Creating a Science-based Strategy to Manage Chesapeake Bay Forage

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Forage Action Team
20 September, 2016

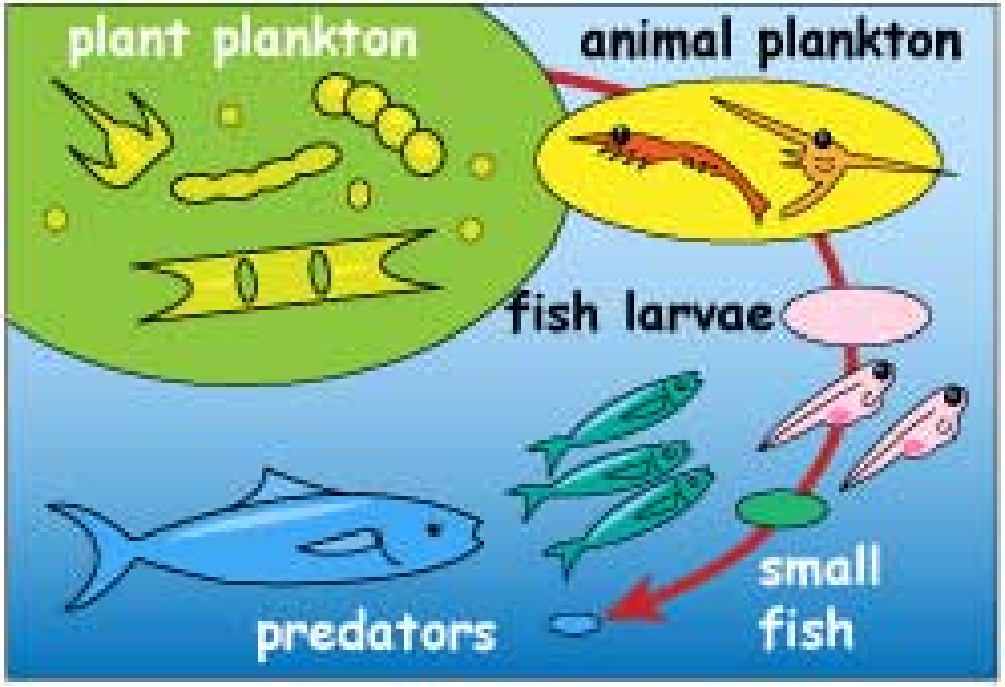
Photo Credit: Aimee Comer, VIMS

Outline

- Outcome and Management Approach
- Timeline
- STAC Workshop results
- Forage Indicator Study (GIT funding)
- Next Steps
- Discussion

Forage Outcome

Continually improve the Partnership's capacity to understand the role of forage fish populations in the Chesapeake Bay. By 2016, develop a strategy for assessing the forage fish base available as food for predatory species in the Chesapeake Bay.



Management Approach

- Define forage species and what comprises the forage base
- Determine the status of the forage base including a definition of “balanced” state
- Inform management decisions to better address sustainability of the forage base
- Maximize the efficiency of monitoring programs and build on existing efforts

Chesapeake Bay Program

Forage Outcome

STAC Forage Workshop

Final Management Strategy

STAC Forage Workshop Report to CBP

Project #1 presented to SFGIT

Draft Workplan Complete

Jun 2014 | Jul 2014 | Nov 2014 | Feb 2015 | Jun 2015 | Jul 2015 | Aug 2015 | Dec 2015 | Mar 2016

#1 Forage Indicator and Predator Study Requested

#1 Forage Indicator and Predator Study Awarded

#2 Drivers of Forage Trends Study Requested

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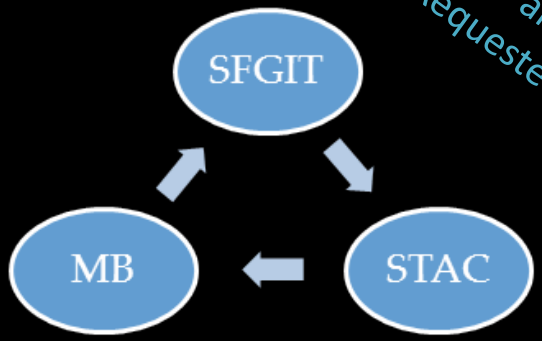
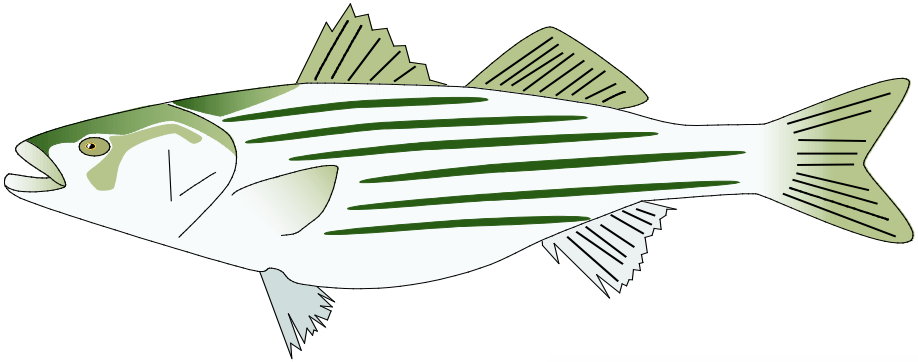
#2 Drivers of Forage Trends Study Awarded

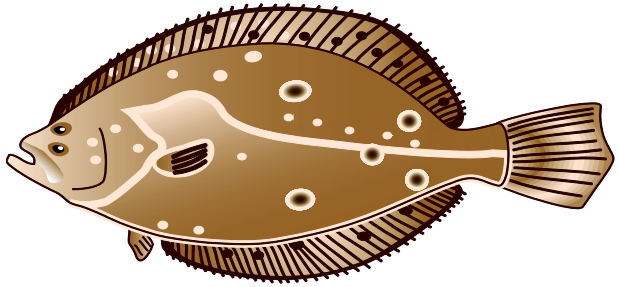


GIT Funded Projects

Indicator Predators

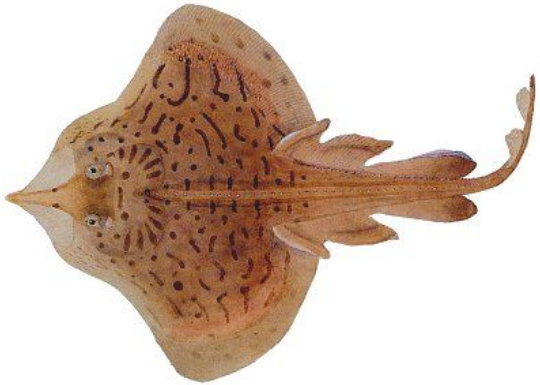


Pelagic Piscivore

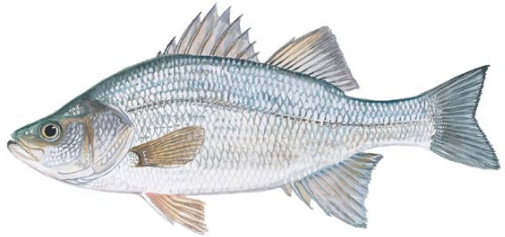


Benthic Piscivore

Benthic Predator



Lower Bay

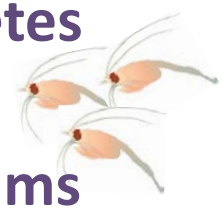


Upper Bay

2014 STAC Workshop Results

Key Forage Species / Groups:

- Bay Anchovy
- Polychaetes

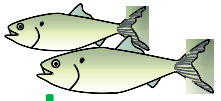


- Mysids
- Razor clams

- Amphipods and isopods
- Weakfish (juveniles)

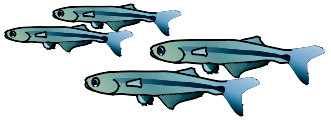
- Spot (juveniles)
- Mantis shrimp
- Sand shrimp
- Atlantic croaker (juveniles)
- Macoma clams

Based on wet weight of prey in stomach analyses from ChesMMAP (VIMS)



- Atlantic menhaden
- Blue crab
- Shad & river herrings

- Small bivalves



- Atl.Silverside
- Mummichog

Managed forage species

Historically Important

Upriver

- ½ species are invertebrates
- Many not usually “forage”

Factors Influencing

- Habitat
- Shoreline hardening/ armoring / protection
- Land use and watershed development
- Climate change and sea level rise
- Water quality
- Predation (including birds)
- Food resources for forage species (including plankton)
- Fishing and catch removals
- Socioeconomic factors (including perceived value)

Indicators/Metrics

Developed a list of 13 types of indicators/metrics that:

1) reflect the status and trends of forage and inform setting targets and thresholds
2) are linked to trends in habitat and water quality
3) are collected routinely (emphasis on existing data sets)
4) are actionable (i.e. inform management actions)

Prioritized Recommendations:

1 Strategic review and data-mining of all available current data to support forage quantification

2/3 Re-establish zooplankton monitoring to develop an index of feeding conditions for key forage (e.g., Bay Anchovy, Menhaden) and to develop abundance indices for key forage taxa (e.g., mysids);

2/3 Develop a standard set (suite) of metrics and indicators

4 Relate forage trends to predator trends

5 Improve understanding of forage dynamics & trends, especially those with limited or no current data (e.g., mysids), system-wide & habitat-specific scales

6 Establish shallow water monitoring of forage in soft-bottom, marsh, and SAV habitats (including up-tributary habitats)

Other Important Findings

- Connect with Habitat GIT to study, map, and manage habitats and areas critical to forage
- Define formal management objectives: (targets and thresholds)
- Align efforts with Atlantic States Marine Fisheries Commission and Mid Atlantic Fishery Management Council
- Develop integrative models
- Improve communications to show importance of forage (video; web)

Prioritized Recommendations:

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2/3 • Develop a standard set of metrics and indicators

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UMCES

Forage Indicators Study Year 1

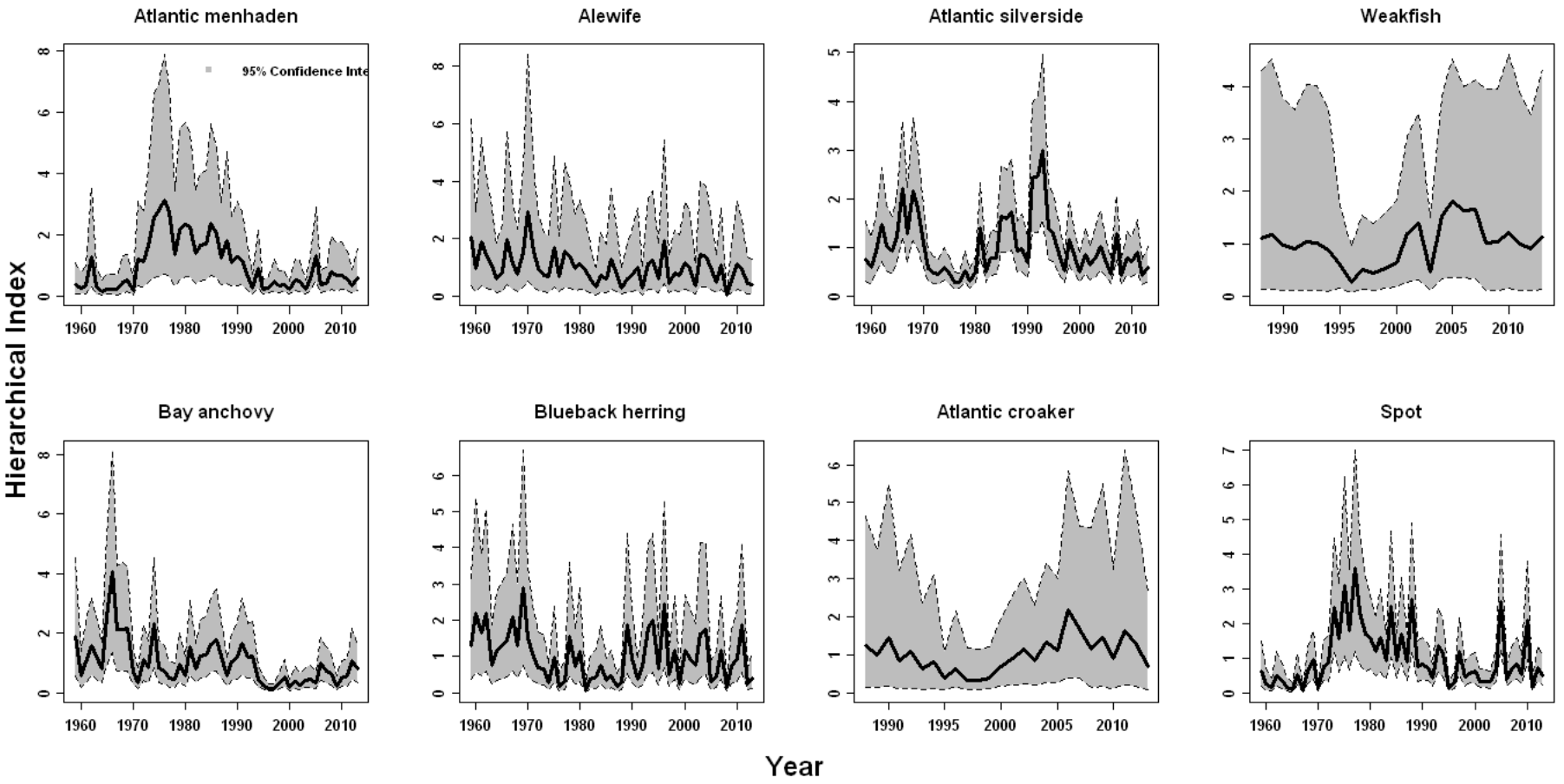
4 Indicators of Forage Status & Trends:

- Relative prey abundance / biomass
- Diet-based indices
- Prey / Predator ratios
- Consumption / Prey ratios

UMCES

Forage Indicators Study Year 1

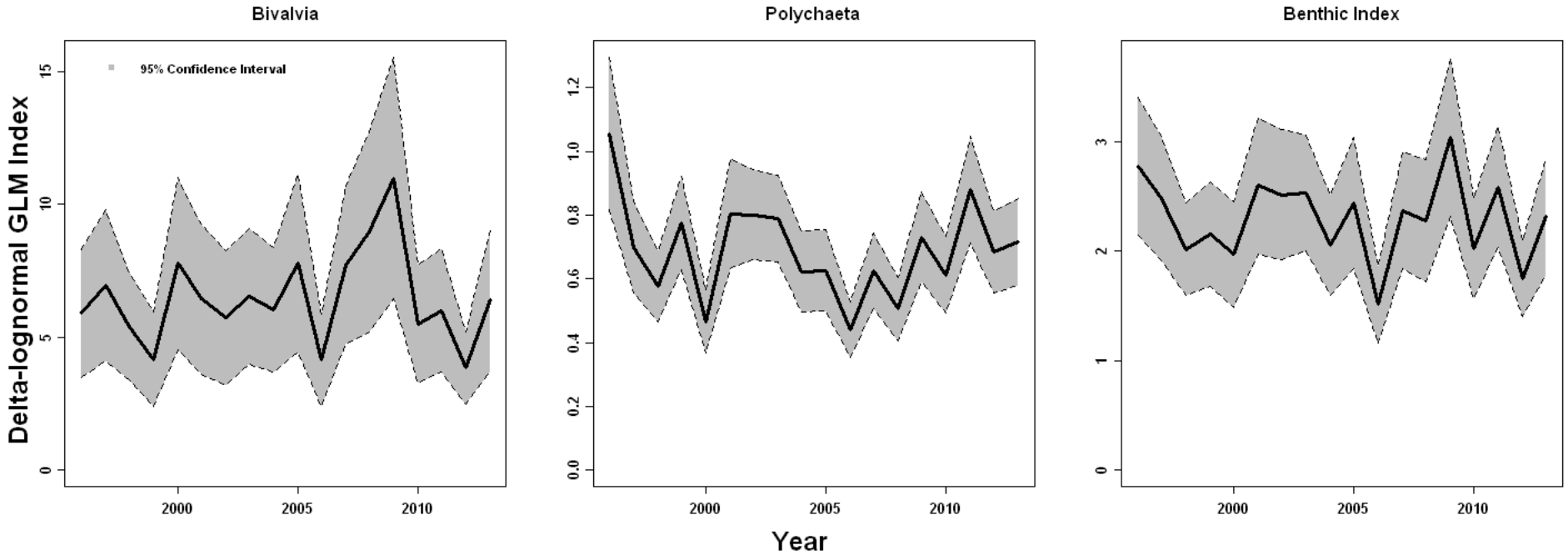
Relative Prey Abundance Through Time



UMCES

Forage Indicators Study Year 1

Relative Prey Abundance Through Time



Prey-Predator and Consumption-Prey Ratios

$$\text{Prey-predator ratio} = \frac{\text{Scaled prey abundance}}{\text{Scaled predator abundance}}$$

Prey-predator ratio is an index of relative prey availability

$$\text{Consumption-prey ratio} = \frac{\text{Scaled consumption on prey (x)}}{\text{Scaled abundance of prey (x)}}$$

Consumption ratio is an index of predation intensity

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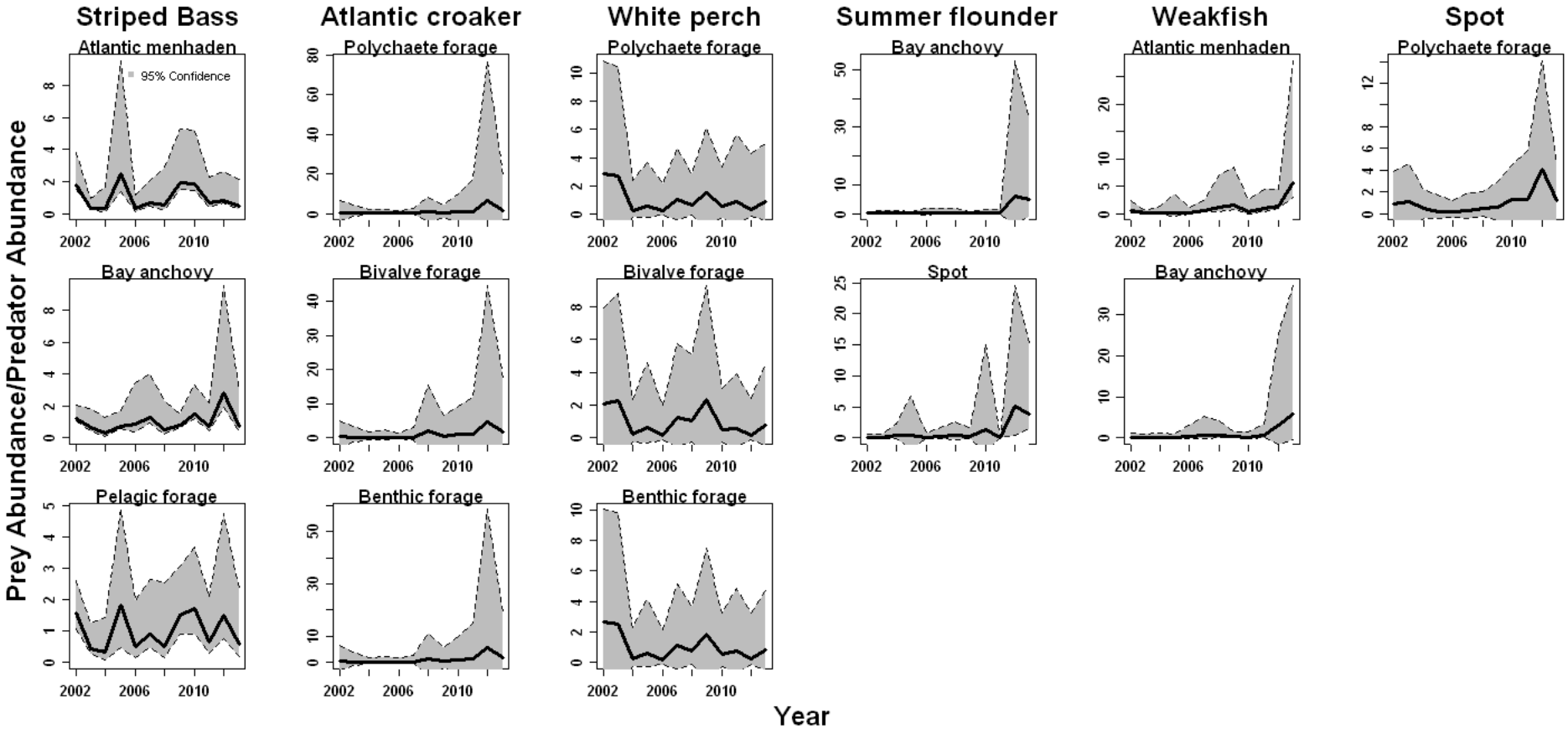
Forage Indicators Study Year 1

Prey to Predator Ratio



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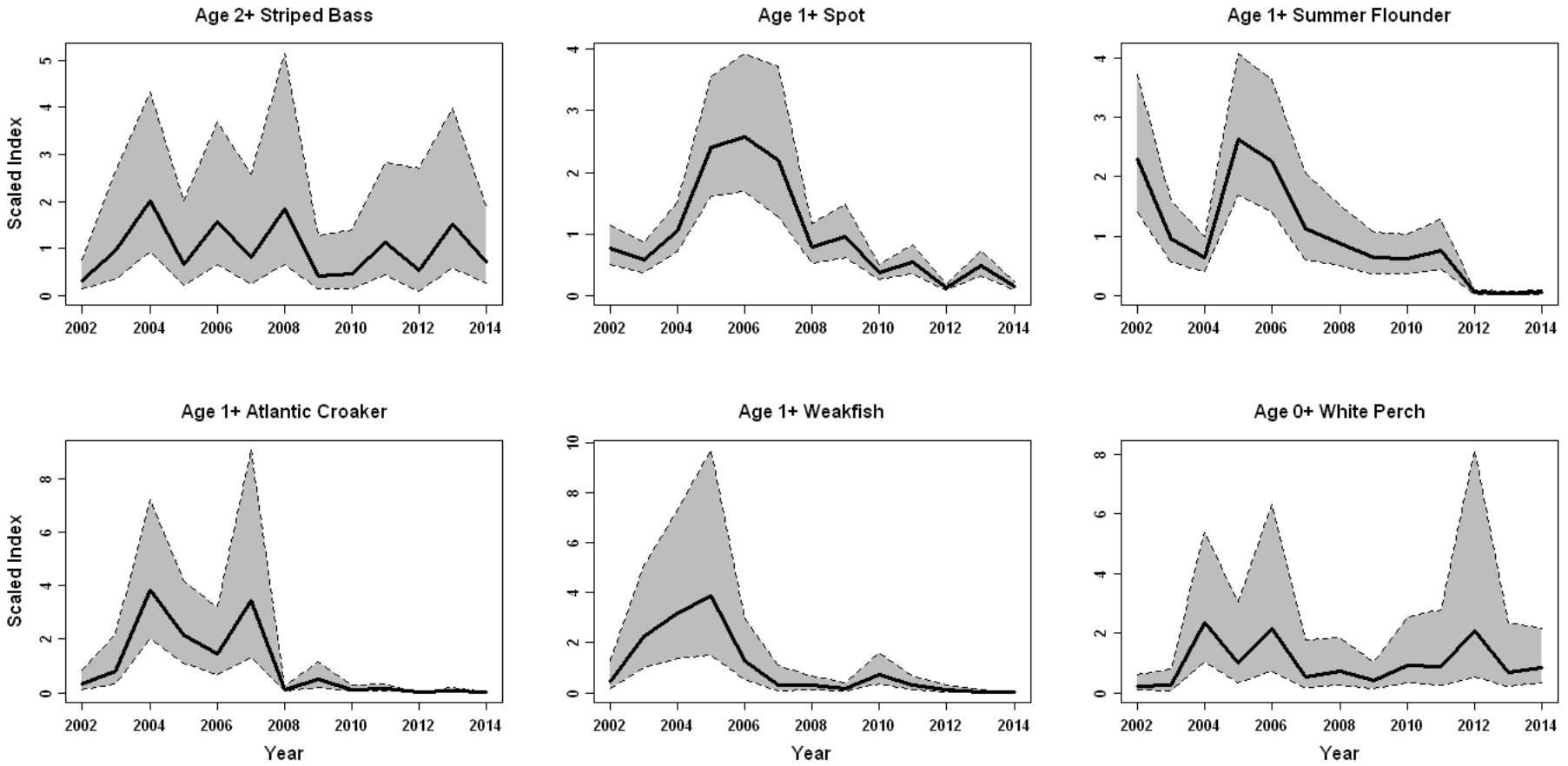
Forage Indicators Study Year 1

Predator Abundance Over Time



Consumption

Annual consumption by predator C (mt)

$$= \sum_{\text{Size}} \sum_{\text{time}} \text{Per capita, daily consumption (c)} \times \text{Predator abundance (N)} \times \text{Time period (t)} \times \text{Diet proportion (D)}$$

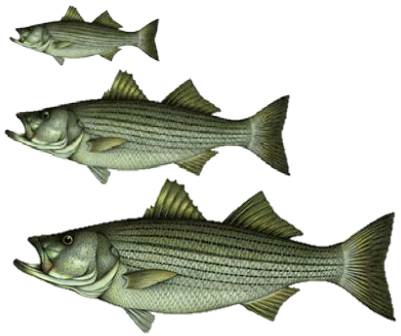
Evacuation rate model
Data inputs:
- Avg. stom. contents
- Water temp.

Area-swept estimates
– No efficiency, selectivity
– Conservative estimates

6-month seasons
Index (higher abund.)
Non-Index

Gut contents

Predator-specific size classes



S: <30 cm

M: 30-50 cm

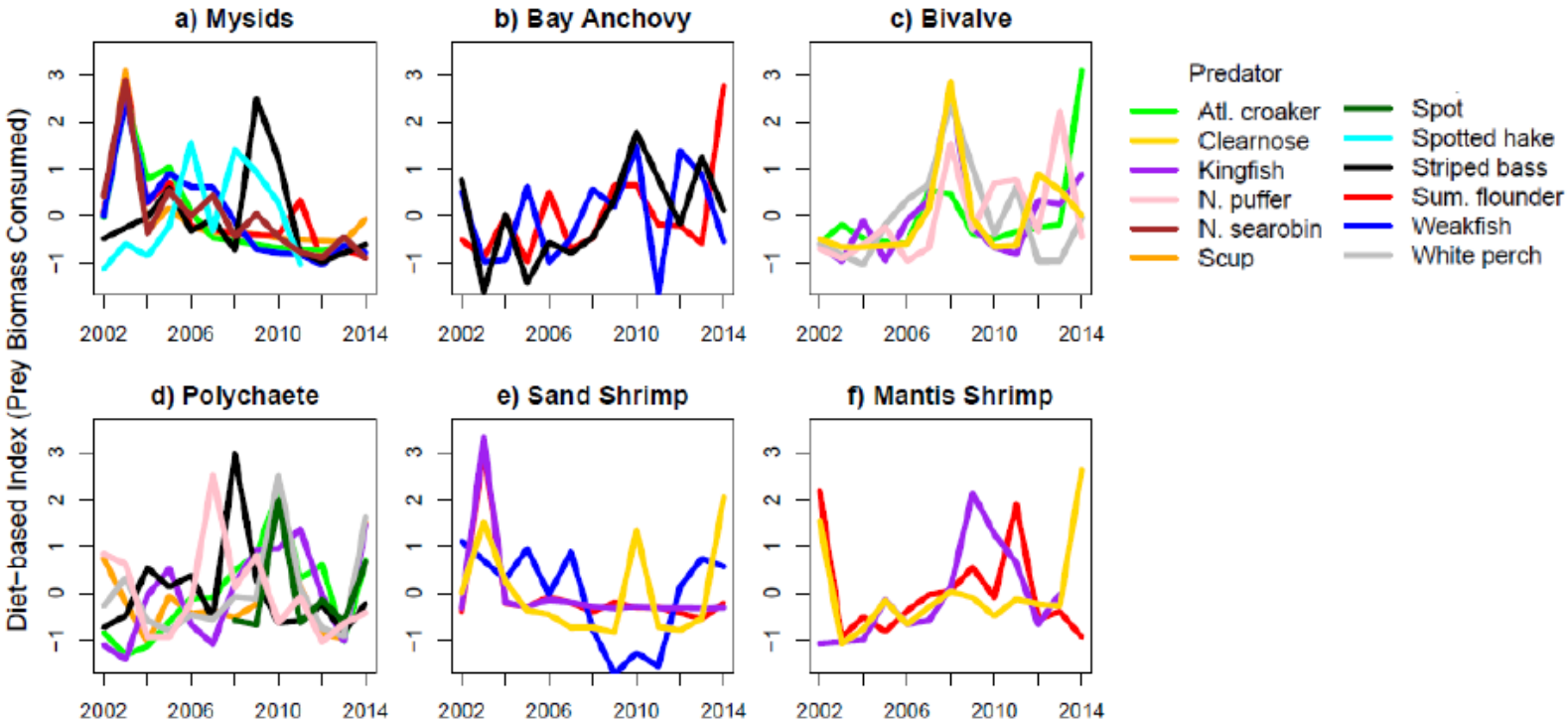
L: >50 cm

Approach accounts for:
- Predator size
- Diet shifts
- "Seasons" (e.g., migration)
- Temperature

E.g., Link and Sosebee 2008, Overholtz and Link 2007

*All data from the ChesMMAP survey

Diet-Based Indices



- General decline in mysids in fish diets
- Increase in anchovy and polychaetes in fish diets

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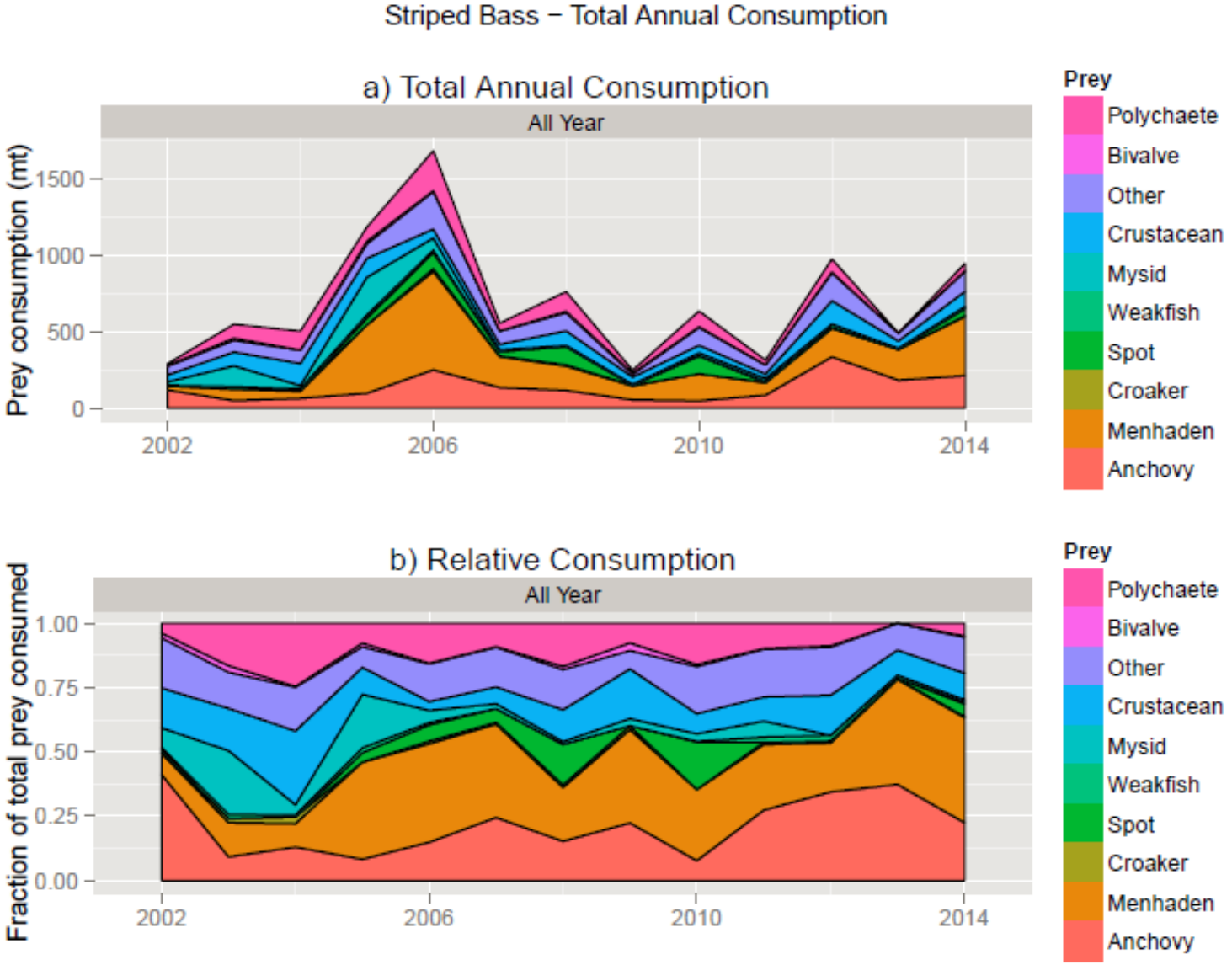
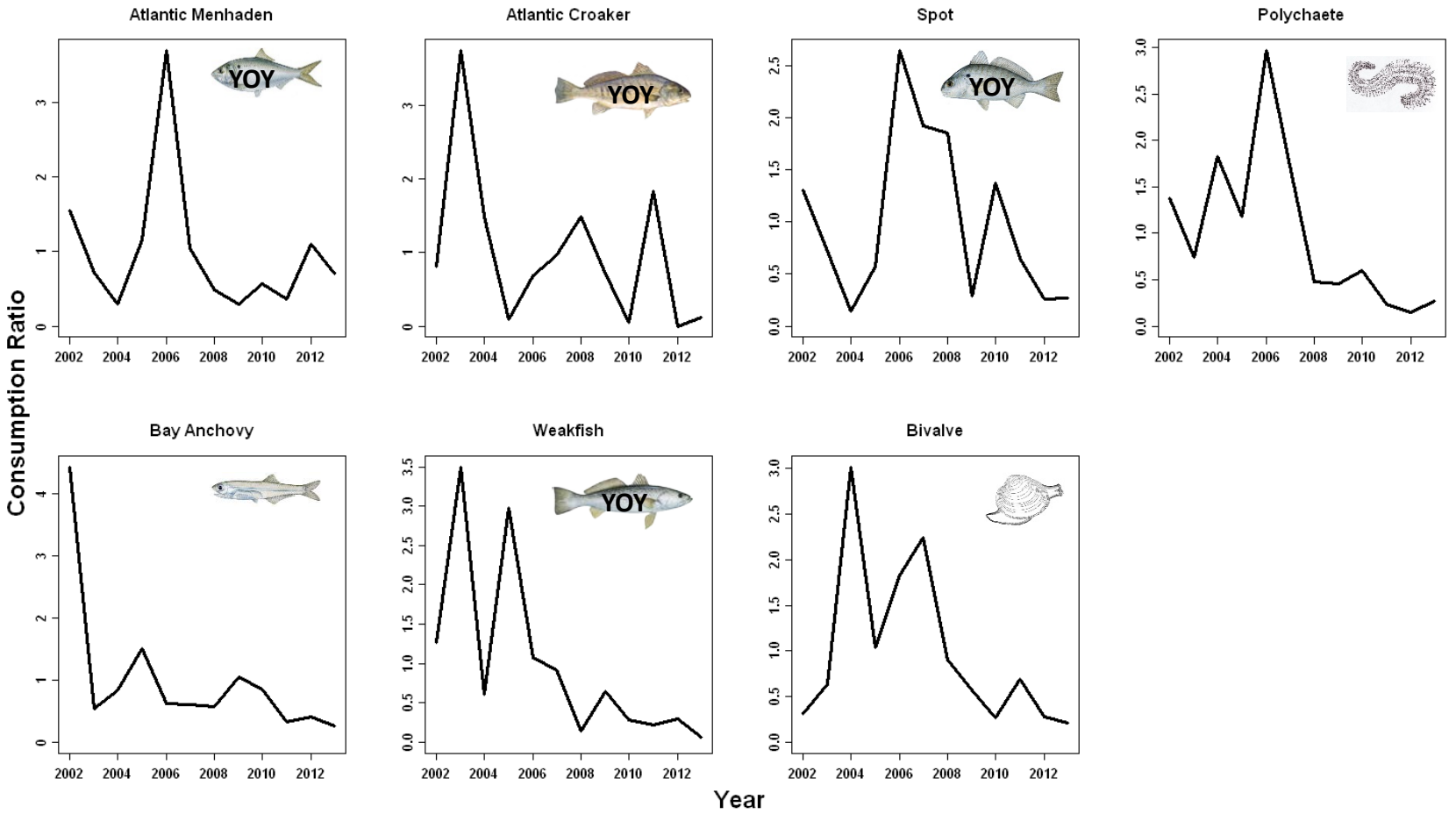
Forage Indicators Study Year 1



Consumption-Prey Ratios



Measure of predation intensity peaked in some years

Decline in predation intensity on benthic prey due to declines in benthivores

UMCES

Forage Indicators Study Year 2

- Variability – effect on predators
- Environmental drivers related to/causing variability

Drivers of forage population trends and consumption patterns

UMCES (CBL), Humboldt State University, VIMS

Co-PIs and collaborators

Investigators

- Ryan Woodland (UMCES-CBL)
- Ed Houde (UMCES-CBL)
- Andre Buchheister (Humboldt State University)
- Robert Latour (VIMS)

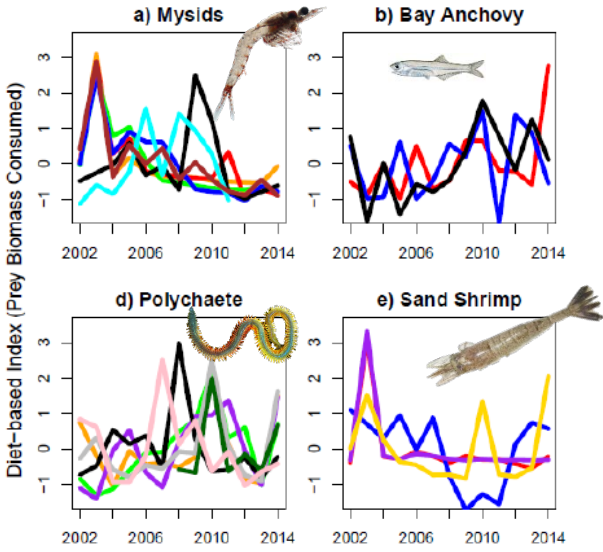
Collaborators

- Mary Fabrizio (VIMS)
- Troy Tuckey (VIMS)
- Carlos Lozano (UMCES-CBL)
- Christopher Sweetman (VIMS)

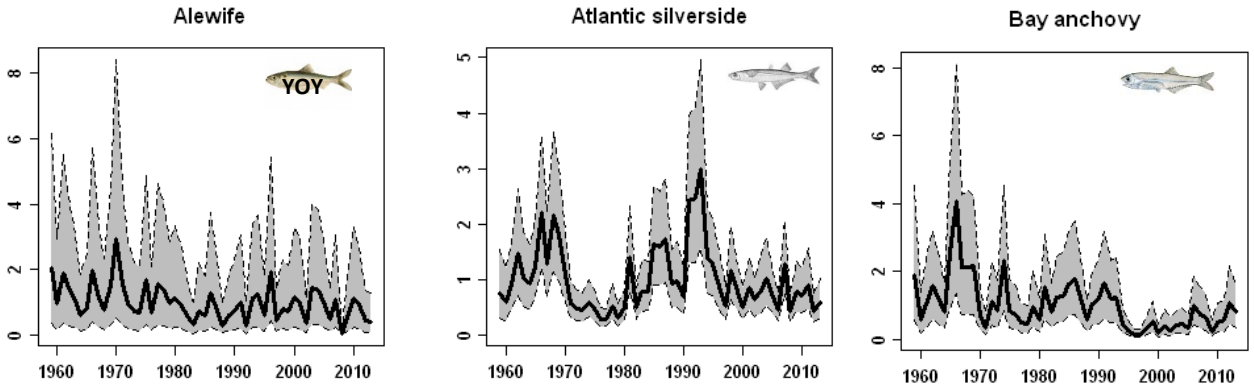
Rationale

- Forage species critical component in EBFM
- Previous work has indicated
  - Diverse interannual patterns in abundance
  - Similar long-term trends in consumption by predators

Predator consumption indicators



Forage abundance indicators

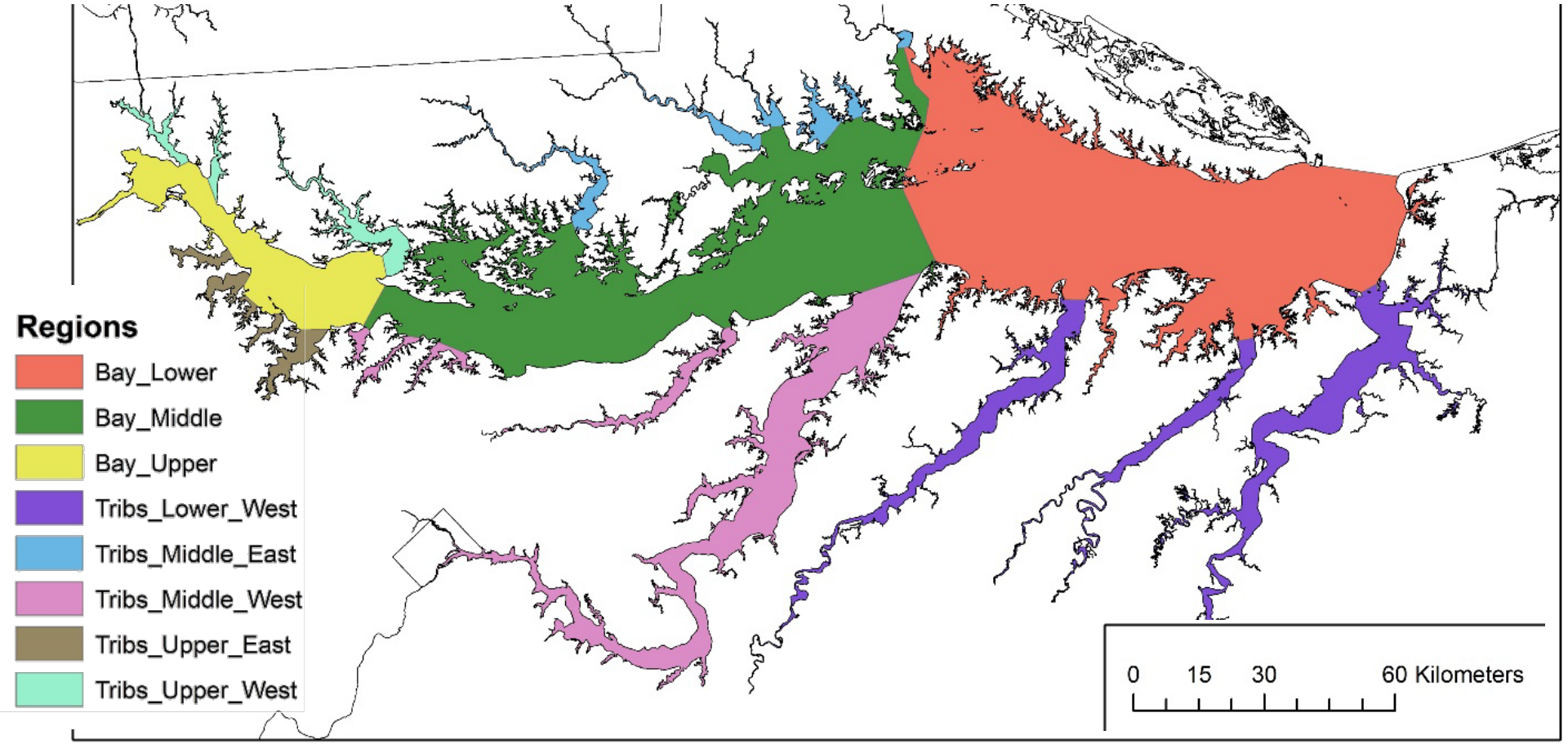


Approach

- Objective 1:
  - Estimate baywide and regional environmental and forage indices
  - Use univariate and multivariate models to analyze forage-environment relationships
- Objective 2:
  - Estimate regional patterns in predator consumption
  - Analyze environmental and biological correlations with predator consumption
  - Explore variance dampening by feeding on functionally similar forage (Portfolio effect)

*Project builds upon outcomes of previous CBT forage project (Buchheister et al. 2016) and Forage Workshop (Ihde et al. 2015)

DATA – Spatial extents

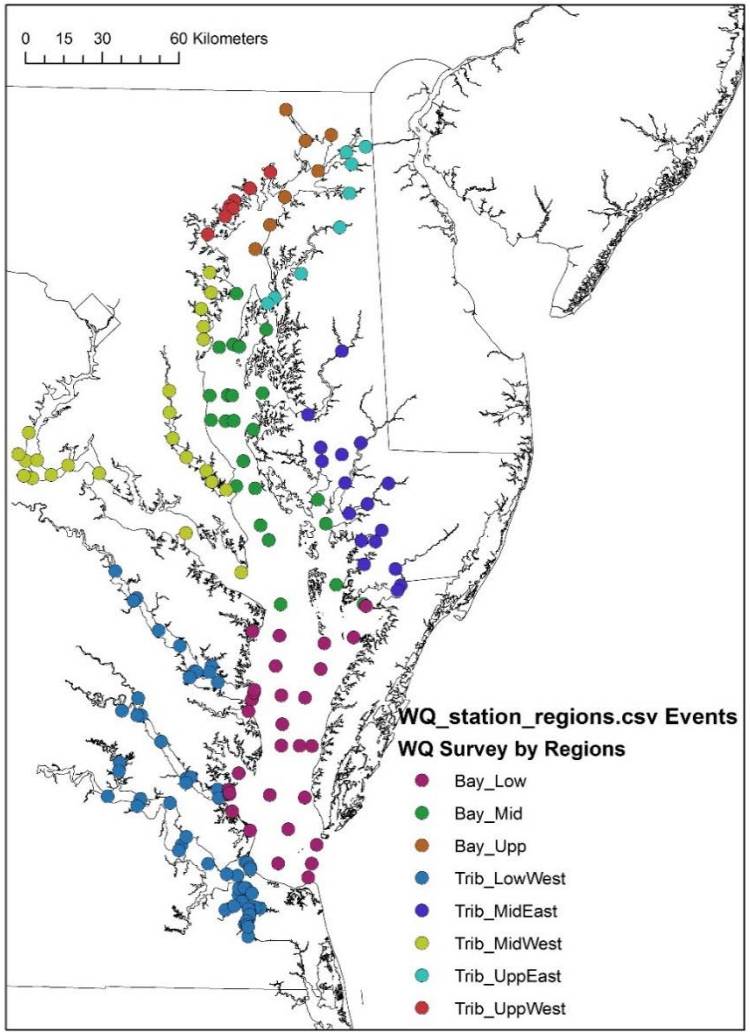


Objective 1: forage & environment

1. Environmental indices: Baywide
   - Teleconnections/climate indices (NOAA, 1950-2015)
   - Susquehanna River flow (USGS, 1967-2015)
   - Cumulative 5°C water temperature degree days (Solomons time-series, 1938-2015)
   - Ordinate DoY at which cumulative 5°C DD > 500 (Solomons time-series, 1938-2015)
   - Chlorophyll concentration (CBP WQ survey, 1984-2015)
   - Hypoxic volume (UMichigan/USGS, 1950-1980 intermittent, 1984-2015 continuous)

2. Environmental indices: Regional
   - Tributary river flow/mainstem flow (USGS, minimum range: 1977-2015)
   - Chlorophyll, water temperature, salinity, DO concentration (CBP WQ survey, 1984-2015)

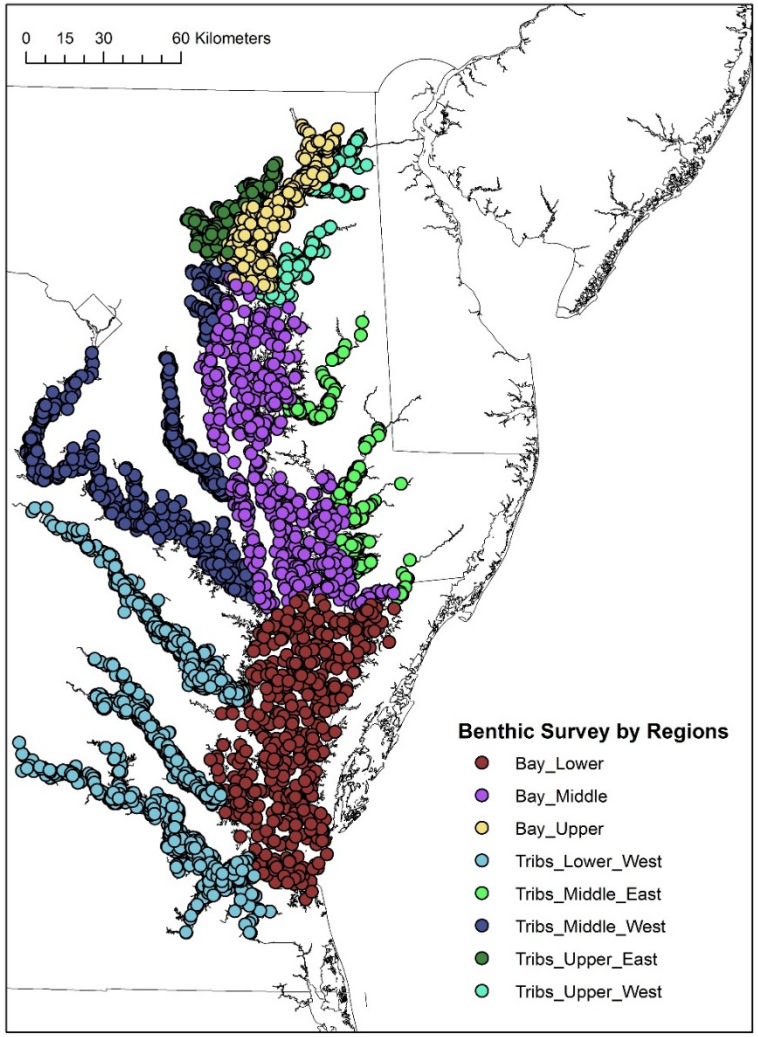
Water quality survey locations



Regional WQ indices

- Parameters
  - Chla, Temp, Sal, DO
  - water column integrated
- Sampling months: 7-9
  - Typically once per month during summer months
- Index of abundance
  - Generalized linear mixed-models
  - Factors: region, month, year
  - Covariate: station depth

Water quality survey locations

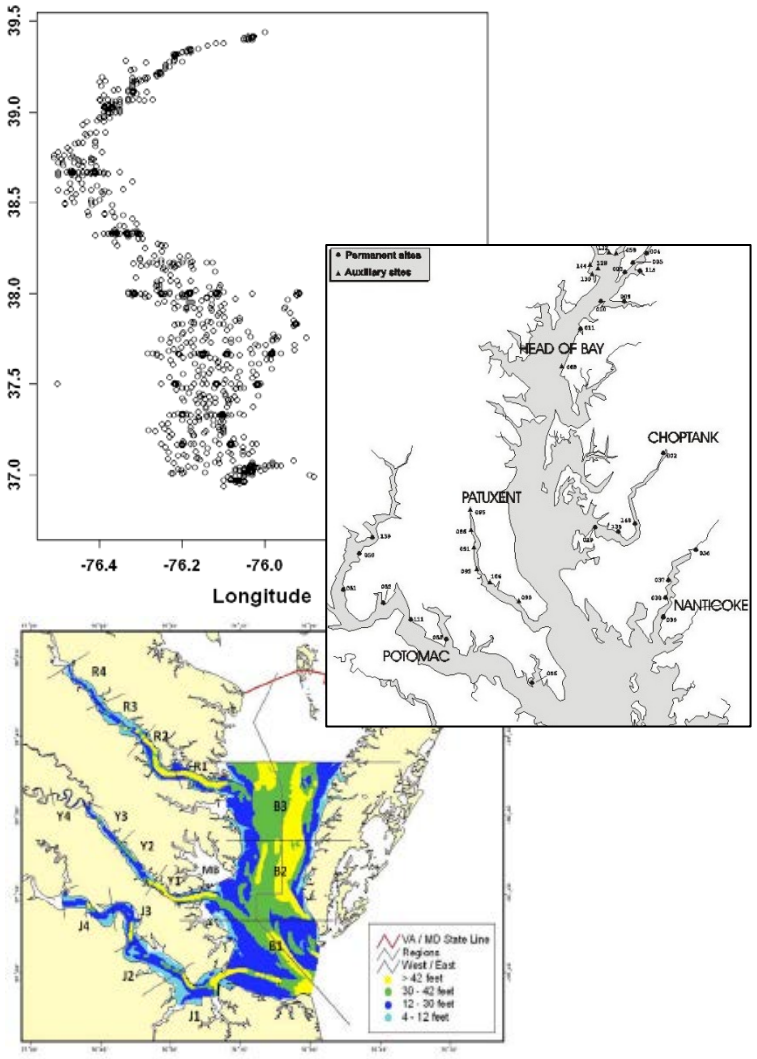


Benthic indices

- Taxa
  - Amphipods/isopods, mysid shrimp, bivalves, polychaetes, other crustaceans
- Sampling months: 8-9 (generally)
  - End of July through 1st week of October
- Index of abundance
  - Delta-GLM
  - Baywide or by region
  - Factors: month, year

Forage fish indices

Multiple surveys and locations



- Taxa
  - Bay anchovy, YOY Atl. menhaden, YOY Atl. croaker, YOY spot, YOY weakfish, Atlantic silversides
- Multiple surveys (n = 6)
  - MD DNR/VIMS juvenile striped bass index seine surveys
  - MD DNR/VIMS trawl surveys
  - CHESFIMS/TIES midwater trawl survey
  - ChesMMaP trawl survey
- Index of abundance
  - Delta-GLM
  - Factors: month, year

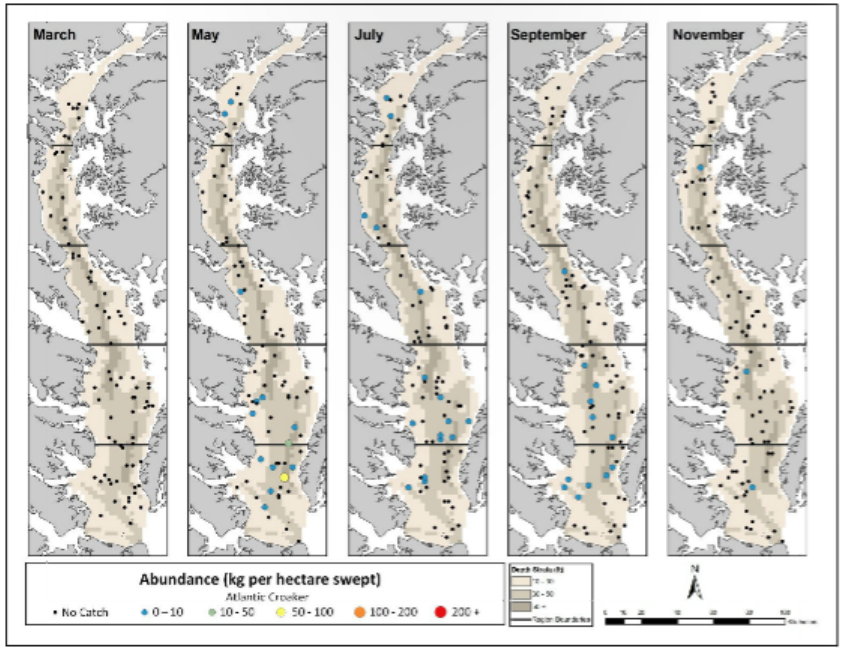
Objective 2: consumption, forage & environment

1. Regional predator abundance and consumption
    1. Multiple size-classes of key predator species
    2. Consumption estimates from stomach contents and evacuation model

2. Indices of consumption relative to environmental/biological conditions
    1. Environmental: Baywide and regional parameters described previously
    2. Biological: local abundance of forage and predator (density-dependence)

3. Variance dampening – evidence of a forage 'portfolio effect'
    1. Estimation of consumption variance for predators upon individual forage taxa
    2. Variance increased/decreased when functionally similar taxa aggregated

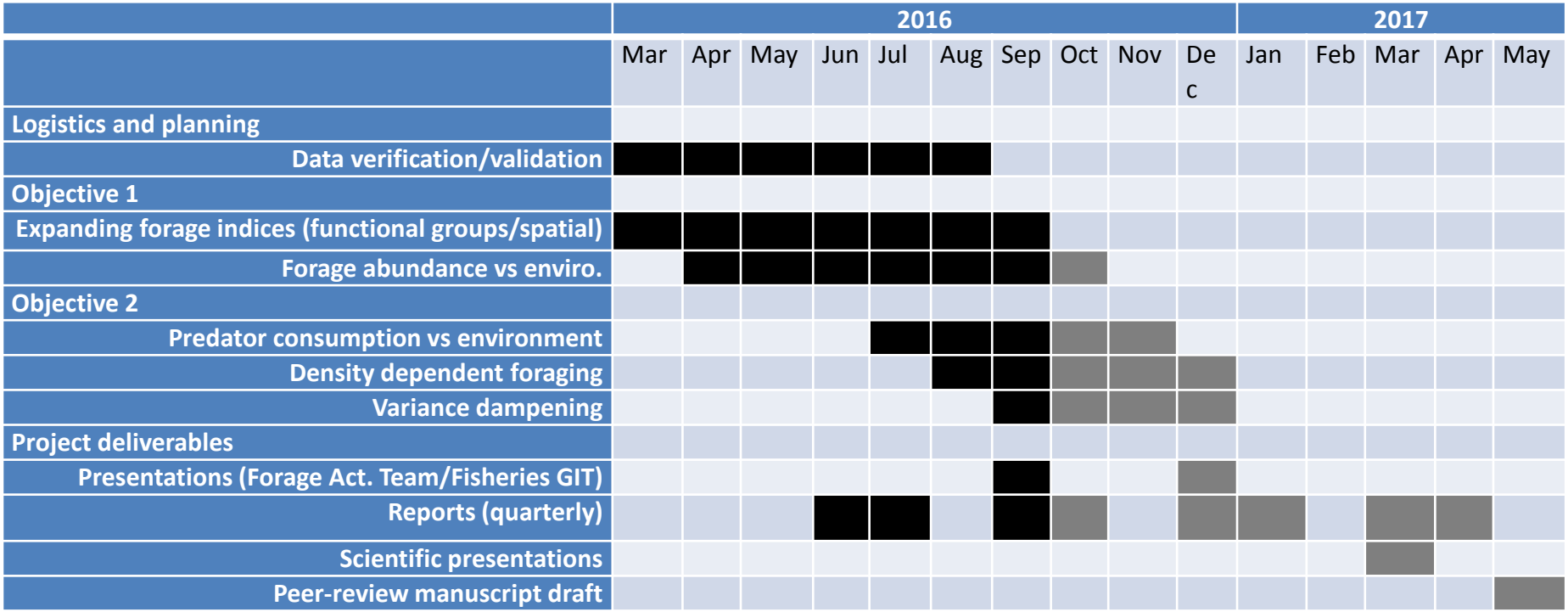
Predator consumption & relative abundance



ChesMMaP trawl survey (example)

- Taxa (multiple size-classes)
  - Striped bass, summer flounder, Atl. croaker, weakfish, white perch, spot
- ChesMMaP trawl survey
  - 2002-2015
  - Predator diet and relative abundance
  - Mainstem only
- Indices
  - Abundance
  - Consumption

Project timeline



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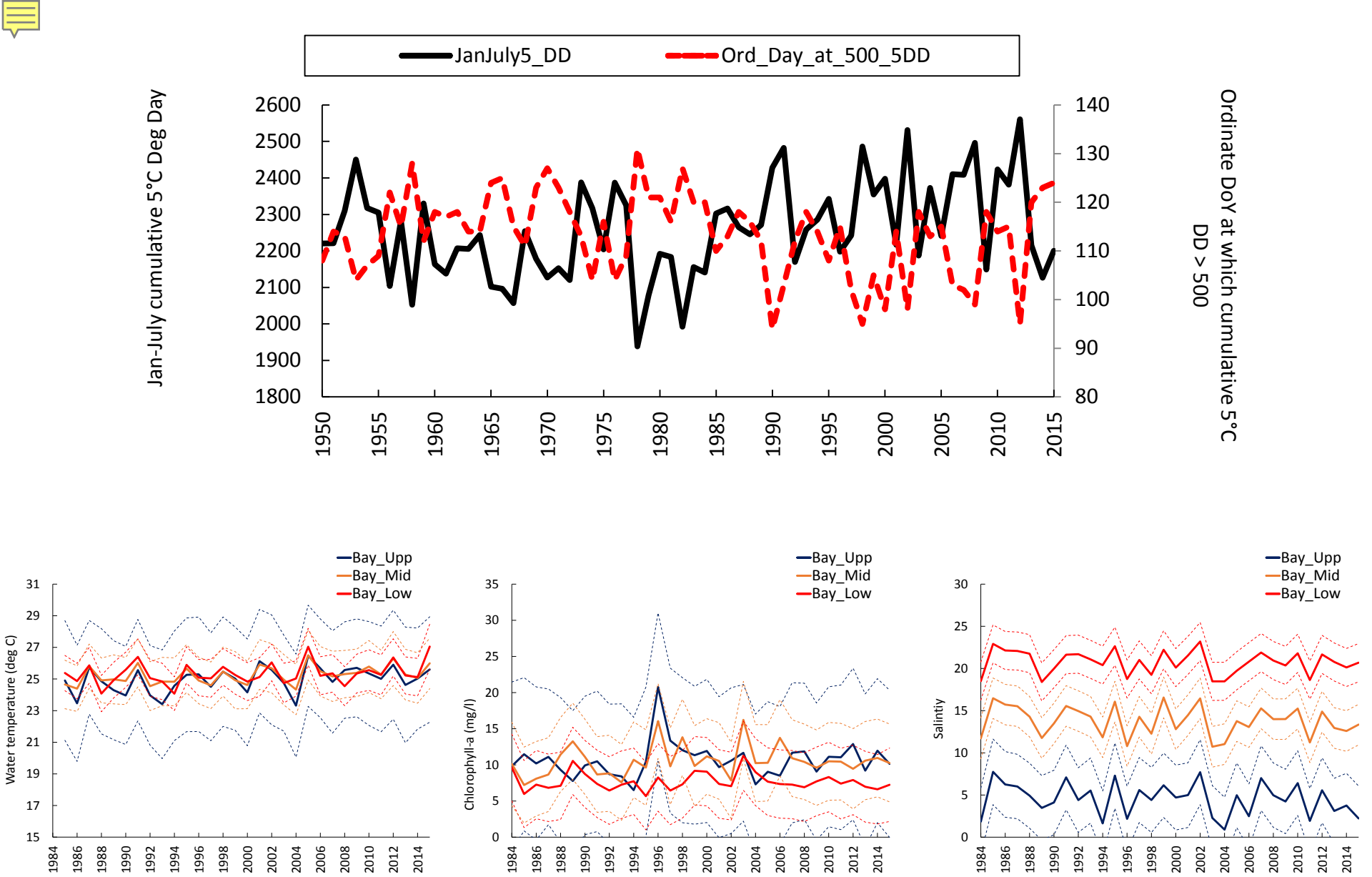
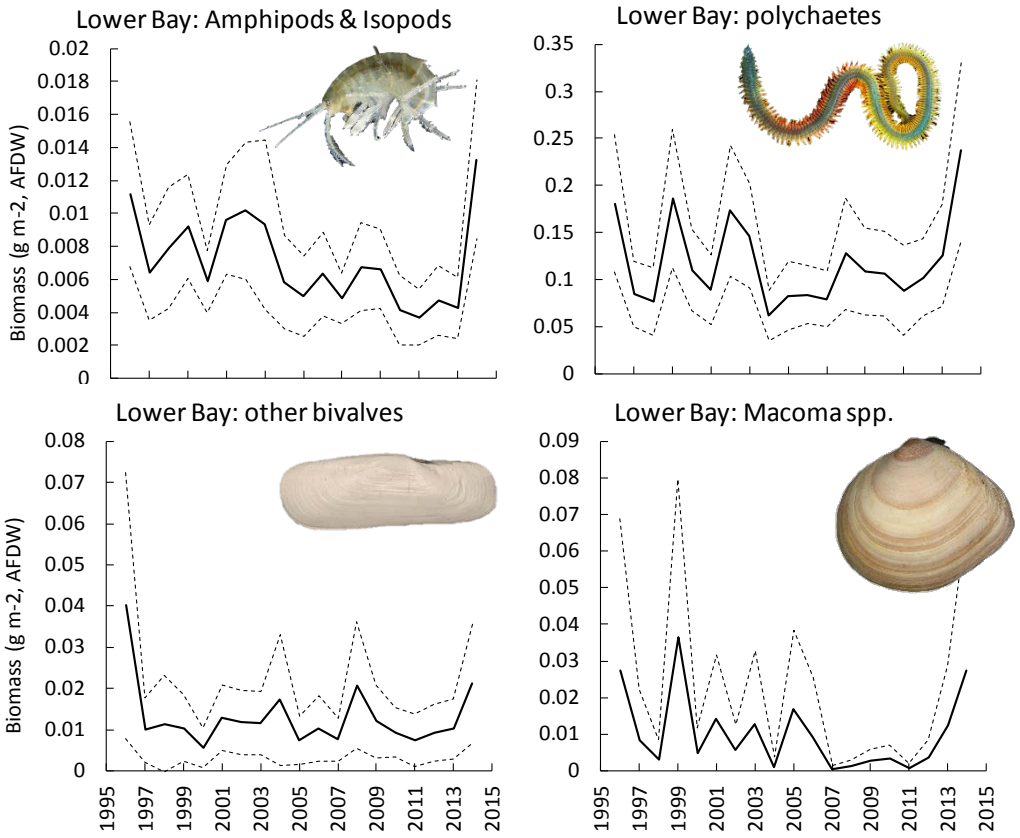
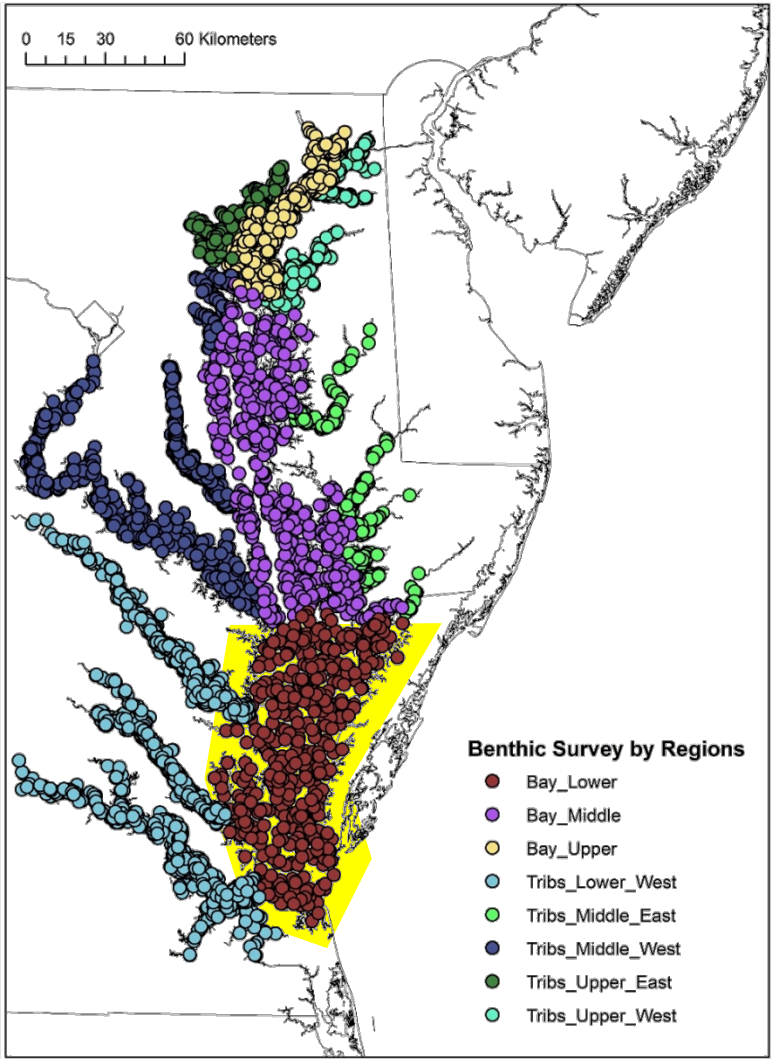

JanJuly5_DD
Ord_Day_at_500_5DD
Jan-July cumulative 5°C Deg Day
Ordinate DoY at which cumulative 5°C DD > 500
2600
2500
2400
2300
2200
2100
2000
1900
1800
140
130
120
110
100
90
80
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Bay_Upp
Bay_Mid
Bay_Low
Water temperature (deg C)
Chlorophyll-a (mg/l)
Salintiy

DATA – Forage


Lower Bay: Amphipods & Isopods
Biomass (g m-2, AFDW)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Lower Bay: polychaetes
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Lower Bay: other bivalves
Biomass (g m-2, AFDW)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Lower Bay: Macoma spp.
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0


0 15 30 60 Kilometers
Benthic Survey by Regions
Bay_Lower
Bay_Middle
Bay_Upper
Tribs_Lower_West
Tribs_Middle_East
Tribs_Middle_West
Tribs_Upper_East
Tribs_Upper_West

Chesapeake Bay Hypoxic Volume Forecasts

Donald Scavia[1], Isabella Bertani[1] and Mary Anne Evans[2]
[1]University of Michigan
[2]US Geological Survey – Great Lakes Science Center

June 13, 2016

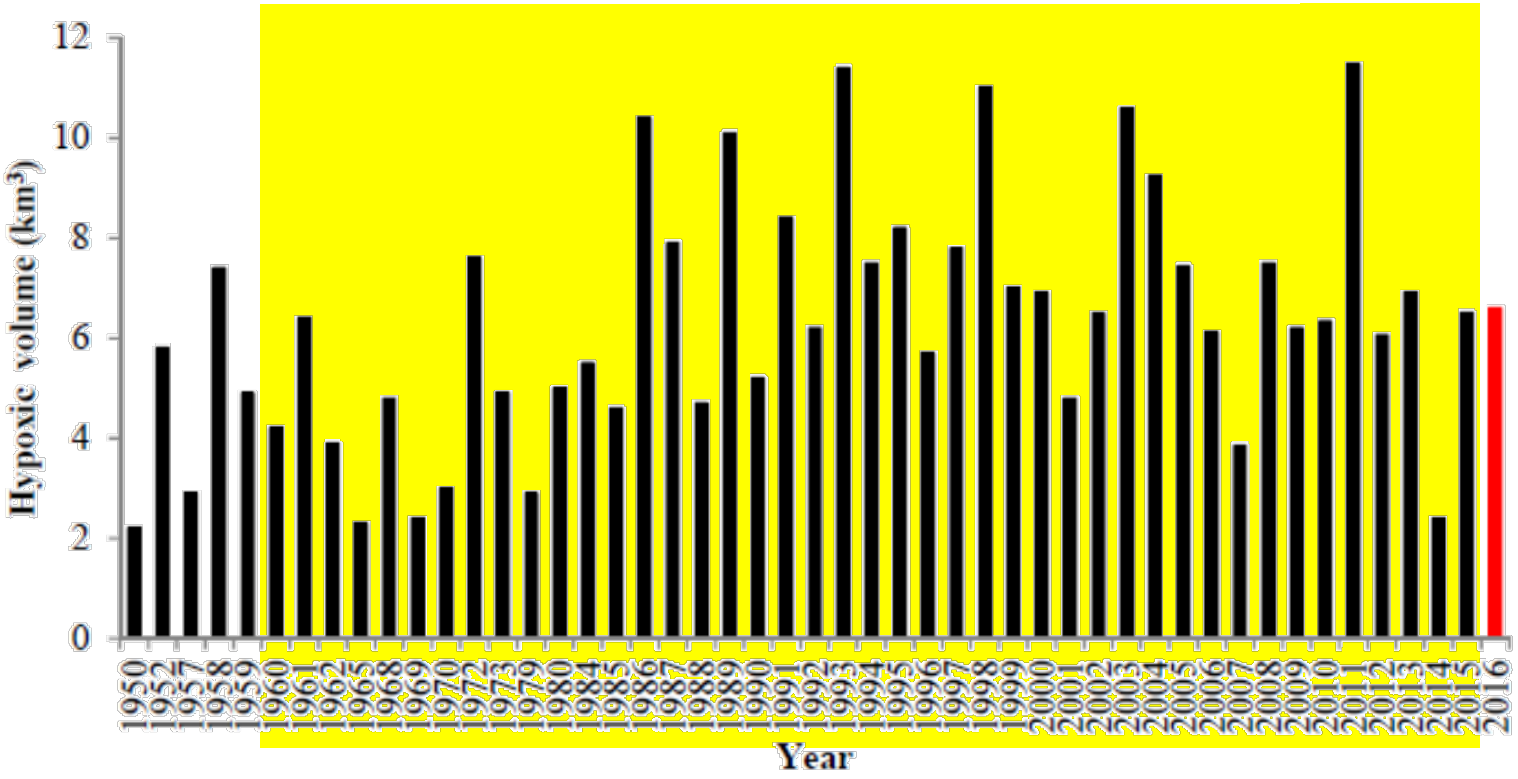
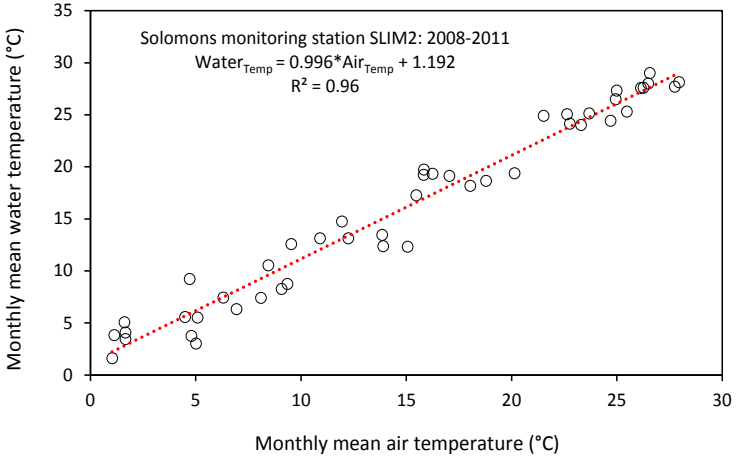
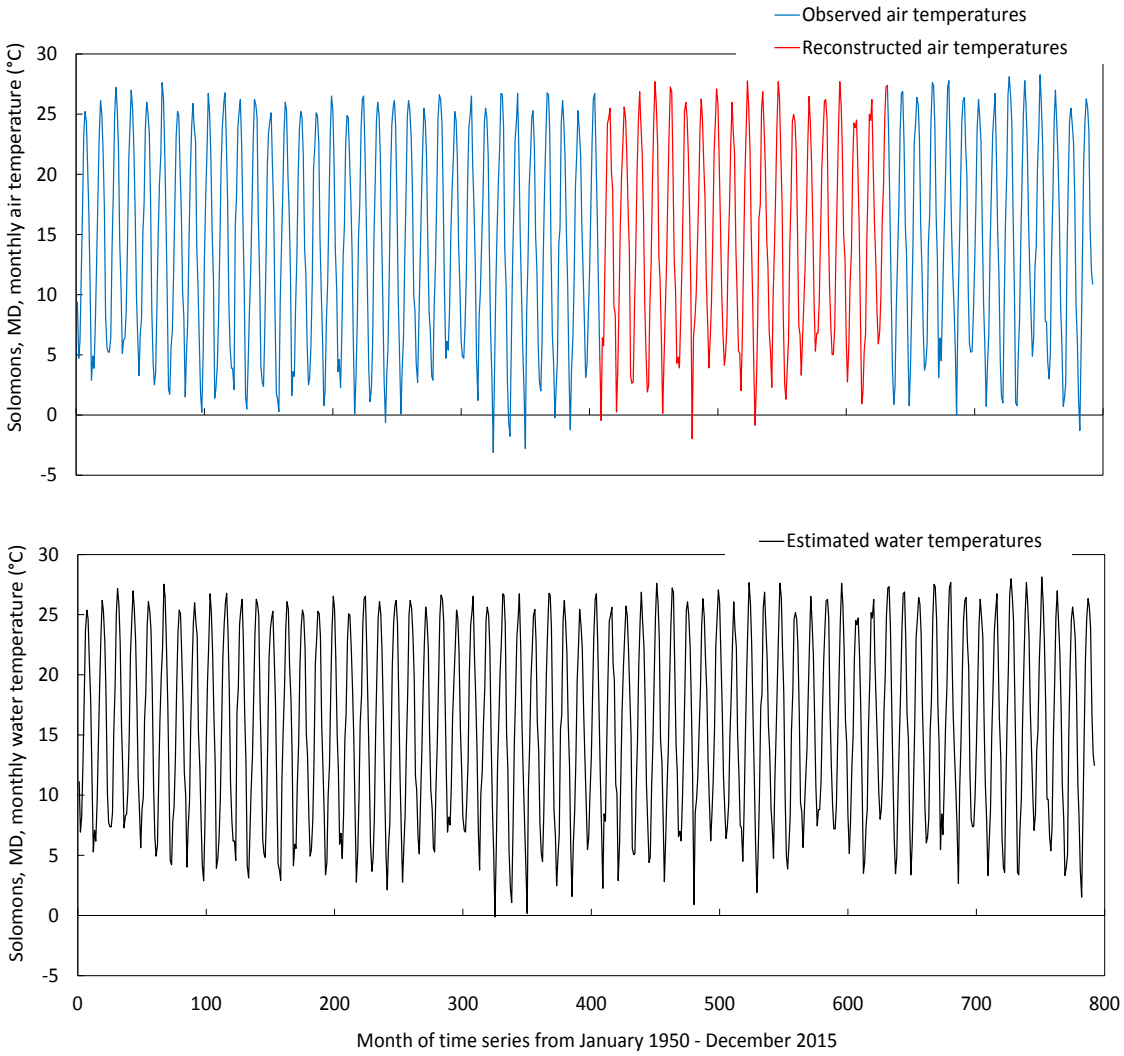


Table x. Estimates of means (SE given in parentheses) for four water quality variables from 1984-2015 in the upper mainstem region of Chesapeake Bay when calculated excluding (Saline stations) or including (All stations) four very low salinity and tidal freshwater stations (salinity < 1). Regression results of saline station estimates (dependent) vs all station estimates (independent) are shown.

Variable	Saline stations	All stations	Regression parameter estimates (SE) and results					
			Alpha	Beta	Adj-r^2	df`	f	p
Chlorophyll	7.63 (0.67)	11.27 (0.41)	-6.01 (2.25)	1.21 (0.20)	0.55	1,30	38.4	<0.001
Dissolved oxygen	5.47 (0.11)	6.58 (0.35)	-2.42 (1.95)	1.26 (0.31)	0.44	1,19	16.38	0.001
Water temperature	24.73 (0.19)	25.28 (0.14)	-0.63 (4.25)	1 .00 (0.17)	0.54	1,29	35.62	<0.001
Salinity	7.84 (0.35)	4.35 (0.31)	3.21 (2.97)	1.07 (0.06)	0.9	1,30	283.18	<0.001


Solomons monitoring station SLIM2: 2008-2011
Water$_{Temp}$ = 0.996*Air$_{Temp}$ + 1.192
R² = 0.96
Monthly mean water temperature (°C)
Monthly mean air temperature (°C)
0
5
10
15
20
25
30
35


Observed air temperatures
Reconstructed air temperatures
Solomons, MD, monthly air temperature (°C)
Estimated water temperatures
Solomons, MD, monthly water temperature (°C)
Month of time series from January 1950 - December 2015
-5
0
5
10
15
20
25
30
0
100
200
300
400
500
600
700
800

Next Steps

- Apply indicator and metric results to workplan
- Define formal management objectives
- Communicate results to Bay partners
- Identify collaborative opportunities with other GITs

Issues for Management Board

- Environmental factors (habitat loss, climate change)
- Monitoring (plankton and shallow water)
- Cross-GIT connections
- Communication and education


Questions