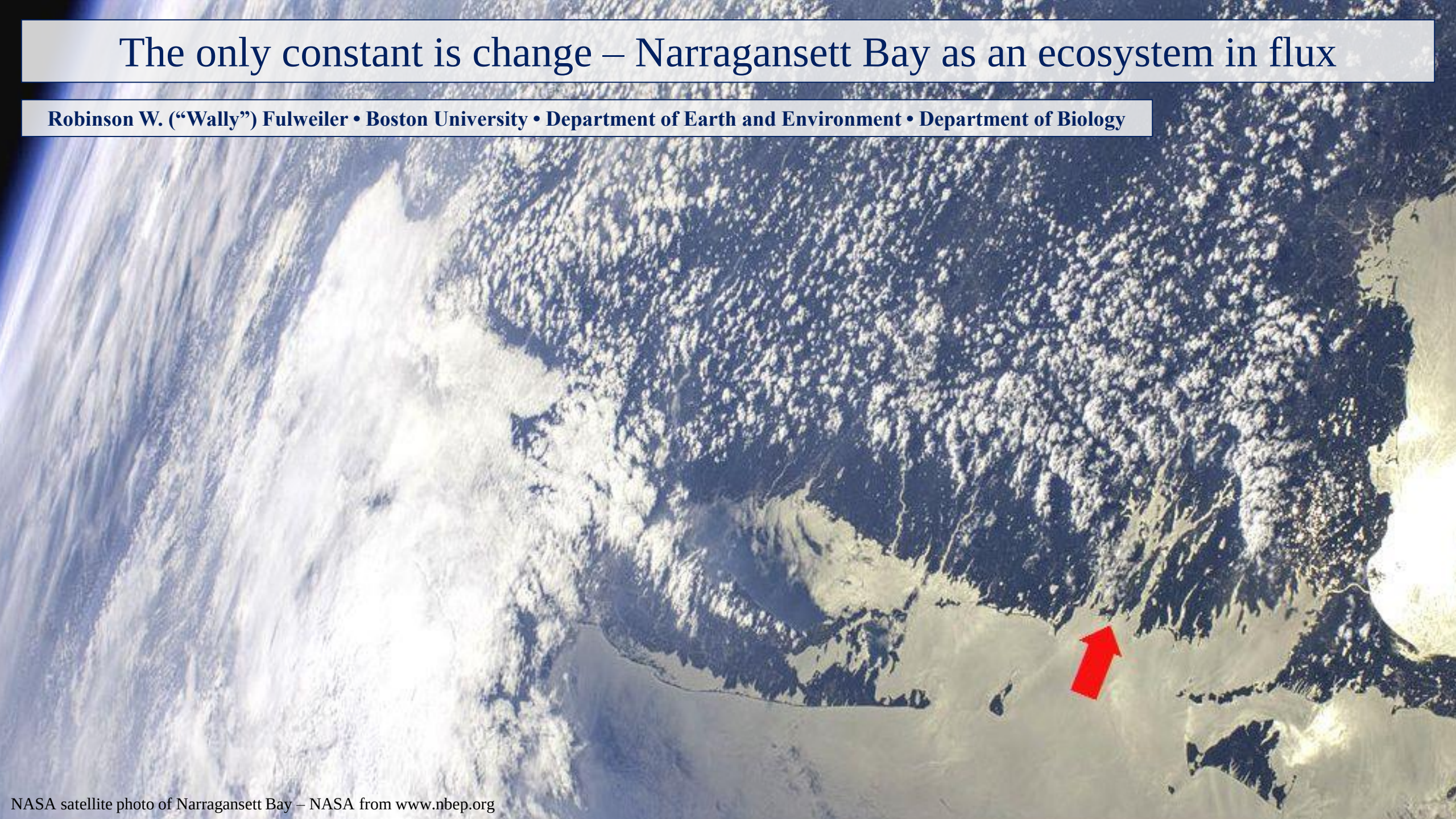
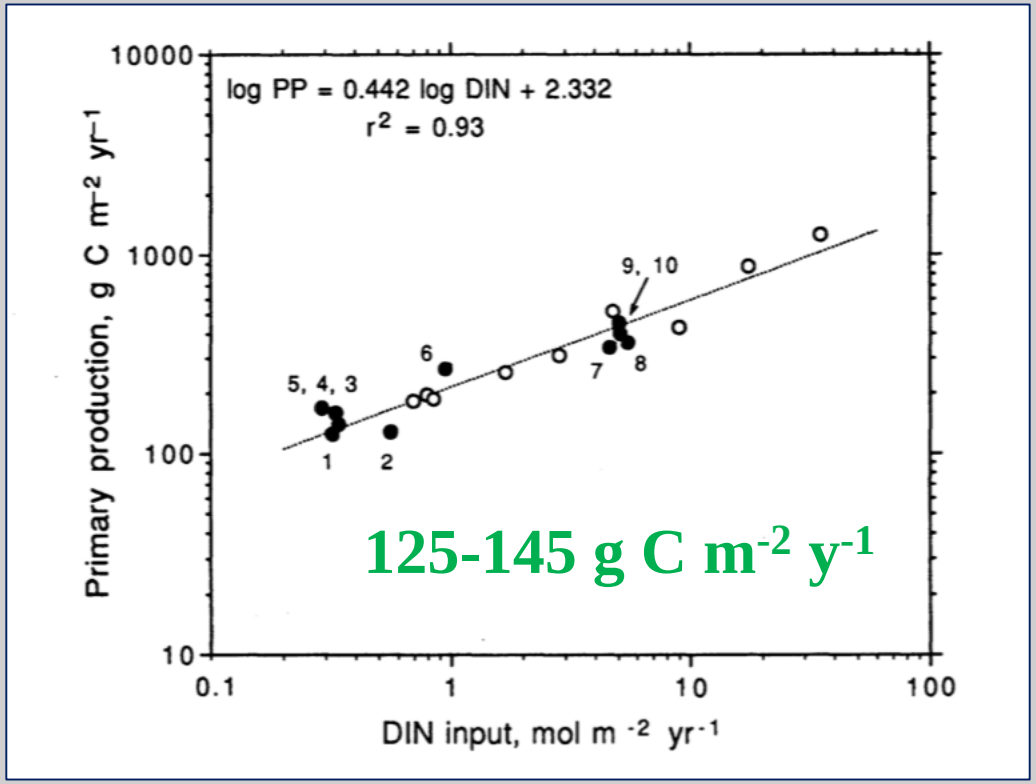
The only constant is change – Narragansett Bay as an ecosystem in flux

Robinson W. (“Wally”) Fulweiler • Boston University • Department of Earth and Environment • Department of Biology



NASA satellite photo of Narragansett Bay – NASA from www.nbep.org

Narragansett Bay Nitrogen Budget: ~ post European Contact

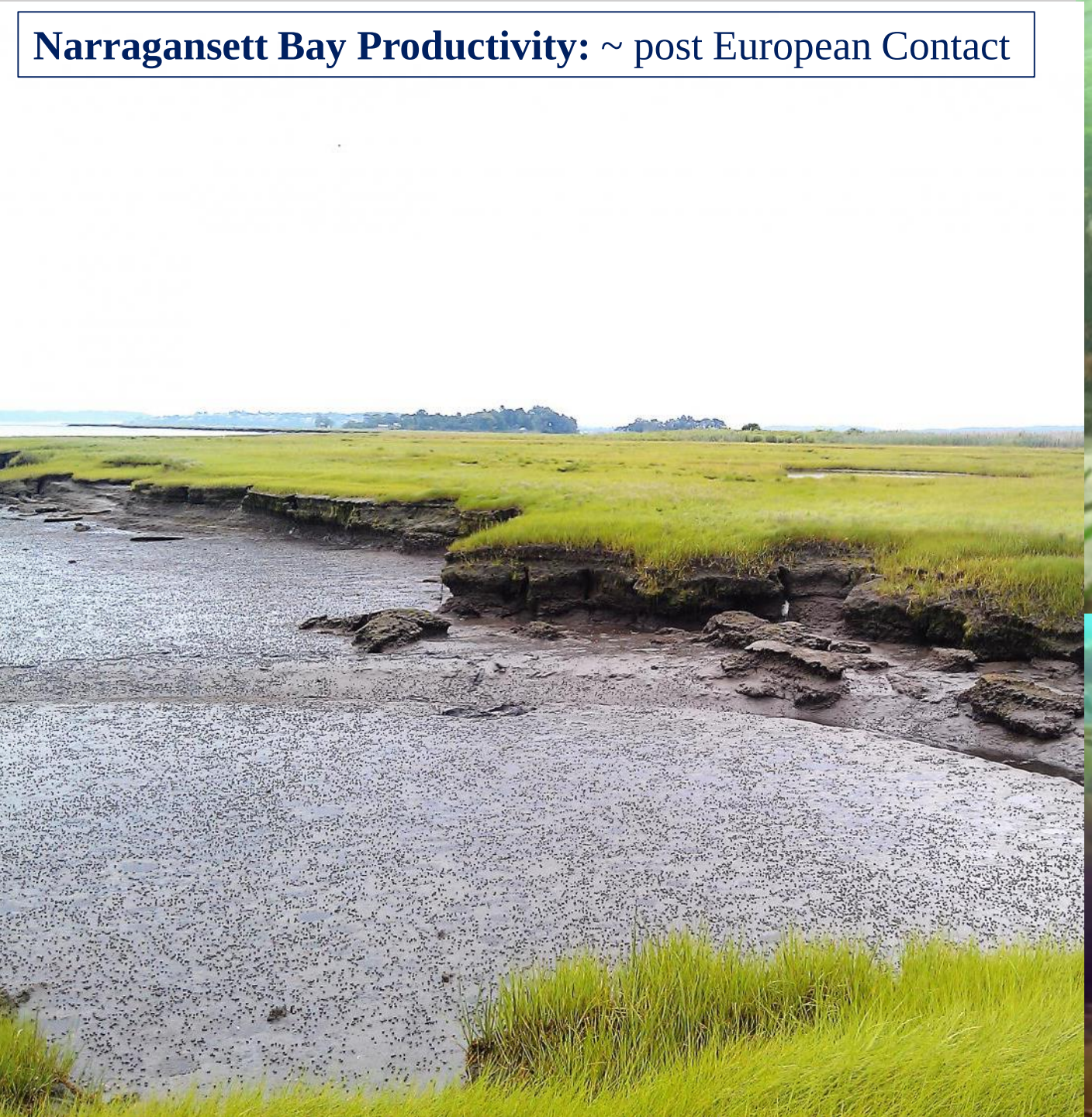


Nixon (1997), Nixon et al. (2008)

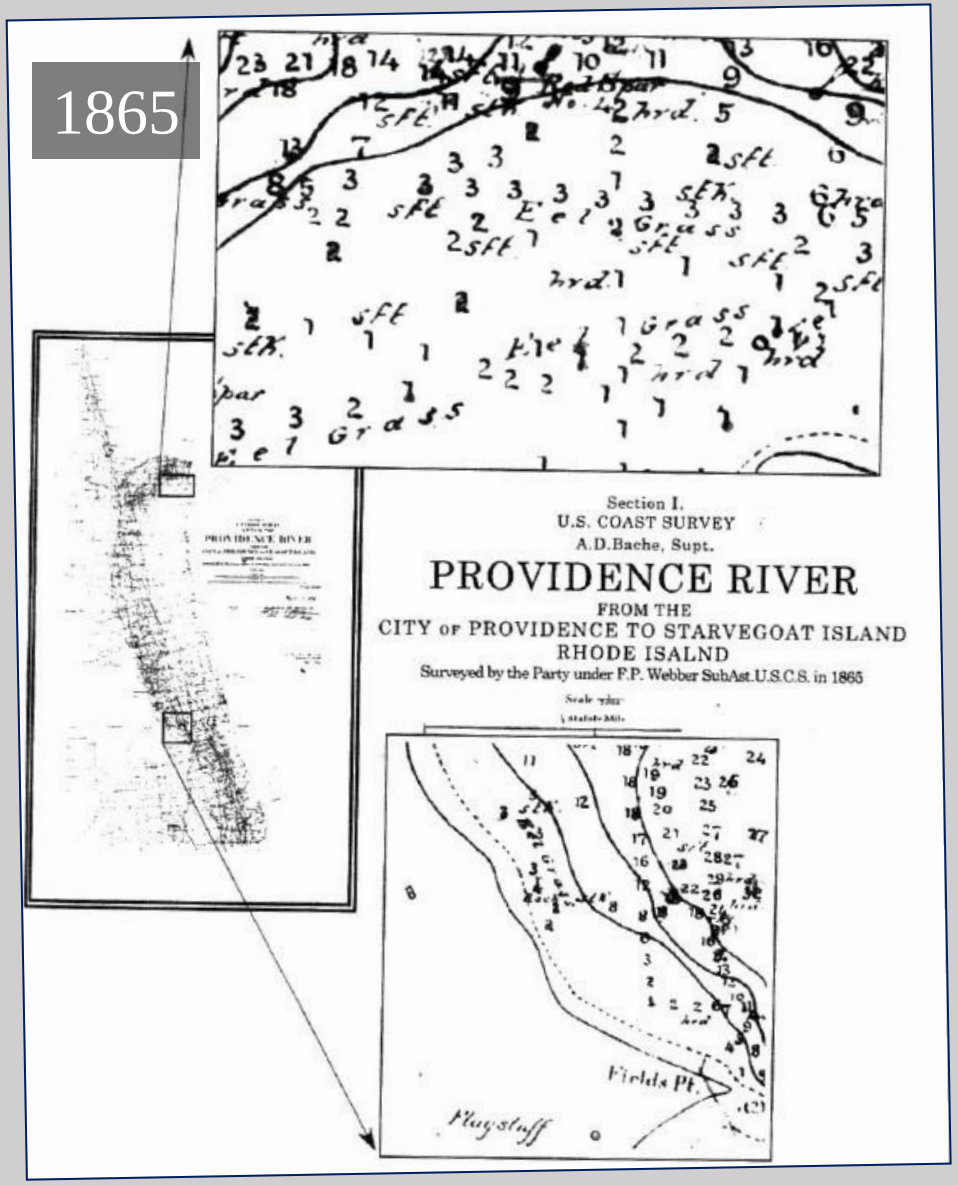
Lobsters be in plenty in most places, very large ones, some being twenty pound in weight . . . . their plenty makes them little esteemed and seldom eaten. The Indians get many of them every day for to bait their hooks withal and to eat when they can get no bass. The oysters be great ones in form of a shoehorn; some be a foot long . . . . This fish without the shell is so big that it must admit of a division before you can well get it into your mouth. Muscles be in great plenty, left only for the hogs . . . . Clams or clamps is a shellfish not much unlike a cockle . . . . When the tide ebbs and flows, a man running over these clam banks will presently be made all wet by their spouting of water . . . . These fishes be in great plenty in most places of the country, which is a great commodity for the feeding of swine both in winter and summer. In some places of the country there be clams as big as a penny white loaf, which are great dainties amongst the natives and would be in good esteem amongst the English were it not for better fish.

William Wood (1635)

Narragansett Bay Productivity: ~ post European Contact



Narragansett Bay Nitrogen Loading: Long term fertilization



1901 → *"…the beaches within a quarter of a mile of the sewer outfall are usually covered with foul-smelling slime and collections of sewage refuse…. Before the Fields Point sewage station was put into operation this shoal was a famous natural oyster bed, but it has been abandoned for a number of years."* (Fuller 1905)

Nixon et al. (2008)

Narragansett Bay Nitrogen Loading: Long term fertilization

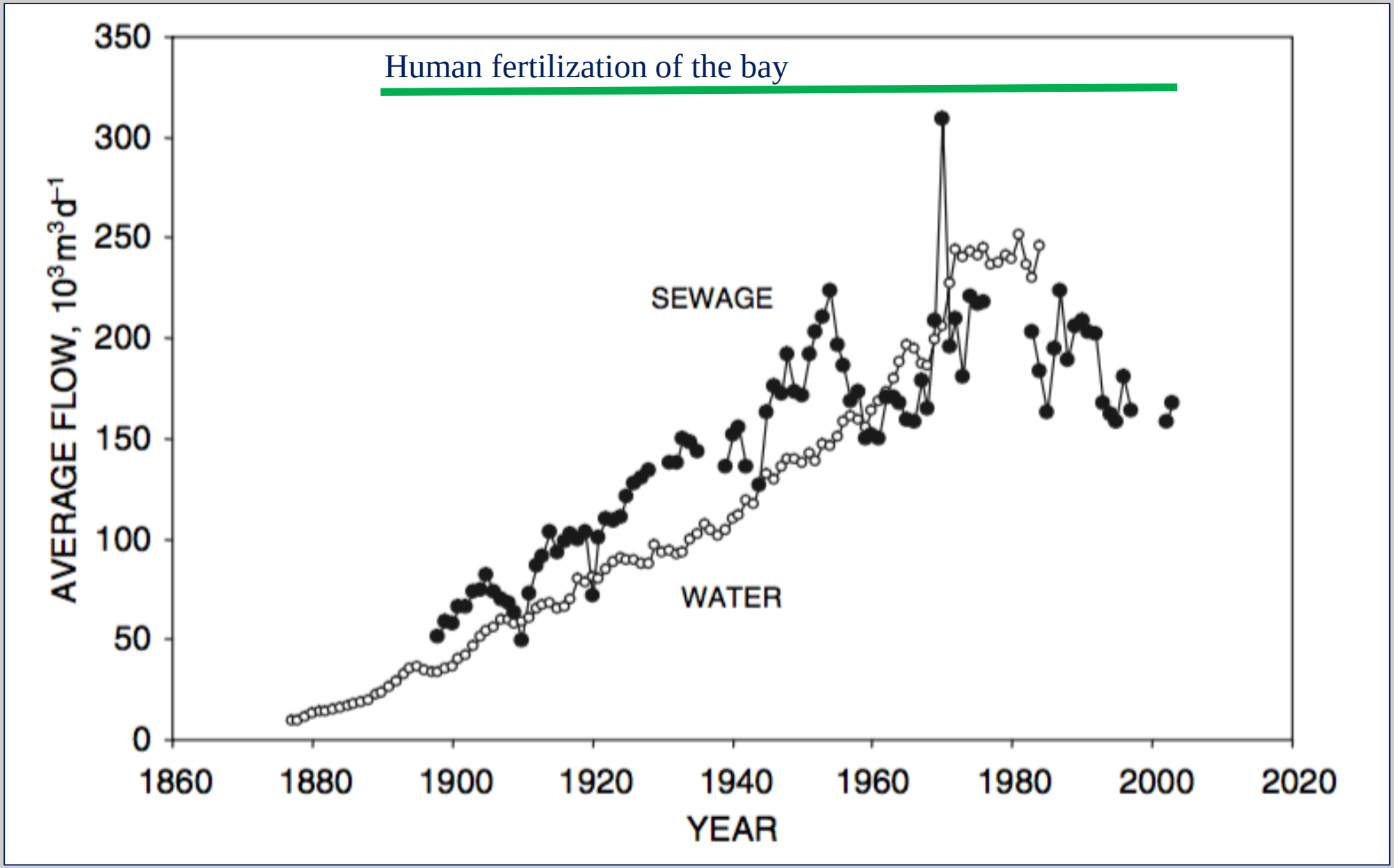
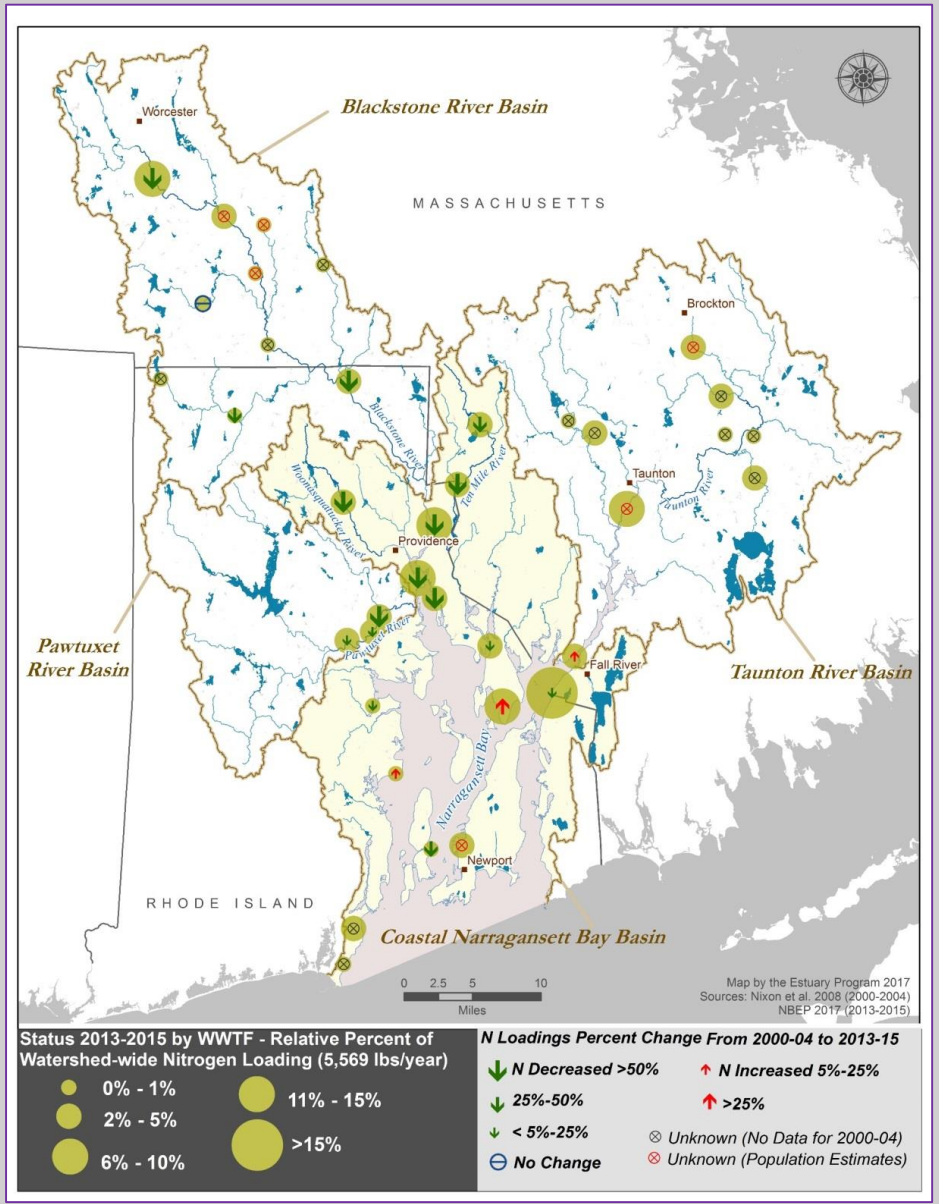


Figure from Nixon et al. (2008)

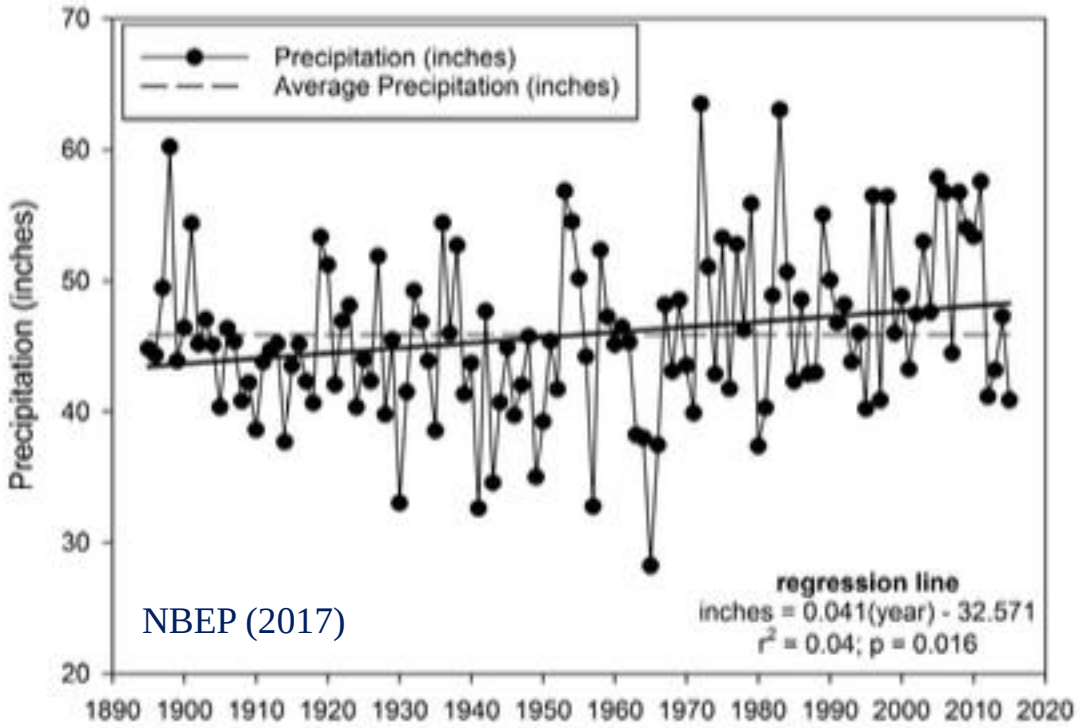
Narragansett Bay Nitrogen Loading: Nitrogen Reductions



NBEP (2017)

- Initial target of 50% N reduction was met in 2012.
- Between 2013 and 2015, additional facilities have upgraded for a total reduction of 62% in sewage N loads from rivers and a 47% reduction in direct WWTF discharges into the bay since 2000.

Climate Change and Narragansett Bay: wetter and stormier



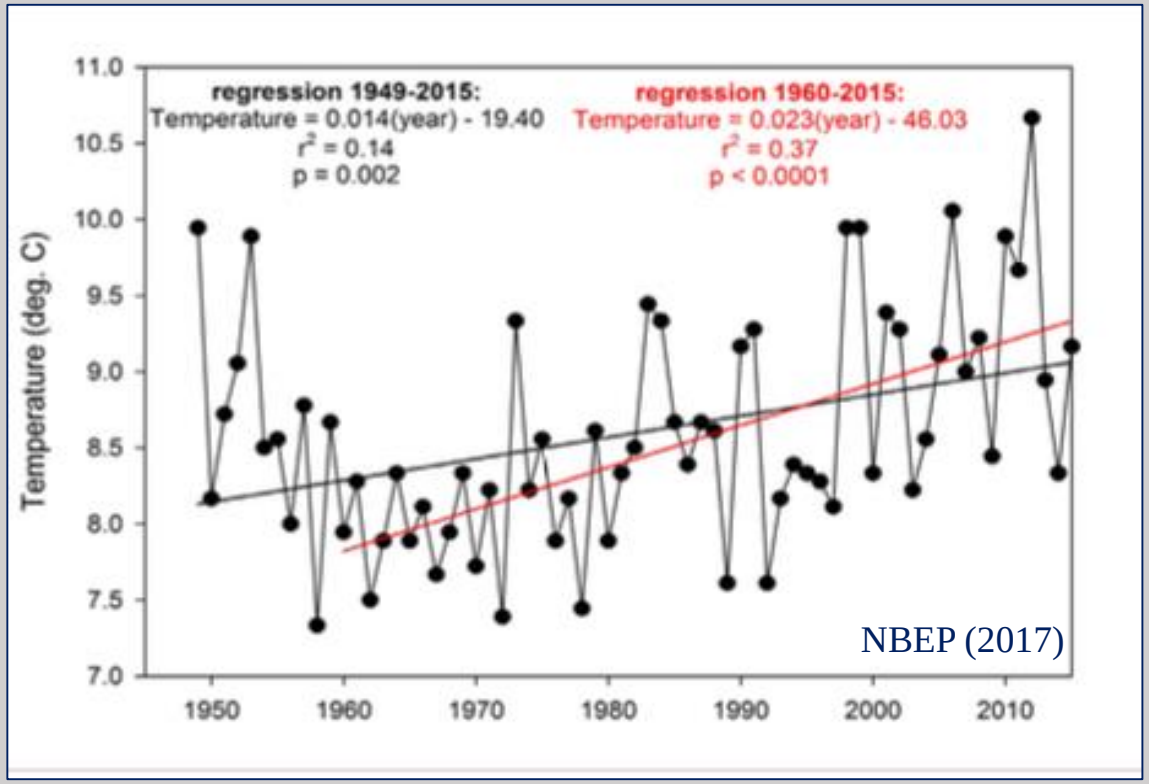
NBEP (2017)

Average annual rainfall has increased 0.4 to 0.7 inches per decade since 1895

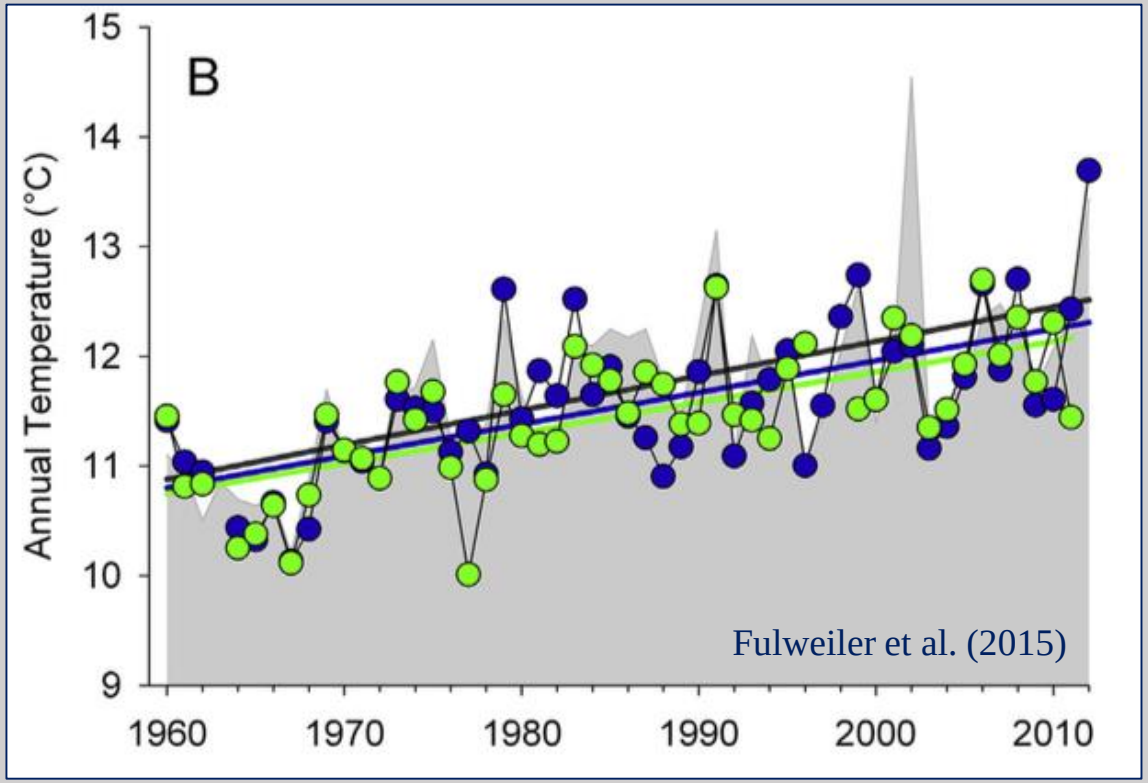
Annual precipitation falling during intense storms has increased 71% since 1965

Climate Change and Narragansett Bay: warmer

Total **air** temperature increase across the watershed–
1.3 ˚C to 1.7 ˚C (1960 – 2015)

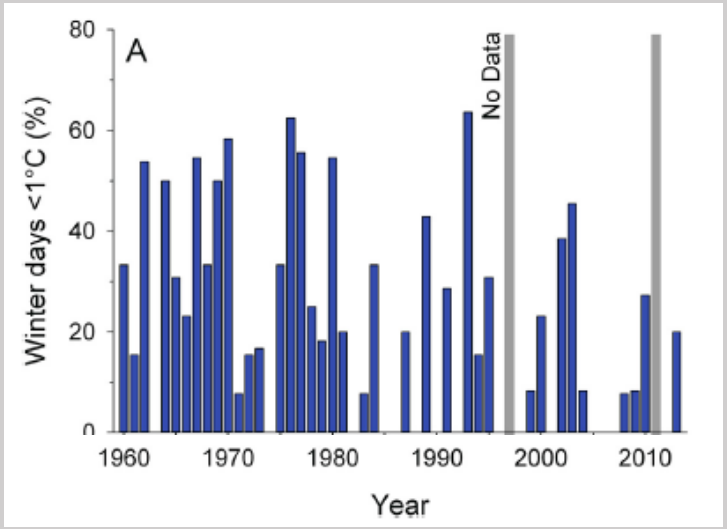


Total **surface water** temperature increase – 1.5 to 1.6 ˚C

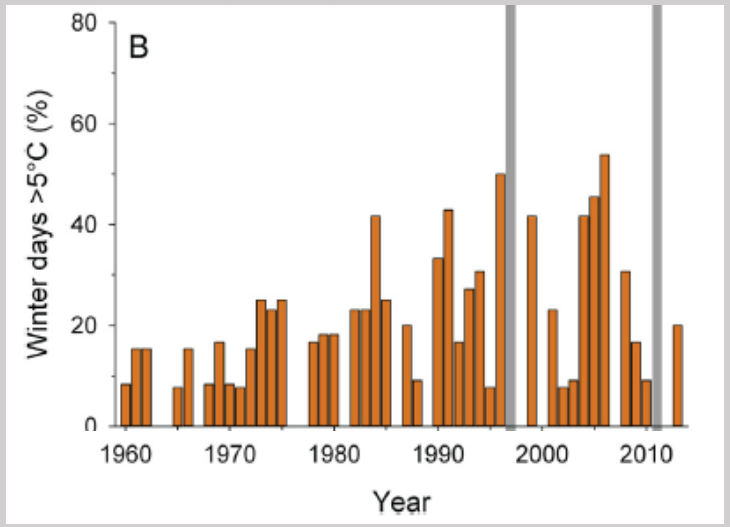


NASA satellite photo of Narragansett Bay – NASA from www.nbep.org

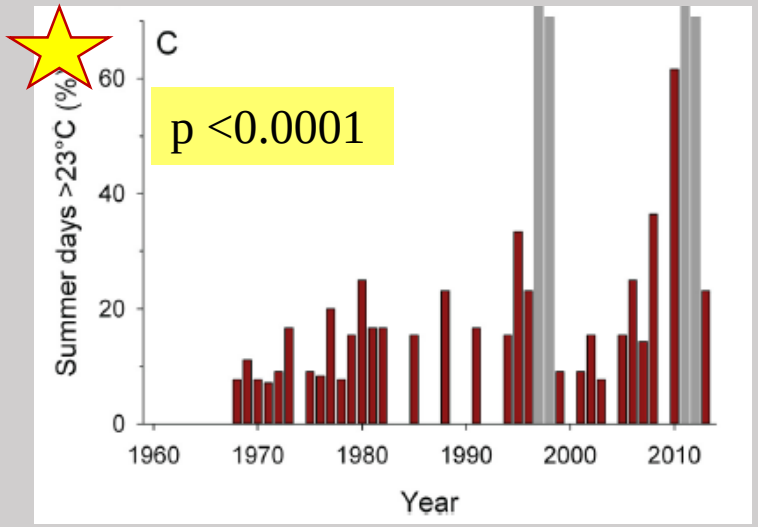
Climate Change and Narragansett Bay: shifting ºC range



Less **winter** days below 1 ºC



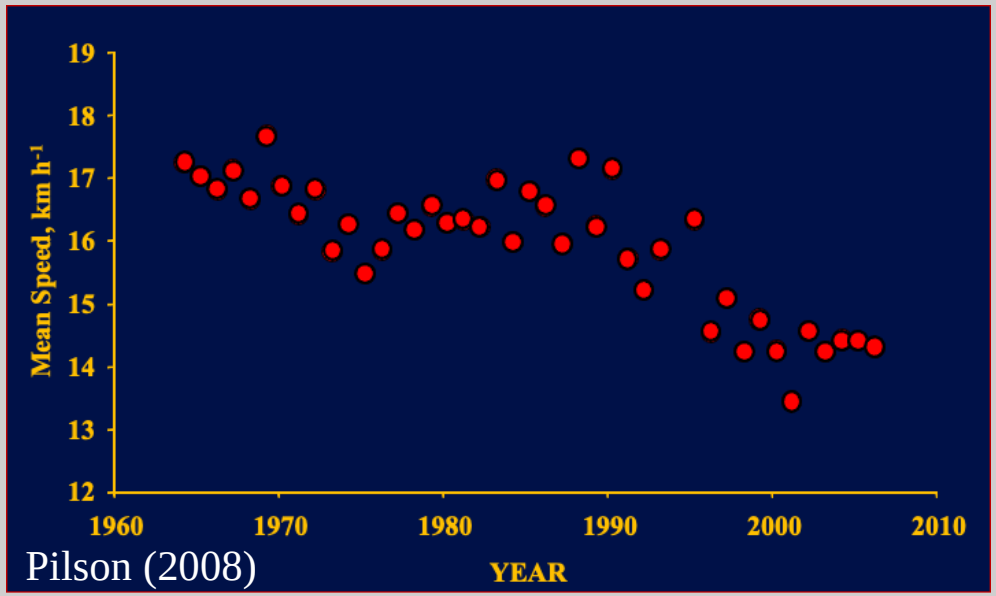
More **winter** days above 5 ºC



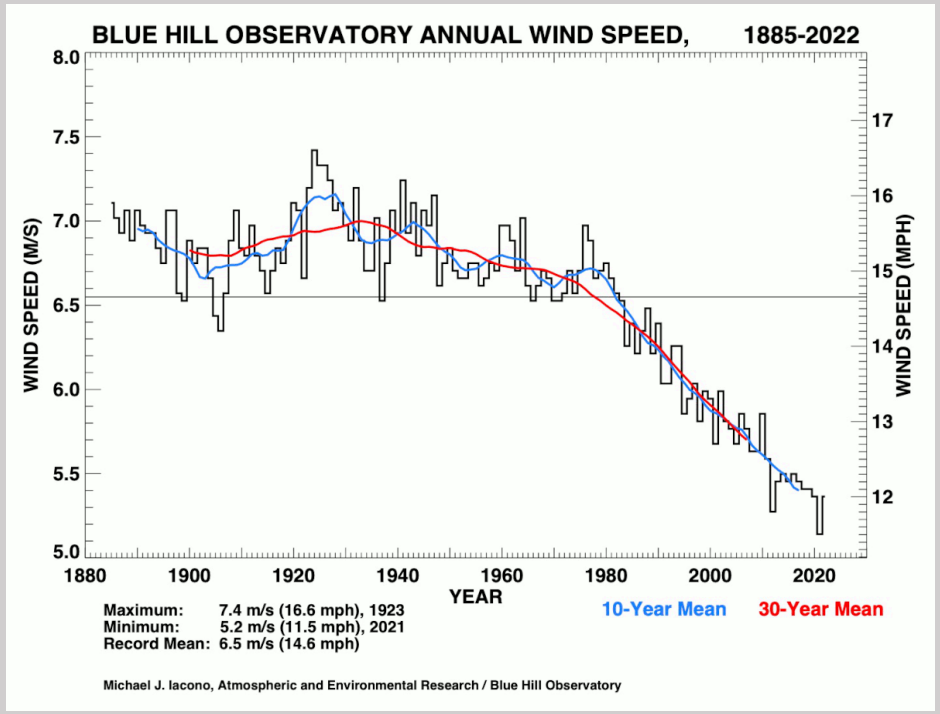
More **summer** days above 23 ºC

Fulweiler et al. (2015)

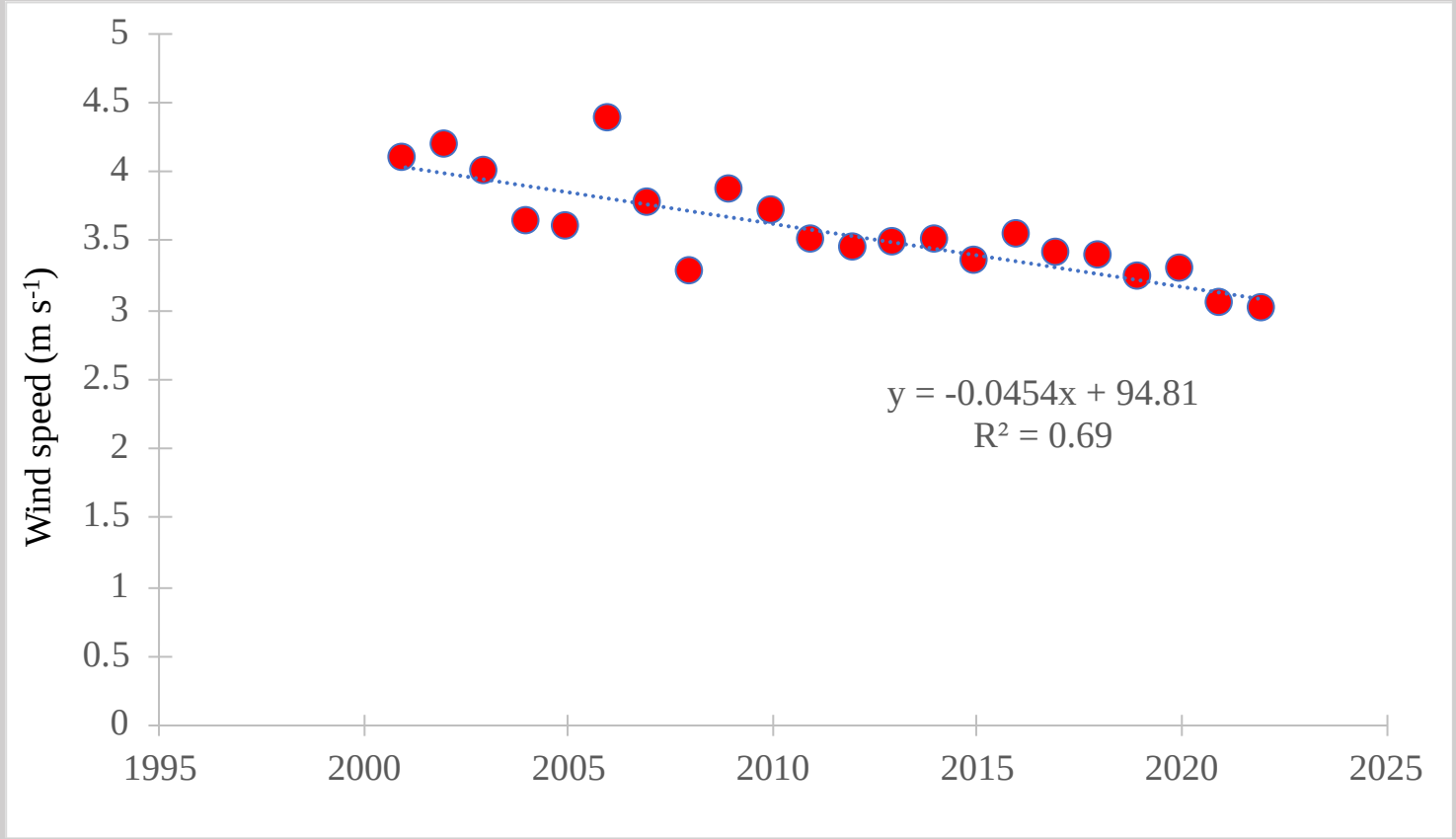
Climate Change and Narragansett Bay: Declining Wind



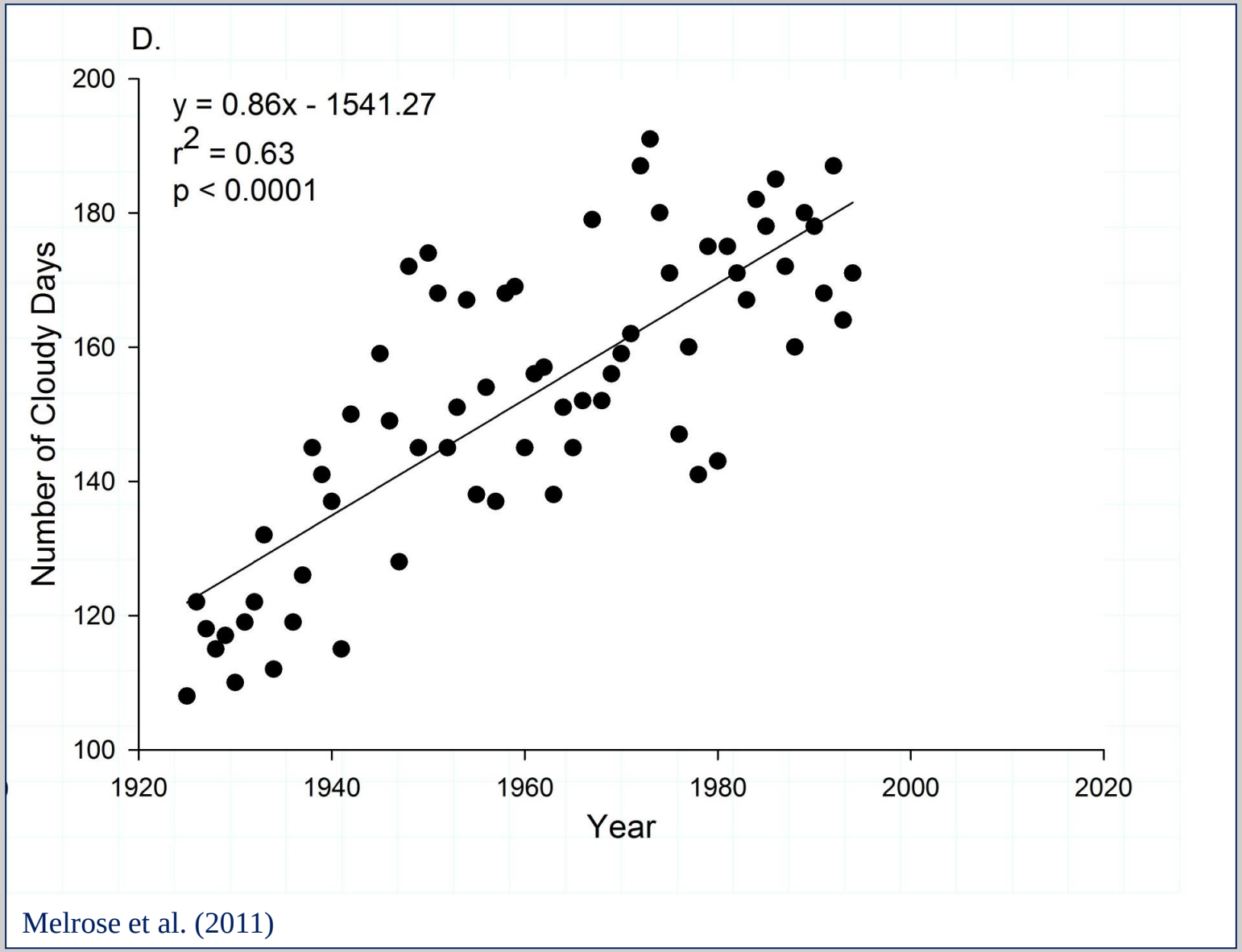
Pilson (2008)



Wind speed from Narragansett Bay NERR



Climate Change and Narragansett Bay: more cloudy days



Melrose et al. (2011)

NASA satellite photo of Narragansett Bay – NASA from www.nbep.org

Long-term Changes in outside forcings on Narragansett Bay: the one constant has been change

Increases in precipitation

Increases in air & water temperature

Increases in cloudy days

Decreases in wind speed

Shifting North Atlantic Oscillation

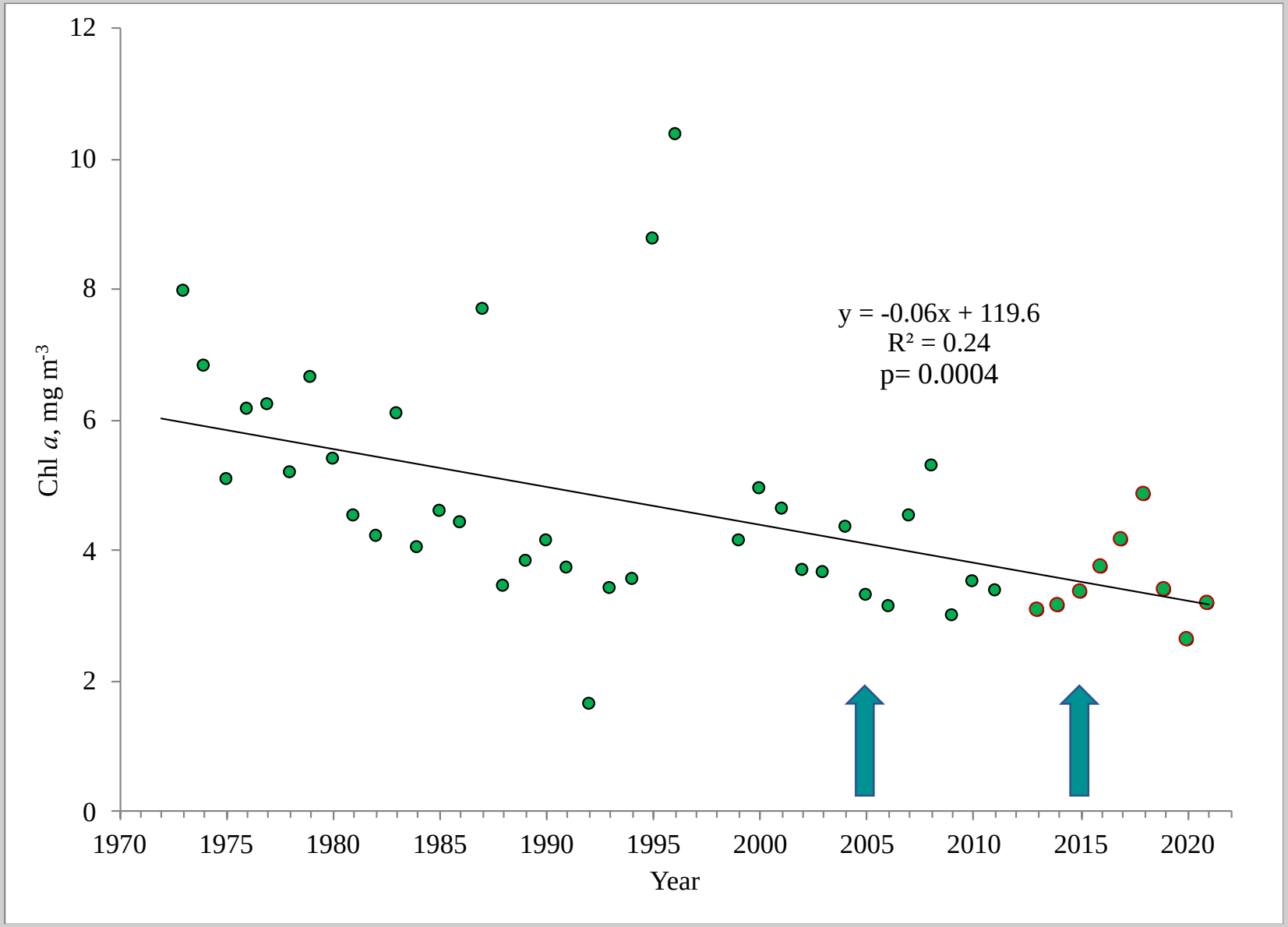
Decreases in Phosphorus Inputs from land

Decreases in Nitrogen Inputs from land

What does it mean for the ecology and biogeochemistry of Narragansett Bay?

NASA satellite photo of Narragansett Bay – NASA from www.nbep.org

Ecological Changes in Narragansett Bay: mid-Bay Annual Water Column Chlorophyll *a*



Li and Smayda (1998), data from: Smayda, T., Candace Oviatt, and Tatiana Rynearson via https://web.uri.edu/plankton/ (back corrected for method change)

Ecological Changes in Narragansett Bay: mid-Bay Maximum Water Column Chlorophyll *a* (1968-2019)

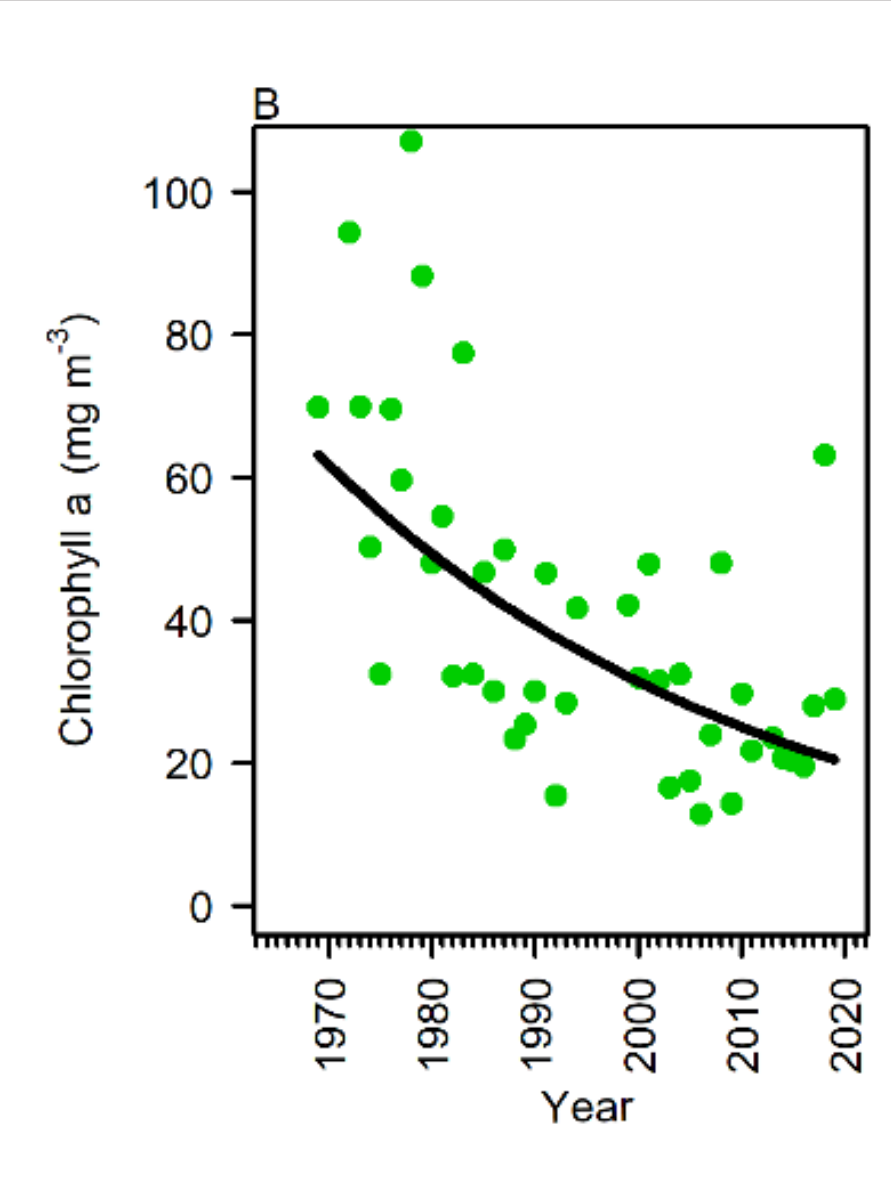
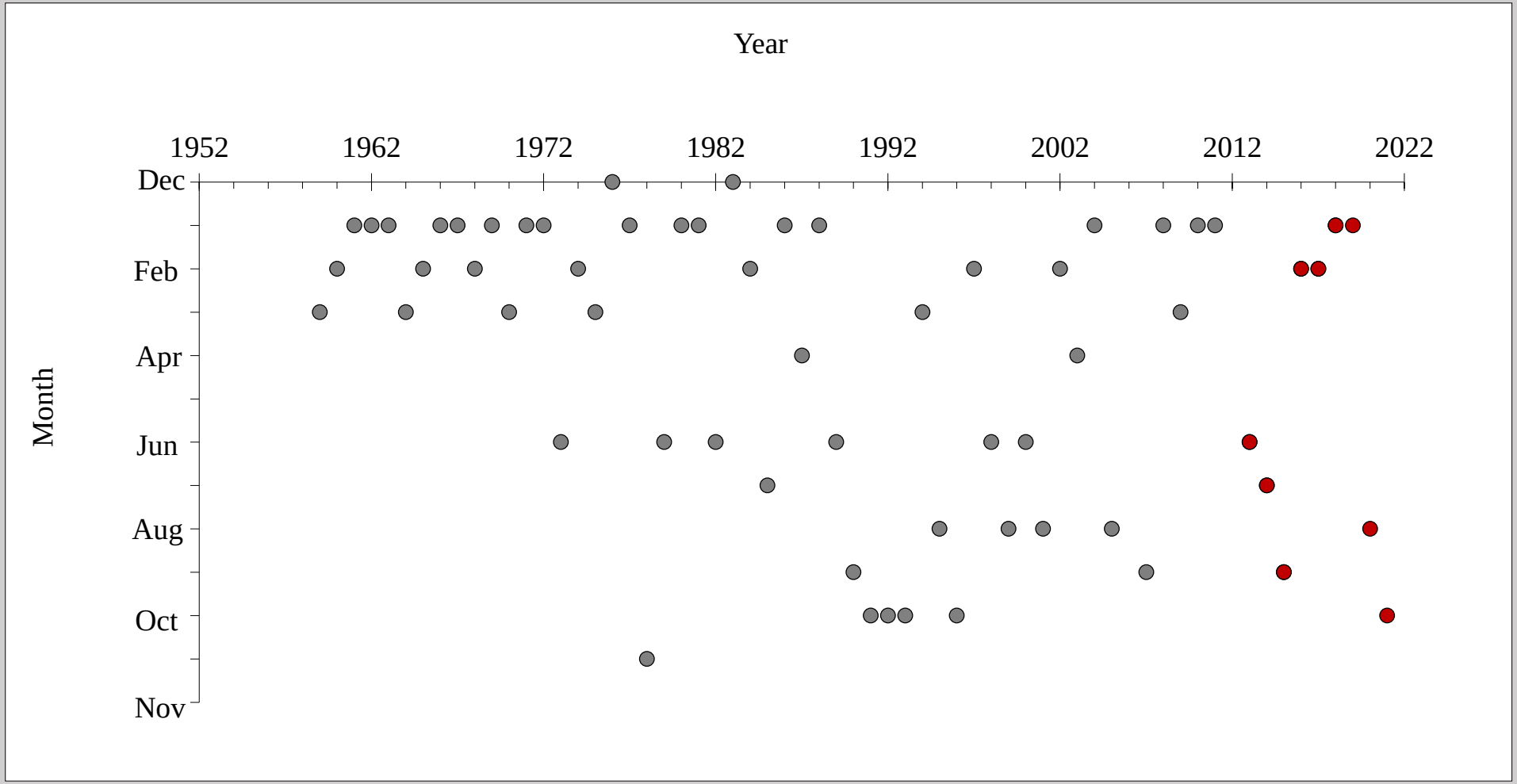


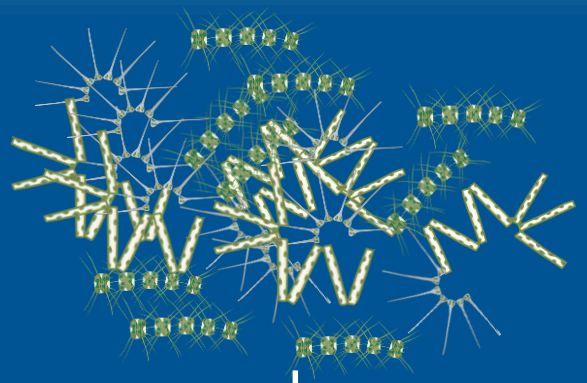
Figure from Thibodeau et al. *In Review*

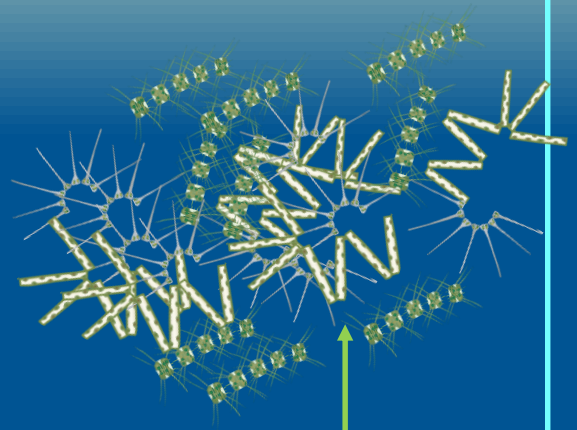
Ecological Changes in Narragansett Bay: mid-Bay maximum bloom timing



Updated from Nixon et al. (2009), data from: Li and Smayda (1998), data from: Smayda, T., Candace Oviatt, and Tatiana Rynearson via https://web.uri.edu/plankton/

Benthic-pelagic coupling – the relationship between the water column and the sediments





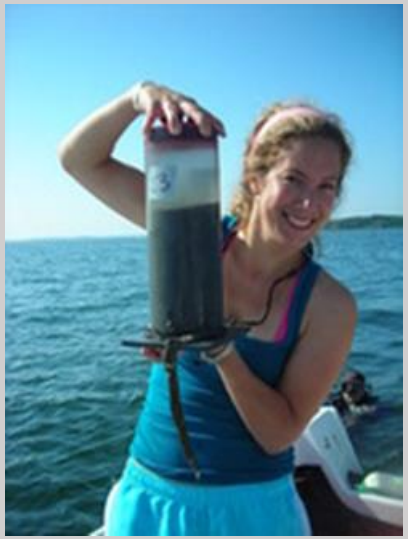
N_2

Decomposition (Reactive N **recycling**): Organic Matter + O_2 → DIN (& other nutrients)

N_2-fixation (Reactive N **addition**): N_2 → NH_4^+

Denitrification (Reactive N **removal**): Organic Matter + NO_3^- → N_2

Phytoplankton images from ian.umces.edu/imagelibrary/



Special Thanks to the Flux Team: Sarah Foster, Elise Heiss, Hollie Emery, Amanda Vieillard, Nick Ray, Alia Al-Haj, Catherine Mahoney, Melissa Hagy, Tim Maguire, Claudia Mazur, Lydia Jefferson

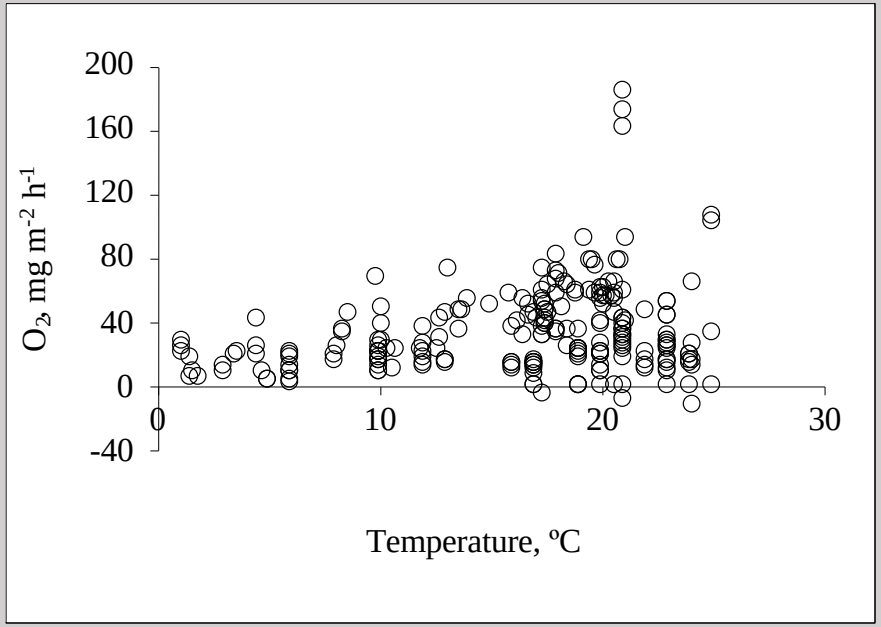
Divers: Anya Hanson, Jason Krumholz, Conor McManus, and many student divers

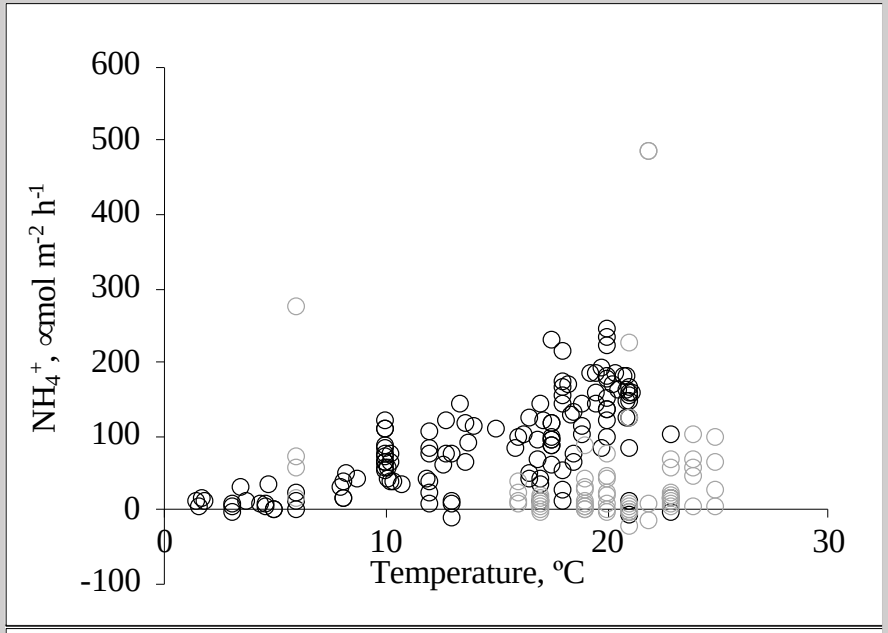
Sediments as barometers of change: fluxes still demonstrate a dampened response to temperature

Grey: 1970s/80s

Purple: 2005-2019

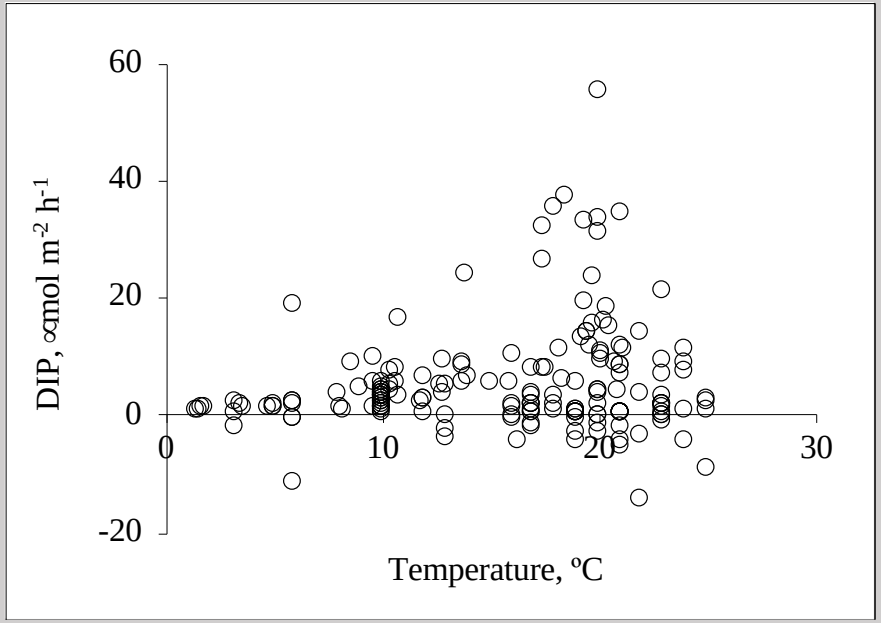
40%

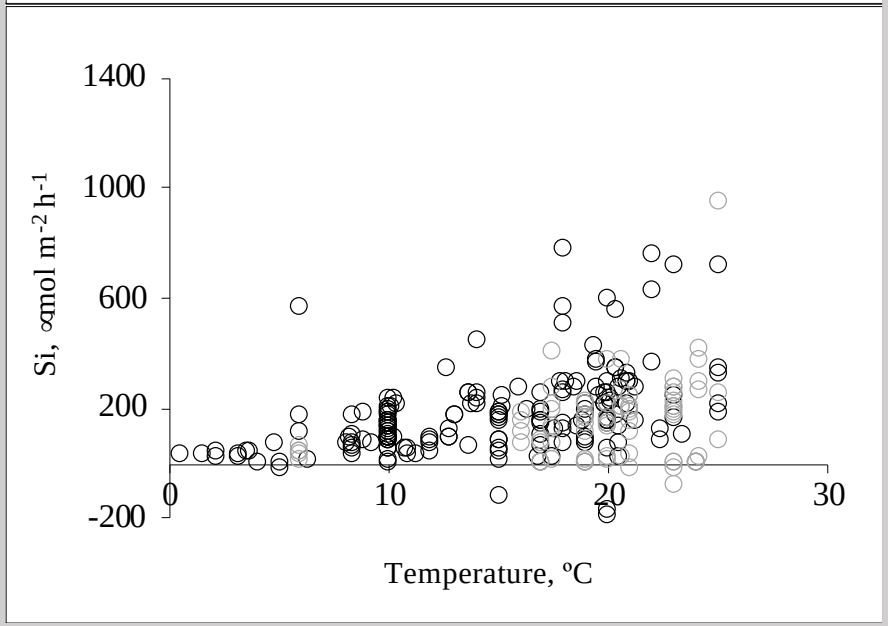




50%

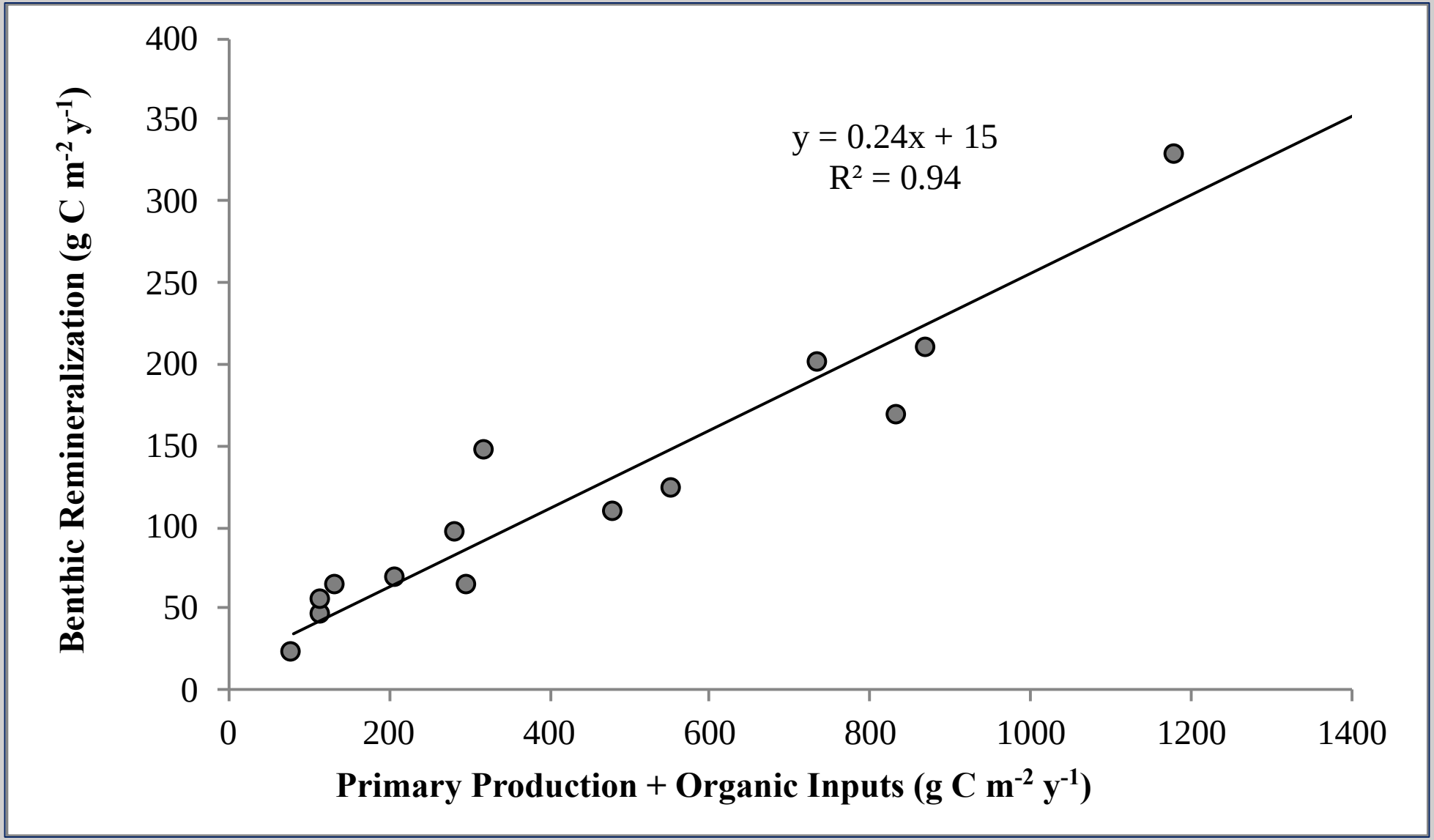
80%



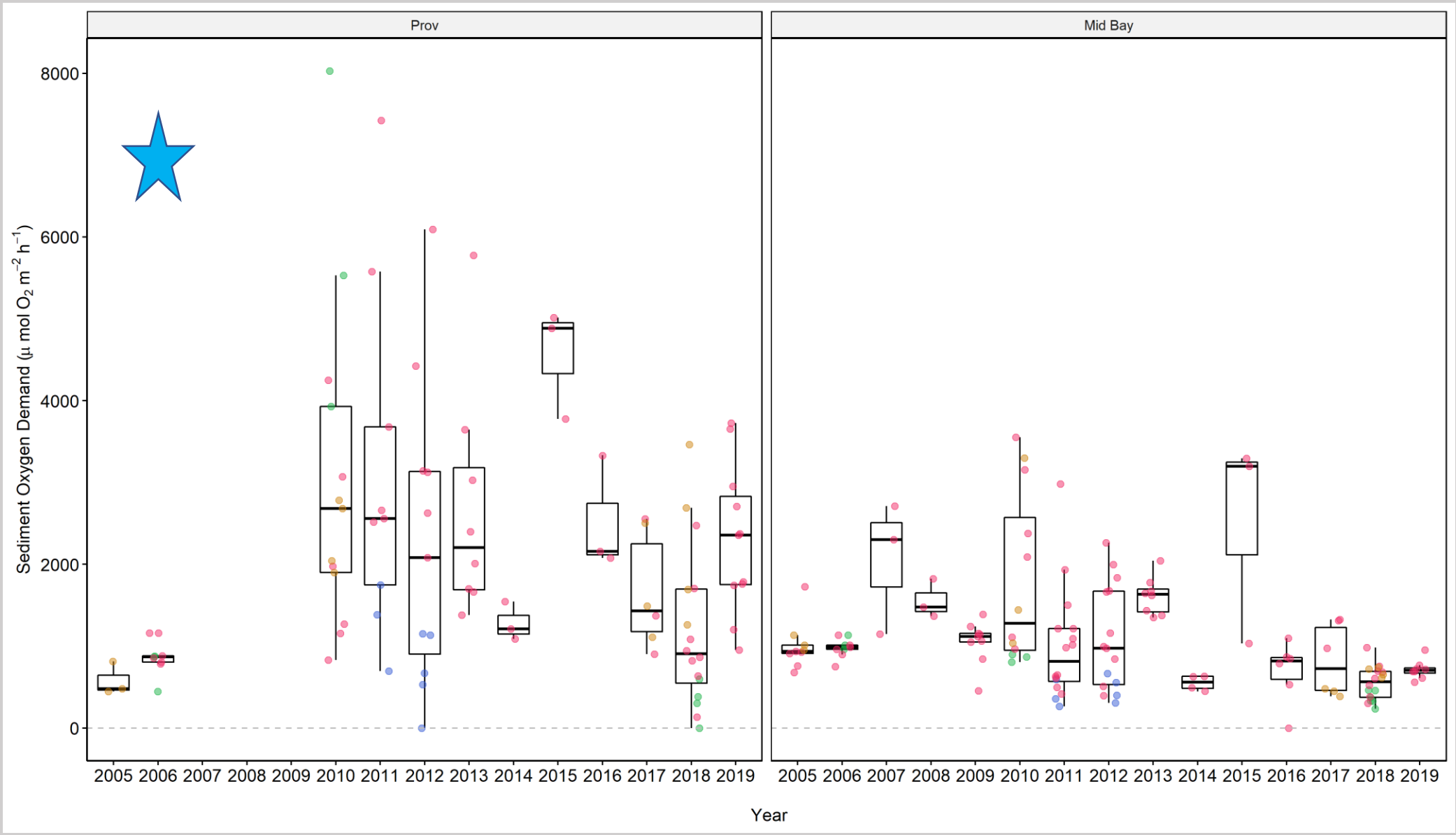


No change

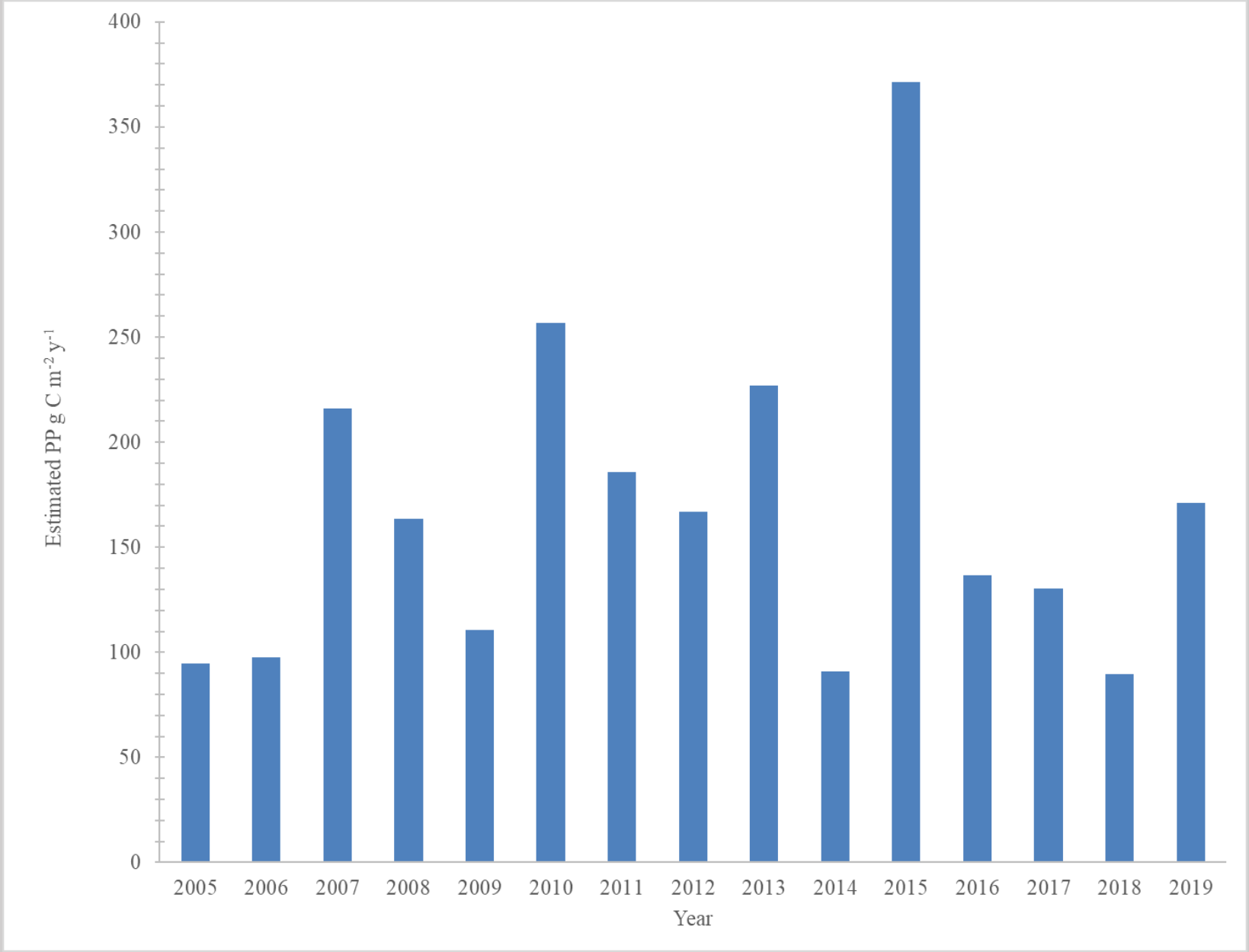
Narragansett Bay Primary Production: An Estimate



Sediment Oxygen Demand – sediment respiration over time



Narragansett Bay Annual Primary Production: An Estimate



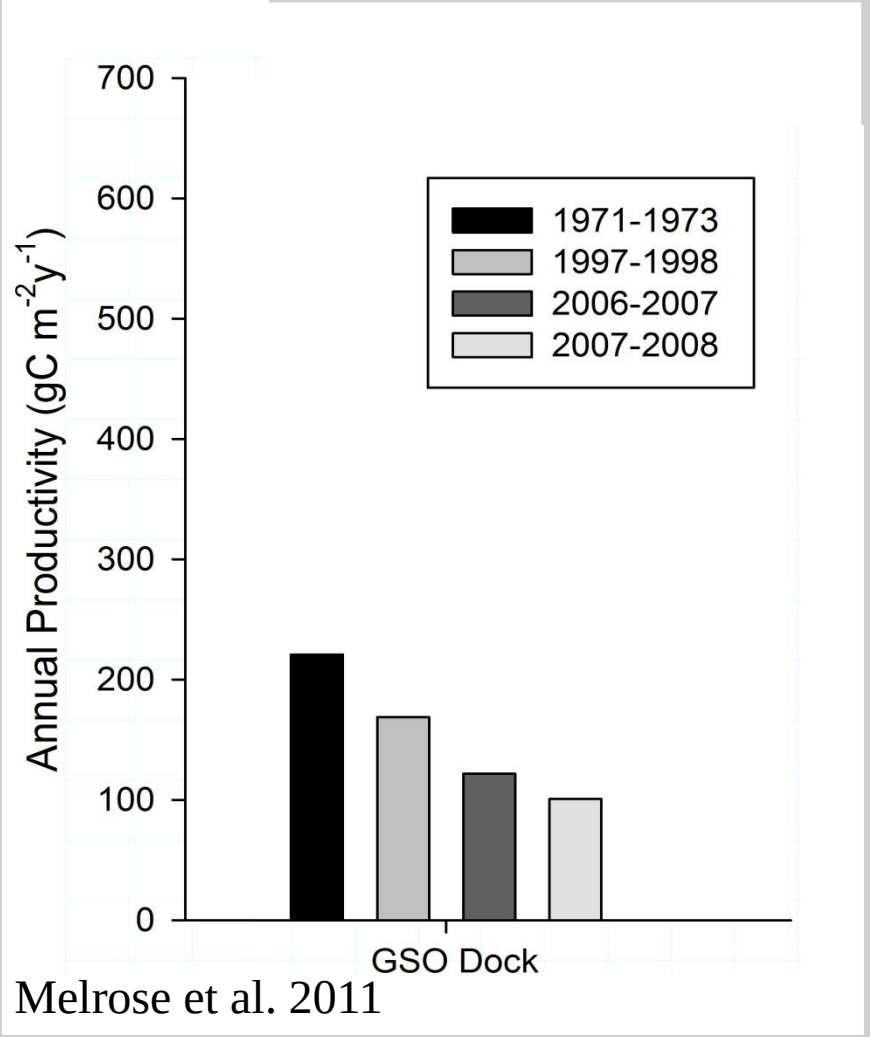
Climate & Nitrogen Management Oligotrophication of mid-Bay

1974: 310 – 370 g C m^{-2} y^{-1} (Furnas et al. 1976, Fulweiler et al. 2007)

***1997-98:** 160 g C m^{-2} y^{-1} (Oviatt et al. 2002)

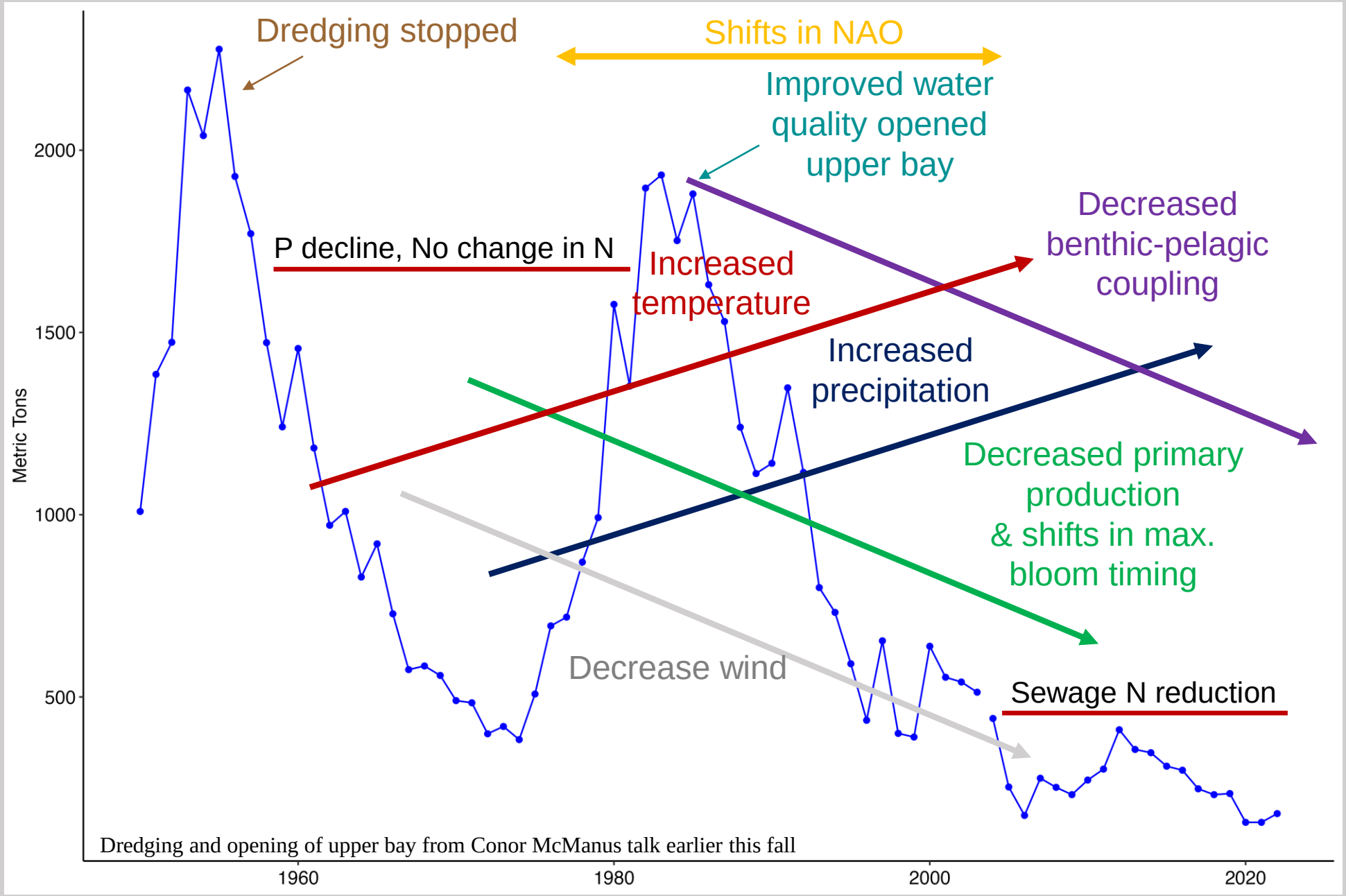
2005-2019: 170 g C m^{-2} y^{-1} (This Talk)

**No winter-spring bloom year*



Melrose et al. 2011

Rhode Island Quahog Landings: *a record reflecting local (e.g., management) & regional/global (e.g., climate) change*



Acknowledgements

Many thanks to all those who study Narragansett Bay – past, present, and future. Thank you to RI Sea Grant, The Coastal Institute, CRMC, and NSF for supporting this work.

My thinking about Narragansett Bay has been enriched by conversations over the years with many colleagues, in particular Candace Oviatt, Chris Kincaid, Mark Brush, Sarah Foster, Anne Giblin, Scott Nixon, Nick Ray, Jane Tucker, Robert Twilley, and Amanda Vieillard.

Thank you to Jason Krumholz, Conor McManus, Anya Hanson, many student divers, and Brian Caccioppoli.

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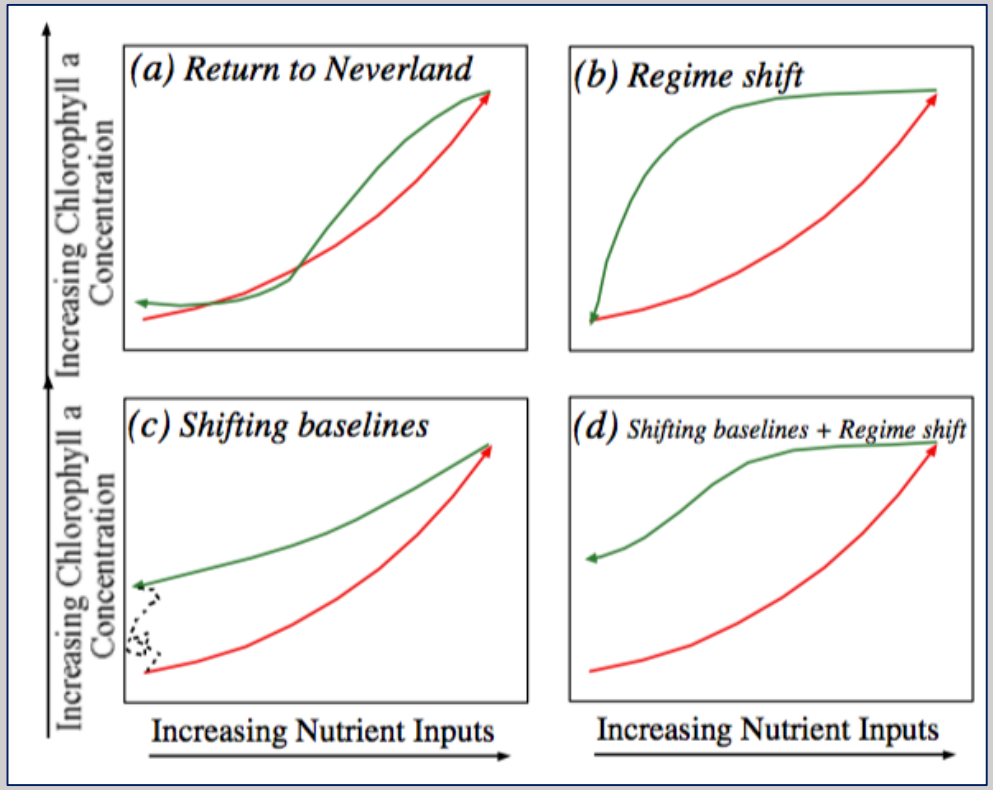
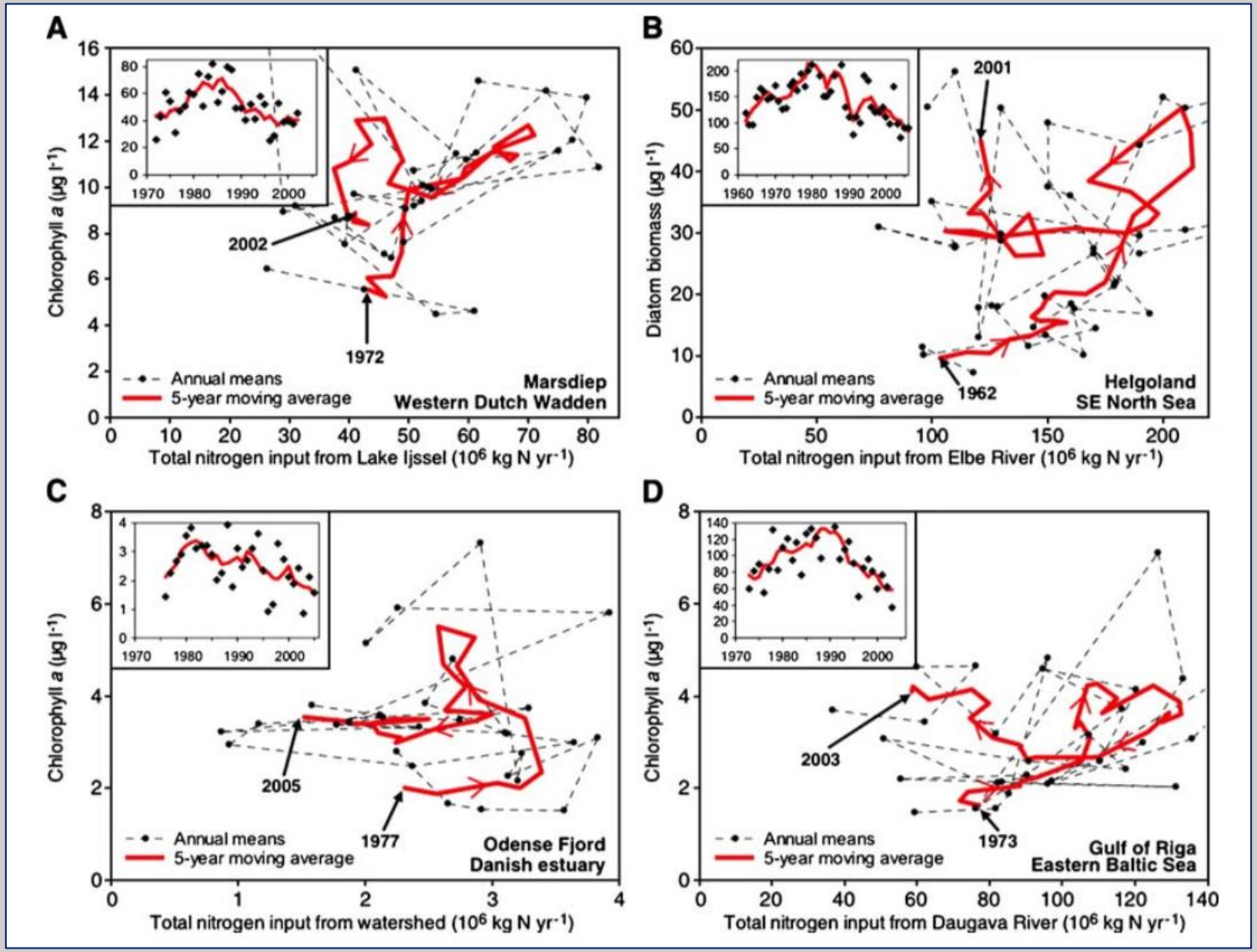
Narragansett Bay: What's next? No "Return to Neverland"





Duarte et al. (2008)