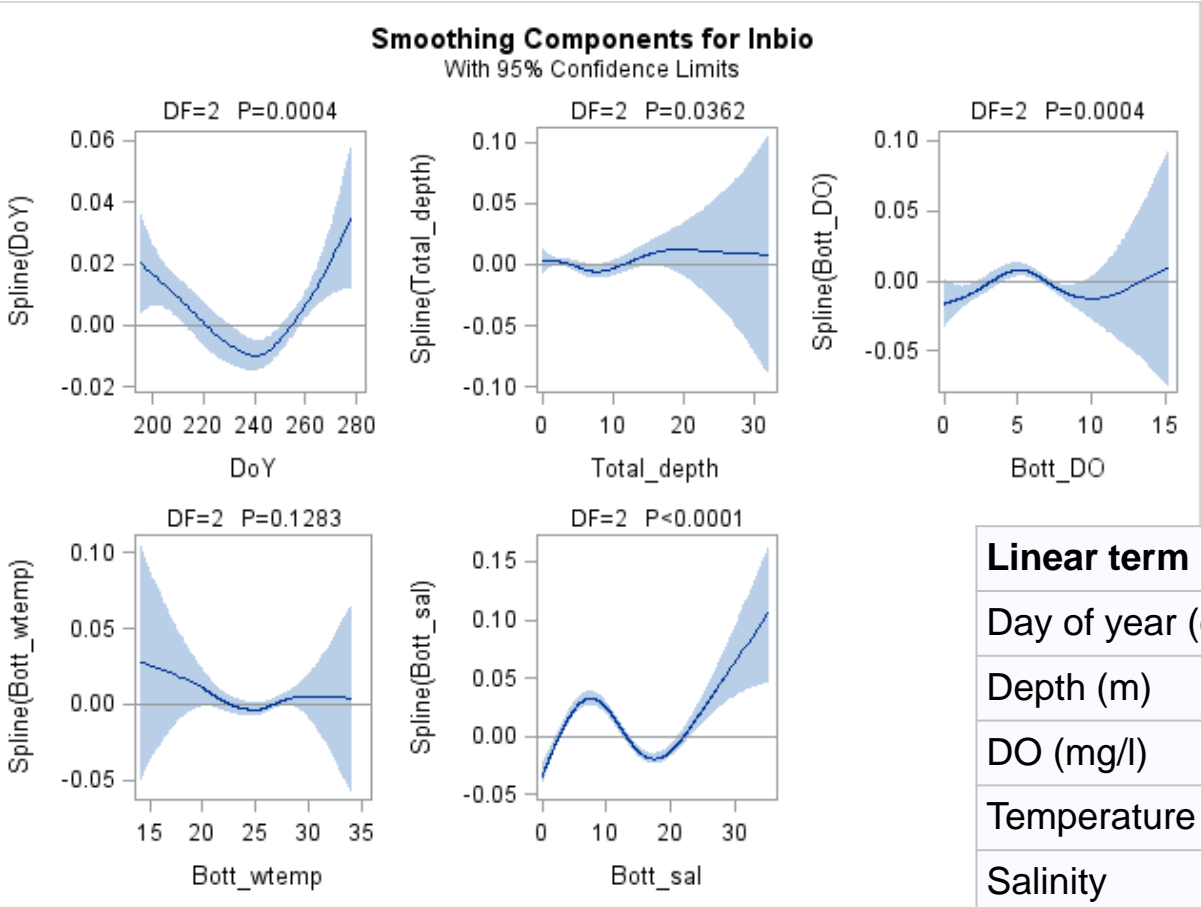
Taxonomic group: *Macoma* spp.



ChesapeakeBay.net

Linear term	Estimate	SE	t-value	p
Day of year (d)	-0.0001	0.0005	-0.29	0.7682
Depth (m)	-0.007	0.002	-3.57	0.0004
DO (mg/l)	-0.006	0.003	-1.76	0.0778
Temperature (C)	-0.002	0.004	-0.47	0.6351
Salinity	-0.006	0.001	-4.49	<.0001

Functional group: Amphipod/Isopods

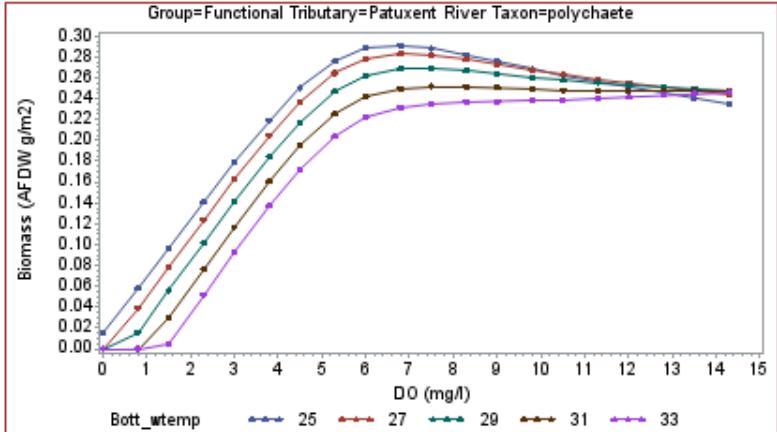
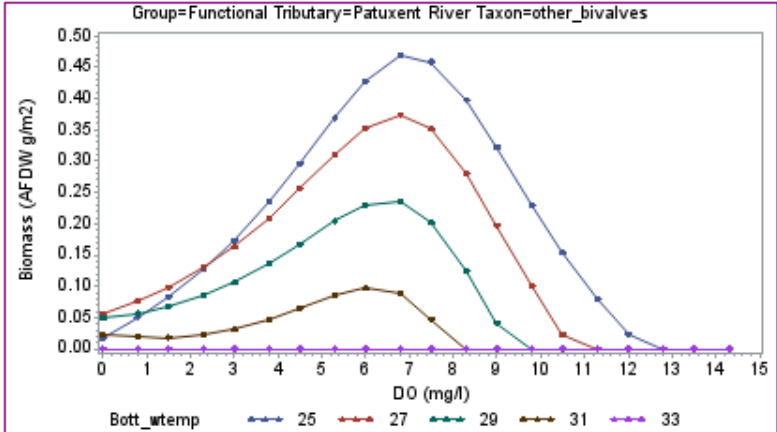
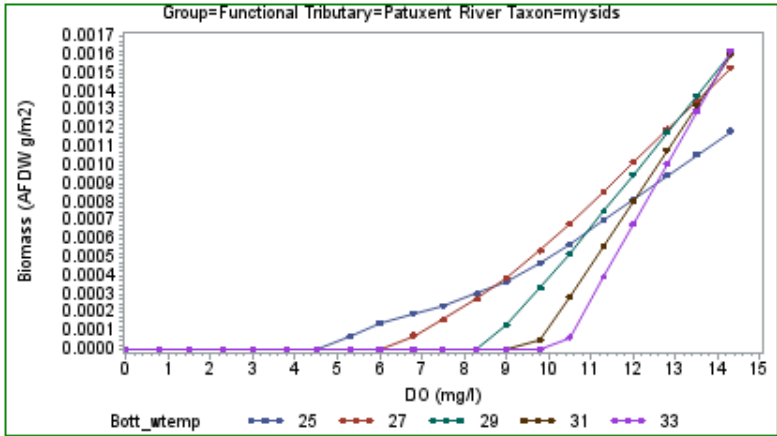
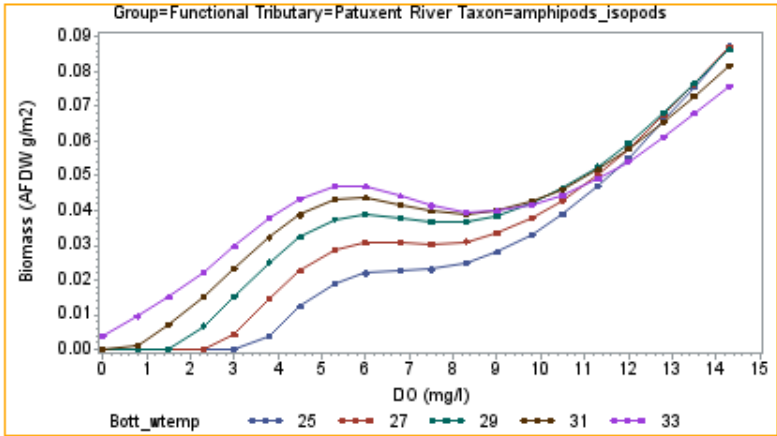
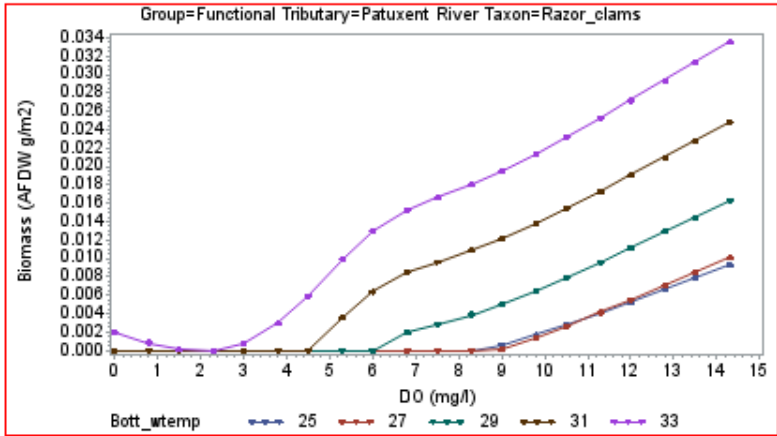
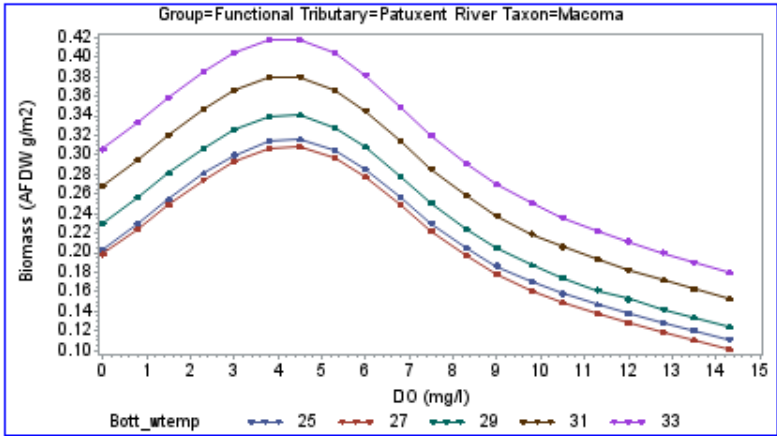


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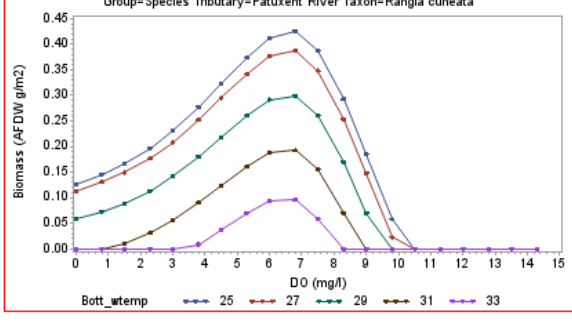
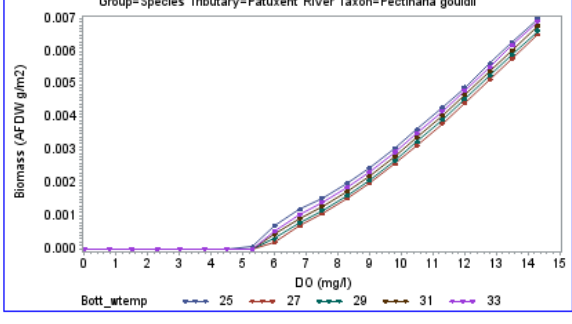
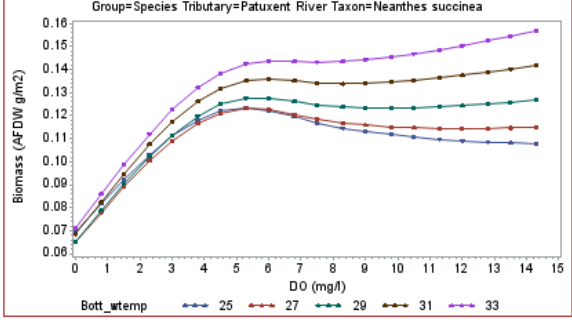
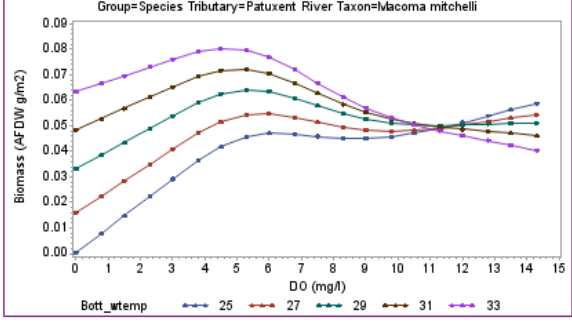
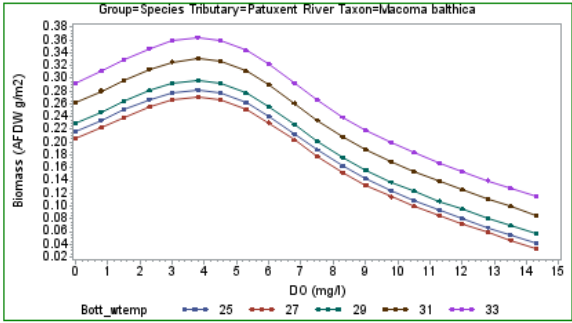
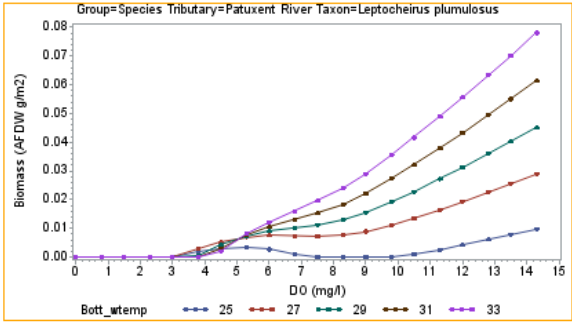
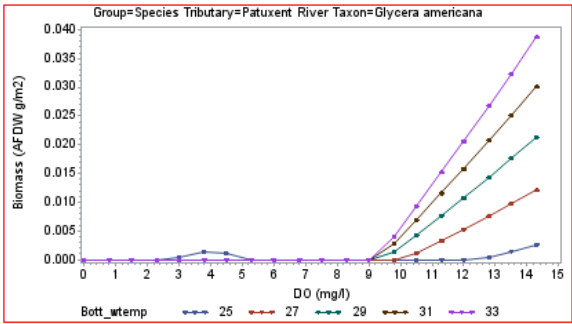
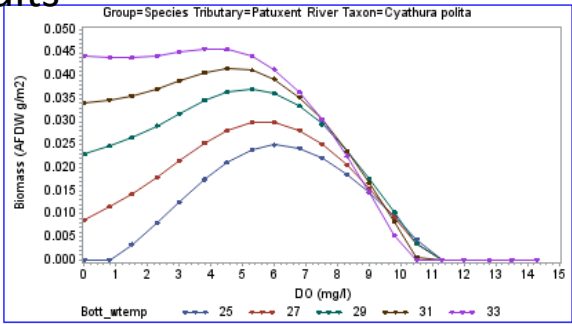


Linear term	Estimate	SE	t-value	p
Day of year (d)	-0.0004	0.0002	-2.17	0.0299
Depth (m)	-0.00002	0.0007	-0.03	0.9779
DO (mg/l)	0.007	0.001	5.15	<.0001
Temperature (C)	0.002	0.002	1.43	0.1527
Salinity	-0.005	0.0005	-10.56	<.0001

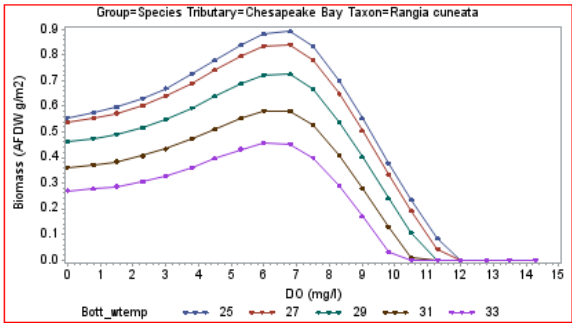
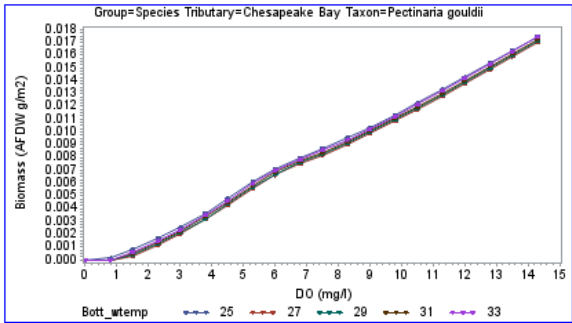
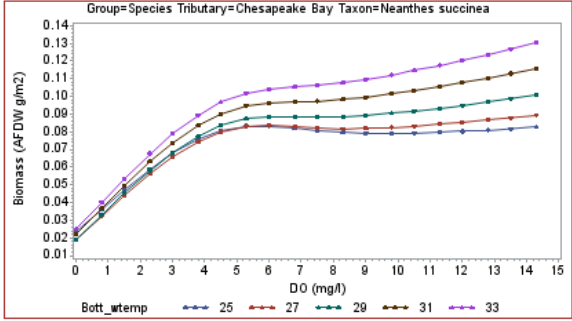
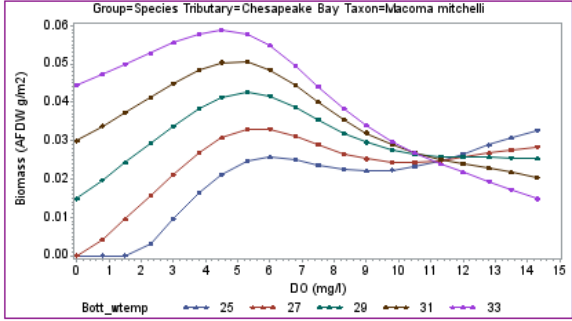
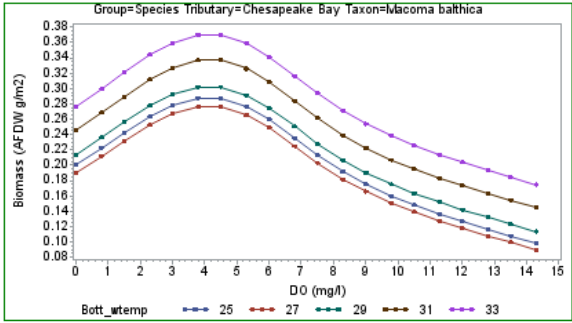
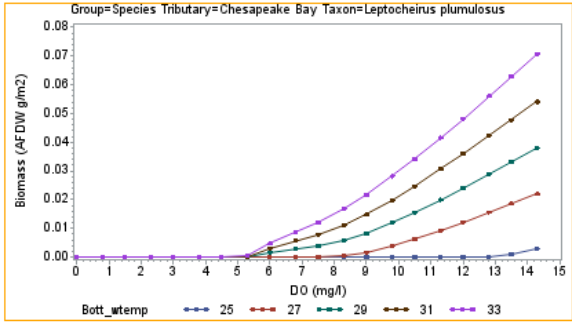
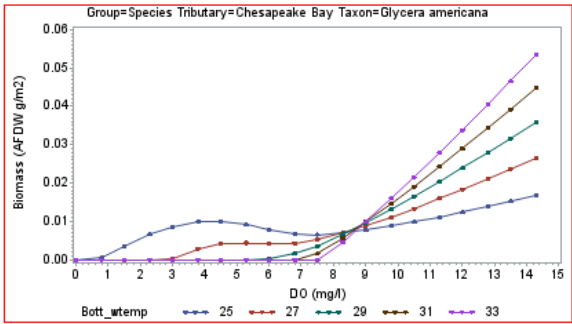
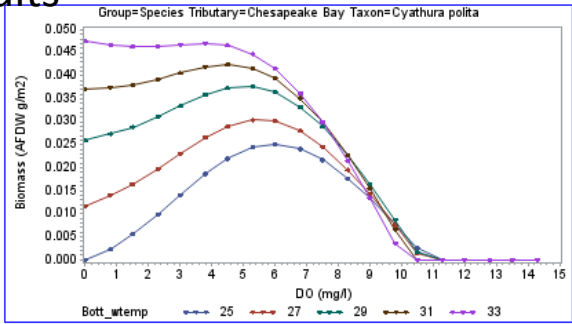
GAMs: patch-scale modeling results



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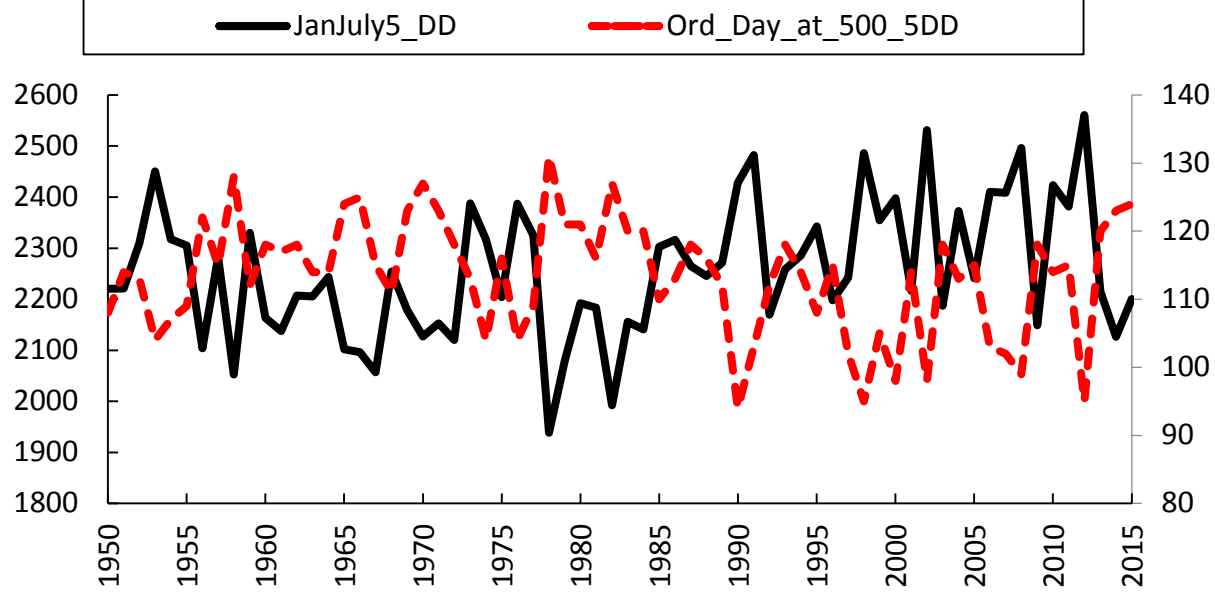


GAMs: patch-scale modeling results



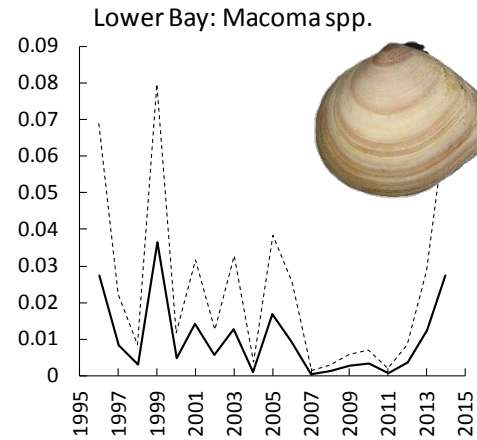
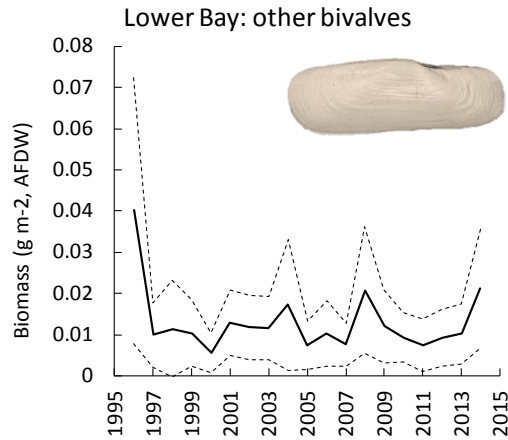
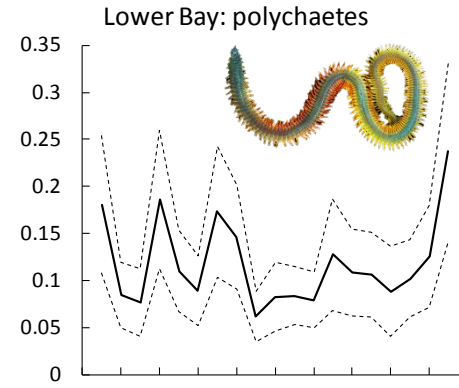
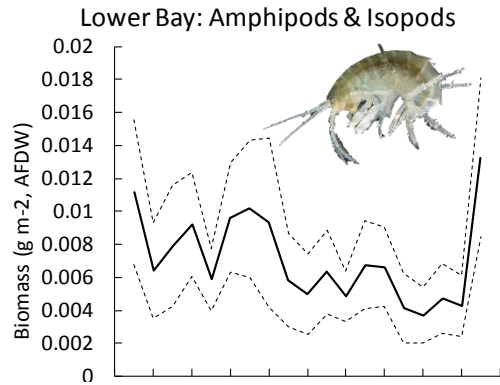


Jan-July cumulative 5°C Deg Day



Ordinate DoY at which cumulative 5°C
DD > 500

DATA – Forage



Chesapeake Bay Hypoxic Volume Forecasts

Donald Scavia¹, Isabella Bertani¹ and Mary Anne Evans²

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June 13, 2016

