Nitrogen Reduction

a Huge Success in

Narragansett Bay

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NBEP - SAC
July 13, 2022

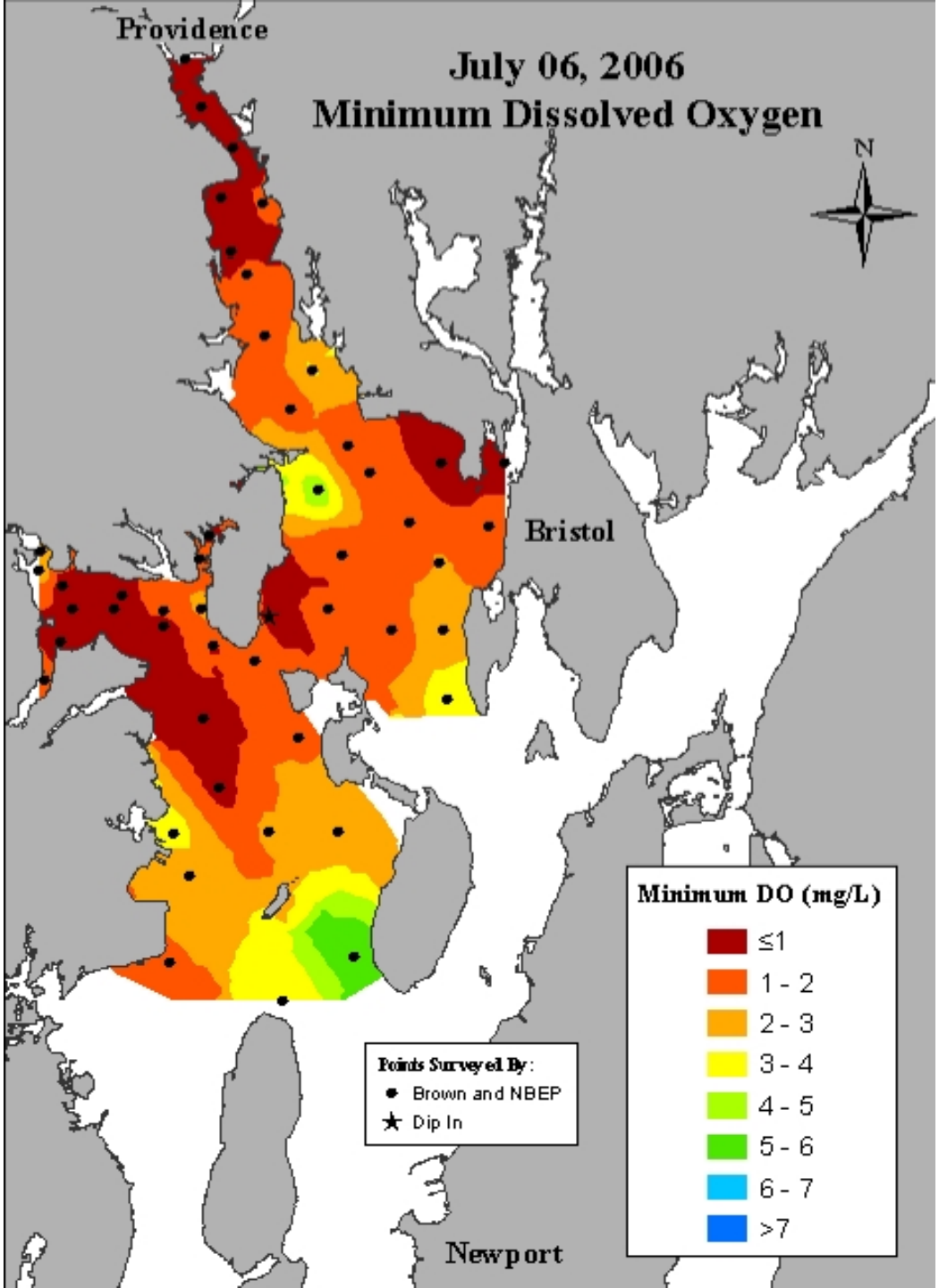
Currently the implementation of advanced waste-water treatment has reduced the nutrient input to the Bay by over 50% and has been a huge success in decreasing upper Bay hypoxia in summer

Before Nutrient Reduction

Too Many Nutrients!
Summer 2003 Menhaden Kill Greenwich Bay

From Chris Deacutis, RI DEM

Summer Hypoxia



From Warren Prell, Brown University

Managed Nutrient Reduction

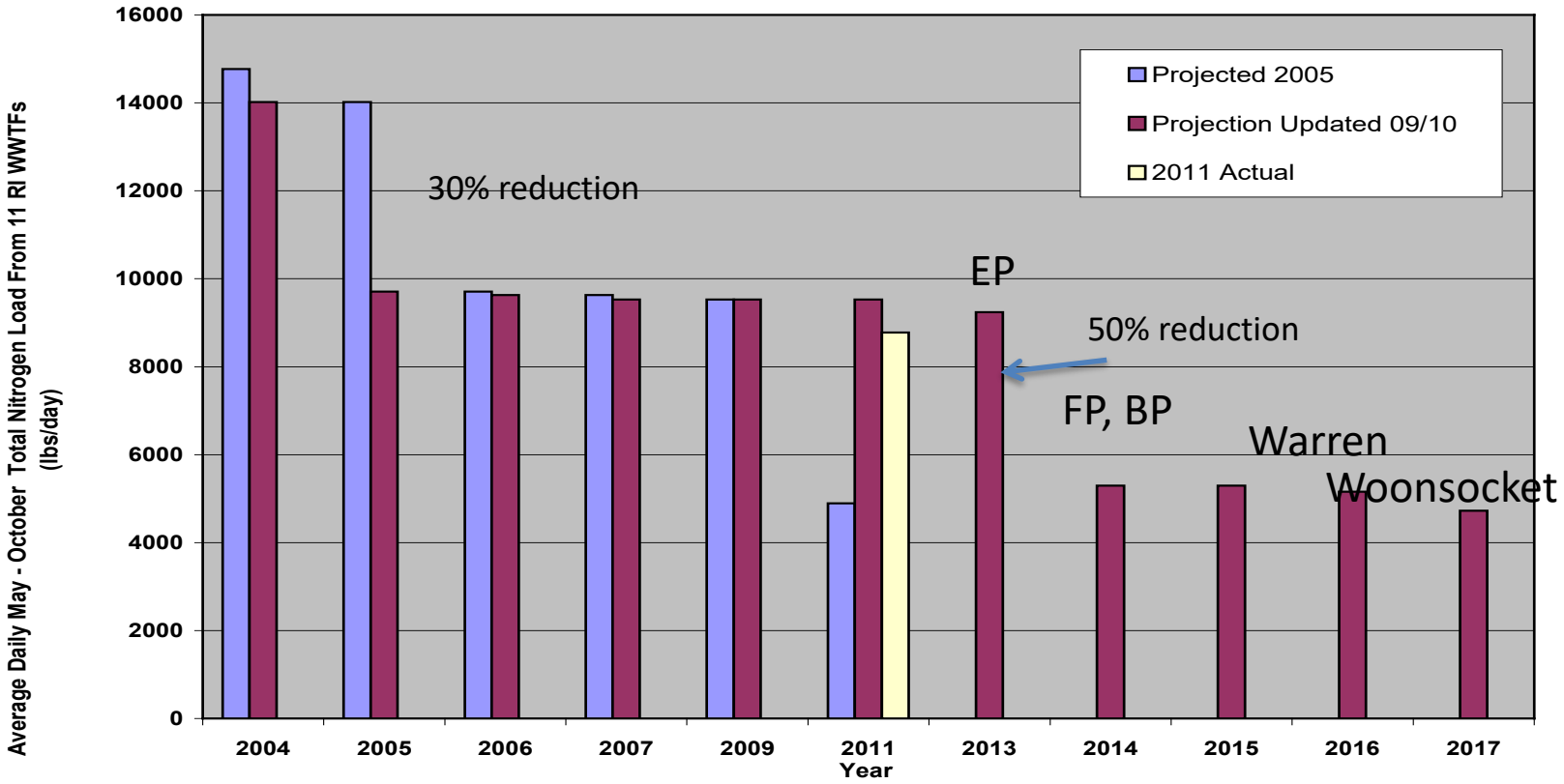
A Huge Success!

The Nutrient Reduction Plan: Reduce Nitrogen by 50%
RI WWTF Nitrogen Reductions

From Angelo Liberti, Chief Surface Water Protection, Office of Water, RI DEM (2012)

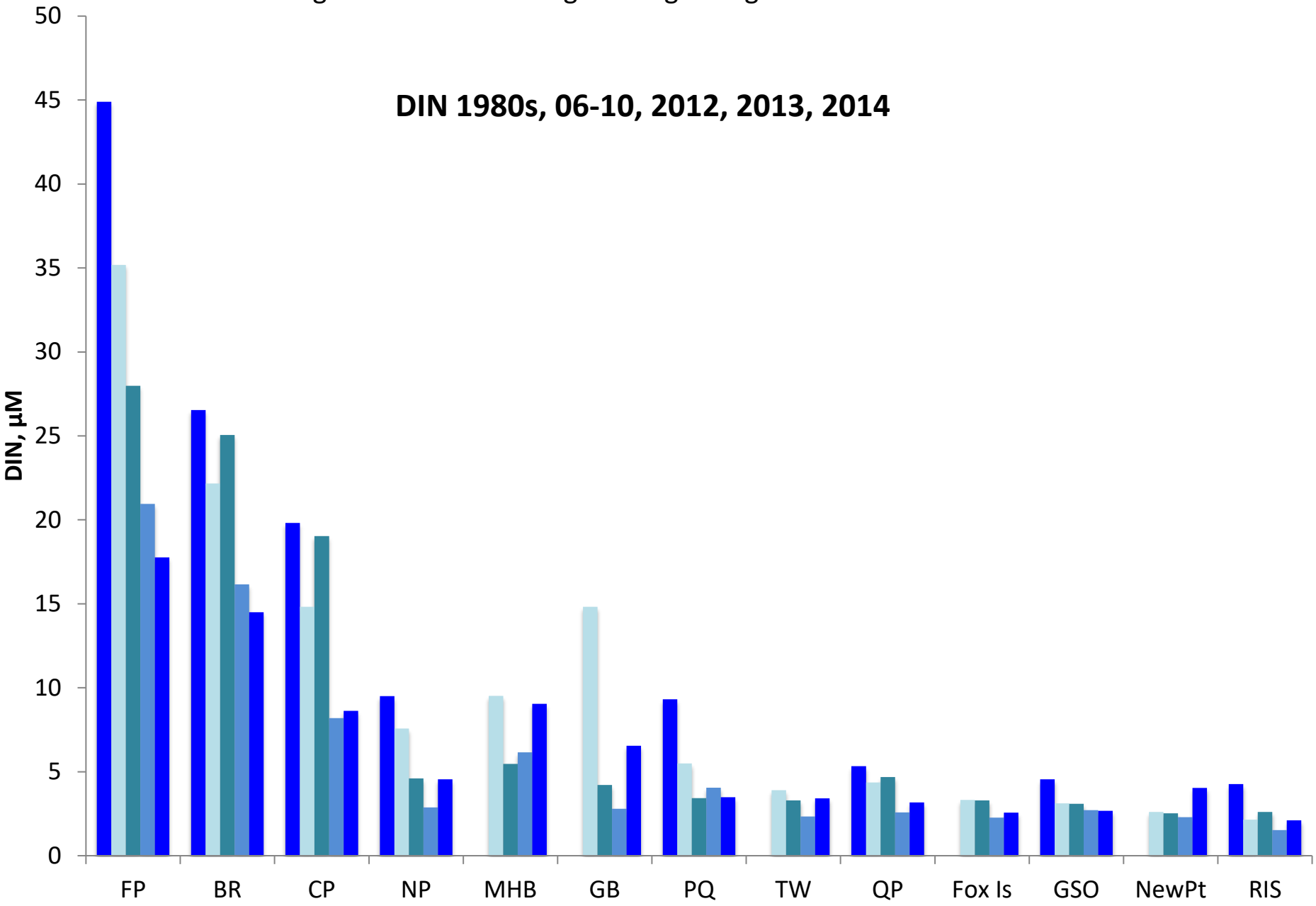
•Nitrogen removal at 11 RI WWTFs - reduces their summer season nitrogen loading by 65%, dropping to 48% as WWTF flows reach approved design flows.

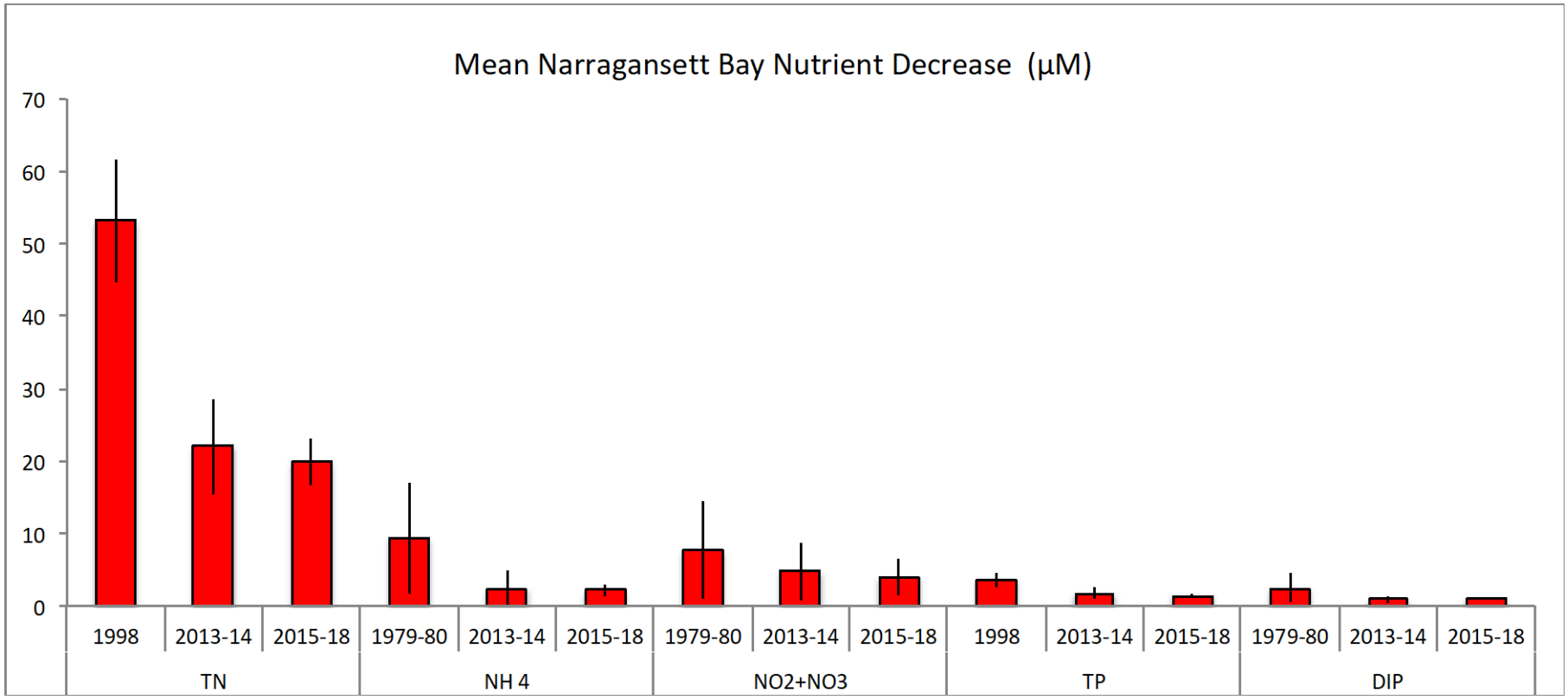
Projected Reduction in Seasonal Nitrogen Load From 11 RI WWTFs Impacting Upper Narragansett Bay.

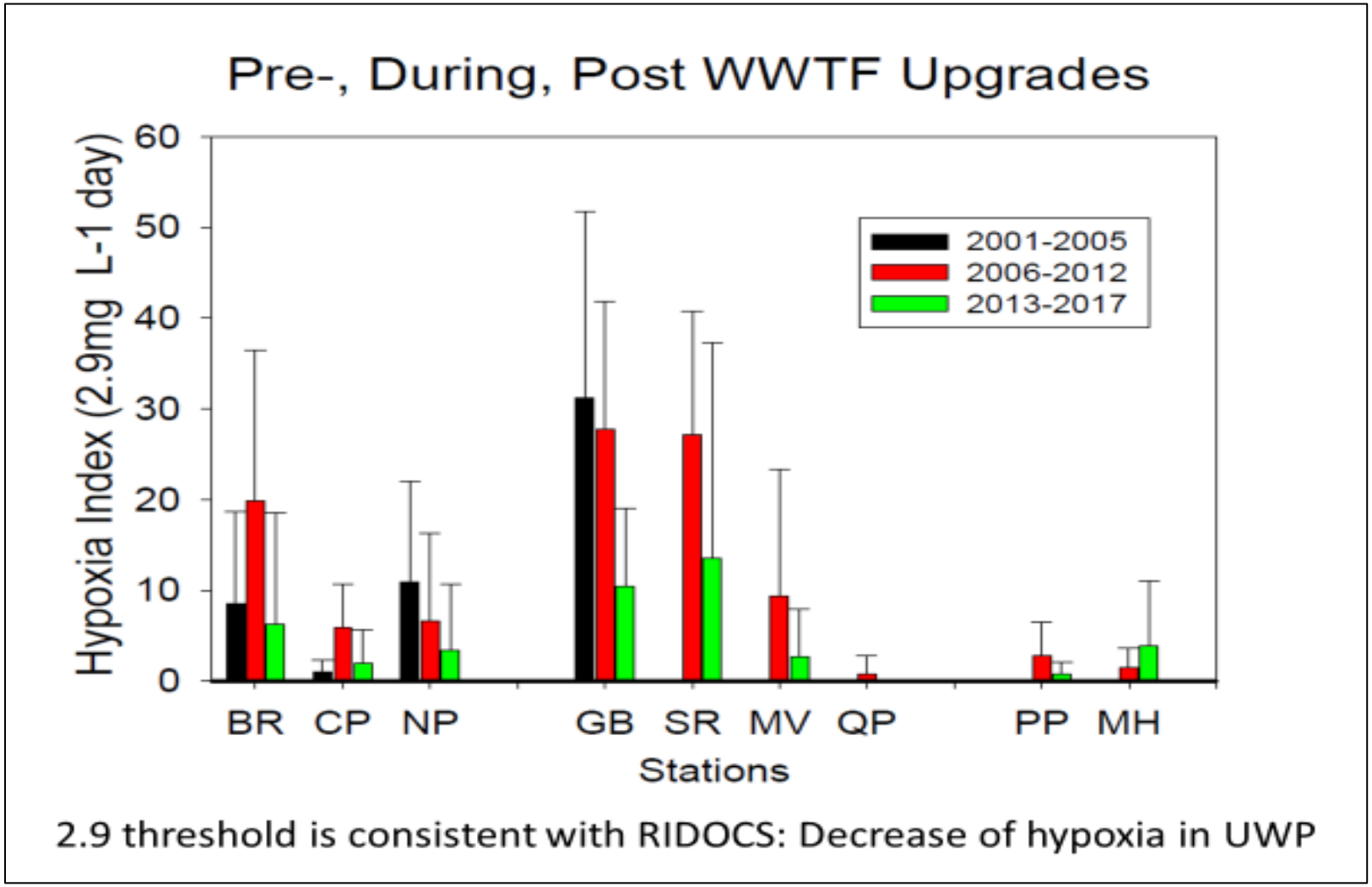


All calculations are based on May-Oct 95-96 WWTF flows. Loadings will increase as WWTF flows increase to their approved design flows.

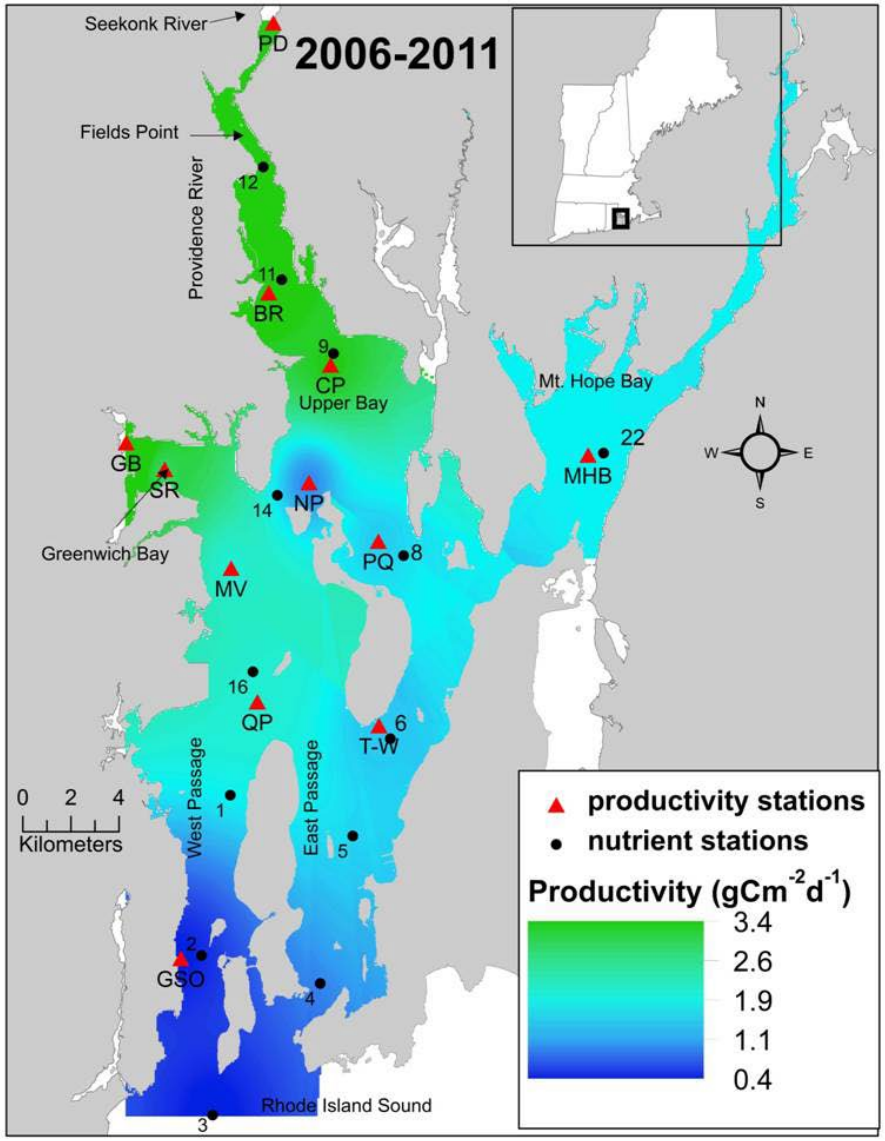
How did the gradient in DIN change during nitrogen reduction?

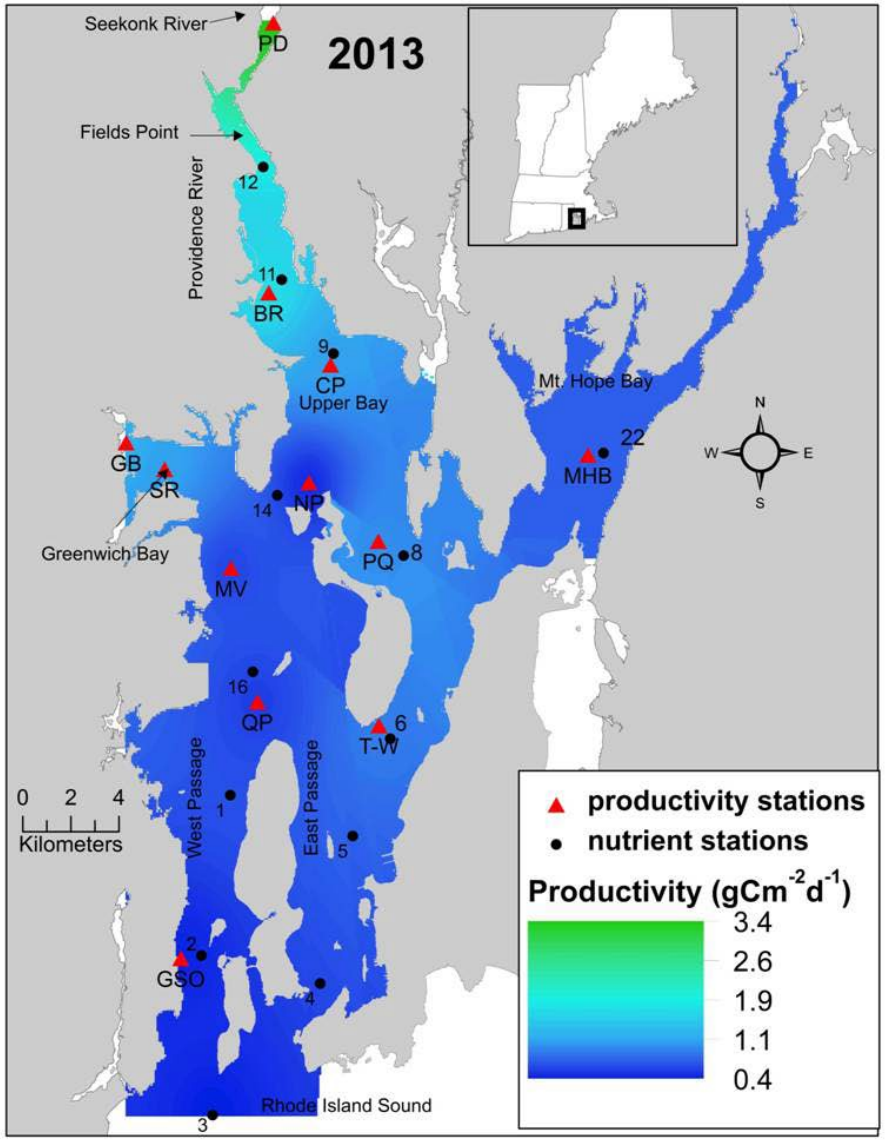



Mean Narragansett Bay Nutrient Decrease (µM)
70
60
50
40
30
20
10
0
1998
2013-14
2015-18
1979-80
2013-14
2015-18
1979-80
2013-14
2015-18
1998
2013-14
2015-18
1979-80
2013-14
2015-18
TN
NH 4
NO2+NO3
TP
DIP


Pre-, During, Post WWTF Upgrades
Hypoxia Index (2.9mg L-1 day)
60
50
40
30
20
10
0
2001-2005
2006-2012
2013-2017
BR
CP
NP
GB
SR
MV
QP
PP
MH
Stations
2.9 threshold is consistent with RIDOCS: Decrease of hypoxia in UWP

Change in Primary Production: 300 to 200 gC m^{-2} y^{-1}





Fine Tuning Nutrient Reduction?

It may be possible, using intensive observations including data from the Narragansett Bay Fixed Site Monitoring Network (NBFSMN) (14 summer stations; 4 year round), developing multi-models and an ecosystem-based management approach, to ascertain nutrient levels system-wide to minimize summer hypoxia, negative impacts of acidification and yet maximize the food environment for wild fisheries and aquaculture.

Two Examples:

1) Release nutrients from Waste Water Treatment Facilities in Winter.

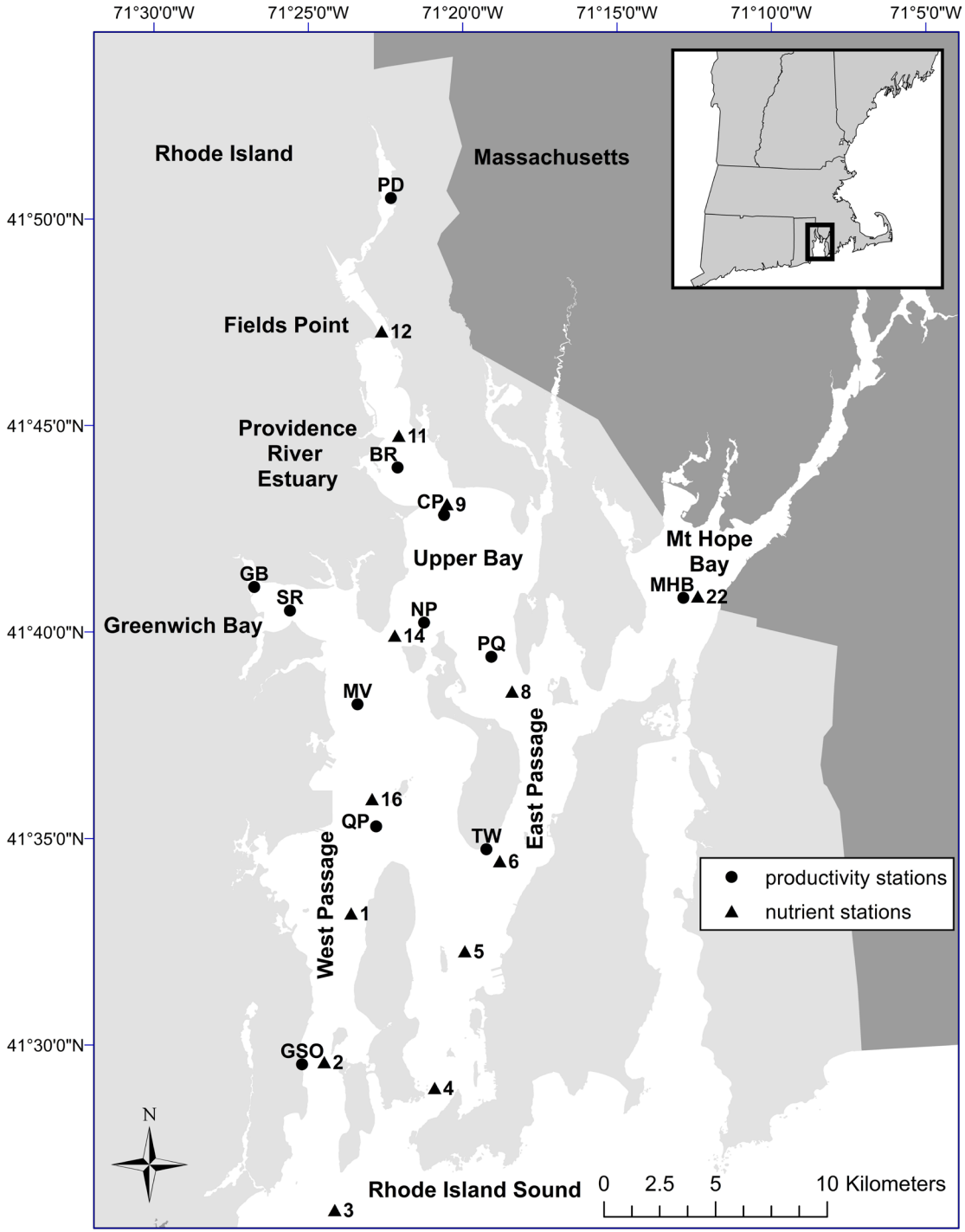
2) Increase nutrients in the mid Bay.

Rationale for Winter Nutrient Release to Upper Narragansett Bay

A major wild fishery left in the Bay is the quahog fishery. The year round nutrient reduction has reduced the quahog yield from the upper Bay, an area of over 10,000 acres. In recent years, over 20 million quahogs with a value of $5 million have been harvested annually from the Bay. Since the nutrient reduction, quahog production has declined by 35 to 40%.

A first step might be to work on restoration and recruitment to this area of the fishery. Recent literature indicates that most quahog growth occurs in the spring and in the fall after diatom blooms in the northeast US. URI Sea Grant mesocosm experiments further suggest that the winter-spring diatom bloom enhances the reproductive potential of hard clams.

Thus a management option to consider is the release of nutrients from the Narragansett Bay Commission's three big WWTFs on the Providence River to support a winter-spring bloom in the upper Bay when summer hypoxia is not a problem. Besides supporting the base of the Bay's food web, the bloom helps counteract acidification when carbonate is low due to low temperature.


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
MV
8
East Passage
16
QP
TW
6
West Passage
1
5
GSO
2
4
3
N
Rhode Island Sound
0 2.5 5 10 Kilometers
productivity stations
nutrient stations

The argument in favor
based on nutrient inputs
during two major storm years:

2010

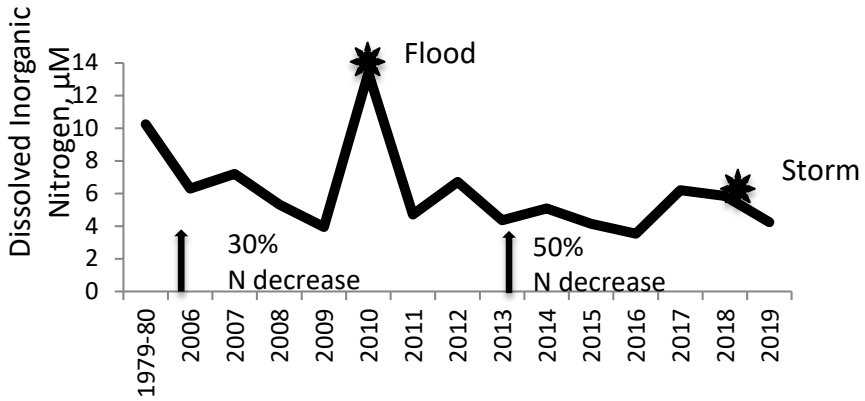
And

2018

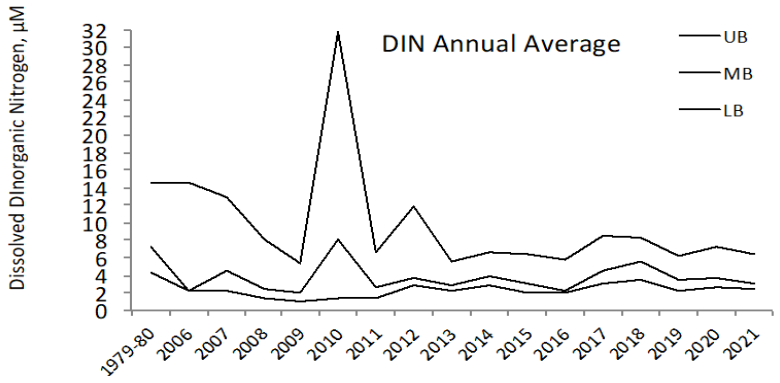
Standing stock of dissolved inorganic nitrogen during managed nitrogen reduction and storms.

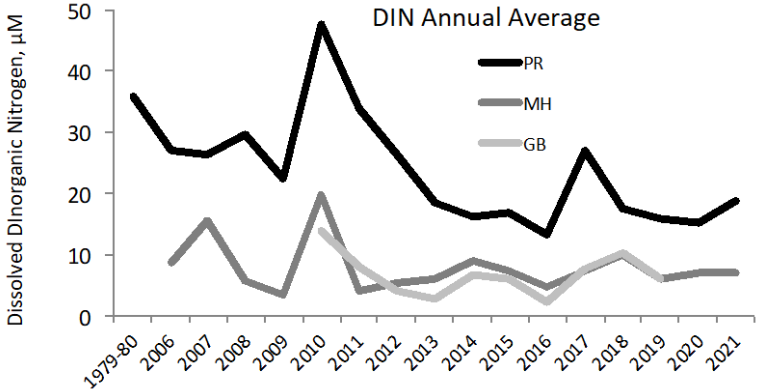
Weather 2017
Kingston, RI
7.9'' of rain October 2017

Providence, RI
5.44" of rain October 2017
14.8 '' of rain Fall (SOND) total
(up to 17" at some stations)



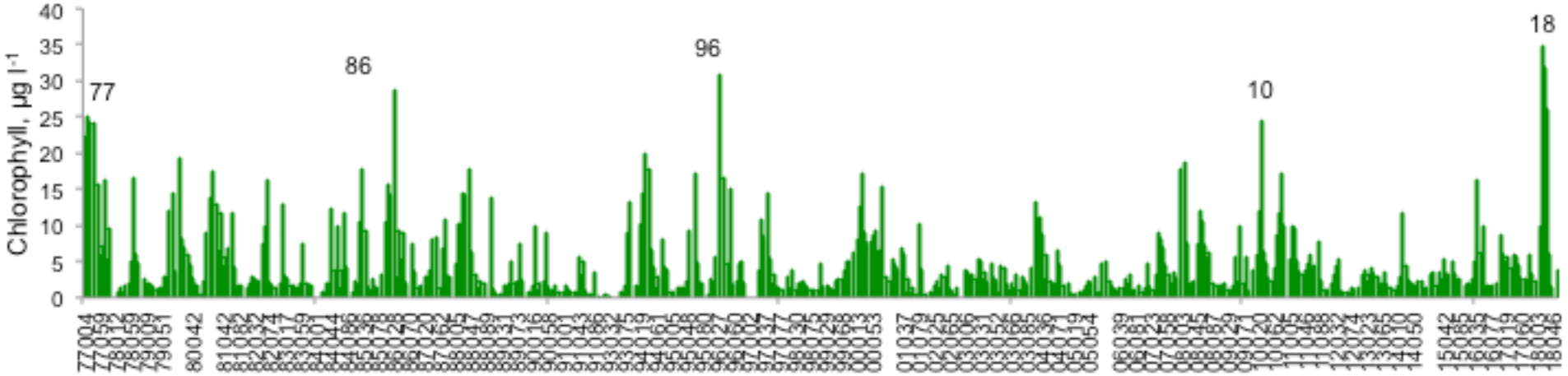
Weather 2010
Providence, RI
16.34" of rain in March 2010
(up to 19" at some stations)



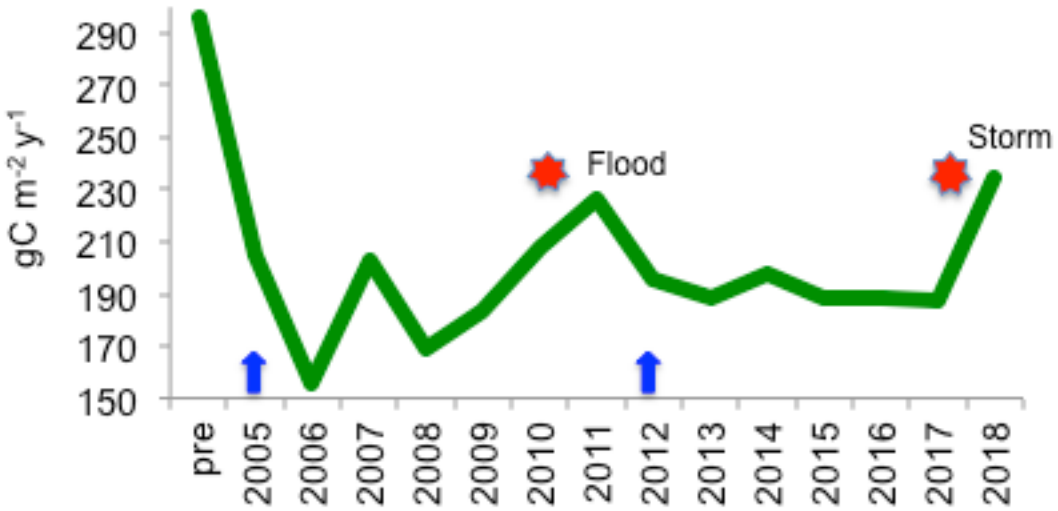


http://www.theweathercollector.com/?gclid=EAIaIQobChMIutuL4LbZ6QIVvOy1Ch0NggCcEAMYASAAEgKeLvD_BwE (accessed 5/20)

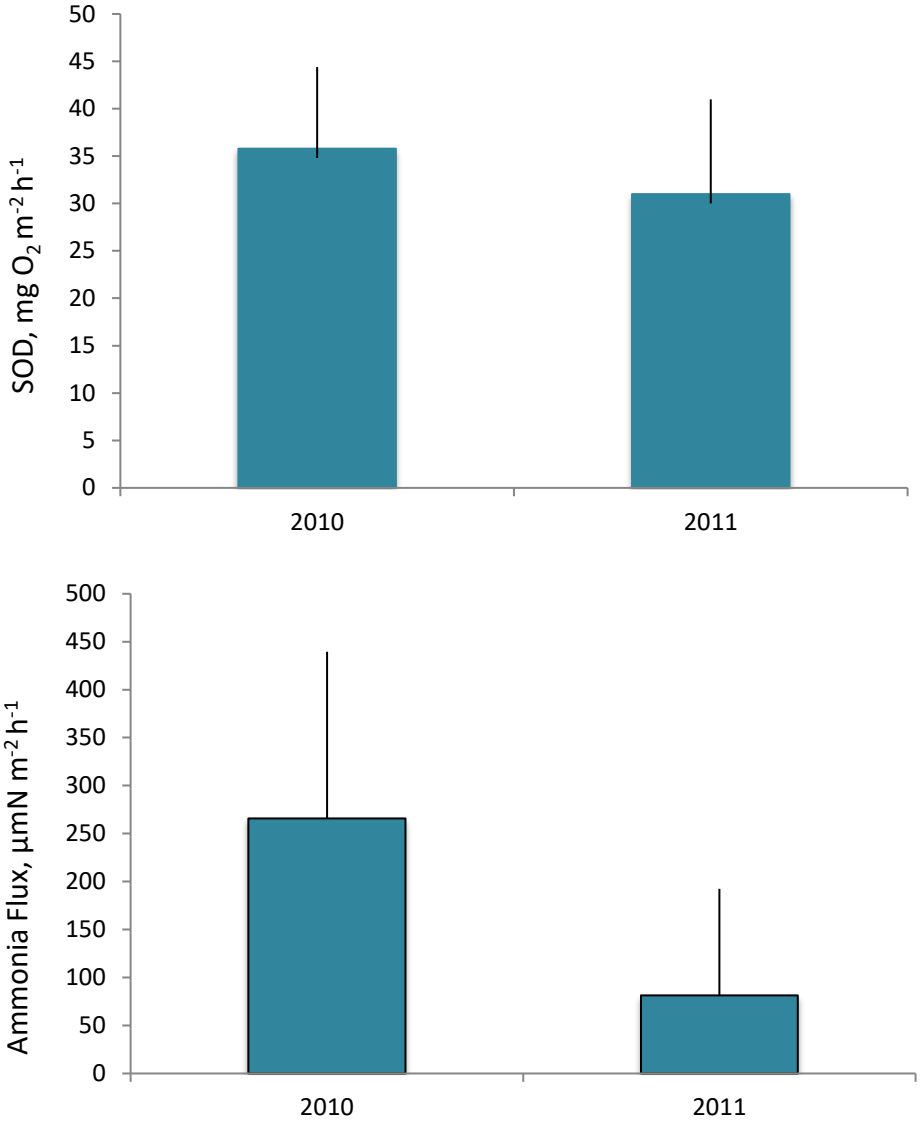
Chlorophyll in the Winter-spring Bloom from 1977 to 2018 at the GSO Dock.



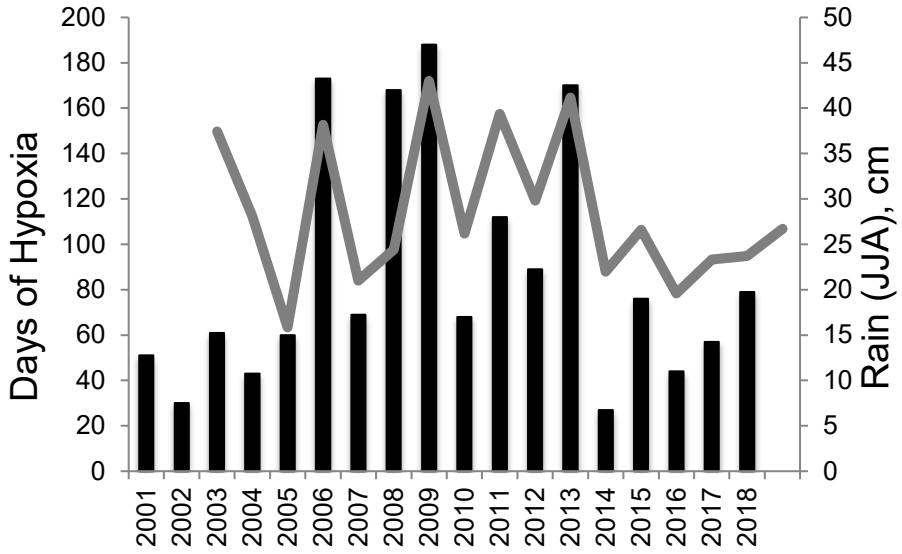
Annual primary production dropped by a third after managed nutrient reduction by 2012 and Increased after flood year 2010 and storm year 2018 nutrient enhancements.



Sediment respiration tended higher and ammonia release was significantly greater in flood year 2010 than in the year following.

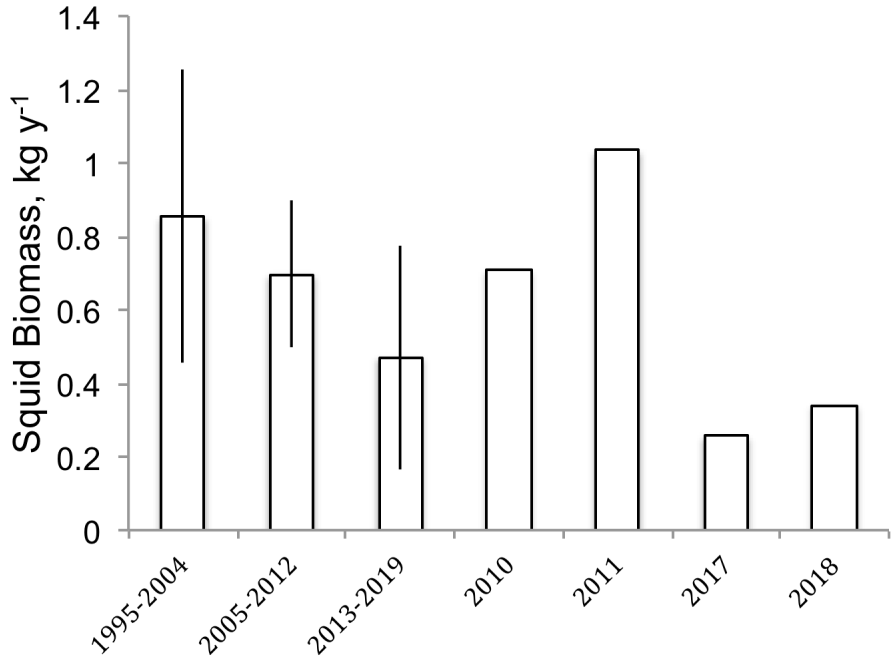


Days of summer hypoxia have tended lower since the managed nutrient reduction. Storm nutrients in colder months in 2010 and 2018 did not cause greater hypoxia than other non-rainy summers.

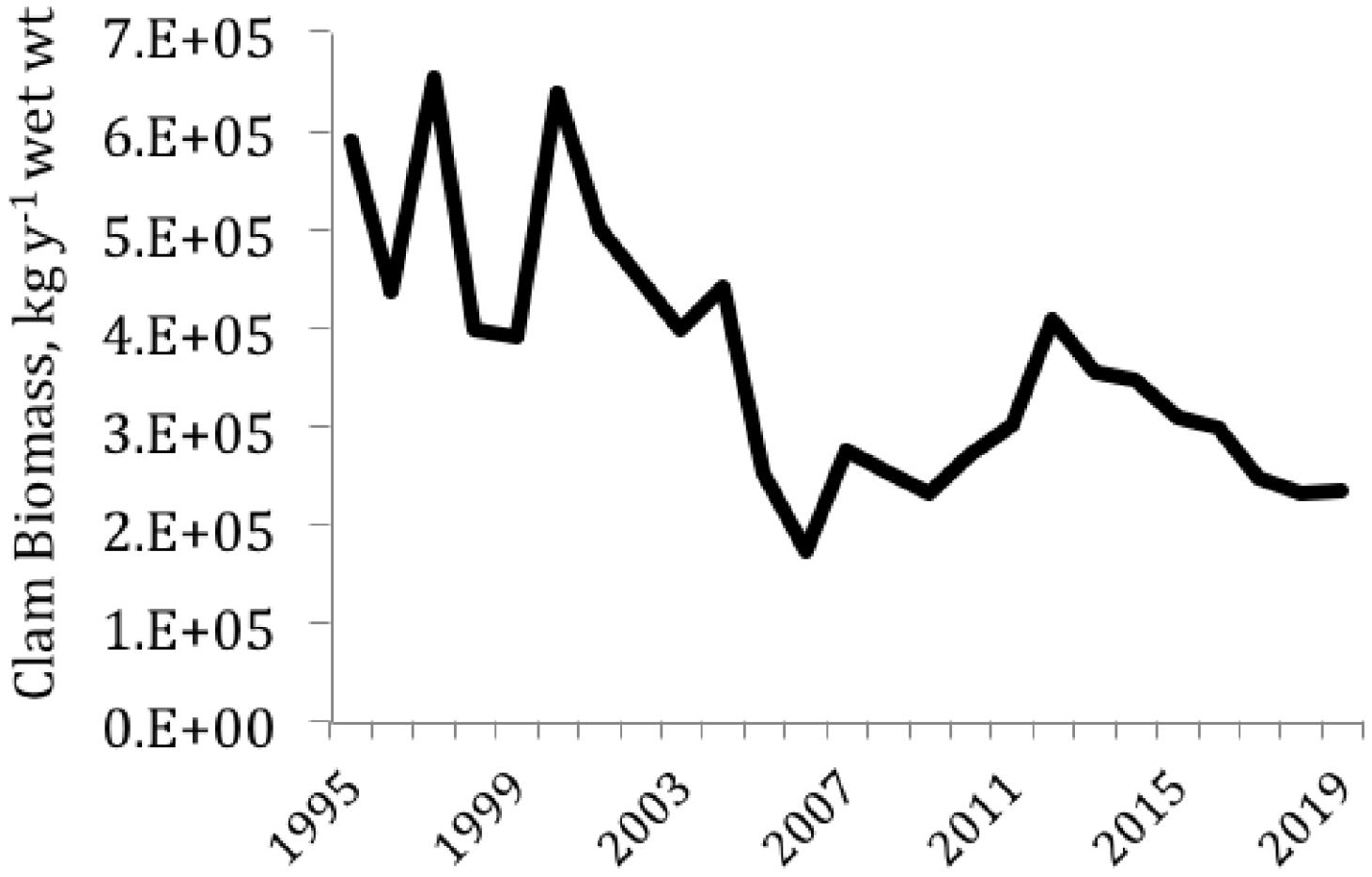


Nutrient release in winter does not cause summer hypoxia!

Squid in Fox Island Trawl decreased with managed nutrient reduction. Flood nutrients in 2010 correlated with increased biomass in 2011. This trend was less apparent in the 2018 storm year.



Clam landings decreased in Narragansett Bay after Managed Nutrient Reduction. Storm nutrients may have enhanced clam recruitment after the 2010 flood year.



Summary of Storm Nutrient Inputs:

Managed nutrient reduction has decreased the nutrient input to Narragansett Bay by over 50% resulting in decreased primary production.

The objective of the managed nutrient reduction was to decrease summer low oxygen in the upper Bay and that was hugely successful. Days of hypoxia have been minimal since 2013.

On two occasions 2010 and in 2018 storm nutrient input during colder months reversed managed nutrient reduction. The more extreme flood year of 2010 had a greater input of nutrients than 2018 but less of an impact on chlorophyll levels and primary production due to an enhanced flushing rate in the more intense storm year.

While storm nutrient impacts extended over the year in terms of increased primary production and benthic nutrient release, summer low oxygen was not increased.

The storm nutrient increase did appear to enhance some fisheries. Squid biomass increased In years after the storms. Clam recruitment tended to increase 3 years after the 2010 flood year but not apparently after the 2018 storm year. The reduction in nutrients from Providence River WWTF after 2012 reduced upper Bay nutrient concentrations reducing clam condition and perhaps causing recruitment failure.

These results suggest that managed nitrogen reduction may not be as necessary and beneficial in colder months as it has been in warms months

2) Lower Bay Nutrient Status

For new studies, down Bay locations and embayments, should be assessed for nutrient sufficiency/deficiency.

Aquaculture locations down Bay should be evaluated for growth conditions/water quality.

GSO Dock area is oligotrophic.

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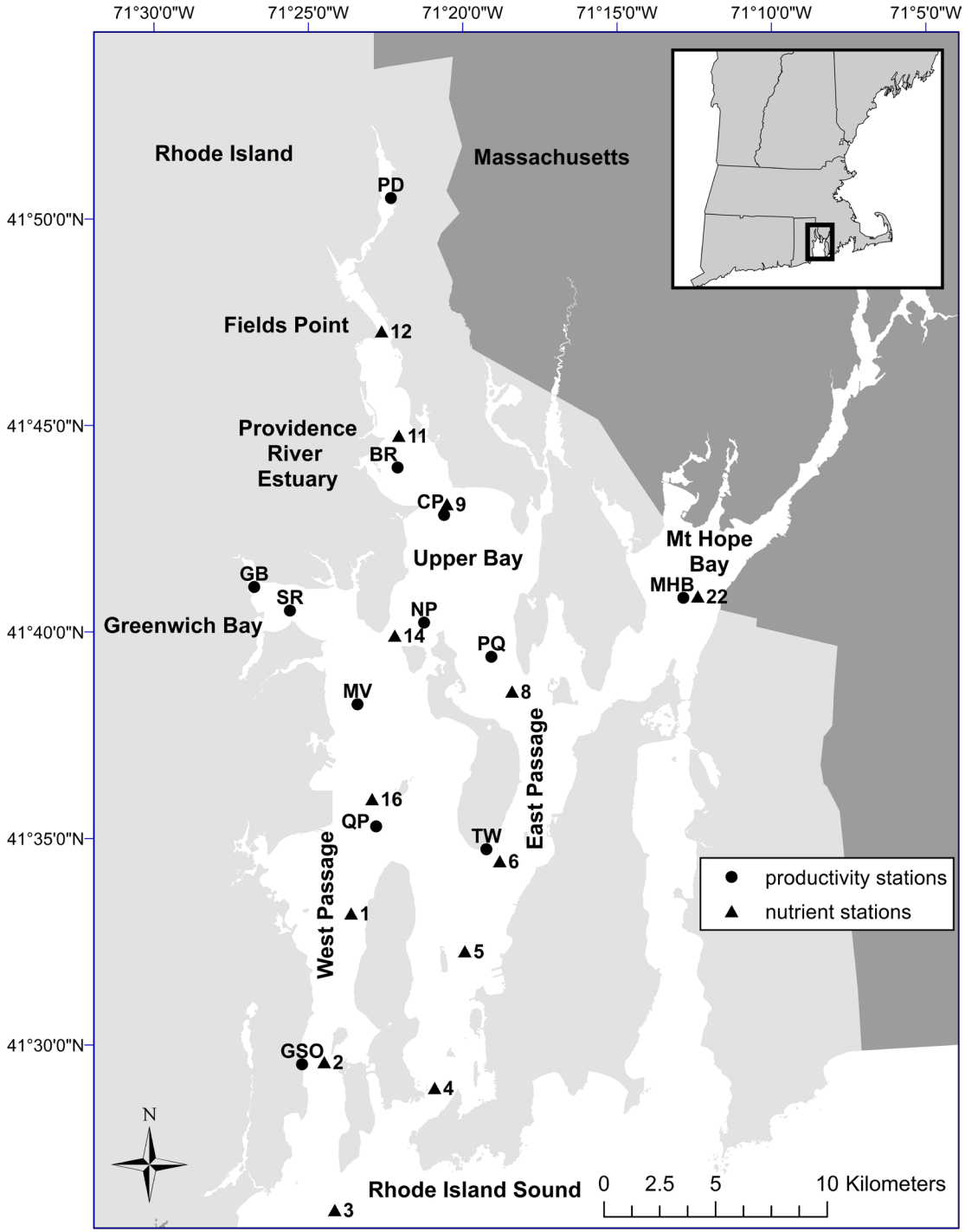
71°30'0"W
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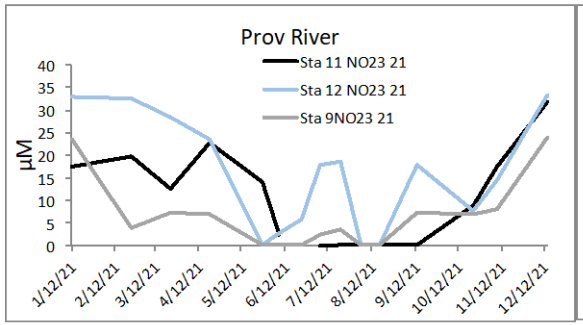
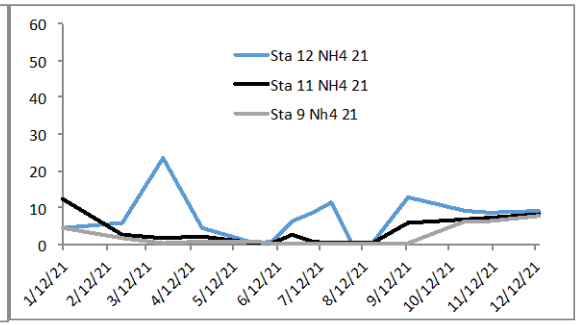
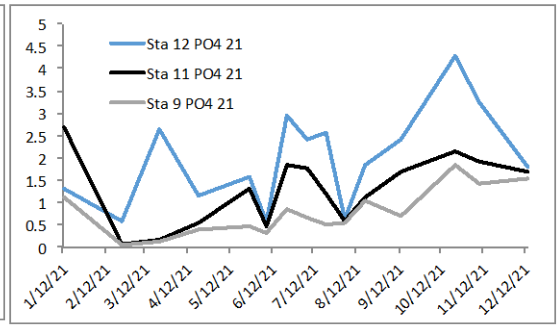
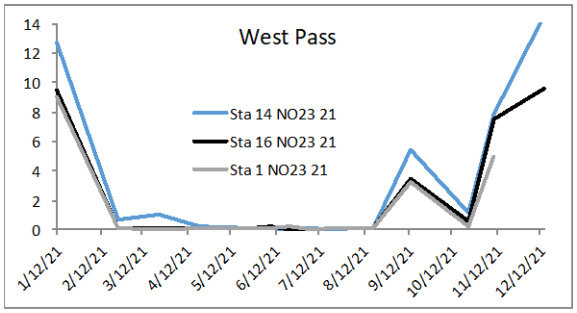
71°15'0"W
71°10'0"W
71°5'0"W
41°50'0"N
41°45'0"N
41°40'0"N
41°35'0"N
41°30'0"N
Rhode Island
Massachusetts
PD
Fields Point
12
Providence River Estuary
11
BR
CP
9
Upper Bay
Mt Hope Bay
MHB
22
GB
SR
Greenwich Bay
NP
14
PQ
MV
8
East Passage
16
QP
TW
6
West Passage
1
5
GSO
2
4
3
N
Rhode Island Sound
0 2.5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

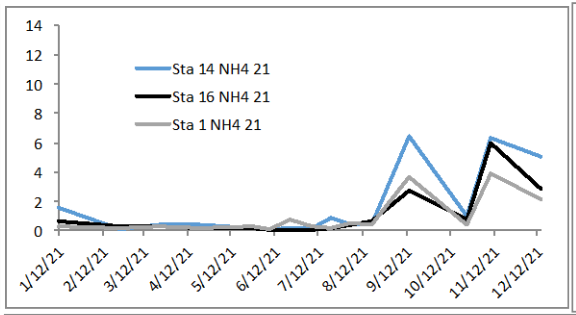
2021 Summer Station Nutrient Cycles North to South in Narragansett Bay

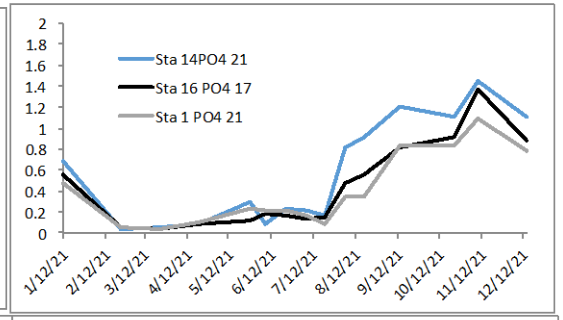


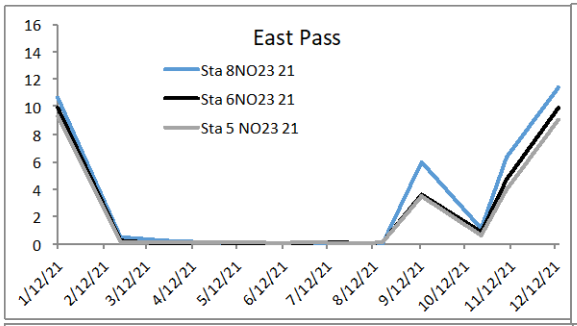


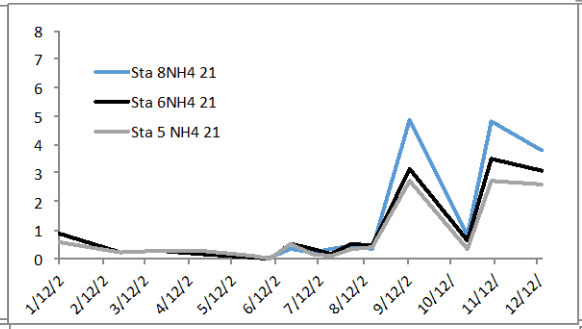


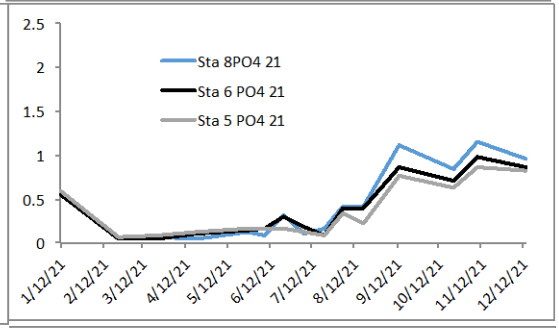


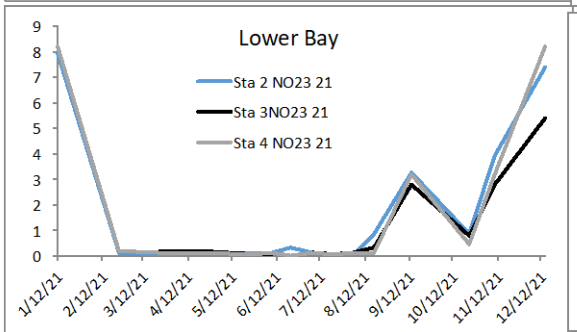


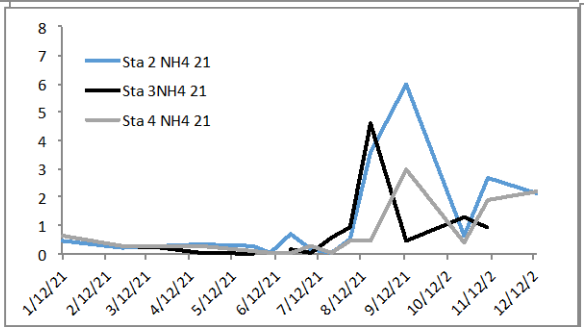


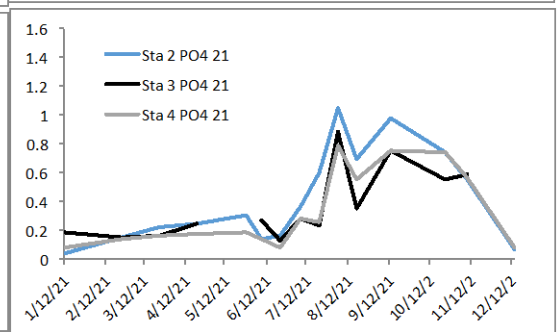




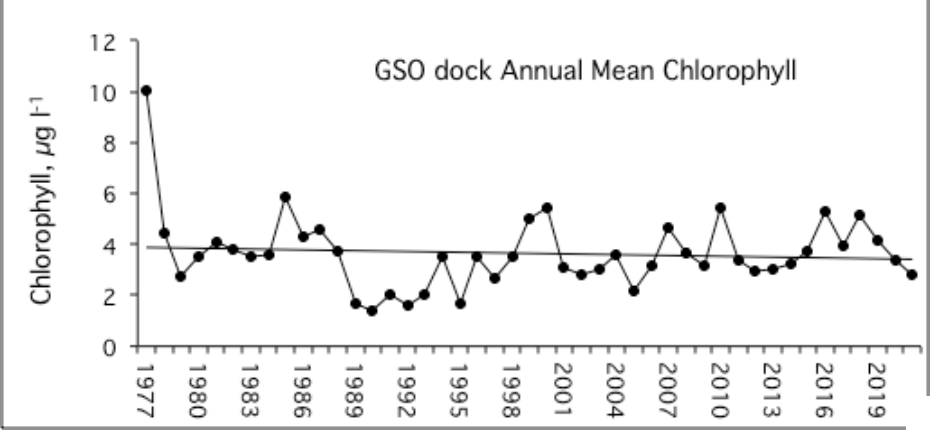


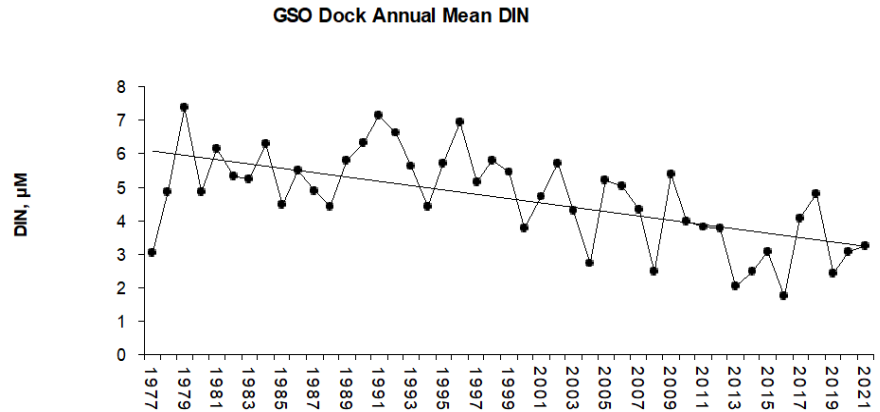


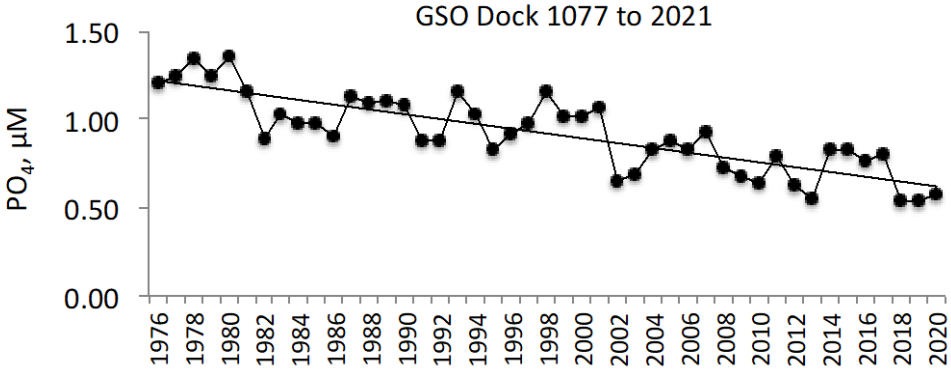


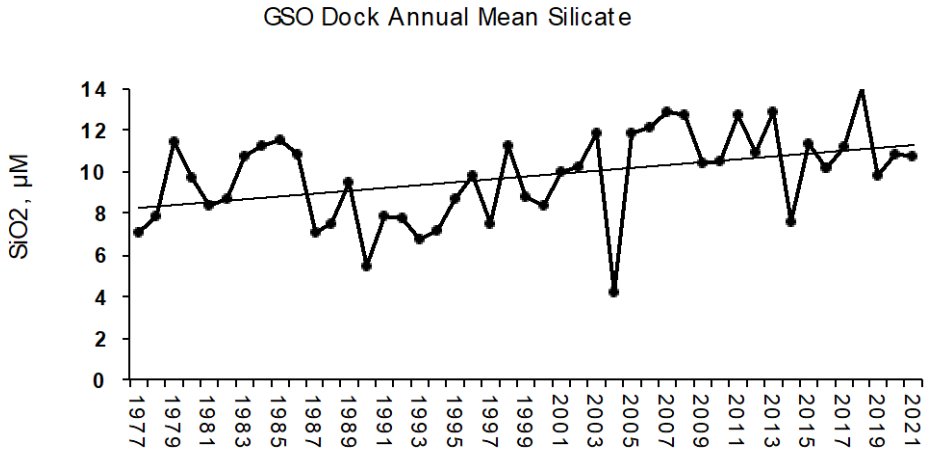


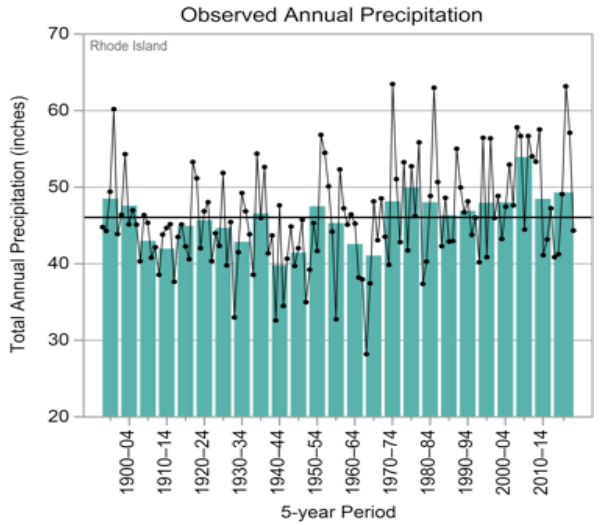
Lower West Passage
Oligotrophic Nutrient Status
1977 to 2021











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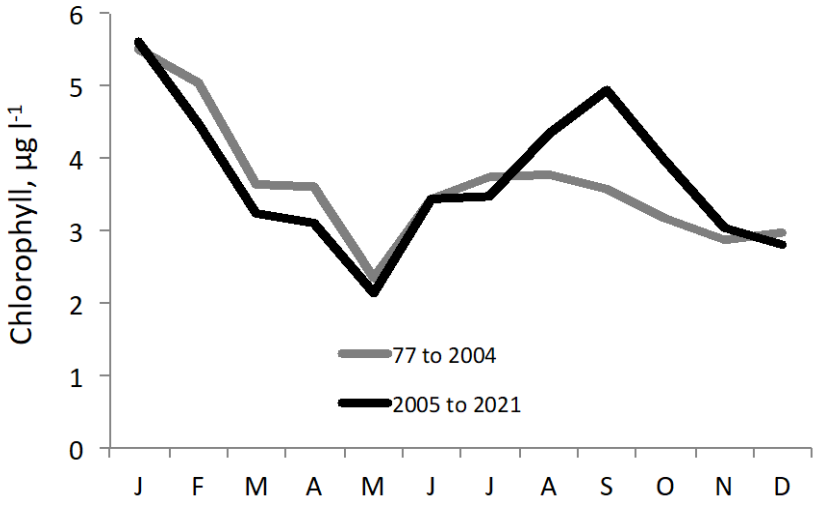
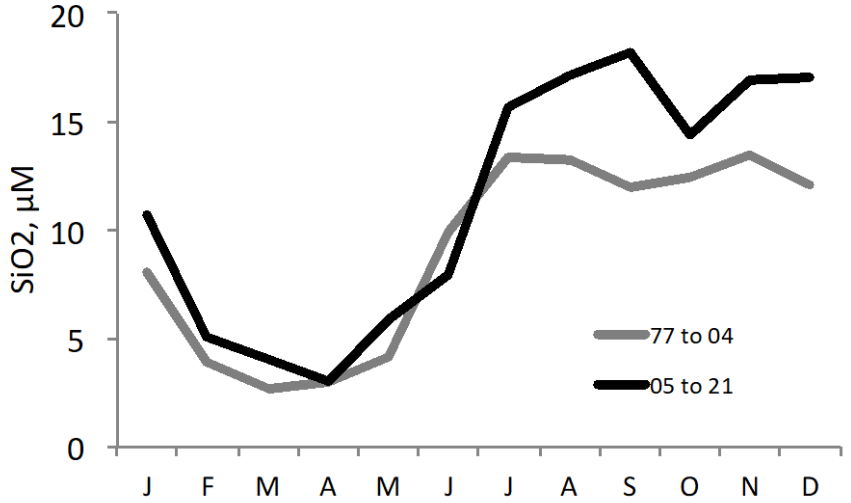
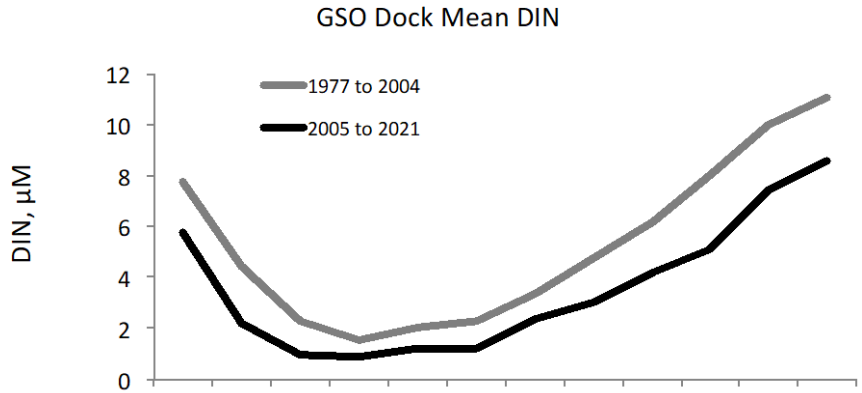
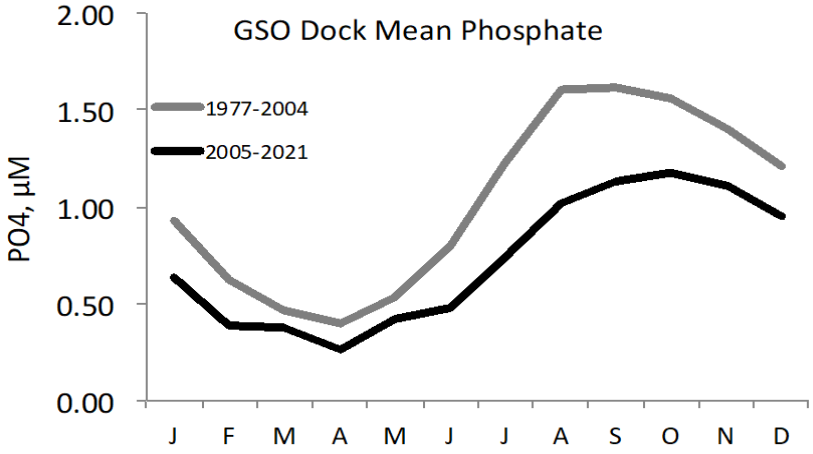
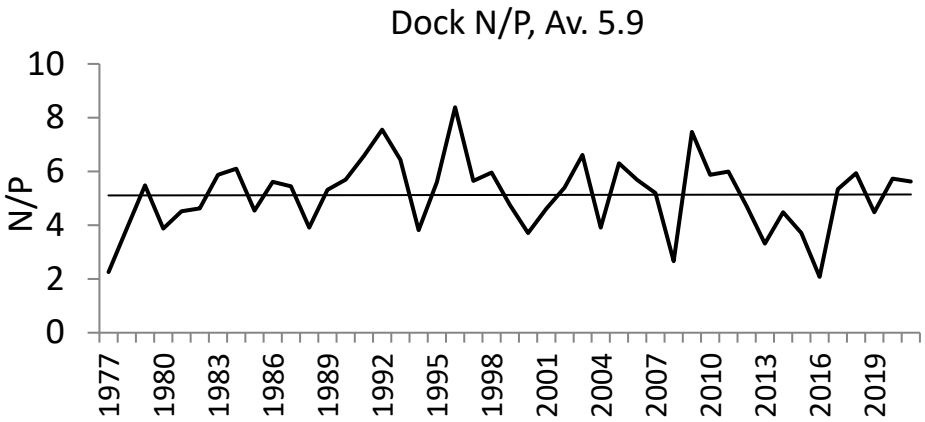








Seasonal Cycle Changes in the Lower West Passage Pre/Post Nutrient Reduction



An option might be for WWTF
in the mid/lower Bay
to release more nutrients
during summer and
still not cause hypoxia.

Conclusions

1) Based on nutrient data from two storms, no hypoxia will result if nutrients from WWTF are released to the Bay in cold months and such nutrients may be beneficial to resource species.

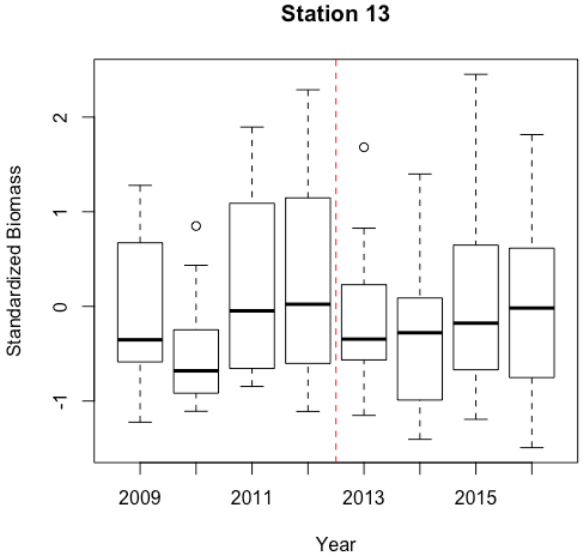
2) The lower Bay is reduced in nitrogen and phosphorus and wild fisheries and aquaculture farms located there might benefit from enhanced nutrients additions.

The question is whether nutrient tuning is a good idea or not?

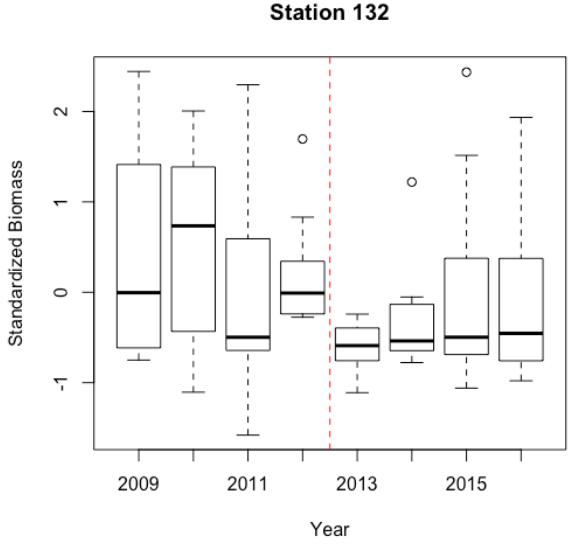
Fish Biomass During/After Nutrient Reduction (all significant decrease except Ohio)

Kruskal-Wallis test Analysis

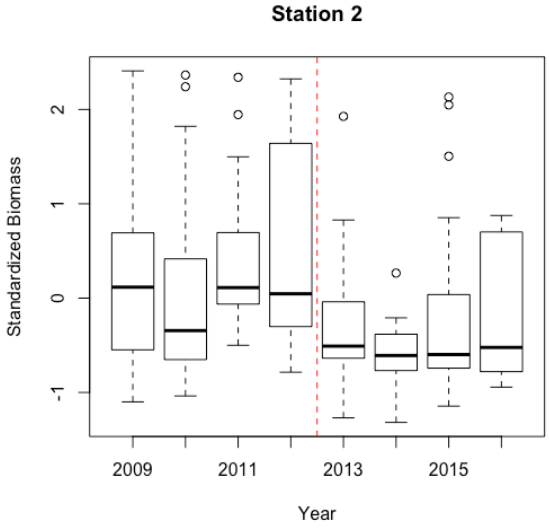
Ohio



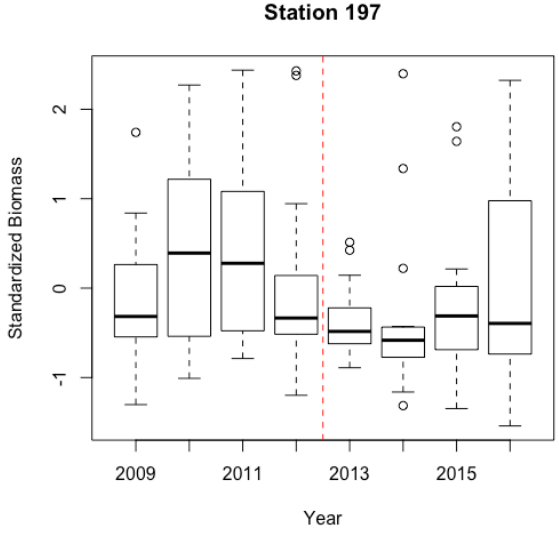
Fox



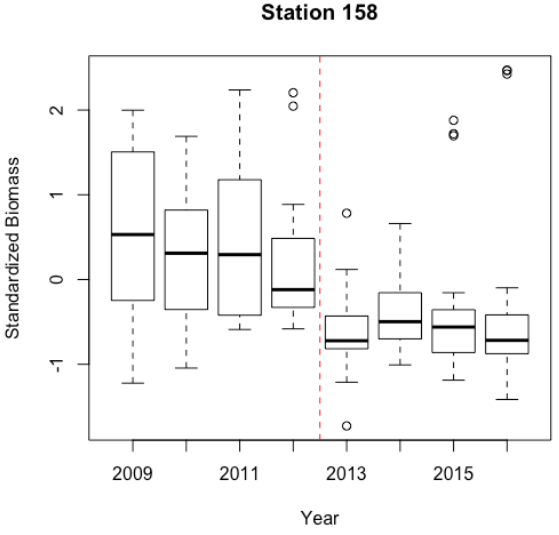
Warwick



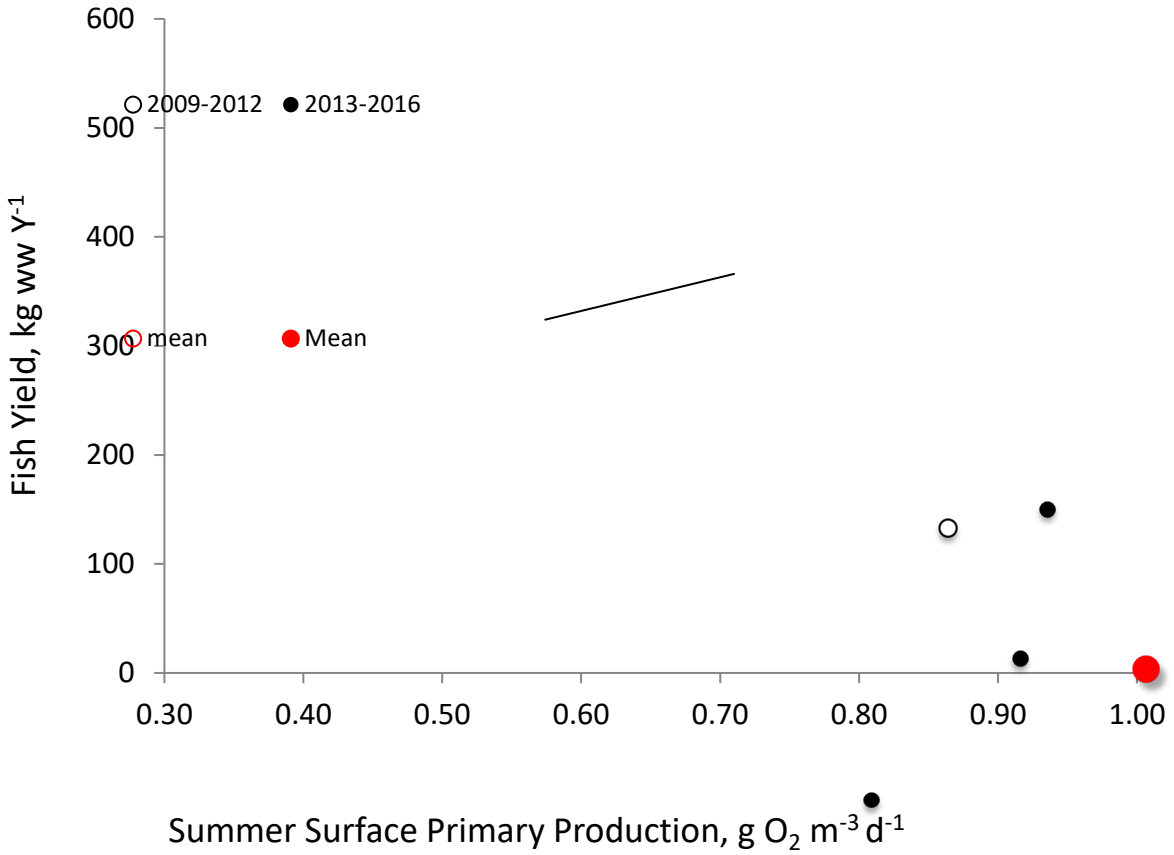
Bonnet



Gould



Narragansett Bay Five Station Transect During to After Nutrient Reduction (After Decapod Decline)

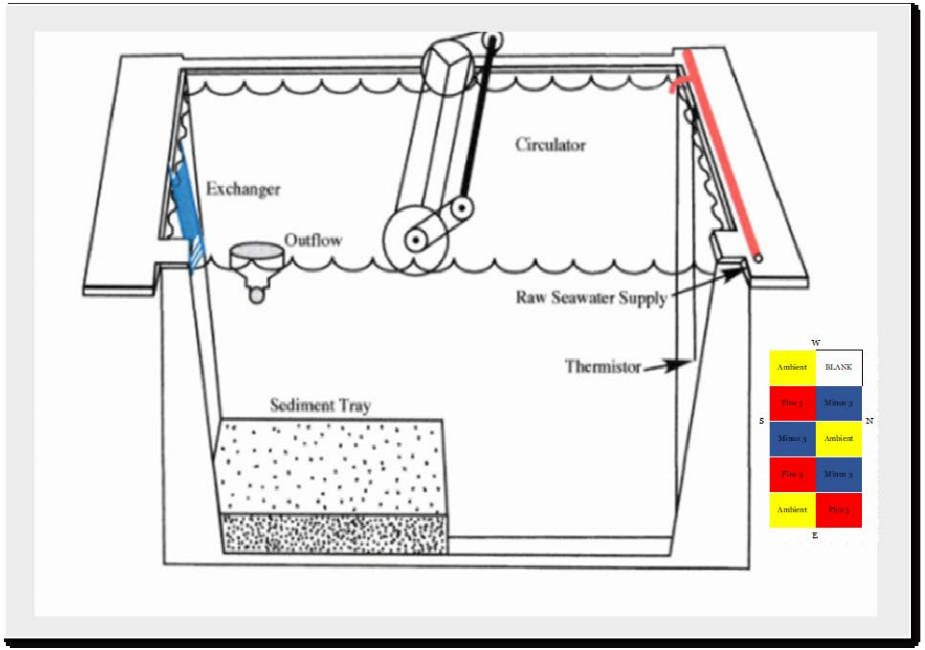


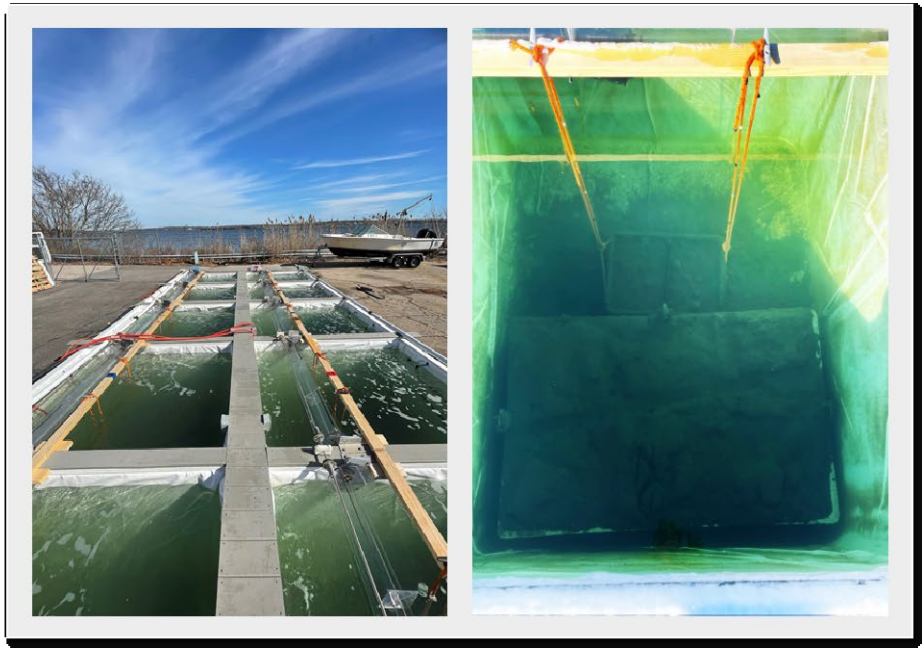
Fish decrease 11%

Quahog Response to Increased Temperature in Mesocosm Experiment

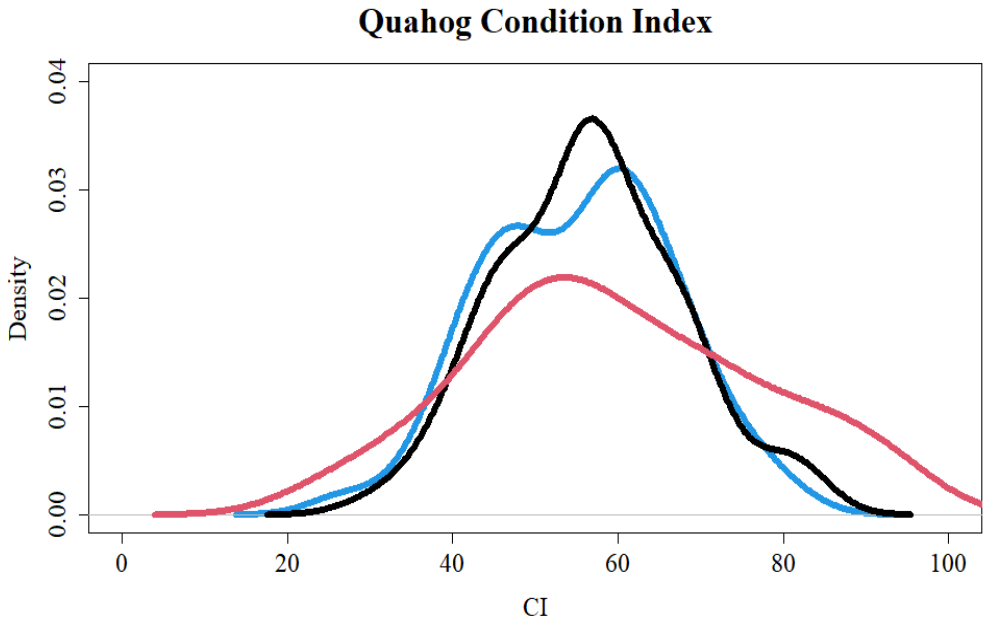
Objective: Does the Winter-spring bloom enhance clam condition, growth and recruitment? Do winter nutrients matter?

Methods

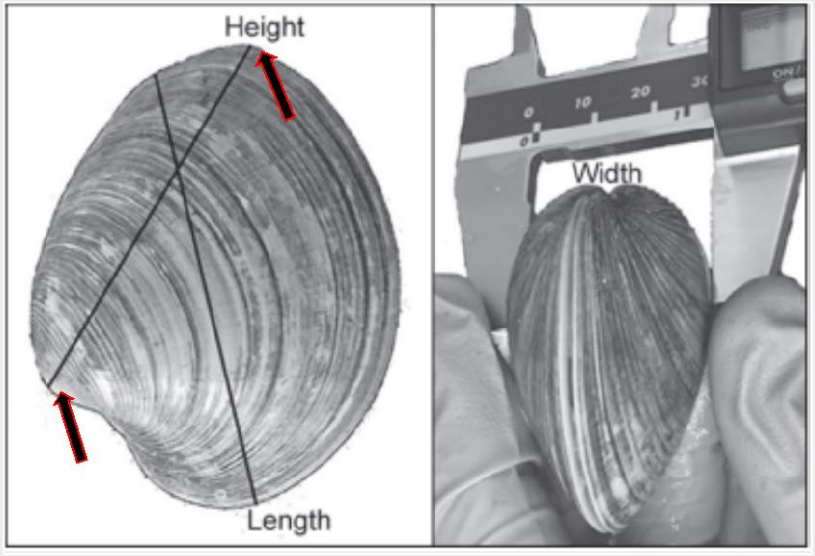




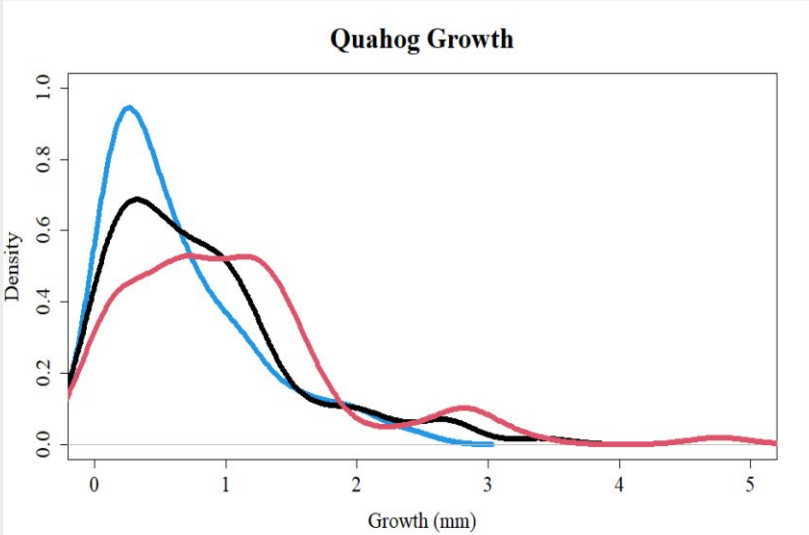
Clam Condition index:
metric for health and fitness of animals

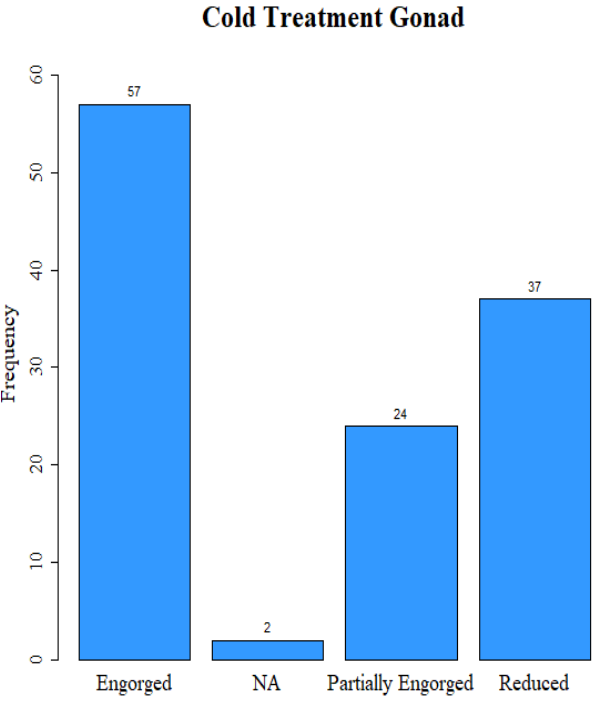


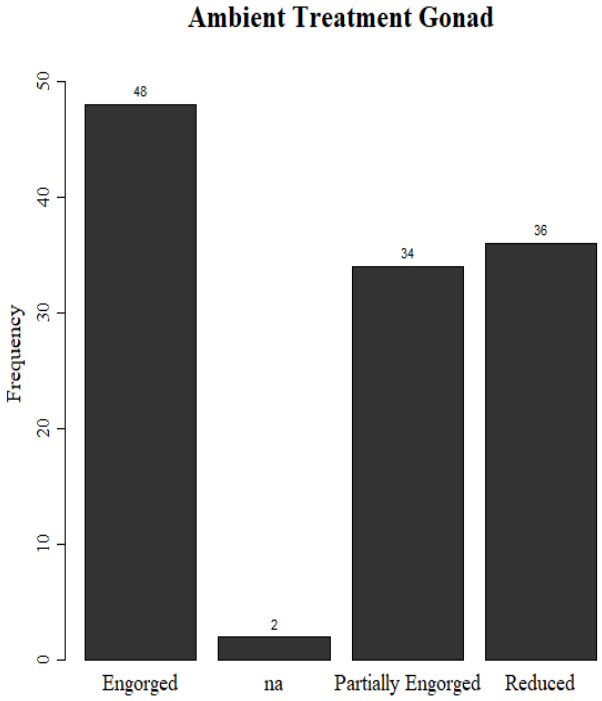
Clam Growth Measurements

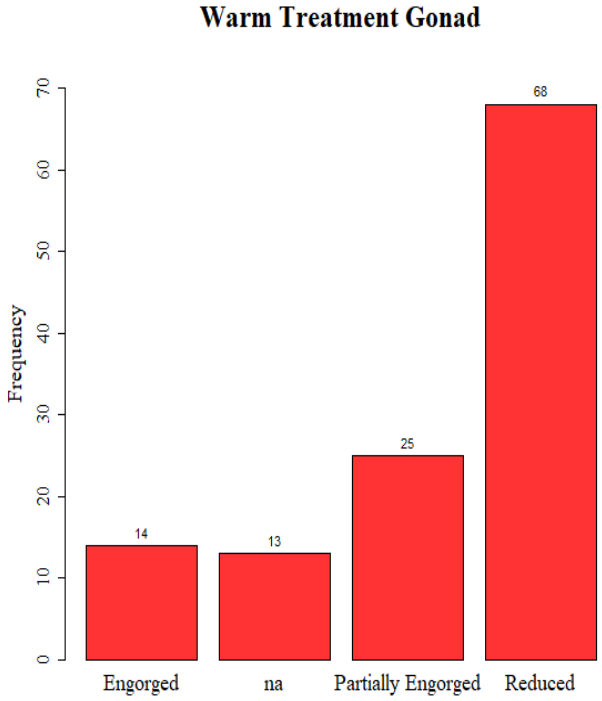


Robison et al. 2020




Cold Treatment Gonad
Frequency
0
10
20
30
40
50
60
57
2
24
37
Engorged
NA
Partially Engorged
Reduced


Ambient Treatment Gonad
Frequency
0
10
20
30
40
50
48
2
34
36
Engorged
na
Partially Engorged
Reduced


Warm Treatment Gonad
Frequency
0
10
20
30
40
50
60
70
14
13
25
68
Engorged
na
Partially Engorged
Reduced

Clams in colder treatments which experience the Winter-spring Bloom have better condition and fecundity than clams that do not experience a Bloom.

Clams in warmer treatments tend to have greater growth than those in cold treatments.

If the Winter-spring bloom fails due to warmer temperatures or low nutrients clam size may increase but recruitment will likely decrease.

Other Locations

Water quality conditions and nutrient levels will be assessed in embayments (such as, the Warren River, Wickford, Bristol, Newport, Sakonnet River).

To keep the work focused on fisheries and water resource management needs, we propose to form an advisory committee with potential members from the RI Department of Environmental Management, Offices of Water and Marine Fisheries, the Coastal Resources Center Council staff, the Narragansett Bay Commission, the Shining Sea Fisheries, and the Rhode Island Aquaculture Association to work with us and advise on fish and shellfish restoration objectives