Appendices

Appendix A: Agenda

SNEP Workshop: Toward Comprehensive Monitoring of Narragansett Bay
Thursday, October 19, 2017
8:00AM – 3:30 PM, RIEMC Meeting to follow 3:30-4:30PM
Coastal Institute Auditorium, Narragansett Bay Campus
Agenda

8:00AM	Coffee and bagels
8:30AM	Welcome and goals for the day—Judith Swift and Nicole Rohr, CI
8:40AM	Brief Overview—Sue Kiernan, RIDEM
	What monitoring do agencies and regulators currently report?
	What are the gaps and vulnerabilities in this monitoring?
8:50AM	EPA Biological Conditions Gradient—Giancarlo Cicchetti, EPA-AED
9:00AM	Other Current Monitoring—5 min. each, Autumn Oczkowski, Moderator
	Benthic Communities—Emily Shumchenia
	Primary Productivity/Nutrients—Candace Oviatt, GSO
	Phytoplankton—Tatiana Rynearson, GSO
	Clarity/Chlorophyll—Eliza Moore, NBC
	Macroalgae—Carol Thornber, URI CELS
	HABs/Shellfish—David Borkman, RIDEM
	Fish—Joe Zottoli, GSO
	Group discussion
	Did we get the monitoring and gaps right?
	What would participants add?
10:15AM	Break
10:30AM	Break-out Groups—Prioritize gaps to best inform environmental health
11:45AM	Lunch
12:30PM	Opportunities to fill data gaps Part I—5 min. each
	New Data Synthesis/Tools—Q Kellogg, CI
	New Data Collection/Technology—Colleen Mouw, GSO
	Comprehensive Efforts—Bethany Jenkins, URI CELS, EPSCoR
12:45PM	Group discussion
	Report out prioritization
	Agree on prioritization (H, M, L)
2:00PM	Break
2:15PM	Group Discussion—Opportunities to fill data gaps, TBD, Moderator
3:15PM	Concluding remarks
3:30PM	EMC Meeting
4:30PM	Adjourn

Appendix B: Attendees

Workshop Attendees

Veronica Berounsky, URI-GSO

Laura Blake, U.S. Geological Survey

David Borkman, RI DEM Water Resources

Caitlin Chaffee, RI Coastal Resources Management Council

Giancarlo Cicchetti, U.S. EPA, Atlantic Ecology Division

Christine Comeau, Narragansett Bay Commission

Karen Cortes, Narragansett Bay Commission

Christopher Deacutis, RIDEM DMF

Bryan Dore, EPA SNEP

Sarah Flickinger, Narragansett Bay Commission

Janet Freedman, RI Coastal Resources Management Council

Walt Galloway, retired EPA

David Gregg, Rhode Island Natural History Survey

Jasper Hobbs, NEIWPCC

Bethany Jenkins, URI

Q Kellogg, URI Coastal Institute

Jim Kelly, Narragansett bay Commission

Sue Kiernan, RIDEM

Chris Kincaid, URI-GSO

Tom Kutcher, RINHS

Charles LaBash, URI Environmental Data Center

Lucie Maranda, Graduate School of Oceanography, University of Rhode Island

Conor McManus, Rhode Island DEM Division of Fish and Wildlife

Eliza Moore, Narragansett Bay Commission

John E. Motta, Narragansett Bay Commission

Colleen Mouw, URI-GSO

David Murray, Brown University

Autumn Oczkowski, US EPA, Atlantic Ecology Division

Candace Oviatt, URI-GSO

Sherry Poucher, RI DOH

Warren Prell, Department of Earth, Environmental, and Planetary Science, Brown University

Kenny Raposa, Narragansett Bay National Estuarine Research Reserve

Anna Robuck, URI-GSO

Lew Rothstein, URI-GSO

Tatiana Rynearson, University of Rhode Island

Courtney Schmidt, Narragansett Bay Estuary Program - NEIWPCC

Sarah Schumann, Fishing community organizer

Elizabeth Scott, RIDEM Office of Water Resources

Emily Shumchenia, Contractor to US EPA, Region 1; E&C Enviroscape

Karen Simpson, US EPA

Heather Stoffel, URI-GSO

Judith Swift, URI Coastal Institute

Carol Thornber, URI

David Ullman, URI-GSO

Thomas Uva, Narragansett Bay Commission

Caitlyn Whittle, US EPA Region 1

Joe Zottoli, URI GSO

Appendix C: Speaker Slides

Sue Kiernan
RIDEM

Overview

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

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NARRAGANSETT BAY ESTUARY PROGRAM

Current Monitoring Capacities

General Observations:

- 12 of 20 monitoring priorities previously identified by the RIEMC relate to coastal waters.

- Only one of those strategies – Rotating Assessment of Coastal Ponds and Embayments (water quality) has not been formally implemented in some form.

- Expanded monitoring efforts will be needed to support continued reporting of some of the indicators included in the NBEP Status and Trends Report (e.g. benthic habitat).

Narragansett Bay: What we measure & report

Chemical/Physical

- Water Chemistry *
  - – DO, pH, salinity
- Chlorophyll *a**
- Temperature*
- Nutrient concentrations*
- Pathogens/Bacteria*
- Clarity*
- Tide height*
- Shoreline Change
- Freshwater flow into the Bay*

* = measured routinely

- Report water quality status relative to state criteria
- Report on severity of hypoxia throughout summer season
- Report status of shellfish growing areas (open/closed)
- Beach advisories

Narragansett Bay: What we measure & report

Biological/Habitat - routinely

- Fish Trawl Surveys –
  - species ID, age, growth
- Lobster surveys
- Shellfish Surveys
- Phytoplankton species composition at limited locations

Fish and shellfish stock assessments

Atlantic Lobster settlement index

Biological/Habitat –periodically

- Extent of sea grasses
- Condition of salt marshes – Tier 2 and Tier 3 assessment methods
- Marine invasive species – Rapid assessment surveys (limited locations)

Reports on extent of SAV including change analysis.

Salt marsh extent and changes in condition.

Presence of marine invasive species.

Recent Developments

- Establishment of fixed site (buoy) water quality monitoring stations in Mt. Hope Bay by MA DEP (2016)
- Development of 3-tiered salt marsh monitoring strategy & expansion of effort (2017)
- Development of expanded strategy for identifying and tracking Harmful Algal Blooms in coastal waters - (2017)
- DEM Marine Fisheries habitat assessment study in Providence –Seekonk River region; field work initiated in 2016.
- Data synthesis products emerging from NBEP Status and Trends, SNEP project, related partner work

Vulnerabilities

- State agency dependency on federal funding for monitoring & uncertainty of future funding levels.
- Unstable funding sources. Over-reliance on limited grants and other stop-gap measures.
- NBFSMN equipment is aging and needs a significant investment to achieve appropriate upgrades.
- Staffing capacity is a constraint for both agencies and partners.

GAPS

What additional data do we need to characterize a changing Narragansett Bay ecosystem?

Examples of gaps:

- Water quality data in certain sub-embayments & the Sakonnet River.
- Chlorophyll *a* and phytoplankton in sub-regions of the bay.
- Clarity data in areas of the bay.
- Data to characterize pollutant inputs from ocean (off-shore) waters.
- Monitoring of benthic habitat quality.
- Additional screening for Harmful Algal Blooms.
- Monitoring of various toxics in fish and shellfish tissue (e.g. mercury, PCBs, others)
- Monitoring of sediments for legacy contaminants.

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Giancarlo Cicchetti
EPA-AED

EPA Biological Condition Gradient

Toward Comprehensive Monitoring of Narragansett Bay

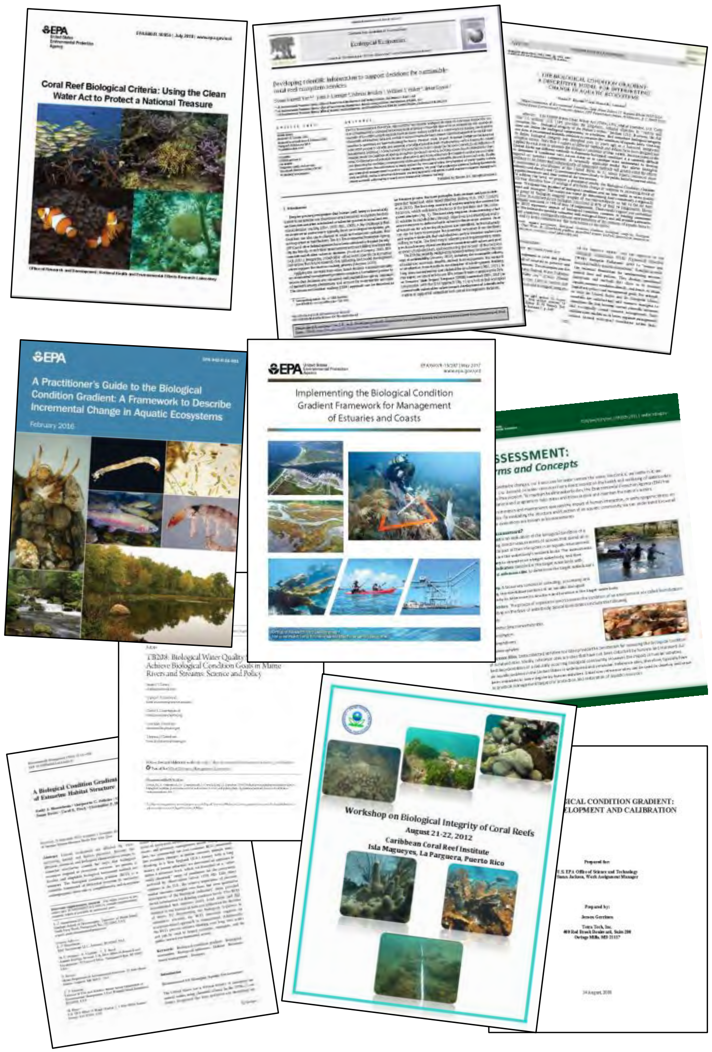
October 19, 2017

The Biological Condition Gradient

An approach that organizes people and biological indicators for setting goals and targets.

- Science part: put different indicators into a common framework for communication to stakeholders
- Stakeholder engagement part: What do we care about, and what future do we want for our estuary?
- Management part: How do we get closer to a desired future estuary?

The Biological Condition Gradient



EPA Office Of Water Biocriteria Program's primary approach to bioassessment:

- Well-supported by Office of Water for over 20 years
- Narragansett Bay BCG efforts are currently supported by Office of Water and Atlantic Ecology Division.
- Used by many states for Clean Water Act regulatory needs in freshwater streams and other waterbody types
- In use by by several NEPs
- Dozens of publications and EPA Reports

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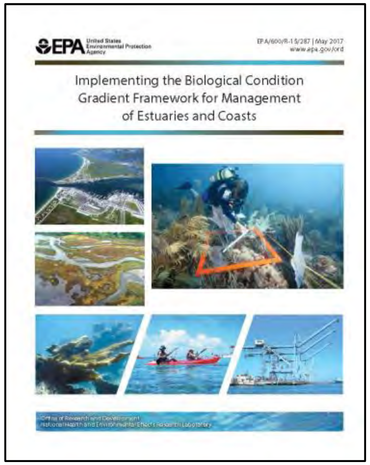
Report

BCG for Estuaries - Steps:



1. Identify stakeholders, problems, and biological indicators

↓

2. Develop a BCG for goal-setting (science)

↓

3. Develop stakeholder visions, set broad goals

↓

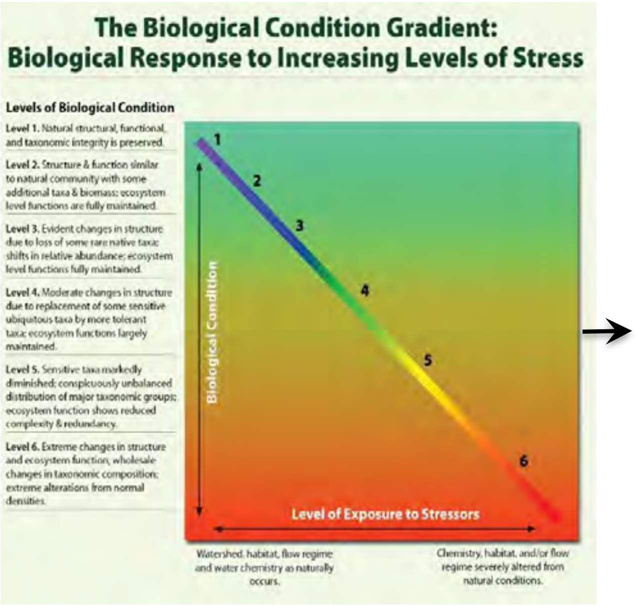
4. Develop targets, management actions, monitor for results of actions. Adapt.

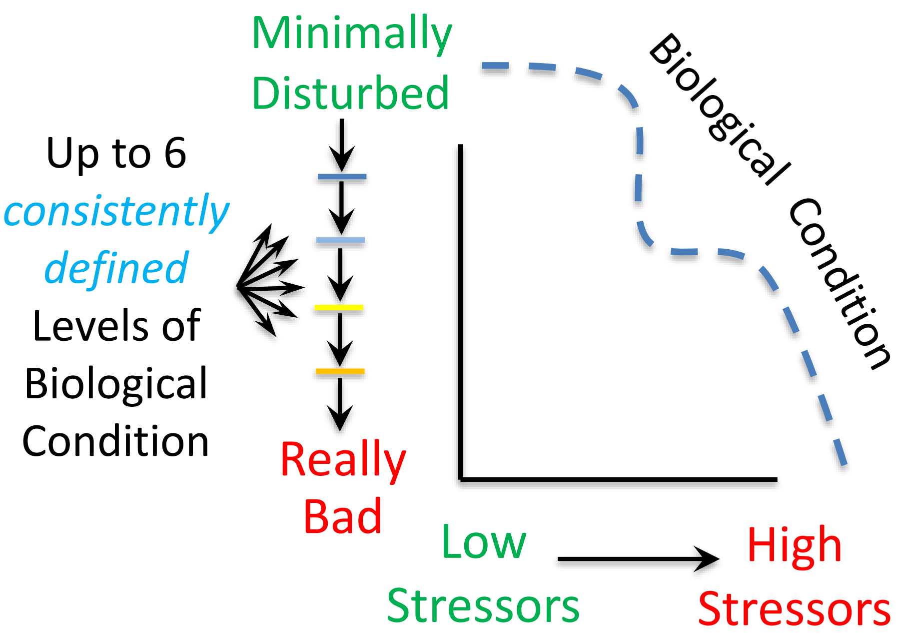
https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100SN3Y.txt

2. Develop a BCG for goal-setting

<u>For each indicator:</u>

- What biological condition did we once have--what is reference?
- What biological condition do we now have?





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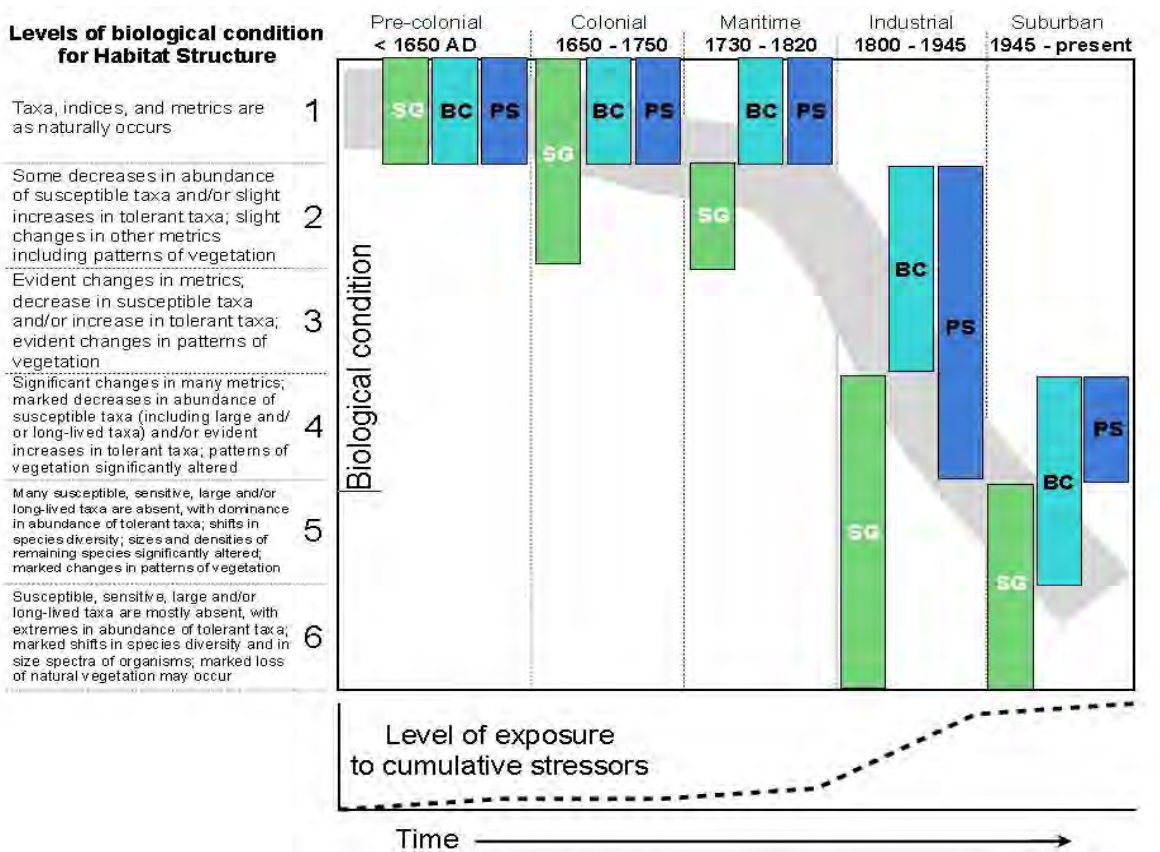
Greenwich Bay Example

Consistent definitions place all indicators in a common framework



SG = Seagrass

BC = Benthic Community

PS = Primary Productivity and Shellfish

Shumchenia et al. 2015

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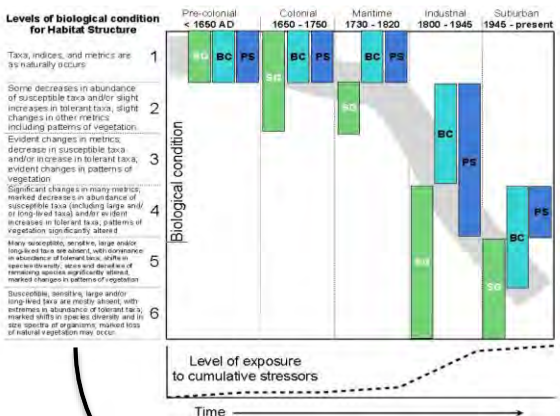
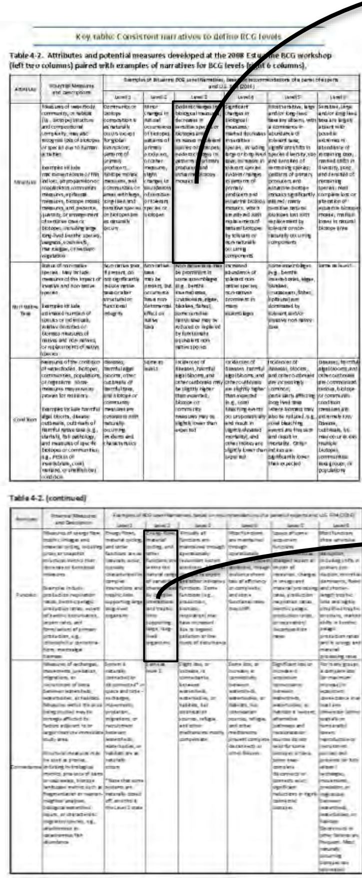
Consistent definitions of Levels can apply to any indicator - - with flexibility - - through scientific workshops



Big Guidance Table



Structure

Level 3

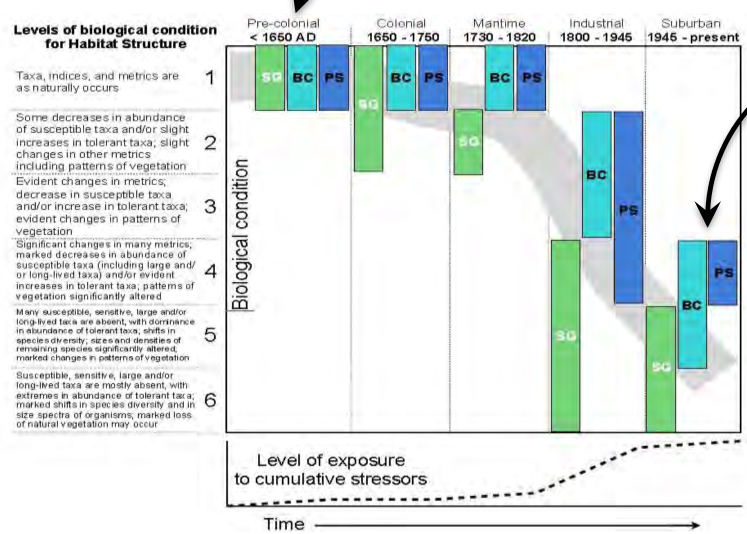
Significant changes in biological measures; marked decreases in sensitive species... changes in patterns of primary producers and estuarine biotopes ...

Function

Level 2

Energy flows, material cycling, and other functions are within the natural range of variability; characterized by ...

3. Communicate condition, engage stakeholders to develop visions, set broad goals



Here's what we had

Here's what we have

What do we want? (stakeholder workshop)

Stakeholder vision of a desired future

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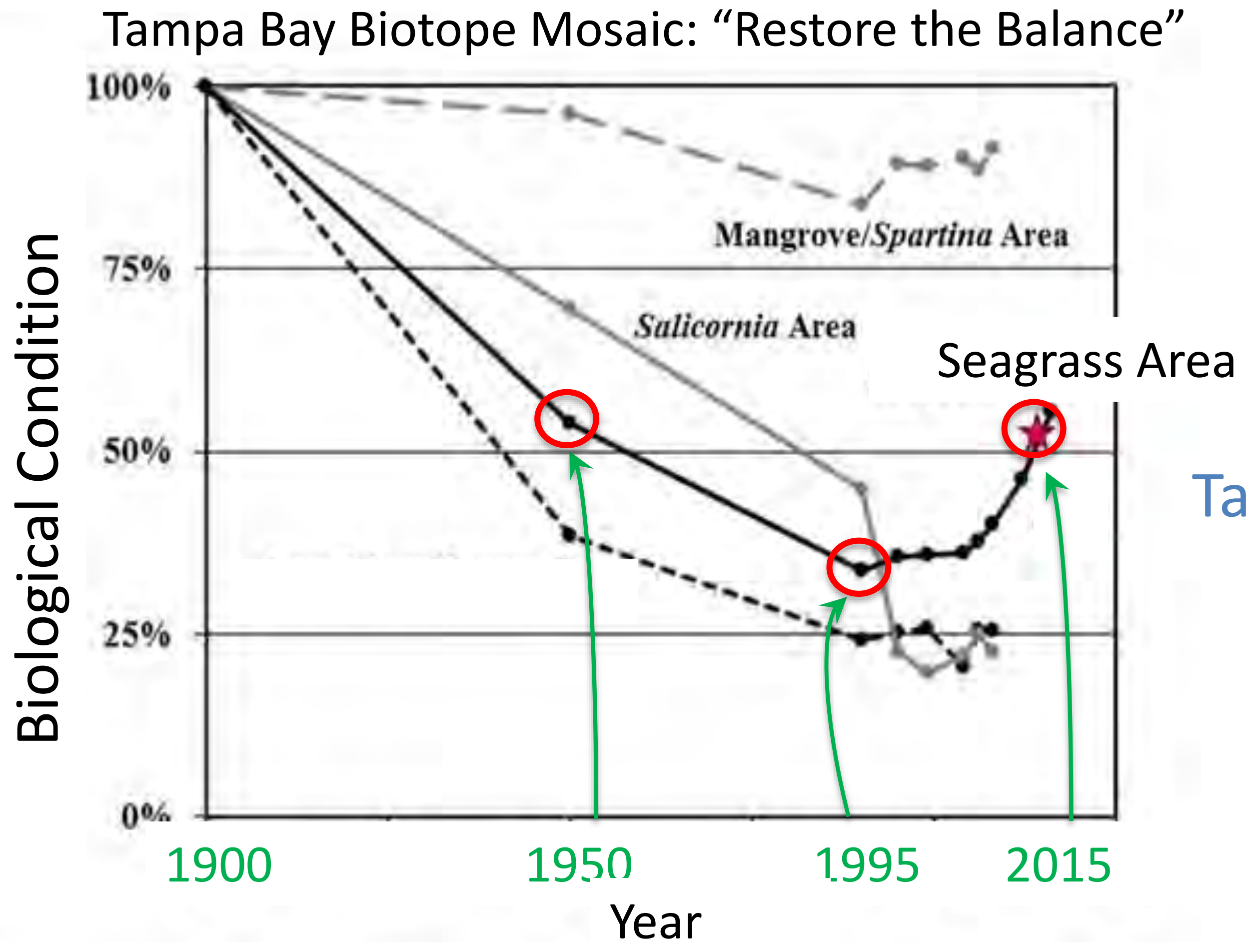
4. Develop targets, management actions, monitor, adapt.



Target met in 2015

Management Action

Target set in 1995: Restore seagrass to the 1950 acreage.

(Cicchetti and Greening, 2011)

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Engaging stakeholders, including the public, has been important to success with BCG

A motivated public is a powerful tool in environmental management

Moving forward in Narragansett Bay - Do we want to use a BCG approach?

What do we have now?

- EPA support, guidance documents
- Interested Estuary Program
- Biological monitoring indicators (today)
- Greenwich Bay BCG publication
- Biotope mosaic BCG in prep
  (G. Cicchetti, E. Shumchenia, K. Ruddock)

What would we do next?

- Discussions on pros and cons?
- Study group to gauge interest?
- Small workgroup?
- Workshop?
- Other?

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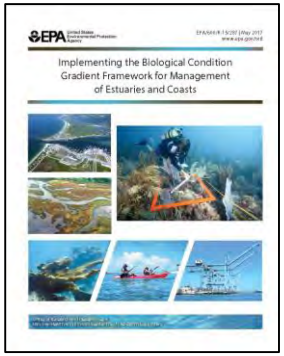
Implementing the Biological Condition Gradient Framework for Management of Estuaries and Coasts



Co-authors:

EPA Atlantic Ecology Division
Giancarlo Cicchetti
Marguerite Pelletier
Ken Rocha
Pat Bradley (ret.)

EPA Gulf Ecology Division
Debbie Santavy

EPA Region 1
Margherita Pryor

EPA Office of Water
Susan Jackson

Great Lakes Environmental Center
Emily Shumchenia

Maine Department of Environmental Protection
Susan Davies (ret.)

RI Department of Environmental Management
Chris Deacutis

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Emily Shumchenia

Benthic Communities

Toward Comprehensive Monitoring of Narragansett Bay

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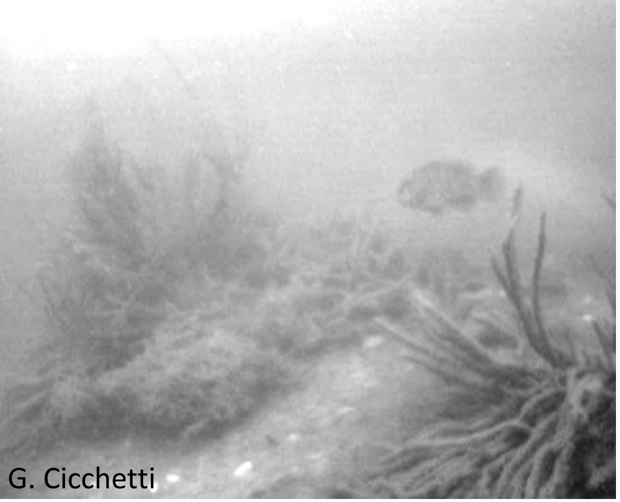
CURRENT MONITORING

Table 1. Recent efforts to monitor benthic habitat and/or community composition in Narragansett Bay.

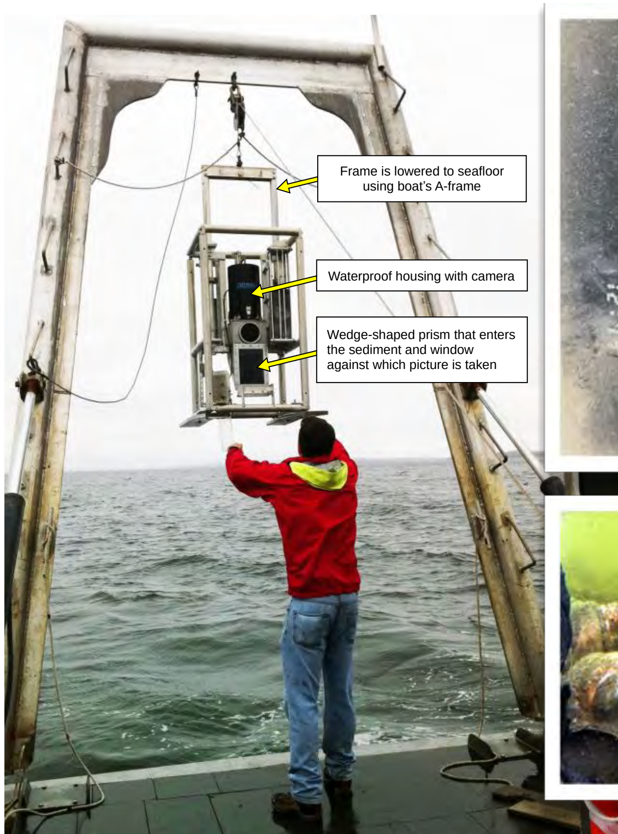
Benthic monitoring strategy	Organizing group	Spatial extent	Temporal extent	Future sampling
Benthic macrofauna community composition and abundance	Marine Ecosystems Research Laboratory, URI-GSO	4 stations in Upper Bay	4 stations 2000, 2001, 2002, 2004; 1 station 2005–2010	None planned
Trends report	EPA	Upper Bay	Trends analysis of data 1950s–2015	None planned
National Coastal Condition Report	EPA	Bay-wide (some stations permanent, others changing)	Summer 2005/6, 2010, 2015	2020
Benthic video sled	Narragansett Bay Commission	3 transects in Providence River Estuary	2–6 times per year, 2014–present	Attempted monthly
Sediment profile imagery	URI	Bay-wide	1988, 2008	None planned

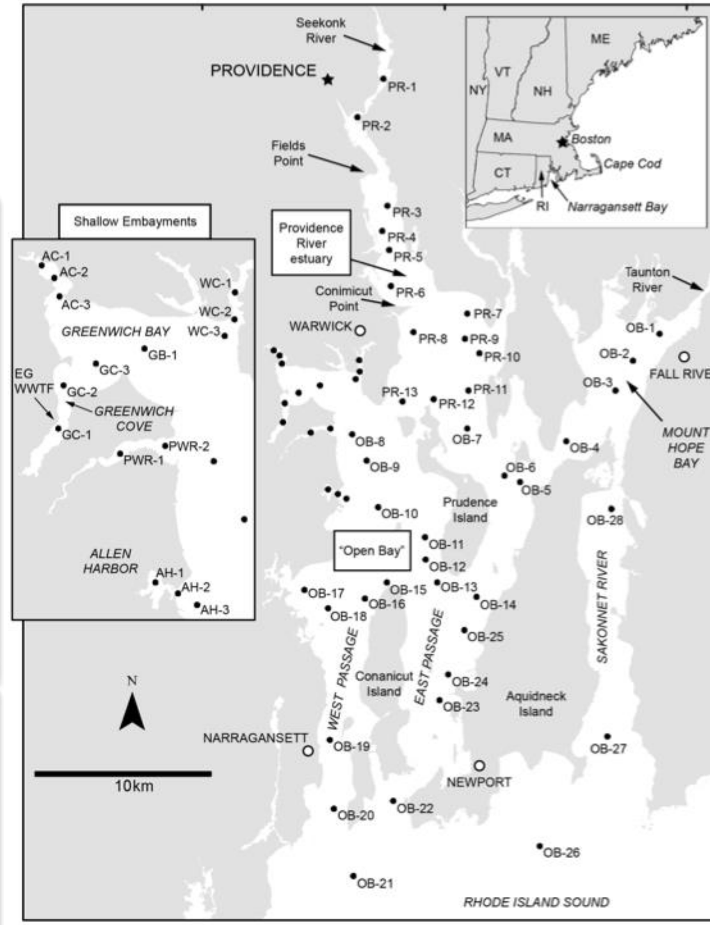
METHODS OVERVIEW



For NCCA sites, see: https://www.epa.gov/national-aquatic-resource-surveys/ncca

For NBC video transects, see map in workshop materials





Shumchenia et al., 2016

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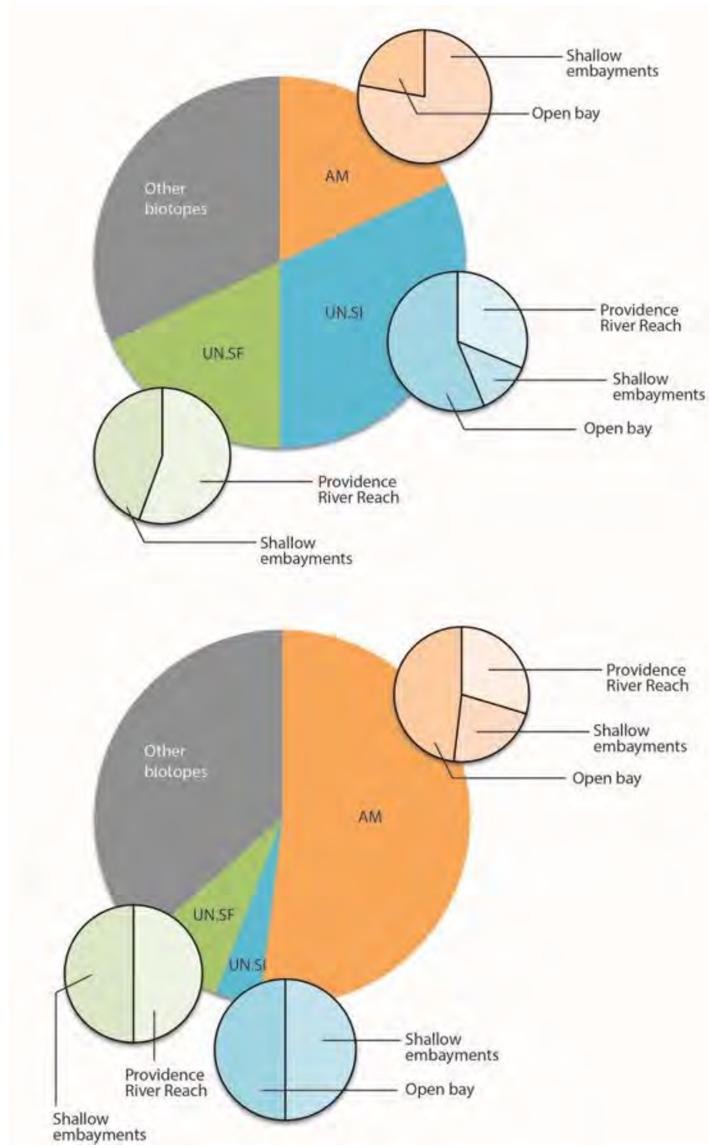
MONITORING RESULTS

Bay-wide, biotopes dominated by *Ampelisca* increased >5x between 1988 and 2008

In 1988 there were zero *Ampelisca* biotopes imaged in the Providence River Reach, whereas in 2008, 78% of stations were *Ampelisca*

Biotopes indicative of organic enrichment and tolerant fauna declined from 24% in 1988 to 5% in 2008

***Ampelisca* biotopes appear to track critical boundaries in organic enrichment between high and low quality habitats**



1988

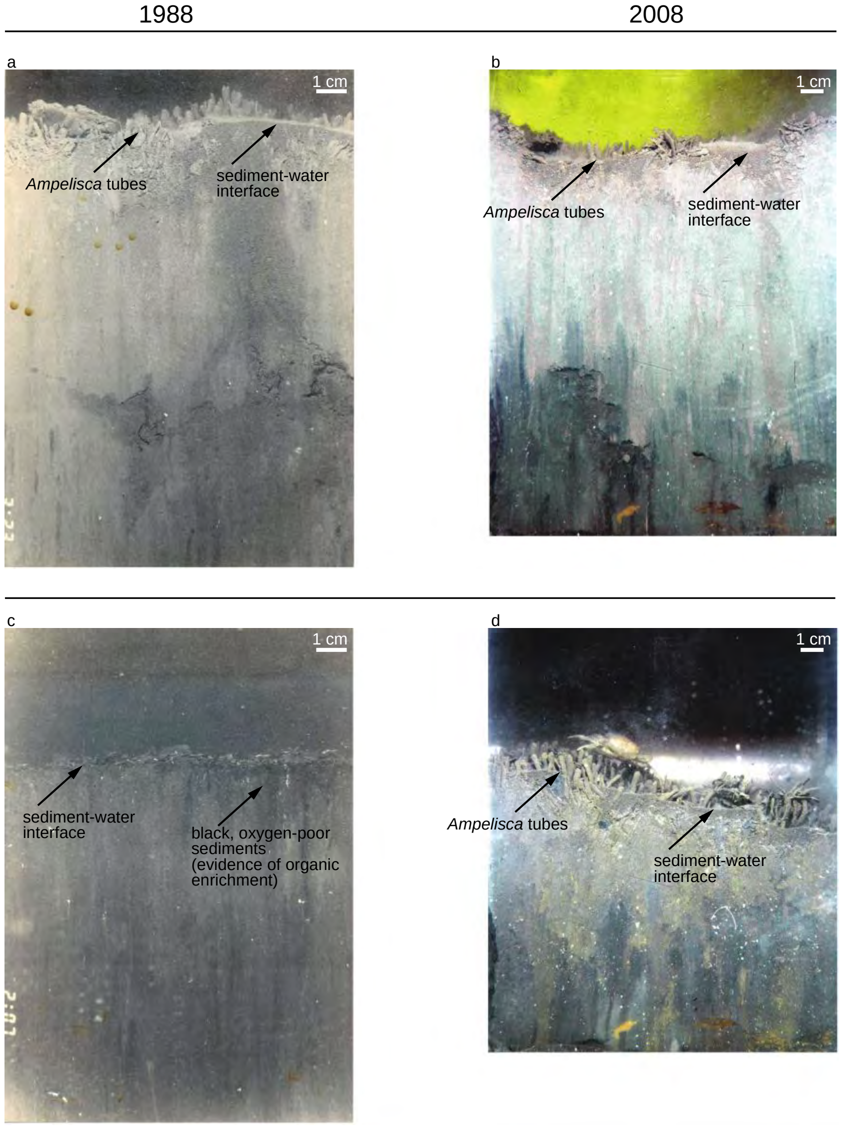
2008

DATA AND FUTURE EFFORTS

1. Ongoing work at EPA on estuarine bioassessment (BCG) with habitat mosaic approach

2. Coordination between EPA, NBC, RI DEM on imagery classification, methods, sampling locations

3. Exploring funding opportunities to repeat the 1988/2008 sediment profile imagery survey in 2018 and into the future



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Candace Oviatt
URI GSO

Candace Oviatt
URI GSO

Primary Productivity/Nutrients (Managed Reduction Impacts on Nutrient Concentration)

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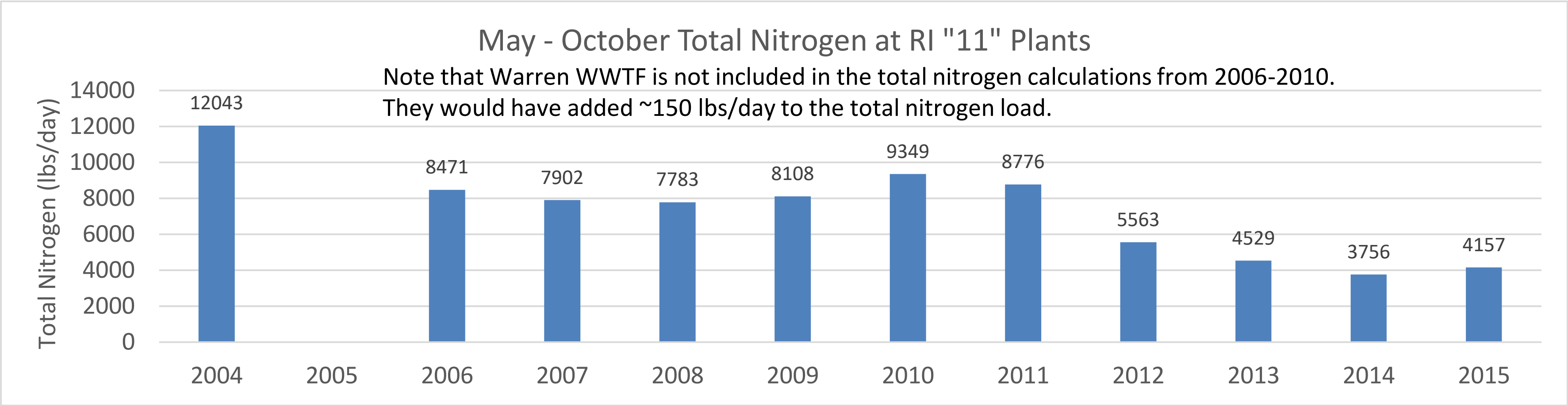
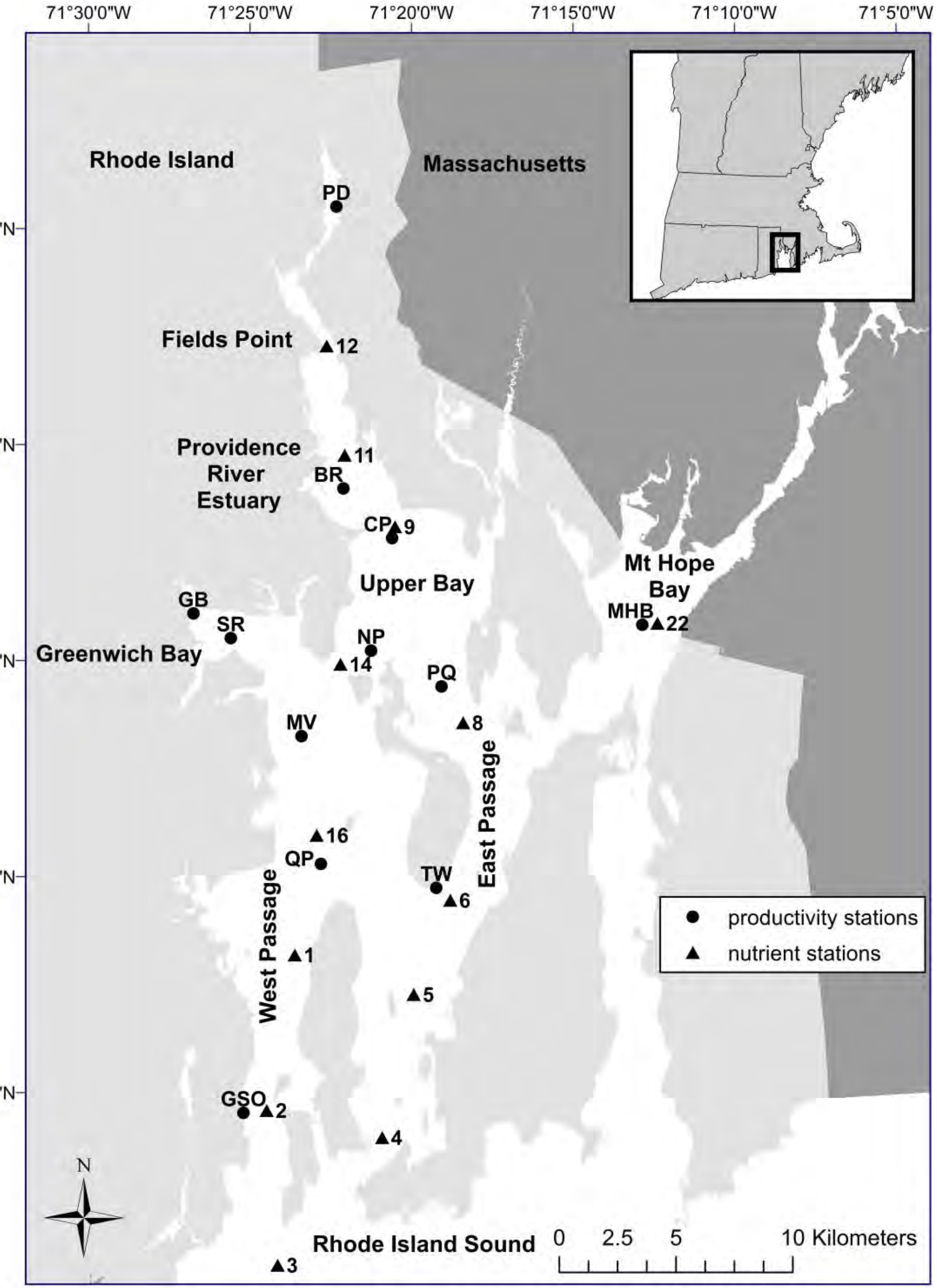
October 19, 2017

RI Department of Environmental Management Summer Total Nitrogen Inputs

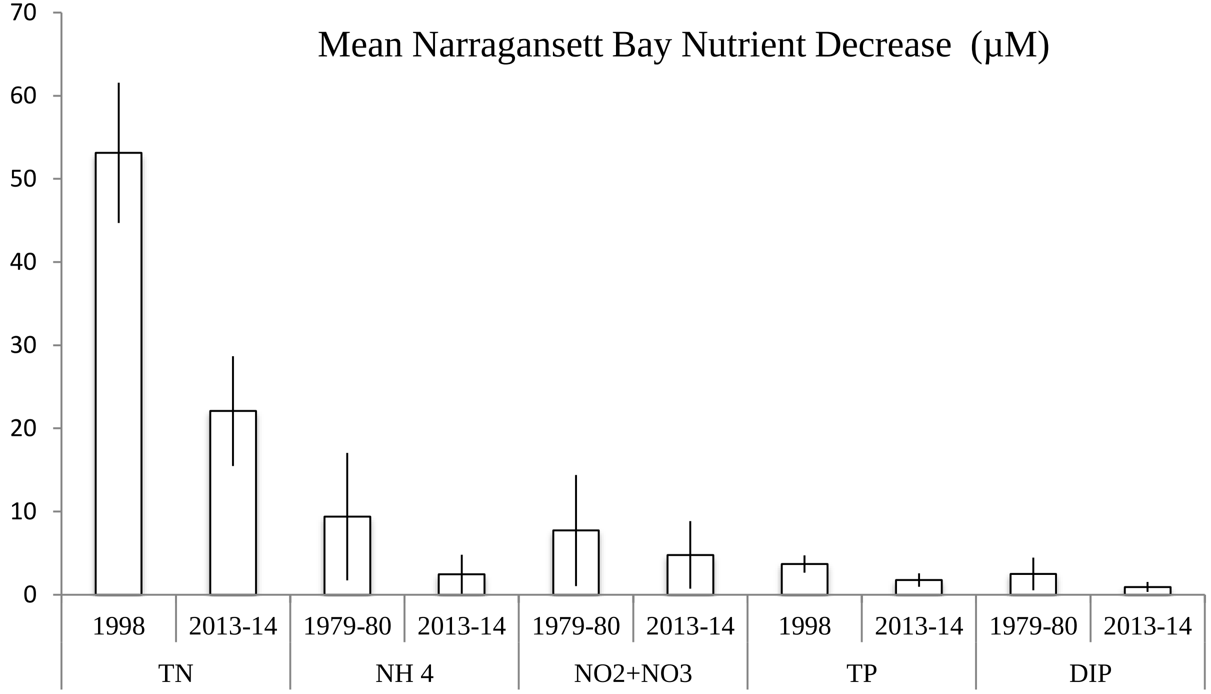


Slide courtesy of Warren Prell and the RI DEM Office of Water Resources



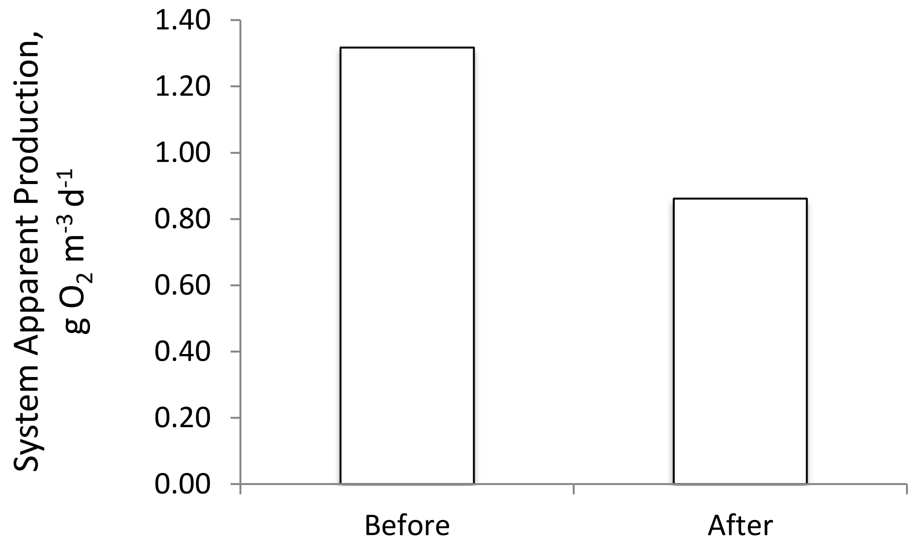
71°30'0"W
71°25'0"W
71°20'0"W
71°15'0"W
71°10'0"W
71°5'0"W
41°50'0"N
41°45'0"N
41°40'0"N
41°35'0"N
41°30'0"N
Rhode Island
Massachusetts
PD
Fields Point
12
Providence River Estuary
11
BR
CP
9
Upper Bay
Mt Hope Bay
MHB
22
GB
SR
Greenwich Bay
NP
14
PQ
8
MV
East Passage
16
QP
TW
6
West Passage
1
5
GSO
2
4
3
Rhode Island Sound
N
productivity stations
nutrient stations
0 2.5 5 10 Kilometers

Bay-wide Nutrient Decreased in the Bay after Managed Reduction in 2012



Station	1980 to 2006-2010	1998 to 2006-2010	2006-2010 to 2013-2014	2006-2010 to 2013-2014	1980 to 2013-2014	1998 to 2013-2014
	DIN	TN	DIN	TN	DIN	TN
Fields Pt	22	53	45	28	59	66
BR	17	57	31	10	58	61
CP	25	52	43	16	71	60
MHB			20	5		
NP	20	56	51	14	72	62
PQ	41	56	32		68	56
QP	18	55	34	2	66	56
T-W		56	26			56
Fox Is		56	27	6		59
Gould Is					54	
GSO	31	57	13		46	55
Newport		58			54	
Beavertail	50	57	16		40	53
Average	28	56	31	12	60	58
	DIP	TP	DIP	TP	DIP	TP
Fields Pt	40	62	20	9	52	57
BR	58	67	19	9	67	60
CP		60	22	11	75	58
MHB			23	14	70	
NP	48	65	16	0	66	61
PQ	56	63	20	8		53
QP	43	62	6		67	52
T-W		56	21	17	61	51
Fox Is		62	8	7		51
Gould Is		0	22	14		
GSO	43	62	16	6	46	47
Newport		59	20	18		
Beavertail	28	57	22	17	41	48
Average	45	56	18	11	61	54

Bay-wide Decrease in Primary Production with Nutrient Reduction



Decrease in Primary Production Along the North-South Axis of Narragansett Bay with Nitrogen Reduction

Station	Prod % Difference 2004 to 2006-2011	Prod % Difference 2006-2011 to 2013-2015	Prod % Difference 2004 to 2013-2015
BR	-13	-21	-31
CP		-15	
MHB		-15	
NP	-29	-22	-44
GB	4	-16	-12
SR		-22	
MV	-28	-24	-45
PQ	-29	-3	-31
QP		-18	
T-W		-29	
GSO		2	
Average	-21	-17	-33
Statistical Significance:	**	N.S.	**

** = *0.01* level of significance
N.S. - not significant at the *0.05* level of significance

Data and Current Monitoring

Buoy and fixed site data:
Temperature, salinity, oxygen, chlorophyll, pH -surface and bottom for most variables.
Data is available on the State BART website, Narrbay.org website at URI and by request.

Data record:
1999-present summers at up to 14 sites; 2005-present year round at up to 4 sites.

Agencies: RI DEM, NBC, NBERR, GSO-MERL

Nutrient data:
Ammonia, nitrite, nitrate, total nitrogen, phosphate, total phosphorous
Data is available on the MERL website and by request.

Data record:
2005 to present at 13 surface water stations.

Agencies: RI DEM, MERL

Tatiana Rynearson
URI GSO

Phytoplankton

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

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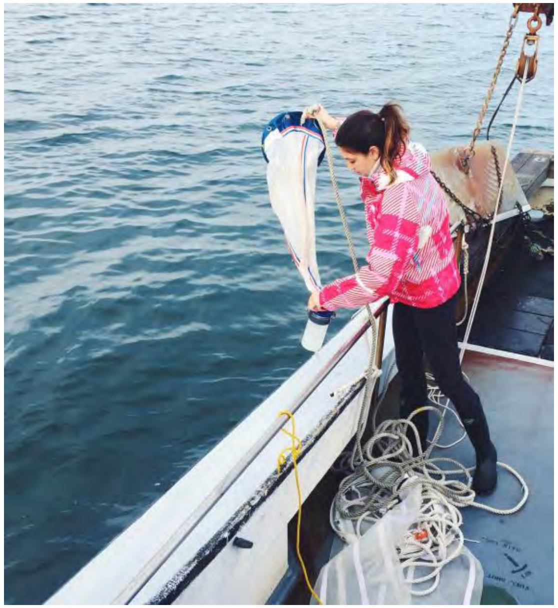
Narragansett Bay Long Term Plankton Time Series

- Weekly samples of biological, chemical and physical variables
- Data since the 1950's
- Annual, interannual, long-term change in the bay
- Harmful algal bloom monitoring
- Comparison of the bay to locations around the globe

http://web.uri.edu/plankton/

METHODS OVERVIEW

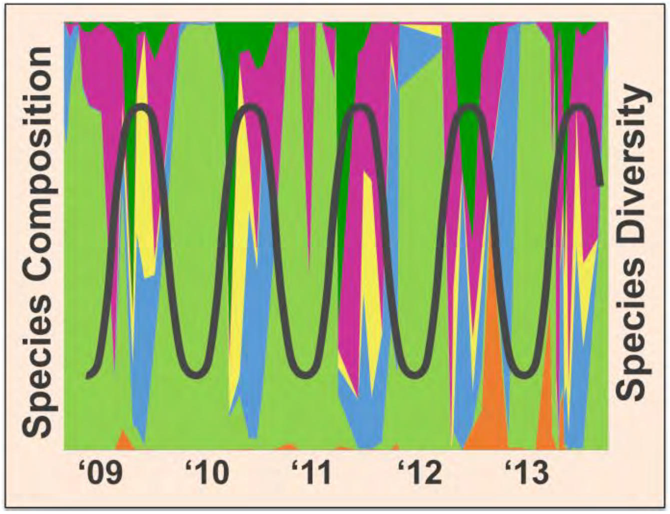
- PHYTOPLANKTON
  - Chl a
  - Species counts
- ZOOPLANKTON
  - Collected but not counted
- CHEMISTRY/PHYSICS
  - Discrete measures
    - Temperature, salinity, secchi depth
    - Nutrients (Nitrate, Nitrite, Ammonium, Phosphate, Silicate)
  - Water column profiles
    - temperature, salinity, pH, dissolved oxygen and chlorophyll fluorescence



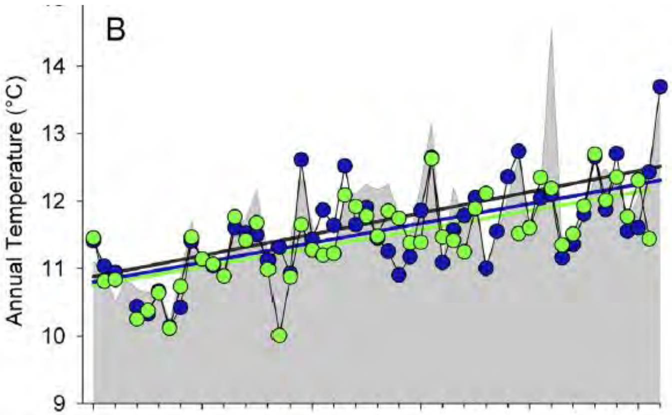
http://web.uri.edu/plankton/

MONITORING RESULTS

- Temperature-dependent dynamics of the most important phytoplankton in NB (Canesi and Rynearson, 2016, MEPS)
  - *Skeletonema* = ~49% of phytoplankton community
  - 7 species look identical but abundance correlated with temperature



- Water temperatures are increasing (Fulweiler et al 2015, Est, Coast, Shelf Sci)



- Genetic diversity and adaptive potential of phytoplankton to climate change is high in Narragansett Bay (Whittaker and Rynearson, 2017, PNAS; Alexander et al. 2015, PNAS)

http://web.uri.edu/plankton/

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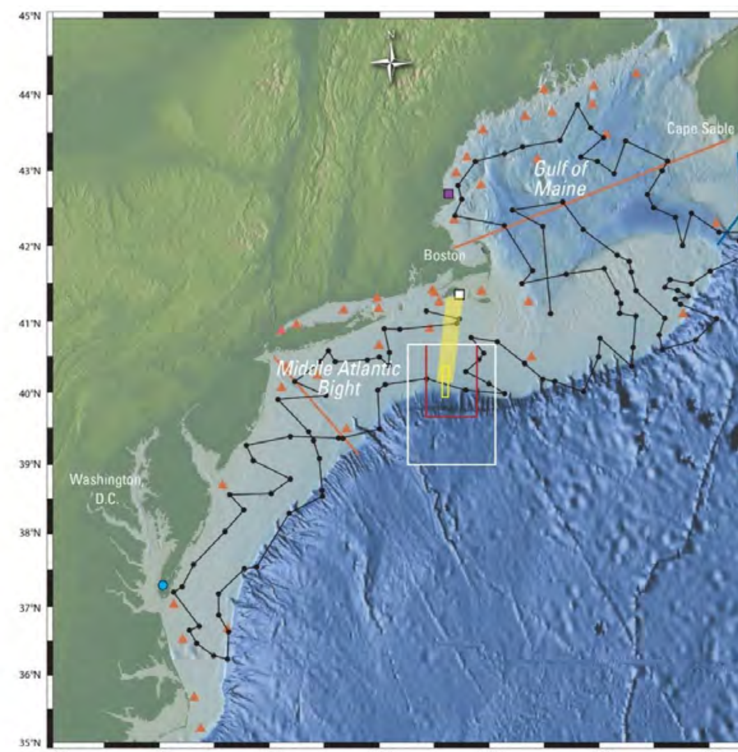
DATA AND FUTURE EFFORTS

- Data publically available (1999-2017)
  - Historical data (nearly all) http://www.nabats.org/
- Keeping the time series funded!
- New NSF-funded EPSCOR
  - Doesn’t fund the time series but leverages the data, the location
  - New underwater Bay observatory
  - New ecosystem models
- New NSF-funded LTER
  - Long term monitoring of shelf water at entrance to NB



http://web.uri.edu/plankton/

Eliza Moore
Narragansett Bay Commission

Clarity/Chlorophyll

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

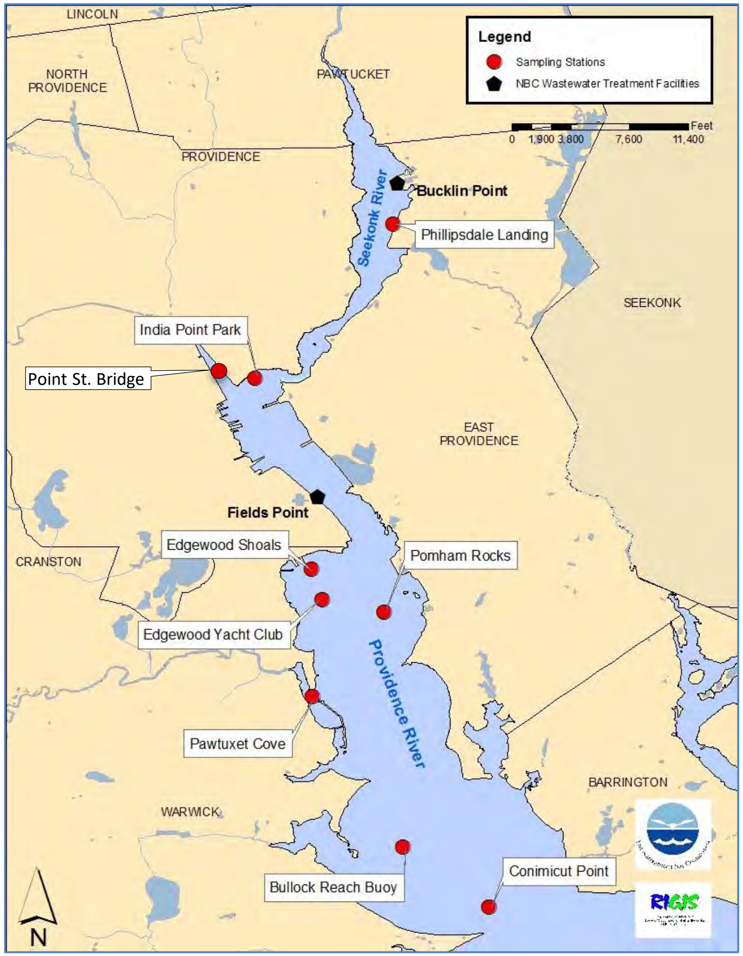
CURRENT MONITORING

- Narragansett Bay Commission Bay Monitoring
  - Fixed-site (2003 – present)
    - Bullock Reach
    - Phillipsdale Landing
  - Bacteria (2004 – present)
  - Surface Temp, Sal, DO, Chl *a* mapping (2004 – present)
  - Nutrients (2005 – present)
  - Water quality profiles (2007-present)
  - Water clarity (Secchi; 2009 – present)
  - Chlorophyll *a* (2011 – present)
  - Phytoplankton (2013 – present)
  - Benthic video (2014 – present)

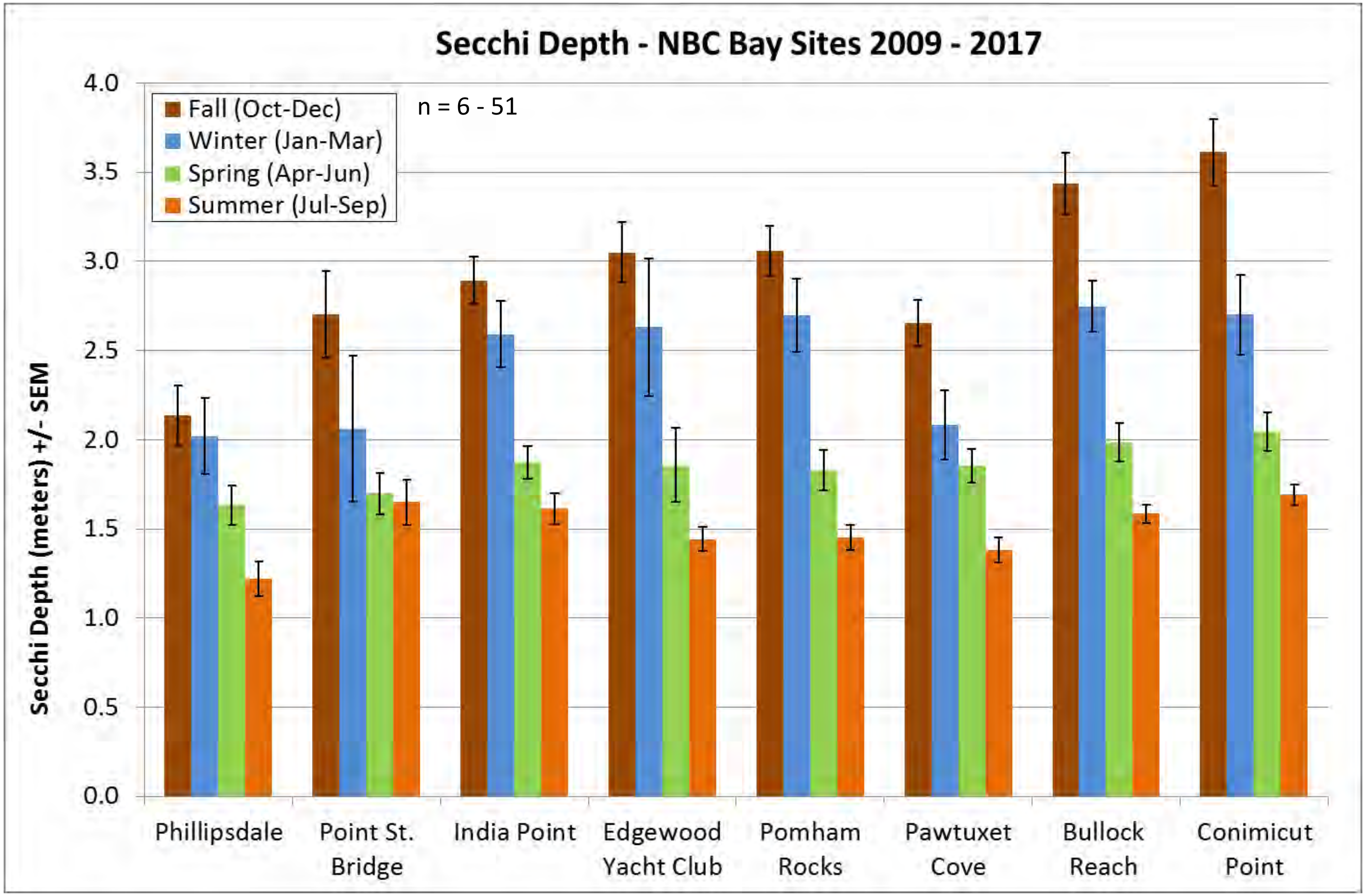
- Primary Uses of Data
  - Monitor receiving water quality as part of NBC's mission
  - Evaluate WQ improvements associated with NBC capital projects (including CSO abatement program and WWTF nutrient removal upgrades)

METHODS OVERVIEW

- Water clarity:
  - Secchi depth measured weekly
  - Photosynthetic active radiation (PAR) profiles weekly
  - Total suspended solids (TSS) (2x/month)
  - Turbidity sensor at Bullock Reach Buoy
- Chlorophyll *a:*
  - Surface water grab samples (2x/month)
  - Surface mapping data collected weekly
  - Fluorescence sensor at fixed sites



MONITORING RESULTS

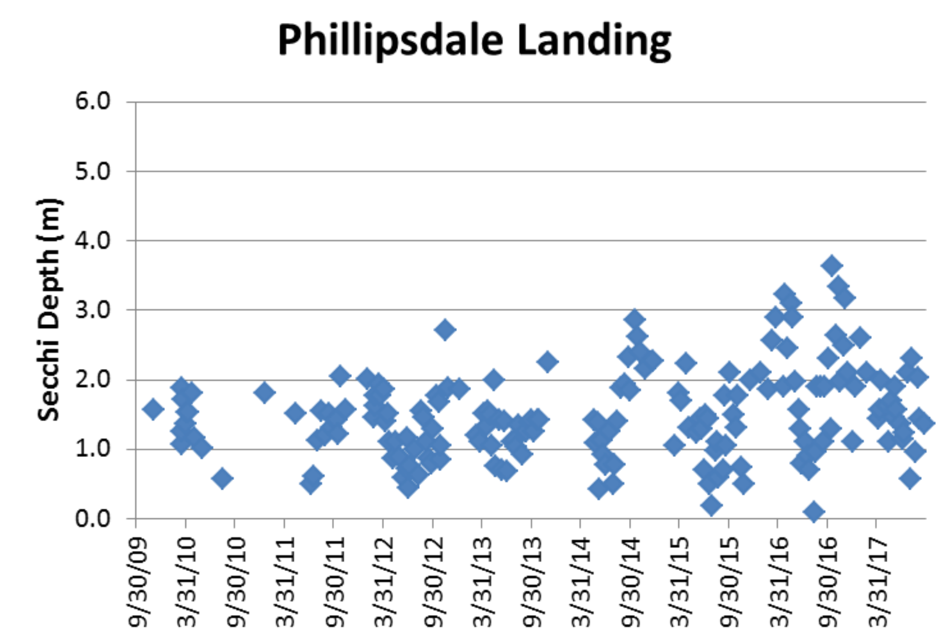


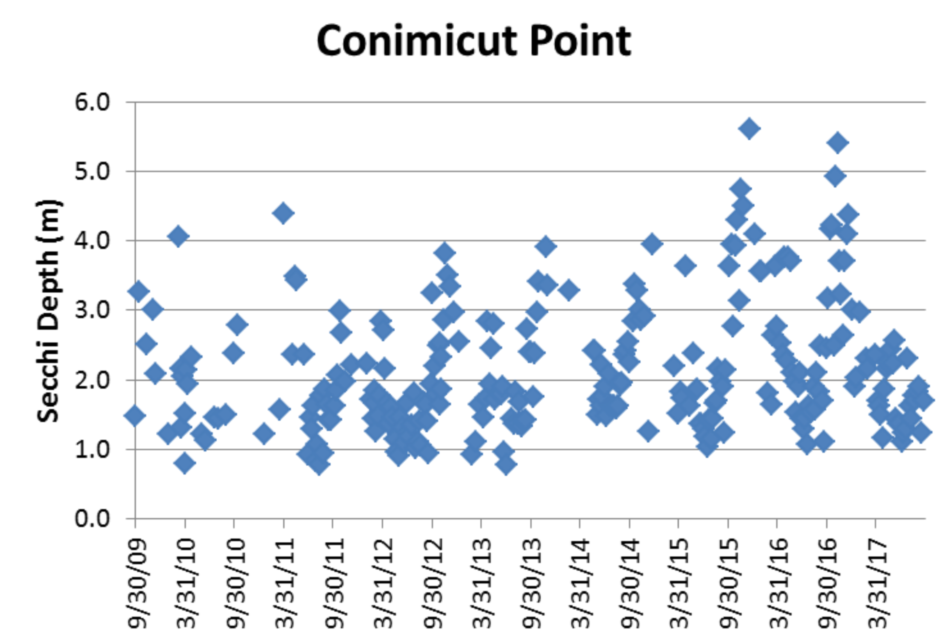
North → South

Toward Comprehensive Monitoring of Narragansett Bay

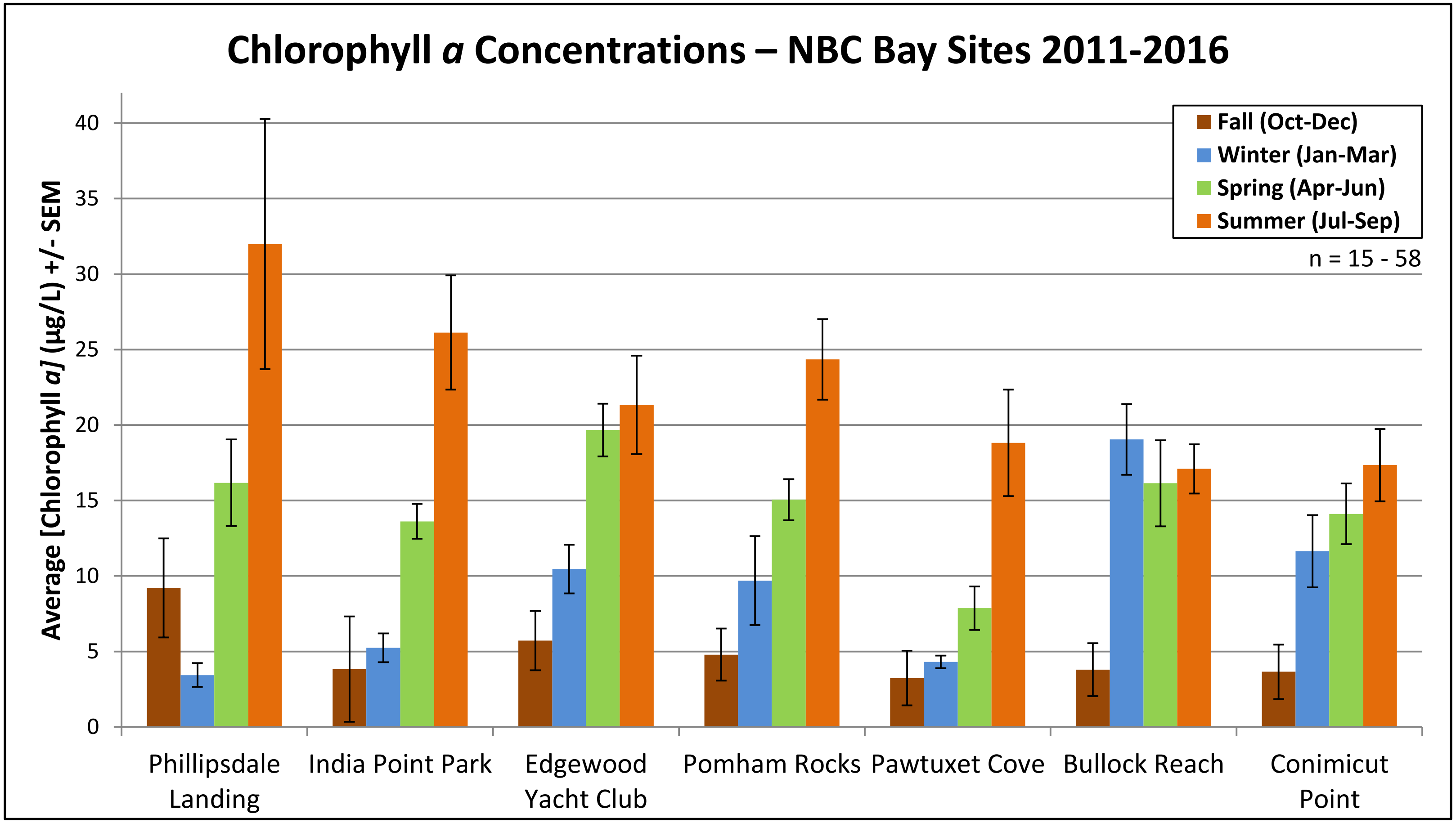
MONITORING RESULTS

- Is clarity increasing over time?
  - NBC data (2009-17) on a short time-scale
- Clarity high in 2016 (dry), reduced 2017 (more wet)





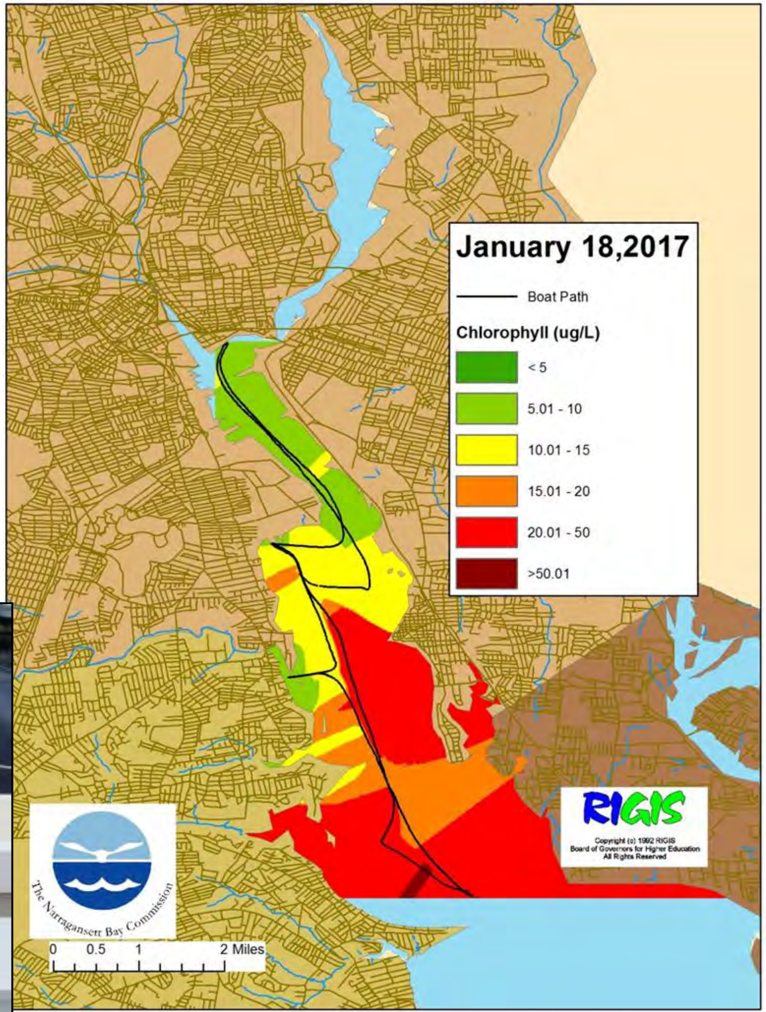
MONITORING RESULTS



North → South

MONITORING RESULTS

- Surface mapping
  - Data greatly interpolated for visibility
- General sense of bloom dynamics/variability



DATA AND FUTURE EFFORTS

- Monitoring will continue
  - Ratepayer funded - Board approval required annually
  - Only urban river bacteria & fixed-site monitoring mandated
- Data are publically available
  - http://snapshot.narrabay.com
  - Or request by email
- NBC's goal is that outside organizations will utilize and synthesize data in novel ways
  - NBC data used extensively in NBEP Status & Trends report

Carol Thornber
URI CELS

Macroalgae

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

CURRENT MONITORING OF MACROALGAL BLOOMS

Carol S. Thornber[1], Michele Guidone[1, 2], Christopher Deacutis[3], Lindsay Green[1], Christine N. Ramsay[4], Melissa Palmisciano[5]

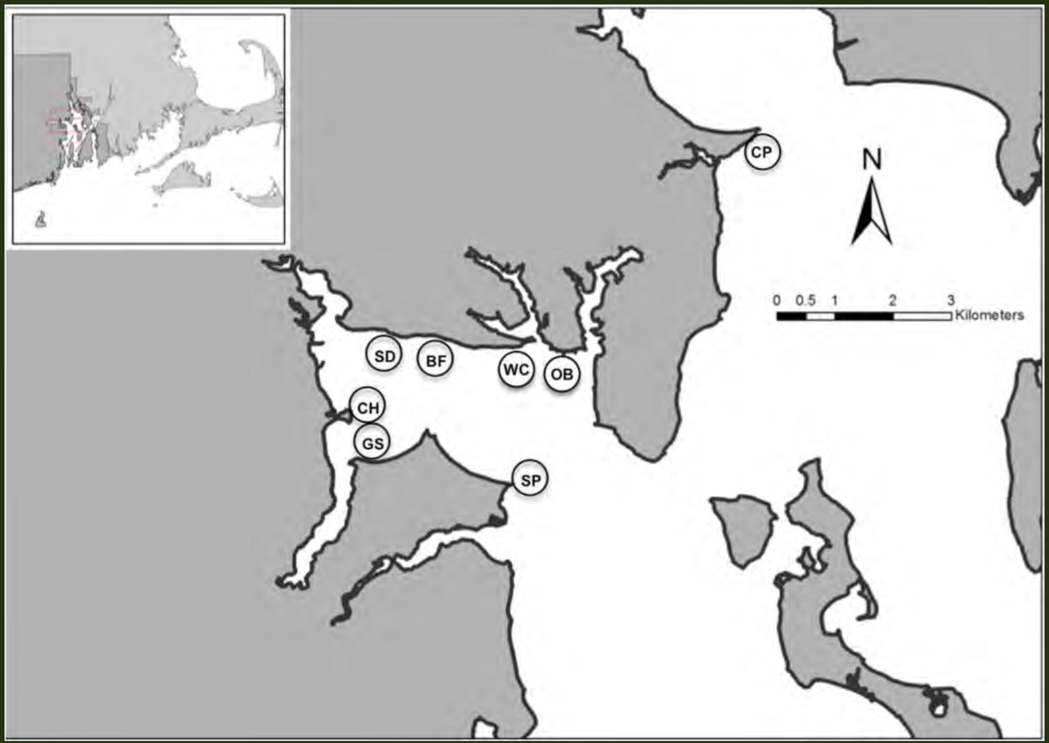
[1]Dept. of Natural Resources Science, University of Rhode Island; [2]Dept. of Biology, Armstrong State University; [3]Rhode Island Dept. of Environmental Management, Division of Fish and Wildlife; [4]Dept. of Life Sciences, Mitchell College; [5]Moss Landing Marine Labs

CURRENT MONITORING

- Macroalgal blooms
  - Aerial surveys: 2007-2012
  - Ground surveys: 2005-present (Greenwich Bay)
- Research questions:
  1. What is the spatial and temporal variability of macroalgal blooms?
  2. How will blooms change in response to N reduction from WWTPs?

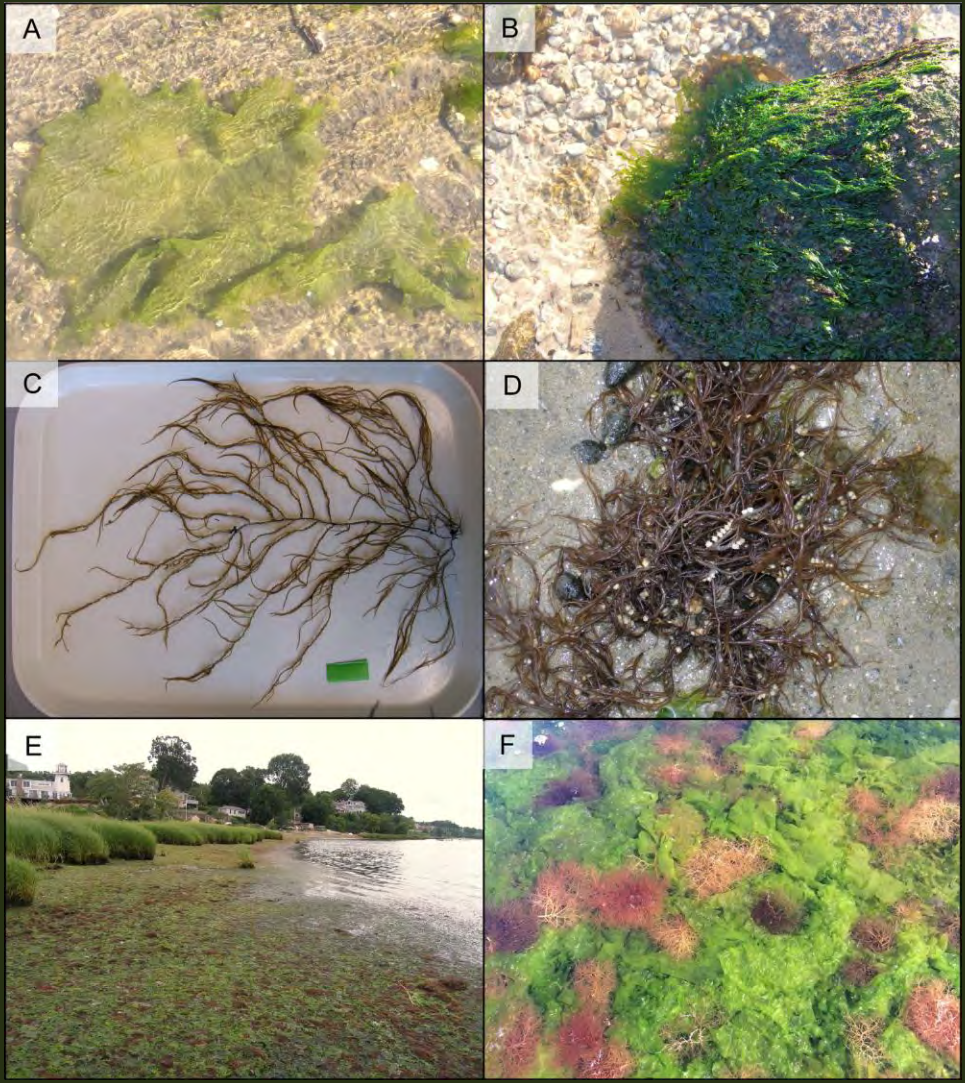
METHODS OVERVIEW

- Intertidal
  - 2 transects/site
  - 10 quadrats (0.25 m^2) per transect
  - % cover, biomass
- Subtidal
  - 10 "scoops" per site
  - Individual species biomass



NARRAGANSETT BAY ESTUARY PROGRAM

MONITORING RESULTS: KEY PLAYERS



- Blade-forming *Ulva* spp.
- Tubular *Ulva* spp.
- *Gracilaria* spp.

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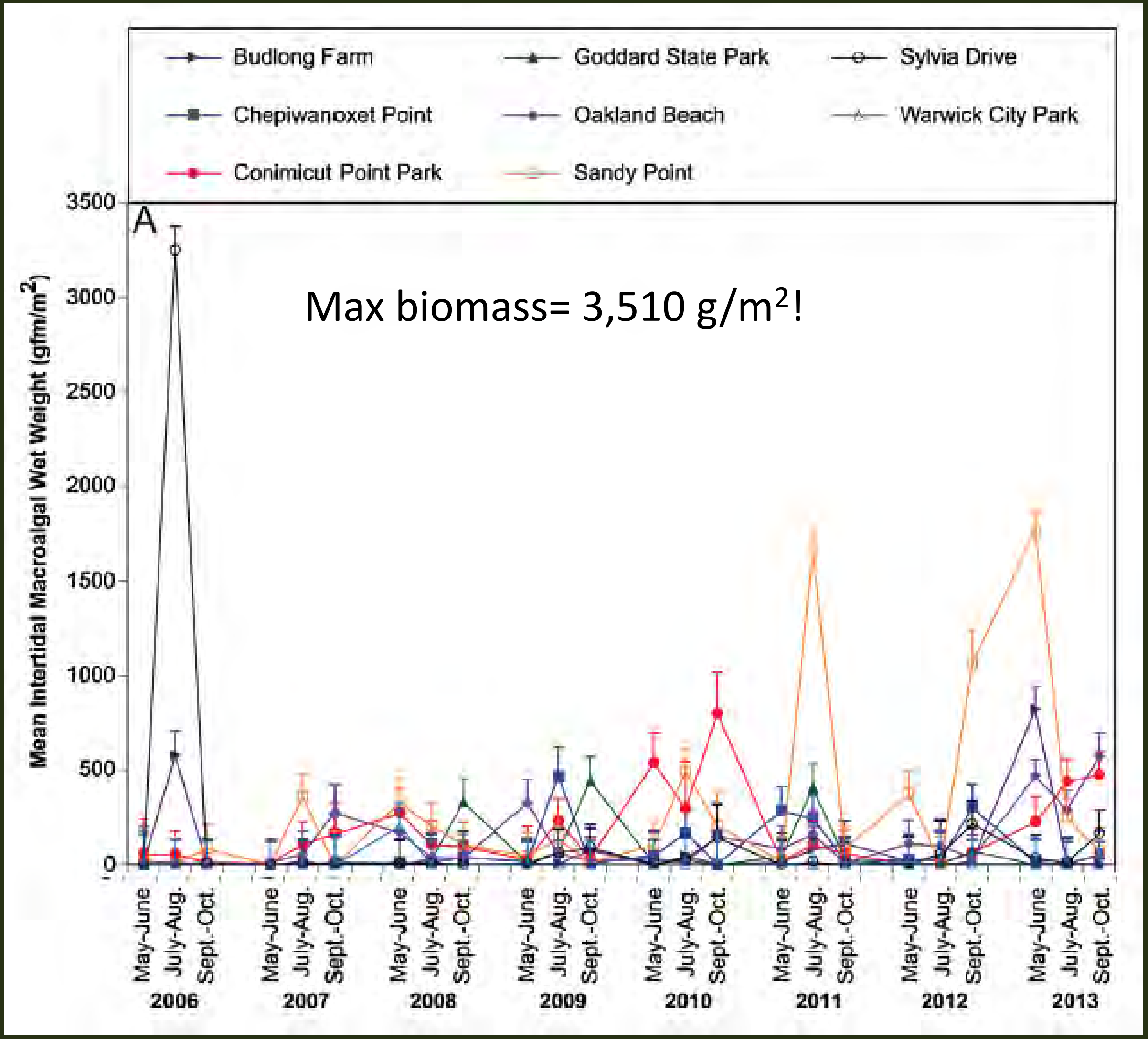
MONITORING RESULTS: INTERTIDAL



Huge spatial and temporal variability

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DEM
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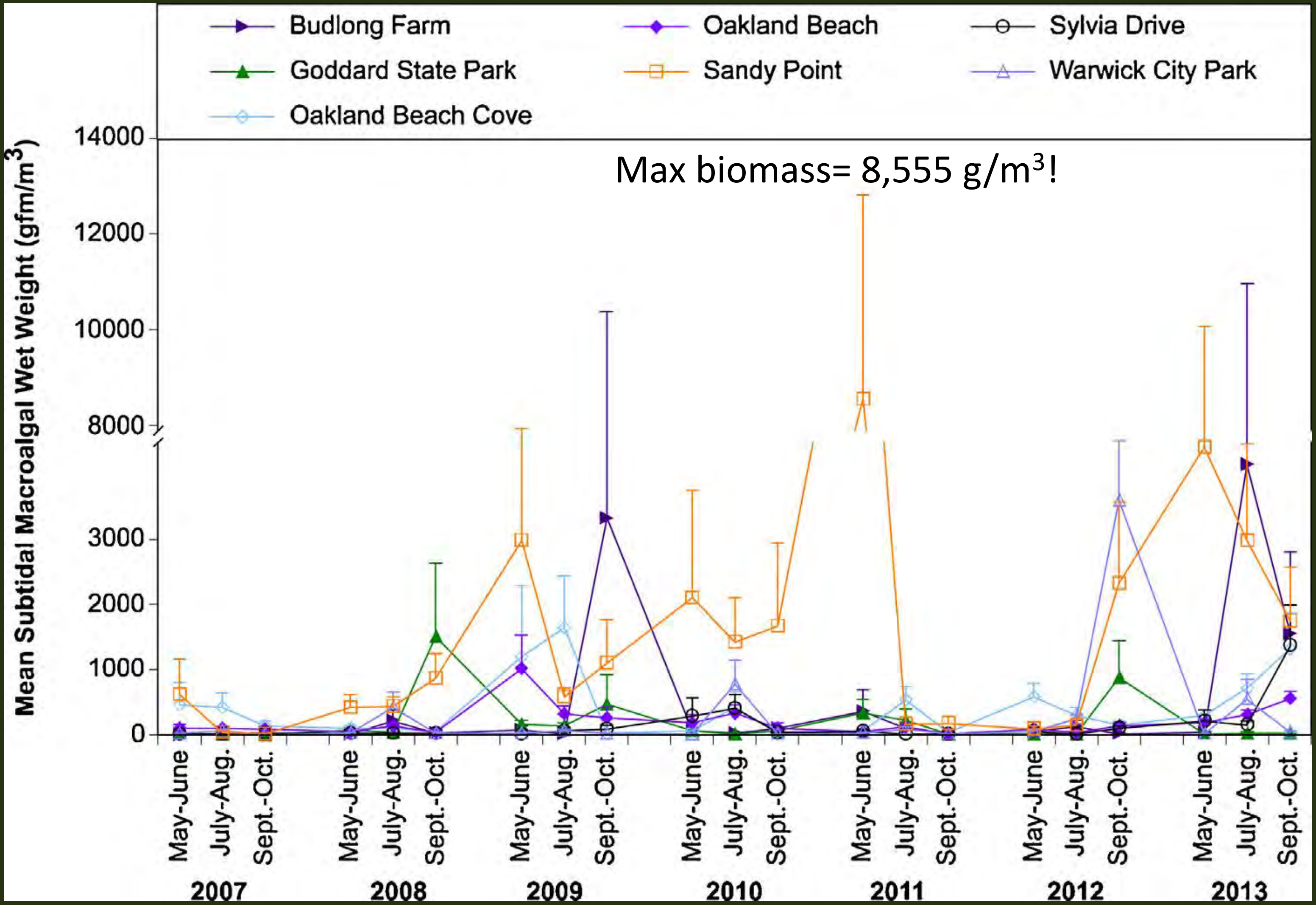
MONITORING RESULTS: SUBTIDAL



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DATA AND FUTURE EFFORTS

- Past collaborations with RI DEM
- Recently published in Harmful Algae with additional online resources available at

http://nbep.org/publications/NBEP-17-179.pdf

- Monitoring continues in order to understand changes as a result of climate change and N reductions

NARRAGANSETT BAY ESTUARY PROGRAM

David Borkman
RIDEM

HABs/Shellfish

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

CURRENT MONITORING

RI DEM & RI DOH HAB Monitoring

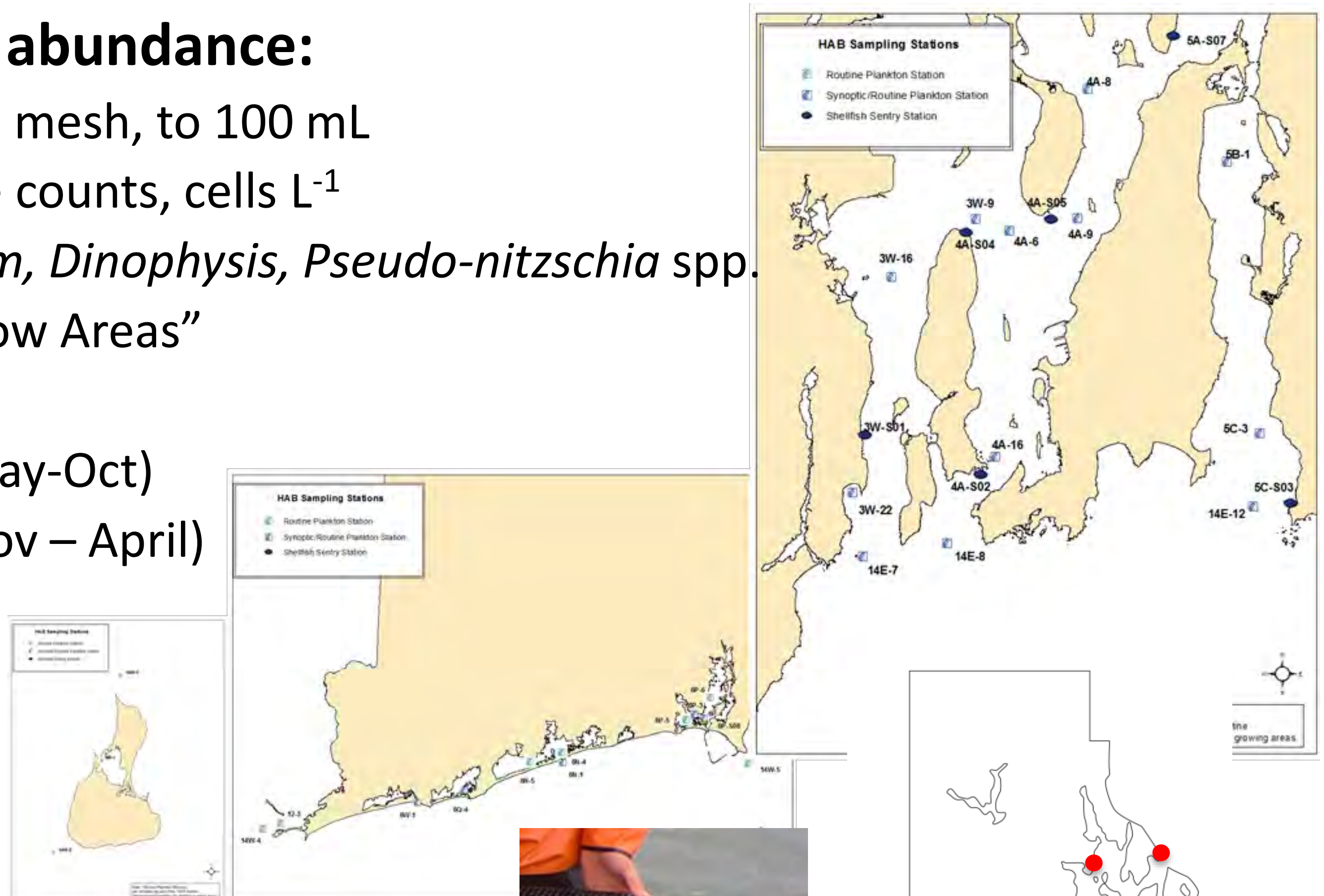
- Routine monitoring of HAB phytoplankton species that may result in shellfish biotoxin:
  - *Alexandrium (PSP), Dinophysis (DSP), Pseudo-nitzschia (ASP)*
- As needed monitoring of shellfish biotoxins
- Associated environmental data:
  - T, S, tide, weather

- Since 2016 (current program)
- Data use:
  - Regulatory compliance
    - (FDA, NSSP)
  - Public health

METHODS OVERVIEW

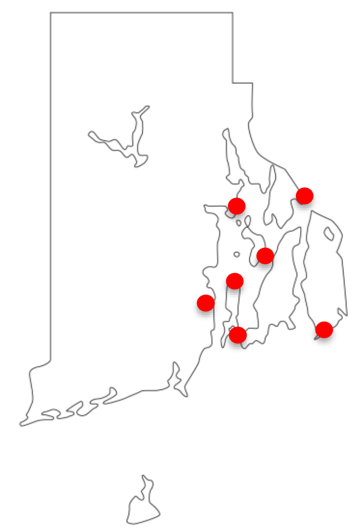
HAB phytoplankton abundance:

- 20 L seawater, 20 µm mesh, to 100 mL
- Light microscopy, live counts, cells L^{-1}
- HAB spp: *Alexandrium, Dinophysis, Pseudo-nitzschia* spp.
- 33 stations in 17 “Grow Areas”
- Sample year round
  - 2X per month (May-Oct)
  - 1X per month (Nov – April)
- 350-400 samples yr.



Shellfish biotoxins:

- 7 sentinel sites
- Shellfish tissue analysis
  - LC MS-MS (ASP)
  - Scotia screening (PSP, DSP)



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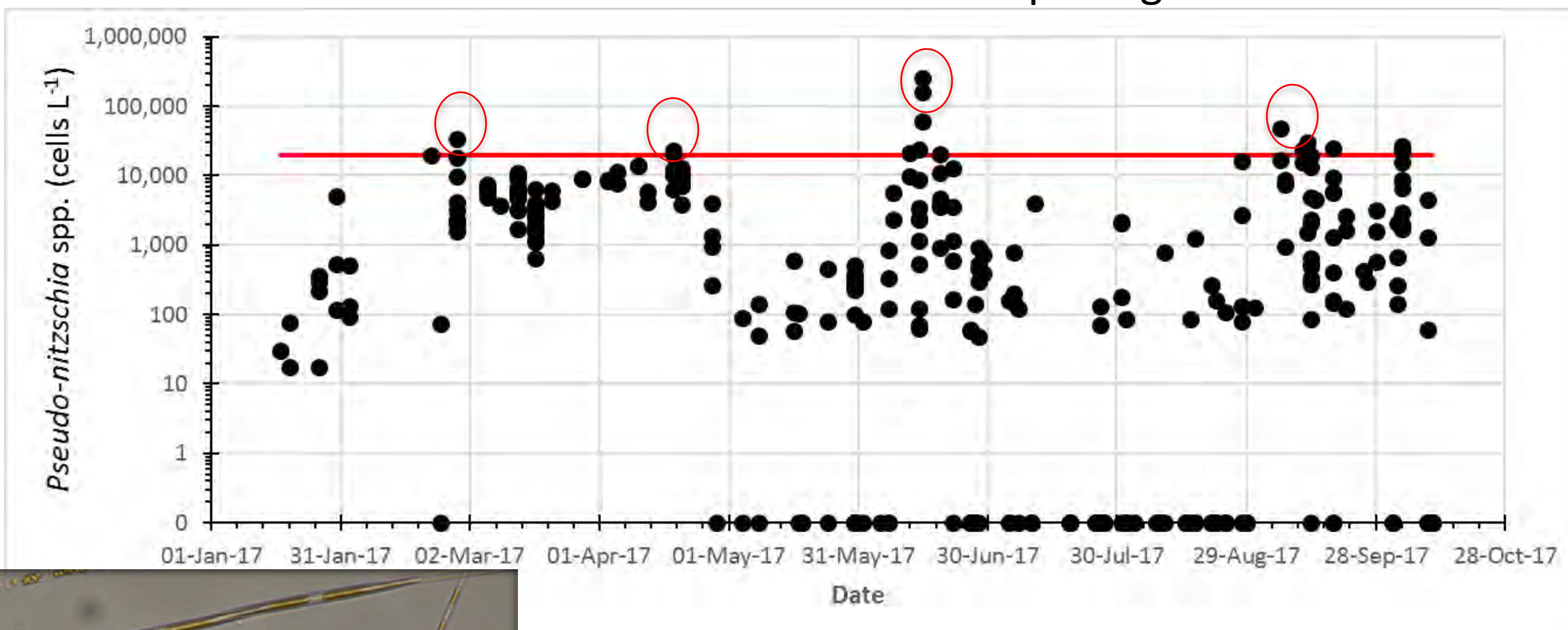
MONITORING RESULTS

HAB phytoplankton

- Early warning
- HAB cell abundance
- Biotoxin in plankton
- Biotoxin in shellfish

Shellfish tissue biotoxins

- Shellfish sentinel sites
- FDA biotoxin standards
- Open, precautionary, mandatory closure
- Reopening



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DATA AND FUTURE EFFORTS

- Data shared with:
  - RI DOH: closures, recalls
  - RI phytoplankton researchers: email list
  - Neighboring states
  - BART reports:(May-Sept) (http://www.dem.ri.gov/programs/emergencyresponse/bart/latest.php)
  - DEM website: (http://www.dem.ri.gov/programs/water/shellfish/)
- Funding:
  - No dedicated funding for RI HAB monitoring
- Monitoring changes:
  - 2017 HAB & Shellfish Biotoxin Monitoring and Contingency Plan (http://www.dem.ri.gov/programs/benviron/water/shellfsh/pdf/habplan.pdf)

Joe Zottoli
URI GSO

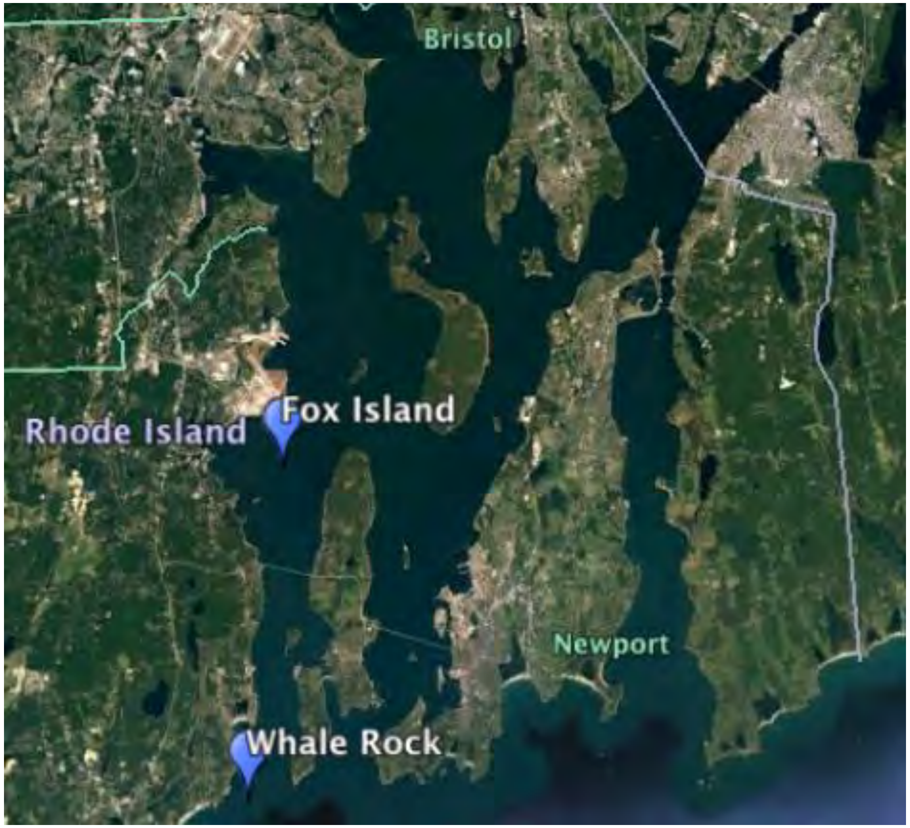
Fish

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

The URI/GSO Fish Trawl Survey

- Weekly (year-round) sampling conducted at 2 stations in Narragansett Bay since spring of 1959.
- Initially developed to quantify the seasonal occurrences of migratory fish populations.



Unique record of long-term community composition.

The fish-trawl data are used for:

- Environmental monitoring of Narragansett Bay;
- Stock assessments conducted by state and federal fisheries agencies;
- Scientific research projects.

An annual summary report highlighting notable information is submitted to RIDEM Marine Fisheries each winter.

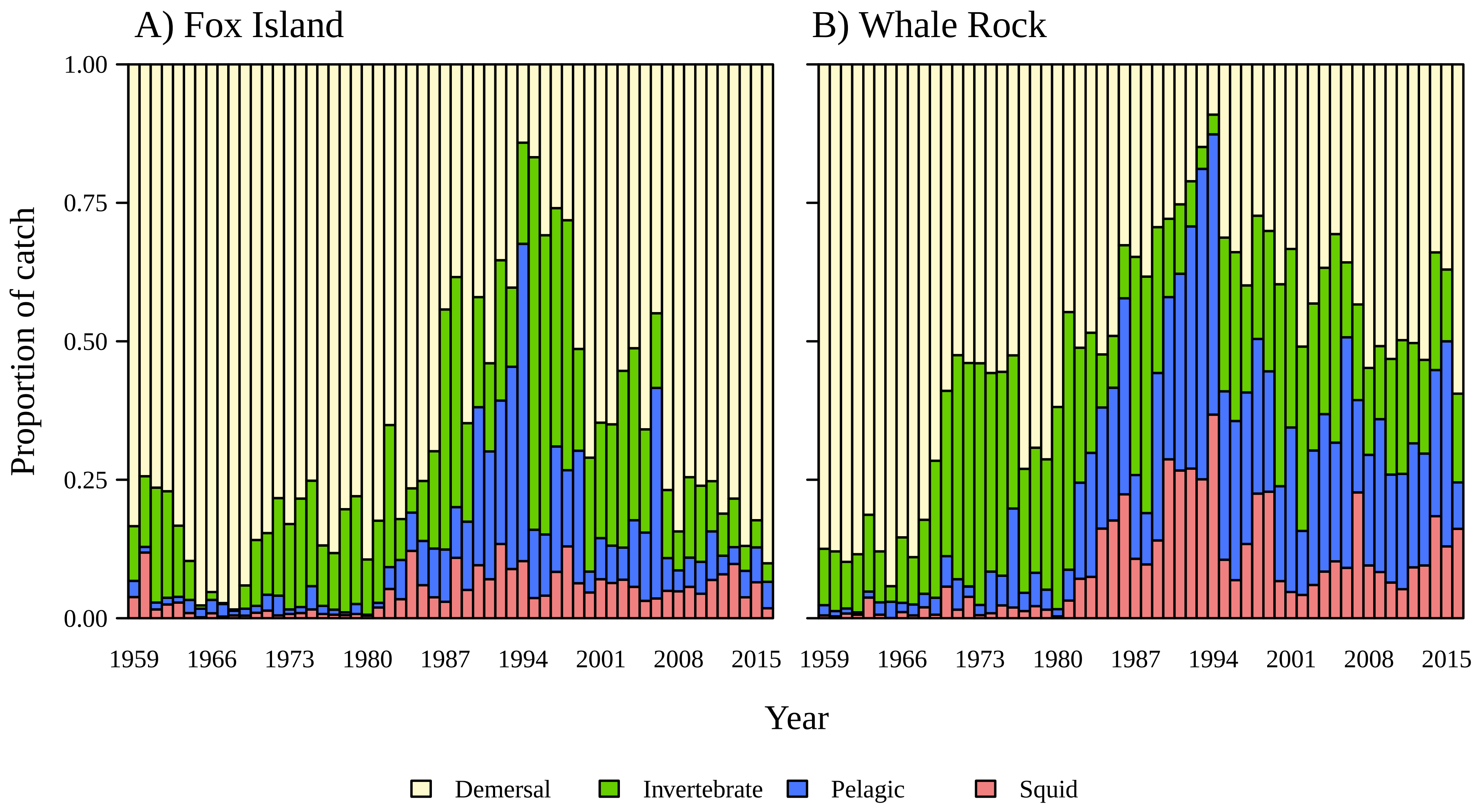
METHODS OVERVIEW

The weekly demersal otter trawl has been conducted at the same speed (2kts), time (morning), duration (30 min) and stations, with the same net dimensions (2” codend).

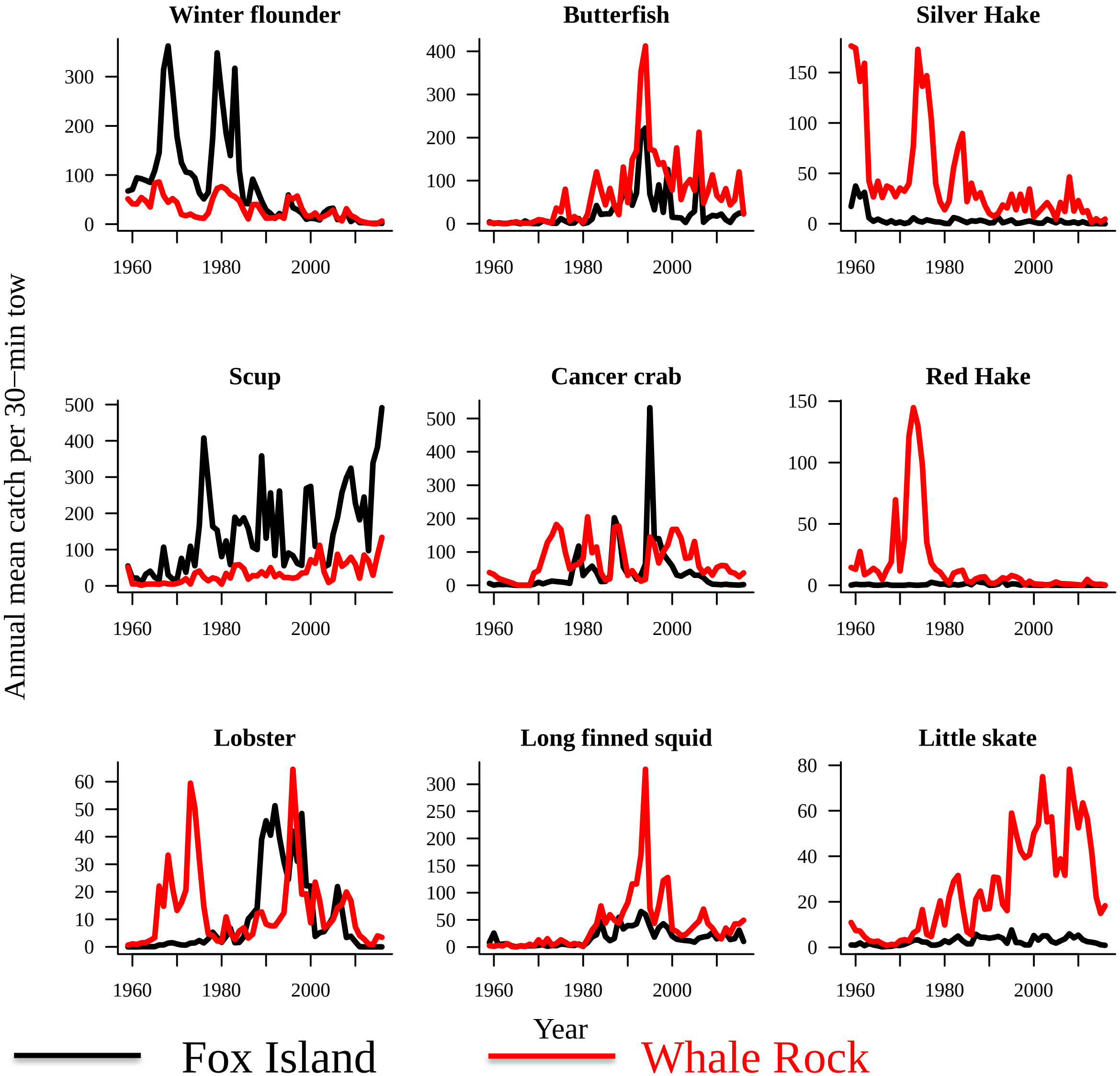
Data collection has expanded over time and now includes:

1. Abundance and Biomass of all fish and invertebrate species.
2. Lengths (50 individuals/species/tow max.)
3. Sex determination of winter flounder, *Pseudopleuronectes americanus*.
4. Surface and bottom temperature, dissolved oxygen, and salinity at each survey site are measured with a YSI Sonde.

Community composition shifted from demersal to pelagic species in the 1980s



MONITORING RESULTS



Losers:

- Winter flounder
- Silver Hake
- Red Hake

Winners:

- Butterfish
- Scup
- Cancer crab
- Long finned squid
- Little skate

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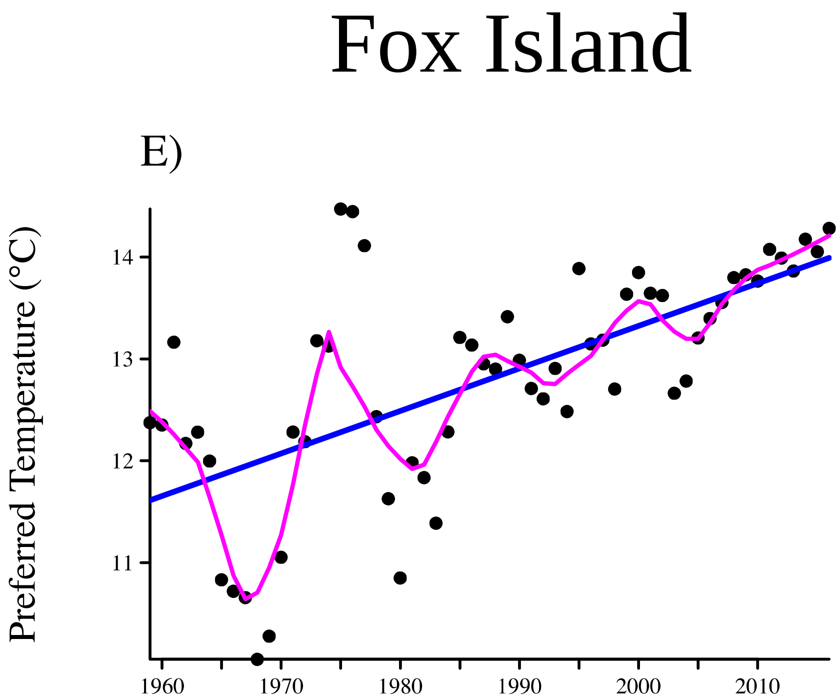
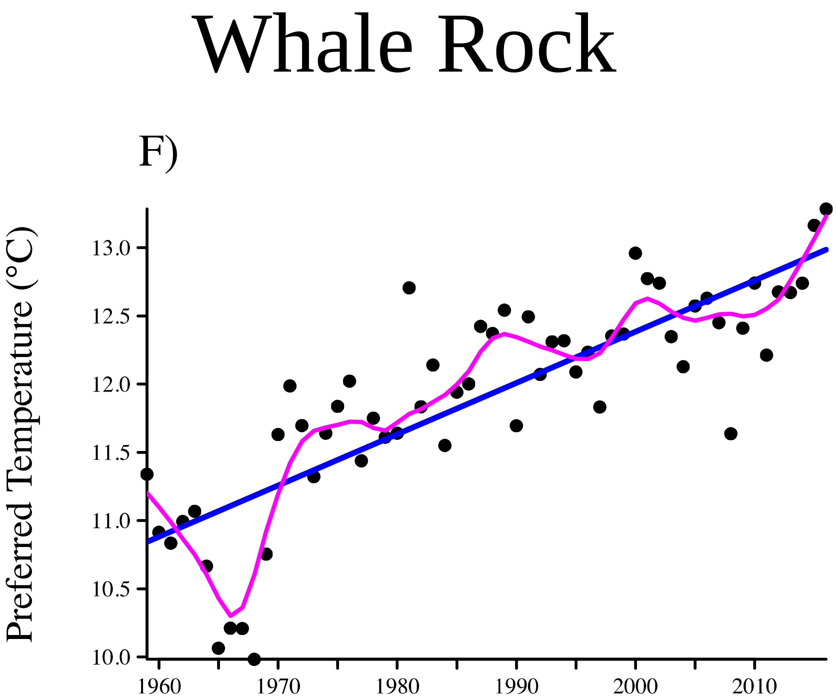
The preferred temperature of the fish community continues to increase





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DATA AND FUTURE EFFORTS

- Summary data are provided on the Fish Trawl website: https://web.uri.edu/fishtrawl/
- Weekly data on individual species are available through customized queries by request.
- Much of the hydrographic data is available online at the fish trawl website
- In addition to the annual report all raw data since 2014 have been submitted to RIDEM Marine Fisheries and updated yearly.
- Data have been used in numerous publications, fish stock assessments, and articles.
- Funding is provided through a URI/DEM partnership.

Q Kellogg
URI Coastal Institute

New Data Synthesis/Tools

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

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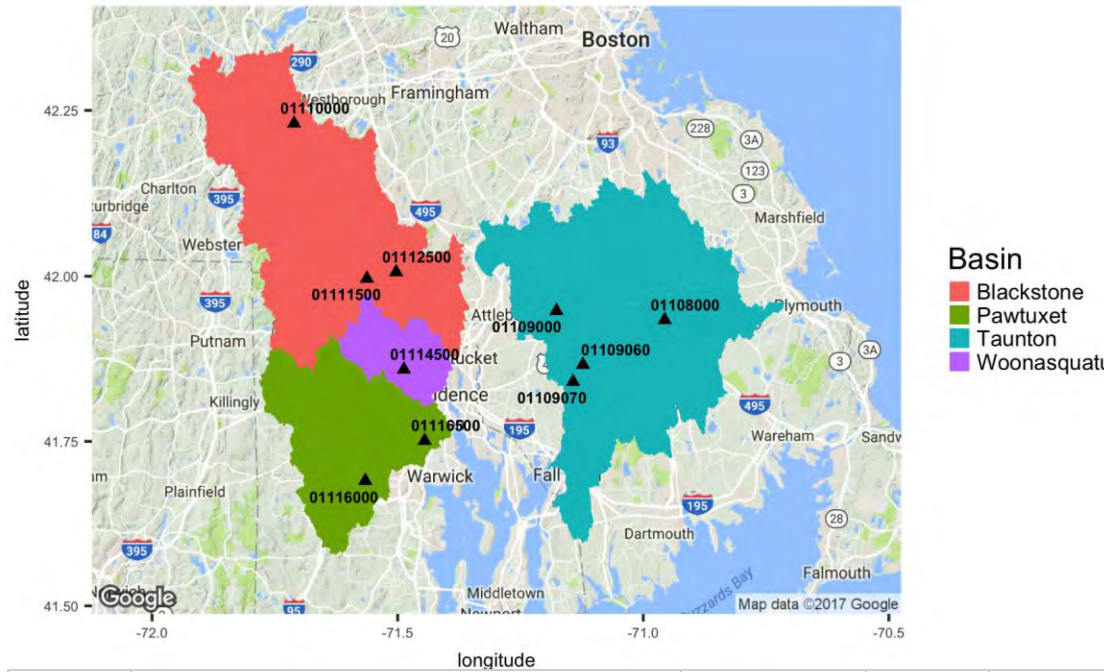
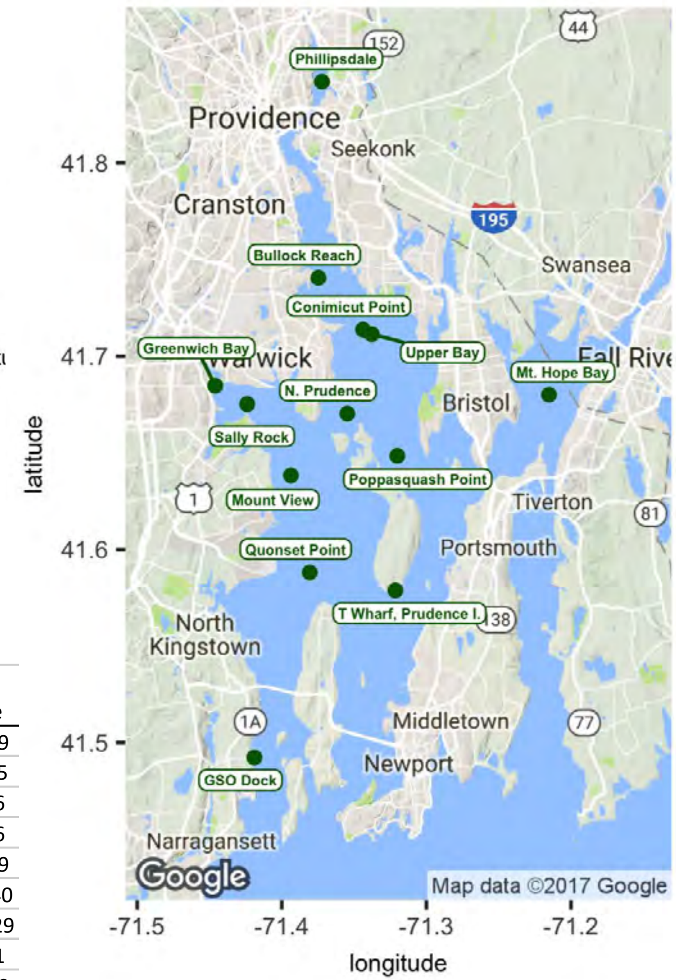
CURRENT MONITORING/ANALYSIS

USGS Stream Gages



Gage ID	Name	Basin	Drainage Area (mi^2)	Start Date
1108000	TAUNTON RIVER NEAR BRIDGEWATER, MA	Taunton	261	1-Oct-1929
1109000	WADING RIVER NEAR NORTON, MA	Taunton	43.3	1-Jun-1925
1109060	THREEMILE RIVER AT NORTH DIGHTON, MA	Taunton	84.3	1-Jul-1966
1109070	SEGREGANSET RIVER NEAR DIGHTON, MA	Taunton	10.6	1-Jul-1966
1110000	QUINSIGAMOND RIVER AT NORTH GRAFTON, MA	Blackstone	25.6	1-Oct-1939
1111500	BRANCH RIVER AT FORESTDALE, RI	Blackstone	91.2	24-Jan-1940
1112500	BLACKSTONE RIVER AT WOONSOCKET, RI	Blackstone	416	22-Feb-1929
1114500	WOONASQUATUCKET RIVER AT CENTERDALE, RI	Woonasquatucket	38.3	9-Jul-1941
1116000	SOUTH BRANCH PAWTUXET RIVER AT WASHINGTON, RI	Pawtuxet	62.8	1-Oct-1940
1116500	PAWTUXET RIVER AT CRANSTON, RI	Pawtuxet	200	6-Dec-1939

Narragansett Bay Fixed Sites



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METHODS OVERVIEW

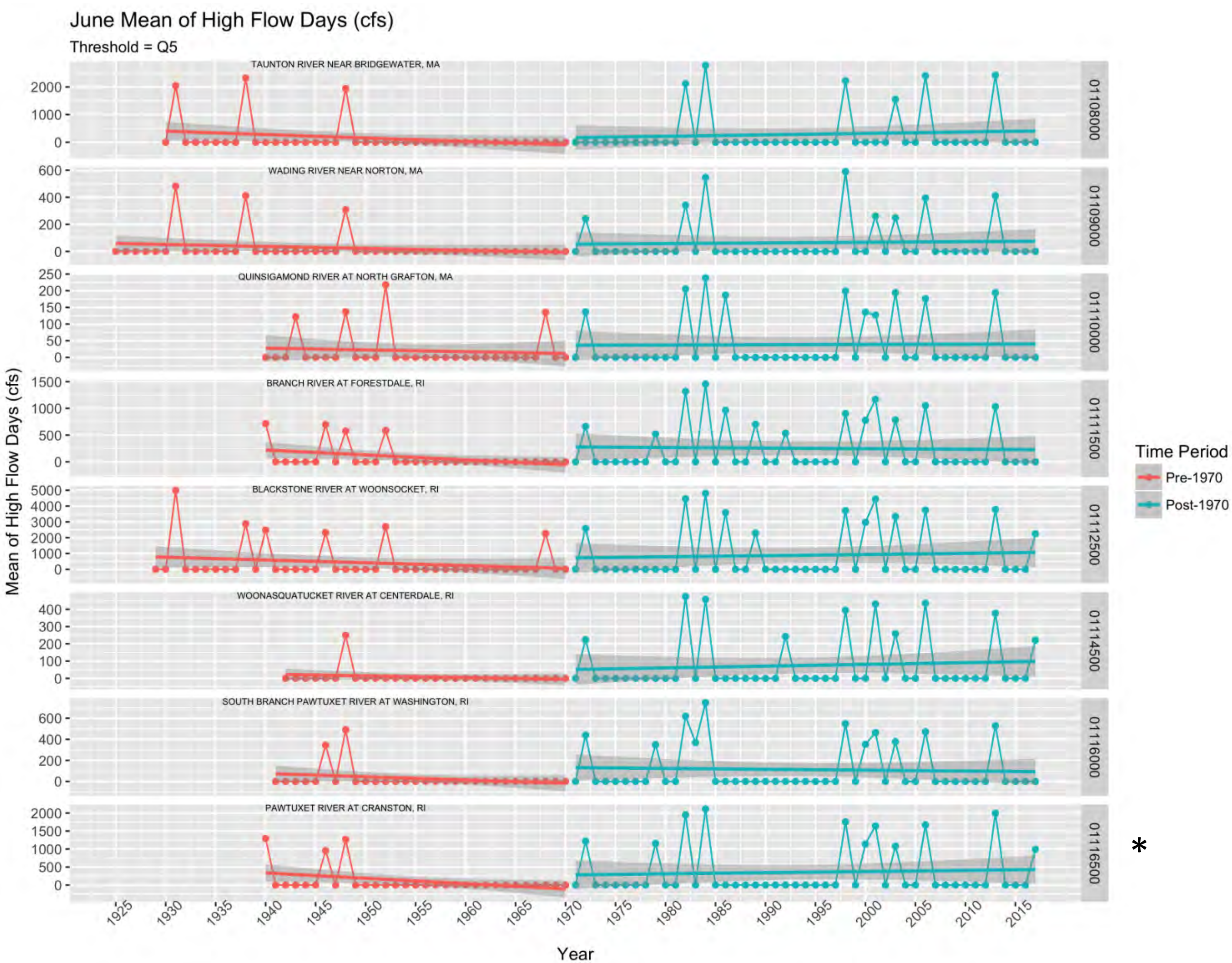
- Questions
  - Has river flow to Narragansett Bay changed over the last 50+ years? Have high flow days/events changed in frequency or magnitude?
  - Can we predict hypoxia events in Narragansett Bay?
    - Correlation with conditions preceding events?
      - River flow, water temperature, Chl a concentrations
      - Implications for the future given trends in river flow
- Tools
  - R open source software
    - Active and growing international R community
    - Packages constantly being developed & improved
      - USGS packages facilitate USGS gage data analyses
        - » dataRetrieval, EGRET
    - Lots of ways to learn and keep learning
      - rhodyRstats, MOOCs (e.g., Coursera), online fun stuff (e.g., R for Cats)

RESULTS/FUTURE PLANS

% change in annual hydrologic measures for the period of record
Shaded values are statistically significant at $p < 0.1$

USGS Gage Name	USGS Gage ID	Start Year	1-day Min	7-day Min	30-day Min	Median	Mean	30-day Max	7-day Max	1-day Max
ANNUAL – START YEAR to 2016										
TAUNTON RIVER NEAR BRIDGEWATER, MA	01108000	1931	74	58	29	18	20	20	5.4	-1.1
WADING RIVER NEAR NORTON, MA	01109000	1927	-29	-50	-43	2.1	4.7	20	17	14
THREEMILE RIVER AT NORTH DIGHTON, MA	01109060	1968	-59	-58	-49	-17	-13	-12	-20	-17
SEGREGANSET RIVER NEAR DIGHTON, MA	01109070	1968	-61	-73	-79	-23	-10	-12	-23	-30
QUINSIGAMOND RIVER AT NORTH GRAFTON, MA	01110000	1941	-80	-69	-17	16	11	33	39	78
BRANCH RIVER AT FORESTDALE, RI	01111500	1941	-29	-52	-48	-0.043	4.5	29	32	44
BLACKSTONE RIVER AT WOONSOCKET, RI	01112500	1930	98	-25	-18	28	17	20	8.8	11
WOONASQUATUCKET RIVER AT CENTERDALE, RI	01114500	1943	1.7	-58	-58	15	16	54	57	84
SO. BRANCH PAWTUXET RIVER AT WASHINGTON, RI	01116000	1942	173	-17	-20	13	12	22	30	32
PAWTUXET RIVER AT CRANSTON, RI	01116500	1941	102	-39	-26	0.17	8.8	30	62	57

RESULTS/FUTURE PLANS



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CHANGES/IMPROVEMENTS

- Build on previous work (e.g., Codiga et al., 2009) using additional 10 years of fixed-site data, combined with long-term USGS gage data.
  - Trends analyses can help us better understand how climate change may influence the frequency and severity of hypoxia events in Narragansett Bay.

- Publish reports online using R Markdown
  - Allows data and R code to be accessed by readers
    - reproducible research!

Colleen Mouw
URI GSO

New Data Collection/Technology

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

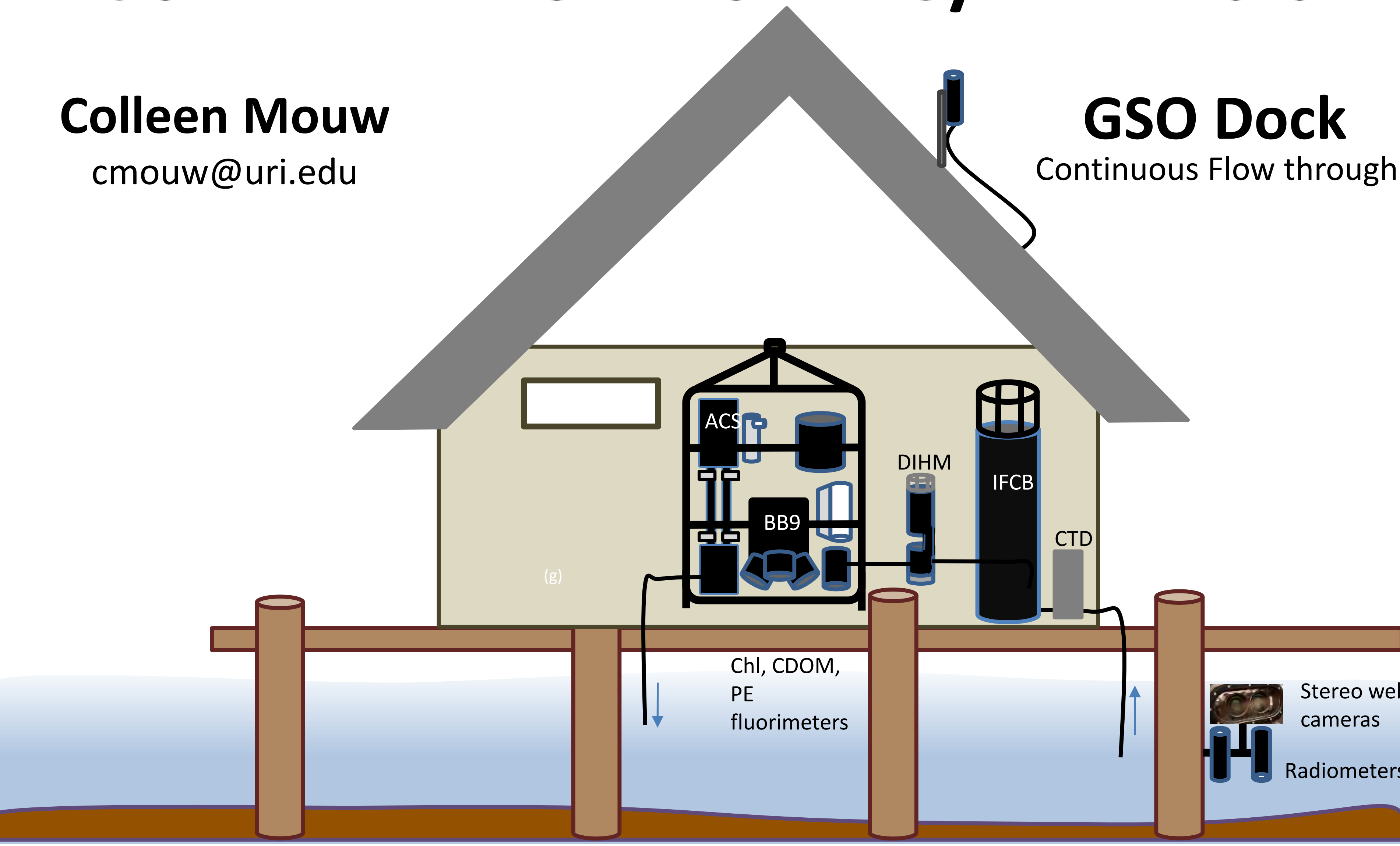
RIEMC D·E·M COASTAL INSTITUTE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY NARRAGANSETT BAY ESTUARY PROGRAM

CURRENT MONITORING/ANALYSIS

Colleen Mouw
cmouw@uri.edu

GSO Dock

Continuous Flow through



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METHODS OVERVIEW

Particle Imaging:

Imaging flow CytoBot

Digital In-line Holographic Microscope

Temperature / Salinity

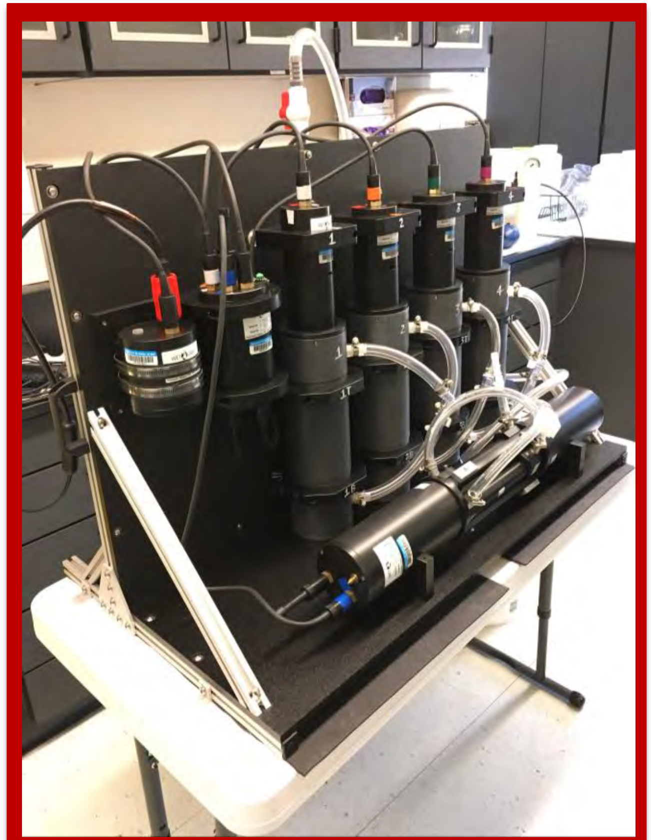
Absorption

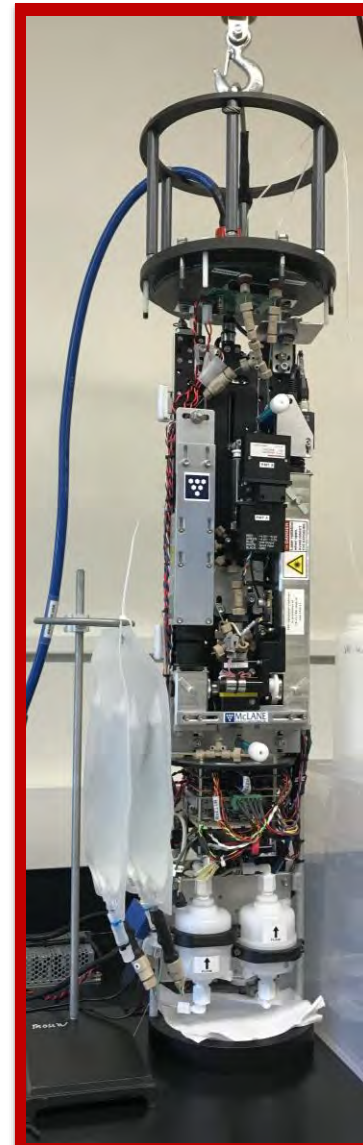
Scattering

Chl, CDOM, PE Fluorescence

Radiometry

Stereo Web Cameras





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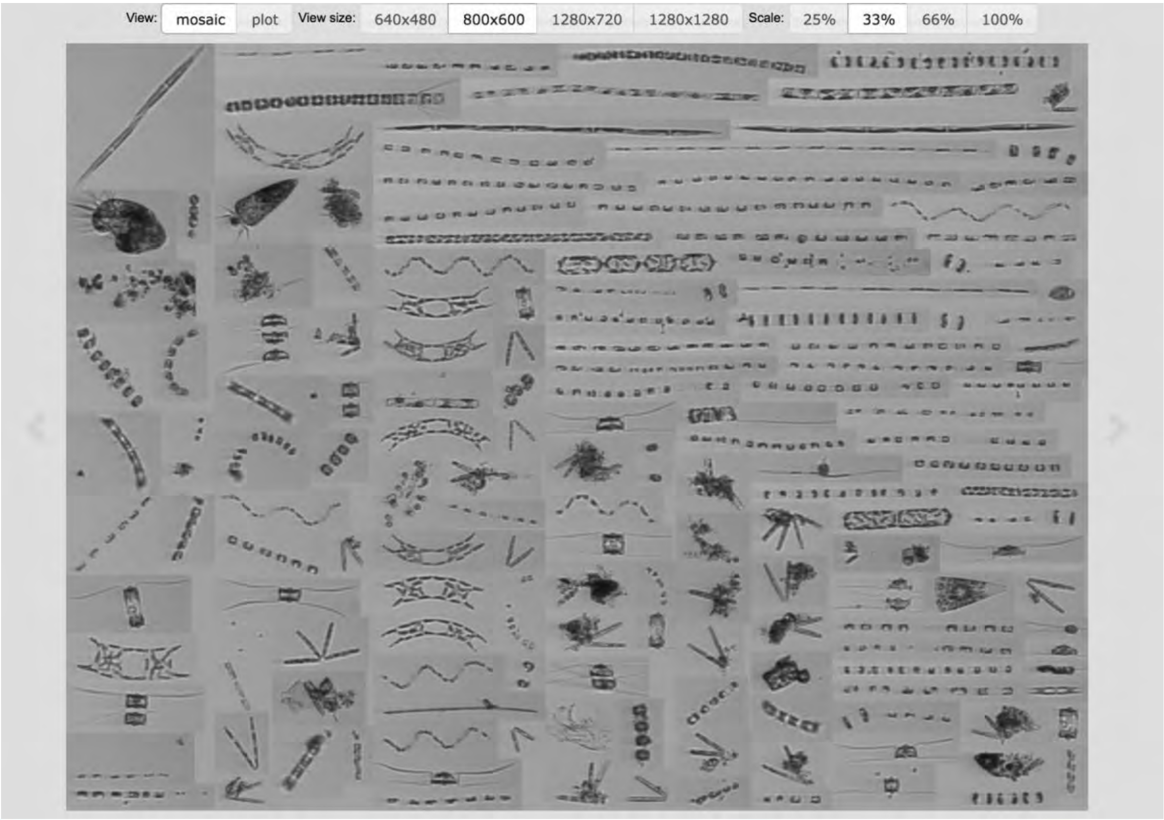
RESULTS/FUTURE PLANS

- Data sharing: http://phyto-optics.gso.uri.edu:8888



2 year continuous operation

Funding

Rhode Island Sea Grant

RIEMC DEM COASTAL INSTITUTE NARRAGANSETT BAY ESTUARY PROGRAM

ADOPTION

How can this technology/data stream be helpful?

– Development of optical relationships for remote sensing development/validation

– Phytoplankton/HAB identification/monitoring

– Non-algal particle (turbidity) quantification

– CDOM variability

– Light availability/attenuation

– Real-time "view" of water column conditions

Bethany Jenkins
URI CELS, EPSCoR

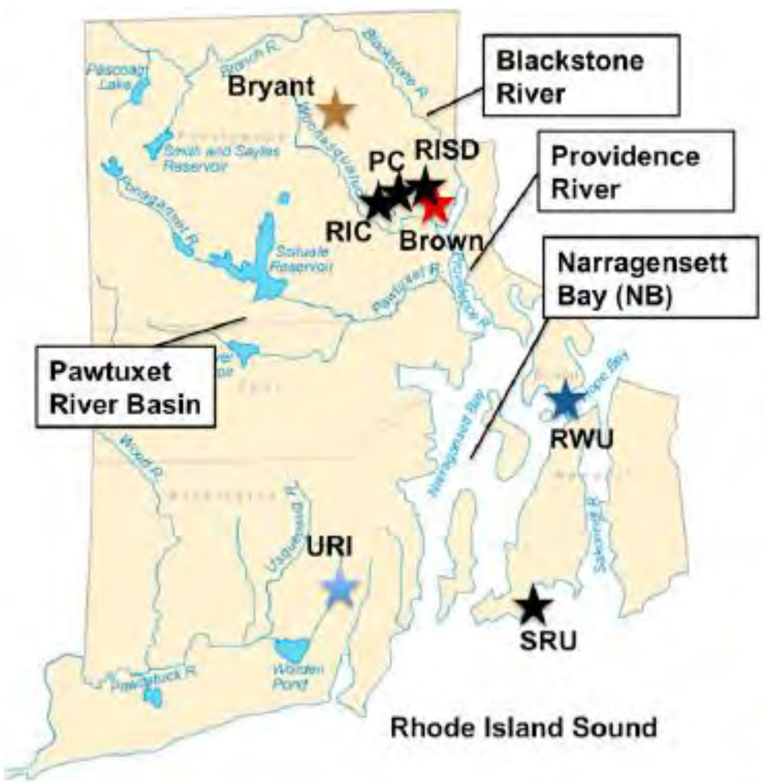
Comprehensive Efforts

Toward Comprehensive Monitoring of Narragansett Bay

October 19, 2017

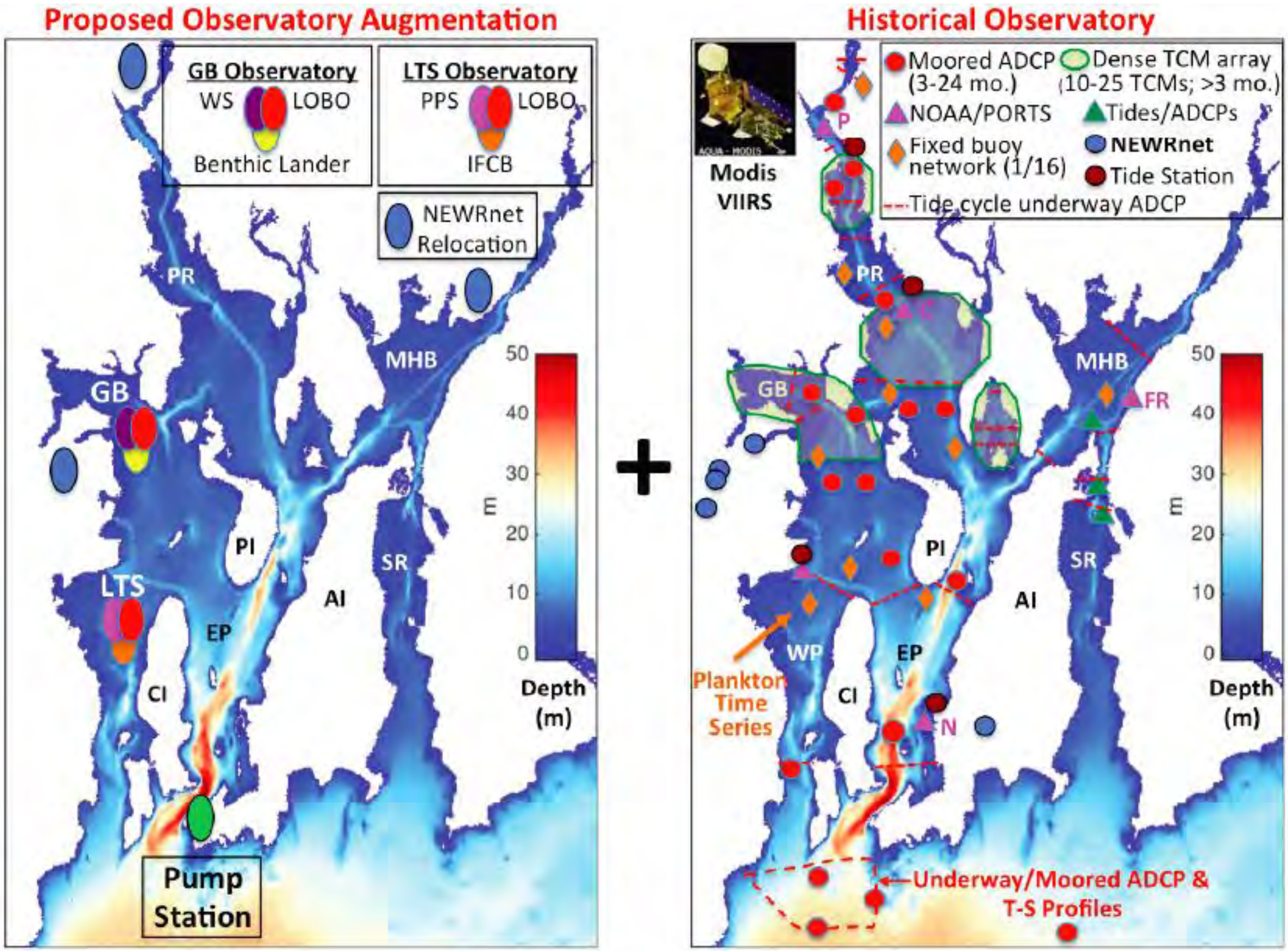
NEW RI EPSCOR C-AIM

$19 million NSF grant to establish a statewide research consortium — the RI Consortium for Coastal Ecology Assessment, Innovation, and Modeling (RI C-AIM) — to study the effects of climate variability on coastal ecosystems (i.e. Narragansett Bay) Dr. Geoff Bothun URI lead PI



Rhode Island
NSF EPSCoR

NEW MONITORING-Bay Observatory



BIOGEOCHEMICAL MONITORING

Satlantic LOBO real time wireless transmission of physical and chemical parameters

BIOGEOCHEMICAL MONITORING

Real Time biogeochemical data from LOBO array

LOBO Land/Ocean Biogeochemical Observatory

HOME LOBOVIZ WIRELESS GE CGI ABOUT CONFIG CONTACT

Latest

Murderkill Estuary
2017-09-17 11:00:00 EST

Battery Voltage	13.0	V
CDOM	13.04	QSDE
Chlorophyll	9.22	µg/L
Conductivity	3.50	S/m
Depth	2.390	m
Nitrate	22.2	µM
Nitrate	0.311	mg/L
Dissolved O_2	7.68	mg/L
Dissolved O_2	240.10	µM
O_2% Saturation	103.30	%
Phosphate	1.30	µM
Phosphate	40.36	µg/L
Salinity	22.71	PSU
Temperature	23.52	°C
Turbidity	16.10	NTU

Google EARTH WAP Device

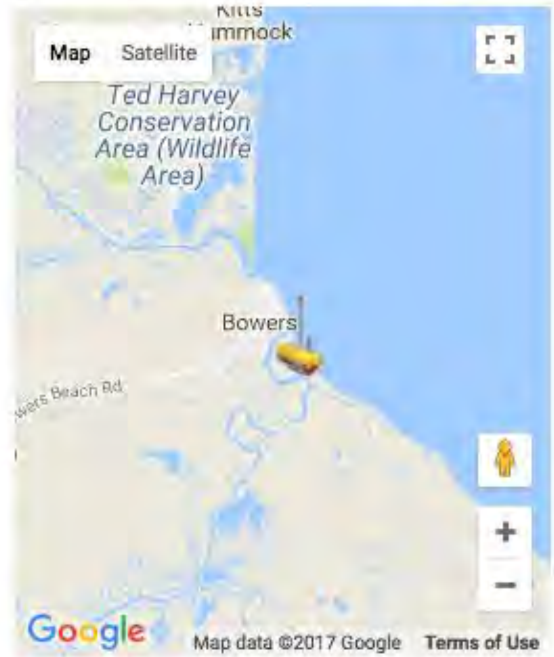
All data is provisional.

LOBO-0031 Murderkill Estuary at Bowers, Delaware

Murderkill Estuary at Bowers, Delaware looking east toward Delaware Bay

The Murderkill Estuary is located in Kent County, Delaware, and drains to Delaware Bay at Bowers, Delaware. The 275 km^2 watershed is primarily agricultural (55%) but has 11% forest cover, 17% wetland cover (including forested wetlands), and 14% is builtup. This estuary receives water and associated nutrients from its watershed, its airshed, and from the Kent County Regional Wastewater Treatment Facility (KCRWTF). The KCRWTF receives wastewater from urban and suburban areas both within and outside of the Murderkill Watershed, including the cities of Dover and Smyrna, to the north, and Milford, to the south, serving a population of about 130,000. Thus, nutrient loading to the Murderkill Estuary represents both the population and land use of its own watershed and an additional larger and more urban source area. This site is operated by the University of Delaware in collaboration with the Delaware Department of Natural Resources and Environmental Control, US Geological Survey, and the Kent County Department of Public Works in order to monitor the estuarine response to nutrient management activities in the watershed.

39° 03' 29.9" N 75° 23' 51.4" W

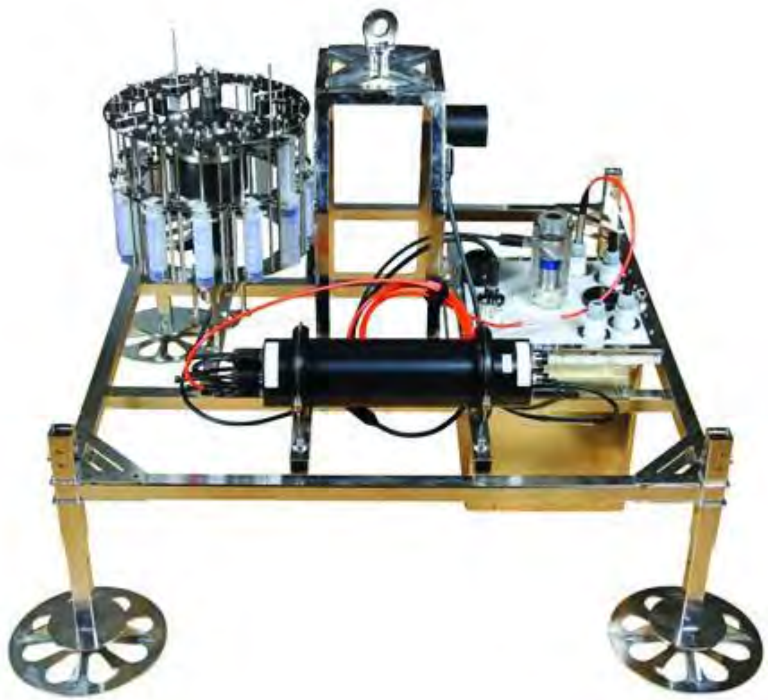


Archived Data

RIEMC COASTAL INSTITUTE NARRAGANSETT BAY ESTUARY PROGRAM

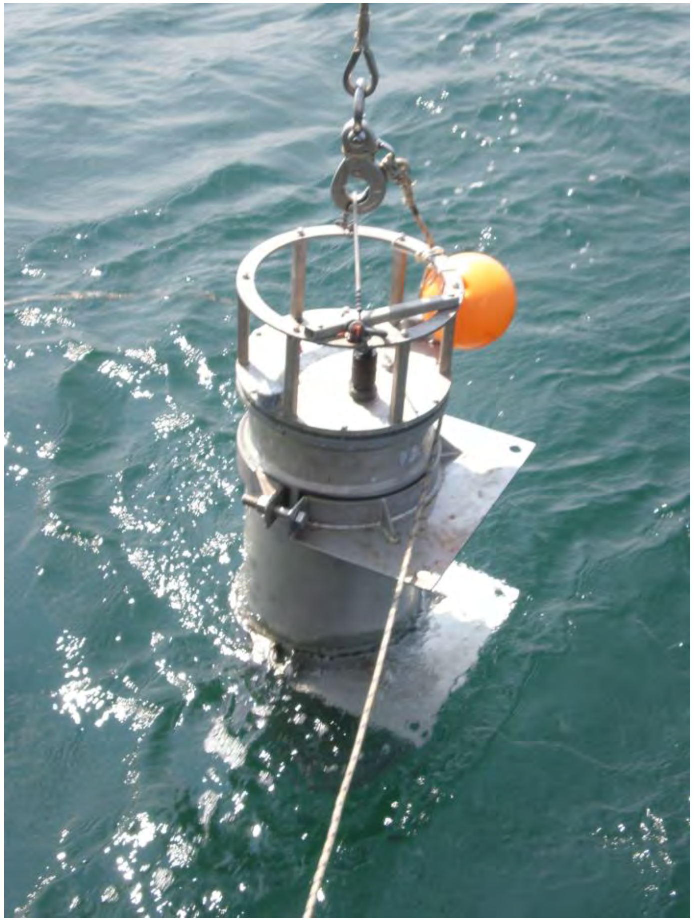
BENTHIC FLUX MONITORING

Benthic lander for measuring nutrient fluxes out of sediments



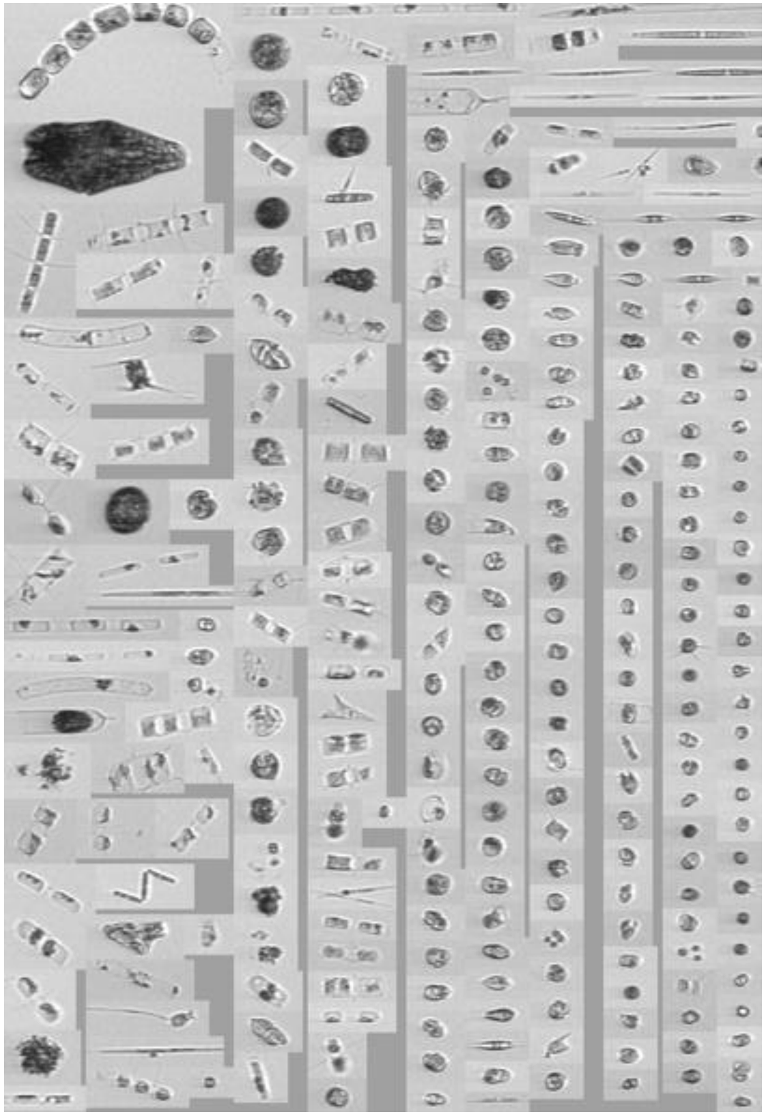
The MiniChamber Lander can measure shallow-water with multiple microsensors (oxygen, H_2, N_2O, pH, H_2S) mounted in the chamber lid.

BIODIVERSITY MONITORING



Imaging flow cytobot (IFCB) for real time images of plankton (floating cells)

BIODIVERSITY MONITORING



Plankton imaged on a FlowCytobot on a recent cruise in the Atlantic, May 2017

RIEMC · DEM · COASTAL INSTITUTE · NARRAGANSETT BAY ESTUARY PROGRAM

EVENT TRIGGERED SAMPLING

Long term goal: event triggered sampling off the LOBO and IFCB for archived biomass for downstream genetic analysis…e.g. preserve water sample when NO_3^- is higher than 40 µm and there are chain forming diatoms in the water

BRIEF DESCRIPTION:

The Phytoplankton Sampler (PPS) is an autonomous particulate sampler that filters up to 24 individual water samples through 47mm filters. Samples are collected in user-defined time series to collect trace metals, phytoplankton and suspended particles. The patented multi-port valve isolates individual samples and distributes water directly to the filter before passing through a pump.

FUTURE PLANS

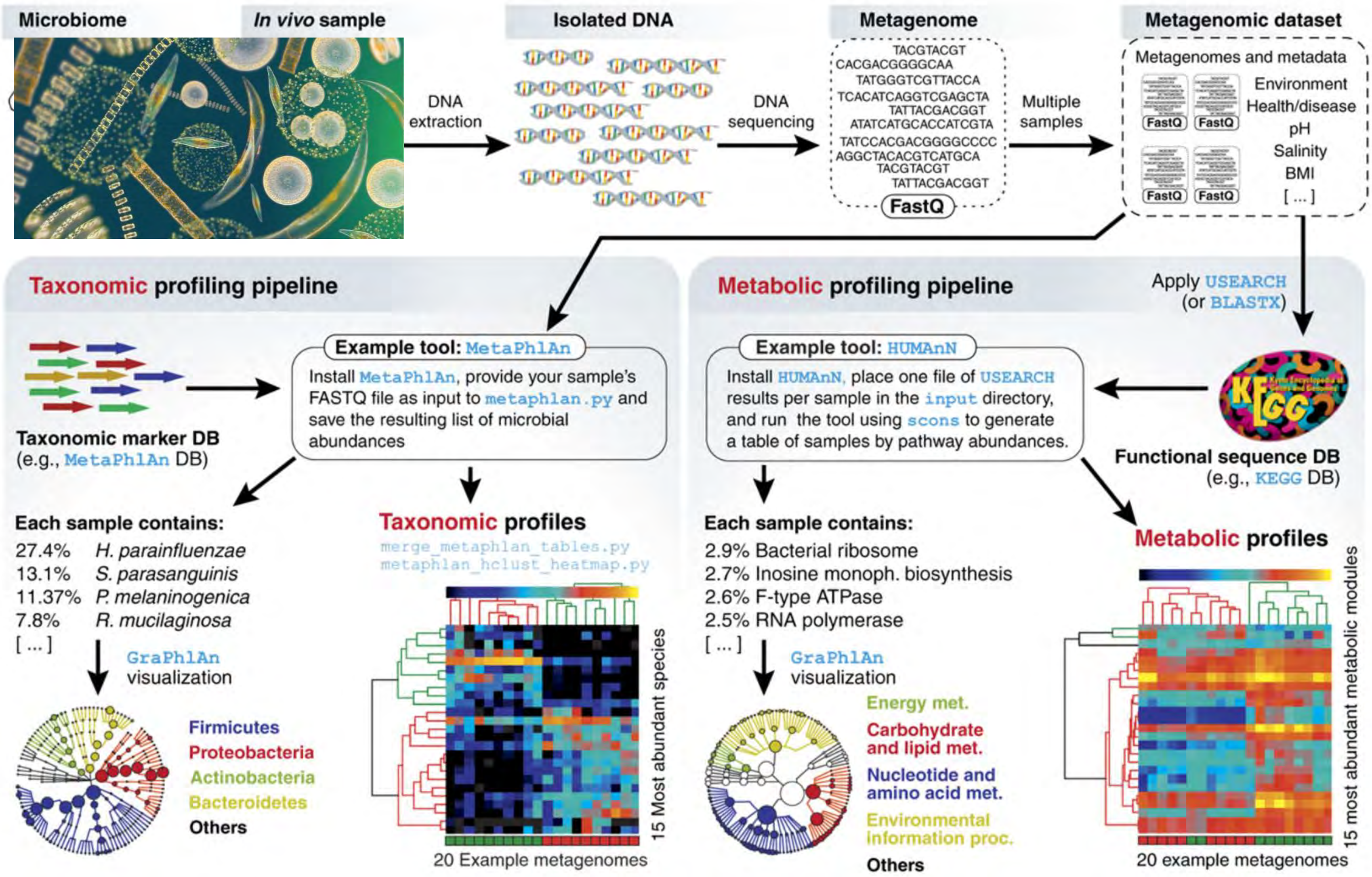
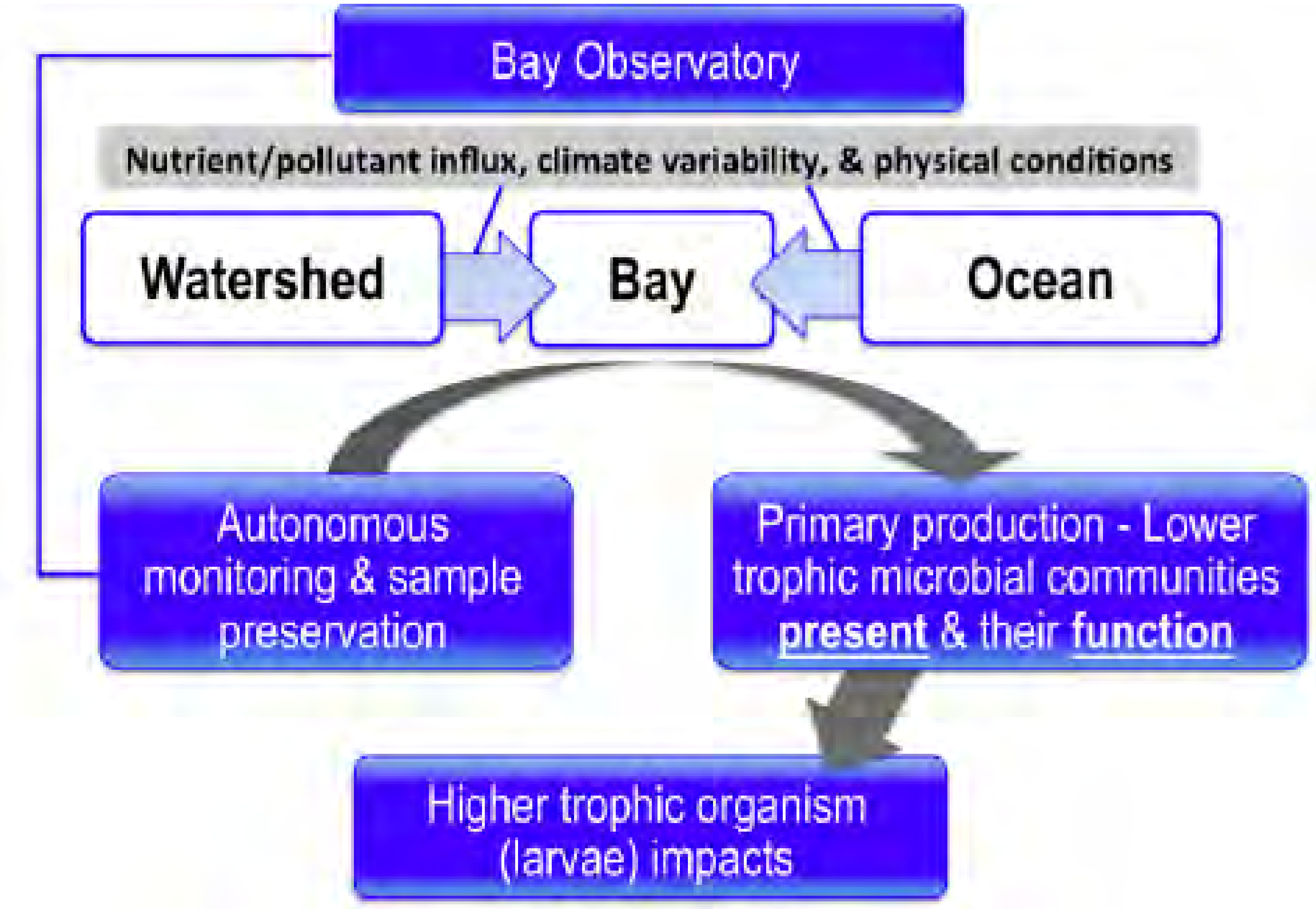


Figure modified from Segata et al. Molecular Systems Biology 2013

RIEMC

NARRAGANSETT BAY ESTUARY PROGRAM

INTEGRATION



RI DATA DISCOVERY CENTER

The 5 year goal of the Rhode Island Data Discovery Center (RIDDC) is to become the national and international go-to- source for data on the Narragansett Bay ecosystem.

RIDDC will become the site where C-AIM investigators will store their data, share their data internally and share their data externally with investigators around the world.

In addition to data collected by C-AIM investigators, RIDDC will also collect and share historical data on the Narragansett Bay ecosystem. In addition to sharing data with scientists, RIDDC will also become the go-to-source where decision makers, land-use managers, relevant industries, citizen scientists and students can find data on the Narragansett Bay ecosystem.

Appendix D: One-Page Monitoring Summaries

Monitoring efforts by Veronica M. Berounsky, Ph.D.

What monitoring do you currently conduct?

My monitoring programs are in the Pettaquamscutt Estuary (Narrow River) which empties into the mouth of Narragansett Bay (See Figure 1). There are 2 separate but related programs. The one in which I am the principal investigator, the Anoxic Basin Comparison Study, is monitoring the environmental conditions of the two anoxic basins in the northern portion of the Pettaquamscutt Estuary. My co-investigators (all at GSO) are David Borkman, Ph.D. with expertise in phytoplankton identification and ecology, Lucie Maranda, Ph.D. with expertise in phytoplankton ecology, and Rebecca Robinson Ph.D. with expertise in nutrients. Future work is being planned with Roxanne Beinart, Ph.D. with expertise in deep sea anoxic areas There have been a number of students who assist in the field, and some also assist with data analysis. The students involved for the longest number of years are Rahat Sharif and Eric Peterson. The second program, called River Watch, I am co-principle investigator with Annette DeSilva (at GSO), and that program monitors the entire estuary and the four largest freshwater point sources for water quality in the near surface waters. The actual sampling is done by myself, Annette DeSilva, and many trained volunteers (187 over the last 26 years).

How long have you been collecting this data?

For the Anoxic Basin Comparison Study, we have been monitoring since October 2007 when the last overturn (or ventilation) of the northern basin occurred. For the RiverWatch Program, we are completing 26 years of monitoring this month. The ten sites in the River itself have been monitored since 1992, the freshwater points sources have been measured since 1992, 1996 2000, or 2004, depending on the site.

What data do you collect, how do you collect it (generally), and what sites do you monitor?

For the Anoxic Basin Comparison Study, we use a boat and YSI Sonde to take profiles of dissolved oxygen, temperature, salinity, chlorophyll, and pH with depth, every other week, at the Upper Pond site and the Lower Pond site (See Figure 2) and once a month we also take water samples at certain depths for nutrients (ammonia, nitrate plus nitrite, inorganic phosphorus, and silica) and phytoplankton at the same locations. We sample May through December, and occasionally in the water if there is sufficient ice to go out on the ponds.

For the RiverWatch Program, there are 10 sites in the river itself, 3 stream sites, and one outfall site (see Figure 2). Every other week samples are taken for dissolved oxygen, chlorophyll, and salinity and temperature measurements are taken. Once a month samples are also taken for bacteria, nutrients (total nitrogen, ammonia, nitrite plus nitrate, total phosphorus, and inorganic phosphorus) and pH. Samples are taken at 0.5m deep and also at 3m in the Upper and Lower Ponds. Samples are taken May through October.

How do you currently reports/share your monitoring data?

We are working on peer reviewed publications, but meanwhile presentations have been made at seminars, and national and local conferences and meetings and some are available on www.narrowriver.org . The Riverwatch data is available in Excell spreadsheets by contacting Annette DeSilva.

How is this monitoring currently funded?

Portions of the Anoxic Basin Comparison study have been funded by URI Completion Grants but most of the work is unfunded. The Riverwatch Study has been funded by the Narrow River Preservation Association, DEM's Aqua Fund, RI Rivers Council, US Fish &Wildlife Service, and grants from the 3 towns in the watershed.

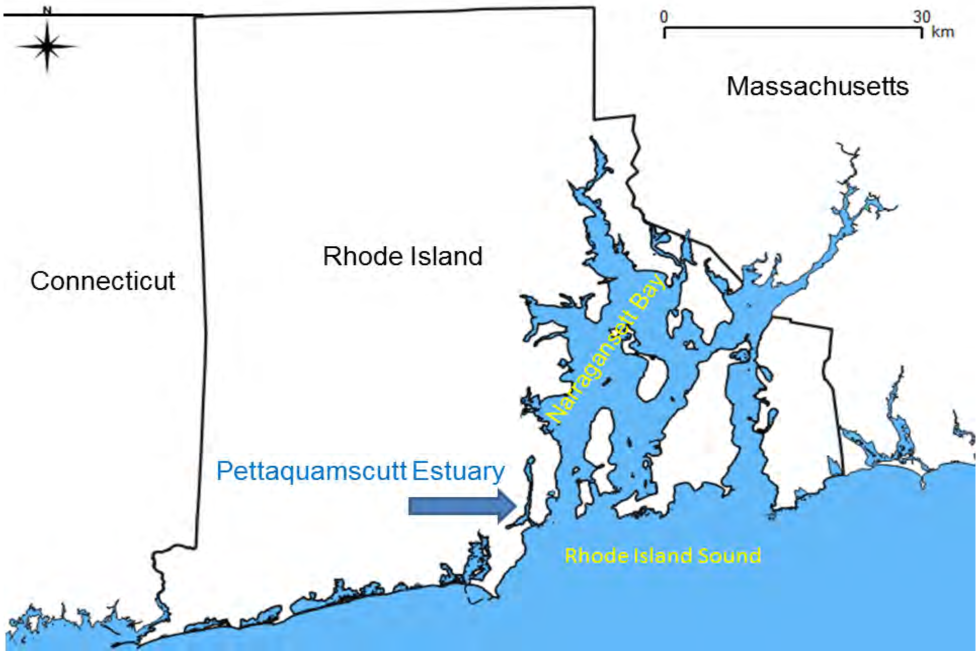
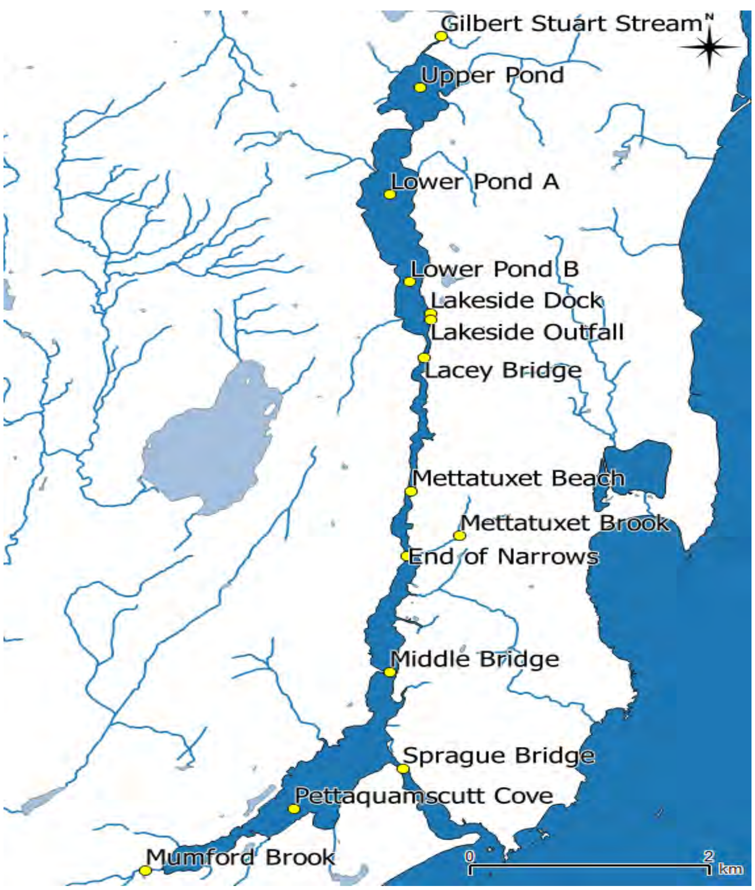


Figure 1 (above) – Pettaquamscutt Estuary location

Figure 2 (below) – Sampling Sites in Pettaquamscutt Estuary



Narragansett Bay National Estuarine Research Reserve — Rhode Island Natural History Survey — Save The Bay Narragansett Bay — CRMC Coastal Resources Management Council

Salt Marsh Monitoring and Assessment Program

The Narragansett Bay National Estuarine Research Reserve (NBNERR), Save The Bay, the RI Natural History Survey (RINHS) and the Coastal Resources Management Council (CRMC) are currently engaged in a collaborative effort to improve long-term salt marsh monitoring in Rhode Island and have developed a strategy for a comprehensive statewide monitoring and assessment program. The Salt Marsh Monitoring and Assessment Program (SMMAP) is a three-tiered framework for application in assessing changes in salt marsh condition, spatial extent, and community composition over space and time. **Tier 1** involves a statewide, landscape-scale analysis based on automated classification of aerial imagery. **Tier 2** involves the development of a rapid assessment protocol that will be implemented annually at a subset of marshes throughout RI. **Tier 3** builds upon the existing Narragansett Bay National Estuarine Research Reserve's Sentinel Sites Program to carry out more intensive monitoring at a smaller subset of sites throughout RI. Tier 3 metrics will also be developed for use in monitoring specific projects and management actions, such as enhancing marsh drainage networks or beneficially reusing dredged material to build marsh elevation.

Photo by Marlo Garnsworthy

Program Goals

The results from this monitoring and assessment program will be used to:

- Evaluate the overall status and condition of RI's salt marshes
- Track changes over time
- Evaluate management outcomes, and
- Prioritize areas where resources should be directed towards management actions.

The SMMAP will facilitate coordinated ecological salt marsh monitoring throughout the state of RI in order to document spatial and temporal patterns in salt marsh conditions and help inform restoration, adaptive management, and prioritization of salt marsh management projects, statewide. The SMMAP will establish standardized protocols for salt marsh monitoring, assessment, data formatting, and data archiving, and will initiate and maintain a long-term salt marsh monitoring and assessment dataset for the state. Data collected according to the SMMAP will also be compatible with established regionally and nationally-implemented programs. When completed, the SMMAP will serve as a component of the broader RI Environmental Monitoring Collaborative Monitoring Strategy.

Three-tiered structure used by the Rhode Island SMMAP

Tier	Description	Frequency	Spatial Extent
1	Landscape-scale marsh habitat mapping	3-5 years	Statewide
2	Salt marsh rapid assess-ments	Annually	Approx. 40 marshes statewide (a subset is assessed each year)
3	Intensive site monitoring	Annually, and as needed for resto-ration / adaptation projects	6-8 marshes statewide and specific individual marshes

Parameters Monitored

Category	Parameter	Tier 1	Tier 2	Tier 3
Geomorphic	Channel widening rate	x		x
	Landward transgression rate	x		x
	Seaward erosion rate	x		x
	Marsh area	x		
	Ponding area	x	x	
Habitat	Habitat composition and zonation		x	x
Physiochemical	Edaphic conditions		x	x
	Elevation			x
	Elevation change (accretion / sub-sidence)			x
	Inundation / hydrology			x
	Nutrients			x
	Total suspended solids (TSS)			x
Biological	Emergent vegetation		x	x
	Marsh crabs			x
	Nekton			x
	Marsh sparrows			x
	Wading birds			x

To view the complete monitoring and assessment strategy document visit:

www.crmc.ri.gov/news/pdf/SMMAP_RI_Strategy.pdf

Questions? Contact Caitlin Chaffee (cchaffee@crmc.ri.gov), Kenny Raposa (Kenny@nbnerr) or Tom Kutcher (tkutcher@rinhs.org)

Workshop on Monitoring Gaps in Narragansett Bay – 2017

D. Codiga GSO/URI 10/9/2017

Long-term monitoring of water circulation and transport in Narragansett Bay

There is a lack of sustained long-term observations of currents anywhere in Narragansett Bay.

(The only exception I know of is the NOAA PORTS program. It includes current measurements at three shallow port sites, in the Providence River, Quonset Point, and Fall River. Currents from these isolated inshore sites, while useful for practical vessel navigation purposes as is their intended application, are not valuable for scientific exploration of processes influencing biological conditions in the bay.)

This constitutes a serious gap, which any effort intending to move bay monitoring activities toward being more comprehensive needs to address. Water quality conditions, and the biological processes forming the primary influences on them, are recognized to be extremely variable in space and time. Much of the variability is associated with advection by currents, so a primary limitation to monitoring and understanding water quality conditions is how little we know about the circulation.

This is not to say that past and present research activities (for example, by Kincaid, Ullman, and others) ignore current measurements. On the contrary, many circulation-related studies have taken place and there will be more. But none so far address the need for sustained long-term sampling to help close the gap in monitoring. These other targeted projects are valuable in their own ways and have provided useful perspectives. But they consist of measurements from different locations in different years, and are rarely sustained for more than one year, let alone on a longer-term basis as needed.

Some good ways to help address the gap include: (1) adding bottom-mounted acoustic Doppler current profiler (ADCP) deployments at some of the Narragansett Bay Fixed Site Monitoring Network sites, routinely, each time the CTD/DO moorings are deployed there; and (2) instrumenting one or more ferries (e,g, Prudence Island ferry, Newport-Jamestown ferry) with a hull-mounted ADCP. These are both standard, proven technologies, suitable for long-term monitoring, with known costs.

In the case of ferry-based sampling, the ADCP can be one component of a more comprehensive multi-disciplinary program – see other one-page description "Ferry-based sampling for long-term monitoring of biological conditions in Narragansett Bay" for explanations of the advantages. Use of ADCPs on ferries is well established and there are many success stories around the world. As noted in that other one-page description, ferry-based sampling in Narragansett Bay includes two main possibilities: the Bristol to Prudence Island ferry and the Jamestown to Newport ferry. These locations can each capture the oceanic-origin Rhode Island Sound water moving north through the East Passage (toward the upper bay where, for example, hypoxia is a problem). A similar sampling program from a ferry in Long Island Sound gave a fundamentally new view of its estuarine exchange flow and rates of transport (citation below), which are of course very relevant to understanding biological conditions (as well as designing successful sampling and monitoring of biological indicators).

Codiga, DL, and DA Aurin, 2007. Residual circulation in eastern Long Island Sound: Observed transverse-vertical structure and exchange transport. Continental shelf research, 27 (1), 103-116. (Available at ftp://www.po.gso.uri.edu/pub/downloads/codiga/pubs/2007CodigaAurin-ResidualCircEasternLIS-CSR.pdf)

Workshop on Monitoring in Narragansett Bay – 2017

D. Codiga, GSO/URI 10/9/2017

Ferry-based sampling for long-term monitoring of biological conditions in Narragansett Bay

- A pumped flow-through system with standard in-situ sensor can measure the suite of surface water quality parameters (temperature, salinity, chlorophyll fluorescence, oxygen, turbidity, pH)
    - Straightforward to add specialty sensors (e.g., wet chemistry nutrients, optics, etc)
    - An automated water sampler can collect water, for later delivery to an onshore lab and more complete analysis (e.g., phytoplankton & zooplankton identification/counts)
- Long-term (typically year-round) and high-frequency (multiple times daily) crossings
    - Captures tidal variations (after a few months all phases of tide are sampled, as opposed to any one tidal period); weather-band events; seasonal cycles; and long-term trends
- Spatial coverage extends along a transect from shore to shore
    - Captures patchy variability better than small number of sites (or single mid-channel site)
    - Ferry routes span East Passage where oceanic Rhode Island Sound water enters bay
- Additional sampling potential of ferries as platforms for sensors
    - Hull-mounted acoustic Doppler current profiler (ADCP) to measure currents throughout the water column; estuarine exchange flow, net volume transports through the transect
    - Meteorological conditions
- The technologies are low-risk and proven (citation below summarizes worldwide examples)
    - Designed for unattended routine operation—ferry staff need not be involved—including real-time remote communication (cellular modems) to retrieve data & monitor sensors
- Methods for analyzing the resulting datasets (including tidal variations) are established
- Overall costs are well-understood and modest compared to other long-term monitoring efforts
- The return on investment is enormous relative to cost of equivalent research vessel time
- Ferry passenger areas are natural showcases for education and outreach displays if desired

There are two main platforms available for ferry-based sampling in Narragansett Bay (in addition to the Block Island ferry, which will not be mentioned here but also represents a great opportunity):

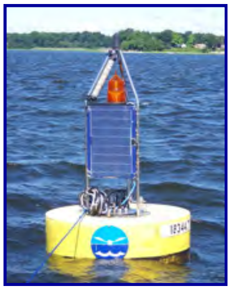
- The Bristol to Prudence Island ferry (runs year-round)
- Jamestown to Newport ferry (runs from May through ~mid-October)

In recent years the Bristol to Prudence Island ferry operator was initially supportive of hosting a sampling system, funding from NOAA to GSO was obtained as part of the Coastal Hypoxia Research Program, and the installation process had begun. However, for completely unrelated reasons, shortly thereafter the company stopped operating, so the project was not completed. A new ferry operator took over then, is now well-established, and the process of contacting them regarding potential for hosting a sampling system on their vessel is underway. Contact has also been made with the Jamestown to Newport ferry operator, who is receptive to the idea of hosting sensors.

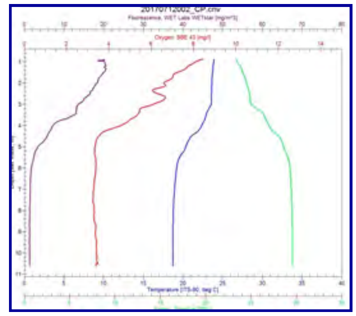
Codiga, D. L., W. M. Balch, S. M. Gallager, P. M. Holthus, H. W. Paerl, J. H. Sharp and R. E. Wilson, 2012: Ferry-based Sampling for Cost-Effective, Long-Term, Repeat Transect Multidisciplinary Observation Products in Coastal and Estuarine Ecosystems. Community White Paper, IOOS Summit, Herndon, VA, November, 2012. (Available at ftp://www.po.gso.uri.edu/pub/downloads/codiga/pubs/2012CodigaEtAl-FerryBasedSamplingWhitePaper-IOOSsummit.pdf)

The Narragansett Bay Commission Water Quality Monitoring Initiatives

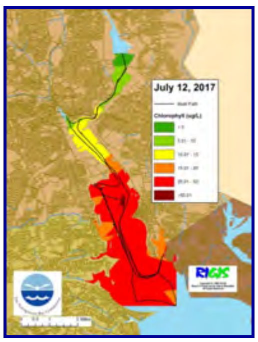
The Narragansett Bay Commission's (NBC) water quality program includes the monitoring initiatives listed below. More information and data for each of these programs are available at: http://snapshot.narrabay.com.



Fixed Site Water Quality Monitoring: The NBC maintains two water quality stations in conjunction with the Narragansett Bay Fixed Site Monitoring Network (NBFSMN). Sensors at Phillipsdale Landing and Bullock Reach record temperature, salinity, dissolved oxygen, pH, chlorophyll *a*, and turbidity at 15-minute intervals during the summer season. Data from the stations are updated on the Snapshot website every hour, providing near real-time conditions of water quality in the Providence and Seekonk Rivers.



Water Column Profiles: The NBC collects water quality profiles at six locations throughout the upper bay every week or every two weeks. These profiles provide a cross-sectional view of the structure of the water column and aid in assessing when the water is stratified and/or at risk for hypoxic conditions. The parameters collected include depth, density, temperature, salinity, dissolved oxygen, photosynthetically active radiation (PAR), and fluorescence.

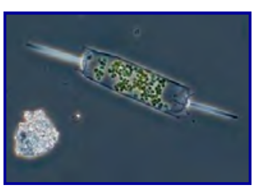


Surface Mapping: The NBC uses a sonde to collect surface water quality data while their vessel, R/V *Monitor*, is underway. The benefit of this monitoring is the ability to document surface water quality over a large area while traveling between the NBC monitoring stations. Parameters measured include temperature, salinity, dissolved oxygen, pH, and chlorophyll *a*. From this data, the NBC can create spatial maps to show and extrapolate data over a large area of the upper bay.

Water Clarity: The NBC collects water clarity samples on a weekly basis at six locations throughout the upper Bay, utilizing both the Secchi disk as well as a PAR meter. Clear water is important so that ample sunlight is available for the aquatic plants, algae, and phytoplankton living in Narragansett Bay.

Pathogen Monitoring: The NBC collects bacteria samples every two weeks at 20 stations throughout the upper Bay, and weekly samples at 23 stations in the urban rivers. This sampling can demonstrate if water quality is suitable for swimming and shellfishing. All samples are analyzed for fecal coliform and 25% of the samples are also analyzed for enterococci.

Nutrient Monitoring: The NBC samples for various nutrient parameters twice a month at six upper Bay stations and 14 river stations. Several river stations are located at the state border to determine what is coming into the bay from outside the state. Parameters monitored include nitrite, nitrate, ammonia, total dissolved nitrogen, total nitrogen, orthophosphate, silicate, and chlorophyll.

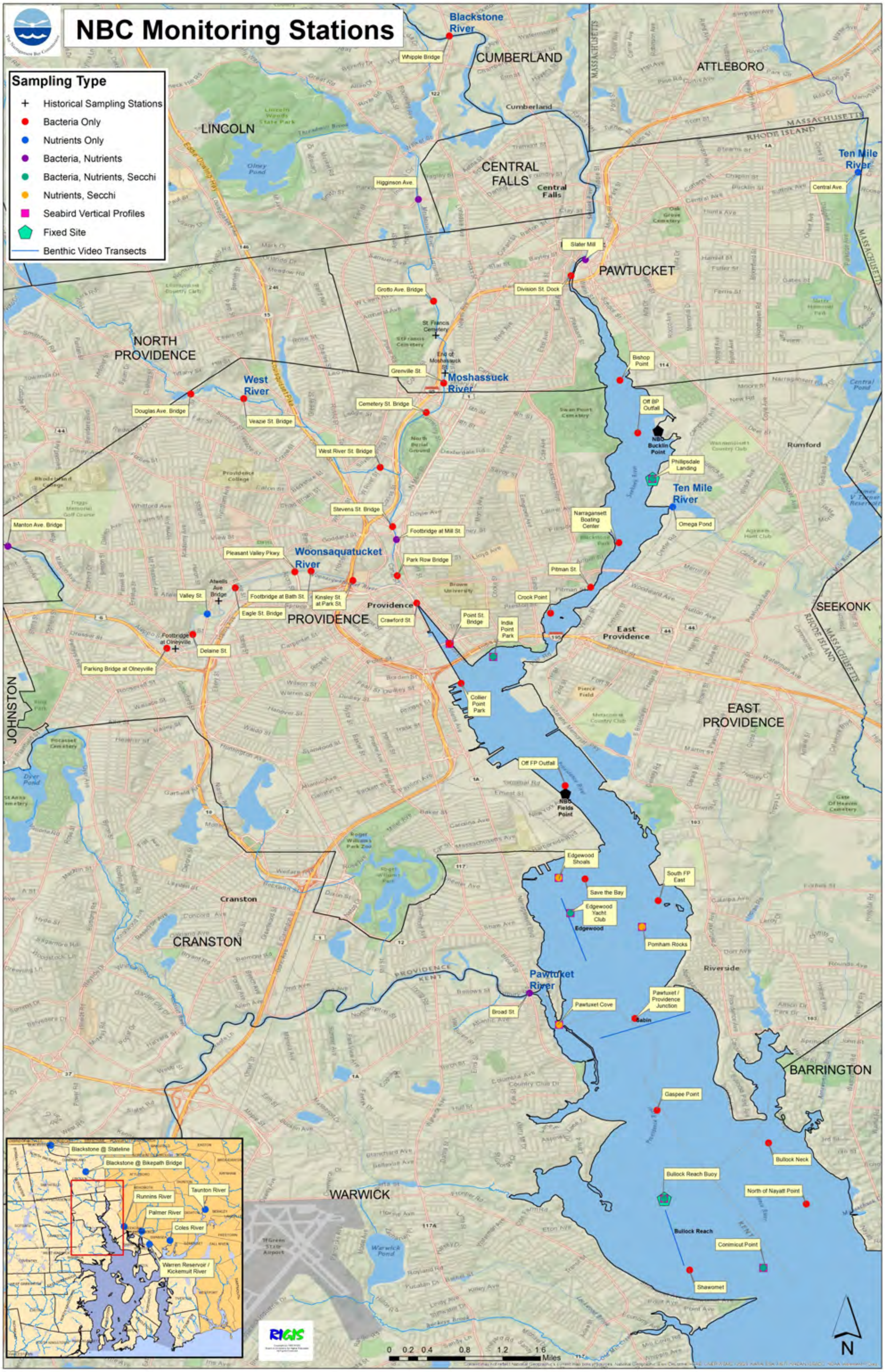


Plankton Monitoring: The NBC collects phytoplankton samples once per week or every other week at the Bullock Reach station. Samples are analyzed to document the presence and number of various groups of phytoplankton present in the sample. Both quantitative counts of common taxa and qualitative presence/absence analysis of rare taxa are performed.

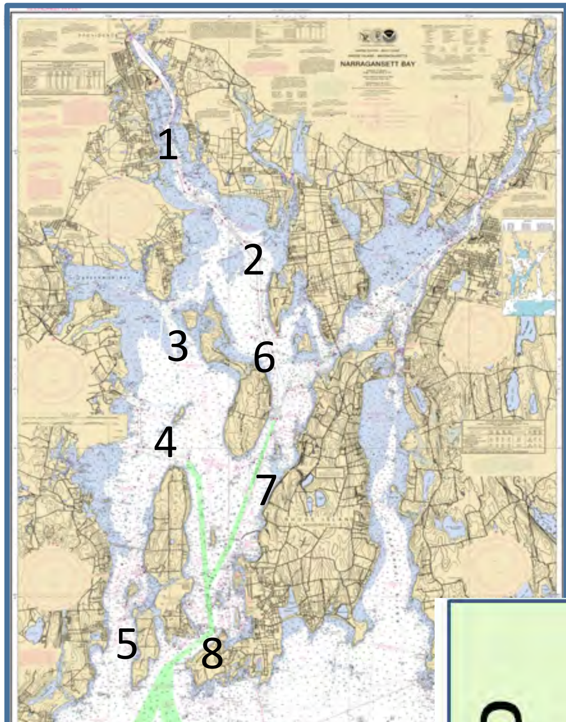
Benthic Video Monitoring: Over the summer months, the NBC collects video footage of the bottom waters of the upper Bay to track potential changes in the benthic habitat as nitrogen loading to the Bay is reduced by WWTFs. An underwater camera is attached to a specialized sled to collect video as the NBC's boat transects areas of the Bay. The NBC targets the Edgewood Shoal area, as well as the Bullock Reach and Sabin Point areas of the upper Bay for these surveys.

For further information, please contact the NBC at:
(401) 461-8848 ext. 261 or emda@narrabay.com or snapshot@narrabay.com
Visit the NBC's websites – www.narrabay.com & http://snapshot.narrabay.com/app/
for information on all Narragansett Bay Commission news, as well as to download NBC water quality data

Map of NBC monitoring stations for all monitoring initiatives

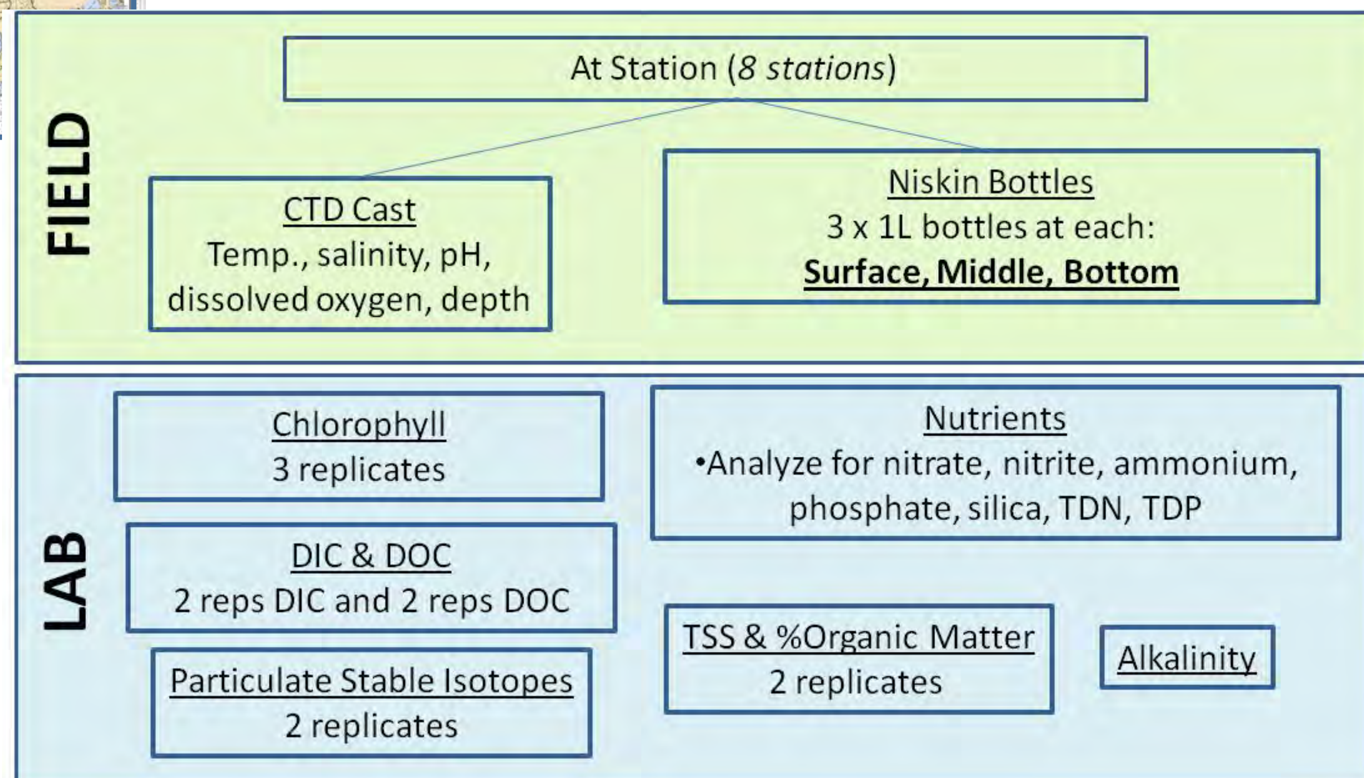


EPA Atlantic Ecology Division's monthly monitoring.

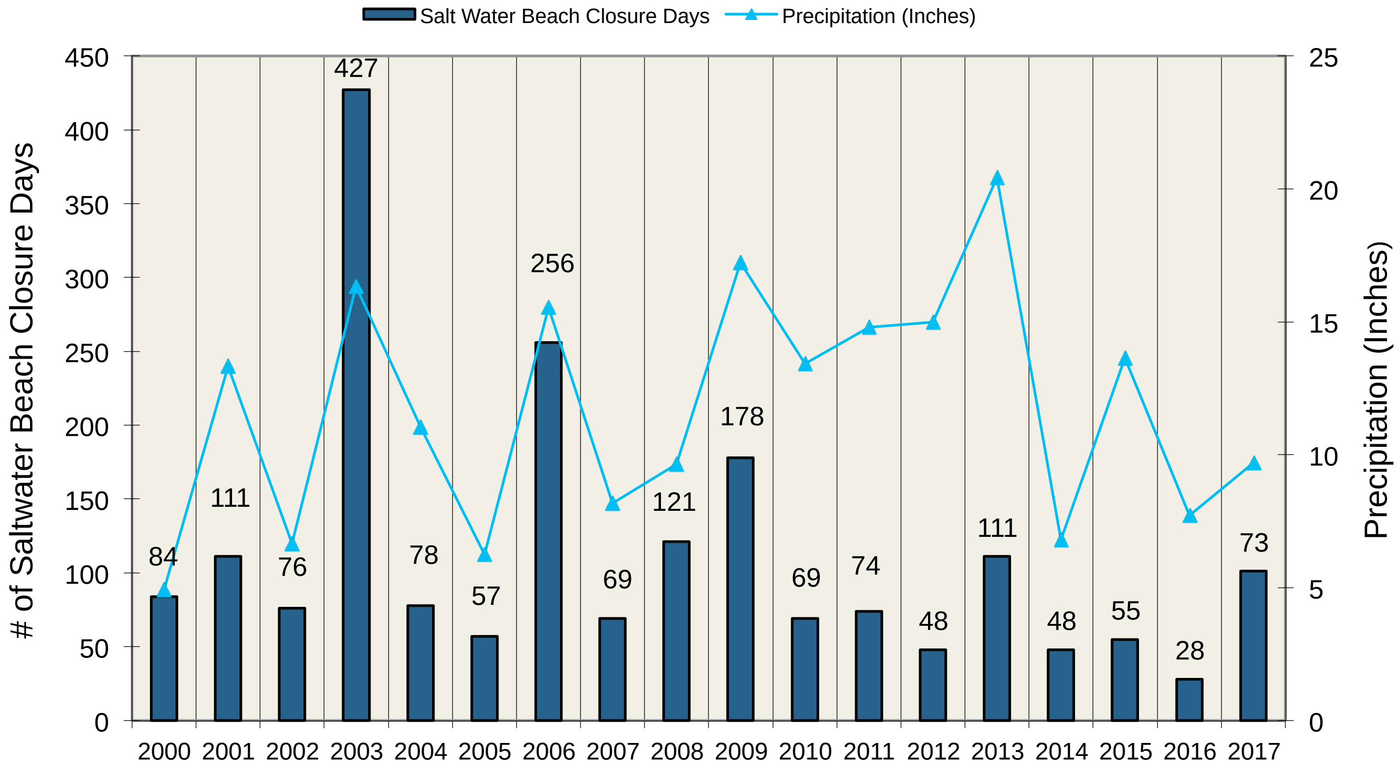


We also:
-periodically measure stable isotopes in seaweeds and hard clams.
-conduct more detailed surveys of carbonate chemistry (latter effort led by Jason Grear, grear.Jason@epa.gov)

POC for this work is Autumn Oczkowski, oczkowski.autumn@epa.gov



Beach Season Saltwater Closure Days and Precipitation, 2000 to 2017



In 2017, 73 closure days occurred across 15 of the 70 monitored saltwater beaches while 55 beaches did not close. This is an increase in closure rate relative to recent years, but much of the increase is due to multiple days of closure per closure event (see table, below).

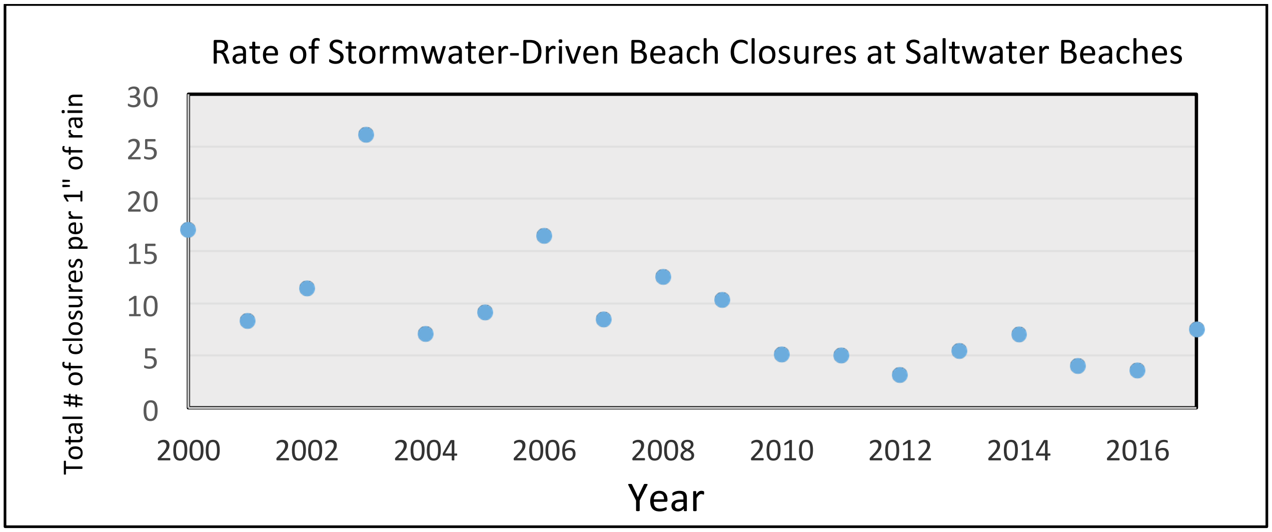
RI Saltwater Beach Closures in 2017: Per Beach, Number of Days/Number of Events.

Name (monitoring frequency)	Year			Name (monitoring frequency)	Year		
Tier I (2x/week)	2015*	2016*	2017*	Tier II Beaches (2x/month)	2015*	2016*	2017*
Oakland Beach	9/6	9/1	26/5	King Park Swim Area	1/1	0	4/3
Conimicut Beach	4/4	6/3	12/2	Saunderstown Yacht Club	0	0	4/1
Goddard State Park	8/7	2/2	1/1	Sandy Point Beach	2/1	0	2/1
Peabody's Beach	7/2	0	3/2	Spouting Rock Beach	0	2/1	2/1
Warren Town Beach	4/3	0	6/3	Mackerel Cove	0	3/2	0
Easton Beach	6/4	1/1	0	Hazard's Beach Newport	0	0	2/1
Barrington Town Beach	0	1/1	5/2	North Kingstown Town Beach	2/2	0	0
City Park Beach	3/2	0	2/1	Fort Adams State Park	1/1	0	0
Third Beach	2/2	0	2/2	Plum Beach	0	0	1/1
Bristol Town Beach	1/1	2/1	1/1				
Scarborough State Beaches	1/1	0	0				

It is notable that, of the Tier 1 beaches (highest risk, most frequently monitored), only Oakland Beach and Warren Town Beach had more closure events in 2017 than in 2016 and none had more events than in 2015.

Six Tier II beaches had closures in 2017, compared with only two in 2016 and four in 2015. There were no Tier III closures in 2017.

The chart below, with beach closure days normalized to total seasonal rainfall, suggests that in recent years stormwater contributes less to the closure rate. This may be a useful metric to track improvements associated with aggressive efforts within the state to manage stormwater!



There were four freshwater beaches that closed during 2017, for a total of 28 days during seven events. Due to the variable sampling frequency at freshwater beaches, between-year comparisons are not valid.

Project Progress in 2017

Rapid Detection Project

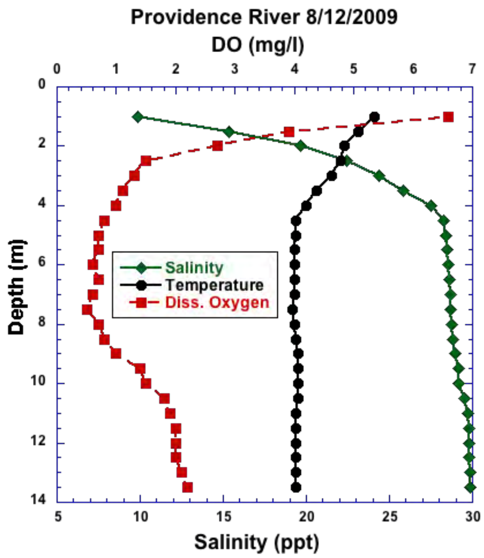
The Enterolert® test is the standard method, nation-wide, for monitoring beach water quality. It is a 24-hour assay, so results represent the previous days' water quality. This delay poses health risks because swimming in impaired waters may occur for up to 24 hours before the risk is discovered. To address this problem, RIDOH received a grant from EPA's Southeast New England Program to develop capacity for Quantitative Polymerase Chain Reaction (qPCR) testing. qPCR provides results in six hours, potentially allowing same-day management actions. While the project achieved a primary objective (to develop RIDOH laboratory proficiency in qPCR for Enterococci enumeration), the strength of the correlation between qPCR and the Enterolert method was poor, leading to concern that the method is not reliable. In the final stage of the study, we will re-test split samples to compare results from Enterolert® and the standard membrane filtration culture method 1600 (EPA, 2002), while also testing with the qPCR method. Results from the two culture-based methods have apparently been found to select for different Enterococcus species (Ferguson et al., 2013), and also may produce false positive results in up to a quarter of tested samples (Raith et al., 2013).

2018 Focus

One objective for the upcoming year will be to continue to engage beach managers to update profiles of health risks, source identification and controls. Most profiles date back to 2003. Additionally, if resources allow, we hope to initiate modelling to predict water quality at the most impaired beaches using EPA's "Virtual Beach" software. The absence of funding to monitor freshwater beaches continues to be a problem.

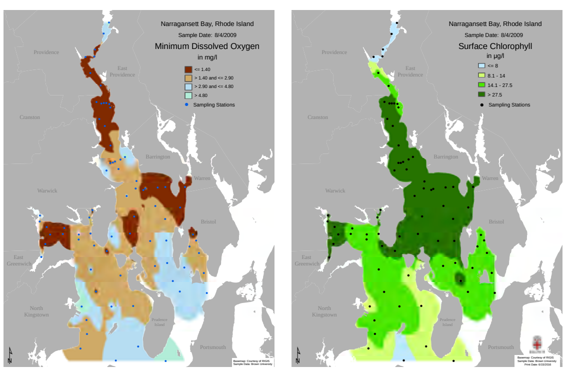
Spatial Surveys of Summer Hypoxia and Water Quality

Warren Prell and David Murray,
Depart. Earth, Environment, and Planetary Science, Brown University

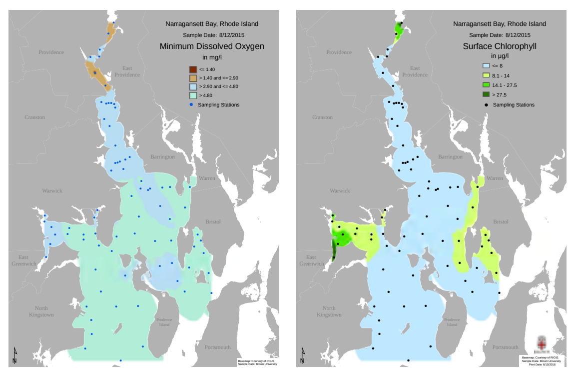


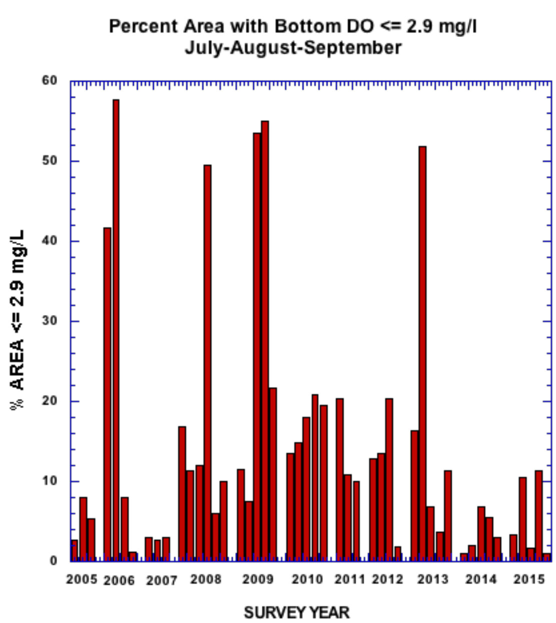
- 3 boat groups: Brown, STB/Brown, URI/DEM
- 77 stations in upper and mid bay, 4 to 7 surveys per year
- Measure temperature, salinity, density, dissolved oxygen (DO), and chlorophyll (Chl)
- 2005-2017, continuous water column profiles using SeaBird CTD
- 71 surveys, ~5100 individual profiles (through 2017)
- Map bottom DO and surface Chl to identify the area of hypoxic and bloom conditions
- Most data is available through NBEP and Brown University
- Data processing and most data collection is unfunded

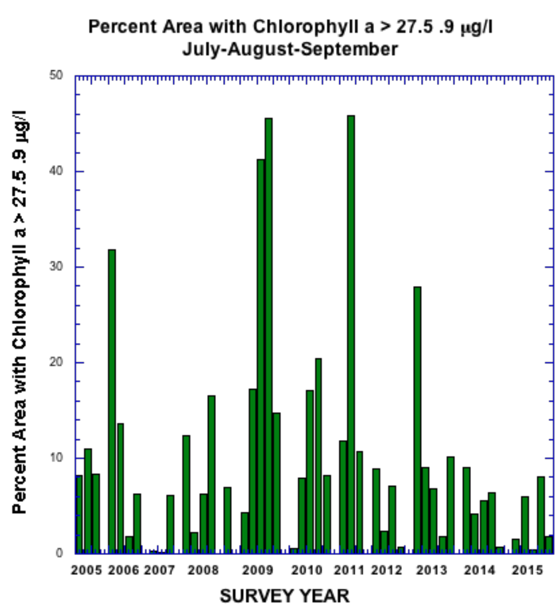
Max hypoxia and Chl 8/04/2009



Min hypoxia and Chl 8/12/2015







Observing and Modeling Post-Storm Intrusion Events

Kevin Rosa, Chris Kincaid, Dave Ullman

In September 1999, an Acoustic Doppler Current Profiler (ADCP) moored in Narragansett Bay's East Passage captured a first-of-its-kind view of how the Bay responds to a tropical cyclone. Hurricane Floyd was a weak tropical storm by the time it made landfall in New England (max windspeed 20 m/s, max surge 0.8 m above predicted tide) but the velocity and the temperature measurements show a substantial intrusion of shelf-water. These data provide a robust test of our numerical models and have lead us to the following conclusion: <u>a 3D stratified model is essential when calculating residual transports, even in a storm event characterized by intense vertical mixing</u>.

The 300 kHz ADCP sat under the Newport Bridge (41.5057°N, 71.3518°W) and sampled velocities at 2 meter vertical bins. Following Floyd's landfall in Narragansett Bay, the bottom temperature at the ADCP dropped nearly 4°C in 3 days. This is the largest magnitude temperature change observed during the deployment.

This temperature drop is caused by an intrusion of cool Rhode Island Sound shelf-water. This poorly-understood exchange process could be a significant source of nutrients after a storm event.

In order to better understand what is forcing the shelf intrusion and to quantify the associated fluxes, we employ the Regional Ocean Modeling System (ROMS) numerical model. Two model configurations are presented here: a baroclinic (i.e. stratified) 3D model with realistic temperature and salinity gradients and a barotropic (i.e. unstratified) 3D model with constant density. Current operational storm surge models are 2D barotropic and there have been several studies assessing the advantages of a *3D* barotropic model. Baroclinic effects have not been shown to have enough of an effect on storm surge to warrant the extra computational power.

The model domain covers all of Narragansett Bay and Rhode Island Sound. Spatial resolution in the East Passage is about 150 m in the cross-channel and 225 m in the along-channel direction. There are 14 terrain-following layers in the vertical.

Atmospheric forcing comes from the ECWMF ERA-Interim reanalysis product. Free-surface height and depth-averaged velocities at the open boundaries come from a basin-scale 2D ADCIRC storm surge model.

Comparing model output for Floyd, there is essentially no difference in sea surface height between the baroclinic and barotropic models, as expected (Fig 1a). Additionally, both models show good agreement with sea surface height observed at NOAA's Newport tide gauge.

Although the instantaneous velocities for the two configurations also appear similar to each other (Fig 1b), it becomes clear when integrating through time that the barotropic model is actually not suitable for calculations of residual transport (Fig 1c).

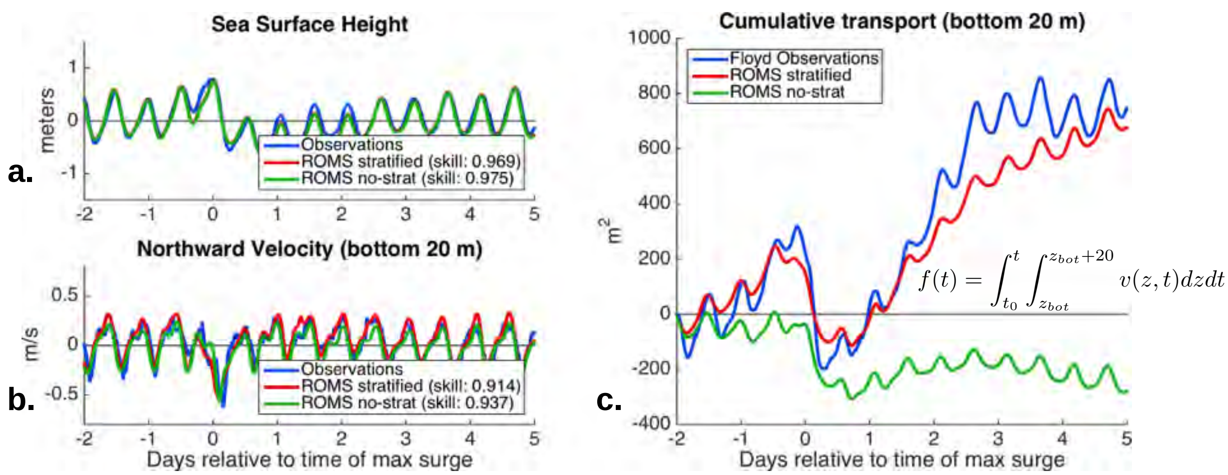


Figure 1: Model-data comparisons. In *a-b*, model-data agreement is calculated using the Willmott Skill. Skill of 1 represents perfect agreement. In *c*, northward velocity is averaged for the bottom 20 meters of the water column and then integrated in time. The stratified model is in good agreement with the residual transport but the unstratified model completely misses it.

In the open ocean, the extreme wind-driven vertical mixing may make the baroclinic pressure gradients negligible but Narragansett Bay is characterized by large *lateral* density gradients in addition to vertical gradients. Strong mixing results in vertical isopycnals which generate non-tidal circulation during the return to normal stratification.

Next steps will be to quantify the nutrient load of such an event. The 4 days following Floyd's landfall saw ~5×10^7 m^3 of river input compared to ~5×10^8 m^3 through the East Passage (according to the ROMS baroclinic model).

Ecological monitoring and assessment framework for Southeast New England coastal waters

Emily J. Shumchenia

United States Environmental Protection Agency

E&C ENVIROSCAPE

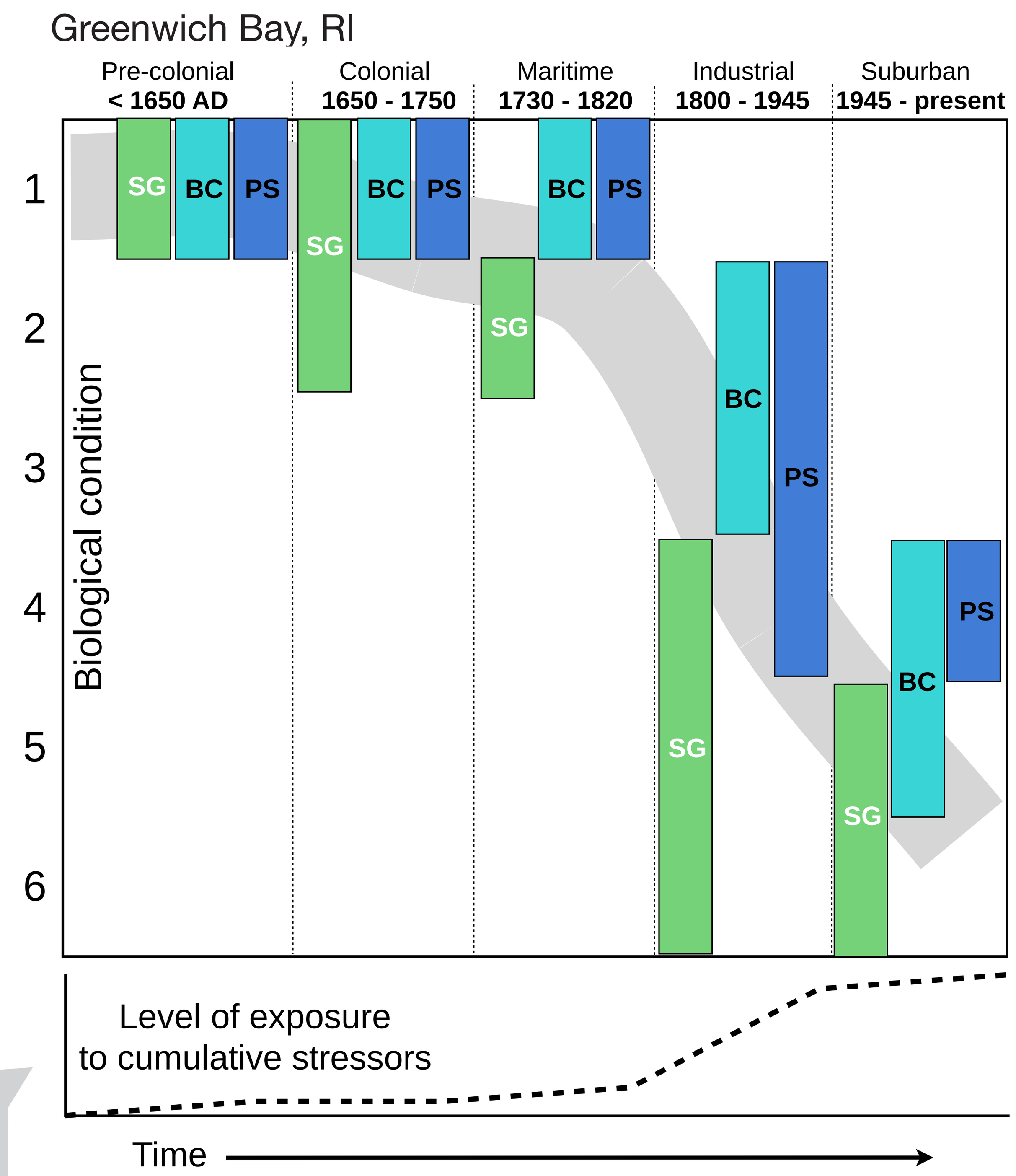
Biological Condition Gradient (BCG)

WHAT IS IT? A comprehensive, descriptive, and ecosystem-based framework that integrates biological, physical, and chemical conditions independent of assessment methods in order to effectively identify, communicate, and prioritize management action.

Describes a gradient in resource condition ranging from undisturbed or minimally disturbed reference condition (Level 1) to severely altered condition (Level 6)

SG = Seagrass
BC = Benthic Community
PS = Primary productivity and Shellfish

Measureable ecological attributes and ecosystem services aid in judging the degree to which a system may have departed from a natural condition



Evaluates cumulative stressors and tracks improvement over time and spatial extent

A BCG synthesizes existing data, observations, and accepted interpretations to document the trajectories (responses) of these measures across a generalized stressor gradient

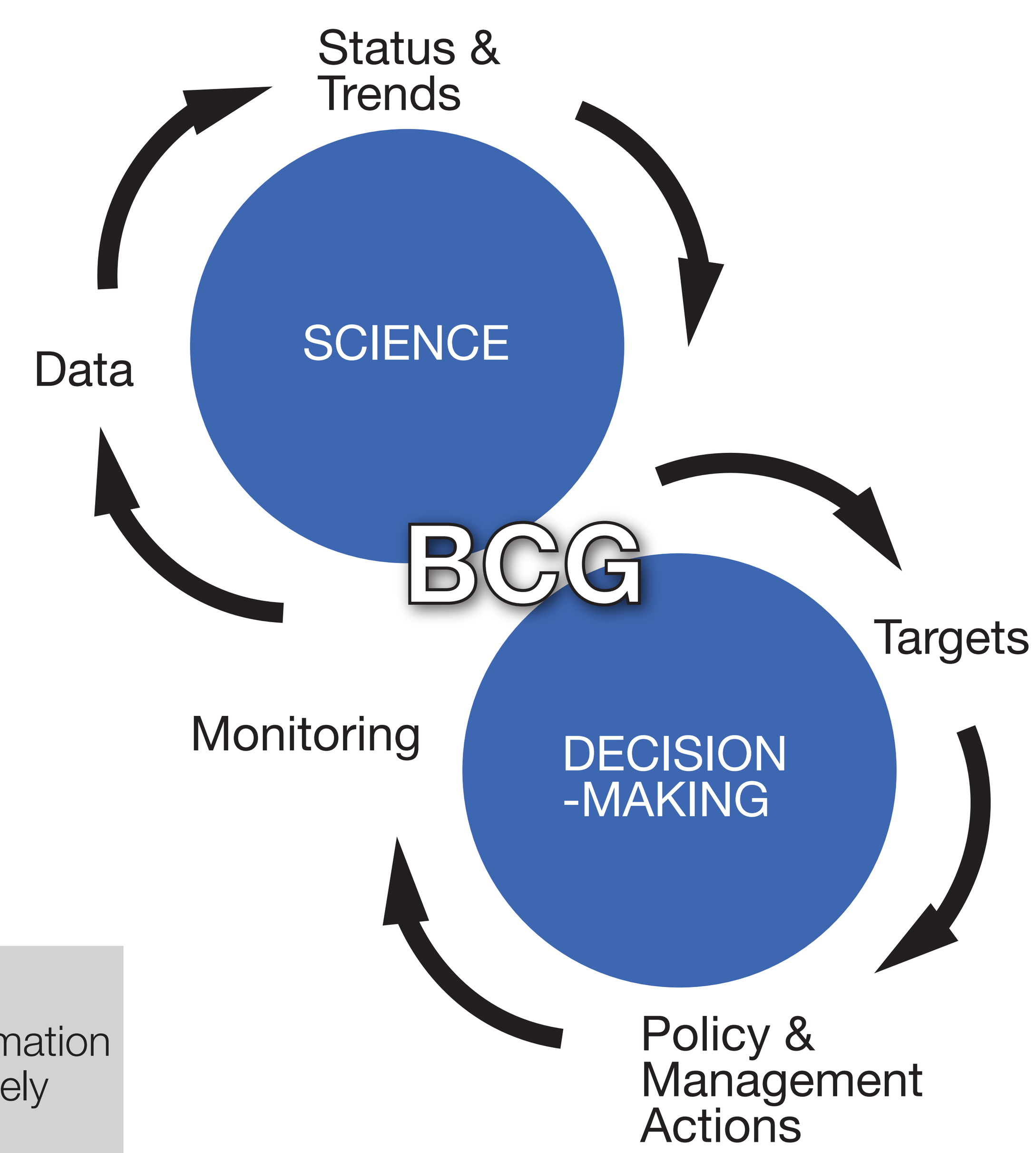
Provides a framework for organizing scientific information so it can be more effectively used and understood by managers and the public

COMMUNICATION: provides the vocabulary and common language to describe ecosystem conditions and answer questions in a meaningful way

GOAL SETTING: helps capture ecologically-based priorities and vision for the system, shifts focus from pollution control to biological impacts (ecosystem health)

CONSISTENCY: enables consistent evaluation of condition that still addresses local priorities and ecological condition

GUIDANCE: assists in prioritizing resource investments



2017+ Examine other habitat types and SNEP areas, like Buzzards Bay

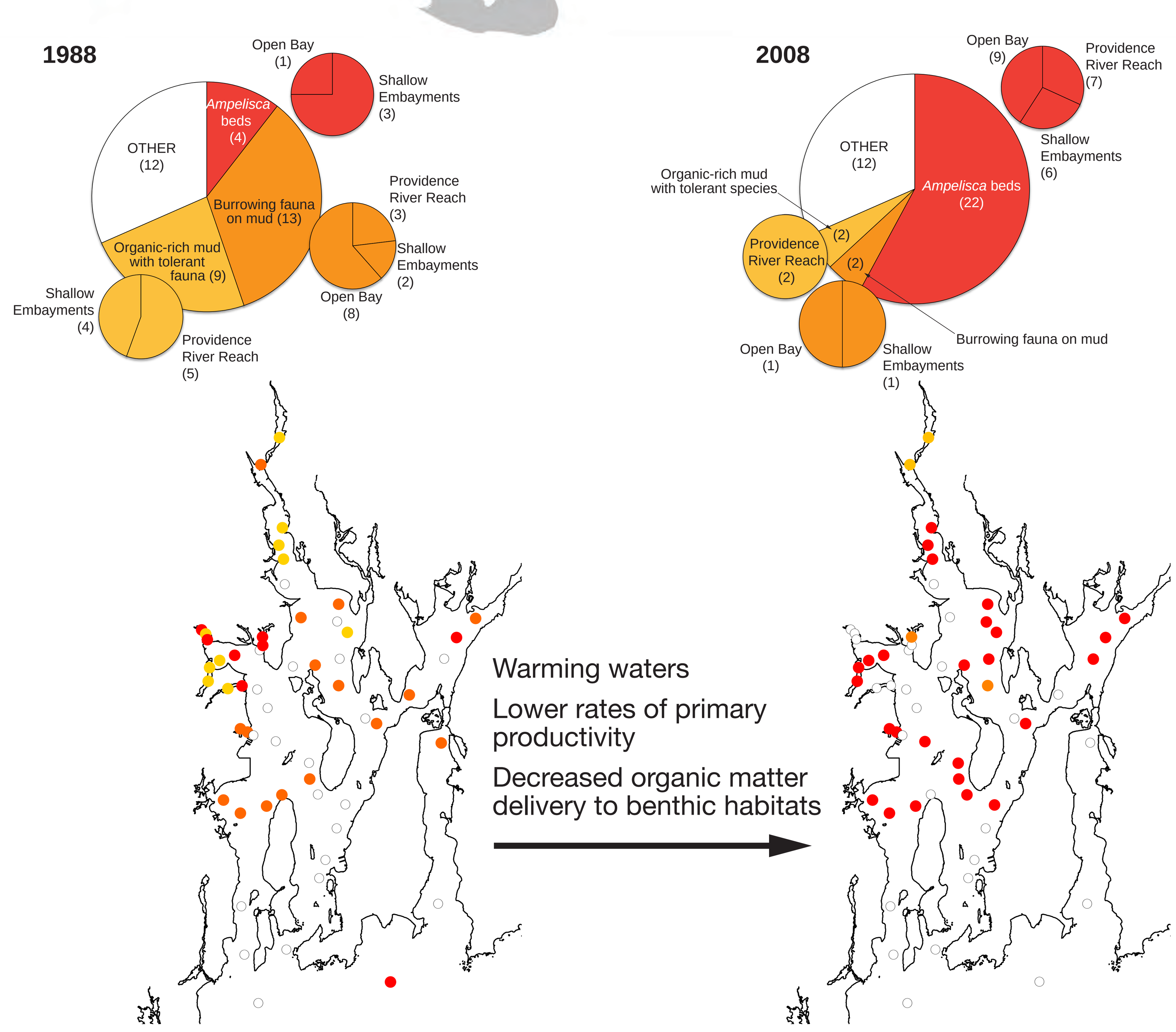
Seagrass, saltmarsh, shellfish beds, and macroalgae in Narragansett Bay >175 years of data

Explore ways to apply BCG + biotope mosaic approaches in other SNEP estuaries

Biotope Mosaic

WHAT IS IT? Evaluates the condition of a water body through the mix of biotopes it contains. One way that the cumulative impacts of stressors manifest is through destruction and conversion of biotopes. Returning the proportions or balance of biotopes to a previous and less-disturbed state would benefit the estuary as a whole, by moving the estuary closer to the mosaic of biotopes under which native species evolved.

For Narragansett Bay, the biotope mosaic approach has already been used to assess changes to benthic communitites (see maps at right). Other important bay habitats with historical quantitative data, such as seagrasses and salt marshes, are good candidates for a future whole-estuary biotope mosaic approach. Because historical changes in the bay's overall biotope mosaic can be related to alterations in the natural functions of and production in the bay ecosystem, this approach could inform and motivate the public, stakeholder, scientific, and management communities to continue and expand efforts to study, protect, and restore the Narragansett Bay ecosystem.



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Questions?

Emily Shumchenia
emily.shumchenia@gmail.com
(401) 226-4294
@hi_em

Characterizing Hypoxic Events for an Assessment Tool for Managers within Narragansett Bay, RI

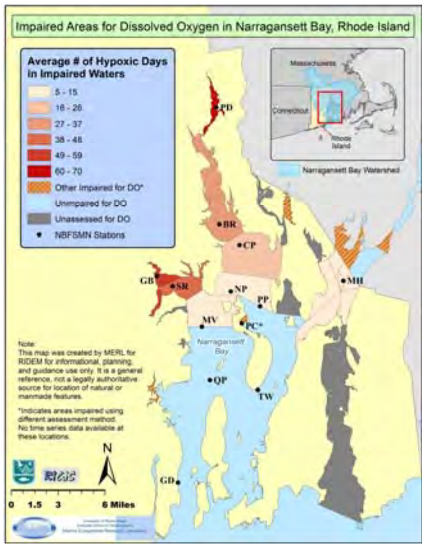
Stoffel, H. , Bernardo, M., Coupland, C., Oviatt, C., Requintina, E., and Kiernan, S.

University of Rhode Island, Graduate School of Oceanography and Rhode Island Department of Environmental Management, Office of Water Resources

ABSTRACT

About 32.5% of Narragansett Bay is impaired for hypoxia. The Bay experiences seasonal intermittent hypoxia events with the potential to threaten ecological health from May-October. Based on previous work, these hypoxic events (daily average oxygen < 2.9 mg O²/L) are correlated with river flow. Years with higher numbers of hypoxic events have anomalously large summer seasonal river runoff and/or high spring/summer temperatures. Years with the lowest temperatures and low flow from river runoff are correlated with the fewest hypoxic events. The time-series records for 12 years (2001-2016) were examined to identify any potential to use hypoxia events to evaluate nutrient loading reductions that are occurring in the watershed. The Narragansett Bay Fixed-Site Monitoring Network (NBFSMN) is necessary to provide managers with assessment tools to evaluate hypoxia in Narragansett Bay.

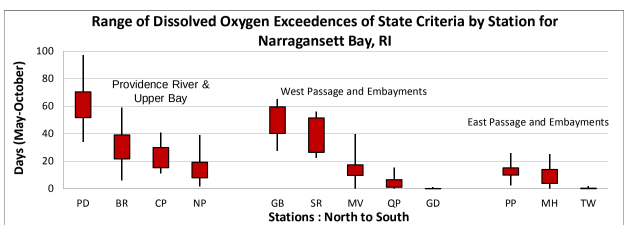
INTRODUCTION



The Narragansett Bay Fixed-Site Monitoring Network (NBFSMN) was created to analyze the spatial and temporal distribution of hypoxia in Narragansett Bay. This goal is achieved through an interagency collaboration.

NBFSMN Partners:

DEM-OWR (Lead Agency), URI/GSO, Narragansett Bay Commission (NBC), and Narragansett Bay National Estuarine Research Reserve (NBNERR).

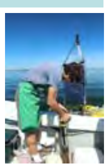


For more information visit: www.dem.ri.gov/bart/stations.htm

METHODS

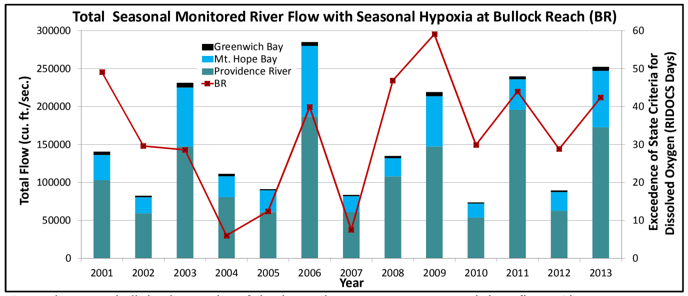
Measurements are made on a15-minute interval at about 1 meter above bottom and below surface.

Parameters measured are temperature (accuracy +/-0.15ºC), salinity (0.1ppt), and dissolved oxygen (0.2 mg/L) at near-surface and near-bottom depths, and near-surface chlorophyll fluorescence.

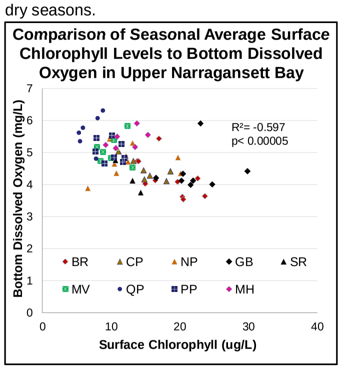


SEASONAL FORCING FACTORS ANALYSIS

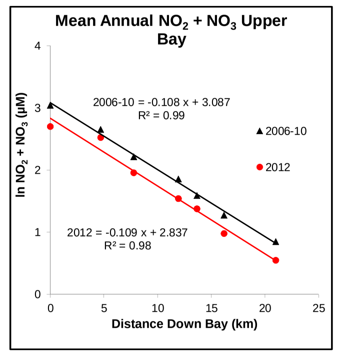
Hypoxia refers low dissolved oxygen (DO) concentrations that adversely affect organisms. Hypoxic events were identified using Rhode Island's water quality criteria for DO which relates a series of thresholds to varying time durations, e.g., DO not be less than 2.9 mg/L/24 hours for waters below a pycnocline. For this analysis, the seasonal spatial extent & seasonal cumulative duration of hypoxia were examined with forcing factors. All years were analyzed from at least June-September based on data availability.



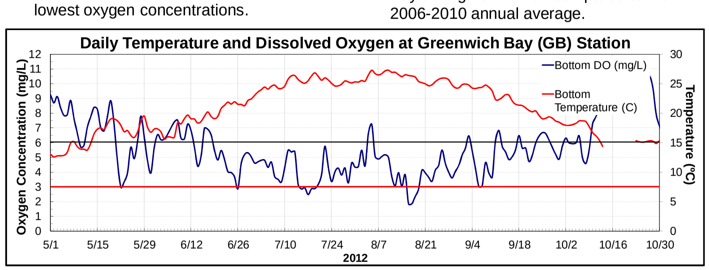
A previous study linked severity of the hypoxic season to seasonal river flow. Above average seasonal flow corresponded with above average number of days of hypoxia and extended spatial extent of hypoxia coverage. 2003, 2006, and 2008 have data missing during hypoxic events (amounts may be under-estimated). 2002, 2005, 2007, 2010, and 2012 are considered dry seasons.



The headwater stations tend to have the highest summer seasonal average chlorophyll levels corresponding with the lowest oxygen concentrations.



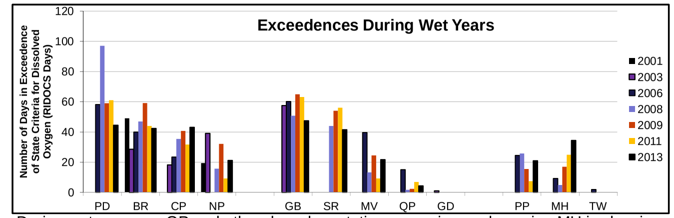
Preliminary analyses show a reduction in nitrogen concentrations in Narragansett Bay during 2012 when compared to the 2006-2010 annual average.



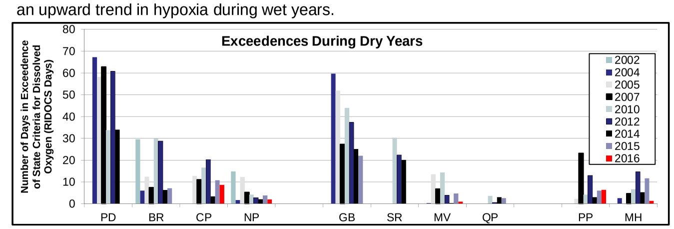
Hypoxic conditions do not usually occur with temperatures under 15º C. Normally, temperatures are below 15º C before the first week in June. In 2012, hypoxia was documented in May for the first time in Greenwich Bay.

ASSESSMENT TOOLS

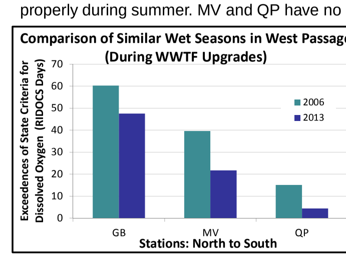
Since 2006, several wastewater treatment facilities (WWTFs) have upgraded their facilities to reduce nutrient loadings to Narragansett Bay. By 2017, nitrogen removal is expected from 11 RI WWTFs and is projected to reduce their summer season nitrogen loading by 65%, but dropping to 48% as WWTFs flows reach approved design flows (data from RIDEM-OWR). Managers are expecting to see hypoxia reductions at outer reaches of the spatial extent for hypoxia first (i.e. Quonset Point). Results from the state assessment tool (RIDOCS) were examined for any potential trends.



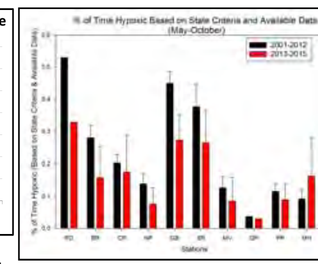
During wet seasons, QP and other down bay stations experiences hypoxia. MH is showing an upward trend in hypoxia during wet years.



NP shows a downward trend. 2010 may be anomalous because of WWTFs not operating properly during summer. MV and QP have no data for 2002.



Although 2006 and 2013 had somewhat similar seasonal flow patterns, stratification was higher in 2006. The downward trend may be influenced by stratification more than nutrient reductions. Sites with data gaps are not included in this graph.



There is a downward trend at most stations from pre and post WWTF upgrades. Although these trends are not statistically significant, yet.

CONCLUSIONS

1. Inter-annual variability in hypoxia is linked to inter-annual variability in flow and temperature. High flow and/or warm years produce longer durations during hypoxic events. The lowest flow years are linked with the lower hypoxia (spatial extent and seasonal duration). Increasing seasonal temperatures (May-Oct) can prolong hypoxic season.
2. Examining similar hypoxic events/seasons allow for intermediate assessments.
3. The data generated by the NBFSMN is vital to monitoring and assessing the impact of reduced pollutant loadings resulting from WWTF upgrades within the Narragansett Bay Watershed.

ACKNOWLEDGEMENTS

The monitoring network is funded in part by RIDEM-OWR, EPA Clean Water Act, NBC, NBNERR, and previously NOAA Bay Window Program. Thank you to all that contribute to NBFSMN. This program could not have been possible without the contributions of the late Dr. Dana Kester.

Spatial and temporal variability in macroalgal blooms in a eutrophied coastal estuary*

Carol S. Thornber[1, 2*], Michele Guidone[1, 3], Christopher Deacutis[4], Lindsay Green[1,2], Christine N. Ramsay[5], Melissa Palmisciano[6]

[1]Department of Biological Sciences, University of Rhode Island, 120 Flagg Road, Kingston, RI 02881; [2]Department of Natural Resources Science, University of Rhode Island, 120 Flagg Road, Kingston, RI 02881; [3]Present Address: Department of Biology, Armstrong State University, 11935 Abercorn Street, Savannah, GA 31419; [4]Rhode Island Department of Environmental Management Division of Fish and Wildlife, 3 Fort Wetherill Rd, Jamestown, RI 02835; [5]Department of Life Sciences, Mitchell College, New London, CT 06320; [6]Moss Landing Marine Labs, 8272 Moss Landing Road, Moss Landing, CA 95039

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Abstract:

All three macroalgal clades (Chlorophyta, Rhodophyta, and Phaeophyceae) contain bloom-forming species. Macroalgal blooms occur worldwide and have negative consequences for coastal habitats and economies. Narragansett Bay (NB), Rhode Island, USA, is a medium sized estuary that is heavily influenced by anthropogenic activities and has been plagued by macroalgal blooms for over a century. Over the past decade, significant investment has upgraded wastewater treatment from secondary treatment to water-quality based limits (i.e. tertiary treatment) in an effort to control coastal eutrophication in this system. The goal of this study was to improve the understanding of multi-year macroalgal bloom dynamics through intensive aerial and ground surveys conducted monthly to bi-monthly during low tides in May–October 2006–2013 in NB. Aerial surveys provided a rapid characterization of macroalgal densities across a large area, while ground surveys provided high resolution measurements of macroalgal identity, percent cover, and biomass.

Macroalgal blooms in NB are dominated by *Ulva* and *Gracilaria* spp. regardless of year or month, although all three clades of macroalgae were documented. Chlorophyta cover and nutrient concentrations were highest in the middle and upper bay. Rhodophyta cover was highest in the middle and lower bay, while drifting Phaeophyceae cover was patchy. Macroalgal blooms of >1000 g fresh mass (gfm)/m^2 (max = 3,510 gfm/m^2) in the intertidal zone and >3000 gfm/m^3 (max = 8,555 gfm/m^3) in the subtidal zone were observed within a heavily impacted embayment (Greenwich Bay). Macroalgal percent cover (intertidal), biomass (subtidal), and diversity varied significantly between year, month-group, site, and even within sites, with the highest species diversity at sites outside of Greenwich Bay. Total intertidal macroalgal percent cover, as well as subtidal *Ulva* biomass, were positively correlated with temperature. Dissolved inorganic nitrogen concentrations were correlated with the total biomass of macroalgae and the subtidal biomass of *Gracilaria* spp. but not the biomass of *Ulva* spp. Despite seasonal reductions in the nutrient output of wastewater treatment facilities emptying into upper Narragansett Bay in recent years, macroalgal blooms still persist. Continued long-term monitoring of water quality, macroalgal blooms, and ecological indicators is essential to understand the changes in macroalgal bloom dynamics that occur after nutrient reductions from management efforts.

Fig 1. Subtidal (left) and intertidal (right) macroalgal blooms in Narragansett Bay are dominated by *Ulva* blades (sea lettuce) and coarsely branched red seaweeds (*Gracilaria/Agardhiella*).

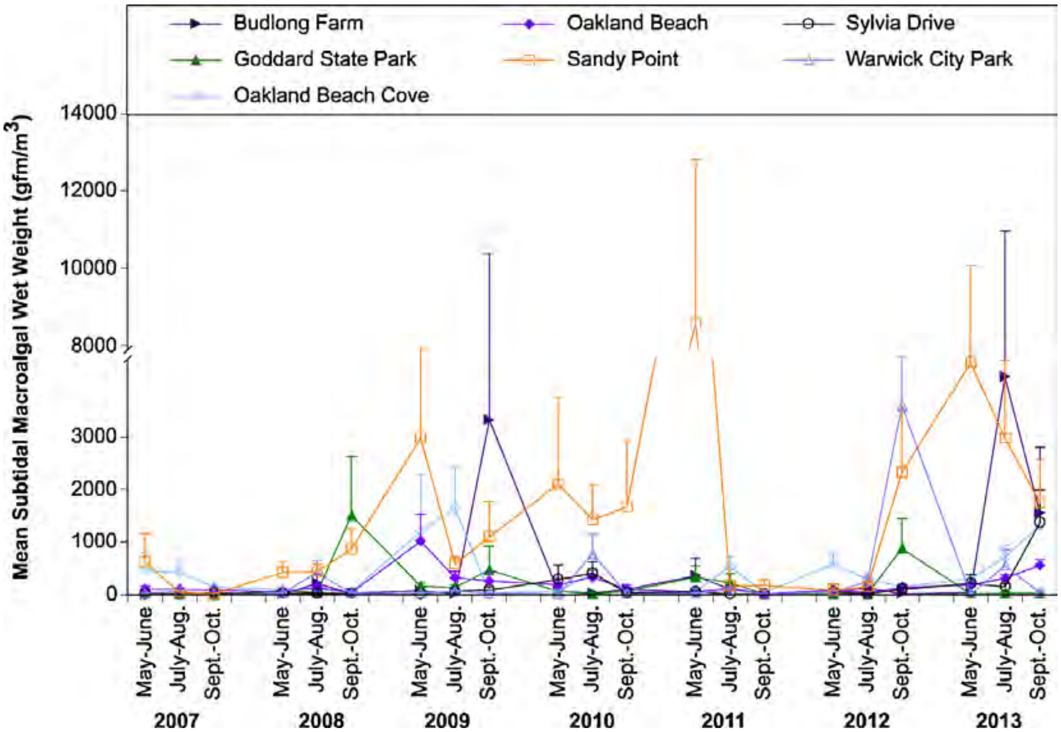


Fig. 2. Mean total algal biomass (grams fresh weight, gfm) observed during subtidal surveys at 7 sites in Greenwich Bay.

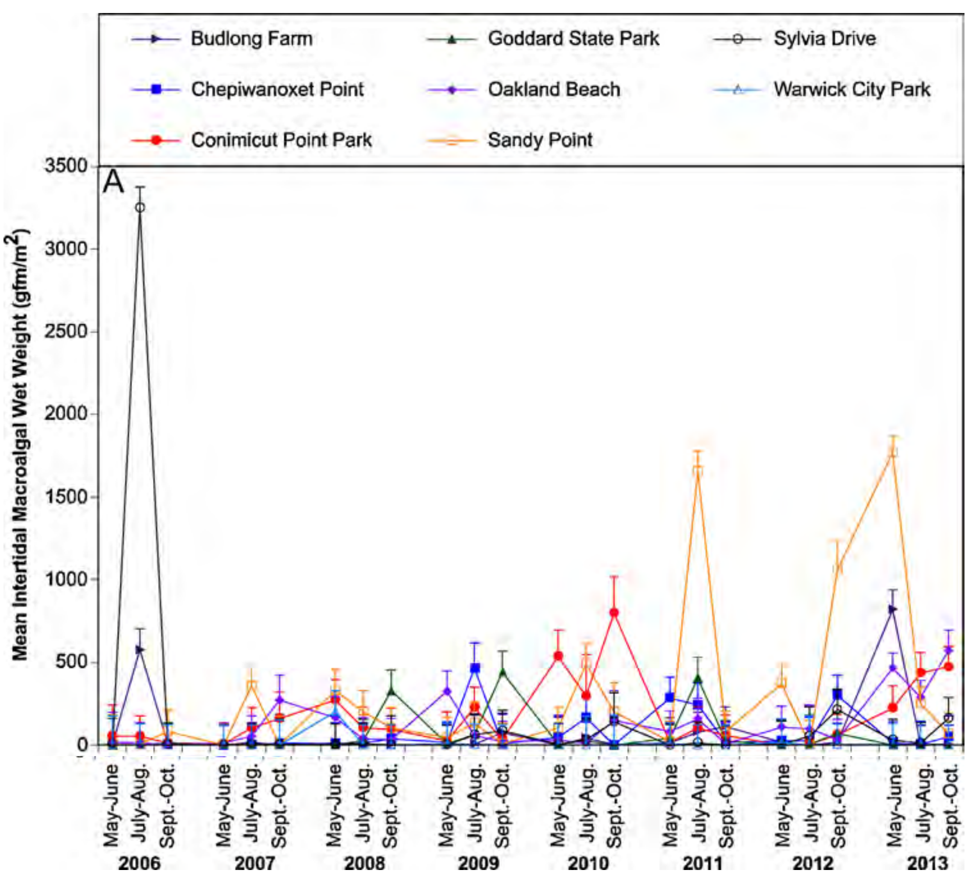


Fig. 3. Mean total algal biomass observed during intertidal surveys at 8 sites in Greenwich Bay.

MyCoast RI – Monitoring for Nuisance Flooding, Storm Damages and Habitat Impacts from Sea Level Rise

Introduction

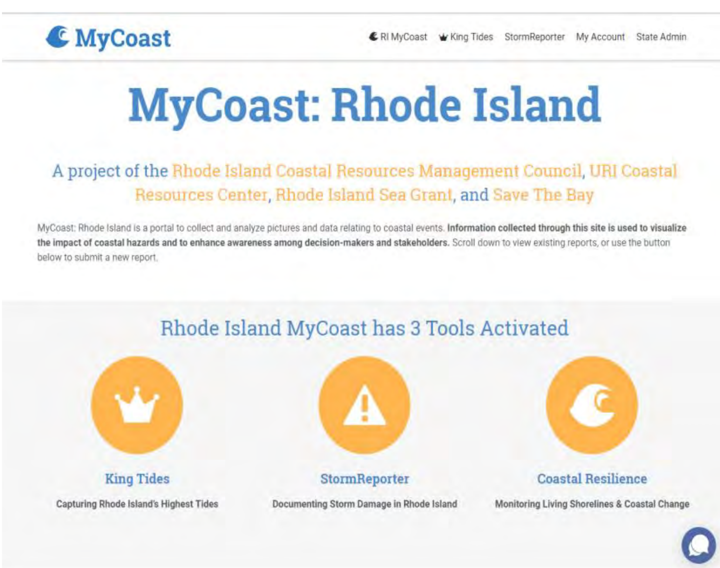
The Narragansett Bay Estuary Program identifies sea level rise as one of the climate stressors in the ***State of Narragansett Bay and Its Watershed - Technical Report***. Rising sea levels impact several bay ecosystems, particularly salt marshes and stresses many elements of the humanly altered landscape. Many low lying roads are currently inundated by nuisance flooding. In the future these transportation systems and other critical infrastructure in coastal areas will be inundated more and more frequently.

Low lying coastal roads are frequently flooded in Rhode Island when tides are higher than normal. This road flooded when tides were 2 feet above MHHW. Nuisance flooding events like this are compared to modeled inundation data to validate the models.

Stormtools 2 foot SLR map matches the observed flood levels.

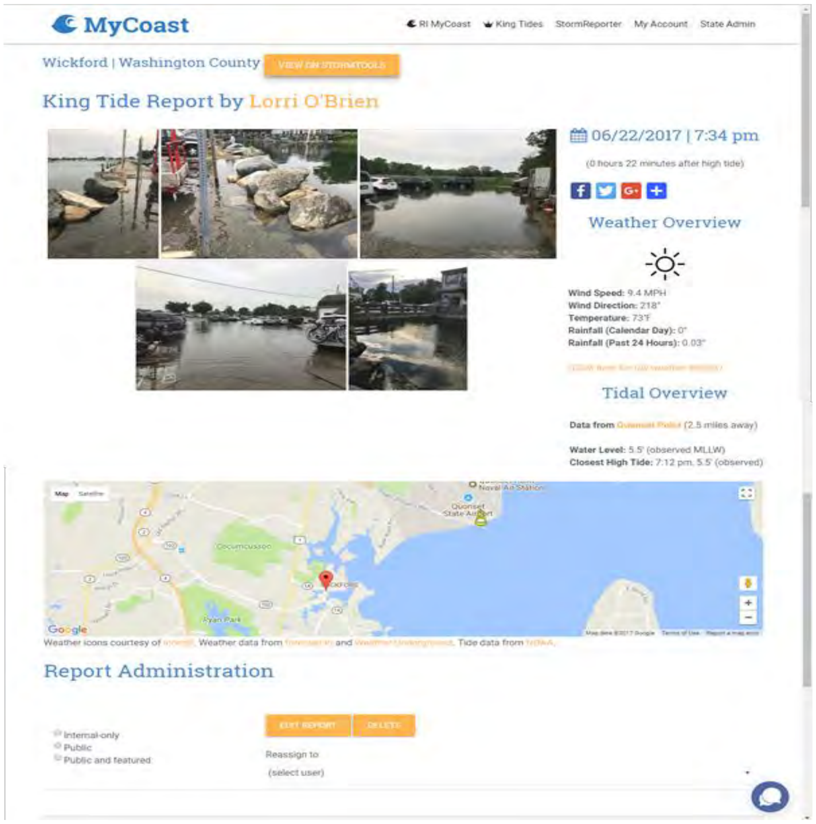
The MyCoast App

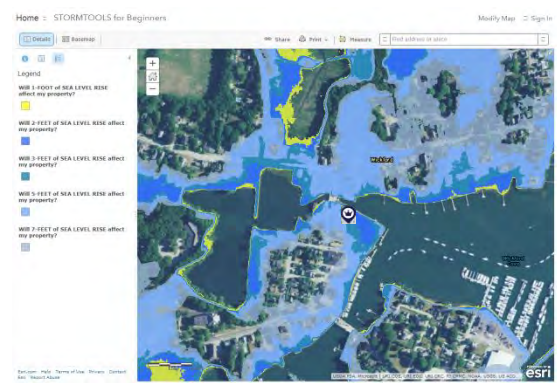
The MyCoast free app for iPhone or android allows citizen scientists to quickly submit photos of coastal events, such as storm damage or nuisance flooding, especially when caused by extreme high tides. The app allows users to quickly and easily upload images taken on a smartphone to a central database. Photographs are automagically geolocated and assigned metadata, including meteorological and tidal conditions. A small selection of that information is then displayed on the public site, where visitors can view the reports on a map, photo gallery, or list.



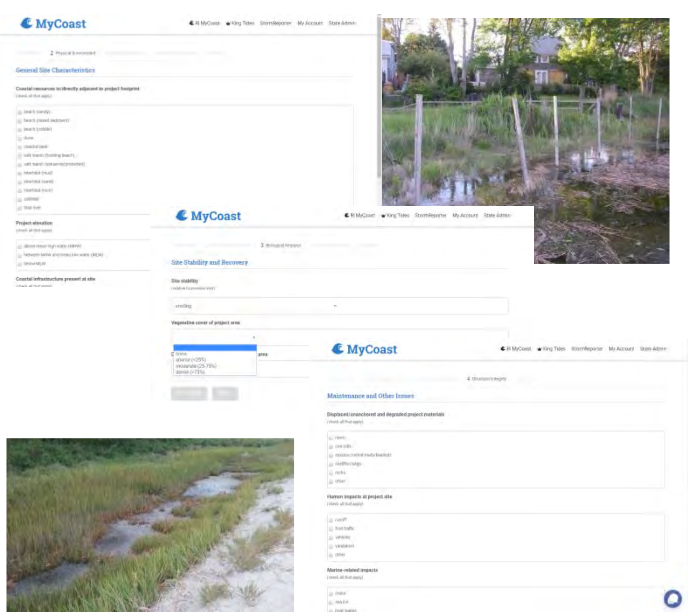
The MyCoast app has three options for coastal flood reporting; extreme high tides, sometimes referred to as king tides; storm reports to document storm damages to coastal properties and habitat; and a new coastal resilience tool to document impacts and changes to coastal ecosystems. The tools have been used to determine thresholds for coastal flooding advisories put out by the National Weather Service, and to identify areas at risk to coastal flooding and to help visualize future daily conditions as sea levels rise. .

Photos highlight current conditions within Narragansett Bay and are indicators of increasing trends of the future. Information collected helps to ground truth Stormtools inundation maps and models, to visualize the impact of coastal hazards and to enhance awareness of community decision-makers and citizens. These data can be used to develop thresholds for nuisance flooding for coastal lands within the bay that are far from the Providence Tide Gage (8454000). A Coastal Resilience component has been recently added to document changes to coastal ecosystems.





MyCoast reports include geolocated photographs, tide and weather data , and a link to Stormtools inundation maps. Photographs and the linked database are downloadable from the website mycoast.org.



The Coastal Resilience tool was recently developed under a coastal resiliency grant from the Northeast Regional Ocean Council and has not been utilized yet. This tool has great potential for documenting the impacts of sea level rise on marshes and marsh migration.

Data inputs include the general site characteristics, site stability and recovery (stable, eroding, accreting; vegetation cover and type), and maintenance issues such as boat wake damage, crab predation, etc. The reporter fills in applicable fields on a pre-populated form for collection of consistent site characteristics. Additional comment may also be entered into the report.

Rhode Island Coastal Resources Management Council, URI Coastal Resources Center, Save the Bay, Northeast Regional Ocean Council, National Weather Service, Northeastern Regional Association of Coastal and Ocean Observing Systems. A Blue Urchin, LLC production

Appendix E: Status Chart for Rhode Island Monitoring Priorities

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
Coastal Water Quality					
Narragansett Bay Water Quality: -temperature -salinity -chlorophyll -dissolved oxygen	1. Fixed-Site Monitoring Network: Network of monitoring stations at 13 fixed locations (8 buoys and 5 fixed dock sites) taking time-series data of water quality in Narragansett Bay. Data used to assess compliance with state water quality criteria. 2. Field Surveys: Boat surveys measuring water quality data at 77 stations; Provides cross-sectional information within the Bay; complements the fixed-site network; and identifies areas that are at significant risk for hypoxic conditions to occur	1. Implemented 2. Implemented	1. RIDEM covers most of this program using federal funds supported by Clean Water Act SRF Funding. **Reliance on SRF funding is not sustainable.** NBC uses rate payer funds and NBNERR uses NOAA funds. 2. No direct state funding for spatial surveys; field operations supported by Brown University, URI GSO/RIDEM, and STB.	1. Annual Unmet Need: $400,000-$650,000 2. At risk of disruption; Annual Unmet Need: $30,000-$75,000	• GAP: Gap analysis needed to ascertain what additional information is required to characterize the ecosystem response to nutrient reductions. • GAP: Additional chlorophyll data representative of all major sub-regions of Narragansett Bay. • GAP: Additional NBFSMN stations in Mount Hope Bay, the Sakonnet River, and the Lower East Passage. • GAP: Assessment to determine whether the existing network of fixed sites provides adequate information for tracking long-term temperature changes. • Funds for major upgrades/replacement of aging equipment in in the network is needed. • Stable funding for operations and data processing is needed. • Analysis of Phillipsdale data to see how upper section of the Seekonk River is changing. • Further analysis of the Chlorophyll Bloom Index. • Additional data synthesis studies or longer-term monitoring to further explore the different temporal and spatial scales of dissolved oxygen variability. • Continued development and validation of a water quality/ecosystem model for Narragansett Bay. • Models for better understanding of the connection between benthic conditions and overlying dissolved oxygen conditions.

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
Water Clarity (NBEP)	Clarity is an important indicator of water quality; Secchi depth and being PAR data collected at certain locations	Partially implemented	Not available	No state funding assigned to these programs	• GAP: Increase spatial coverage and reliability of clarity measurements through Narragansett Bay. • Comparison of Secchi Depth and PAR methods for measuring clarity. • Satellite remote sensing-based measurements of coastal water clarity. • Event-based study of water clarity.
Shellfish Growing Areas	Pathogen monitoring in shellfish growing areas for public health protection; 300 established stations in bay and other coastal waters	Implemented	State general revenues - RIDEM	Currently stable	• GAP: Additional sampling in prohibited harvesting areas. • Synthesis of existing data and development of site-specific models. • Additional data collection and analysis to reassess the relationship between precipitation and pathogens. • Further data synthesis and analysis to relate water quality improvements to reduced pathogen loadings due to non-point source management actions. • Development of a metric more sensitive to water quality improvements using pathogen data.
Harmful Algal Blooms (Coastal)	Monitoring phytoplankton to screen for potential public health risks associated with harmful algal blooms	Implemented; Plans to expand effort for 2018;	State General Revenues - RIDEM & RIDOH	State funding is limited; expanded program unmet need: $200,000-$440,000	• Analysis of changes in phytoplankton species composition and abundance over time.

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
Rotating Assessment of Coastal Waters	Intended to systematically address water quality data gaps in coastal coves and embayments	Not implemented Some data collected by RIDEM and volunteers	No state funding assigned to this program	Annual Unmet Need: $250,000	• GAP: Data collection in certain coves, embayments and coastal ponds: DO, nutrients, Chl, temperature, salinity.
Toxic Contaminants in Fish and Shellfish	Data needed to identify and assess public health risks of toxic contaminants in fish and shellfish.	Not implemented Available data generated primarily by researchers	No state funding assigned to these programs	Annual Unmet Need: $150,000	• GAP: Expansion of state monitoring programs to include estuarine and near-shore fish to create a holistic assessment of mercury in commercially and recreationally important species throughout the Bay. • GAP: Collection of data to assess other legacy contaminants including PCBs, pesticides, and cadmium in fish. • GAP: Addition of a Mussel Watch monitoring station to Mount Hope Bay to track legacy contaminants in that region. • Incorporation of Brayton Power Plant maintained metals-monitoring data in quahogs (Mercenaria mercenaria) into status and trends analyses. • Hydrodynamic model of Narragansett Bay to better understand the transport, behavior, and fate of contaminants.
Legacy Contaminants in Sediments (NBEP)	Data on persistence of contaminants in the benthic environment helps characterize habitat quality and potential public health concerns	Available data has been collected primarily by researchers	Not available	No state funding assigned to these programs	• GAP: Ensure periodic data collection to support indicator reporting over time and meet management needs.

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
Emerging Contaminants (NBEP)	Data on emerging contaminants reflect anthropogenic influence the environment; effects are not yet well understood	Available data has been collected primarily by researchers	Not available	No state funding assigned to this program	• Continued research is needed to better understand the potential exposure and assess the likelihood of ecological and human health risks. • An assessment should be performed to identify key CECs prior to further investment in initiating a monitoring program.
Physical Conditions					
River and Stream Flows (RI Stream Gage Network)	Provides vital data for flood forecasting, flood response and risk management, water pollution control, water quality management including modeling, water supply planning and management, drought management	Implemented	Limited state funding USGS (30%) RIDEM & RI WRB (70%) of 21 stream gages; Providence Water Supply Board also funds gages	At risk of disruption Annual Unmet Need: $110,000	• GAP: Need updated assessment of existing network of stream gages to identify key gaps.
Shoreline Change/Sea Level Rise	Provides data critical to development of CRMC's Shoreline Change Special Area Management Plan and to understand the threat of coastal erosion on public and private infrastructure and natural ecosystems	Partially Implemented	Federal funds with support from URI, CRMC	Annual Unmet Need: $100,000	• GAP: Enhanced bathymetry data. • Expansion of the STORMTOOLS model to include the Massachusetts portion of Narragansett Bay to identify and evaluate high-risk areas. • Analysis of potential impacts of sea level rise on groundwater, drinking water supplies, floodplains, and individual wastewater treatment systems. • Trend analysis of sea level rise trend for Mount Hope Bay using data from the Fall River tide gauge.
Biological Communities and Habitats					

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
Marine Fisheries Surveys	Fisheries trawl surveys; supports stock assessments and management decision-making for important commercial fisheries, both finfish and shellfish, also provides data to track ecological status and trends	Implemented - Program enhancements recommended	RIDEM using USFW federal funds matched primarily with license receipts	Projected as stable for current programs; Expansion of programs would require additional resources - TBD	• Analyses of comparability of the GSO and RIDEM trawl data over time, including an examination of the timing and effects of any gear changes. • Consultation with experts to advise on other approach(es) to use in the future to characterize changes in estuarine fish communities. • Compilation and analysis of data on estuarine fish communities in the Upper Bay, including the Providence River Estuary and Greenwich Bay. • Analysis of data collected since 2012.
Lobster Population Surveys	Commercial logbooks, ventless trap surveys, and diver-based young-of-the-year settlement surveys; improves characterization of the abundance and recruitment of lobster	Implemented	RIDEM using NMFS Inter-jurisdictional Fisheries Funding, NOAA	Funding not yet secured for 2018;	
Eelgrass Beds	Aerial photography mapping extent and area of eelgrass beds to characterize the status and trends for this important habitat	Partially Implemented	STB, NBNERR, and CRMC using RI Coastal and Estuarine Habitat Restoration Trust Fund	Currently stable Annual Unmet Need: FY15 $85,000 (periodic investment for overflights)	• GAP: Full implementation of Rhode Island Eelgrass Task Force's recommendations for a three-tiered approach.

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
Saltmarshes	Three-tiered monitoring strategy includes landscape scale-GIS assessment, field-based rapid assessment protocol, and intensive research-based assessment of salt marshes	Partially implemented	CRMC, using RI Coastal and Estuarine Habitat Restoration Trust Fund, RIDEM using USFWS Coastal Program and EPA funds. NBNERR using NOAA funds. RINHS is key partner.	Funding is not stable Annual Unmet Need: TBD	• GAP: Full implementation of the multi-parameter Rhode Island Salt Marsh Monitoring Strategy. • Research and monitoring to evaluate methods that will facilitate salt marsh resilience to sea level rise. • Field research and modeling to better understand the process of landward marsh migration under regimes of accelerated rates of sea level rise.
Arrival and Spread of Marine AIS	Identifies invasive species, to allow for proper eradication and management techniques	Partially implemented	Program partners: CRMC, RIDEM, RINHS, NBNERR, EPA AED, RWU	Limited federal funding (USFW) has steadily declined Annual Unmet Need: $150,000	
Benthic Habitat (NBEP)	Characterization of benthic habitat supports bay resource management decision-making	Available data has been collected primarily by researchers	Not available	No state funding assigned to this program	• GAP: The sites characterized in 1988 and 2008 should be revisited every five years using sediment profile imagery. • GAP: Need to coordinate sediment profile imagery with surveys of larger fauna, e.g. shellfish. • Future assessments of benthic habitat quality to incorporate measurements of benthic biogeochemistry, and for future benthic biogeochemistry studies to take a habitat-based approach.

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
Volunteer Monitoring of Coastal Waters	Provides supplemental data that may be used state agencies to target monitoring programs, identify pollution sources and track change in condition over time	Implemented	Multiple sources including state and local sponsors	At risk of disruption Annual Unmet Need: $25,000	
Saltwater Beach Water Quality	Monitors saltwater beaches to protect public health, reduce illness associated with swimming in potentially contaminated bathing waters, and to find and eliminate sources of contamination	Implemented	No state funding; RIDOH uses EPA BEACH Act funding. No federal funding may be available after 2015 field season.	At risk for disruption Annual Unmet Need: $212,000	
Other RIEMC Indicators related to watersheds (not the focus of Workshop discussion)					
Water Quality in Large Rivers	Monitors water quality in major rivers to track long term trends for managing water pollution sources; these programs also evaluate pollutant loadings into Narragansett Bay and coastal waters. MA rivers (Taunton, upstream portion of Blackstone) to be similarly monitored to support effective watershed management.	Implemented Additional stations recommended in Pawtuxet River watershed	USGS, RIDEM, NBC	At risk of disruption Annual Unmet Need: $155,000	

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
Water Quality in Wadeable Rivers and Streams (rotating assessment)	Assesses water quality in rivers and streams and guides water pollution control programs for rivers, streams, salt ponds and Narragansett Bay	Disrupted in 2017 due to loss of staff and federal funding uncertainties	RIDEM using EPA funds	Disrupted/ Uncertain Annual Unmet Need: $300,000	
Arrival and Spread of Freshwater AIS	Identifies species to support more effective management and control strategies	Partially implemented	RIDEM using USFWS & EPA funds, RINHS, URI	Funding is limited & unstable Annual Unmet Need: $150,000	
Freshwater Wetlands	Provides ecological condition data for freshwater wetlands and the stressors adversely affecting their functions and values	Partially implemented	RIDEM using EPA and RINHS funds	Relies on competitive grants; limited funding available to continue program Annual Unmet Need: $125,000	
Volunteer Monitoring	*Rivers and Streams* Supplements data collected by the State to help assess changing conditions in rivers and streams *Lakes and Ponds* Collects data on State's lakes and ponds that would	Implemented Implemented, no funding for recommended expansion to unassessed lakes	URI Cooperative Extension, RIDEM using EPA funds, and various local sponsors Clean Ocean Access using EPA and other funding	At risk of disruption Annual Unmet Need: TBD At risk of disruption Annual Unmet Need: $80,000	

Status of RIEMC Coastal Monitoring Programs/Indicators - October 2017
(including enhancements suggested in State of Narragansett Bay Technical Report)

Program/ Indicator	Utility	Status	Current Funding & Program Support	State Funding Outlook - 2018	Identified Gaps/Suggested Enhancements
	otherwise go un-assessed; this data improves statewide water quality assessments and management, but needs to be expanded to fill gaps.				
Freshwater Beach Water Quality	Freshwater beaches make up nearly half of RI's licensed swimming beaches, but are monitored far less frequently than saltwater beaches. Of particular concern are freshwater swimming beaches at youth summer camps.	Partially implemented by freshwater beach owners and operators	No funding available to enhance the limited existing program	Annual Unmet Need: $100,000	

Appendix F: NBEP Research Gaps

APPENDIX E. Compiled List of Data Gaps and Research Needs

This is a compiled list of data gaps and research needs from the 2017 *State of Narragansett Bay and Its Watershed* Technical Report. The Estuary Program has organized the data gaps and research needs from the Technical Report into two major categories: 1) **projects where data is available but needs further analysis**, or 2) **projects that need new data collected**.

Chapter 1. Temperature

1. **Continuous temperature data in rivers and streams is a major data gap. A sustained river/ stream temperature monitoring network in the Narragansett Bay Watershed needs to be established to include long-term monitoring stations in key locations. Lacking that, a conversion factor between air temperature and freshwater temperature (e.g., Morrill et al. 2005) would estimate changes in stream temperature from existing air temperature data.**
2. **An assessment is needed to determine whether the existing network of fixed sites for collecting water temperature data continuously in the Bay provides adequate information for tracking the long-term changes. Data collection in embayments is a recognized gap. Prior monitoring strategies recommended building capacity to periodically assess water quality conditions in such areas. Rising temperatures are likely to affect shallow and highly urbanized basins before the rest of Narragansett Bay (Oczkowski et al. 2015).**
3. **Further analysis of trends in air and water temperature datasets is needed. While the Estuary Program and other researchers (e.g., Nixon et al. 2004, Oviatt 2004, Pilson 2008) used 1960 as a start date for regressions, the perception of a recent acceleration in warming may be a consequence of using that date. An analysis of the datasets could determine whether this trend is meaningful and potentially identify other significant trends, such as seasonal variability (e.g., freeze/thaw cycles).**
4. **Experiments using mesocosms are needed to determine how the Narragansett Bay ecosystem may be affected by climate change (e.g., Bintz et al. 2003). Latitudinal gradient studies would be beneficial to predict future ecosystem and species shifts resulting from changing temperature trends (e.g., Crosby et al. 2017).**

Chapter 2. Precipitation

1. **The existing network of stream gages in the Narragansett Bay Watershed should be assessed to ascertain key gaps, and data records should be analyzed to characterize variability in rainfall across the watershed and identify where additional rain gages may be needed (e.g., the Pawtuxet River watershed). Sustained funding for the network is critical to ensure adequate hydrologic data is available to support management decision-making.**
2. **Extreme precipitation and drought in the Narragansett Bay Watershed need to be further investigated using a combination of approaches, such as the Palmer Drought Severity Index, the Crop Moisture Index, and Cornell University's effort to analyze frequency and intensity of precipitation (Cornell University 2016). The results of these efforts will detail the impacts that extreme precipitation and drought have on water resources management and water quality.**
3. **The frequency, amount, seasonality (freeze/ thaw cycles), and type (rain, snow) of precipitation influence physical, chemical, and biological processes within the Narragansett Bay Watershed. The impacts of climate change on precipitation need to be further explored using downscaling of climate models or other methods. Results of these efforts will increase**

knowledge of how sensitive habitats will change, and how to plan for the resiliency of infrastructure.

Chapter 3. Sea Level

1. **The STORMTOOLS model should be expanded to include the Massachusetts portion of Narragansett Bay to identify and evaluate high-risk areas.**
2. **An analysis of the potential impacts of sea level rise on groundwater, drinking water supplies, floodplains, and individual wastewater treatment systems is needed (Walter et al. 2016).**
3. **Data and research are needed to evaluate the effects of sea level rise on other ecological systems at the landscape and seascape level, such the impacts on bird, mammal, and amphibian migration and breeding habitat, submerged aquatic vegetation, freshwater wetlands (palustrine and lacustrine), shellfish habitat, and fish passage habitat (diadromous and anadromous fish).**
4. **A sea level rise trend analysis is needed for Mount Hope Bay using data from the Fall River tide gauge, which NOAA has operated since 1955. This analysis is especially important because of the low elevations of the Taunton River watershed.**
5. **Enhanced bathymetry data would improve the resolution of the hydrodynamic models that are used to predict flooding potential from sea level rise and storm surge.**

Chapter 4. Population

1. **There are no critical data gaps or research needs, assuming that detailed US Census Bureau data continue to be collected each decade and that funds are made available to conduct geospatial analyses. This research is needed to provide a more comprehensive understanding of trends and to provide context for other indicators of stressors and conditions in Narragansett Bay and its Watershed. More robust data analyses should be performed to interrelate total population changes with developed area per capita and housing density, two factors that are linked to the effects of population on other landscape and chemical indicators.**

Chapter 5. Land Use

1. **Data from the NOAA Coastal Change Analysis Program (C-CAP) should be utilized to improve the spatial and classification accuracy of land cover classes and change analysis for the Watershed.**
2. **Further data analysis to correlate land use and other attributes of the landscape with water quality and habitat conditions is needed to improve understanding of such relationships.**
3. **Additional research is needed to provide better tools for estimating the value of ecosystem services provided by forest lands in the Watershed. Examples of these ecosystem services are water quality protection for both surface and groundwater, wildlife habitat conservation, climate change adaptation, and stormwater mitigation.**

Chapter 6. Impervious Cover

1. **Data on sites where stormwater best management practices have been installed are not readily available. To address this important data gap, information could be compiled from state and local permitting records. Mechanisms to capture the data moving forward need to**

be developed. The data should include location, drainage area being captured, type of treatment provided, and effectiveness of treatment.

2. Research is needed to examine hydrological regimes and runoff to major rivers and streams at appropriate subwatershed scales to evaluate the relationship between percent impervious cover and various water quality and habitat indicators, such as water temperature, water quality for aquatic life, stream invertebrates, fish communities, and all public health indicators. Likewise, spatial data on impervious cover, in conjunction with other indicators such as land use, should be investigated as a proxy to estimate nutrient loadings from non-point sources at varying watershed scales.

Chapter 7. Wastewater Infrastructure

1. To improve data quality, a more systematic means of periodically updating public sewer service information should be developed, and the information should be made easily accessible and shareable. It should include data on buildings and population that have been connected to the sewer systems over time.
2. There is a need to improve the capacity to compile data from state (Rhode Island) and local (Massachusetts) records to map locations and types of onsite wastewater treatment systems (OWTS), including traditional and advanced systems and cesspools. Data should include buildings that have converted from cesspools to conventional or advanced septic systems, or from conventional to advanced septic systems. This information would allow for further analyses related to water quality and climate change vulnerabilities.
3. To address the above data gaps, one option that can be standard and trackable, for both sewered areas and onsite systems, is to include in the parcel data an attribute or attributes that define the type of sewage treatment, across all towns within the Watershed, when parcel data are updated.
4. There is a need to integrate other readily available data such as soils, natural buffers, streams, and land use, among others, to identify whether groundwater at areas where onsite systems are estimated to be located, based on the preliminary results in this chapter, is likely at higher or lower risk of sewage contamination due to soil properties, proximity to resources of concern, or other constraints. A study similar to the one by Sowah and colleagues (2017) should be replicated in the Narragansett Bay Watershed to develop more robust mapping and information related to high-density onsite systems and their effects on water quality for aquatic life and human health. The Estuary Program has already advanced in this research need, by engaging soil scientists in both Massachusetts and Rhode Island with the US Department of Agricultural, Natural Resources Conservation Service (USDANRCS) to start compiling soil data and properties to develop a suitability map for the Watershed.
5. There is limited data analysis on groundwater across the Watershed, except for areas in Greenwich Bay. This is an outstanding data need that is imperative for understanding groundwater direction, flow, and attenuation, and other factors that can provide a more complete picture of the risks of sewage contamination to surface waters or the Bay, via onsite systems, whether septic systems or cesspools. Alternatively, or while methods are developed for groundwater monitoring, other approaches can be undertaken, such as coordinating with partners at the University of Connecticut to follow their methods to start gathering information about groundwater inputs to the Bay, and consequently assess the

impacts of onsite systems to public health (due to pathogen loadings, primarily) and habitat (due to increase of nitrogen or phosphorus loadings to freshwaters and the estuary).

6. Additional data on the performance of advanced treatment OWTS should be collected. Analysis of data should be completed to evaluate whether advanced systems are achieving expected treatment efficiencies during actual use.
7. Improved field studies and models to estimate nutrient and pathogen loadings from onsite systems are needed to quantify and evaluate the impacts on streams and embayments, such as Greenwich Bay.

Chapter 8. Nutrient Loading

1. A monitoring strategy is needed to address data gaps in the information required to ascertain the ecosystem response to nutrient reductions. It would be expected to include additional monitoring of biological and water quality parameters, such as benthic species and phytoplankton species composition and productivity—two ecosystem components that are expected to be responsive to the changes in nutrient loading. Data should be suitable to validate relevant water quality and ecosystem models.
2. Data used to estimate the contribution to nutrient budgets from nonpoint sources need to be refined. The data should include atmospheric deposition, stormwater contributions, agriculture, and other nonpoint sources.
3. Continued development and validation of a water quality/ecosystem model for Narragansett Bay is needed to provide an additional tool for evaluating nutrient dynamics. Such models need to be linked with validated hydrodynamic modeling and may also need to be appropriately applied to sub-regions of the Bay, particularly embayments.
4. Groundwater inputs of nutrients to estuarine and surface fresh waters in the Watershed continue to be a major data gap.
5. An assessment should be conducted to determine whether there is a need to standardize monitoring of total nitrogen and total phosphorus concentrations year-round at wastewater treatment facilities.
6. Further refinement of nutrient budgets is needed to provide insight into differences among seasonal load changes (winter, summer, and spring) at different scales aligned with potential ecosystem impacts, such as limiting the productivity of the Bay.

Chapter 9. Legacy Contaminants

1. The concentration of legacy contaminants, including mercury, in estuarine and freshwater fish and shellfish is a data gap. More studies using an approach similar to that used by Taylor et al. (2012) and Taylor and Williamson (2017) for mercury are needed to determine the human health risk posed by the uptake of legacy contaminants by fish and other human-consumed biota (e.g., shellfish). Future work would be to expand the state monitoring programs to include estuarine and near-shore fish (i.e., Taylor's work) to create a holistic assessment of mercury in commercially and recreationally important species throughout the Bay. Other legacy contaminants that need to be assessed include, at a minimum, PCBs, pesticides, and cadmium.
2. The concentration of legacy contaminants in river sediments within the Narragansett Bay Watershed is a data gap that can contribute to delays in pursuing riverine restoration actions. Studies like Cantwell et al. (2014) need to be conducted to assess the amount of contaminants in the sediments and water column before and after dam removals.

3. **Brayton Power Plant maintained metals-monitoring data in quahogs (*Mercenaria mercenaria*) that could be incorporated into the status and trends analyses. Given Brayton Power Plant's pending shut down, it is unlikely this monitoring program will continue. Adding a Mussel Watch monitoring station to Mount Hope Bay would be useful in tracking legacy contaminants in that region.**
4. **These results are framed around a north-to-south gradient, with the study sites reflecting that preference. However, sediment contaminant maps have pinpointed localized hotspots throughout the Bay—such as near the East Greenwich Wastewater Treatment Facility in Greenwich Bay—that warrant further research (Figures 2 and 4).**
5. **The climate change section of this chapter showed that there is little knowledge of how these legacy contaminants will behave under a changing climate. While release into the environment is decreasing, these contaminants may still pose health risks due to relic deposits in sediments. Understanding how climate change will affect mobility and toxicity of these contaminants both directly and indirectly is important to inform human and environmental risk assessments.**

Chapter 10. Emerging Contaminants

1. **Continued research is needed to better understand the potential exposure and assess the likelihood of ecological and human health risks resulting from existing and newly identified contaminants of emerging concern (CECs). This includes research into the fate and transport of CECs in the environment.**
2. **An assessment should be performed to identify key CECs prior to further investment in initiating a monitoring program. Any monitoring program will need to adapt to changes in the use of CECs. For example, as compounds are banned or phased out from use, compounds that may replace them should be considered for inclusion in monitoring.**
3. **For CECs that are highly soluble and remain in the dissolved phase of the water column for extended periods of time, it would be beneficial to have an improved understanding of the hydrodynamic processes within Narragansett Bay. This information along with eco-toxicity and bioaccumulation data, the direct measurement of CECs, and the use of spatial models will help to identify potential locations of concern as well as ascertain the transport, behavior, and ultimately the fate of CECs within Narragansett Bay.**

Chapter 11. Seagrasses

1. **The Rhode Island Eelgrass Task Force's recommendations for a three-tiered approach to seagrass mapping and monitoring (Raposa and Bradley 2009) need to be implemented in order to conduct seagrass analysis more systematically, including more refined methods to examine extent and condition.**
2. **Warming temperatures, changes in precipitation patterns, and sea level rise can all affect how seagrass beds survive from year to year. Research is needed to fully understand how Narragansett Bay's seagrass beds will respond.**
3. **A better understanding is needed of the life history traits of eelgrass and widgeon grass in Narragansett Bay. More knowledge of the life history traits will aid in conservation and restoration of seagrass beds to maintain or increase acreage or condition of the beds. Of particular interest is widgeon grass, as it is far less studied than eelgrass. Extensive mesocosm experiments on the response of eelgrass to nutrients, temperature, and other interactive factors have been conducted in Rhode Island (e.g., Bintz et al. 2003, Taylor et al.**

1999). These types of studies should be pursued for widgeon grass, as well as for seagrass communities composed of both eelgrass and widgeon grass.

Chapter 12. Salt Marsh

1. The multi-parameter Rhode Island Salt Marsh Monitoring Strategy (Raposa et al. 2015) needs to be fully implemented, including refining methods, in order to document status and trends in salt marsh extent in Narragansett Bay, and changes in marsh cover types (after Watson et al. 2017). This information is needed to assess the effects of sea level rise and other stressors on the long-term sustainability of marshes.
2. Research and monitoring is needed to evaluate methods that will facilitate salt marsh resilience to sea level rise (e.g., thin layer deposition; preservation of upland to allow for migration). A cost-benefit analysis coupled with multi-year monitoring could be used to help determine the best methods to improve long-term sustainability.
3. The existing SLAMM maps (RICRMC 2015) identify areas where marshes could migrate landward. Field research and modeling are needed to better understand the process of landward marsh migration under regimes of accelerated rates of sea level rise.
4. Sea level rise is a major factor contributing to the recent trend of Narragansett Bay's marshes tending toward submergence, but there are also many other factors interacting with sea level rise (e.g., nutrients, grazing, sediment supply, increasing temperature, increasing carbon dioxide). Additional empirical research and modeling are required to understand the complexity of these interactions so that effective adaptation strategies can be implemented.

Chapter 13. Benthic Habitat

1. The sites characterized in 1988 and 2008 should be revisited every five years using sediment profile imagery to quantify benthic habitat type, conspicuous species, and sediment oxygen penetration to link benthic habitat quality with water column conditions.
2. The sediment profile imaging technique used in this analysis may not adequately represent the presence of shellfish such as quahogs, soft-shell clams, and blue mussels, or larger fauna such as mantis shrimp and lobster. There is a need to coordinate benthic monitoring efforts in the upper Bay—such as any future sediment profile imagery surveys, the Narragansett Bay Commission's benthic video work, and the RIDEM's fish habitat projects—to provide a more complete assessment of benthic habitats.
3. There is a need for future assessments of benthic habitat quality to incorporate measurements of benthic biogeochemistry, and for future benthic biogeochemistry studies to take a habitat-based approach.

Chapter 14. Estuarine Fish Communities

1. Analyses are needed to better characterize the comparability of the GSO and RIDEM trawl data over time, including an examination of the timing and effects of any gear changes.
2. There is a need to convene experts to advise on other approach(es) to use in the future to characterize changes in estuarine fish communities, including consideration of different or additional focal species, and different or additional metrics, such as a weighted-mean preferred temperature metric (e.g., Collie et al. 2008).
3. Data on estuarine fish communities in the Upper Bay, including the Providence River Estuary and Greenwich Bay, were not included in this analysis. Existing data on those areas

need to be compiled and analyzed to provide a more complete understanding of Bay-wide trends.

4. This chapter only analyzed the RIDEM and GSO datasets through 2012. Data collected since 2012 need to be analyzed to identify more recent changes in the estuarine fish community.

Chapter 15. Dissolved Oxygen

1. A major gap with the Narragansett Bay Fixed Site Monitoring Network and spatial survey is the lack of resource commitment (e.g., funding and personnel) to continue these field monitoring and data processing efforts. The NBFSMN and spatial survey require constant equipment maintenance and costly upgrades. Additionally, gaps in the NBFSMN for dissolved oxygen exist for portions of Mount Hope Bay, the Sakonnet River, and the Lower East Passage where there are no monitoring stations.
2. High inter-annual variability limits the discernment of temporal trends in available datasets. Additional data synthesis studies or longer-term monitoring are needed to further explore the different temporal and spatial scales of dissolved oxygen variability and their relationships to other forcing factors (e.g., seasonal rainfall or temperature) and the physical structure of the water column.
3. The Phillipsdale site, which has unique circulation patterns and is proximal to a major freshwater source (the Blackstone River), was not analyzed for the Hypoxia Index or the Chlorophyll Bloom Index (see "Chlorophyll" chapter). In light of nutrient reductions and changes to the dissolved oxygen and chlorophyll concentrations in other sections of the Bay, the Phillipsdale data need to be analyzed to see how this upper section of the Seekonk River is changing.
4. The combination of dissolved oxygen data and hydrodynamic modeling efforts can provide a better understanding of how hydrodynamic properties of the Bay are influenced by physical forces, such as wind, precipitation, and river flow, and how dissolved oxygen levels respond. Models should be used to better understand the connection between benthic conditions and overlying dissolved oxygen conditions.

Chapter 16. Chlorophyll

1. Collection of additional chlorophyll data is needed in order to be representative of all major sub-regions of Narragansett Bay and improve the spatial resolution of existing datasets.
2. High interannual variability makes it difficult to detect temporal trends in existing datasets. Synthesis studies are needed to further explore the different temporal and spatial scales of chlorophyll variability and their relationships to other influencing factors (e.g., sunlight, pH, and temperature) as well as the physical structure of the water column.
3. Further analysis of the Chlorophyll Bloom Index is needed, including whether the 80th percentile fully encompasses the definition of a bloom, or if a second percentile should be added (such as the 20th percentile). Additionally, all three methods show high variability, and a sensitivity analysis should be done to reduce this variability.
4. Analysis of changes in phytoplankton species composition and abundance over time is needed to understand how species composition impacts chlorophyll concentration trends. The results will also inform any monitoring or analysis for phytoplankton nuisance or harmful algal blooms. Species composition has been studied before (Windecker 2010), and the GSO Phytoplankton Survey and NBC continue to record species-specific information.

5. **Controlled mesocosm studies should be done to evaluate the response of the benthic community to increased water clarity and decreased phytoplankton production (i.e., decreased input of organic matter to the benthos). This would address how the ecosystem is responding to nutrient reductions and inform a discussion regarding an appropriate balance of nutrient levels and ecosystem response.**

Chapter 17. Water Clarity

1. **There are gaps in the availability of clarity data for portions of the Bay, especially the embayments. Devising a plan to achieve more consistent methods, greater frequency of sampling, and better spatial coverage throughout the Bay is appropriate.**
2. **In devising a sampling plan, attention should be paid to the appropriate sampling intervals in order to reduce variability in the datasets and to enhance the ability to detect change. Accordingly, it would be valuable to conduct a careful analysis of the various datasets and/or a field study to determine an optimal sampling frequency to detect changes in water clarity.**
3. **The Estuary Program compared *k* values for both Secchi depth and PAR to maximize the use of available data. Ideally, one monitoring method—either Secchi depth or PAR—would be used throughout the Bay. However, the Estuary Program will continue to evaluate the comparison between Secchi depth and PAR using data collected in Narragansett Bay. Comparison of *k* values from the two monitoring methods would facilitate accurate use of *k* as a water clarity metric throughout the Bay.**
4. **Improving the spatial resolution of coastal water clarity measurements based on satellite remote sensing would reduce the need to take field measurements and would allow for a Bay-wide assessment, including embayments.**
5. **An event-based study of water clarity is needed to determine how closely total suspended solid loading is related to storm events, and how to manage those loads.**

Chapter 18. Water Quality Conditions for Aquatic Life

1. **Bi-state coordination across state agencies, MassDEP and RIDEM, could improve and streamline sample water quality of specific streams/rivers/lakes that share state boundaries to provide data that can reflect the most current water quality conditions of individual state-assessed waterbodies; however, limitations by the states and the nature of the assessments, including those discussed in this chapter, should be considered.**
2. **Coordination between the Estuary Program and state partners is needed to share data that can streamline the tracking of this indicator by linking the time of sampling (year, season) and assessment for each individual waterbody, freshwater or estuarine areas; also, to track new listings and de-listing of water impairments as they occur between cycles of water quality assessments, with the goal of quantifying changes overtime; these can shed light on water quality improvements or decline for aquatic life, more precisely due to the response of increased or reduced nutrient loadings.**
3. **Many different entities, particularly watershed NGOs and universities, monitor and routinely collect data on nutrients and dissolved oxygen parameters at varying frequencies (i.e., monthly) and scales (i.e., Taunton River watershed). Further evaluation is needed to determine whether water quality data from these efforts could be reconciled, combined, and standardized with the state datasets to improve temporal and spatial coverage for this indicator.**

4. **Research is needed to understand how landscape stressors (e.g., impervious cover, land use) and climate change stressors (e.g., precipitation, temperature) relate to increases in nutrient enrichment in waterbodies that can result in eutrophication and hypoxia events, harmful to aquatic life, in freshwaters of the Watershed and estuarine waters of the Bay. This should be explored on a variety of scales from larger watersheds to individual catchment areas.**
5. **There is a need to develop or utilize available tools to allow evaluation of the efficacy of stormwater management practices, including retrofitting of existing infrastructure, at appropriate scales (e.g., sub-Basin). This includes practices designed to treat/retain nitrogen and phosphorus loadings as well as those designed to address peak flows, as precipitation exacerbates the impacts of nutrient enrichment.**
6. **While cyanobacteria blooms are primarily a public health issue, monitoring cyanobacteria blooms in freshwaters and other harmful algal blooms in marine waters is needed. Data on harmful algal blooms, including inventory of waterbodies with history of blooms, frequency of events, and collection of other parameters during these events, can augment the understanding of the causes and consequences of blooms and the dynamics of bloom suppression, whether nutrient enrichment, oxygen depletion, low stream flows, water levels or flushing, or high-water temperatures, or a combination, can result or predict these blooms.**

Chapter 19. Stream Invertebrates

1. **Existing macroinvertebrate sampling protocols are not appropriate for all rivers and streams in the watershed. To address coastal streams left unassessed, a multi-year effort of data collection and evaluation is needed and should be conducted at a regional scale to sample a sufficient number of locations in the lowland ecoregion streams. The data should be used to develop a robust biotic index for use in the lowland ecoregions for which the current rapid bioassessment protocol is not appropriate.**
2. **Further analysis of existing data is needed to evaluate how well the existing monitoring strategies represent the conditions of the wadeable rivers and streams throughout the entire Watershed.**
3. **Characterization of stream segments (by calculating stream miles) and drainage area (by defining the contributing catchment area to the site) is needed to study the influences of landscape stressors and other factors on stream conditions. The characterization should focus on sites where macroinvertebrate health was poor but habitat conditions were good. The findings could be used to help identify and ameliorate potential threats at sites with good macroinvertebrate health and good habitat quality that need protection.**

Chapter 20. Freshwater Fish Communities

1. **Further development of freshwater fish communities as an indicator for status and trends reporting will require an expanded effort to collect fish community data. Evaluation of the resources to support the desired level of fish data collection across the Watershed is an appropriate next step.**
2. **Targeted collection of data on brook trout is needed to better refine brook trout habitat and clarify coldwater stream designations and support the integration and update of the Eastern Brook Trout Joint Venture Salmonid Catchment Assessment and Habitat Patch Layers model.**

3. Additional data for freshwater habitats that were not considered here, but may have ecological significance to maintain healthy habitat for fish, should be gathered, created, defined, and analyzed, including intermittent streams, freshwater reaches of tidal rivers, wetlands, and riparian areas. Specialized methods for collection of fishes in these habitats may need to be identified or developed.
4. Development of an indicator related to stream connectivity should be explored. It could reflect stream continuity in miles open, partially open, and obstructed for freshwater fish and other aquatic life communities, following other efforts already started in the Watershed, such as those led by the U.S. Army Engineer Research and Development Center (Foran et al. under review).
5. Provided data collection can be expanded, bi-state efforts and approaches to refine the freshwater fish indicator could involve the development of an IBI or MMI for the Narragansett Bay Watershed. These resulting metrics can be related to the Biological Condition Gradient framework, as has been done in Connecticut (Stamp and Gerritsen 2013).
6. Future data analysis should explore and quantify the relationships between freshwater fish metrics and stressors at appropriate scales (e.g., site, watershed, catchment areas). Armstrong and colleagues (2011) quantified the effects on fluvial fish abundance in response to alterations on stream flow and impervious cover, among other anthropogenic stressors.

Chapter 21. Open Space

1. Geospatial tools should be used to identify unprotected open space parcels adjacent to currently protected open space parcels. Protecting these natural areas would augment habitat connectivity, increase natural buffers to receiving waters, and improve the resilience of the ecosystem to land use stressors and climate change.
2. In addition to CAPS, other tools are useful for open space decision making. Critical Linkages (2012) identifies locations in the landscape that can provide greater ecological benefits to increase connectivity and continuity of habitats. Mass Audubon's Mapping and Prioritizing Parcels for Resilience tool identifies priority parcels for open space protection based on habitat quality, climate change resilience, parcel size, and adjacency to existing protected parcels. Use of such tools should be pursued to assist with planning efforts in the Narragansett Bay Watershed.
3. Further analyses of riparian buffer protection and restoration opportunities should be developed at a range of watershed scales, including Watershed Planning Areas.
4. Further refinement via a parcel-based analysis is needed to more specifically identify unprotected lands that may provide restoration opportunities such as areas for salt marsh migration as sea levels rise.
5. Spatial analyses of open space changes conducted at intervals of a decade or less, with a focus on protected ecologically significant natural lands, are necessary to track advances and spatial trends in conservation in the Narragansett Bay Watershed.

Chapter 22. Water Quality Conditions for Recreation

1. Data gaps exist with respect to assessing the recreational use of waters in the Taunton River and Blackstone River Basins in Massachusetts and the Coastal Narragansett Bay basin in Rhode Island. Monitoring efforts need to be expanded to address these gaps.
2. Additional research into the fate and transport of pathogens discharged into the ground from onsite wastewater systems is a need. Research should focus on those sub watersheds

or drainage areas in which onsite wastewater treatment systems, including cesspools, are known or suspected of contributing to pathogen pollution problems.

Chapter 23. Marine Beaches

1. The beach indicator should be refined by the development of other metrics. One option to explore is the development of a bi-state dataset that uses bacterial counts normalized by monitoring frequency (number of samples per season per beach) for the period of 2000 to the present to develop a more consistent and sensitive metric. Further analysis using bacteria counts associated with sampling dates will allow for cross-comparison between years with differing monitoring frequency and regulatory stringency. A protocol is needed to evaluate bacterial counts in the context of sampling frequency. Furthermore, the results of future analyses should be compared to current findings to corroborate the preliminary trends noted in this report.
2. Further work is needed to develop appropriate metrics for freshwater beaches in the Narragansett Bay Watershed. Data are limited and were not reviewed for this report.
3. As recent preliminary trends indicate a weakening relationship between rainfall and beach closure events, it will be important to continue to evaluate beach closures in wet years. With an indicator based on bacterial counts, the Estuary Program anticipates that a robust statistical analysis could address temporal trends and relationships with precipitation. Additional factors that influence microbial contamination and its persistence at beaches can be used to develop predictive models on a beach-specific basis. These include wind direction and speed, water temperature, wave height, changes in wastewater infrastructure and land use (Wu and Jackson 2016), and patterns in human use.
4. For High Concern beaches, development of models to support management is of interest. With appropriate input data and validation, predictive models can drive better management to reduce exposure to high-risk conditions. Unlike current microbiological analyses which typically characterize water quality on the previous day, models can predict when a beach should be closed (i.e., at the times when adverse conditions result in high levels of enteric microbes).
5. Detailed analyses of existing management actions such as CSO abatement projects, storm-water infrastructure improvements, and waste management initiatives based on bacterial counts and sampling history as metrics are likely to be useful in informing BMPs. Improvements at specific beaches are likely related to localized management actions. Pinpointing successful management strategies that target sources of contamination will be beneficial from economic, social, and public health perspectives.
6. While continuing to build on the information gained through both state beach monitoring programs, it will also be imperative to relate beach assessments to other programs that evaluate microbial contamination in the Bay's waters. These include assessments of long-term and comprehensive water quality characterizations of the Bay's waters to meet standards for recreational uses, including primary and secondary contact, as well as designations of shellfishing areas.

Chapter 24. Shellfishing Areas

1. Conditionally approved areas are monitored frequently, but fewer data are available for prohibited areas. Additional sampling in certain areas may be needed to better document progress of these areas toward water quality improvement goals.

2. **Synthesis of existing data and development of site-specific models would improve understanding of relationships among land use, point and non-point sources, and bacterial concentrations in receiving waters.**
3. **Recent changes showing a decline of prohibited areas and an increase of approved and conditionally approved areas in the Upper Estuary have been attributed to improvements at wastewater combined sewer overflows abatement and other pollution control efforts. However, additional data collection and analysis are needed to reassess the relationship between precipitation and pathogens as conditions continue to change. Additionally, further data synthesis and analysis could be conducted to relate water quality improvements to reduced pathogen loadings due to non-point source management actions.**
4. **Refinement of this indicator using pathogen data could provide a metric more sensitive to water quality improvements, such as by discerning partial progress toward water quality goals.**

Appendix G: U.S. EPA BCG report

Biological Monitoring and Bioassessment

Living things respond to the combined harms of many stresses, and tell us how an area is doing overall. Certain biological groups are more sensitive to specific stressors, and tell us what problems to fix. Monitoring biology over time tells us how an area is improving or declining in response to our management and to natural stresses (e.g., hurricanes), and guides future management options. People care about the overall condition of their local waterbody and about the plants and animals that live there−and a motivated public is a powerful force in management.

Selecting the best biological components to monitor is critical to management success. The most effective biological indicators will be:

- ecologically and societally important,
- susceptible to human disturbance
- relevant to current and future management objectives
- relatively easy to assess
- quantifiable, and
- maintained or maintainable over long time periods.

Considered together, the suite of indicators should ideally 1) address management objectives (e.g., human health, nutrient pollution, reporting overall Bay condition, habitat loss, sea level rise, specific ecological aspects that resonate with the public) and 2) cover important spatial/ecological aspects of the bay (e.g., the North-to-South gradient; watershed, intertidal, and subtidal; benthic and pelagic; different trophic levels).

Clearly, meeting all these criteria is nearly impossible, and decisions will have to be made to prioritize current and new indicators that achieve the right balance for Narragansett Bay now and in the future. That is the challenge of this workshop.

(((Suggest a graphic here as a visual thought-piece, listing management objectives on top of a 3D cartoon of a generic Bay from watershed to northern to southern Bay, intertidal and subtidal, with a 3D water column, and a few fauna thrown in to emphasize biota??)))

A framework for organizing these biological indicators and presenting a clear public message would be an important part of this effort. Several approaches have been effectively used, for example the Chesapeake Bay "report cards" for individual indicators and for the Bay as a whole. Ideally, the individual report cards would be consistently scaled, and consistent criteria would define levels of condition and agreed-upon goals and targets, so that monitoring could track progress towards these targets. The Biological Condition Gradient is a related approach.

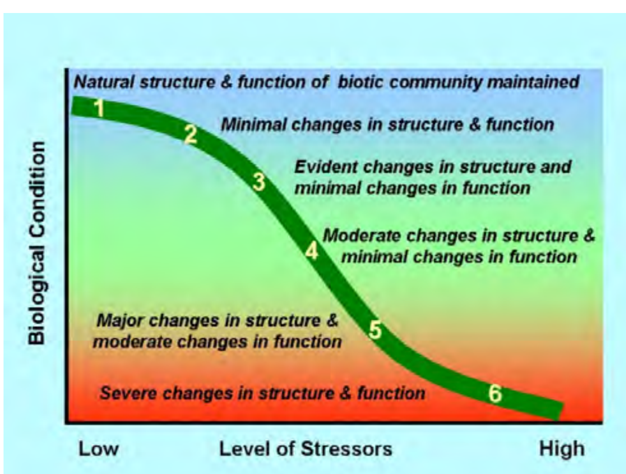
The Biological Condition Gradient (BCG)

The Biological Condition Gradient (BCG) is an approach to organize measurements of individual indicators along a gradient from 'minimally disturbed', 'as naturally occurs', or 'historical' (level 1) to 'severely altered' (level 6), with up to four more levels between those two extremes. Descriptive text consistently defines all levels as degree of departure from minimally disturbed, as related to human stressors. Expert workgroups can then assign quantitative criteria for levels of each indicator. Condition can be presented in any way that appeals to the public: as explained BCG levels, as letter grades, as red-yellow-green, etc.

The BCG benefits management in several ways.

- Consistent criteria for biological condition put indicators on a common scale and help set goals and quantitative targets that can be tracked through monitoring.
- A consistent and intuitive framework for reporting (departure from natural) helps engage the public and stakeholders in the health of their estuary.
- Historical data and long-term monitoring allow managers to present the concept of 'what biology did we once have, what biology do we now have, and what biology do we want to have in the future' to help the public and stakeholders create a vision of a desired future estuary.
- This vison can be used to set biological goals and targets, develop actions, then monitor and adjust to achieve the targets and move towards the goals and vision.

The Figure below represents a generalized Biological Condition Gradient. The Y-axis of a BCG can put different biological indicators (and different waterbodies) into a "common language" by providing a consistent meaning for each level, a well-defined narrative for each level, and a process for translating specific indicator scores into levels. These levels can be used as targets for environmental protection and restoration. The X-axis ties biological condition to anthropogenic stressors and guides management actions that control those stressors.



The central role of the BCG is to provide consistent narrative and quantitative descriptions that define each level of condition for any biological component of an ecosystem, as related to stressors. The BCG provides a framework to evaluate overall condition of the estuary, compare condition across time and space, develop visions of desired future estuarine condition, set goals and targets, develop actions, monitor progress towards goals, and communicate with the public.

The BCG as applied to estuaries and coasts is described in detail in an EPA report available at www.xxxxxx (print doc and pdf are available but EPA website has not yet been assigned).