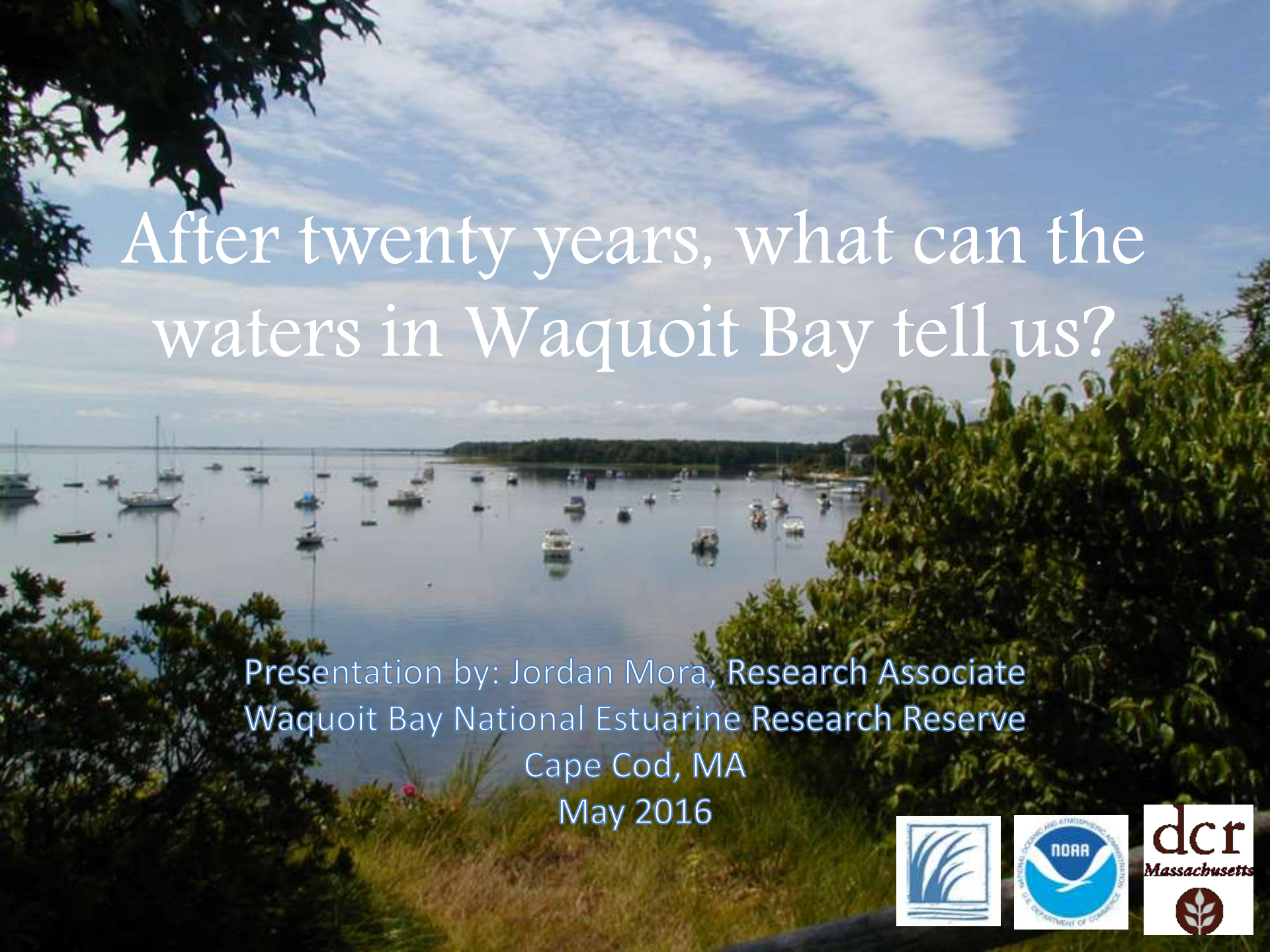


After twenty years, what can the waters in Waquoit Bay tell us?

Presentation by: Jordan Mora, Research Associate
Waquoit Bay National Estuarine Research Reserve
Cape Cod, MA
May 2016



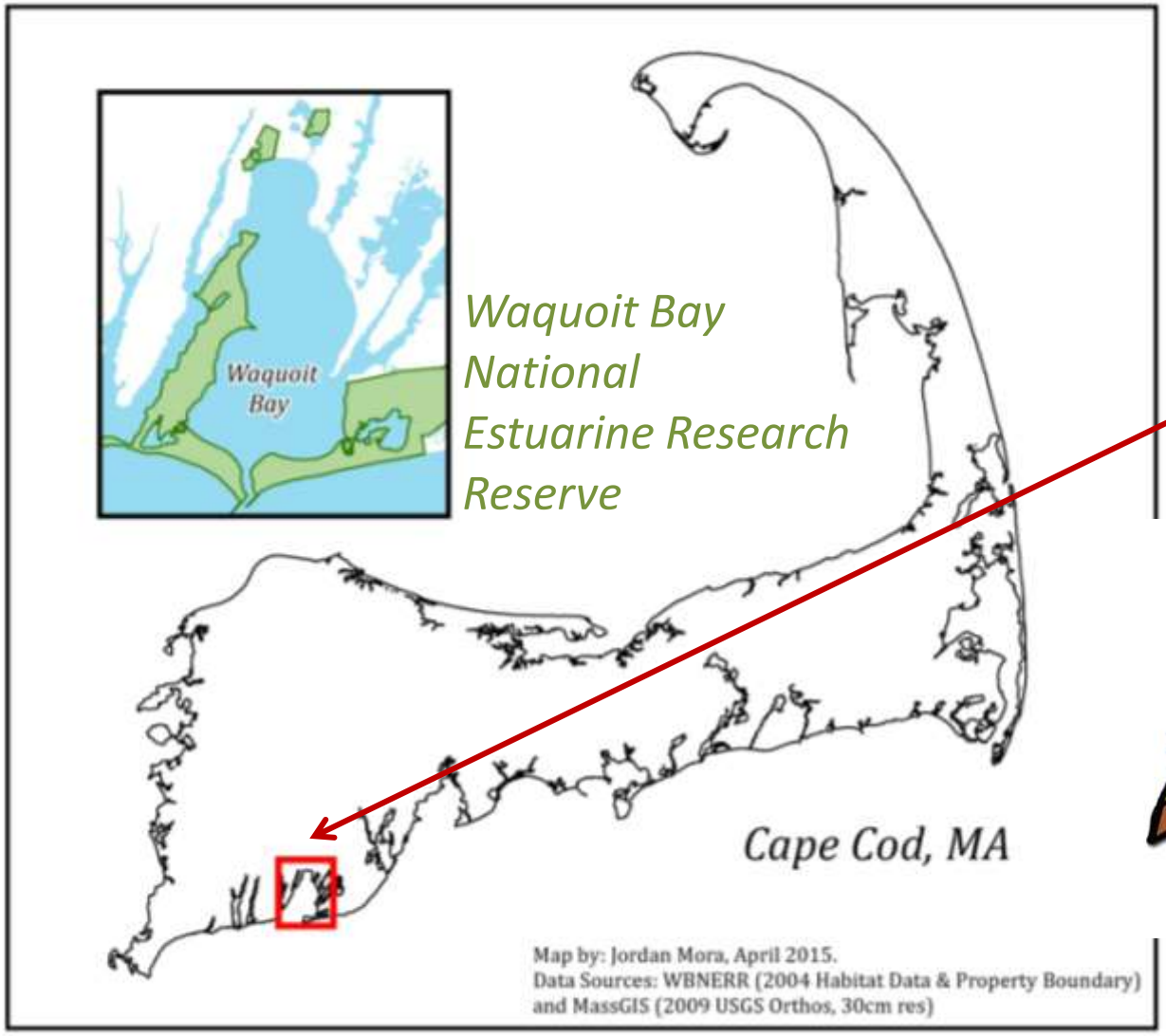









National Estuarine Research Reserve System



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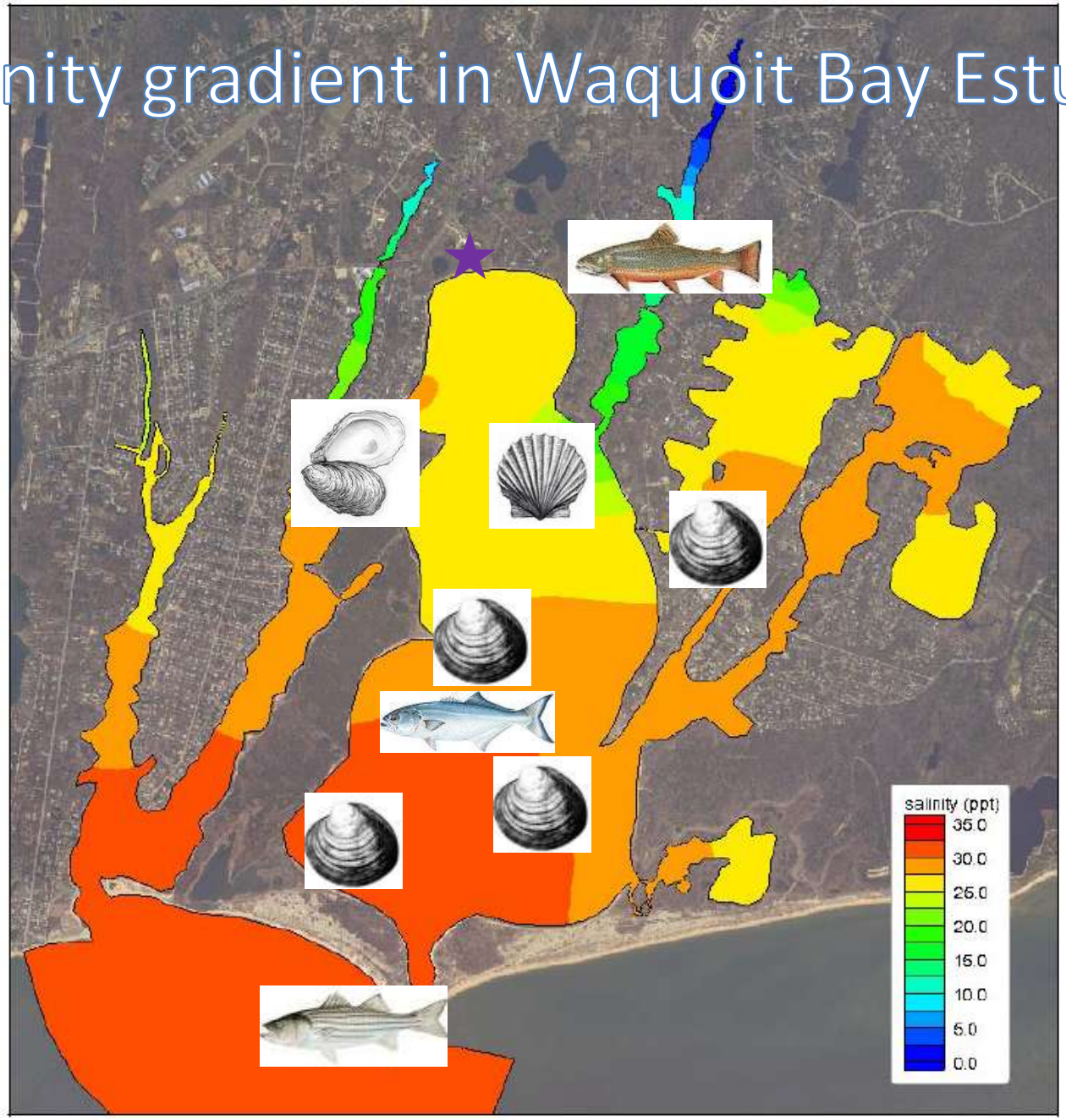
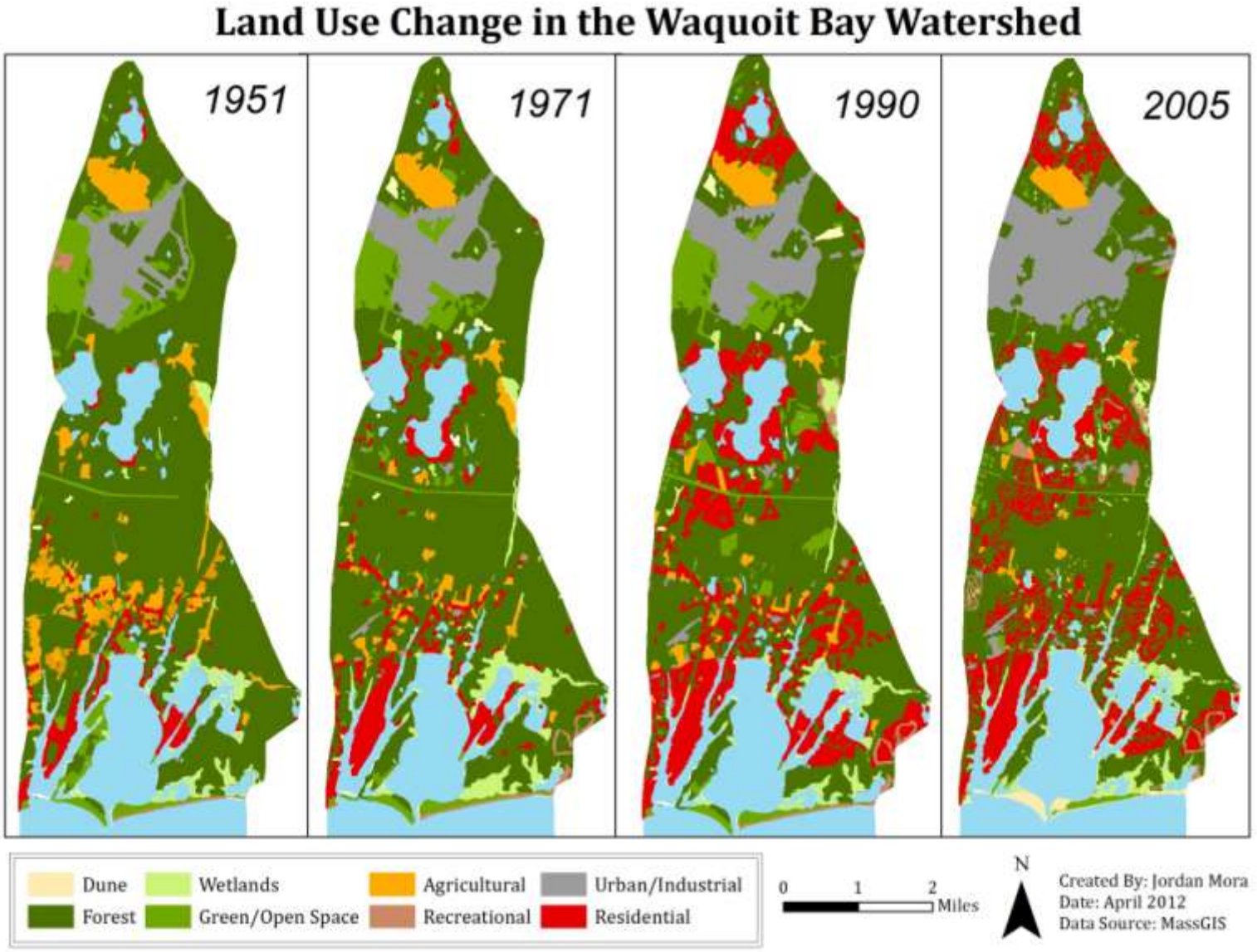
Salinity gradient in Waquoit Bay Estuary



MEP, May 2012

Background

EUTROPHICATION



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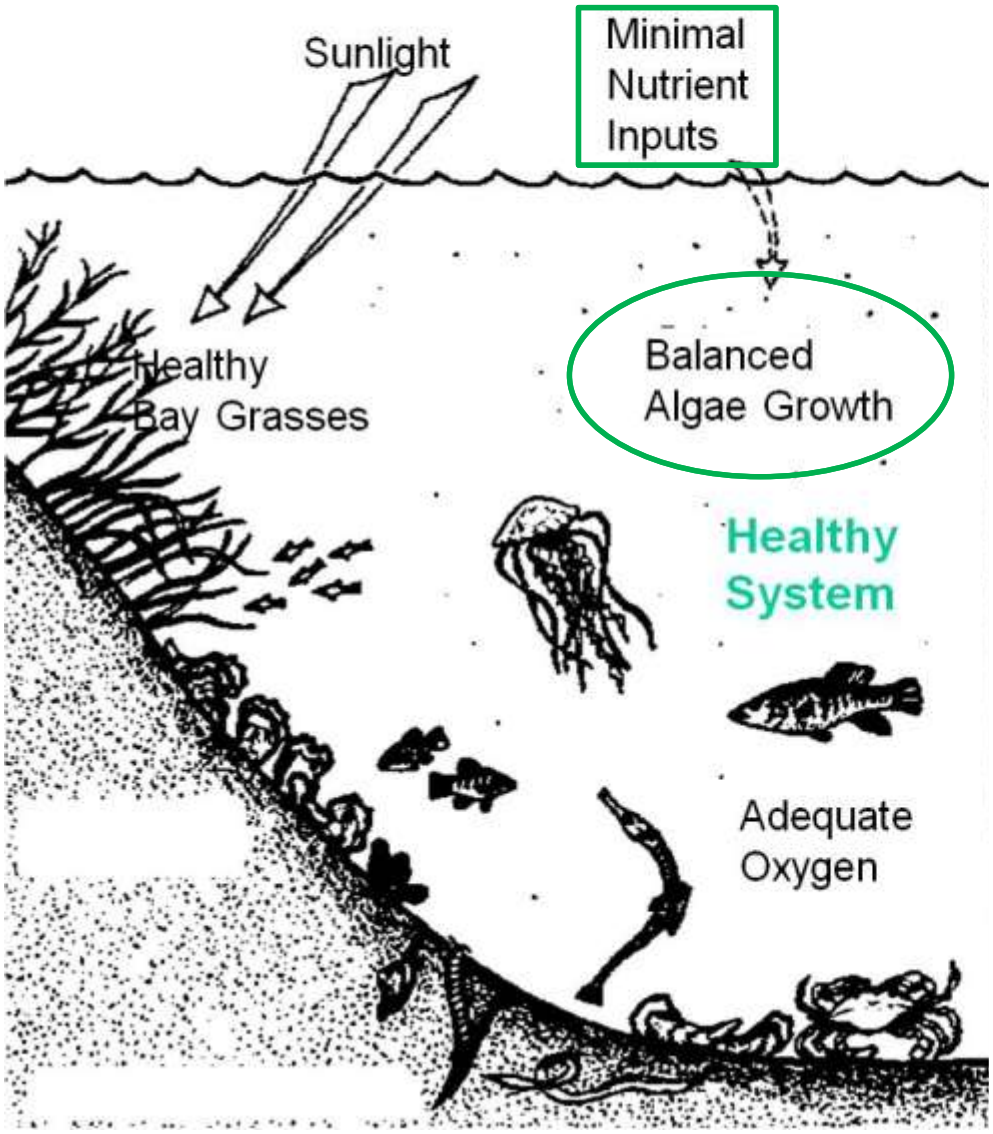

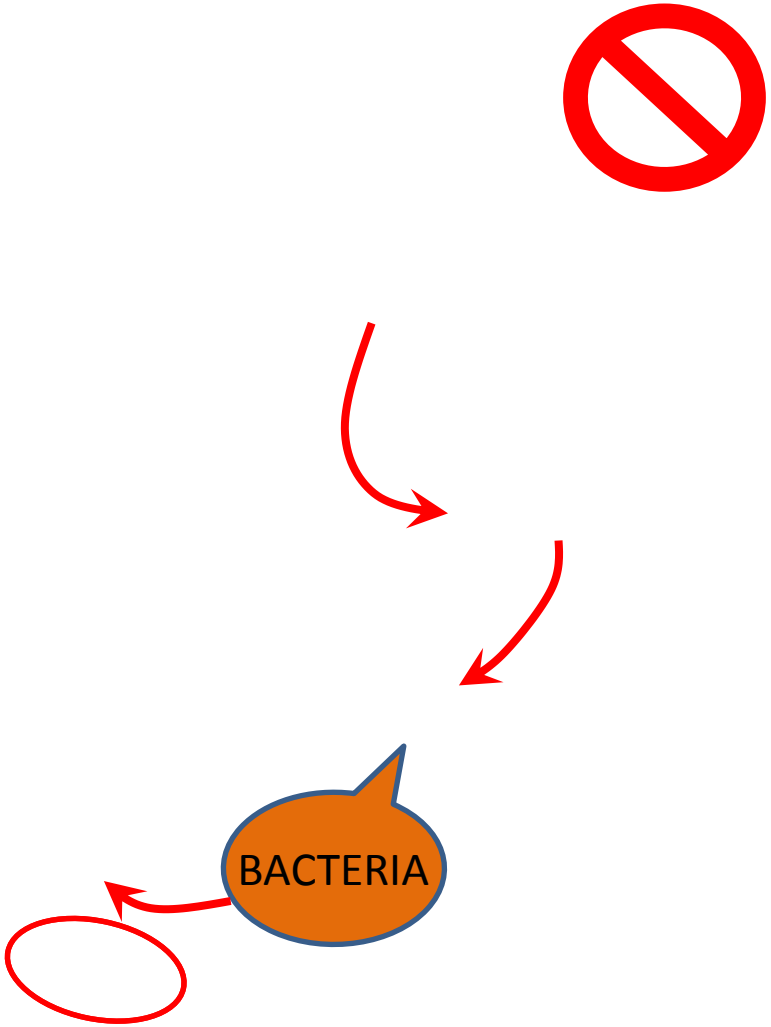

http://www.inlandbays.org/wp-content/images/healthy_bay_eutrophication.jpg

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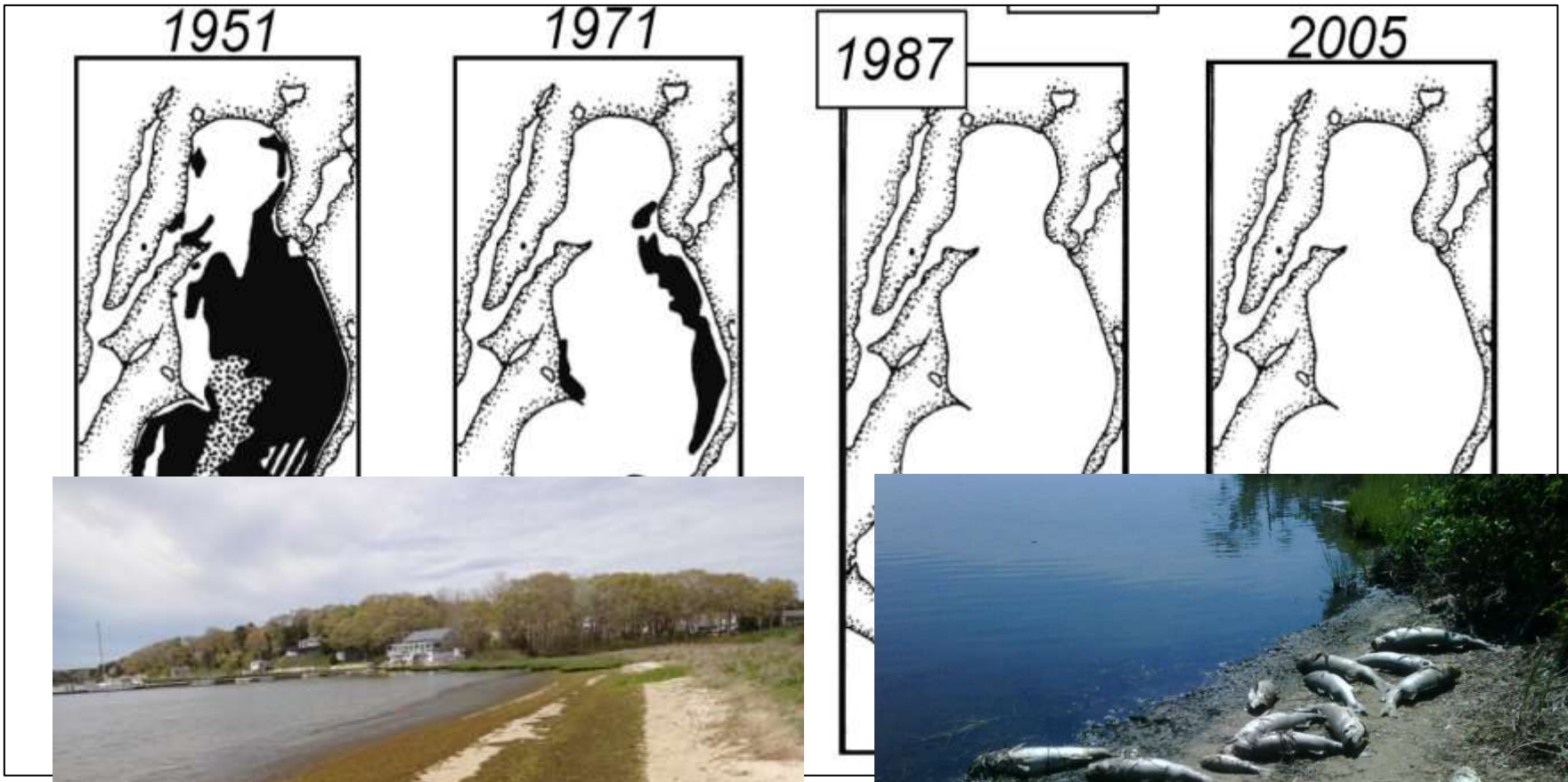

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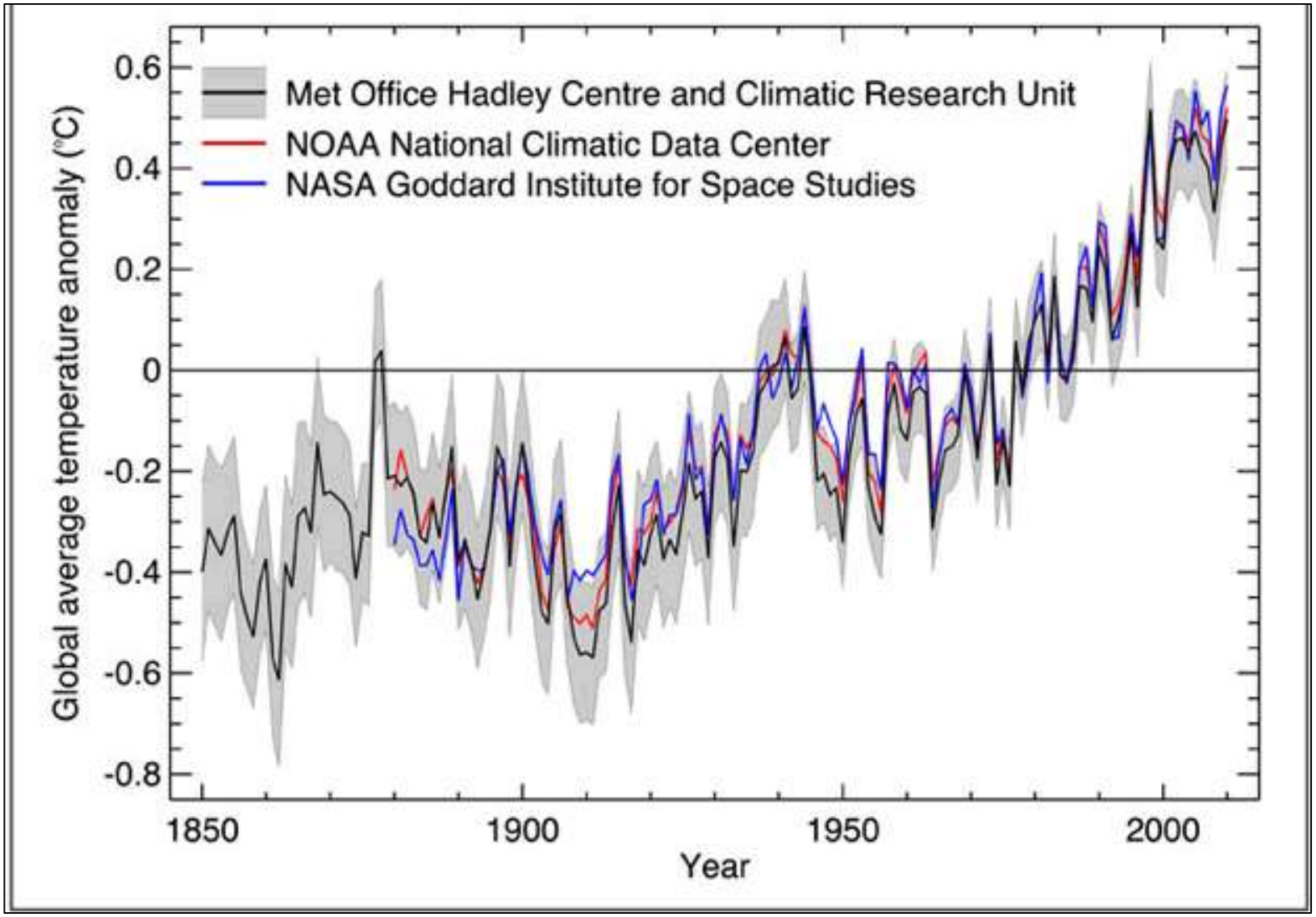
Background CLIMATE CHANGE



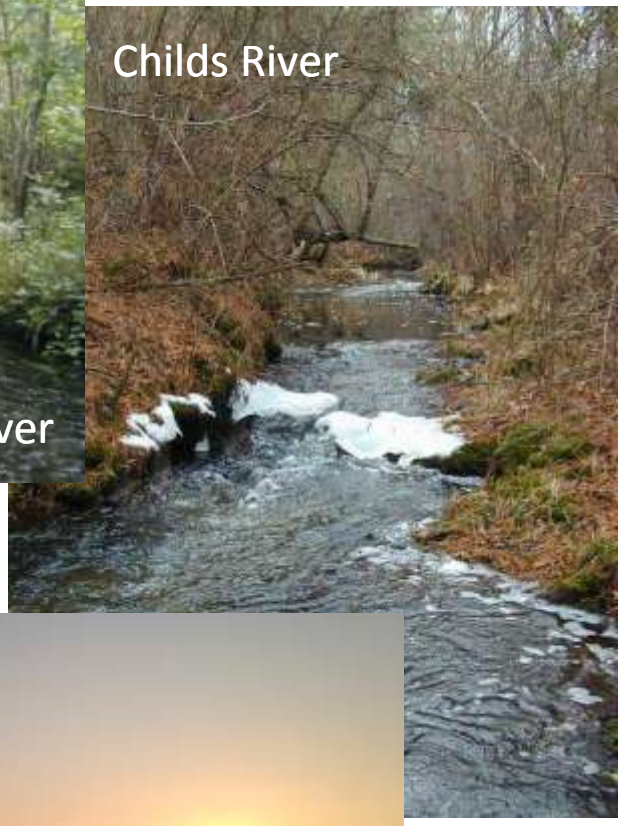
Long-term Water Quality Monitoring Programs

- System-Wide Monitoring Program (SWMP)
  - 1998-present (~15+ years)

- BayWatchers (BW)
  - 1993-present (~20+ years)

Baywatchers: Citizen-based WQ Monitoring

- Objectives:
  1) Track trends or changes over time,
  2) Document seasonal variations & episodic events,
  3) Maintain a reliable stream of information for researchers & decision-makers,
  4) Increase public awareness, education, and involvement,
  5) Augment the WQ database for other WBNERR monitoring programs.
     - Longer timeframe and wide-area coverage (SWMP)



METHODS & ANALYSIS

Waquoit Bay NERR Water Quality Monitoring Sites

Map by Jordan Mora,March 2016. Data provided by WBNERR and MassGIS.

BayWatcher (BW) Citizen Water Quality Monitoring Program

Site #1-5: 1993 - present
Site #6: 1995 - present
Site #7: 1996 - present
Site #8: 2003 - present
Site #9: 2008 - present

Parameters Collected:

- Water Temperature
- Turbidity
- Surface & Bottom Depth
- Salinity
- Dissolved Oxygen (mg/L and %)
- Nutrients (NH4, NO2/3, PO4, SiO4, DON)
- Chlorophyll - a

System-Wide Monitoring Program (SWMP)

Site #1: Metoxit Point	(1998 - present)
Site #2: Menauhant Yacht Club	(2001 - present)
Site #3: Sage Lot	(2002 - present)
Site #4: Childs River	(2002 - present)

Parameters Collected:

- Water Temperature
- Turbidity
- pH
- Water Depth
- Specific Conductivity/Salinity
- Dissolved Oxygen (mg/L and %)
- Nutrients (NH4, NO2/3, PO4, SiO4, DON, TN)
- Chlorophyll - a

SWMP Program

- YSI multi-parameter sondes
  - Continuous 15-minute data
- Year-round data at all four sites

BayWatchers Program

- Summer & Winter Sampling (this has changed overtime)
- 3

2016 marks major turning point:

- **WHOI lab can't run samples anymore**
- **handhelds are old and failing**

Do we keep it going???

What does the data say???

er

  - Filtered for chlorophyll analysis (WBNERR)

Parameters of Focus

Annual Trends & Seasonal Variation

- Temperature
- Dissolved Oxygen (% saturation)
- Chlorophyll-a

BayWatchers: Sampling History

Parameter	1993																					2015
Temperature	1-5																					1-9
Salinity	1-5																					1-9
Dissolved Oxygen	1-5																					1-9
Depth	1-5																					1-9
Chlorophyll																						1-9
Turbidity															1-8	1-9	1-9	1-9	1-9	1-9	1-9	1-9
SiO4								1-7	1-7	1-7	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	?	?	?	?
PO4								1-7	1-7	1-7	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	?	?	?	?
NH4								1-7	1-7	1-7	1-8	1-8	1-8	1-8	!	!	!	!	?	?	?	?
NO23								1-7	1-7	1-7	1-8	1-8	1-8	1-8	1-8	1-8	1-8	1-8	?	?	?	?
TDN												1-8	1-8	1-8	?	!	!	!	?	?	?	?

Site Number	Site Name	Years as Active Site
		1993-present
		1993-present
		1993-present
		1993-present
		1993-present
6	Menauhant*	1995-present
		1996-present
8	Eel River*	2003-present
9	S_Waquoit Bay	2008-present

* Indicates current year-round sites

! Indicates rejected nutrient data: available but not within acceptable range

? Still waiting for this data from lab at WHOI.

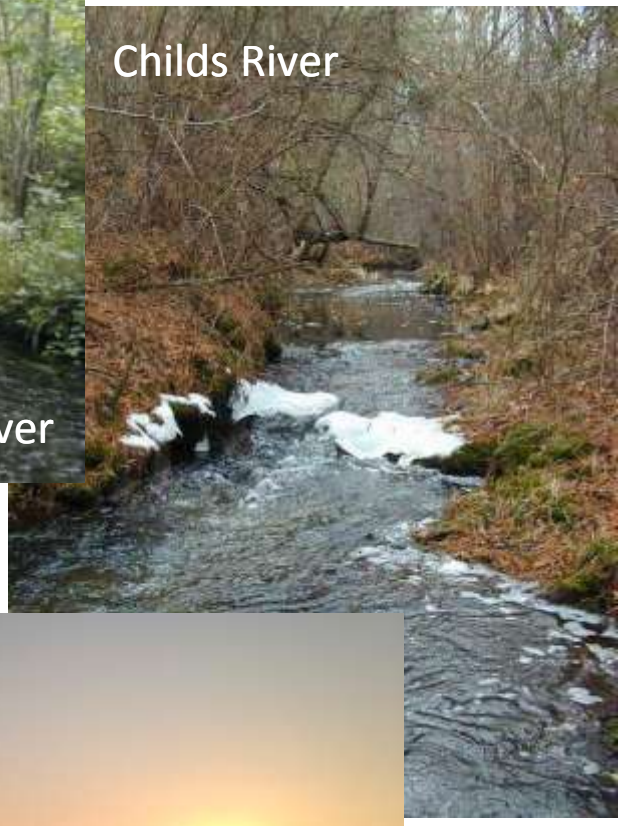
Analysis

SWMP (15-minute, continuous data)

- LOWESS (locally weighted scatterplot smoothing) regression of annual means

Baywatchers (Monthly/Biweekly data)

- Linear regression of annual means
  - Split DO and CHL regressions by month or season
- Transformations:
  - DO: Square root
  - Temperature: Square root
  - Chlorophyll-a: Log_{10}

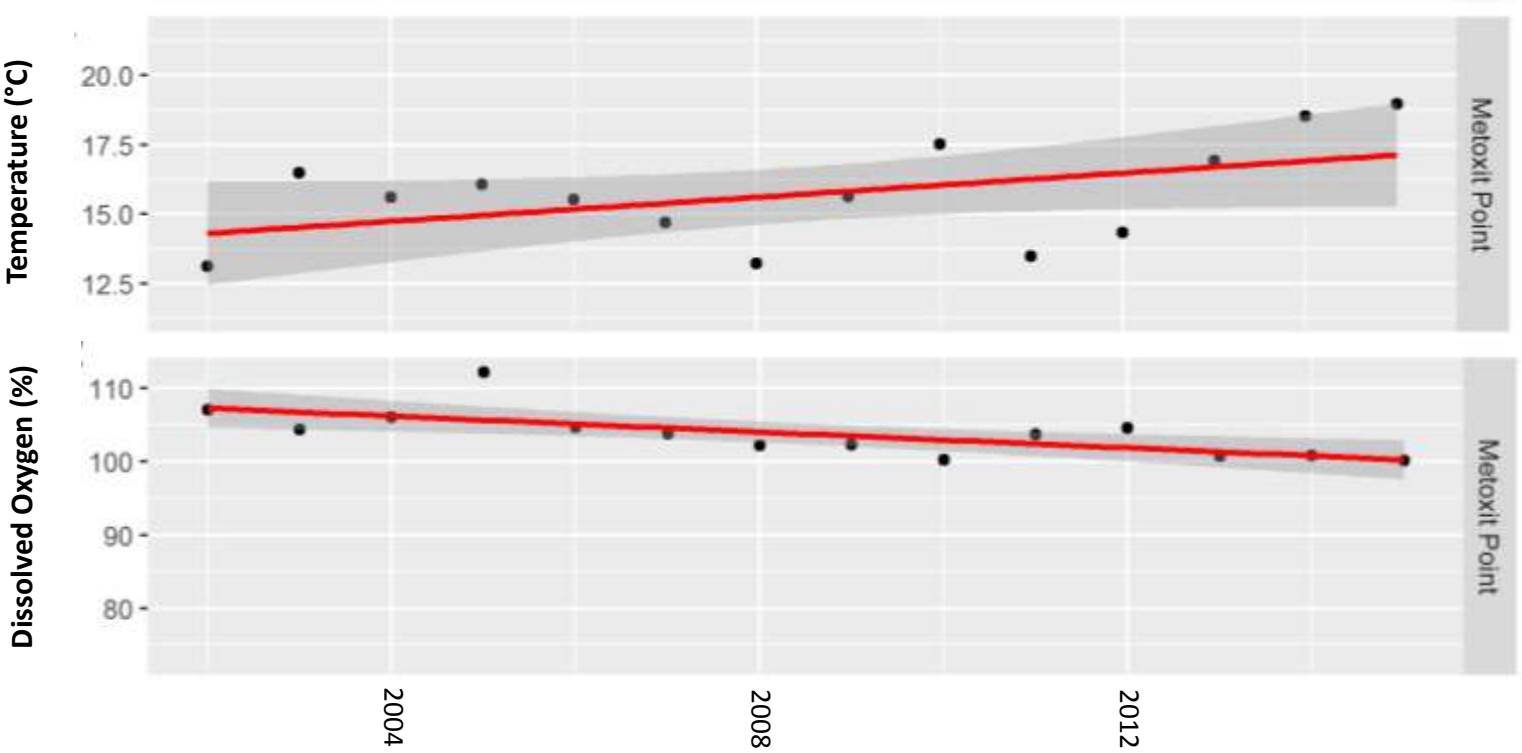


Annual Trends - SWMP

RESULTS

SWMP

Metoxit Point

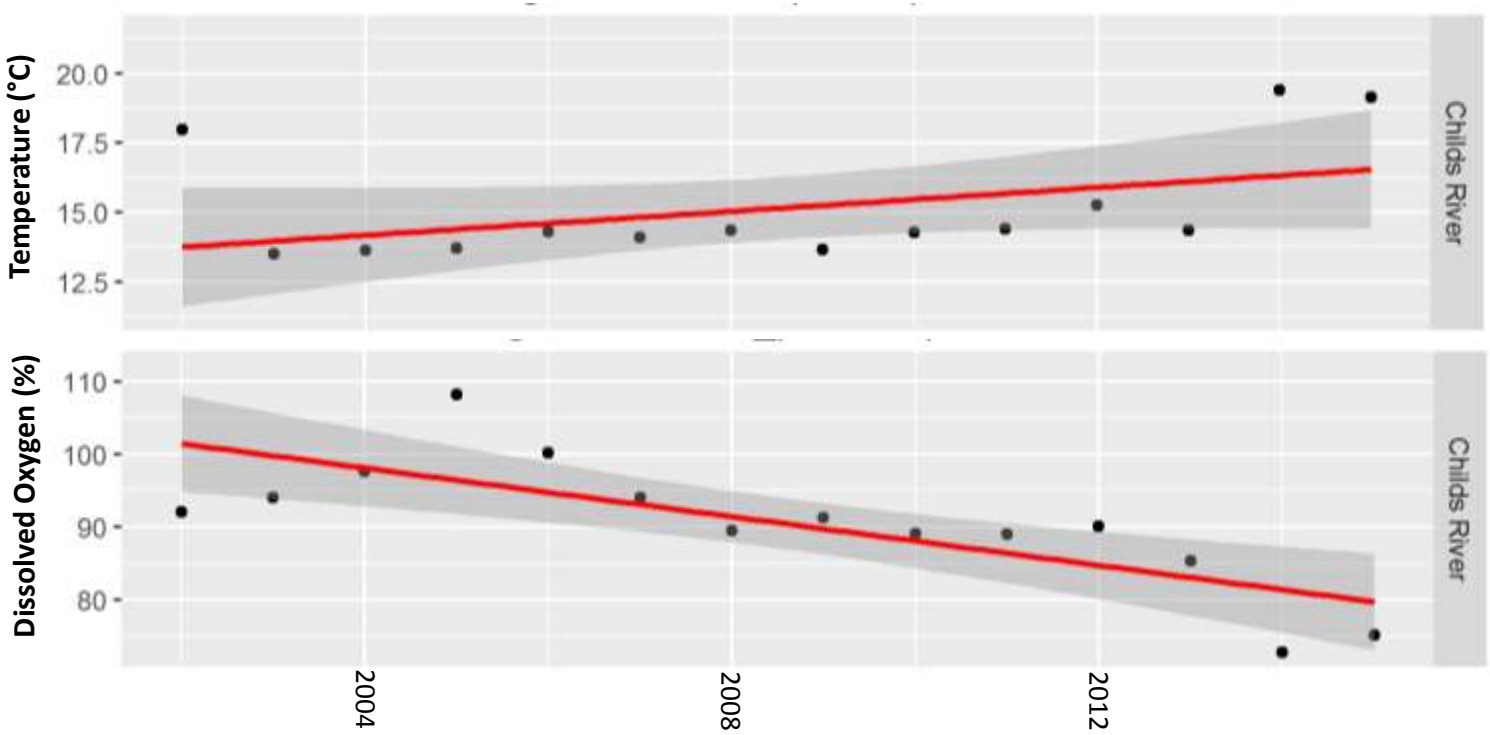


- Temperature (+0.2°C per year)
  - Adjusted R-squared = 0.176
  - F = 3.78
  - P = 0.076
- **Dissolved Oxygen (-0.5% per year)**
  - **Adjusted R-squared = 0.444**
  - **F =11.38**
  - **P = 0.006**

Tom Grothues, JCNERR, & Owen Doherty, Eagle Rock Analytics

SWMP

Childs River



- Temperature
  - Adjusted R-squared = 0.121
  - F = 2.79
  - P = 0.121

- **Dissolved Oxygen (-1.7% per year)**
  - Adjusted R-squared = 0.561
  - F = 17.61
  - P = 0.001

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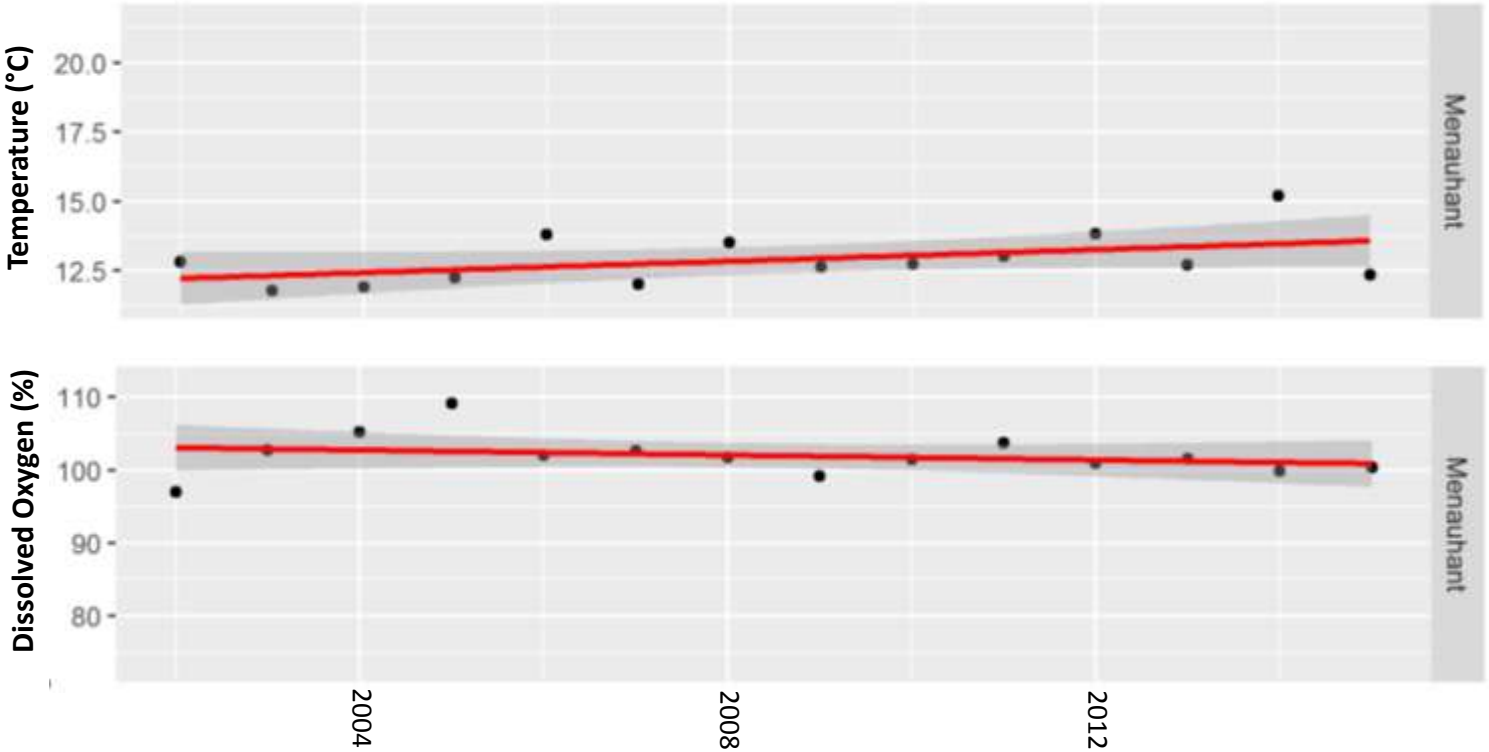
SWMP

Menauhant



- **Temperature (+0.1 °C per year)**
  - **Adjusted R-squared = 0.153**
  - **F = 3.352**
  - **P = 0.092**
- Dissolved Oxygen
  - Adjusted R-squared = -0.017
  - F = 0.7725
  - P = 0.397

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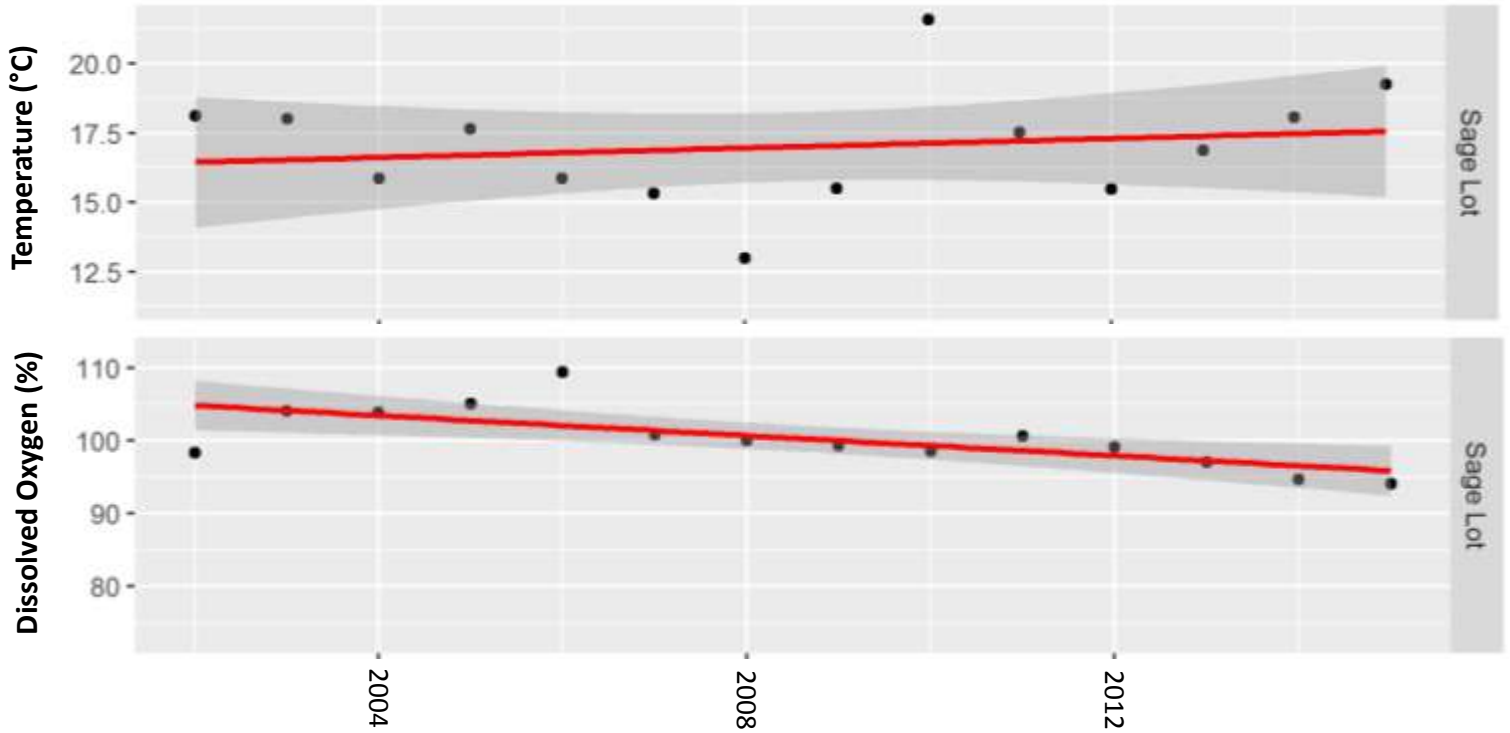
SWMP

Sage Lot



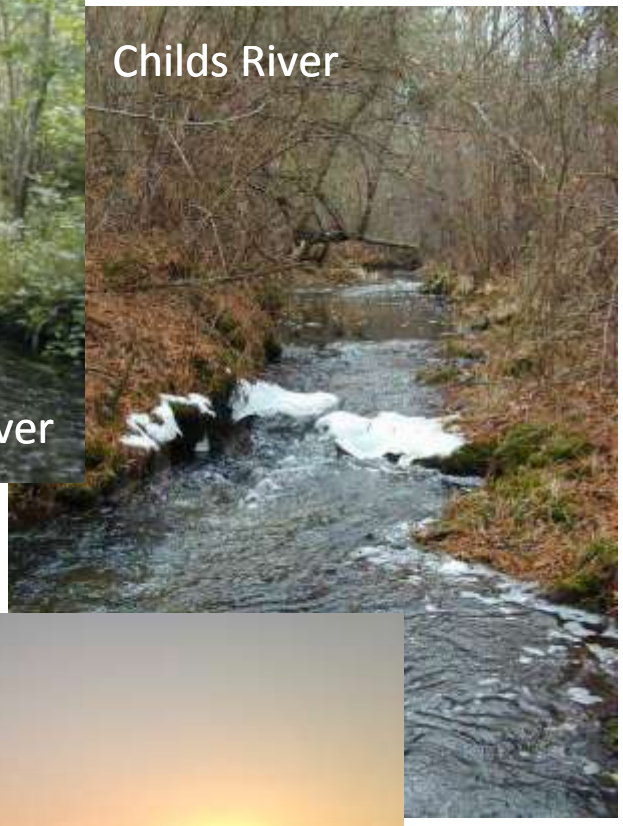
- Temperature
  - Adjusted R-squared = -0.052
  - F = 0.363
  - P = 0.558

- **Dissolved Oxygen (-0.7% per year)**
  - **Adjusted R-squared = 0.442**
  - **F =11.28**
  - **P = 0.006**

Tom Grothues, JCNERR, & Owen Doherty, Eagle Rock Analytics

Quashnet River

Sage Lot Pond



Childs River

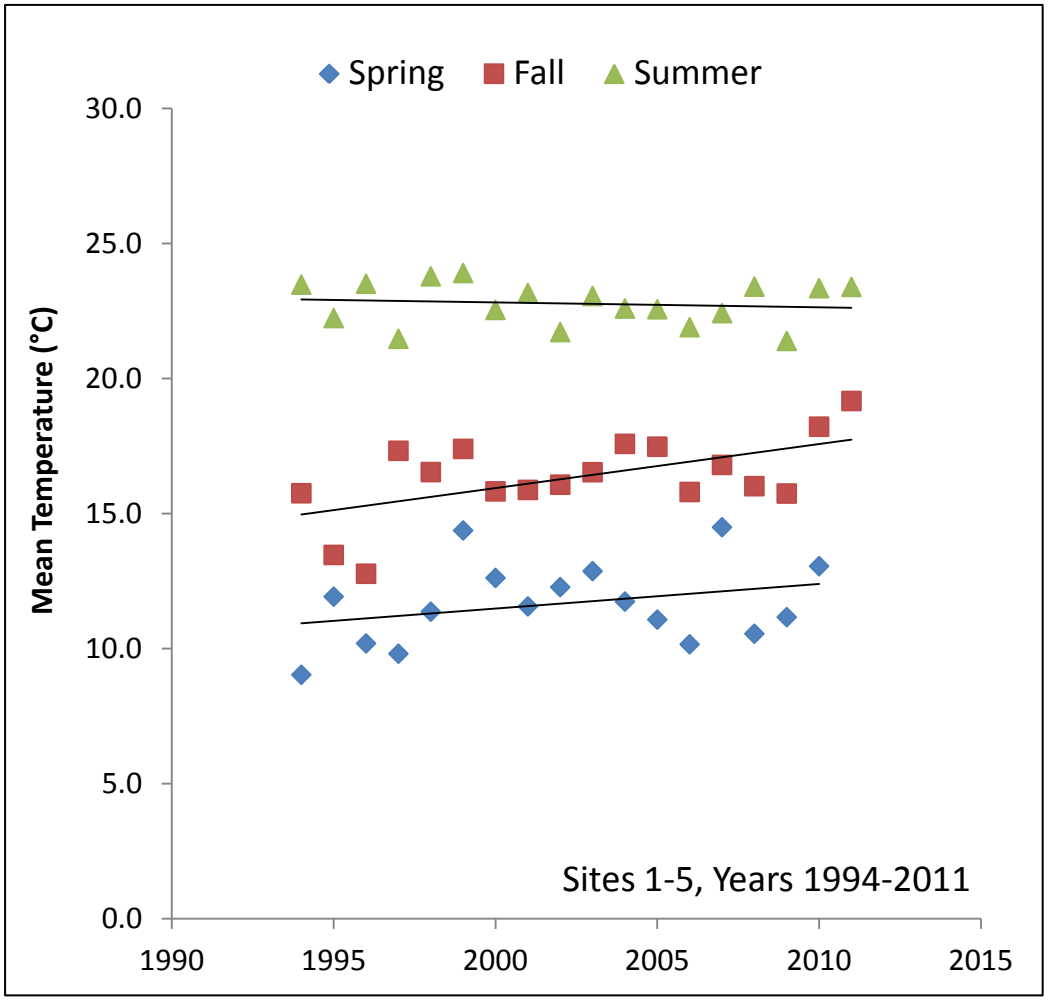
Seasonal Trends - Baywatchers

RESULTS

Hamblin Pond

BayWatchers – Temperature

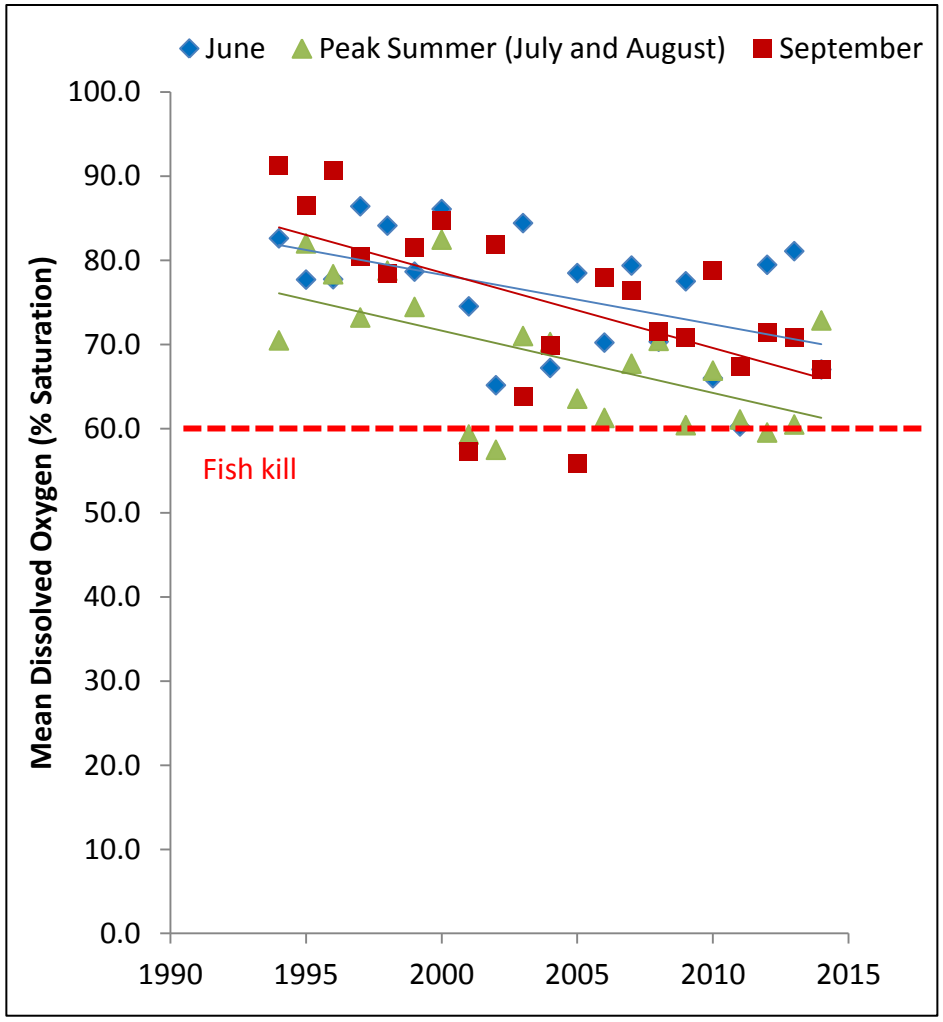
Spring: Mar – May
Summer: June – Aug
Fall: Sept – Nov



- **Spring**: $R^2 = 0.011$, F = 6.081, p = 0.014
  Rate of change: 0.09°C/yr **(4° F over 20 years)**
- **Summer**: $R^2 = 0.009$, F = 9.903, p = 0.002
  Rate of change: -0.02°C/yr **(-1° F over 20 years)**
- **Fall**: $R^2 = 0.015$, F = 11.274, p = 0.001
  Rate of change: 0.16°C/yr **(6°F over 20 years)**

Note: Did not include years 2012-2014 because of sampling frequency change in fall season

Baywatchers – Dissolved Oxygen



Sites 1-5, Years 1994-2014

- June: $R^2 = 0.035$, F = 13.870, p =0.000

  Rate of change: -0.6% per year **(12% over 20 years)**

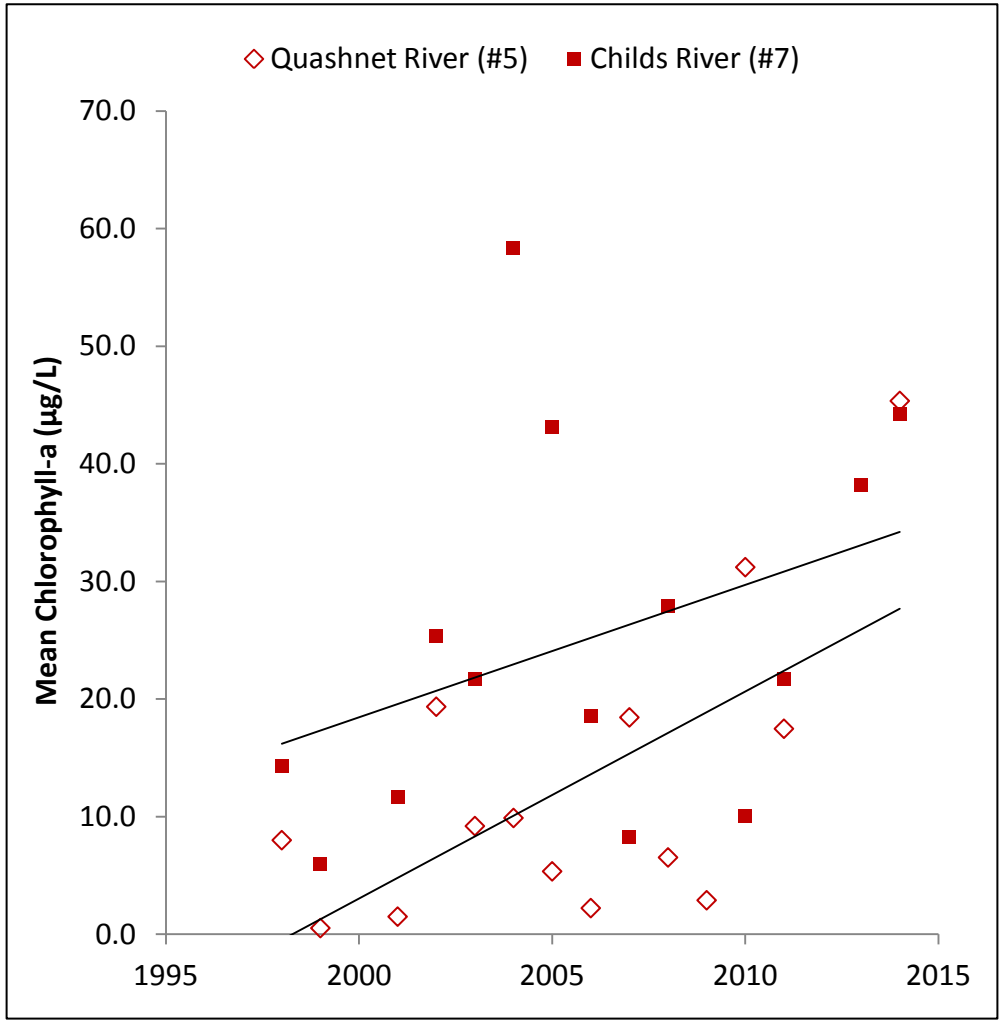
- Jul/Aug: $R^2 = 0.039$, F = 32.518, p = 0.000

  Rate of change: -0.7% per year **(14% over 20 years)**

- September: $R^2 = 0.054$, F = 20.709, p = 0.000

  Rate of change: -0.9% per year **(18% over 20 years)**

Baywatchers Chlorophyll-a (September Only)



Years 1998-2014; Head of tide, riverine sites

September Only: $R^2 = 0.133$, N = 28, F = 4.148, p = 0.052

Rates of change:

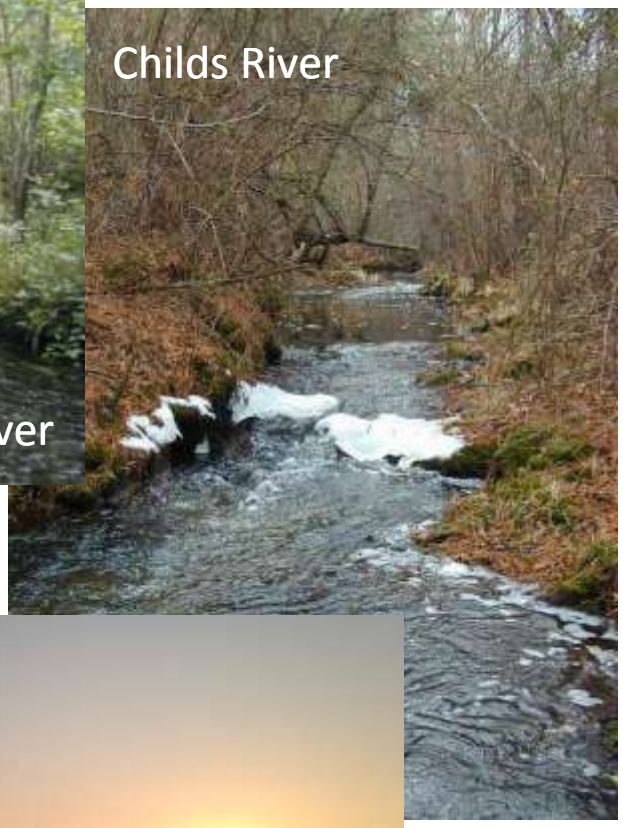
Childs River = 1 µg/L per year

Quashnet River = 2 µg/L per year

April showed significance of p = 0.063, with negative change rate (CHL going down in April over the years)


Sage Lot Pond


Quashnet River


Childs River

CONCLUSIONS


Hamblin Pond

Summary

- Temperature results show increasing trends, but the rate of change is not the same across the seasons.
  - Seasonal breakdown indicates significant increases in spring and fall and that greatest rates of change are occurring in the fall

- Average dissolved oxygen is declining steadily.
  - Looking closely at growing season (four months) indicates greatest rates of decline in September

- Chlorophyll-a concentrations are significantly increasing at upstream sites for the month of September over time.

Conclusions and Implications

- Extreme rates of change in the fall may be an indication of additive effects from eutrophication and climate change
- Implications for biological interactions
  - Changes in fish and waterfowl migrations patterns
  - Increased fish kills & resulting trophic cascades
  - Aquatic species distribution shifts: invasion of non-natives (tunicates, Asian shore crab, green crab, etc)

Conclusions and Implications

- Management considerations
  - Section 208, Clean Water Act: Update to Water Quality Management Plan
    - Adjust nitrogen mitigation models from Massachusetts Estuaries Project (MEP) to account for temperature increases

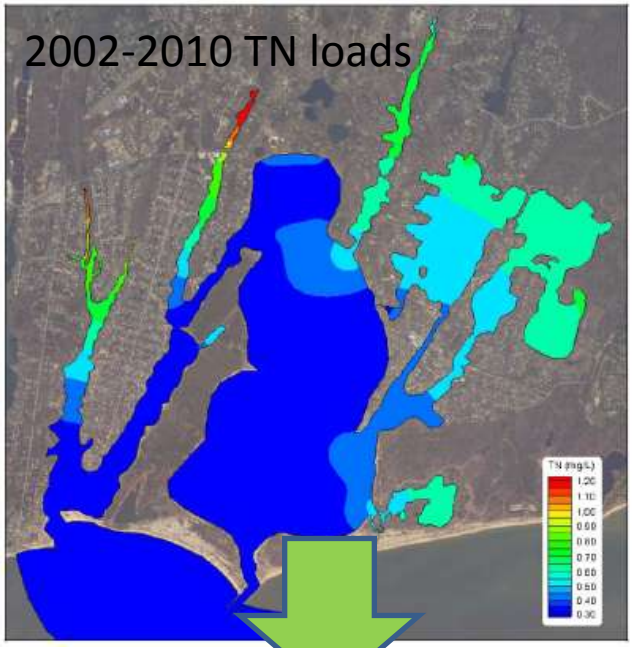
Massachusetts Estuaries Project – UMASS Dartmouth School for Marine and Science Technology

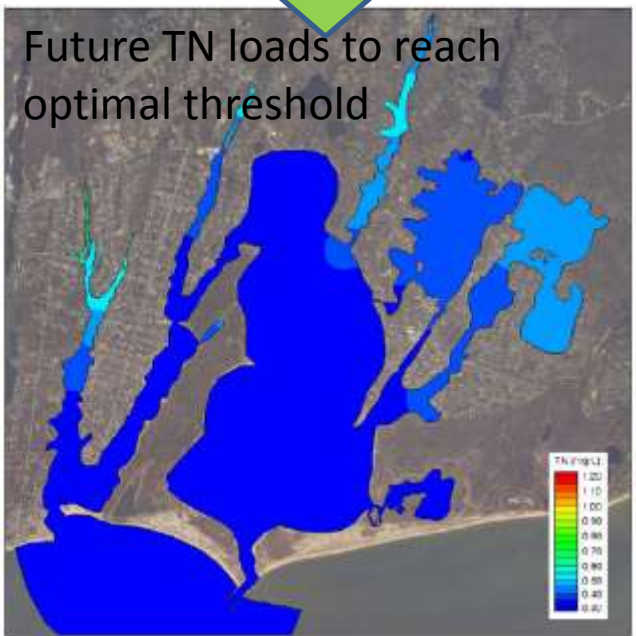
Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Waquoit system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present load (kg/day)	threshold load (kg/day)	threshold % change
Waquoit Bay	1.397	1.397	+0.0%
Childs River - upper	9.929	1.986	-80.0%
Eel Pond - east branch	1.688	0.338	-80.0%
Eel Pond - south basin	0.458	0.458	+0.0%
Eel Pond - west branch	12.548	5.019	-60.0%
Quashnet River	1.904	0.628	-67.0%
Hamblin Pond	3.427	0.000	-100.0%
Little River	0.885	0.000	-100.0%
Jehu Pond	2.888	0.000	-100.0%
Great River	2.674	0.000	-100.0%
Sage Lot Pond	1.132	0.000	-100.0%
Childs River - freshwater	8.134	1.627	-80.0%
Moonakis River (upper Quashnet)	10.504	3.466	-67.0%
Red Brook -freshwater	6.575	0.658	-90.0%
Total	64.142	15.576	-75.7%

Table VIII-5. Comparison of model average total N concentrations from present loading and the threshold scenario, with percent change above background concentration offshore Waquoit Bay (0.28mg/L), for the Waquoit Bay system. The threshold stations are shown in bold print.

Sub-Embayment	monitoring station	present (mg/L)	threshold (mg/L)	% change
Seapit River	WB11	0.383	0.321	-59.5%
Waquoit Bay - upper basin	**WB12**	**0.402**	**0.327**	**-61.0%**
Waquoit Bay - lower basin	WB13	0.303	0.289	-55.3%
Childs River - upper	CR01	1.146	0.494	-75.2%
Childs River - middle	**CR02**	**0.651**	**0.374**	**-74.6%**
Childs River - lower	CR03	0.342	0.307	-55.8%
Eel River - upper	**ER01**	**0.669**	**0.486**	**-47.1%**
Eel River - middle	ER02	0.428	0.356	-48.7%
Eel Pond	ER03	0.307	0.293	-51.3%





Acknowledgements

- Baywatcher Volunteers (2015-2016):
  - West Side Teams: Doc Taylor, Phil and Leah Wright, Mimi Gregory, Hila Jeanne, Wendy Murphy
  - Central Team: John Russo, Jerry Karush, Charles Anastasia, Sue Rau
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  - Chlorophyll assistants: John Brazier, Linda and Ken Duffy
  - Turbidity analyst: Patty Calkins-Martin
- Baywatcher analysis help: Eric Sundquist, U.S. Geological Survey in Woods Hole, & Jennie Rheuban, Woods Hole Oceanographic Institute
- R script: Tom Grothues, JCNERR, and Owen Doherty
- Data compilation: Sarah Devine, Summer Intern

Questions

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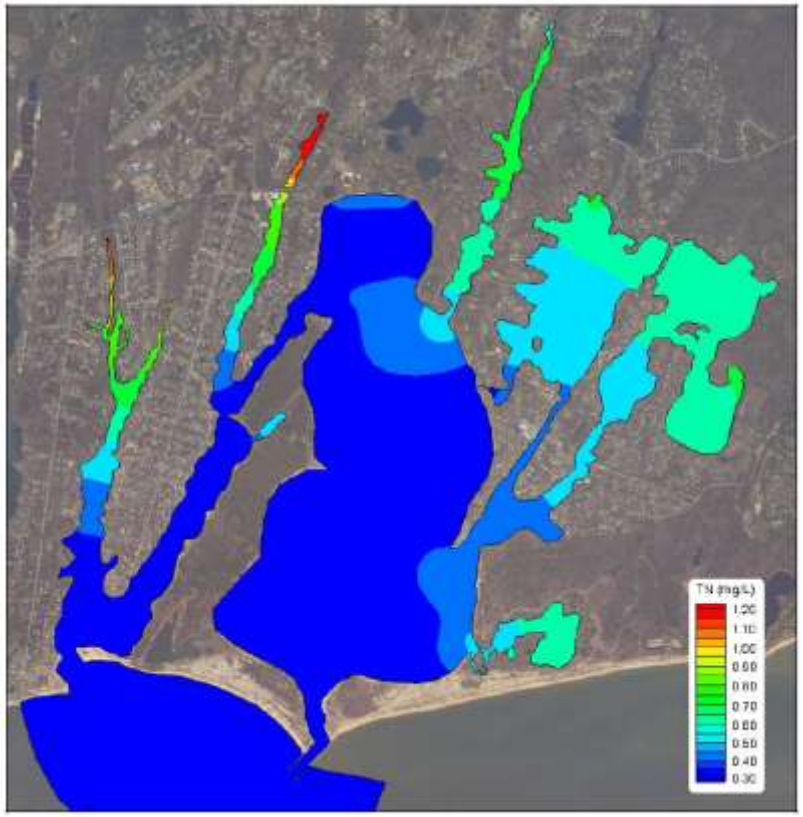
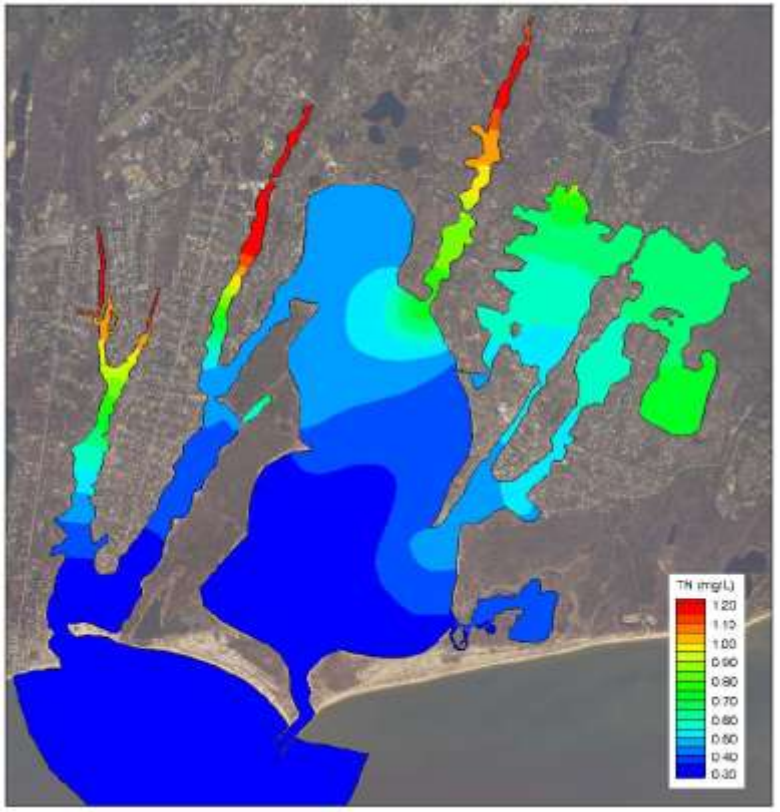
Massachusetts Estuaries Project – UMASS Dartmouth School for Marine and Science Technology

2002-2010



Contour plots of modeled total nitrogen concentrations based on measured nitrogen loadings (data collected between 2002-2010)

Build-out scenario (based on area of developable land)



Contour plots of modeled total nitrogen concentrations based on projected build-out loading conditions (41% increase in loadings)