How Narragansett Bay hypoxia is responding to management-imposed nitrogen load reductions

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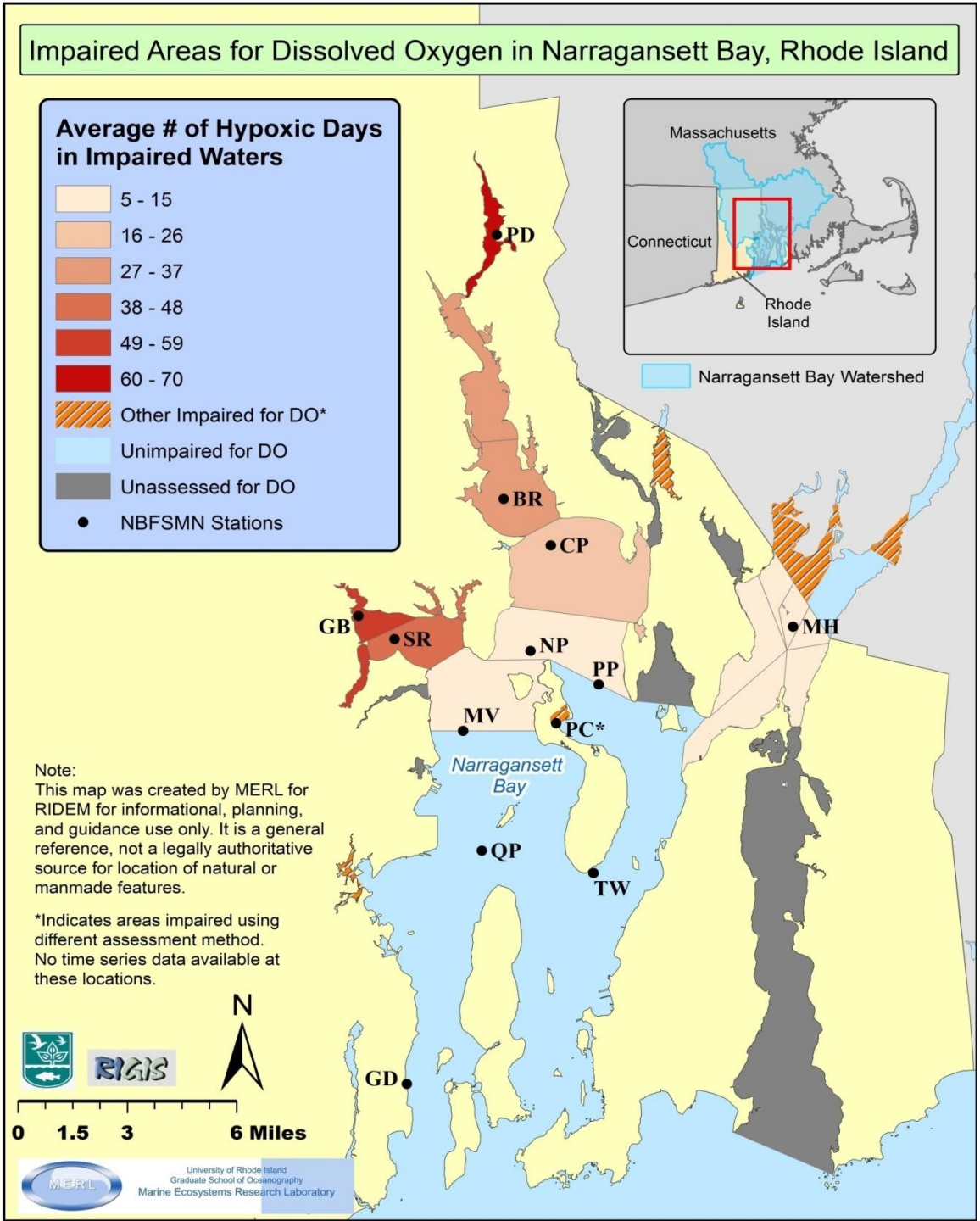


Background

Narragansett Bay is a mid-sized, partially stratified, temperate estuary about 3 to 15 m

North to South gradient in nutrient pollution, primary productivity, chlorophyll levels, and hypoxia

Seasonal intermittent hypoxia events from May to Oct threaten ecological health

Most intense hypoxia: far north (Seekonk River) and west (Greenwich Bay)

Events (< 2.9 mg L^{-1}) last from ~1 day to about ~2 weeks, typically 2-7 days

Typically, 2 to 5 events per season, depending upon location/weather patterns

Data Collection
NBFSMN

YSI EXO V2/6600 EDS

Started 2001

Every 15 min (May-Oct)

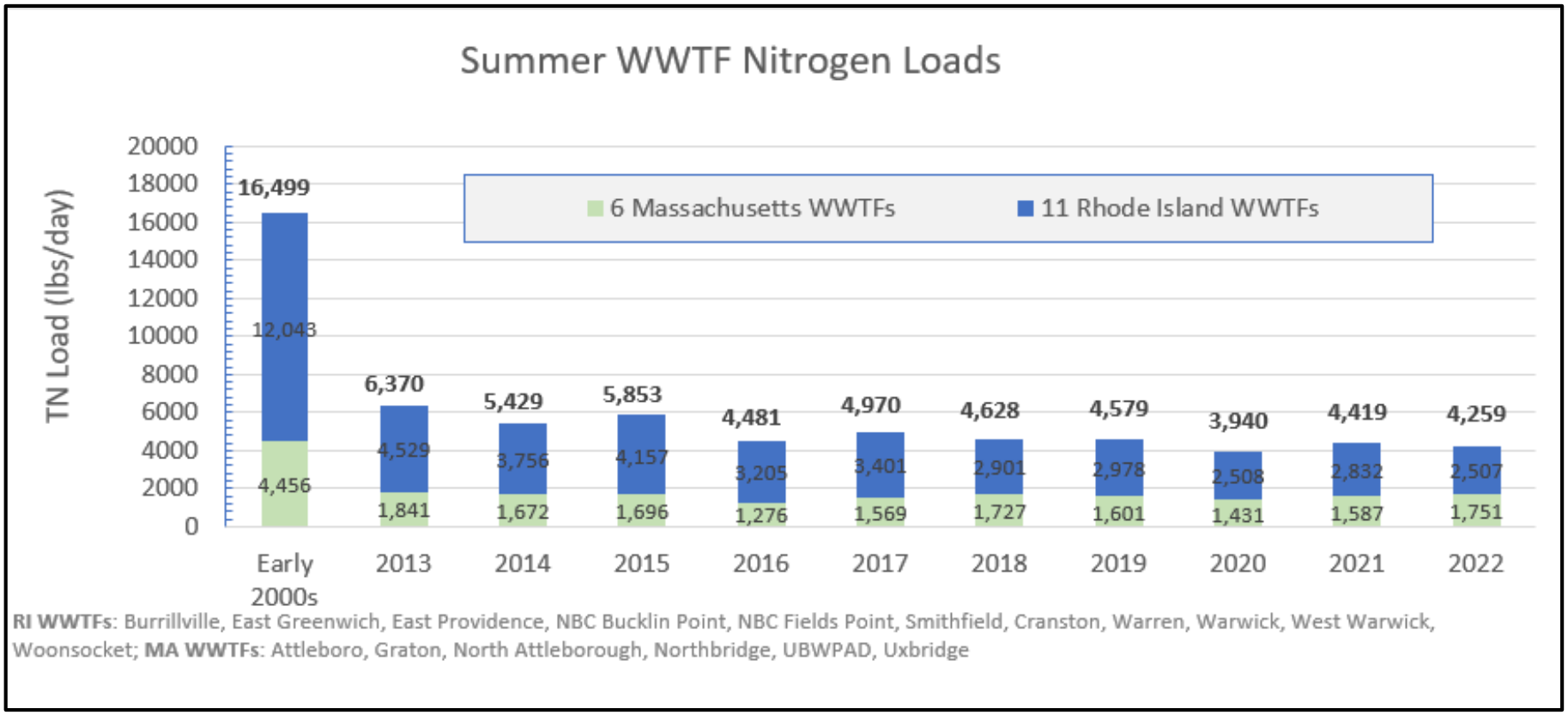
Near Surface (1m)
Near Bottom (.5 m)

14 Stations in Network

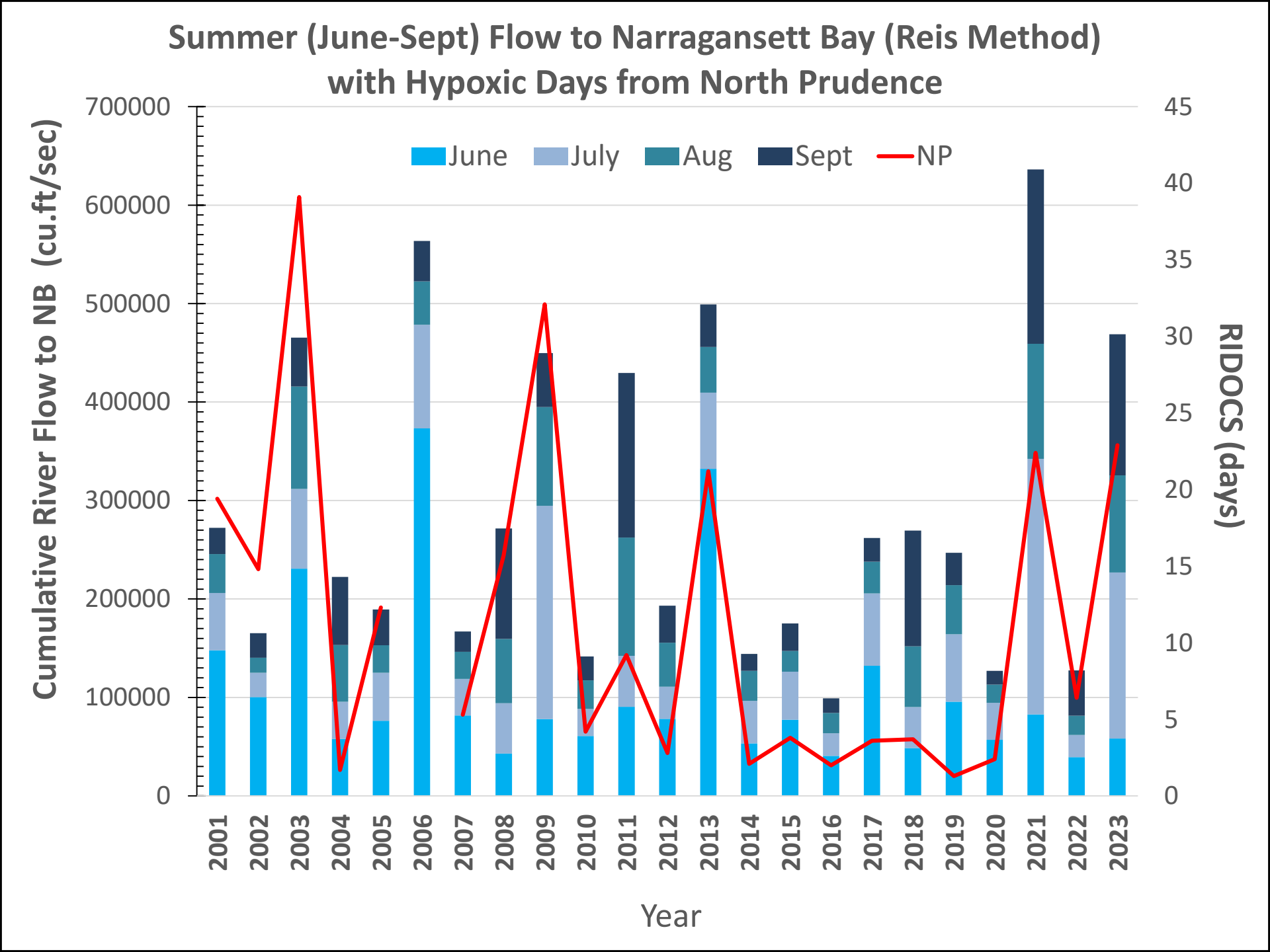
Stations serviced bi-monthly

Temperature
Salinity
Dissolved Oxygen
pH
Chlorophyll
Depth
<u>Grab Samples:</u>
Nutrients & Chlorophyll

Summer Nutrient Loads from Wastewater Treatment Facilities



50% reductions occurred during 2012. However, for the comparison analysis we used 2013 as the post upgrade time since it was the first full year of nitrogen reductions >50%. Graph courtesy of RIDEM (Heidi Travers).

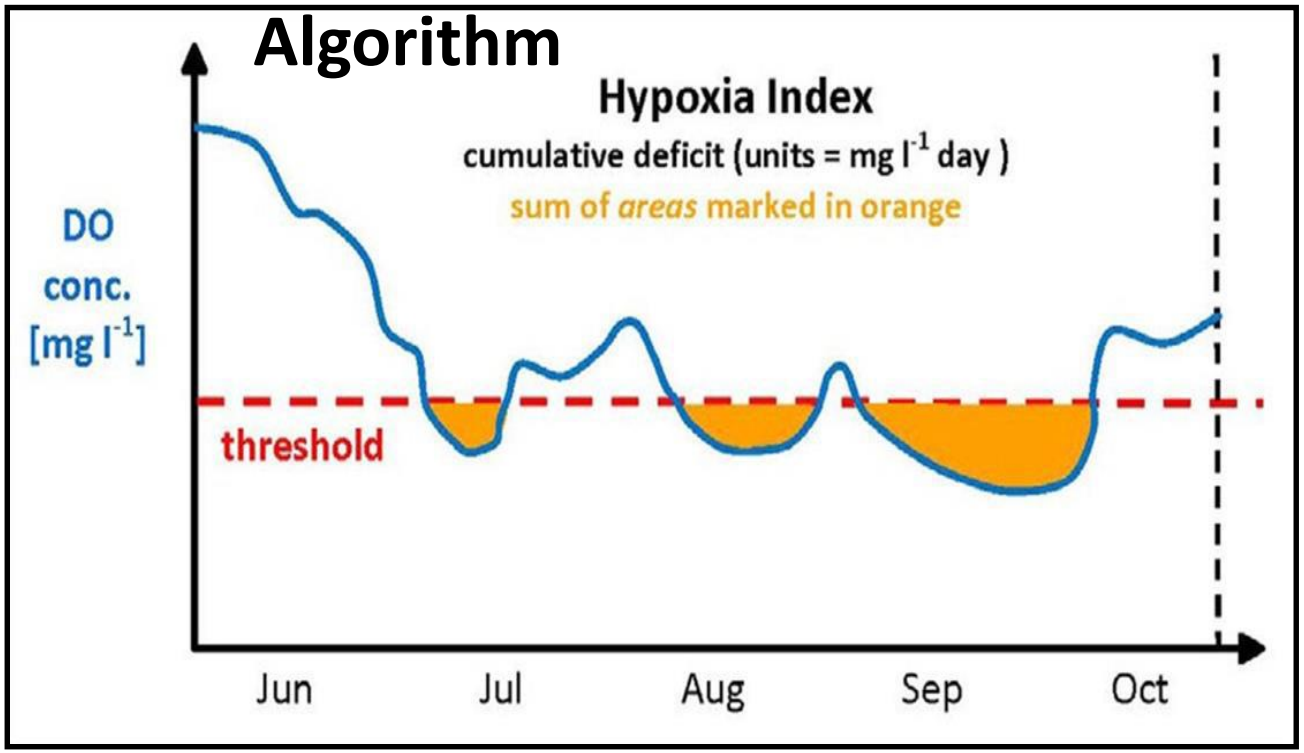

Summer (June-Sept) Flow to Narragansett Bay (Reis Method)
with Hypoxic Days from North Prudence
Cumulative River Flow to NB (cu.ft/sec)
RIDOCS (days)
June
July
Aug
Sept
NP
700000
600000
500000
400000
300000
200000
100000
0
45
40
35
30
25
20
15
10
5
0
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Year

Hypoxia characterized using two metrics

1. State regulatory criteria: Rhode Island Dissolved Oxygen Criteria Software (RIDOCS)

- EPA thresholds, protect larval recruitment
- Identify **days of exceedances** using duration of exposure

2. Hypoxia Index: Moving Window Trigger Algorithm



- Summed areas under curve over multiple events
- Event duration and intensity
- 2 thresholds: 2.9, and 1.4 mg L^{-1}
- Units: mg L^{-1} day

Gray shading: Bathymetry

River inputs

Station groupings for analysis:

Providence River & Upper Bay

Upper West Passage

Upper East Passage

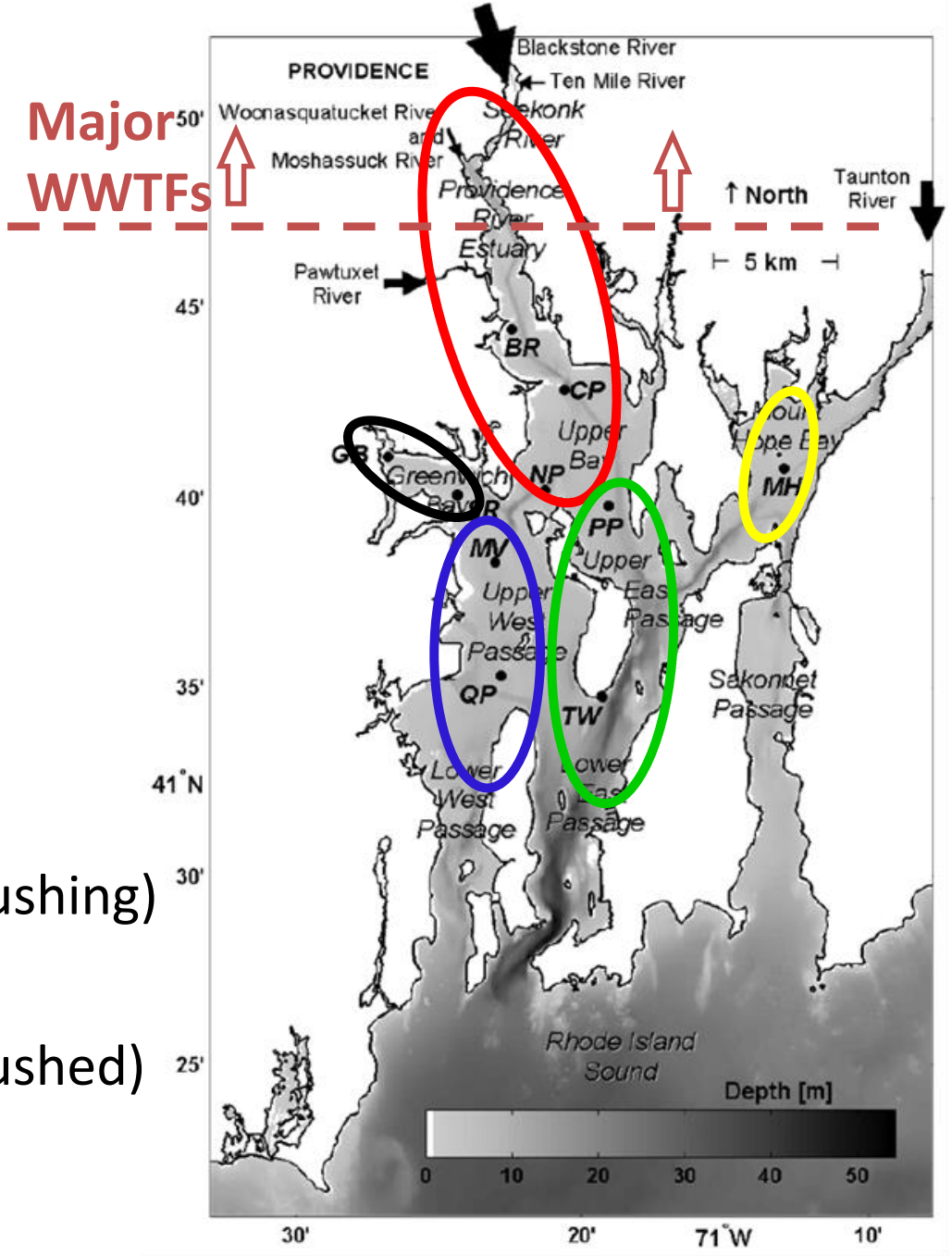
Embayments:

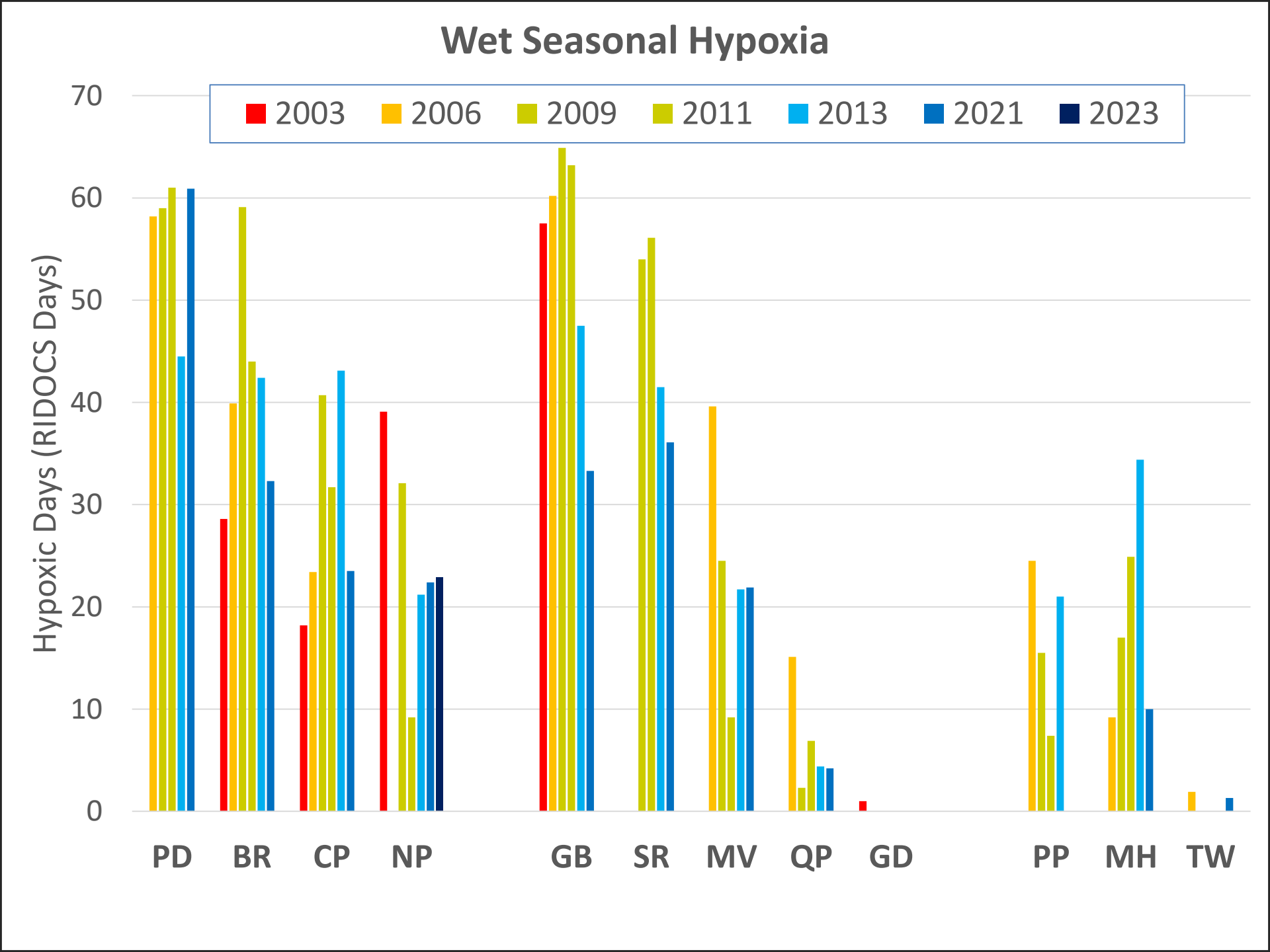
Greenwich Bay

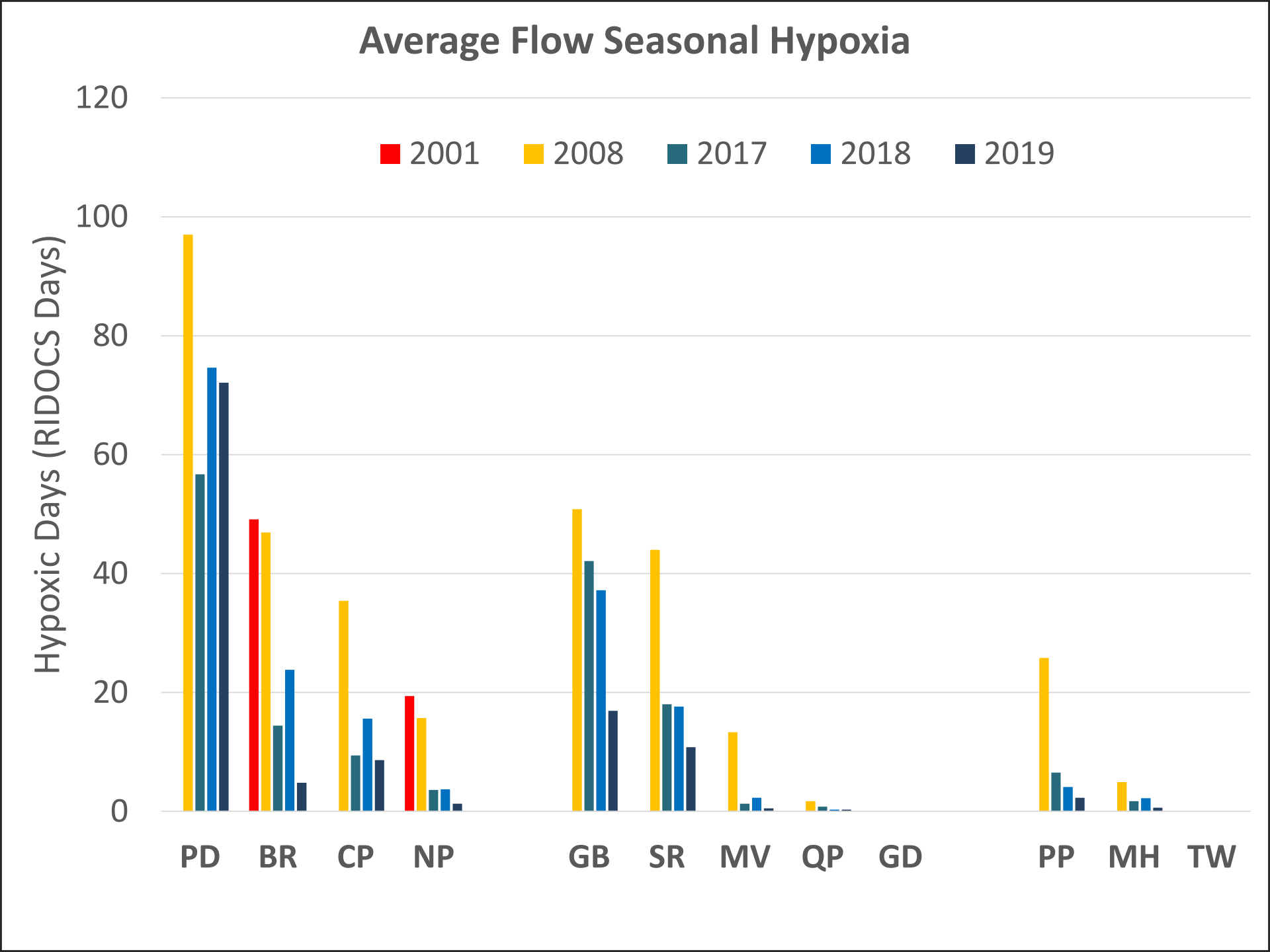
(shallow(3-4m), poor flushing)

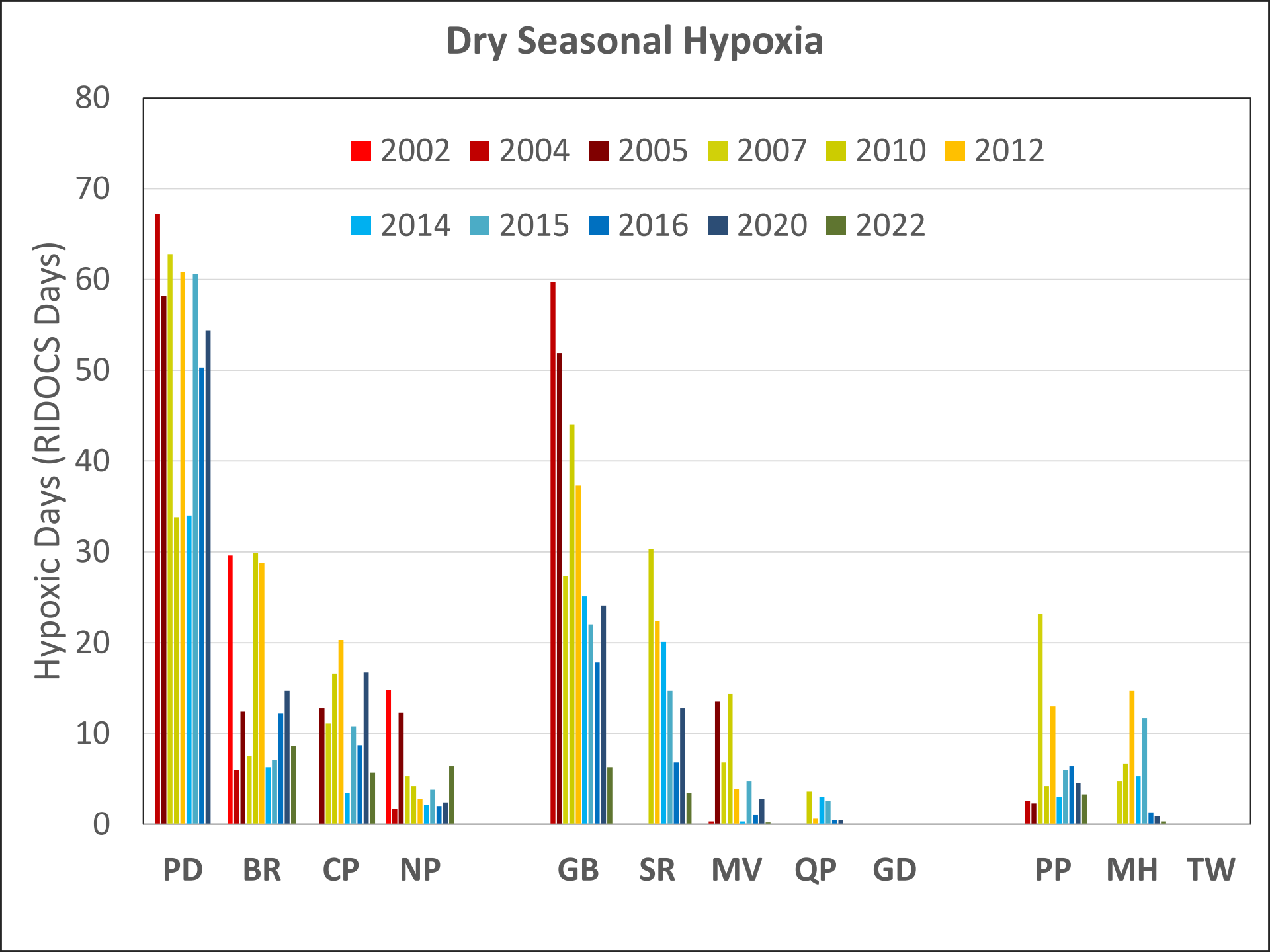
Mt Hope Bay (MH)

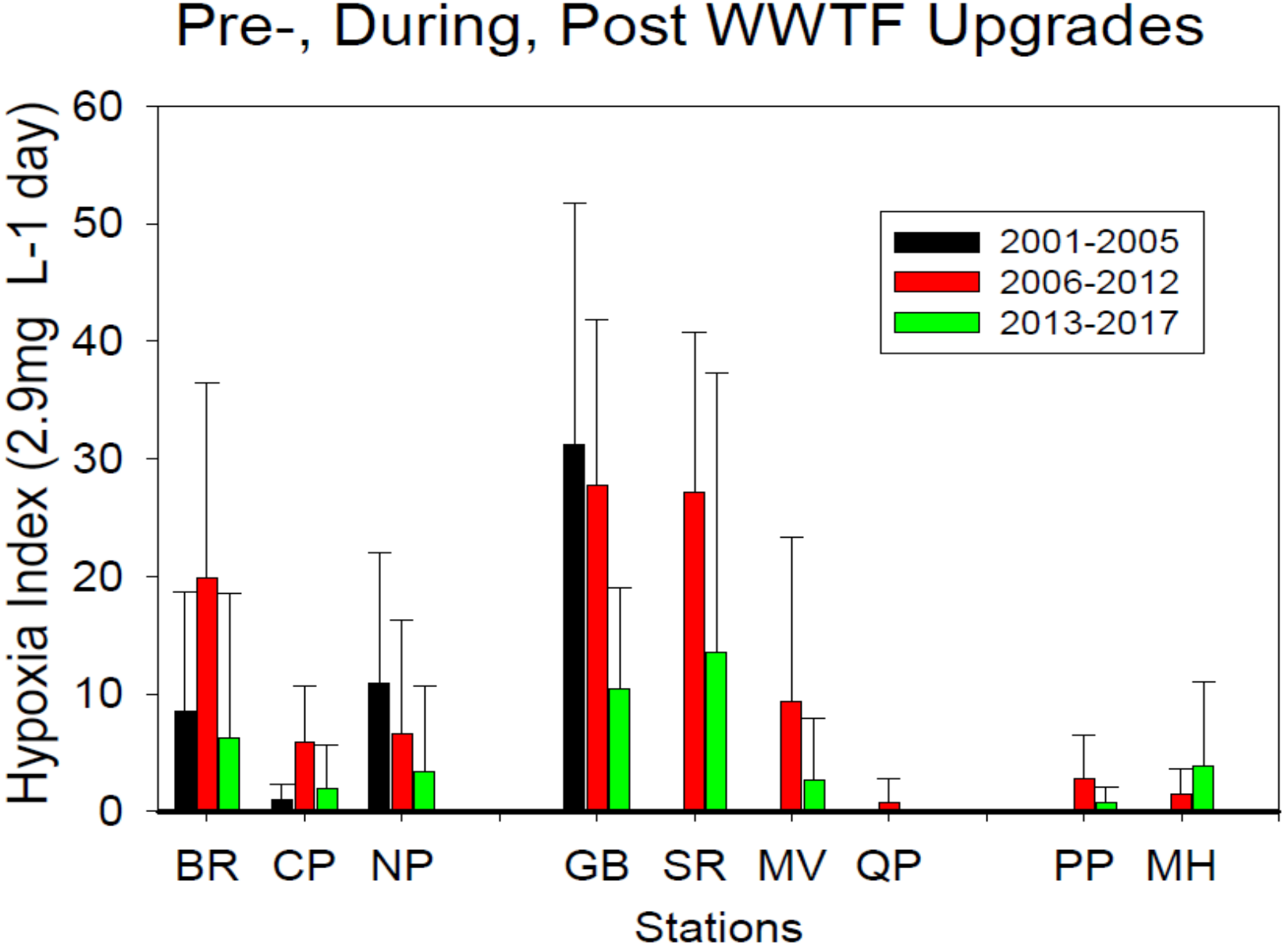
(shallow (5m), better flushed)



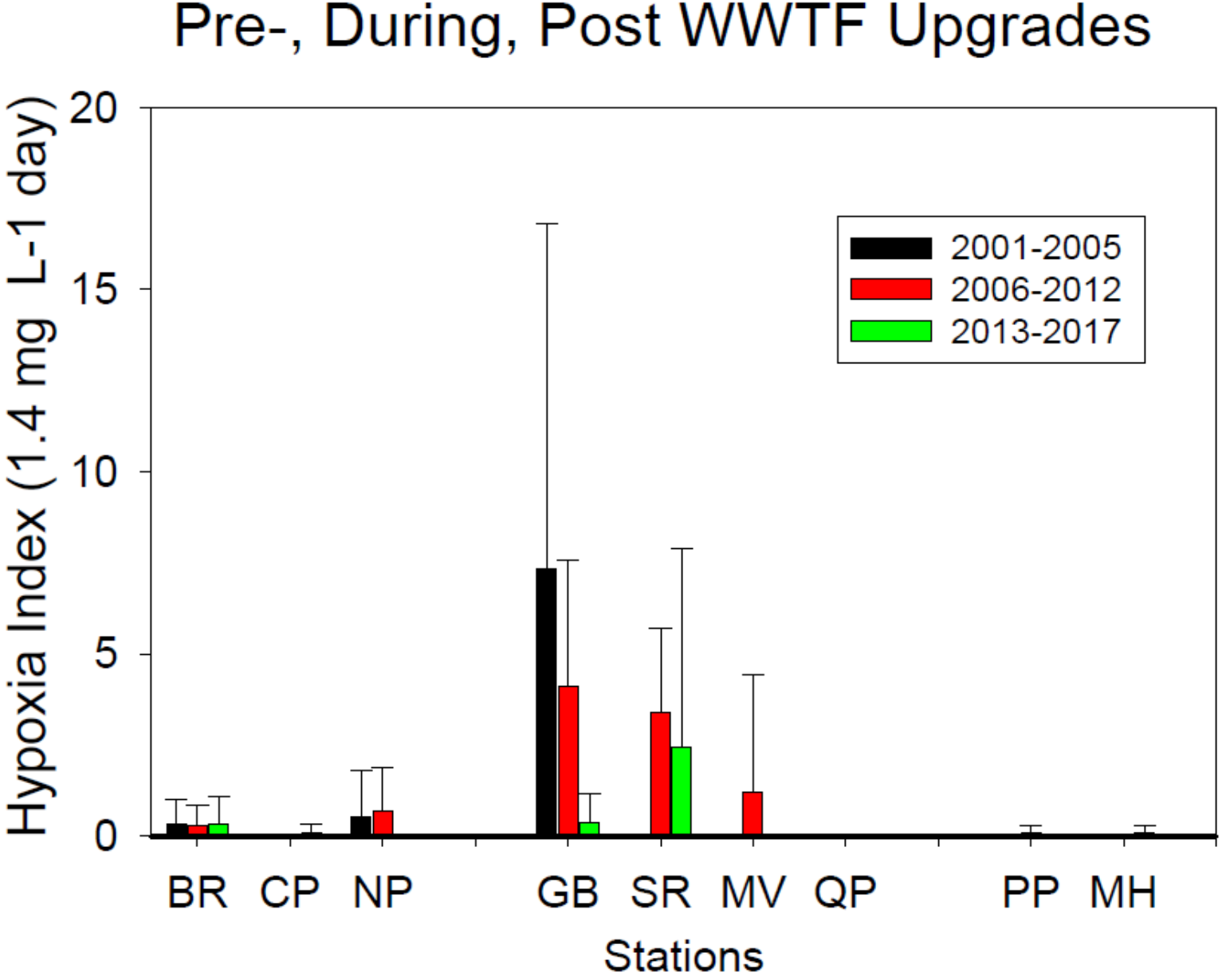

Wet Seasonal Hypoxia
2003
2006
2009
2011
2013
2021
2023
Hypoxic Days (RIDOCS Days)
70
60
50
40
30
20
10
0
PD
BR
CP
NP
GB
SR
MV
QP
GD
PP
MH
TW


Average Flow Seasonal Hypoxia
120
100
80
60
40
20
0
Hypoxic Days (RIDOCS Days)
2001
2008
2017
2018
2019
PD
BR
CP
NP
GB
SR
MV
QP
GD
PP
MH
TW


Dry Seasonal Hypoxia
Hypoxic Days (RIDOCS Days)
80
70
60
50
40
30
20
10
0
2002
2004
2005
2007
2010
2012
2014
2015
2016
2020
2022
PD
BR
CP
NP
GB
SR
MV
QP
GD
PP
MH
TW



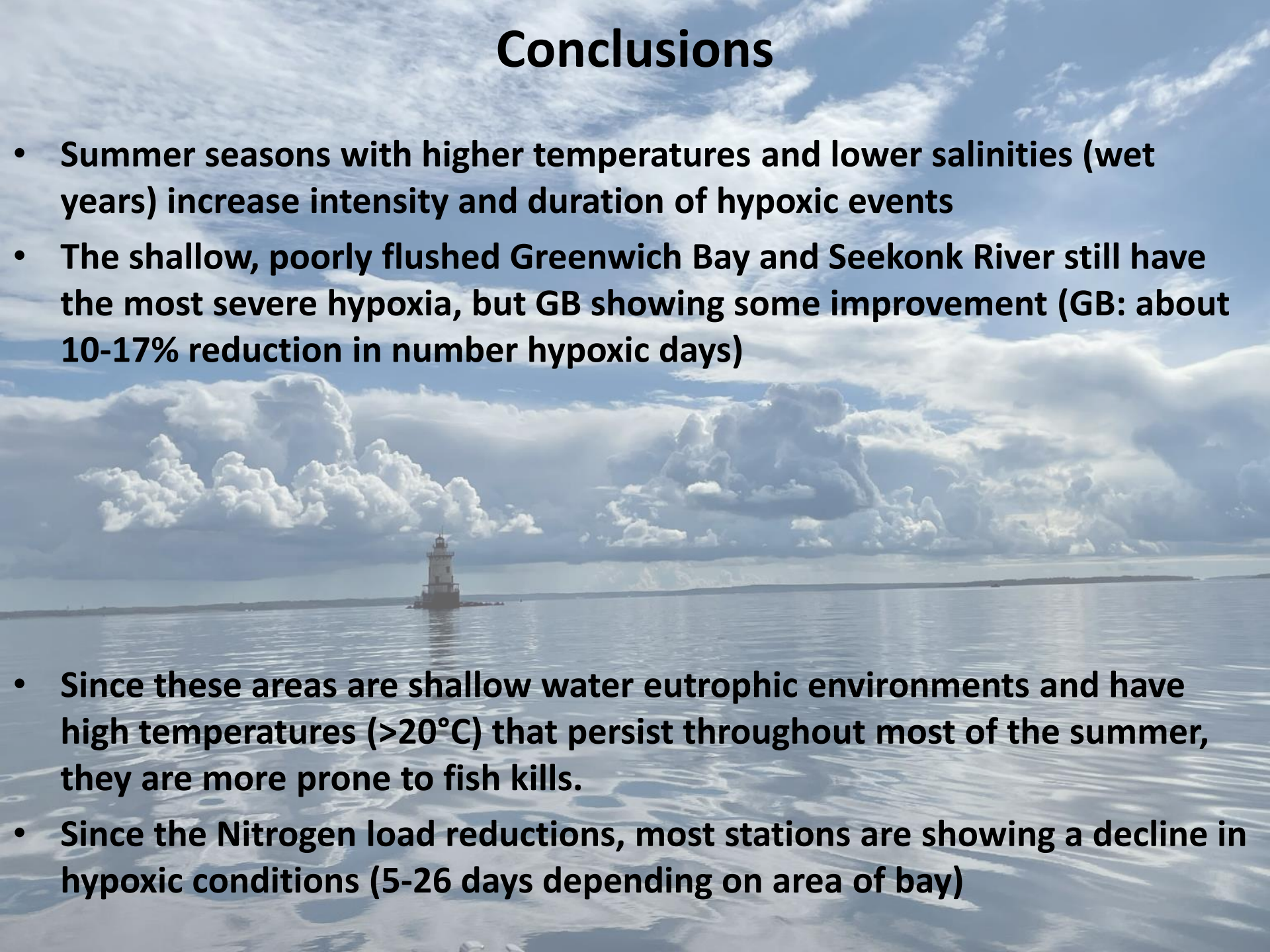
2.9 threshold is consistent with RIDOCS: Decrease of hypoxia in UWP



Greenwich Bay stations show the highest number of exceedences at the 1.4 mg/L threshold

Conclusions

- Summer seasons with higher temperatures and lower salinities (wet years) increase intensity and duration of hypoxic events
- The shallow, poorly flushed Greenwich Bay and Seekonk River still have the most severe hypoxia, but GB showing some improvement (GB: about 10-17% reduction in number hypoxic days)



- Since these areas are shallow water eutrophic environments and have high temperatures (>20°C) that persist throughout most of the summer, they are more prone to fish kills.
- Since the Nitrogen load reductions, most stations are showing a decline in hypoxic conditions (5-26 days depending on area of bay)

Special Thanks

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- **References & Data Links for NBFSMN:**
- Codiga, D., **Stoffel, H.,** Oviatt, C., Schmidt, C. 2022.Managed Nitrogen Load Decrease Reduces Chlorophyll and Hypoxia in Warming Temperate Urban Estuary Front. Mar. Sci., 22 July 2022 Sec. Marine Ecosystem Ecology Volume 9 - 2022 | https://doi.org/10.3389/fmars.2022.930347
  - https://dem.ri.gov/environmental-protection-bureau/water resources/research-monitoring/narraganset-bay-assessment