Upper Mt Hope Bay Water Quality Monitoring through Narragansett Bay Fixed Site Monitoring Network (NBFSMN) SNEPWG20-6-URI-MHB

Grant Period: October 1, 2020 – December 31, 2022 (no cost extension through 3/31/23)

Grantee Organization: University of Rhode Island's Graduate School of Oceanography-Marine Ecosystem Research Laboratory (URI/GSO MERL)

Report Contact Person: Heather Stoffel (401-874-6860; stoffel@uri.edu)

Executive Summary

The purpose of this grant project is to increase water quality monitoring in Mt. Hope Bay, which has recently undergone changes, not only to nutrient loadings from Narragansett Bay watershed nitrogen reduction efforts, but also from fluctuations in temperature and circulation from the shutdown of a power plant in May 2017 that utilized cooling water from Mt. Hope Bay. This project documented how the ecosystem responded to nitrogen loading and management changes to heating/cooling circulation processes within Upper Mt Hope Bay and how these processes relate to dissolved oxygen (DO) levels in the bay. The parameters measured include temperature, salinity, pH, DO, chlorophyll, and nitrate, which are used to assess DO within the estuarine system. Continuous long-term monitoring defined the temporal water quality variability. This project monitored two stations within Massachusetts's waters and utilized sensor and buoy platform equipment provided by the Massachusetts Department of Environmental Protection (MassDEP). The two stations were operational seasonally (May-Nov) during 2021 and 2022. This report summaries the main findings from the 2021-2022 sampling seasons.

The main findings show that 2021 was a wetter summer season compared to 2022. Based on previous work in the Narragansett Bay area, wetter summer seasons have more intense and longer duration of hypoxic event than drier summer do (Codiga, 2022). The main reasons are stresses from forcing factors on the physical water quality. Wetter years produce larger differences in stratification which sets up barriers for rich oxygenated surface waters from reaching depleted bottom waters. In addition, larger river flows increase the amount of nutrients that can be delivered to the receiving waters in the estuary. These conditions tend to set up and environment for low oxygen levels to become more intense and it takes more time and force (tidal mixing and wind events) to break up the stratification to replenish the oxygen in the bottom waters. Based on preliminary analysis of daily averages using components of the MassDEP criteria for dissolved oxygen, the Cole River buoy station saw 84 days below 5 mg/L during 2021 and Taunton River saw 71 days of daily average conditions below 5 mg/L. During 2022, both stations had 12-14 days below 5 mg/L. 2021 reportedly had about 40% more hypoxic days in 2021 vs 2022. This information would not have been possible without the methodology modified and adopted by the Narragansett Bay Fixed Site Monitoring network's QAPP during this project.

Continuous (unattended) water quality monitoring in the upper portion of Mt Hope Bay helps to address monitoring data gaps in estuaries and facilitates a more comprehensive assessment of water quality in the upper portion of the bay. These data support multiple MassDEP water quality management objectives, including evaluation of potential revisions to coastal and marine criteria in the Massachusetts Surface Water Quality Standards (SWQS) at 314 Code of Massachusetts Regulations (CMR) 4.00 (MassDEP, 2021); calculation of effluent discharge limits to protect against pollutants that may cause or contribute to impairments in the bay; and application of water quality assessment procedures to support Clean Water Act (CWA) Section 305b and 303d decisions (info courtesy of MassDEP's website for this project). All data from this project will be posted to: https://www.mass.gov/info-details/mount-hope-bay-marine-buoy-continuous-probe-data.

Regional funding for continuous monitoring projects is imperative for understanding the dynamics of eutrophication in estuaries and how these events can negatively impact organisms in watersheds that cross state lines. The spatial and continuous monitoring can be used in conjunction to determine the full extent of low oxygen events and provide critical information to water resource managers. In addition, a monitoring program such as this has many benefits with long term commitment to allow for status and trends analysis and assessing climatological along with management actions within the watershed.

SNEP Watershed Grants Final Report

1. Cover Information

Date: 7/15/2023

Project Name Contract Number: SNEPWG20-6-URI-MHB

Grant Period: October 1, 2020 – December 31, 2022 (no cost extension through 3/31/23)

Grantee Organization: University of Rhode Island's Graduate School of Oceanography-Marine Ecosystem Research Laboratory (URI/GSO MERL)

Report Contact Person: Heather Stoffel (401-874-6860; stoffel@uri.edu)

Reporting Period Report: Final Report

2. Project Report Narrative

The purpose of this grant project is to increase water quality monitoring in Mt. Hope Bay, which has recently undergone changes, not only to nutrient loadings from Narragansett Bay watershed nitrogen reduction efforts, but also from fluctuations in temperature and circulation from the shutdown of a power plant in May 2017 that utilized cooling water from Mt. Hope Bay. This project gathered monitoring data to document how the ecosystem responded to nitrogen loading and management changes to heating/cooling circulation processes within Upper Mt Hope Bay and how these processes relate to dissolved oxygen (DO) levels in the bay. The parameters measured include temperature, salinity, pH, DO, chlorophyll, and nitrate, which are used to assess DO within the estuarine system. Continuous long-term monitoring defined the temporal water quality variability. This project monitored two stations within Massachusetts's waters and utilized sensor and buoy platform equipment provided by the Massachusetts Department of Environmental Protection (MassDEP). This is the final report for this project. During the progress report period of Jan 1, 2022 – March 31, 2022, the University of Rhode Island's MERL finalized the project for the grant period.

Workplan Overview: A total of $301,289 was requested. This funding was used to operate sensors and maintain data collection at two Mt. Hope Bay stations. Also, eight spatial data surveys (1 spring, 2 summer, 1 fall) were conducted in 2021 and 2022. This workplan included data analysis and outreach to stakeholders through SNEP events. Sensor instrumentation and buoy platforms from MassDEP served as match at the two monitoring stations. URI/GSO provided survey equipment and personnel needed to conduct spatial surveys.

2.A. Project Completion

During the final report period, the 2022 data were processed and initially analyzed (task 9) and reported to MassDEP for their internal review process. Equipment was inventoried for MassDEP match. Supply funds were used to execute task 10 of the grant activities. As part of the preparation process, Submersible Ultraviolet Nitrate Analyzer (SUNA) sensors were inspected, YSI replacement parts were procured, and all equipment were tested before returning to MassDEP. All items were reconditioned for MassDEP by the end of the granting period (March 31, 2023). The funds spent on these items included returning equipment to the same operational state as received from MassDEP at the beginning of the SNEP granting process. These final tasks complete all outstanding tasks left on the project.

2.B. Work finalized this period

Major tasks, subtasks, and deliverables that are scheduled to be completed by the end of the granting period (3/31/2023) for this project are summarized in the table 1 below.

Table 1. Remaining Tasks this period

Task No.	Task Description	Deliverable	Schedule
Task 13.	Review and analyze data 2022	Report data files to MassDEP in accordance with NBFSMN QAPP	Completed
Task 15.	Progress and final grant reports	Progress and final reports.	Completed

2.C. Compliance

The NBFSMN currently has an active approved Quality Assurance Project Plan (QAPP) that includes the stations in this project (NBFSMN, 2020). The SNEP QAPP advisors have agreed that grant project tasks will be conducted under the current NBFSMN EPA approved QAPP. We agree to work on updates to the existing QAPP as necessary in accordance with EPA guidelines.

2.D. Project Partners (NBFSMN partners)

• University of Rhode Island – Graduate School of Oceanography (URI-GSO-MERL) – (site operations, QAPP preparation, data management, and data transfer to MassDEP).

• Massachusetts Department of Environmental Protection – (participate in QAPP process, participate in monthly partner meetings, provide equipment for the project, review and finalize data for publications from the project).

• Narragansett Bay Estuarine Research Reserve (NBNERR) – (participate in QAPP process and maintain one station within the NBFSMN).

• Narragansett Bay Commission (NBC) (participate in QAPP process and maintain two stations within the NBFSMN).

• Rhode Island Department of Environmental Management – (provide NBFSMN web site to host data and NBFSMN QAPP): (http://www.dem.ri.gov/programs/emergencyresponse/bart/netdata.php)).

2.E. Volunteer and Community Involvement

Since this is the final phase of the project, there was not any community involvement. The focus was to finalize outstanding purchase orders, reporting results to agencies, and generating reports.

2.F. Outreach & Communications

Data are shared with MassDEP through monthly calls, emails, posting data to a shared google drive for partners, and real-time communications with buoys. Data descriptions are shared with the public in the form of a weekly water quality report during the monitoring season (http://www.dem.ri.gov/programs/emergencyresponse/bart/latest.php). All metadata and data from the two monitoring seasons were shared with MassDEP via a share google drive to facilitate MassDEP's internal review and validation procedures.

Throughout this project, outreach and communication has been a component of the tasks. During the final reporting period, preliminary analyses were used for a poster presentation at a SNEP conference in June 2023. This poster presentation will focus on characterization of low oxygen in Upper Mt Hope Bay based on data generated by this grant-funded project focusing on the 2021 and 2022 seasons. All outreach materials produced during the grant period are added to the end of this document in the supplemental materials section.

2.G. Results

This project gathered monitoring data to document how the ecosystem responded to nitrogen loading and heating/cooling circulation processes controlling dissolved oxygen (DO) levels including hypoxia in the Upper Mt Hope Bay area at two temporal stations (Taunton River (TR) and Cole River (CR)) (Figure 1; these two stations are located in upper Mt. Hope Bay proper, not in or near the mouth of the rivers). The parameters measured during the buoy deployment period include temperature, salinity, pH, DO, chlorophyll, and nitrate, which are needed to assess DO within the estuarine system. The results shared in this report utilized the following parameters characterizing the eutrophic conditions in Upper Mt Hope Bay: temperature, salinity, bottom dissolved oxygen, chlorophyll levels and nitrate concentrations from June-October. June-October is sufficient for this analysis two reasons: 1.) Based on

preliminary work, no evidence suggests high chlorophyll or low oxygen levels during the months of May and November. 2.) May and November were excluded from the results because of incomplete data during buoy deployment and retrieval at different times each year.

Temperature and Salinity

This project covered two very different seasons for water quality in Mt Hope Bay. Based on weather information, 2021 received over 5 inches more of rain than in 2022 during the sampling season from June-October. This resulted in a larger flow from the Taunton River in 2021 vs 2022 (Figure 2). Because of this, 2021 is considered a "wet" summer season in comparison to 2022 (a "dry" summer season). Based on previous work in Narragansett Bay, wetter summer seasons produce more hypoxic days than a drier than average seasons because river flow is likely the main driver of inter-annual variability in hypoxia with increased nutrient loads, increased density stratification, and chlorophyll in wetter years (Codiga, 2022).

Analysis of the preliminary data from 2021 and 2022shows that average surface water temperatures at the CR buoy station are about 0.2 ºC warmer than at the TR station (Figure 3). In 2021, the average surface temperature at the CR station was 21.86 ºC and 21.62 ºC at TR station. During 2022, average surface temperatures at the CR and TR stations were 22.19 ºC and 22.08 ºC, respectively. 2022 had about a 1.1 ºC large standard deviation (2022: CR-3.65 ºC; TR-3.63 ºC) of values than 2021 (2021: CR-2.58 ºC; TR-2.48 ºC). 2022 reported warmer maximum temperatures with 16 days over 26.7 ºC at the Cole River surface station and 14 days at the Taunton River surface station over the 26.7 ºC threshold. This resulted in 2022 being the warmest summer on average based on all years of recent data (2017-2022). Drier summers tend to have more sunny days; therefore, temperatures can be higher than wetter years.

In addition, during wet years, surface salinities tend to be lower, which leads to increased stratification that inhibits oxygen exchange with the surface and bottom waters. In 2021, data collected from the stations showed some of the lowest salinities recorded in recent years at both the TR and CR stations (Figure 4a and 4b). In addition, 2021 reported the largest standard deviation for salinity (2.34 psu at TR and 2.13 psu at CR). Increased stratification influences the duration and intensity of hypoxic events.

Table 2. Seasonal Statistics of Daily Surface Temperature, Surface Salinity, Bottom Dissolved Oxygen, and Total Surface Chlorophyll

Site	Year	Statistic	Surface-Temp ºC	Surface Salinity PSU	Bottom-DO mg/L	Surface CHL µg/L
CR	2021	Ave	21.863	24.873	4.645	12.348
CR	2021	Max	27.185	27.902	7.412	35.958
CR	2021	Min	14.958	17.409	0.960	1.476
CR	2021	St Dev	2.584	2.134	1.622	7.244

CR	2022	Ave	22.190	29.250	6.316	12.726
CR	2022	Max	27.709	31.187	8.322	29.139
CR	2022	Min	15.069	23.795	3.980	2.307
CR	2022	St Dev	3.656	1.248	0.895	5.940
TR	2021	Ave	21.623	24.284	5.121	8.313
TR	2021	Max	26.377	28.423	7.568	28.286
TR	2021	Min	14.846	15.927	2.524	0.747
TR	2021	St Dev	2.482	2.341	1.138	6.029
TR	2022	Ave	22.083	28.853	6.206	9.460
TR	2022	Max	27.689	30.808	7.713	26.412
TR	2022	Min	15.214	23.382	4.453	1.787
TR	2022	St Dev	3.629	1.310	0.819	5.535

Dissolved Oxygen

Dissolved oxygen (DO) is necessary for life and among the most reliable indicators of water quality. Hence, low oxygen (hypoxic) events can have adverse consequence for aquatic species. Dissolved oxygen is one of the most common criteria used to describe the health of waterbody. Tracking water quality conditions, including dissolved oxygen, over several years allows for assessment of conditions with large inter-annually variability. The data from the two continuous monitoring stations owned by MassDEP and located in the Massachusetts portion of Mt. Hope Bay are designed to track changes in DO on a fine temporal scale to track water quality conditions in areas known to be vulnerable to hypoxic conditions. This grant project allowed for monitoring conditions during a wet year (2021) with several hypoxic events and a dry year (2022) with minimal low oxygen conditions recorded.

Figures 5A and 5B show the intensity and duration of hypoxic events at the Taunton River (Figure 5A) and Cole River (Figure 5B) during 2021 and 2022 seasons. These figures were generated using hourly reading at known thresholds. During 2021, at both stations, hypoxia thresholds (between 2.9 mg/L and 5 mg/L) and severe hypoxia/anoxia (< 2.9 mg/L) was more severe in seasonal duration and episodic intensity (lower oxygen levels during events) than observed in 2022. During 2021, based on daily average preliminary data, Taunton River reported 71 days below 5 mg/L from June 6-October 8, 2022. While during 2022, only 12 days below 5 mg/L were recorded with a seasonal duration of June 25-August 8,2022. Cole River reported similar results with 84 days below 5mg/L during June5-September 21, 2021, and 14 days below 5 mg/L from June 21-September 14, 2022. Based on figure analysis of the two years, CR station experienced more severe hypoxia in intensity compared to the TR station. In addition, based on the spatial survey maps of dissolved oxygen, a larger area near

the CR buoy experiences lower oxygen levels than the area near the TR buoy (Figure 6). River flow can influence the inter-annual variability in hypoxia. Other drivers, such as chlorophyll and nutrient levels, can also influence variability among stations/areas.

Chlorophyll

Chlorophyll *a* concentration is an accepted indicator of eutrophication that can be examined to assess if the input of anthropogenic nutrients is affecting an ecosystem. Chlorophyll *a* is a primary indicator; it responds to increasing nutrient inputs before more serious and difficult to reverse damage has occurred, such as loss of seagrass and other submerged aquatic vegetation (Boyer et al. 2009). The instrumentation used during this grant period estimates *in-situ* chlorophyll (which includes chlorophyll *a* and other chlorophylls), based on relative fluorescence (RFUs). Using estimated chlorophyll readings, preliminary daily average chlorophyll was generated for analysis.

During 2021, the TR station reported 13 days with chlorophyll average readings above 20 µg/L and 6 days in 2022. The Cole River station recorded 19 days with chlorophyll average readings above 20 µg/L in both 2021 and 2022. When examining the ranges and intensities at the Cole River station, 2021 had higher peaks in chlorophyll than in 2022 (Figure 8). Cole River had a daily max chlorophyll reading of 35.9 µg/L in 2022. 2021 experienced larger variability with a standard deviation of 6.0 µg/L at Taunton River (TR) and 7.24 µg/L at Cole River (CR) compared to 2022 (St Dev: 5.5 µg/L (TR) and 5.9 µg/L (CR)).

Nitrate

As part of the decomposition process of organic matter, nitrification, which is the process oxidizing ammonium via nitrite to nitrate and simultaneously consuming oxygen, is important in estuaries. Agencies can directly manage for nutrients (in particular nitrogen) to alleviate the negative effects of eutrophication, and monitoring for nitrogen is part of the management strategy. Continuous monitoring is a more cohesive approach to monitoring nitrogen and identifying problem areas compared to grab sampling. To address this issue MassDEP has utilized the latest technologies in continuous sensors for nitrogen, using SUNA sensors. Both the Cole River and Taunton River stations were equipped with a surface SUNA nitrate sensor for the duration of this project.

In general, measured concentrations of NO_3-N between June and September were the lowest, typically dropping below the detection limits of the SUNA sensor. This can be attributed to primary production using available forms of nitrogen for growth. As the summer transitions to fall, primary production decreases as temperature decreases and results in an increase in nitrate levels. Large peaks can be observed (as in late September 2021 at Taunton River station) when primary production is at a minimum and a large storm event brings nutrient rich waters into the estuary.

Inter-station and inter-annual differences were observed. Cole River and Taunton River have variable nitrate levels throughout the seasons. On average, Taunton River is slightly higher than the Cole River (diff TR-CR: 3.38 mmol in 2021 and 3.18 in 2022). The SUNA nitrate sensor can have a +/- 4 mmol max difference, therefore, differences between stations are not significant. With the wet conditions of 2021, nitrate concentrations were higher than in 2022.

Figure 8 shows the daily average readings for both stations from June-October for both 2021 and 2022. The seasonal statistics for the SUNA time series are as follows:

Table 3. Seasonal Statistics of Daily Surface SUNA Nitrate (µmol) by Station

	TR 2021	**TR2022**	**CR 2021**	**CR 2022**
Average	8.5259	5.1276	6.8810	3.6933
Maximum	21.8725	15.0875	20.2500	12.4313
Minimum	0.8311	0.0477	0.9177	0.0689
Standard Deviation	4.0901	4.3648	4.1827	3.2846

All observations show that 2021, as a much wetter year, and resulted in more severe low oxygen levels compared to 2022. These years of data can help managers better understand how forcing factors influence low oxygen levels in Upper Mt Hope Bay. The spatial surveys show a similar seasonal pattern as that recorded at the continuous monitoring systems.

Conclusions:

This project allowed for more information to be gathered in the Upper portion of Mt. Hope Bay. Continuous (unattended) water quality monitoring in Mt Hope Bay helps to address monitoring data gaps in estuaries and facilitates a more comprehensive assessment of water quality in the upper portion of the bay. These data support multiple MassDEP water quality management objectives, including evaluation of potential revisions to coastal and marine criteria in the Massachusetts Surface Water Quality Standards (SWQS) at 314 Code of Massachusetts Regulations (CMR) 4.00 (MassDEP, 2021); calculation of effluent discharge limits to protect against pollutants that may cause or contribute to impairments in the bay; and application of water quality assessment procedures to support Clean Water Act (CWA) Section 305b and 303d decisions (info courtesy of MassDEP's website for this project). All data from this project will be posted to: https://www.mass.gov/info-details/mount-hope-bay-marine-buoy-continuous-probe-data.

Funding for continuous monitoring projects is imperative for understanding the dynamics of eutrophication in estuaries and how these events can negatively impact organisms. In addition, a monitoring program such as this has many benefits when complemented by spatial surveys. The spatial and continuous monitoring can be used in conjunction to determine the full extent of low oxygen events and provide critical information to water resource managers.

Project Budget Report

The following budget report is the final budget report and including the period from Jan 1, 2023, through March 31, 2023. This project was underway during this period and reaching the completion phase. The primary charges reflect field activities during the end of the 2022 monitoring season (May – November 2022). Elevated phytoplankton biomass is one of the most visible and early symptoms of eutrophication, and long-term increasing trends of phytoplankton biomass (chlorophyll a) can be an indication that nutrient inputs into a system are increasing (Bricker et al. 1999; Fisher et al. 2006; Boyer et al. 2009).

A. Summary Budget Tables

Table 4 and Table 5 reflect charges to the grant for the invoices for this period (Jan 1-March 31, 2023). Re-budgets reflected in categories: Travel, Supplies, Tuition and Indirect. Re-budget details are in caption of table 4. These re-budgets are below the 10% of the overall budget and do not require prior approval.

Table 4 : Summary Budget Expenditures by Federal Cost Category

Budget Category	Total Budgeted Funds	Total Budgeted Match	Grant Funds Expended This Period	Grant Funds Expended Cumulative	Match Funds Expended This Period	Match Funds Expended Cumulative	Match Source (note cash or in-kind)
Personnel	$118,330 Re-budget total to $114,408	$8,467	$2,812.42	$114,408.42		$8,694	MassDEP (contract)
Fringe	$31,500 Re-budget total to $28,957	$3,642	$570.27	$28,956.09		$3,290	MassDEP (contract)
Travel	$8,600 Re-budget Total: $3,362		$281.66	$3,362.52			
Equipment	$0	$56,000	$0	$0		$56,000	MassDEP (equipment)
Supplies	$42,830 Re-budget total: $59,578		$18,520.30	$59,578.75			

Contractual							
Other (TUITION)	$24,763 Re-budget Total: $19,717	$3,769	$0	$19,717		$3,895	MassDEP contract (tuition)
Total Direct	$226,023	$71,878	$22,184.65	$226,024.68		$71,879	
Indirect	$75,266	$27,548	$7,387.52	$75,266.22		$37,704	MassDEP contract/ Modified Ind.
Total	**$301,289**	**$99,425**	**$29,572.17**	**$301,289**		**$109,583**	

Table 4. The amounts in columns 2 and 3 should match the categories and totals in the approved grant budget. Re-budgets occurred on: 2/16/22 from travel to Operating $5238 (prior approval granted); 7/18/22 Tuition to Operating and Indirect $4728; and 10/18/22 Tuition to Operating (fuel) $318. To finalize the grant, in January 2023, a re-budget from personnel ($3,922) and fringe ($2543) was transferred to operating (supplies). These re-budgets occurred because the graduate student (level) changed during 2022 and travel to meetings were done virtually. These re-budgets are below the 10% of the overall budget and do not require prior approval (total re-budget $16,749). Modified indirect refers to URI F&A on match, waived F&A on direct expenses. There is no contractual category associated with this grant (category blank). Match for this grant has been reached totaling $109,583.

Table 5. Summary Budget Table of Expenditures by Project Tasks (Grant Funds Only)

Budget Category	Budgeted Grant Funds	Expended Progress Period 1	Expended Progress Period 2	Expended Progress Period 3	Expended Progress Period 4	Expended Progress Period 5	Expended Progress Period 6	Actual Expended to Date
Task 1. Attend Grant Ceremonies	$720	$720						$720
Task 2 Execute agreements with MassDEP	$719	$719						$719
Task 3. Assess what is needed to complete operations for 2021 season	$20,000		$15,621	$4,445				$20,066
Task 4. Procure equipment to two MassDEP owned stations	$719	$719						$719
Task 5. Buoy operations of 2 stations 2021	$59,000		$21,300	$39,962				$61,262
Task 6. Conduct spatial surveys 2021	$3,050		$978	$2,078				$3,056
Task 7. Retrieve seasonal buoys 2021	$2,450			$2,721				$2,721
Task 8. Review all equipment and prep for next season	$22,818			$5,391	$23,688			$29,079

Task 9. Review and analyze data from 2021 season	$59,000			$16,439	$33,795			$50,234
Task 10. Buoy operations of 2 stations 2022	$59,000				$18,267	$42,462		$60,729
Task 11. Conduct spatial surveys 2022	$3,520				$880	$2,640		$3,520
Task 12. Retrieve seasonal buoys 2022	$2,453					$2,453	$282	$2,735
Task 13. Review and analyze data and equipment/ supplies 2022	$60,000				$1,610	$26,275	$26,477	$54,362
Task 14. Attend SNEP and RAE	$2,000				$530	$145		$675
Task 15. Progress and final grant reports	$5,840		$978	$1,984	$2,934	$1,984	$2,812	$10,692
Total	**$301,289**	**$2,158**	**$38,877**	**$73,020**	**$81,704**	**$75,959**	**$29,572**	**$301,289**

3.B. Budget Narrative

During the final reporting period one invoice was submitted. Match funds for this project were reached as of fourth reporting period, so no match funds were reported during Jan 1, 2023 – March 31, 2023. Therefore, URI will not report any expenses as match during this invoice period. During this final period, purchase orders from the previous period were finalize as were datasets for the 2022 season. All numbers have been rounded to the nearest dollar so added charges may vary by a few dollars when compared to the actual totals for each category.

Personnel : Personnel costs charged to this grant total for this period $2,812.42 J – M (Grant Request Funds Total : $114,408.42 and match funds: $8,497). Throughout the granting period

personnel for this grant consist of the PI, Heather Stoffel, nutrient analyzer, Laura Reed, and graduate student help with day-to-day operations, Nicole Flecchia and Riley Secor. In addition, undergraduates were hired to assist with day-to-day tasks of this project. During the final grant period, time consisted of grant operations, coordinating efforts with MassDEP (overseeing tasks 13-15). Laura's time was for nutrient sampling operations totaling $1,282.81(J – M), which falls under Tasks 15. Nicole Flecchia (incoming graduate student Fall 2022) took over Riley's duties, as well as, spatial surveys, data entry, preparation of reports, presentations, and attended conferences during this reporting period. Her graduate assistantship totaled $1,111.11 (J-M) to complete grant related task 15. During the reporting period undergraduate interns were used to help with data entry (tasks 15). An undergraduate was hired part-time during this period totaling $418.50 (J-M).

Fringe: Total fringe costs for personnel were $570.27 (J-M) with a grant total of $28,956.09 and match total of $3,290. January through March 2023 charges were inclusive of Laura's time ($570.27; J – M, rate 44.4%) fringe costs. It also includes the graduate assistantship and undergraduate positions do not generate AY fringe costs.

Travel: Total travel charges this period were $281.66 (with a total cost of $3,362.52; no match was used for this category). Travel is used for getting to and from the stations (Grant total charges breakdown: gas for boat (other travel) ($2,173.36), tolls ($127), and truck use ($1,062.16)). URI trucks are used to trailer the boat to a launching area to access the buoy stations in Upper Mt Hope Bay. Total truck travel charged to the grant this period of $281.66 J-M falls under Task 10 and 11.

Equipment: There was no equipment associated with requested funds through SNEP. MassDEP provided all equipment for this project and was categorized as match ($56,000) during the first reporting period.

Supplies: Supply funds were used to execute Task 13 of the grant activities totaling ($18,520.30 J-M) ($59,578.75). During this period, there was four purchase orders over $1,000 for equipment supplies and repairs for Seabird $1,354 (SUNA wipers), YSI parts ($9,928.70), YSI sonde repairs ($1,265.43 and $2,531.03). POs over $1000 are attached in supplement items at the end of this report. Other supply purchases under $1000 included nutrient supplies, YSI EXO sensor supplies, calibration solutions, tools, lab items, and boat supplies/services (totaling $3,441.14). These supplies were used to maintain the monitoring equipment throughout the 2022 monitoring season and replace items damaged to restore all items to the condition in which received by MassDEP. In addition, costs for shipping items for repair and outreach/conference items fall under this category. All POs and items purchased were received during the no cost extension period from Jan 1, 2023 through March 31,2023 to finalize all grant activities.

Other: Other costs consist of tuition charges. There were no tuition charges for the last reporting period. The grant utilized $19,717 in graduate tuition funds throughout period 2-4 and $3,895 in match from MassDEP during period 2 of the grant. The total of other costs was $23,612 combine for match and grant requested funds.

Total Direct: Total direct charges are 226,024.68 ($22,184.74 J–M). Tuition is the only category subject to indirect costs. Total direct in match was $71,879.

Total Indirect: Total indirect was charged at 33.3% rate to the total direct charges. Indirect costs consisted of overhead charges to the following categories: Personnel, Fringe, Travel, and Supplies (totaling $75,266.22 ($7,387.52 J – M). Match indirect reached $37,704.

Grant Totals: The total for this reporting period, January 1, 2023 – March 31, 2023, being charged to the grant is $29,572.17. A total of $301,289 has been charged to the SNEP grant and $109,583 has been expended in match through equipment and funds through MassDEP. The total match rate for this grant was 36.3%.

4. Supporting Materials

The QAPP and station locations for this project can be found at **http://www.dem.ri.gov/programs/emergencyresponse/bart/netdata.php**

5. Certification

Include this language: *The undersigned verifies that the descriptions of activities and expenditures in this final report are accurate to the best of my knowledge; and that the activities were conducted in agreement with the grant contract. I also understand that matching fund levels established in the grant contract must be met.*

Grantee Signature:

Name: Heather Stoffel

Job Title: Marine Research Associate III

Date: 7/15/23

Organization: URI/GSO MERL

6. Figures

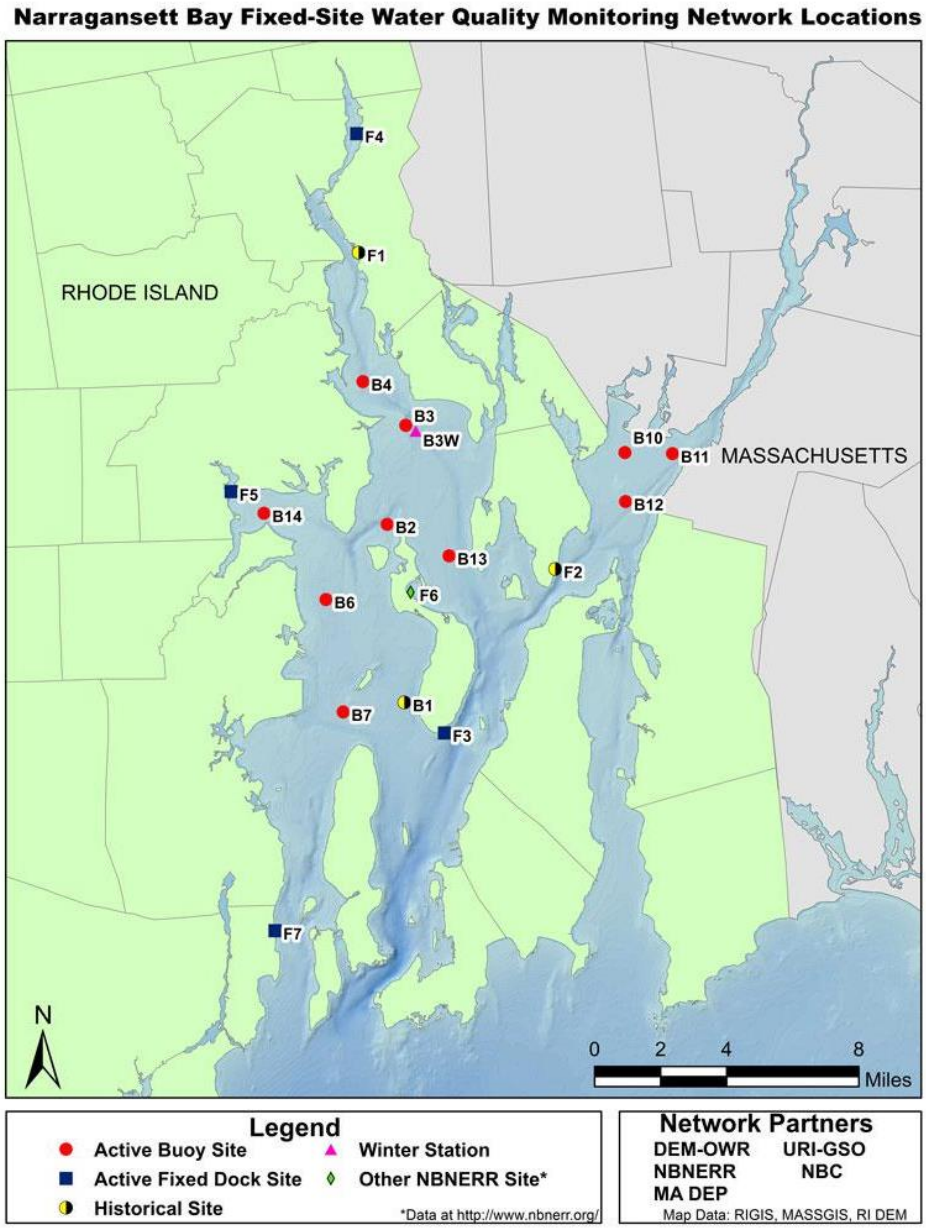

Figure 1: Map of Narragansett Bay Fixed-Site Monitoring Network buoy locations. Station B10 indicates the Cole River buoy, and station B11 indicates the Taunton River buoy.

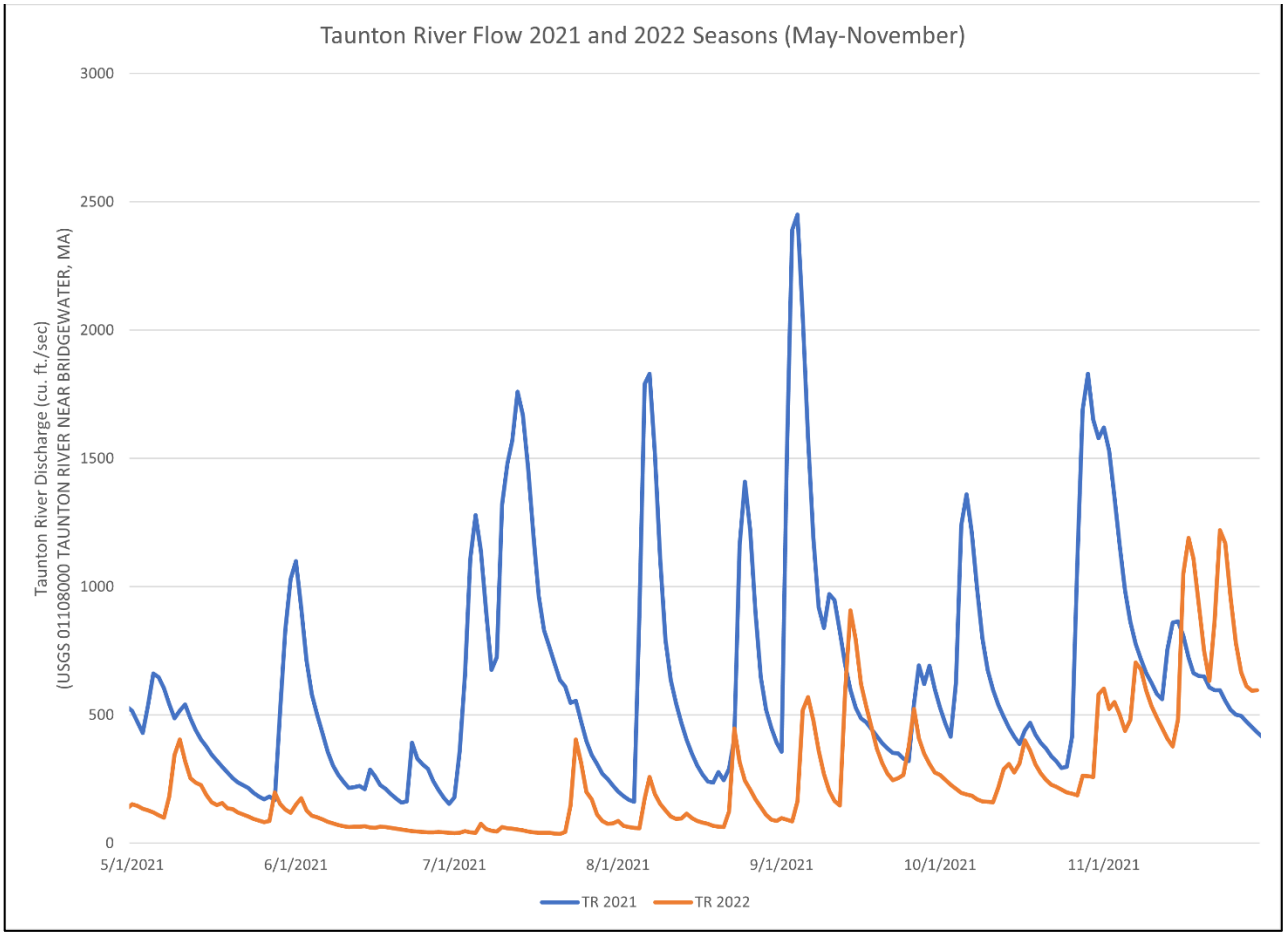

Figure 2. Daily river flow data from USGS 01108000 TAUNTON RIVER NEAR BRIDGEWATER, MA. Data curtesy of https://waterdata.usgs.gov/monitoring-location/01108000/

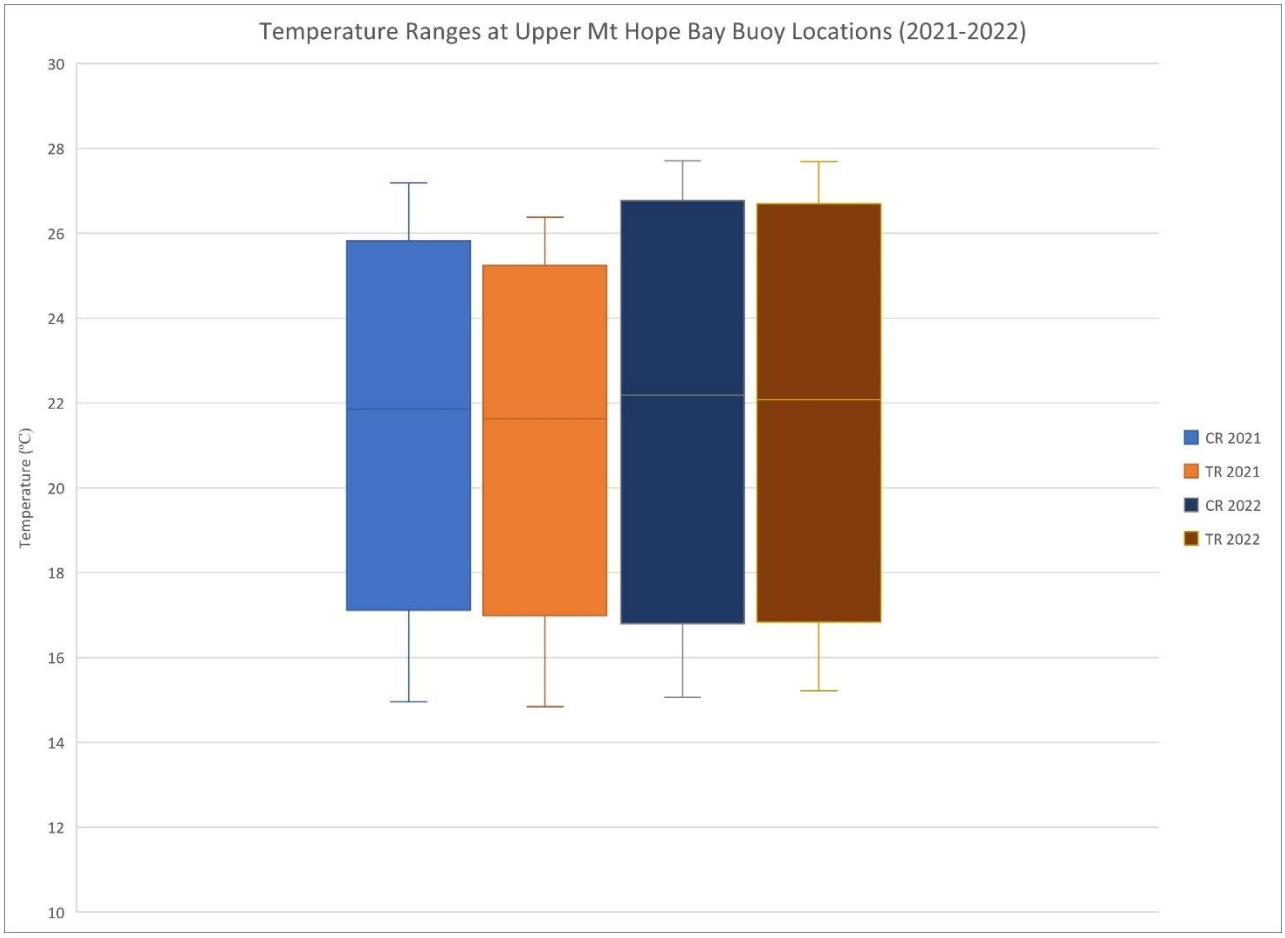

Figure 3. Surface temperature ranges in box and whisker plots (+/- 1 St deviation around mean with seasonal max and min) at the two buoy locations. 2022 was slightly warmer than 2021. Season defined as June 1- October 31.

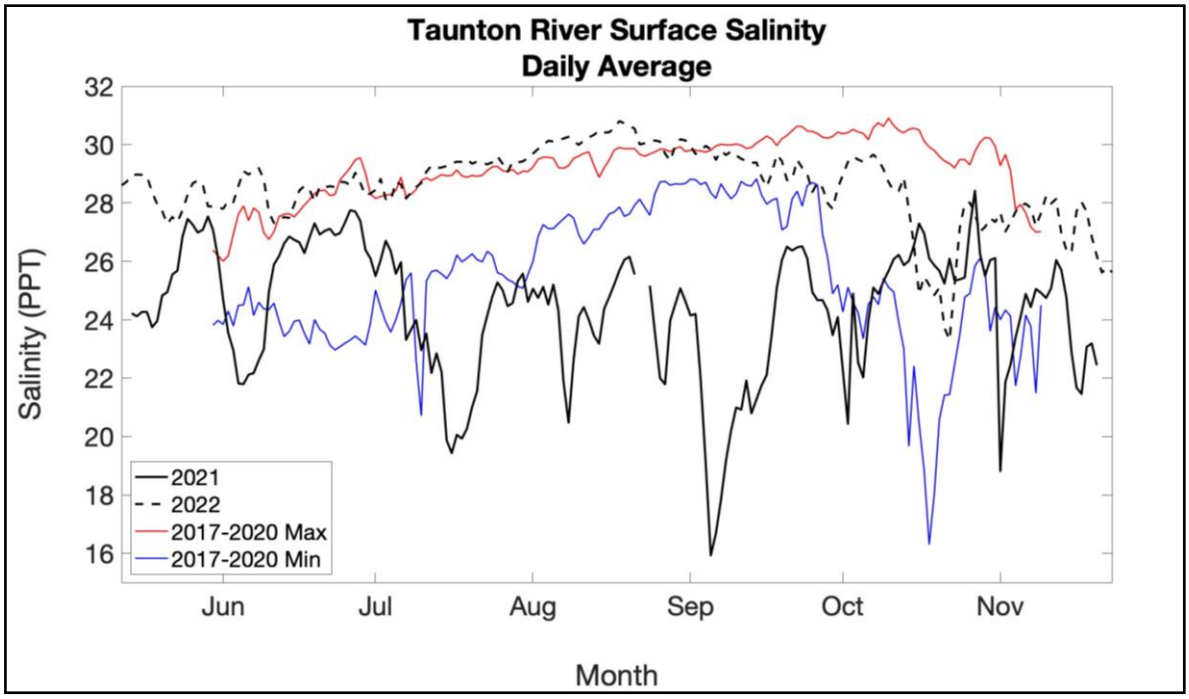

Figure 4A: Daily average salinities at the Taunton River buoy. Solid black line indicates the 2021 daily averaged data. Dashed back line indicates the 2022 daily averaged data. Daily maximum (red) and minimum (blue) values between 2017-2020 are indicated by the respective colors. These data for all figures are considered draft.

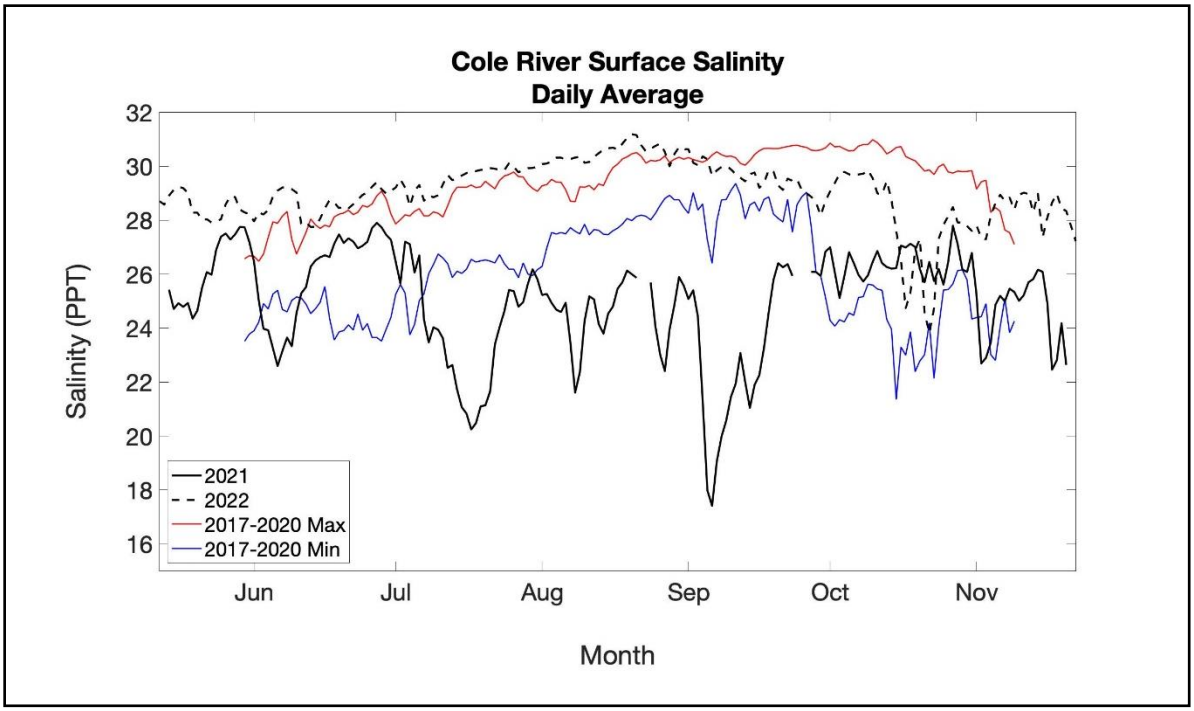

Figure 4B: Daily average salinities at the Cole River buoy. Solid black line indicates the 2021 daily averaged data. Dashed back line indicates the 2022 daily averaged data. Daily maximum (red) and minimum (blue) values between 2017-2020 are indicated by the respective colors.

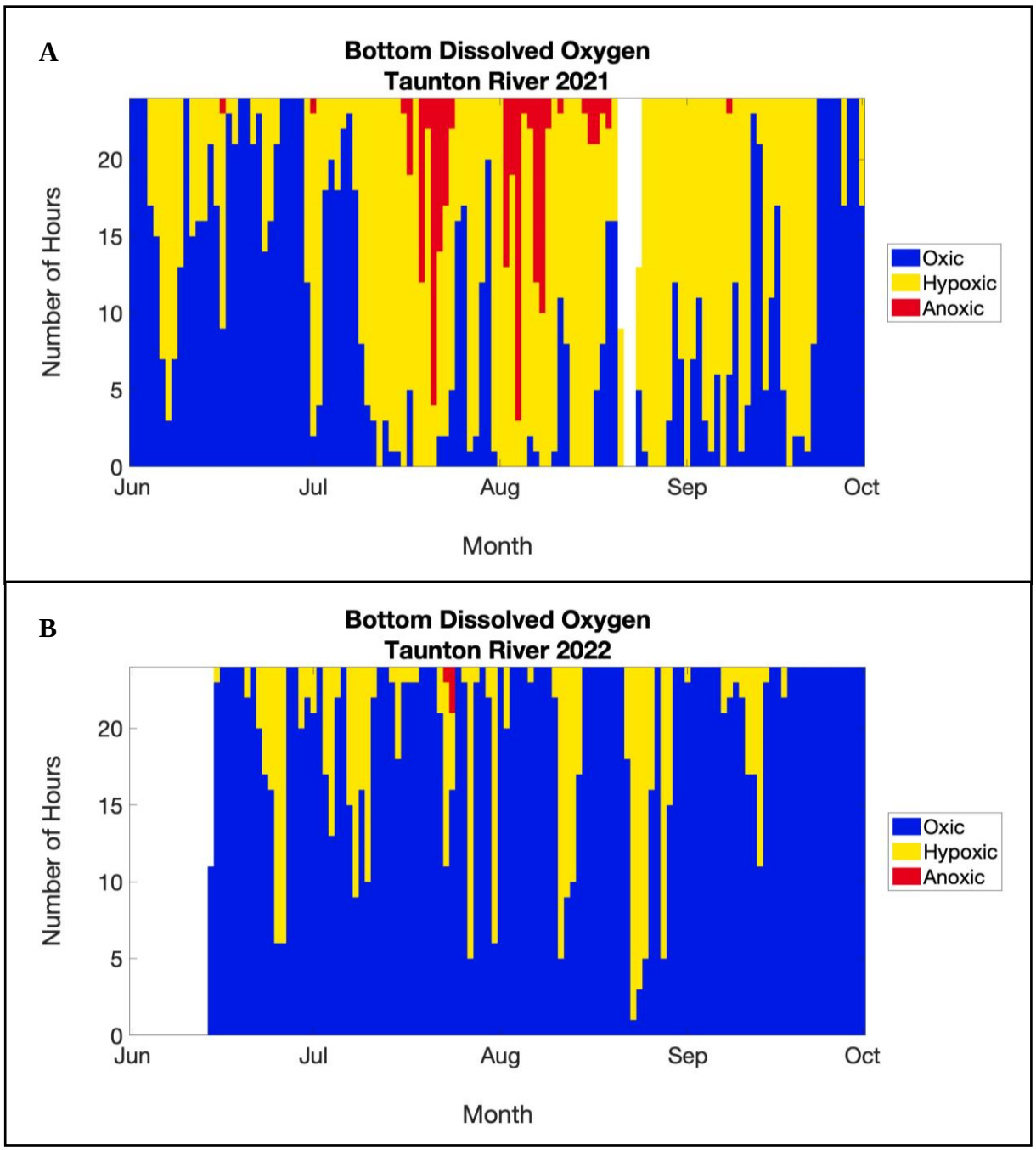

Figure 5a: Hourly dissolved oxygen data measured by the Taunton River bottom sonde in 2021 (A) and 2022 (B). Each vertical bar is a day between June and October. The amount of shaded blue, yellow and red areas note the number of hours of good oxic conditions (> 5 mg/L), hypoxia (between 2.9 mg/L and 5 mg/L) and severe hypoxia/anoxia (< 2.9 mg/L), respectively.

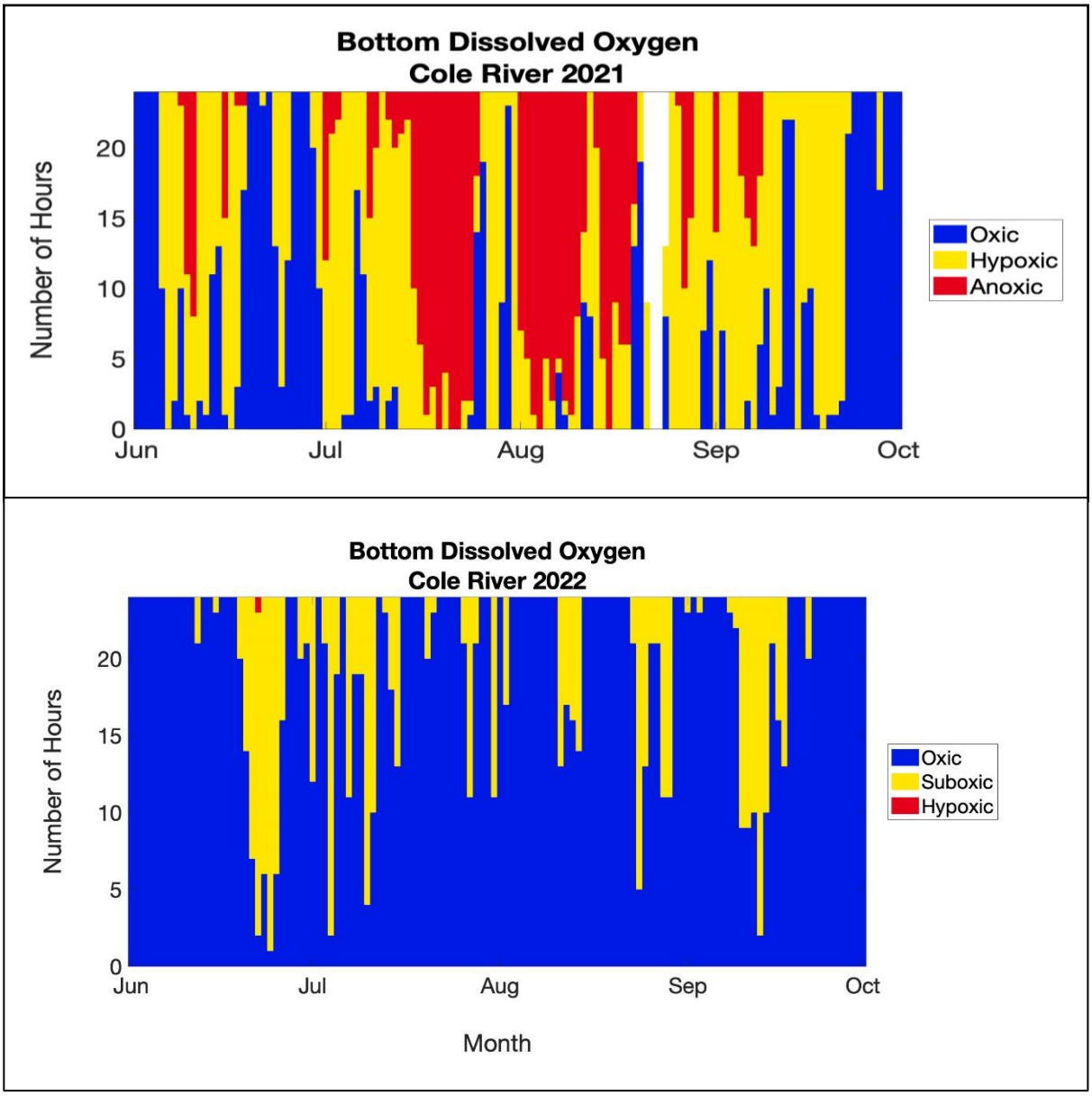

Figure 5b. Hourly dissolved oxygen data measured by the Cole River bottom sonde in 2021 and 2022. Each vertical bar is a day between June and October. The amount of shaded blue, yellow and red areas note the number of hours of oxia (> 5 mg/L), hypoxia (between 2.9 mg/L and 5 mg/L) and anoxia (< 2.9 mg/L), respectively.

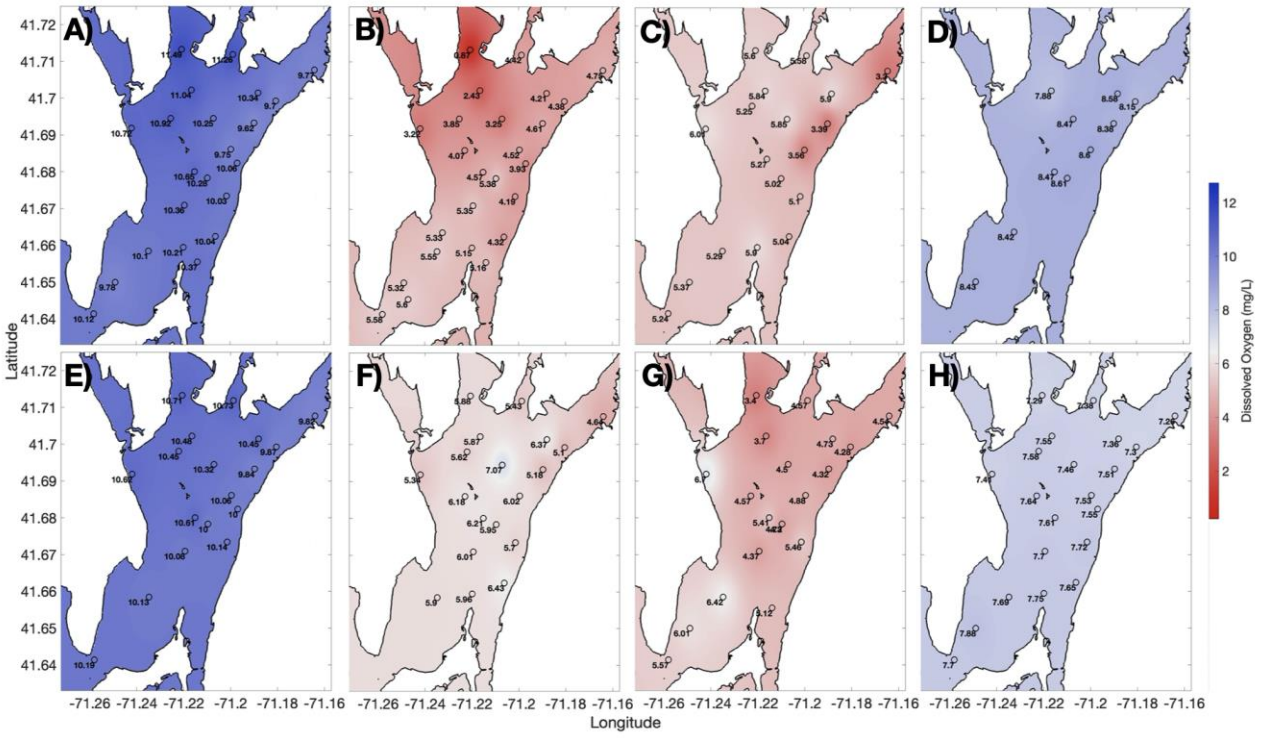

Figure 6. Bottom dissolved oxygen levels during the March, July, August and November 2021 (A-D) and 2022 (E-H) spatial surveys. Localized hypoxia events occurred in July while more widespread hypoxia occurred in August. Waters returned to having sufficient oxygen levels in November.

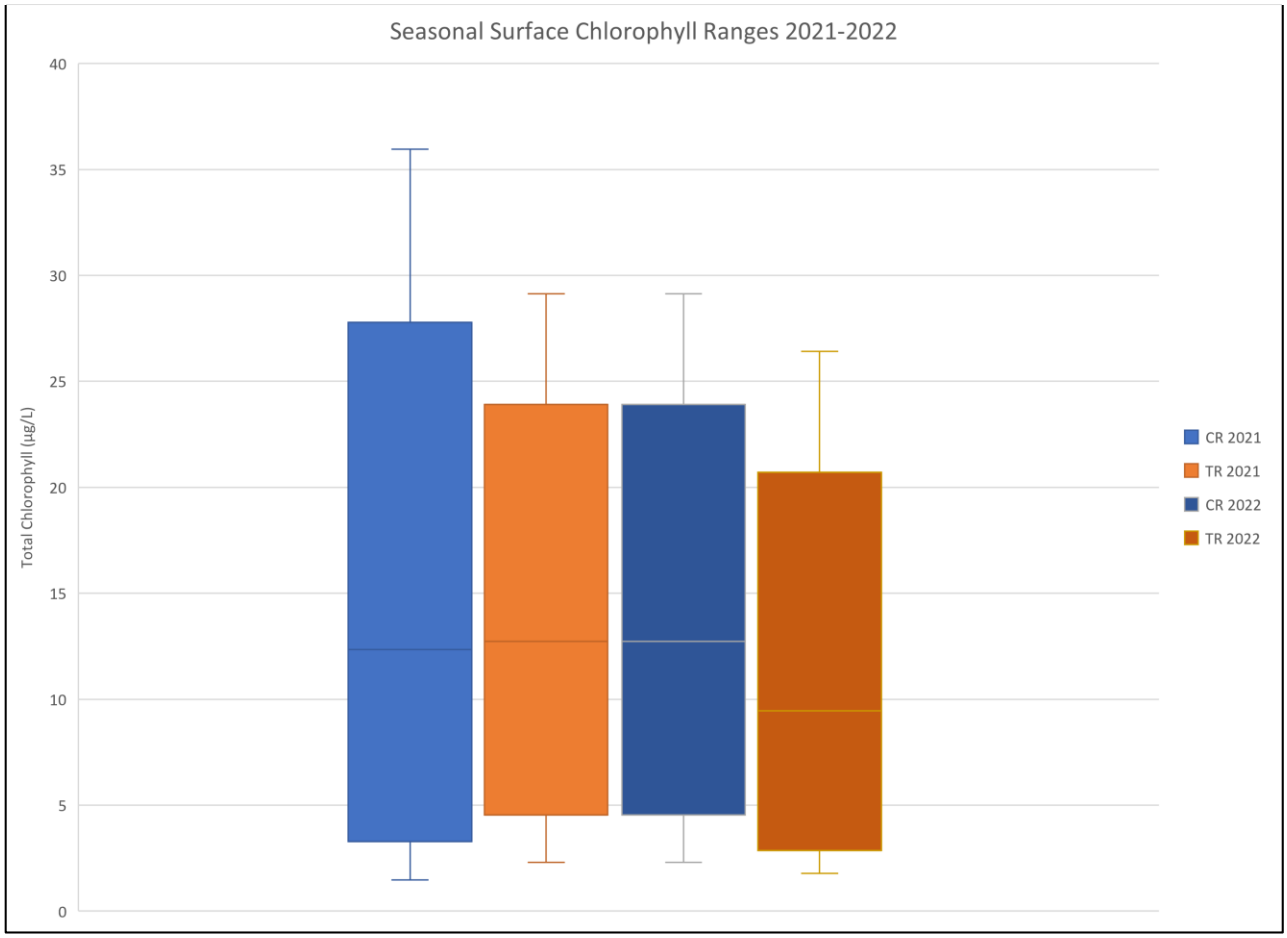

Figure 7. Total surface chlorophyll ranges for Cole River and Taunton River for 2021 and 2022 using daily average readings. Surface daily chlorophyll ranges, based on preliminary sensor data, in box and whisker plots (+/- 1 St deviation around mean with seasonal max and min) at the two buoy locations.

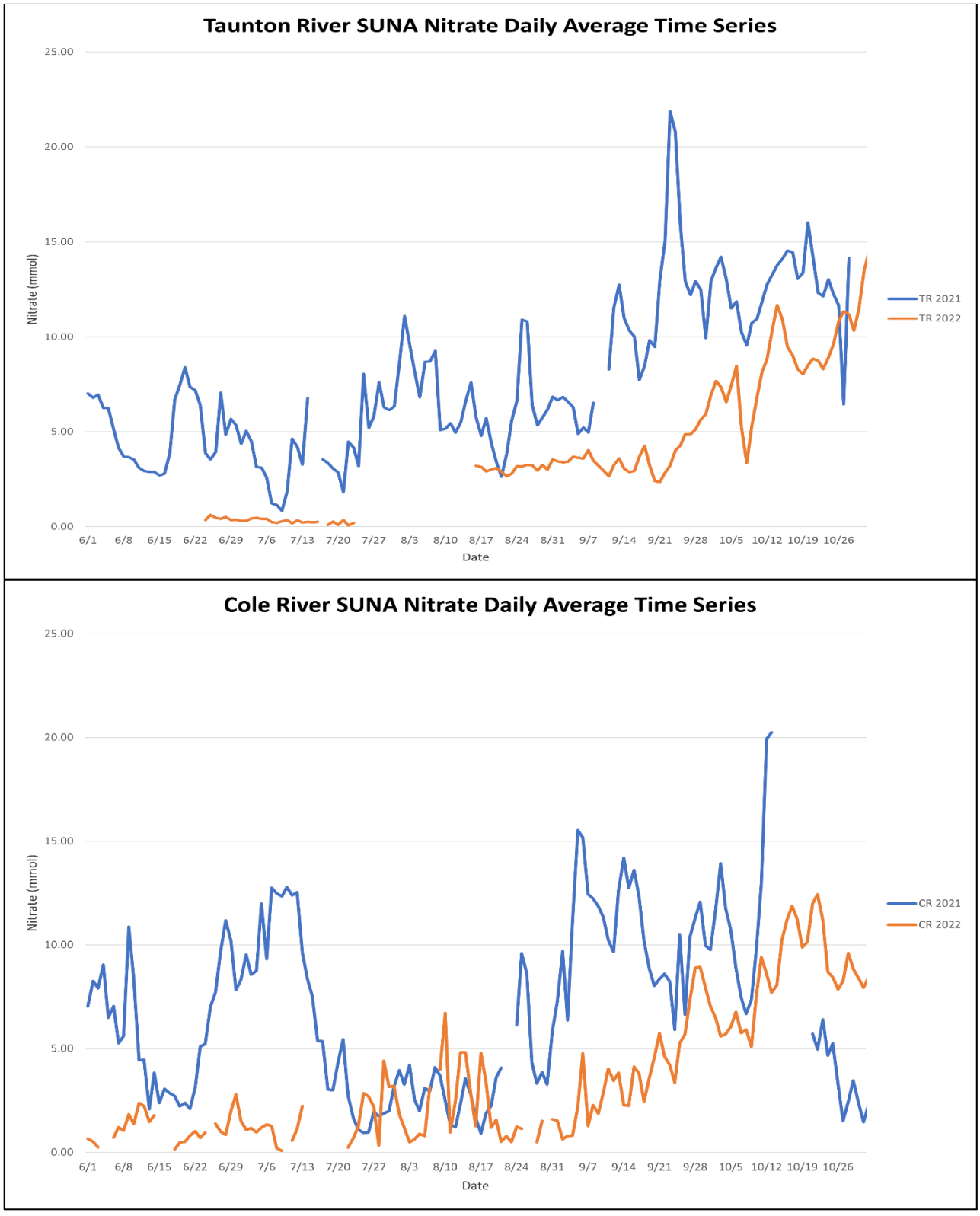

Figure 8. SUNA nitrate time series data using daily averages by site for Taunton River and Cole River (2021-2022). Nitrate has a seasonal pattern with minimums during highest productivity during warm summer months. Nitrate increases in late summer and fall as temperatures cool and productivity decreases.

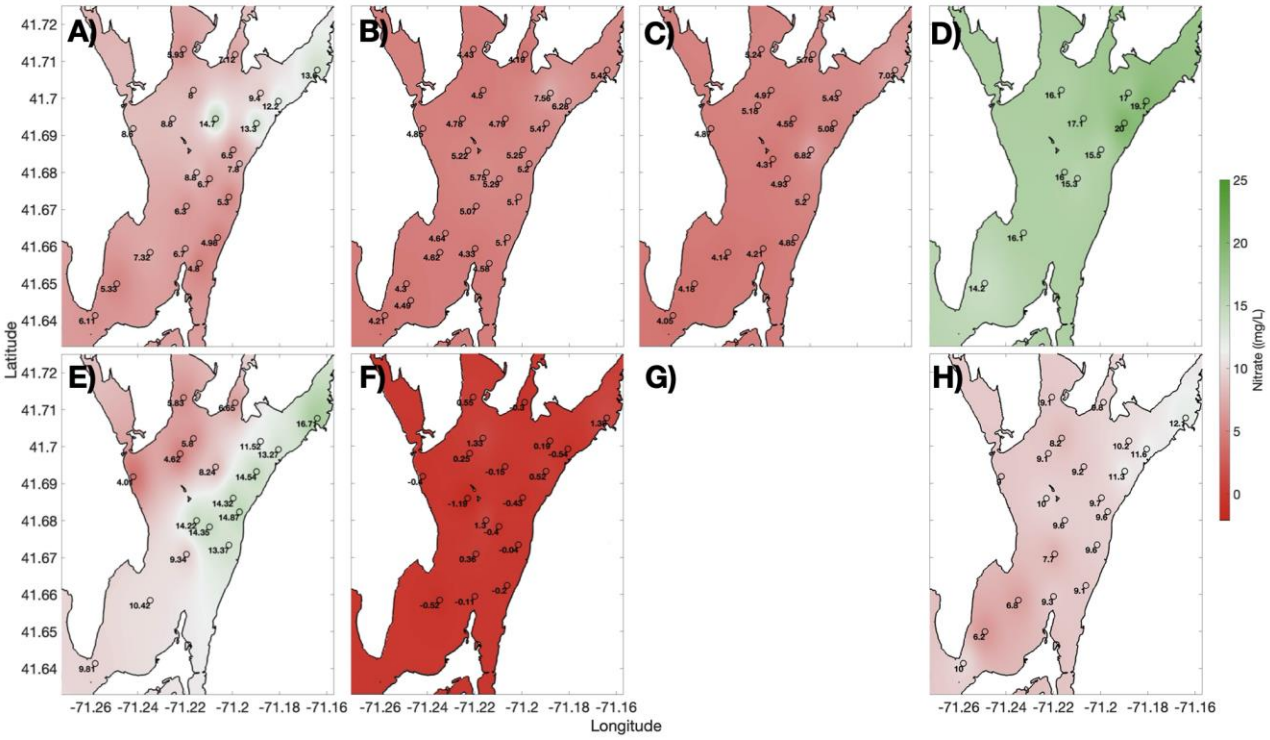

Figure 9. Nitrate levels as measured during the March, July, August, and November 2021 (A-D) and 2022 (E-H) spatial surveys. Note the low values throughout the summer and increasing values in the fall, especially in and near the mouth of the Taunton River.

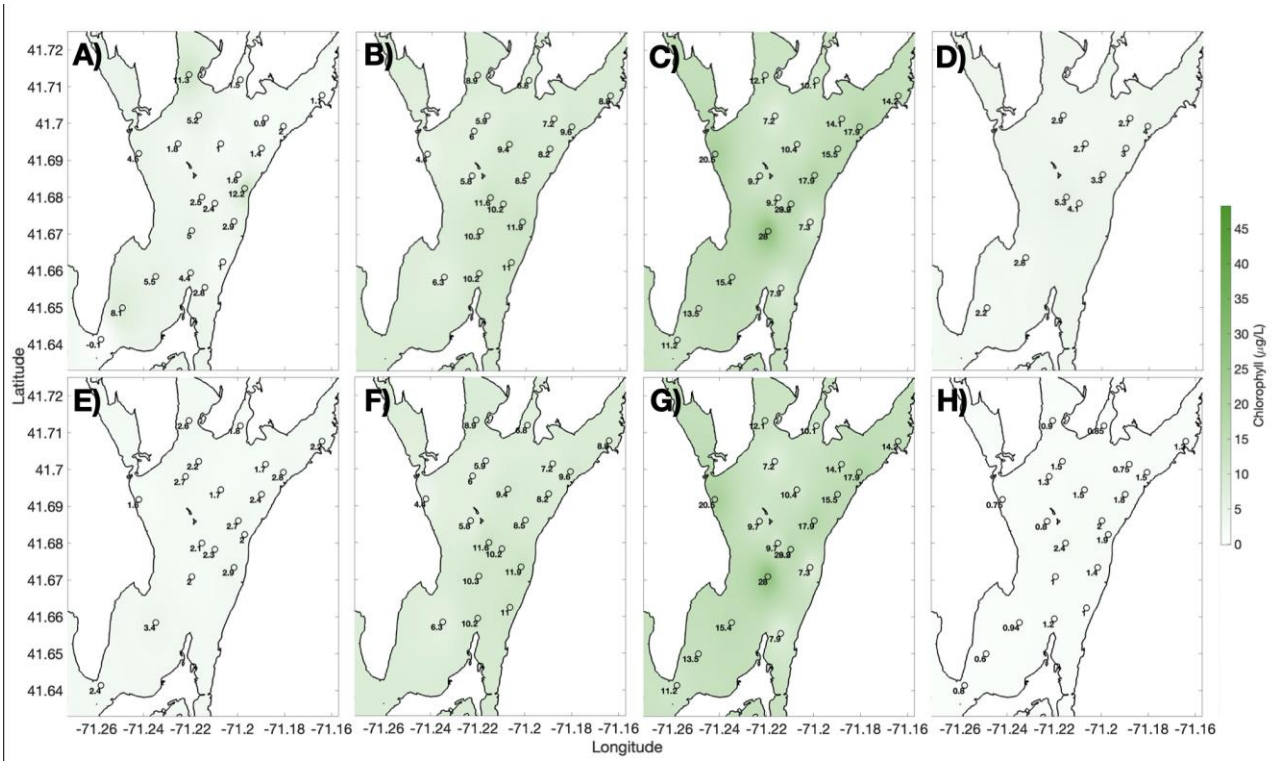

Figure 10. Surface chlorophyll-a levels as measured during the March, July, August and November 2021 (A-D) and 2022 (E-H) spatial surveys.

7. Public outreach publications:

Stoffel, H., DiPanni, R., Reed, L., Potter, M., and Oviatt, C., 2022. The Narragansett Bay Fixed Site Monitoring Network Linking Low Oxygen Events to Fish Kills. Public Poster Session at GSO. December 7, 2022.

Codiga, D., Stoffel, H., Oviatt, C., and 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. https://doi.org/10.3389/fmars.2022.930347

8. References:

Codiga, D., Stoffel, H., Oviatt, C., and 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. https://doi.org/10.3389/fmars.2022.930347

MassDEP, 2021. 314 CMR 4: The Massachusetts Surface Water Quality Standards. https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards.

NBFSMN, 2020. Quality Assurance Project Plan for Narragansett Bay Fixed Site Monitoring Network (NBFSMN) Seasonal Monitoring. https://dem.ri.gov/sites/g/files/xkgbur861/files/programs/benviron/water/quality/surfwq/pdfs/nbfsmn.pdf

Supplement Items:

-POs greater than $1000

-Public Outreach posters and presentation slides

Limited Value Purchase Order

THE
UNIVERSITY
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Date Ordered	Revision	P.O.# 0000195545
01/18/2023		
Payment Terms: Net 30	Freight Terms: FOB DESTINATION	Ship Via: BEST WAY
Buyer: Autocreate	Phone/Email	Due Date: 02/03/2023
Requester: Stoffel,Heather E	Phone: 401/874-6860	Requester Email: stoffel@uri.edu

Supplier: 0000005884
Sea-Bird Electronics Inc
13431 NE 20th Street
Bellevue WA 98005

Bill To: Accounting - aprec@etal.uri.edu
URI, Carlotti Admin. Bldg.
75 Lower College Rd., Suite 1
Kingston RI 02881
(401) 874-7553

Ship To: URI GSO Central Receiving
Narragansett, RI 02882-1197
GSO Faculty
NBC, 20 Receiving Rd.

Tax Exempt? Y **Tax Exempt ID:** 230597640

Line-Sch	Item/Description	Quantity	UOM	PO Price	Extended Amt	Due Date
1-1	SUNA wipers (quote100863672v1)	1.00	TOT	1,354.00	1,354.00	02/03/2023

suna wipers

Amount 1,354.00

NOTES TO VENDOR:

THE ABOVE PO# MUST APPEAR ON ALL INVOICES

Rhode Island law requires that an MSDS be provided for each product containing hazardous chemicals as defined by OSHA and Rhode Island regulations. Please include a copy with the shipment and send an additional copy to the Department of Public Safety, Environmental Health and Safety, 177 Plains Road, Kingston, RI 02881

This purchase is made in accordance with the Board of Governors Procurement Regulations and Conditions of Purchase located at: https://web.uri.edu/purchasing/files/BOGREG.pdf

INTERNAL USE ONLY

Period Accounts	Projects	Activity	Category		Requisition ID	PO Type	FAB
FY2023 5333-500-2802-0000	0008744	RESEARCH	333A	1,354.00	0000210758	LVPO	

CERTIFICATE
I HEREBY CERTIFY THAT THE ITEMS LISTED ABOVE HAVE BEEN RECEIVED IN GOOD CONDITION AND ARE ACCEPTED BY ME. THIS IS A JUST AND PROPER CHARGE AGAINST THE ACCOUNTS LISTED AND HAS NOT BEEN PAID BEFORE. I AM DULY AUTHORIZED TO SIGN THIS CERTIFICATE

X _____ Date 2/20/23
URI Authorized Individual

2/24

Vice President
Administration and Finance

_____
Abigail Rider

Purchase Order

THE
UNIVERSITY
OF RHODE ISLAND

Date Ordered	Revision	P.O.# 0000185669
03/18/2022		
Payment Terms	**Freight Terms**	**Ship Via**
Net 30	FOB DESTINATION	BEST WAY
Buyer	**Phone**	**Due Date**
Soriano, Shanyka L	14018749334	03/24/2022
Requester	**Phone**	**Requester Email**
Breeden, Michelle M	401/874-6136	mbreeden@uri.edu

Supplier: 0000013777
YSI Inc
Aanderaa Data Instruments
Xylem
1725 Brannum Ln
Yellow Springs OH 45387

Bill To: Accounting - aprec@etal.uri.edu
URI, Carlotti Admin. Bldg.
75 Lower College Rd., Suite 1
Kingston RI 02881
(401) 874-7553

Ship To: URI GSO Central Receiving
Narragansett, RI 02882-1197
GSO Grant Management Support
NBC, 20 Receiving Rd.
Attention: Heather Stoffel

Tax Exempt? Y **Tax Exempt ID:** 230597640

Line-Sch	Item/Description	Quantity	UOM	PO Price	Extended Amt	Due Date
1-1	Buoy work	1.00	TOT	9,928.70	9,928.70	03/24/2022

Per the Quote # B201928 attached

Amount 9,928.70

NOTES TO VENDOR:

THE ABOVE PO# MUST APPEAR ON ALL INVOICES

Rhode Island law requires that an MSDS be provided for each product containing hazardous chemicals as defined by OSHA and Rhode Island regulations. Please include a copy with the shipment and send an additional copy to the Department of Public Safety, Environmental Health and Safety, 177 Plains Road, Kingston, RI 02881

This purchase is made in accordance with the Board of Governors Procurement Regulations and Conditions of Purchase located at: https://web.uri.edu/purchasing/files/BOGREG.pdf

Every person or business entity providing goods or services at a cost of $5000 cumulated value is required to file an affidavit regarding political campaign contributions with the RI State Board of Elections even if no reportable campaign contributions have been made. (RI General Law 17-27) Forms can be obtained at the Board of Elections, Campaign Finance Division, 50 Branch Avenue, Providence, RI, 02904 (401-222-2056).

INTERNAL USE ONLY

Period	Accounts	Projects	Activity	Category		Requisition ID	PO Type	FAB
FY2022	5333-500-2802-0000	0008744	RESEARCH	333A	9,928.70	198319	S3SS	

CERTIFICATE

I HEREBY CERTIFY THAT THE ITEMS LISTED ABOVE HAVE BEEN RECEIVED IN GOOD CONDITION AND ARE ACCEPTED BY ME. THIS IS A JUST AND PROPER CHARGE AGAINST THE ACCOUNTS LISTED AND HAS NOT BEEN PAID BEFORE. I AM DULY AUTHORIZED TO SIGN THIS CERTIFICATE.

x Michelle Breeden
URI Authorized Individual

Digitally signed by Michelle Breeden
Date: 2023.01.05 08:16:11 -05'00'

Shanyka Soriano
Buyer

Limited Value Purchase Order

THE
UNIVERSITY
OF RHODE ISLAND

Date Ordered 12/08/2022	**Revision**	**P.O.#** 0000194536
Payment Terms Net 30	**Freight Terms** FOB DESTINATION	**Ship Via** BEST WAY
Buyer Autocreate	**Phone**	**Due Date** 12/19/2022
Requester Stoffel,Heather E	**Phone** 401/874-6860	**Requester Email** stoffel@uri.edu

Supplier: 0000013777
YSI Inc
Xylem
275 Martine St., Ste 200 #12
Fall River MA 02723

Bill To: Accounting - aprec@etal.uri.edu
URI, Carlotti Admin. Bldg.
75 Lower College Rd., Suite 1
Kingston RI 02881
(401) 874-7553

Ship To: URI GSO Central Receiving
Narragansett, RI 02882-1197
GSO Faculty
NBC, 20 Receiving Rd.

Tax Exempt? Y **Tax Exempt ID:** 230597640

Line-Sch	Item/Description	Quantity	UOM	PO Price	Extended Amt	Due Date
1-1	Repair/parts EXO sonde TRB (quote356741)	1.00	TOT	2,496.92	2,496.92	12/19/2022

TRB Sonde parts/repair quote 356741

Amount 2,496.92

$2531.03

NOTES TO VENDOR:

THE ABOVE PO# MUST APPEAR ON ALL INVOICES

Rhode Island law requires that an MSDS be provided for each product containing hazardous chemicals as defined by OSHA and Rhode Island regulations. Please include a copy with the shipment and send an additional copy to the Department of Public Safety, Environmental Health and Safety, 177 Plains Road, Kingston, RI 02881

This purchase is made in accordance with the Board of Governors Procurement Regulations and Conditions of Purchase located at: https://web.uri.edu/purchasing/files/BOGREG.pdf

INTERNAL USE ONLY

Period	Accounts	Projects	Activity	Category		Requisition ID	PO Type	FAB
FY2023	5333-500-2802-0000	0008744	RESEARCH	333A	2,496.92	0000209310	LVPO	

$2531.03

Michelle Breeden

Digitally signed by Michelle Breeden
Date: 2023.02.23 09:40:30 -05'00'

CERTIFICATE

I HEREBY CERTIFY THAT THE ITEMS LISTED ABOVE HAVE BEEN RECEIVED IN GOOD CONDITION AND ARE ACCEPTED BY ME. THIS IS A JUST AND PROPER CHARGE AGAINST THE ACCOUNTS LISTED AND HAS NOT BEEN PAID BEFORE. I AM DULY AUTHORIZED TO SIGN THIS CERTIFICATE.

X _____ Date
URI Authorized Individual

Vice President
Administration and Finance

Abigail Rider

Limited Value Purchase Order

THE
UNIVERSITY
OF RHODE ISLAND

Date Ordered	Revision	P.O.# 0000196279
02/10/2023		
Payment Terms	**Freight Terms**	**Ship Via**
Net 30	FOB DESTINATION	BEST WAY
Buyer	**Phone/Email**	**Due Date**
Autocreate		02/24/2023
Requester	**Phone**	**Requester Email**
Breeden,Michelle M	401/874-6136	mbreeden@uri.edu

Supplier: 0000013777
YSI Inc
SonTek
Division of YSI Inc.
9940 Summers Ridge Road
San Diego CA 92121

Bill To: Accounting - aprec@etal.uri.edu
URI, Carlotti Admin. Bldg.
75 Lower College Rd., Suite 1
Kingston RI 02881
(401) 874-7553

Ship To: URI GSO Central Receiving
Narragansett, RI 02882-1197
GSO Grant Management Support
NBC, 20 Receiving Rd.
Attention: Heather Stoffel

Tax Exempt? Y **Tax Exempt ID:** 230597640

Line-Sch	Item/Description	Quantity	UOM	PO Price	Extended Amt	Due Date
1-1	Sonde Repair	1.00	TOT	1,252.42	1,252.42	02/24/2023

Refer to Service Request # 355998 dated 2/8/23

Amount 1,252.42

NOTES TO VENDOR:

THE ABOVE PO# MUST APPEAR ON ALL INVOICES

Rhode Island law requires that an MSDS be provided for each product containing hazardous chemicals as defined by OSHA and Rhode Island regulations. Please include a copy with the shipment and send an additional copy to the Department of Public Safety, Environmental Health and Safety, 177 Plains Road, Kingston, RI 02881

This purchase is made in accordance with the Board of Governors Procurement Regulations and Conditions of Purchase located at: https://web.uri.edu/purchasing/files/BOGREG.pdf

INTERNAL USE ONLY

Period	Accounts	Projects	Activity	Category		Requisition ID	PO Type	FAB
FY2023	5333-500-2802-0000	0008744	RESEARCH	333A	1,252.42	0000211833	LVPO	

$13.01 Shipping - approved

CERTIFICATE

I HEREBY CERTIFY THAT THE ITEMS LISTED ABOVE HAVE BEEN RECEIVED IN GOOD CONDITION AND ARE ACCEPTED BY ME. THIS IS A JUST AND PROPER CHARGE AGAINST THE ACCOUNTS LISTED AND HAS NOT BEEN PAID BEFORE. I AM DULY AUTHORIZED TO SIGN THIS CERTIFICATE.

Michelle Breeden

Digitally signed by Michelle Breeden
Date: 2023.04.03 09:11:01 -04'00'

X _____ Date

URI Authorized Individual

Vice President
Administration and Finance

Abigail Rider

The Narragansett Bay Fixed-Site Monitoring Network Linking Low-Oxygen Events to Fish Kills

Stoffel, H., DiPanni, R., Reed, L., Potter, M., Oviatt, C.
University of Rhode Island, Graduate School of Oceanography

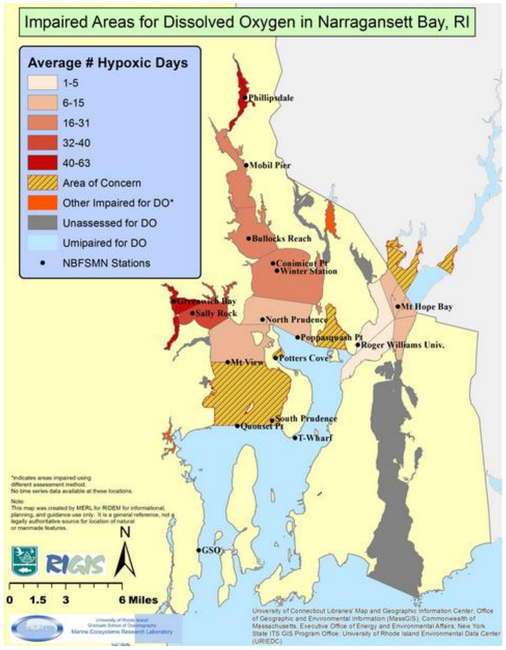
ABSTRACT

About 1/3 of Narragansett Bay is impaired for dissolved oxygen. Seasonal (June-September) intermittent low-oxygen (hypoxia) events have the potential to threaten ecological health. These events are documented in Narragansett Bay, RI using time-series records (2001-present) of temperature, salinity, and dissolved oxygen collected through the Narragansett Bay Fixed-Site Monitoring Network. The data is gathered real-time and posted in weekly summaries to the public. This data is currently used to help assess water quality in the Narragansett Bay.

MONITORING STATIONS

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.

Narragansett Bay Fixed-Site Water Quality Monitoring Network Station Locations



MAP. NBFSMN Station Locations

NBFSMN Partners: DEM-OWR, URI/GSO, Narragansett Bay Commission (NBC), Narragansett Bay National Estuarine Research Reserve (NBNERR), and Narragansett Bay Estuary Program (NBEP).

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

METHODS


Buoy deployment

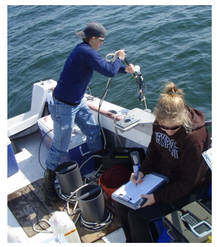
Measurements are made every 15-minutes at 1 meter above bottom and below surface.
Parameters measured are temperature, salinity, and dissolved oxygen at near-surface and near-bottom depths, and near-surface chlorophyll fluorescence.

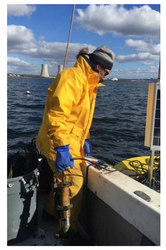
FIELD AND LAB WORK


Nutrient Sampling


Sensor Calibration


Chlorophyll Sampling

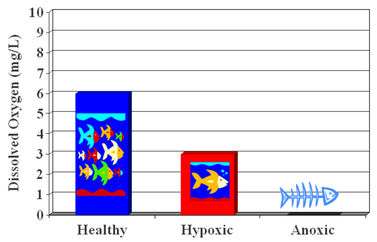

Water Column Profiling

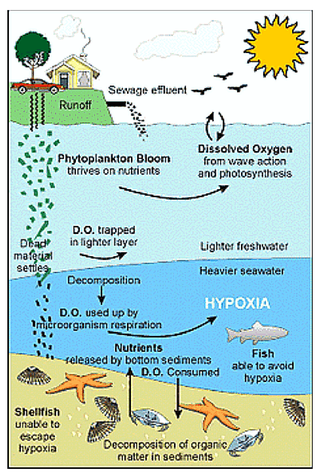

Sonde Swap

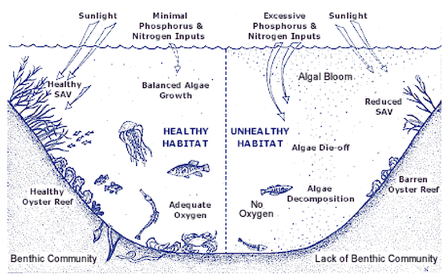

Buoy Servicing

HYPOXIA DESCRIPTION

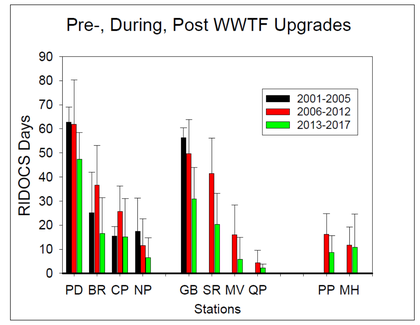
Hypoxia refers low dissolved oxygen (DO) concentrations (daily average oxygen < 2.9 mg O^2/L) that adversely affect organisms.
The State of Rhode Island has DO criteria for Narragansett Bay designed to protect all life stages of aquatic life from excess nutrients which often cause hypoxic conditions.





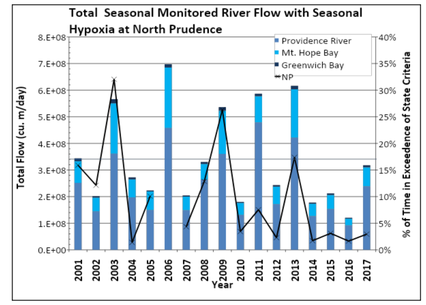


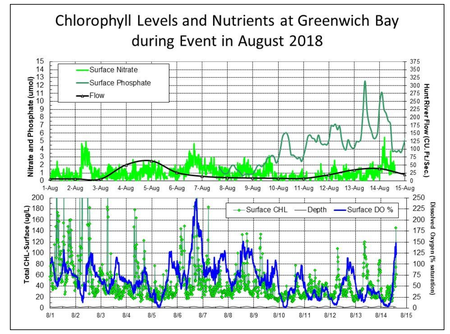
ECOSYSTEM THREATS CASUSED BY LOW OXYGEN



With 50% reduction in nitrogen loading to Narragansett bay completed in 2013, there has been a decrease in total hypoxic days.

Hypoxia remains intermitted influenced by river flow on a seasonal bases. Wet years see more hypoxia events and dry years see less.





On 8/10/2018, about 75-100 dead fish found in the Western part of Greenwich bay.

AGENCY DATA LINKS

The data from the monitoring network is gathered in real-time via cellular connections to give scientist the most up to date data to assess the environmental conditions and response accordingly.

- Real Time DATA link: http://neracoos.org/data/
- URI/GSO-daily observations: https://web.uri.edu/gso/research/marine-ecosystems-research-laboratory/datasets/
- NBC-Narragansett bay commission: https://snapshot.narrabay.com/
- NBNERR-station data available real-time through national program: www.nbnerr.org
- MassDEP-Mt Hope Stations: https://www.mass.gov/info-details/mount-hope-bay-marine-buoy-continuous-probe-data
- ALL DATA SETS- weekly blog, yearly data, and monthly graphics: www.dem.ri.gov/bart

ACKNOWLEDGEMENTS

The monitoring network is funded in part by RIDEM-OWR, MassDEP, SNEP and NERACOOS., EPA Clean Water Act (sections 319 & 106), NBC, and NBNERR. Thank you to all that contribute to NBFSMN.

Upper Mt Hope Bay Water Quality Monitoring through Narragansett Bay Fixed Site Monitoring Network (NBFSMN)

Flecchia,N., Stoffel, H., Reed, L., Huizenga, K., Secor, R., Oviatt, C.
University of Rhode Island, Graduate School of Oceanography

University of Rhode Island
Graduate School of Oceanography
Marine Ecosystems Research Laboratory

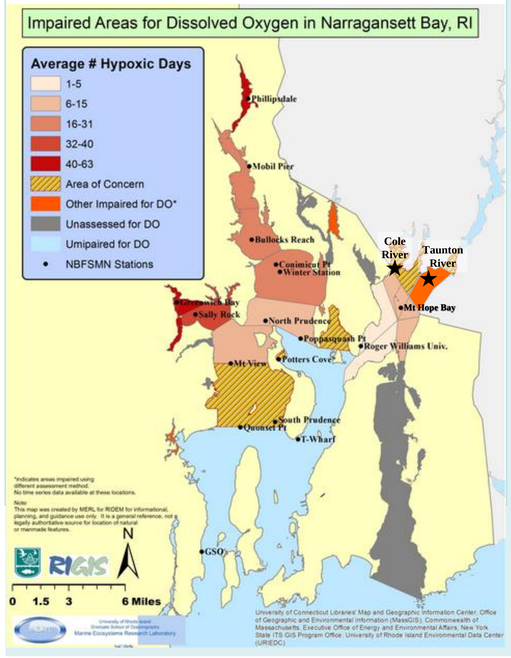
ABSTRACT

About 1/3 of Narragansett Bay is impaired for dissolved oxygen. Seasonal (June-September) intermittent low-oxygen (hypoxia) events have the potential to threaten ecological health. These events are documented in Narragansett Bay, RI using time-series records (2001-present) of temperature, salinity, and dissolved oxygen collected through the Narragansett Bay Fixed-Site Monitoring Network. This project focused on Upper Mt Hope Bay because it was critical data gap for managers. This data is currently used to help assess water quality in the Upper Mt Hope Bay area of Narragansett Bay.

MONITORING STATIONS

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.

Narragansett Bay Fixed-Site Water Quality Monitoring Network Station Locations



PICTURE. NBFSMN buoy with continuous, remote water quality monitoring equipment attached.

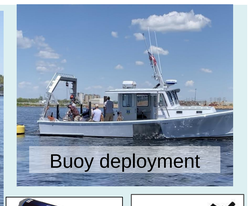
MAP. Narragansett Bay hypoxia map with NBFSMN station locations. **Upper Mt Hope Bay stations (stars) are funded through SNEP grant .**

(SNEPWG20-6-URI-MHB)

NBFSMN Partners: RIDEM-OWR, URI/GSO, Massachusetts Department of Environmental Protection (MassDEP), Narragansett Bay Commission (NBC), Narragansett Bay National Estuarine Research Reserve (NBNERR), and Narragansett Bay Estuary Program (NBEP).

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

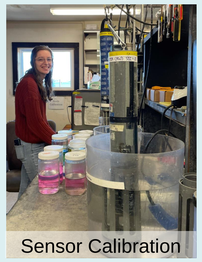
METHODS


Buoy deployment

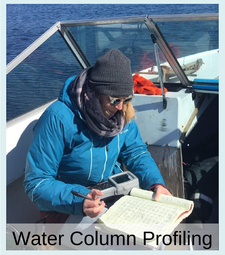
Measurements are made every 15-minutes at 0.5 meter above bottom and 1 meter below surface.
Parameters measured are temperature, salinity, pH, dissolved oxygen and chlorophyll-a fluorescence. All data in results are considered preliminary.

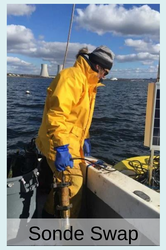
FIELD AND LAB WORK

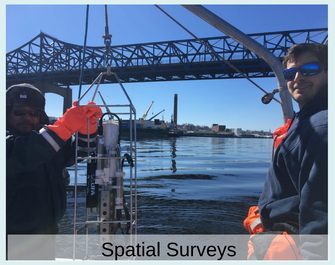

Nutrient Sampling


Sensor Calibration


Chlorophyll Sampling

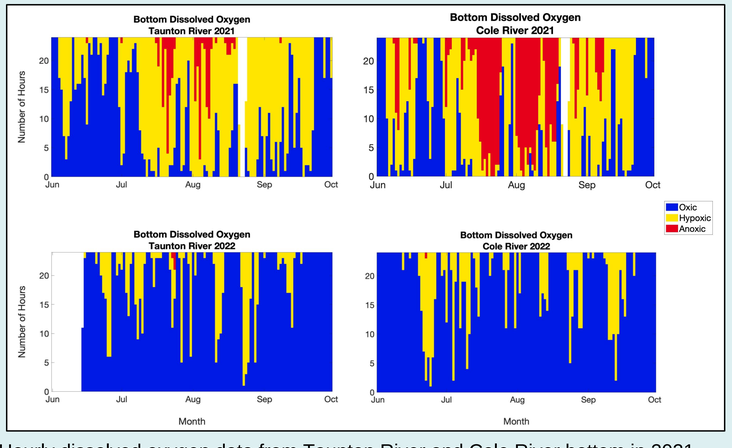

Water Column Profiling


Sonde Swap

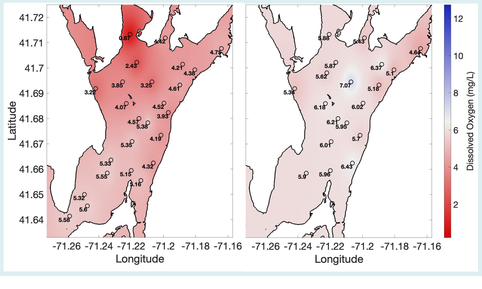

Spatial Surveys

HYPOXIA DESCRIPTION

Hypoxia refers low dissolved oxygen (DO) concentrations that adversely affect organisms. The states of Massachusetts and Rhode Island have DO criteria for Narragansett Bay designed to protect all life stages of aquatic life.

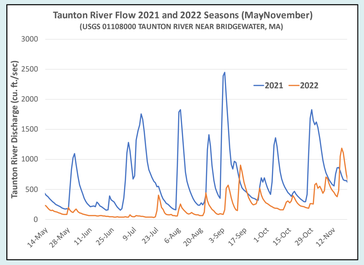


Hourly dissolved oxygen data from Taunton River and Cole River bottom in 2021 (top row) and 2022 (bottom row). Each vertical bar is a day between June and October. The amount of shaded blue, yellow and red areas note the number of hours of good oxic conditions (> 5 mg/L), hypoxia (between 2.9 mg/L and 5 mg/L) and severe hypoxia/anoxia (< 2.9 mg/L), respectively.

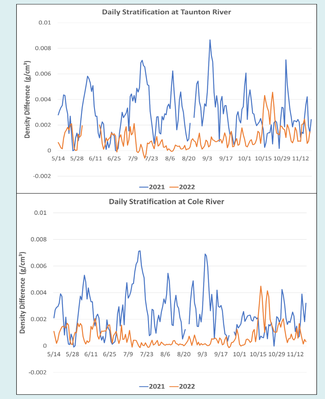


Bottom dissolved oxygen data collected from spatial surveys during July of 2021 (left) and 2022 (right).

FORCING FACTORS ON LOW OXYGEN 2021-2022

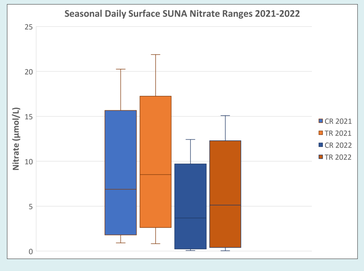


Hypoxic conditions are often caused by excess nutrients and salinity-driven stratification. Hypoxia is seasonally and event driven by river flow. Wet years see more hypoxia events and dry years see less. Wet summer seasons allow for stratification to build and block vertical mixing along with delivering larger amounts of nutrients from rivers.

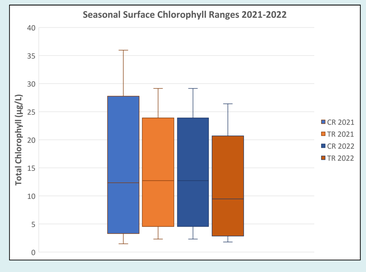


Stratification is more pronounced in 2021 vs 2022 and track event pulses based on river flow data. Taunton River has higher peaks in density differences than Cole River due to larger river discharge.

Nitrate levels were higher in 2021 vs 2022. More nutrients can be delivered to the estuary during wet summers via river flow and rainfall events.



As a result, Chlorophyll levels were also higher in 2021 vs 2022. More nutrients can be delivered to the estuary during wet summers via river flow and rainfall events. Chlorophyll levels tend to be higher at Cole River than Taunton River potentially contributing to more intense hypoxic events.



CONCLUSIONS & AGENCY DATA LINKS

Continued funding for monitoring is essential for public, managers and scientists. The spatial and temporally continuous monitoring can be used in conjunction to determine the full extent of a low oxygen event and allow management insight on focus areas.

The data from the monitoring network is gathered in real-time via cellular connections to give scientist and the public the most up to date data to assess the environmental conditions and response accordingly.

- MassDEP-Mt Hope Stations: https://www.mass.gov/info-details/mount-hope-bay-marine-buoy-continuous-probe-data
- ALL NBFSMN DATA SETS- weekly blog and yearly data: www.dem.ri.gov/bart

ACKNOWLEDGEMENTS

This project was funded through SNEP under SNEPWG20-6-URI-MHB with match from MassDEP. NBFSMN is funded by all participating partners (RIDEM-OWR, MassDEP, SNEP, NBC, NBNERR, and NERACOOS.) NBFSMN has also been funded in part by EPA Clean Water Act (sections 319 & 106) over the years. Thank you to all that contribute to NBFSMN.

Upper Mt Hope Bay Water Quality Monitoring

SNEP 2020: SNEPWG20-6-URI-MHB

PI: Heather Stoffel and Dr. Candace Oviatt
University of Rhode Island
Graduate School of Oceanography

Project Partners:

University of Rhode Island GSO Graduate School of Oceanography

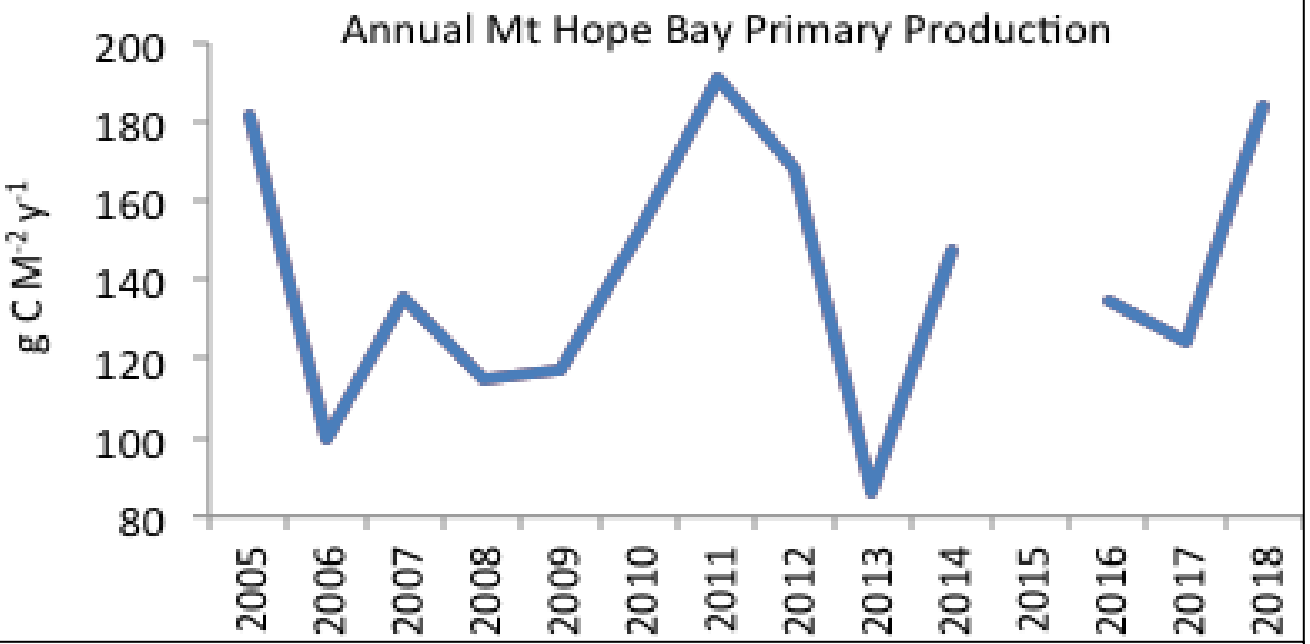
MassDEP Commonwealth of Massachusetts Department of Environmental Protection

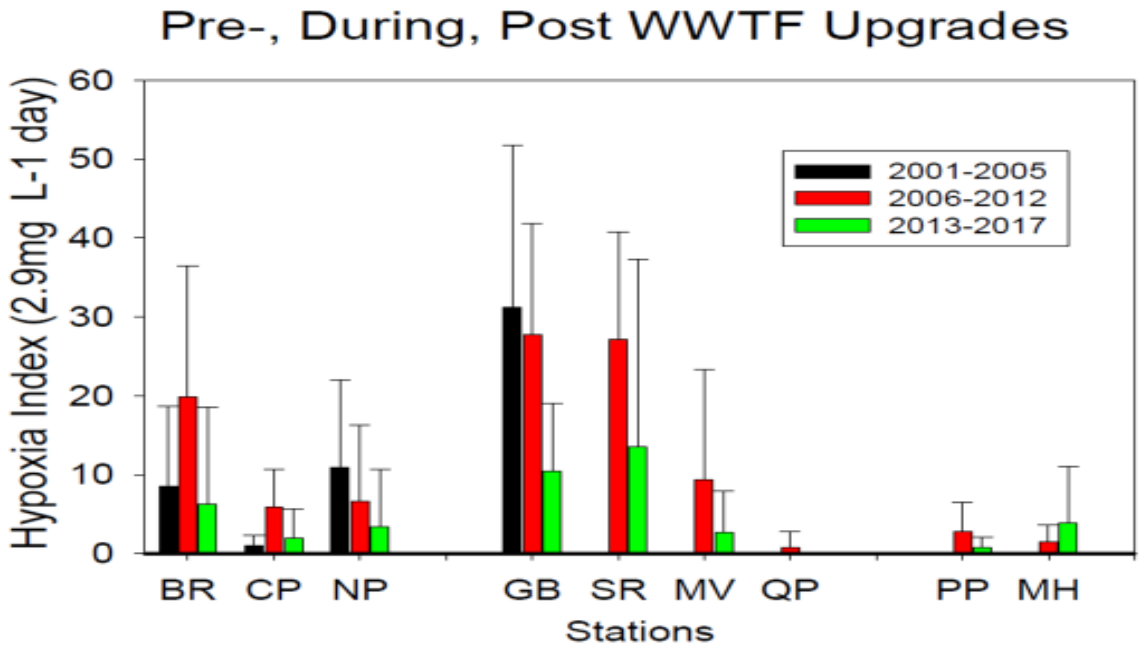
Other Narragansett Bay Fixed Site Monitoring Network Partners:

RIDEM

Narragansett Bay Research Reserve
Based on Prudence Island

NERACOOS





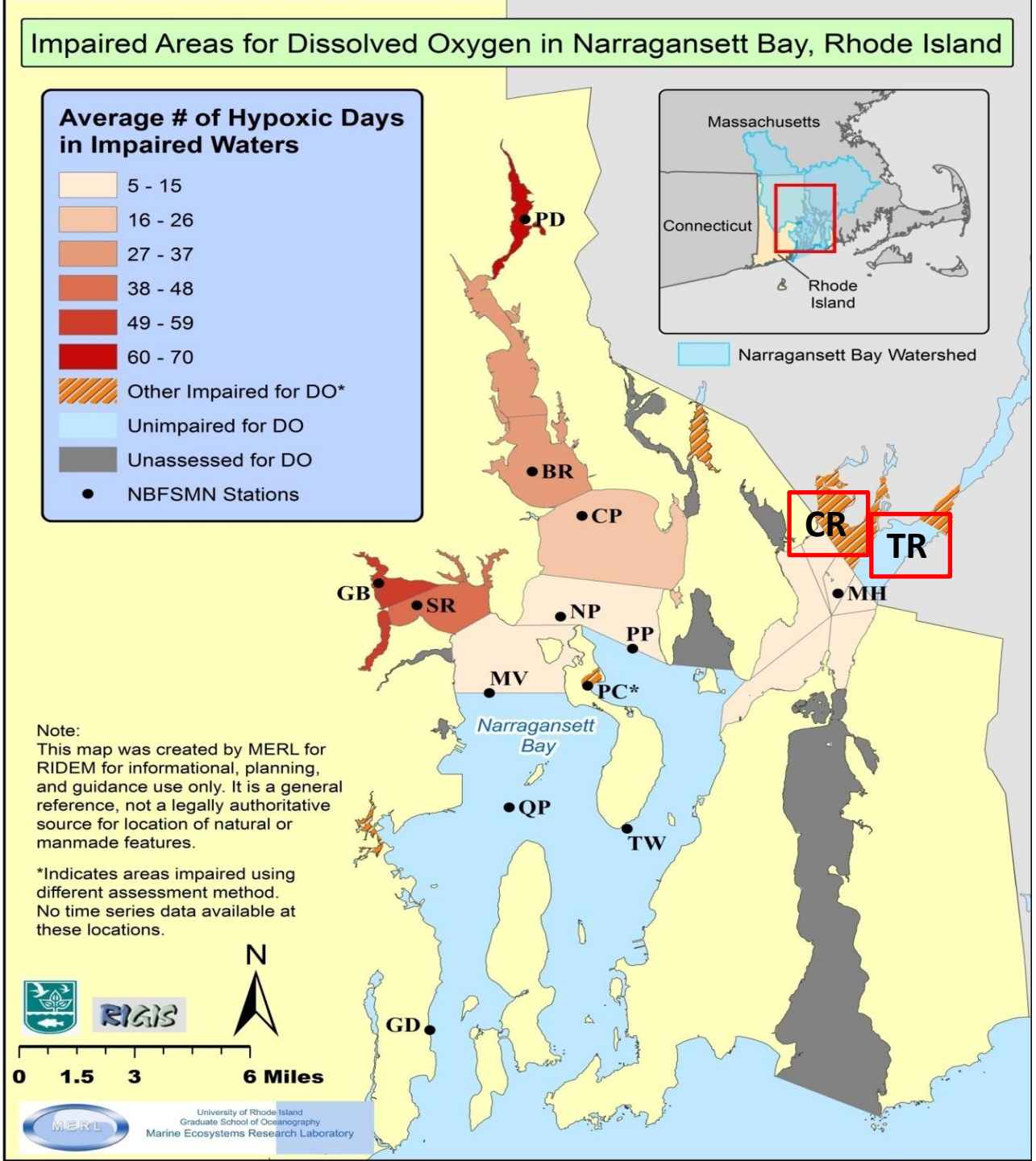
2.9 threshold is consistent with RIDOCS: Decrease of hypoxia in UWP

Since 2012, about a fifty percent (50%) reduction in the total loading of nitrogen into Narragansett Bay was achieved through upgrades to wastewater treatment plants in both Rhode Island and Massachusetts.

In addition, Mt. Hope Bay has recently undergone changes not only to nutrient loadings from Narragansett Bay watershed wide reduction efforts, but also fluctuations in temperature and circulation patterns from operational changes to the power plant within Mt. Hope Bay.

Primary production in the Bay had dropped after nitrogen reductions in 2005 and 2012 but recovered both times, indicating sustained nutrient sources (Figure 1).

Hypoxia is also showing signs of increasing compared to other stations throughout Narragansett Bay (Figure 2).



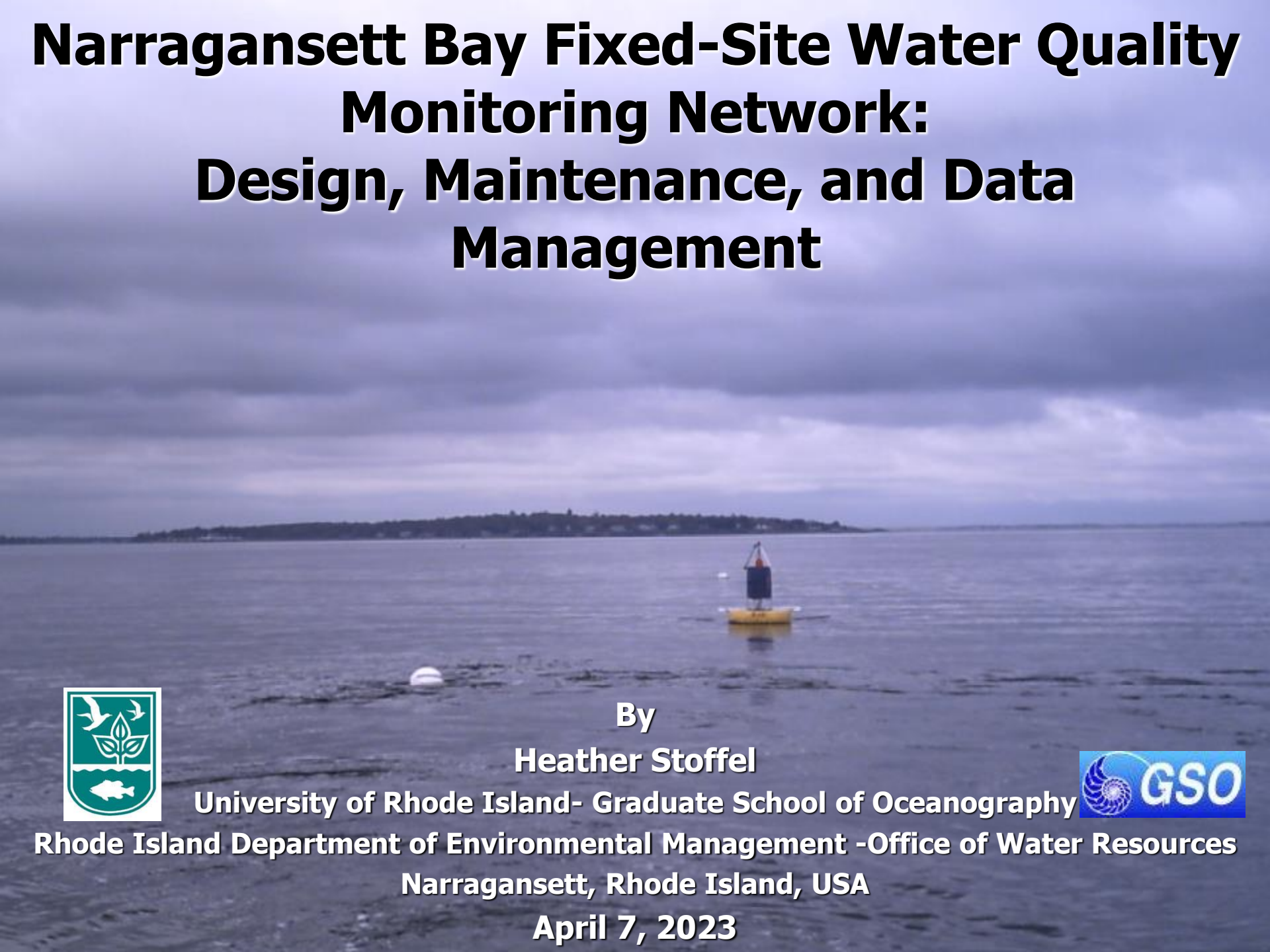
Purpose and Goals: Support monitoring efforts in Mt Hope Bay, focusing on upper Mt Hope Bay area. Conduct spatial surveys to improve understanding of the extent of hypoxia in Mt Hope Bay.

SNEP Project Partners: MassDEP will provide match through equipment and support through an existing contract with URI and MassDEP.

Project Timeline: Monitoring conducted Jan 2021-Dec 2022 (Buoy monitoring May-Oct 2021 & 2022) 4 spatial surveys in Mt Hope Bay

NBFSMN Program Partners Operating Stations in the Network: The NBFSMN is a collaborative effort to continuously monitor physical water quality parameters at 14 stations within Narragansett Bay, primarily from May – October, annually. Partners: RIDEM-OWR, URI/GSO, Narragansett Bay Commission, NBNERR, MassDEP, NERACOOS

Narragansett Bay Fixed-Site Water Quality Monitoring Network: Design, Maintenance, and Data Management



By

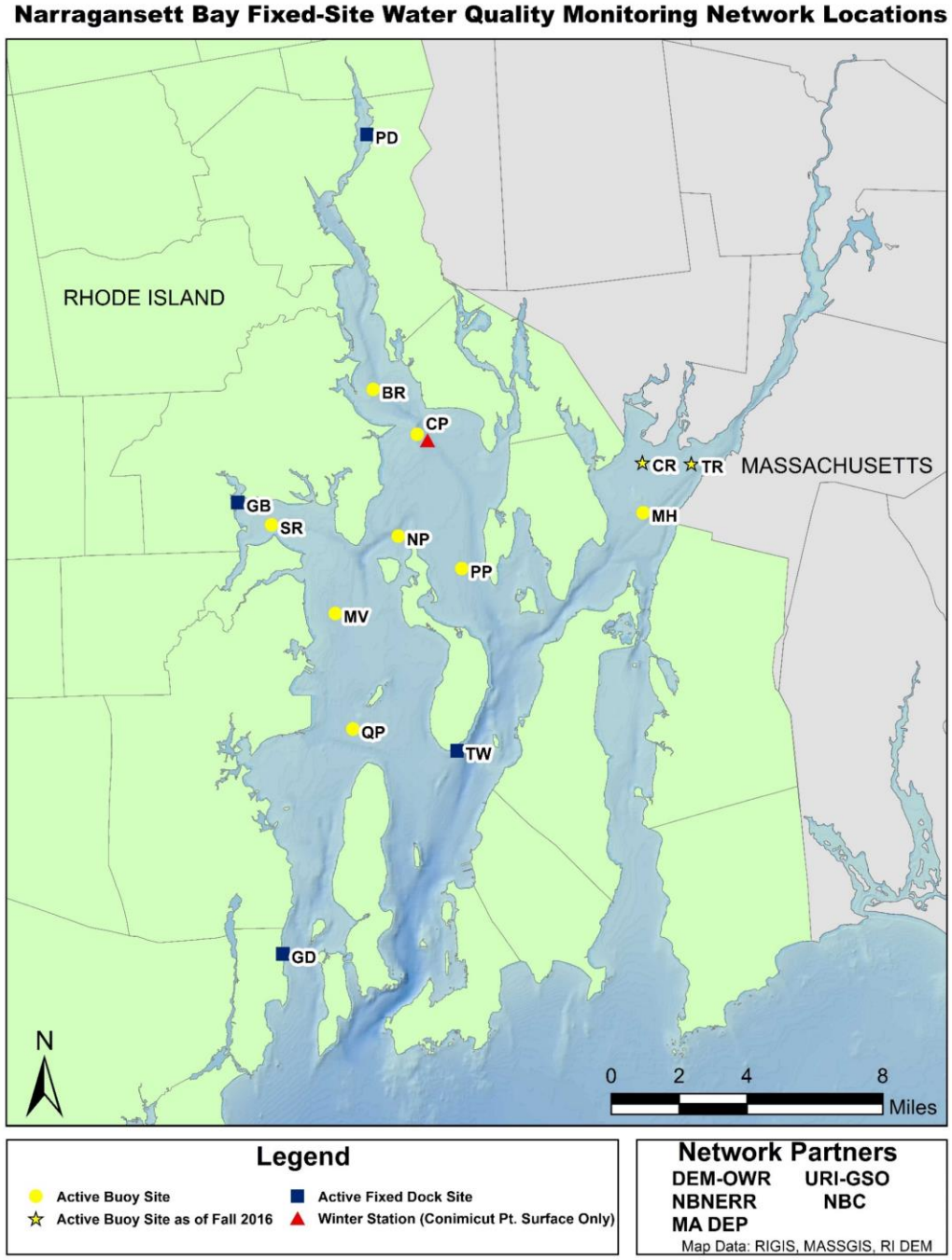
Heather Stoffel

University of Rhode Island- Graduate School of Oceanography

Rhode Island Department of Environmental Management -Office of Water Resources

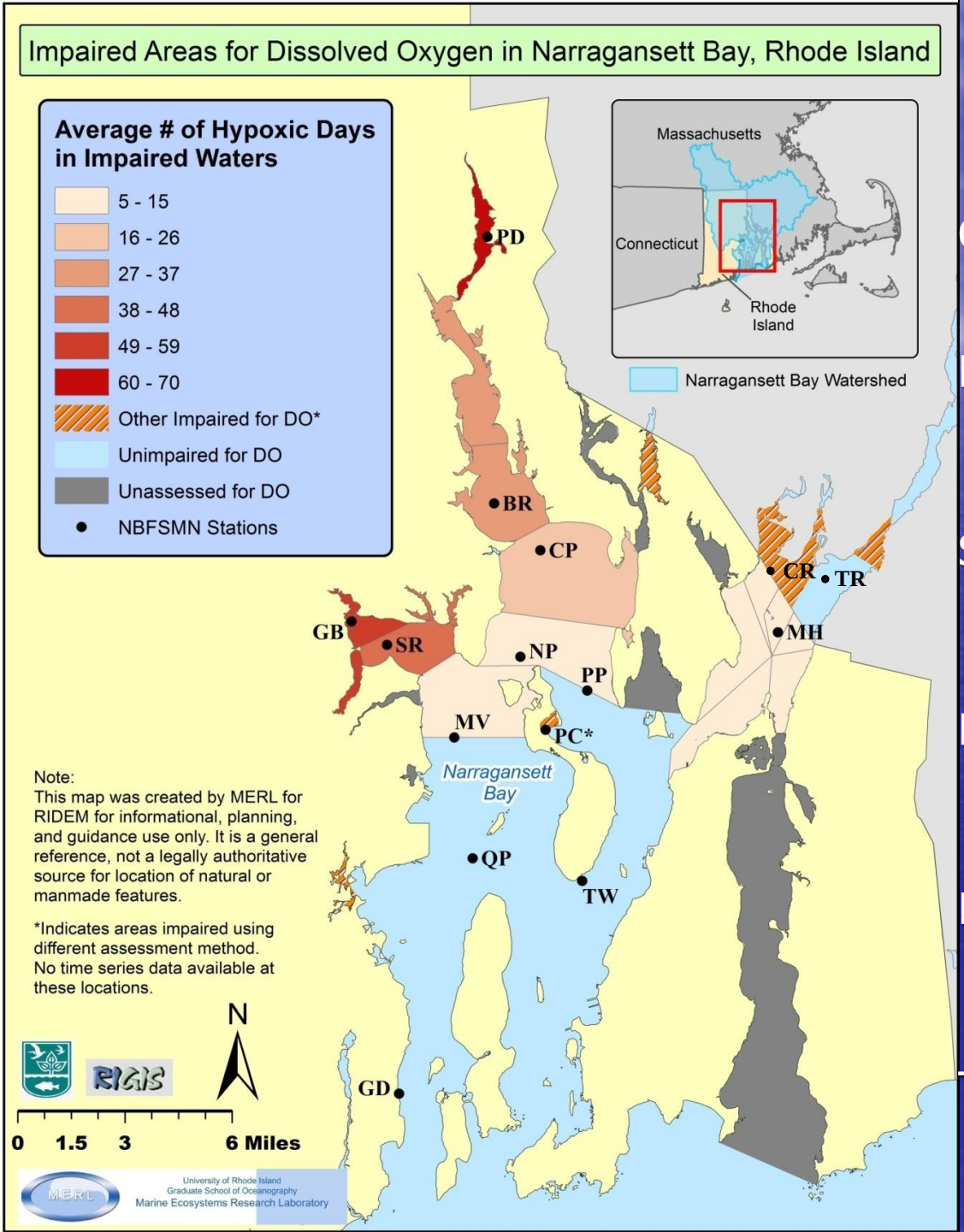
Narragansett, Rhode Island, USA

April 7, 2023



Monitoring Network

- Monitoring focuses on critical areas primarily for assessment purposes (point-source discharge)
- The NBFSMN is a collaborative effort to continuously monitor water quality at 14 stations within Narragansett Bay, primarily from May – October, annually.
- Using a continuous long-term monitoring approach



Purpose of NBFSMN

- Complex coastline with multiple passages and embayments
- 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

Fixed-Site Water Quality Monitoring Network Costs/Funding Sources

Annual Support: RIDEM-OWR, URI/GSO, NERACOOS, NBNERR, MassDEP, Narragansett Bay Commission (WWTFs)

Grant Support: USEPA, SNEP, NOAA

Buoy Annual Operational Costs Estimates:

-start up cost per buoy= $100,000-$150,000 US

-staff= 3 (field, lab, & QA/QC staff) & student support

-maintenance per site=$5000-8000 & repairs/upgrades= $15,000 (3-5 yr)

What is Time-Series Data & Uses?

- **Continuous water quality monitoring of the physical conditions**
- **Data used for event response, assessments, research needs, and permit compliance**
- **Other Supporting Data: spatial surveys, weather, tidal & flow data**

Data Collection

YSI EXO V2

<u>YSI Brand:</u>
Temperature
Salinity
Dissolved Oxygen
pH
Chlorophyll
Turbidity
Depth

<u>Seabird Brand</u>:
Seabird 19 Plus
SUNA (Nitrate sensor)
Phosphate

Station Design: Land-Based & Buoys

Stations are equipped with near surface and near bottom YSI sondes.

Surface Sensors: Temp, Sal, DO, pH, CHL, and Nitrate sensor* (*4 locations)

Bottom Sensors: Depth, Temp, Sal, DO, pH, Turbidity* (*3 locations)

Data is collected every 15 minutes and is transferred to a base station computer 1-2 times per day via cell phone modem.

This buoy design has been used in water depths up to 12m on seasonal basis. Land-based design operate year-round.

Buoy Design and Methodology

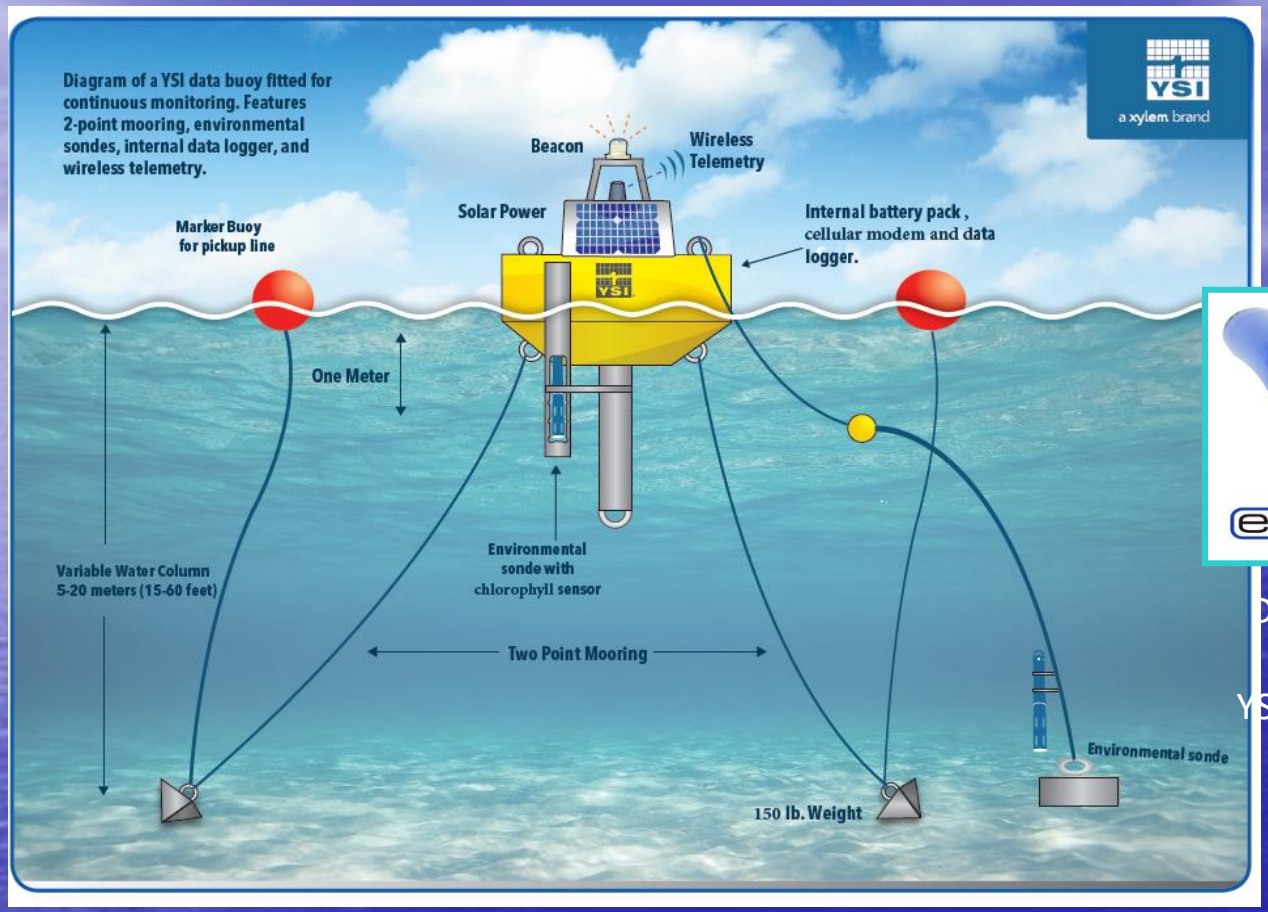


Diagram and sonde photo courtesy of YSI/Xylem Integrated Systems

Methodology: Narragansett Bay is equipped with network compatible equipment (YSI Brand). The NBFSMN stations are in critical areas for evaluating the recent management decisions to reduced nitrogen loadings to the bay and in known areas with water quality issues to provide information during event scenarios (ie fish kills). These stations provide web-based data delivery, custom data acquisition and data visualization systems using network partnered data portals.

Maintenance/Deployment Schedule

- Each agency is responsible for maintaining their own water quality stations
- Buoy stations are operational seasonally & land-based stations are operational year-round
- Bi-monthly sonde swap during high fouling times (summer)

  -fouling factors, damage
- 3-week deployments during low fouling times
- Battery and memory length of sonde
  - **4 weeks maximum**

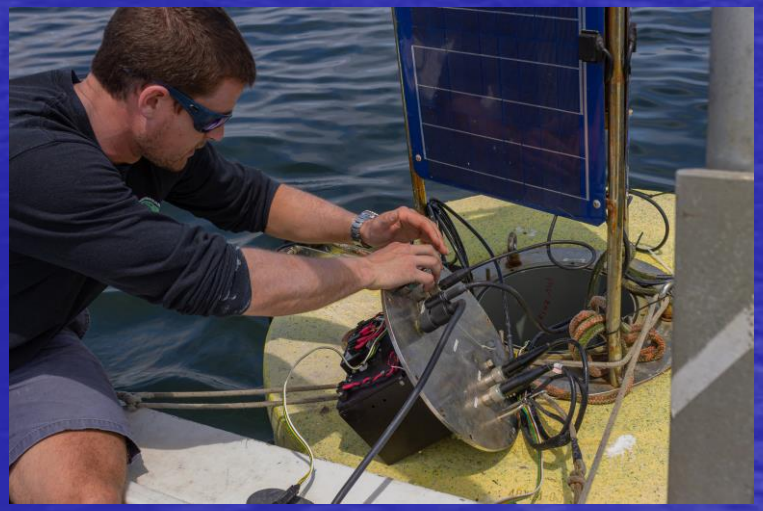
Buoy, Land-Based Stations and DCP Maintenance

- Complete check all equipment seasonally
  - Cables, antenna, DCP, batteries, solar panels, etc.
  - Test all equipment before buoy deployment
  - Visually inspect for damage during each sonde swap

Common Sensor Damage

1. CHL-scratches on optics & dirty or spread-out wiper
2. DO membrane replacement every 2 yrs
3. PH sensor caps replacement required every 12-18 months
4. Corrosion on C/T bulkhead connector/ PINS breaking on EXO wipeable C/T sensor(water damage)
5. Check for common signs of damage seasonally

Troubleshooting other Problems

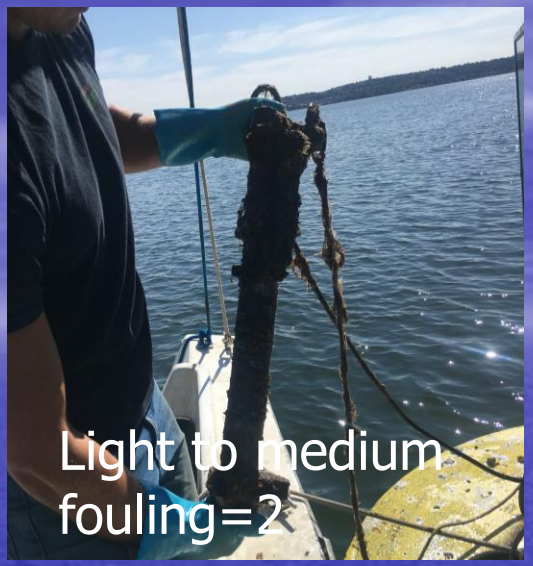


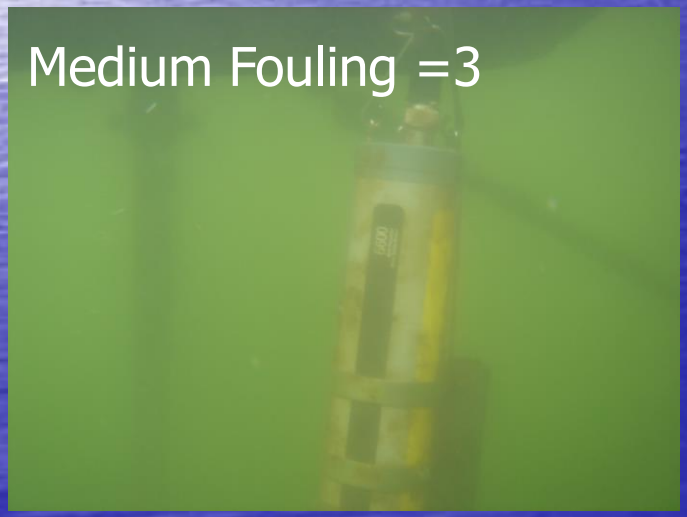
- Water damage & stress on cables
  - Plan replacement every 5 years depending on use
- O-Rings: change regularly (seasonally)
  - Check connections for corrosion
  - Flexibility in connector casing or pealing of casing
- Communication issues: cellular modem, configuration files, update codes, etc.
  - Update sonde codes and configuration files seasonally
- Boat traffic & vandalism

Limiting Fouling Effects on Data

1. Use copper tape/ protective sleeves on sensors
2. Maintenance scheduling 10-14 day periods during summer. Three to four weeks in the winter.
3. YSI Extended Deployment System (central wiper). Remember to change wiper with deployment.
4. Crab guards and brass guards. Prevent animals and fouling from damaging sensor without reducing flow.
5. Proper cleaning when sondes in lab.
6. Having 2 sets of sondes per station

Fouling Scale





Data QA/QC Procedures

1. Triple check sonde swap data- profile, last reading of retrieved sonde, first deployment reading of new sonde, & other field sampling (i.e. nutrients, chlorophyll samples).
2. Post-deployment check-observe all sensors in clean standards before cleaning to check accuracy. Note fouling.
3. Plot all parameters data from the site (surface & bottom plot together).
4. Run check for outliers (95% rule, 2X neighbor rule, 2X Stdev rule).
5. Check for calibration errors or offsets & sensor failures using triple check info & plots.
6. Check for fouling effects (somewhat subjective).
7. Note all suspicious data in metadata document.

All procedures are outlined in NBFSMN QAPP:
https://dem.ri.gov/environmental-protection-bureau/water-resources/research-monitoring/narraganset-bay-assessment-0

Software Tools

- YSI *Kor and Ecowatch*
  - Used for communication with instrumentation & quick view files
- *Streamline* by Interactive Oceanographic
  - View data, process data, initial QA/QC of data, & generate reports
- *Excel* (macros)
  - QA/QC data, format data for distribution
- *Sigmaplot* graphics
  - Plot data for distribution & analysis
- *Matlab/R*
  - Analysis of data

Absolute Data Deletions

- **No sensor installed Values:** All probes will register a value even if there is no sensor installed on the sonde

- **Times of pre- and post-deployment when transporting the sonde:** (missing time stamps or readings out of the water)

- **An Unexpected Tidal Fluctuation or an Improperly Deployed Sonde:** if not deployed at designated depth (i.e. sub-surface or readings while sonde is in the mud)

- **Always reject data that are outside of the range of the probes:**

  Temperature: -5 to 45 oC
  Specific Conductivity: 0 to 100 mS/cm
  Salinity: 0 to 70 ppt
  Dissolved Oxygen (% Saturation): 0 to 200, 200-500
  Dissolved Oxygen (mg/L): 0 to 20 and 20 to 50 mg/L
  Shallow Depth: 0 to 9.1m
  pH: 2 to 14 units
  Chlorophyll: 0 to 500 ug/L
  Turbidity: 0 to 1000 NTU

Discretionary Data Deletions

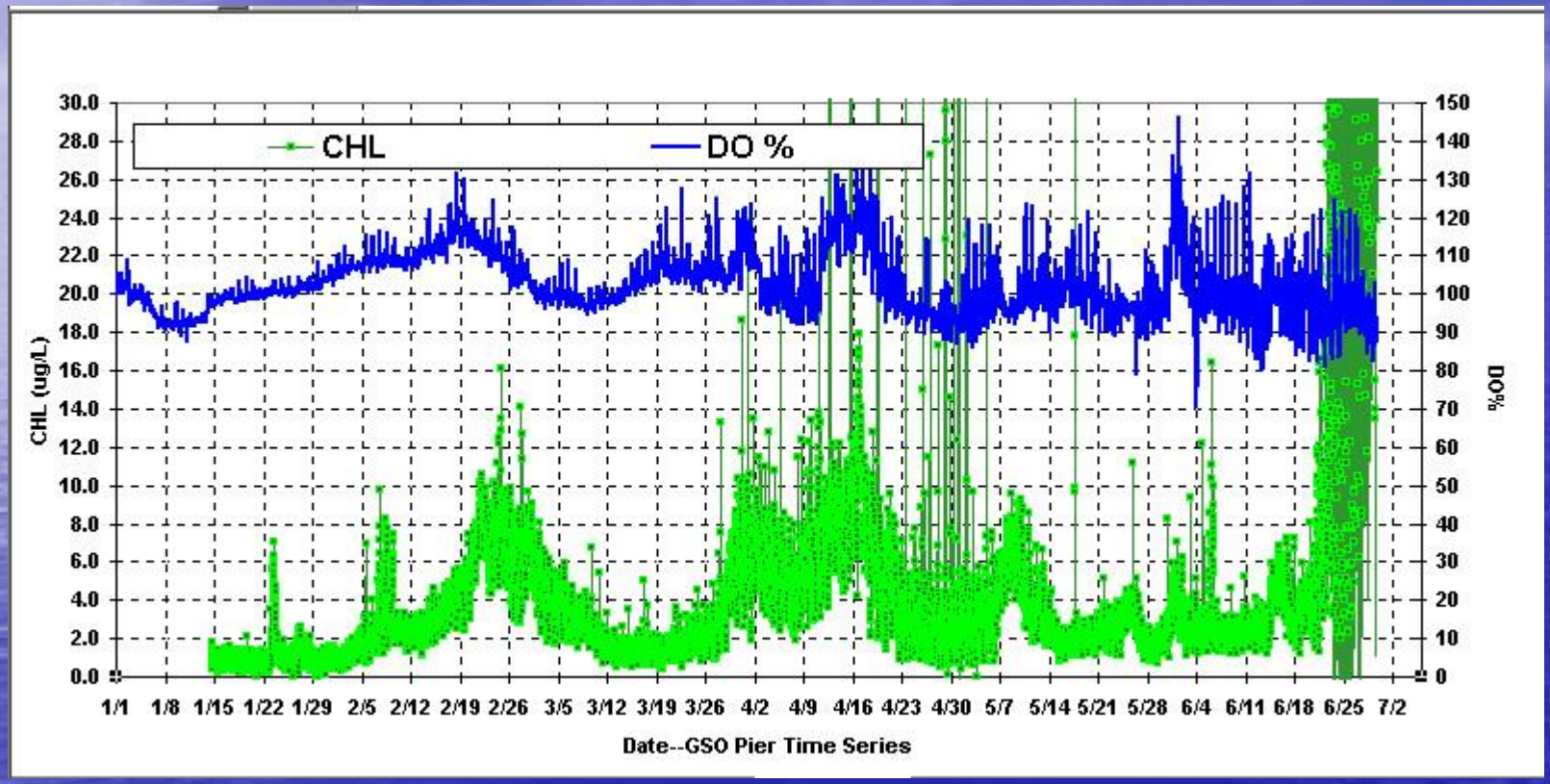
Data Spikes: Two automate data screening techniques for data spikes (low salinity spikes, CHL, Turbidity). Generally, there are two comparable methods used to screen for data spikes:

2 Standard Deviation Rule- Since not all parameters are normally distributed, such as conductivity, a 95% rejection method can also be applied. Any value that is outside the 95% range around the median or greater than 2 stdev will be deleted (median based on monthly averages).

Nearest Neighbor Rule- incorporates overall range data observed at the site and rate of change between each data point. The change between each data point should not exceed a 2 times the 2-standard deviation number or 95% rate. This method works well for CHL & Turbidity.

Other Methods (salinity)-If a surface and bottom is recorded, true salinity spikes from bottom station that are less than surface salinity should be noted & deleted. Graphic interpretations are best to identify these types of spikes.

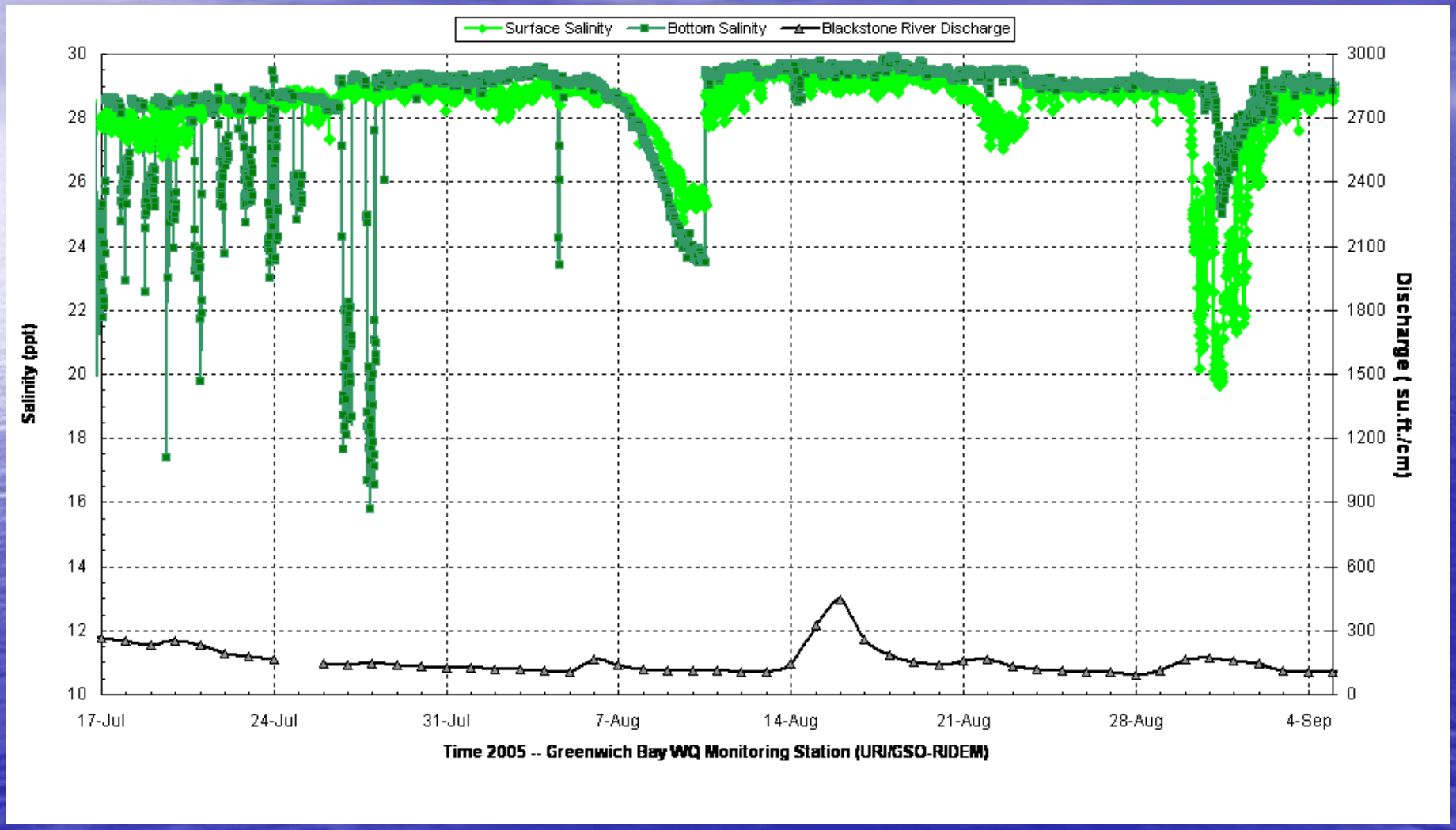
Data Spikes from the Chlorophyll Sensor



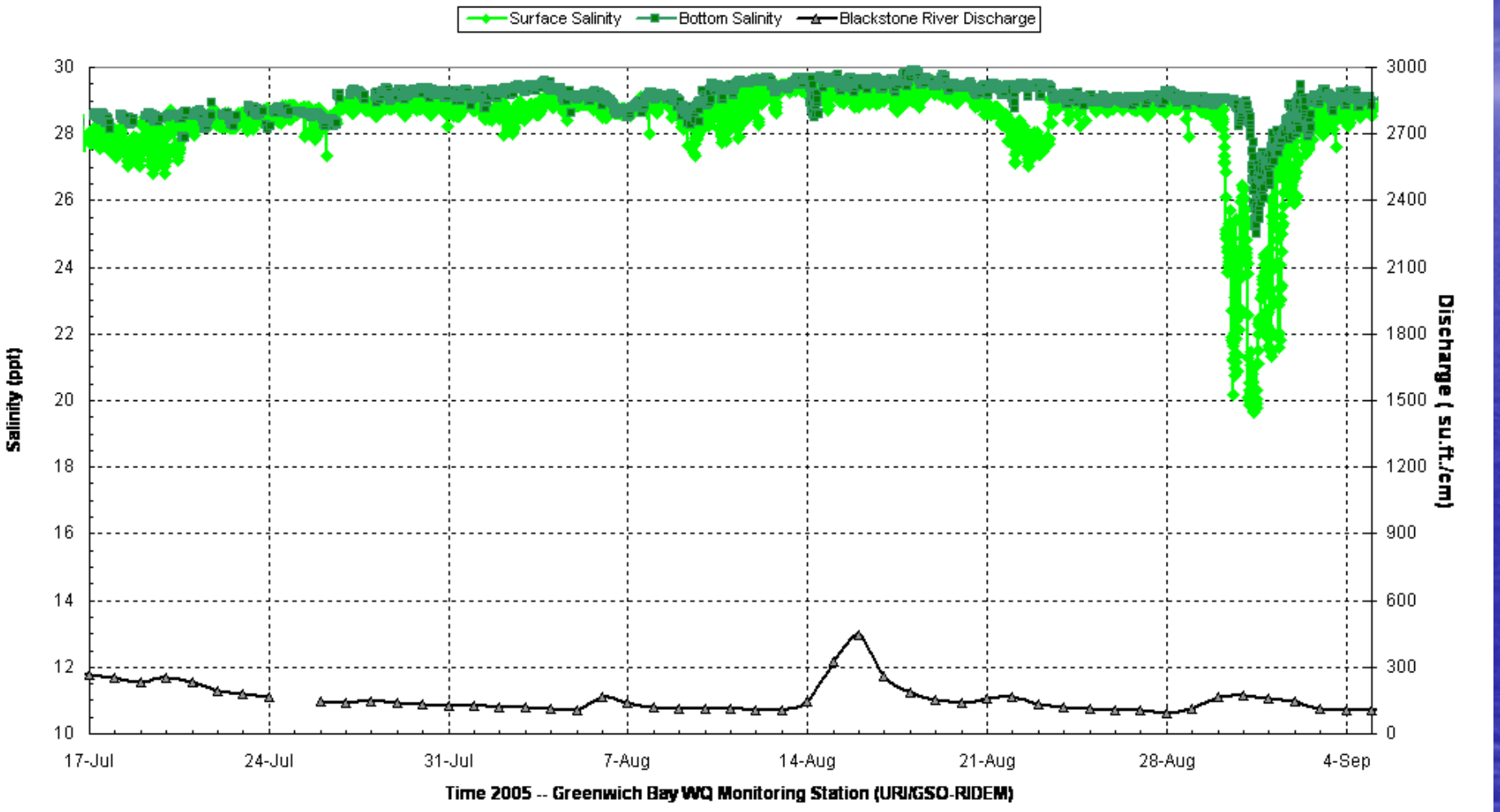
Discretionary Data Deletions (cont.)

Sensor Fouling: Graphic interpretations & post deployment check information will allow the data reviewer to assess the extent of the drift. If a drift is suspected, a linear compensation based on quality assurance data (pre-, mid-, and post-deployment) is possible using calculating it linearly.

Data Spikes & Fouling of the Salinity Sensors



Corrected Data for Fouling & Data Spikes



Metadata

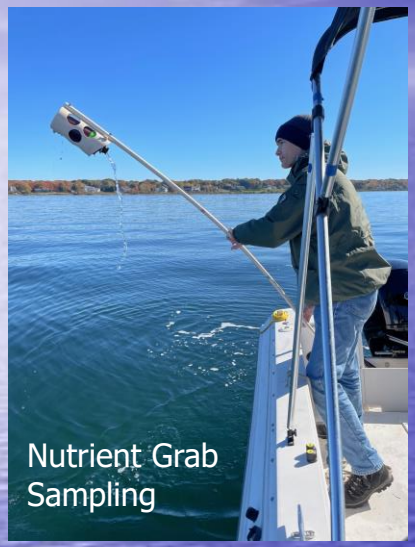
Participating Agencies & Contact Information

Monitoring Objectives
Entry Verification or QA/QC Procedures
Monitoring Methods
Data Distribution & Citation
Associated Monitoring Efforts
Sensor Specifications

Site Location and Character
Coded Variable Definitions
Sensors generally in use at monitoring stations

Data Collection Period
Anomalous/Suspect/Corrected Data
Post Deployment Information
Other Remarks/Notes

Other Sampling Technologies and Data used in assessment of NBFSMN data in Narragansett Bay, Rhode Island


Nutrient Grab Sampling


Spatial Survey in Mt Hope Bay

USGS Stream gage station on the Blackstone River


Chlorophyll analysis

- Grab Sampling
- Spatial Surveys
- Weather Data
- River Flow Data


NBNERR Weather Station on Prudence Island

How Data is Distributed to Coastal Managers, Scientists, & Public

- BART (RIDEM-OWR): weekly public posting of bay conditions https://dem.ri.gov/latest-bay-area-report
- NERACOOS: real-time data https://www.neracoos.org/data/index.html
- NBC: reports/real-time data https://snapshot.narrabay.com/
- URI/GSO: daily observations (csv master file) https://web.uri.edu/gso/research/marine-ecosystems-research-laboratory/datasets/
- NBNERR: linked to SWMP www.nbnerr.org
- MassDEP: QA/QC data access https://www.mass.gov/info-details/mount-hope-bay-marine-buoy-continuous-probe-data

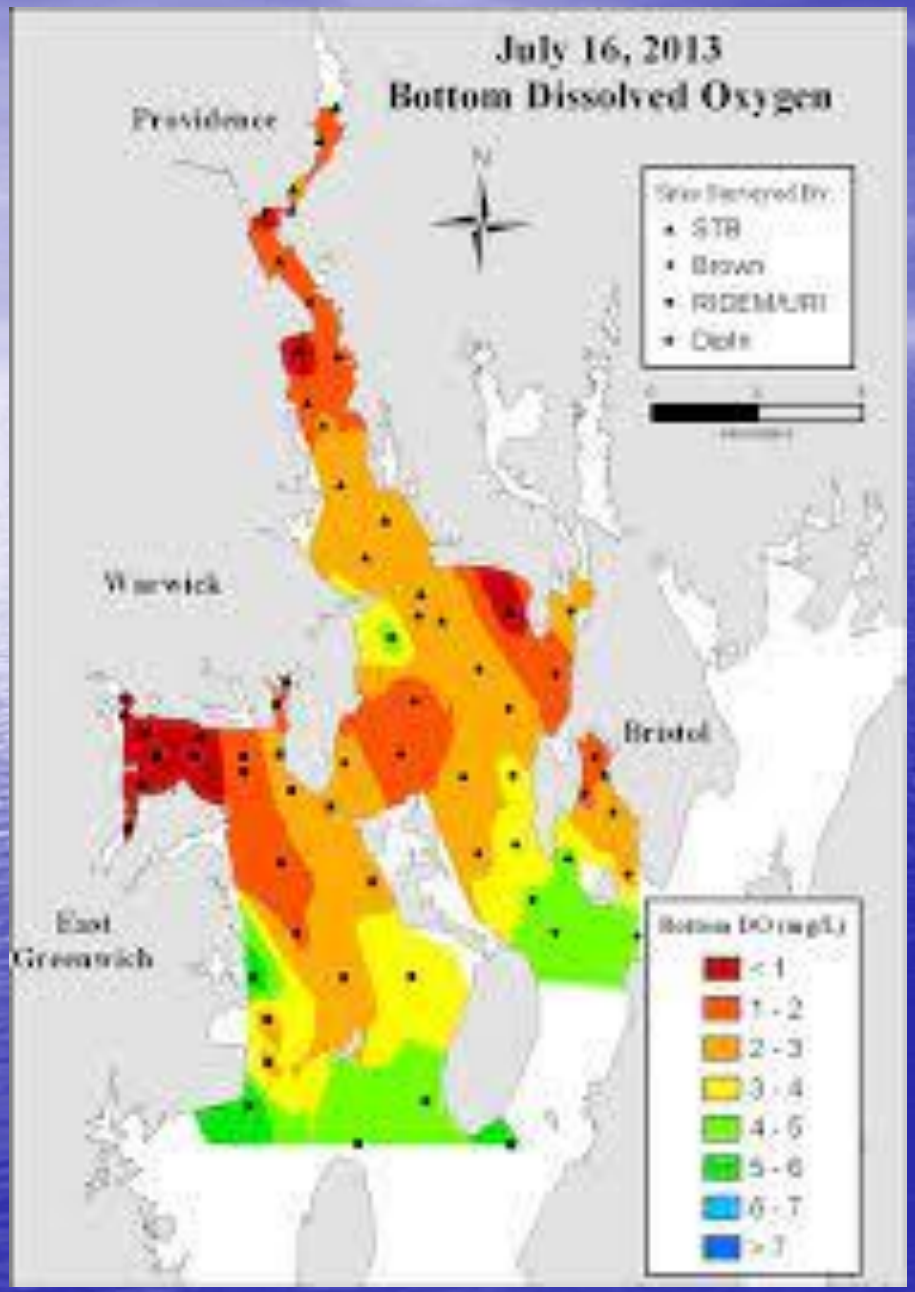
- RIDEM-OWR (lead agency): yearly raw, edited, corrected data & metadata www.dem.ri.gov/

Key Components for a Successful Monitoring Network:

- ✓ Design monitoring network based on long-term goals
- ✓ Designated staff for lab, field, data management, and support staff (oversight, website, & budgeting)
- ✓ Maintenance of all components are required for proper function

Extras

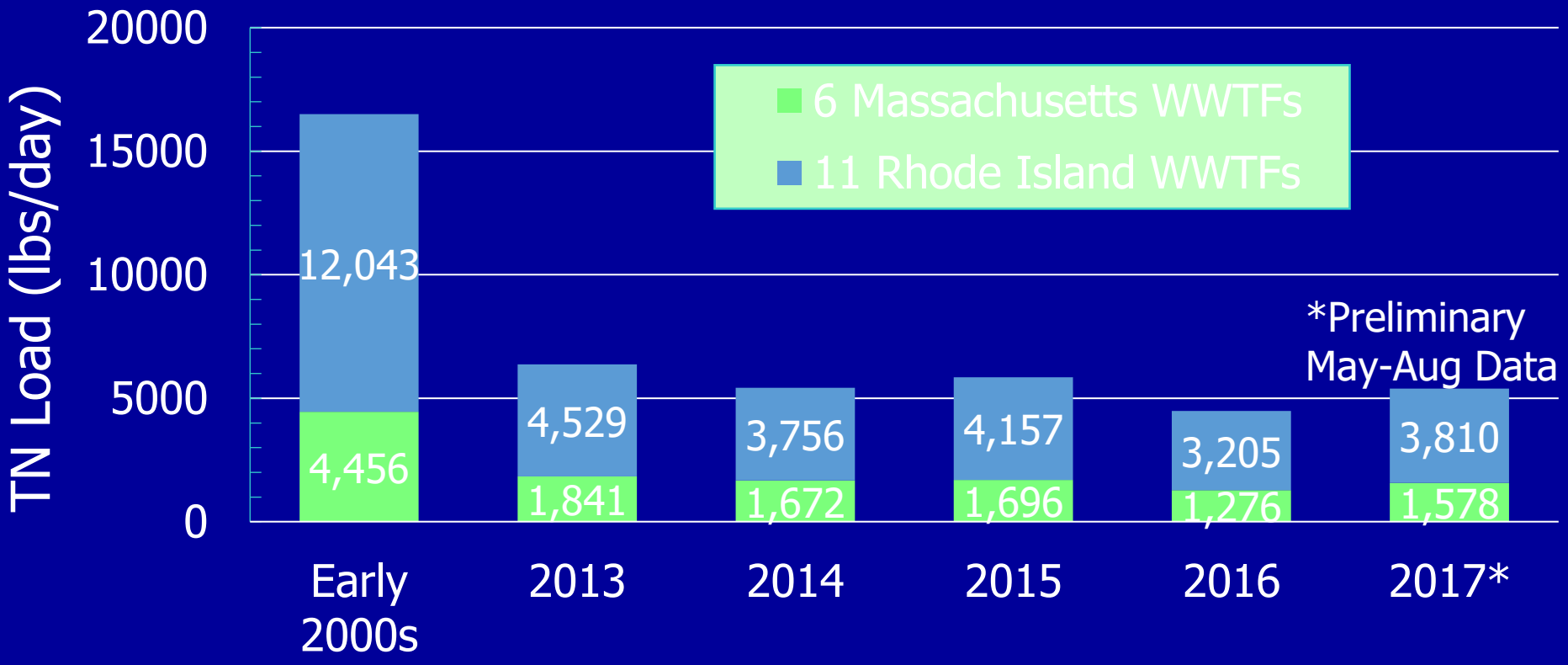
- Other programs used in data analysis of low oxygen in Narragansett Bay



Day Trippers

- Season of the spatial DO surveys associated with the CHRP project.
- These surveys target neap tide intervals during the summer months (June-September) to provide snapshots of water column properties (T,S, density, DO, chlorophyll, and turbidity).
- Sample profiles at more than 70 stations using Sea-Bird SBE 19 Plus SEACAT at High resolution (sample rate= 0.25 sec/m)
- Three boats and three instruments are used for these surveys.

Summer WWTF Nitrogen Loads (May-October)



RI WWTFs: Burrillville, East Greenwich, East Providence, NBC Bucklin Point, NBC Fields Point, Smithfield, Cranston, Warren, Warwick, West Warwick, Woonsocket;
MA WWTFs: Attleboro, Graton, North Attleborough, Northbridge, UBWPAD, Uxbridge

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%.

Gray shading: Bathymetry

River inputs

Station groupings for analysis:

Providence River & Upper Bay

Upper West Passage

Upper East Passage

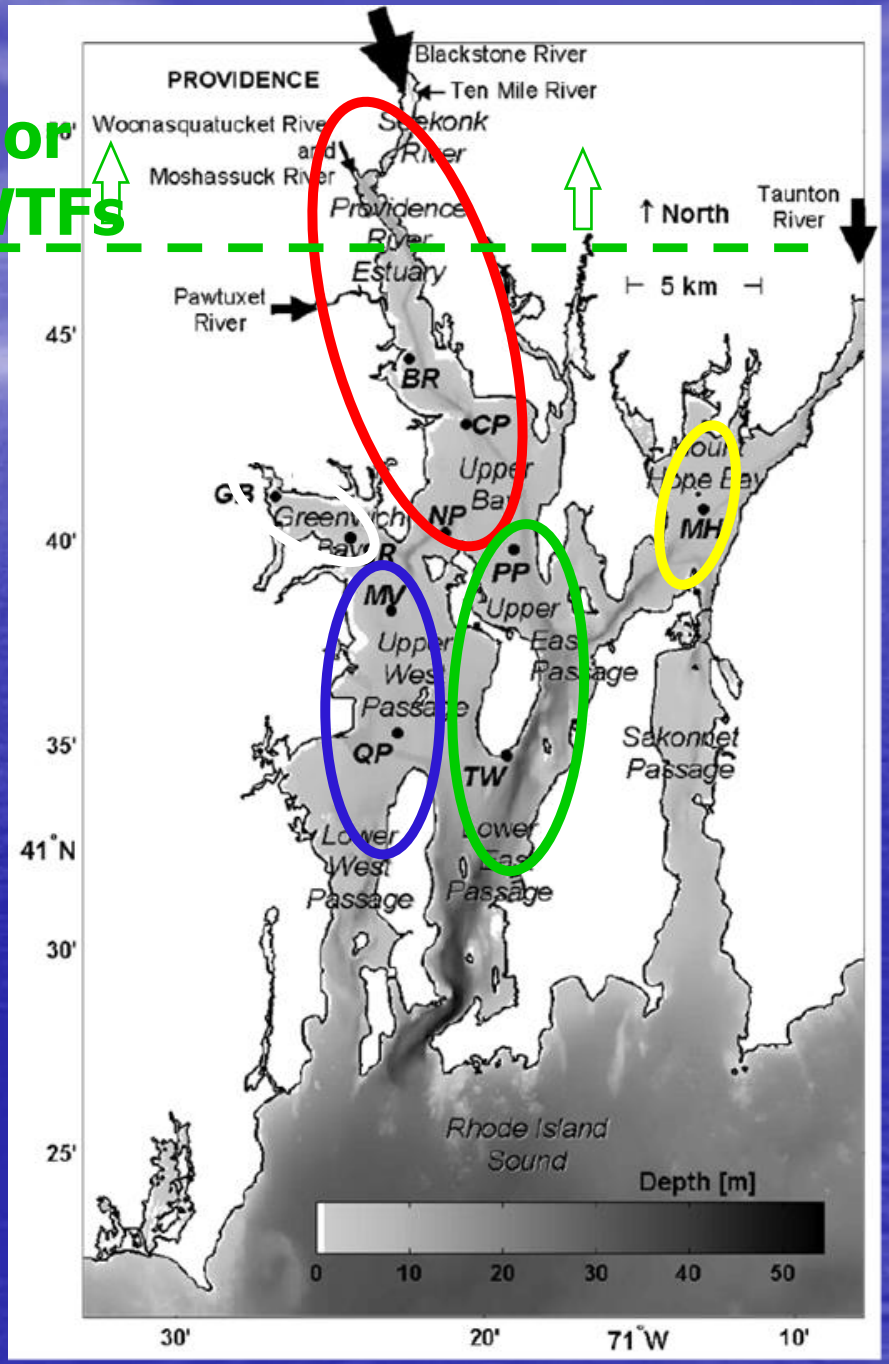
Embayments:

Greenwich Bay

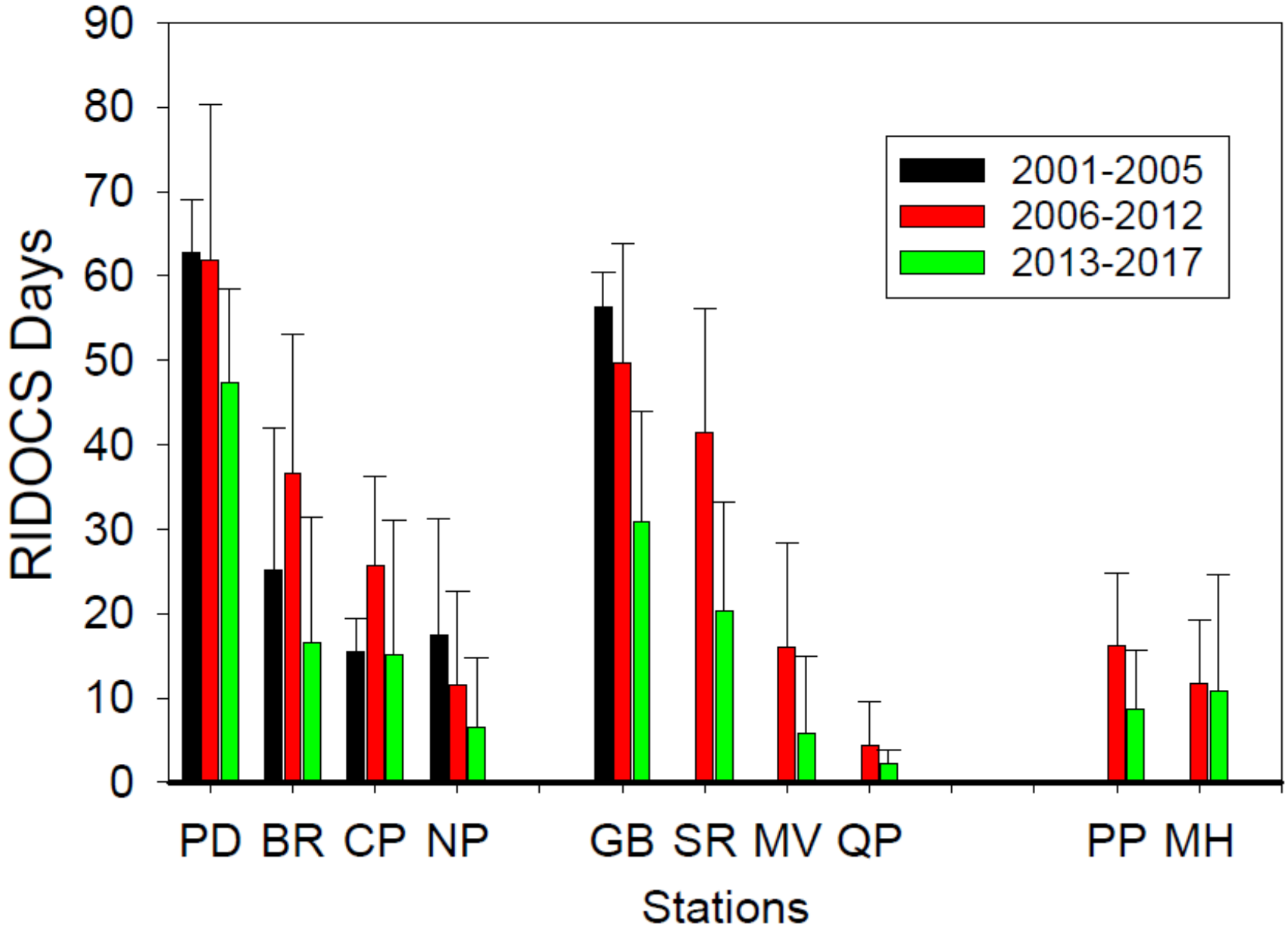
(shallow(3-4m), poor flushing)

Mt Hope Bay (MH)

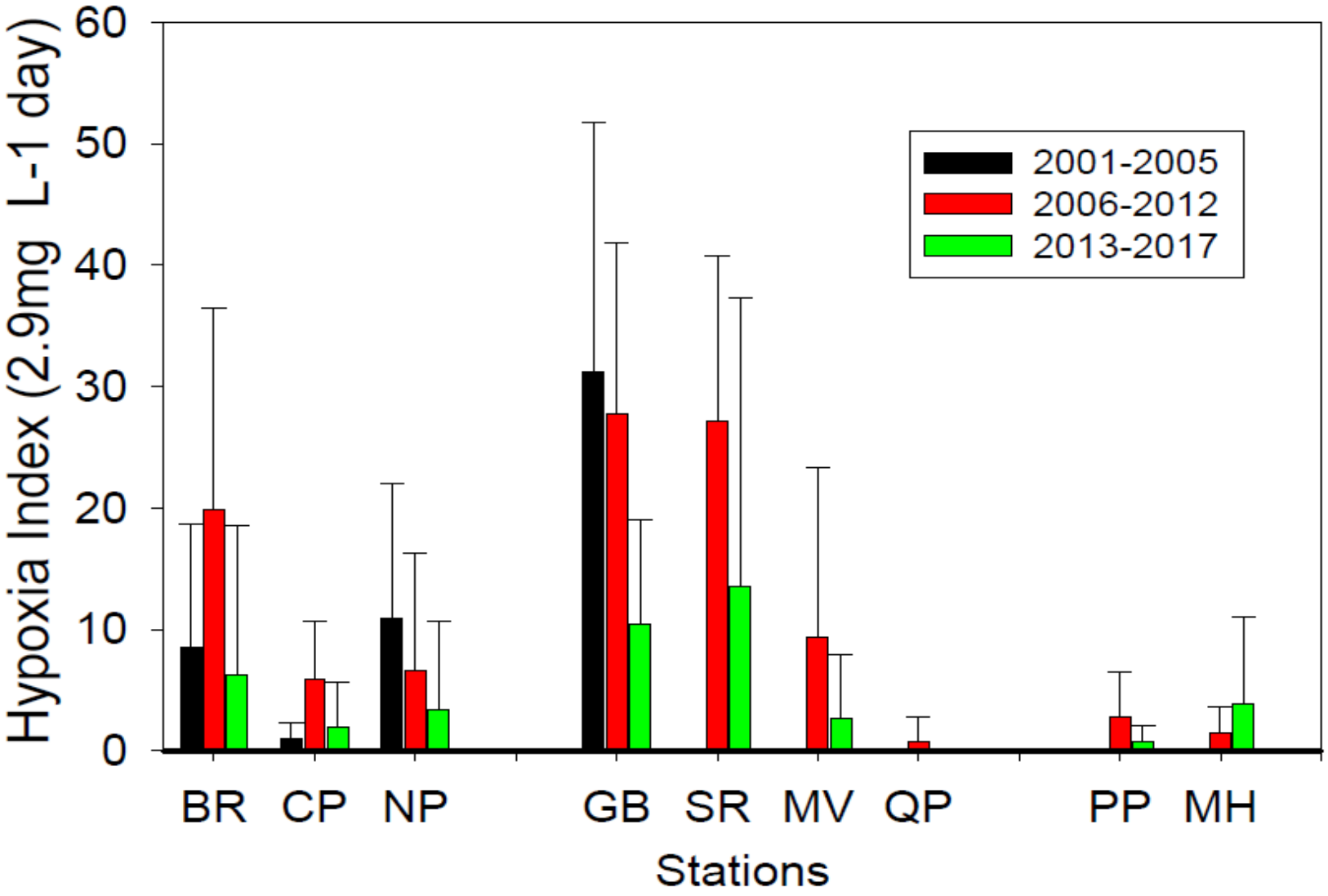
(shallow (5m), better flushed)



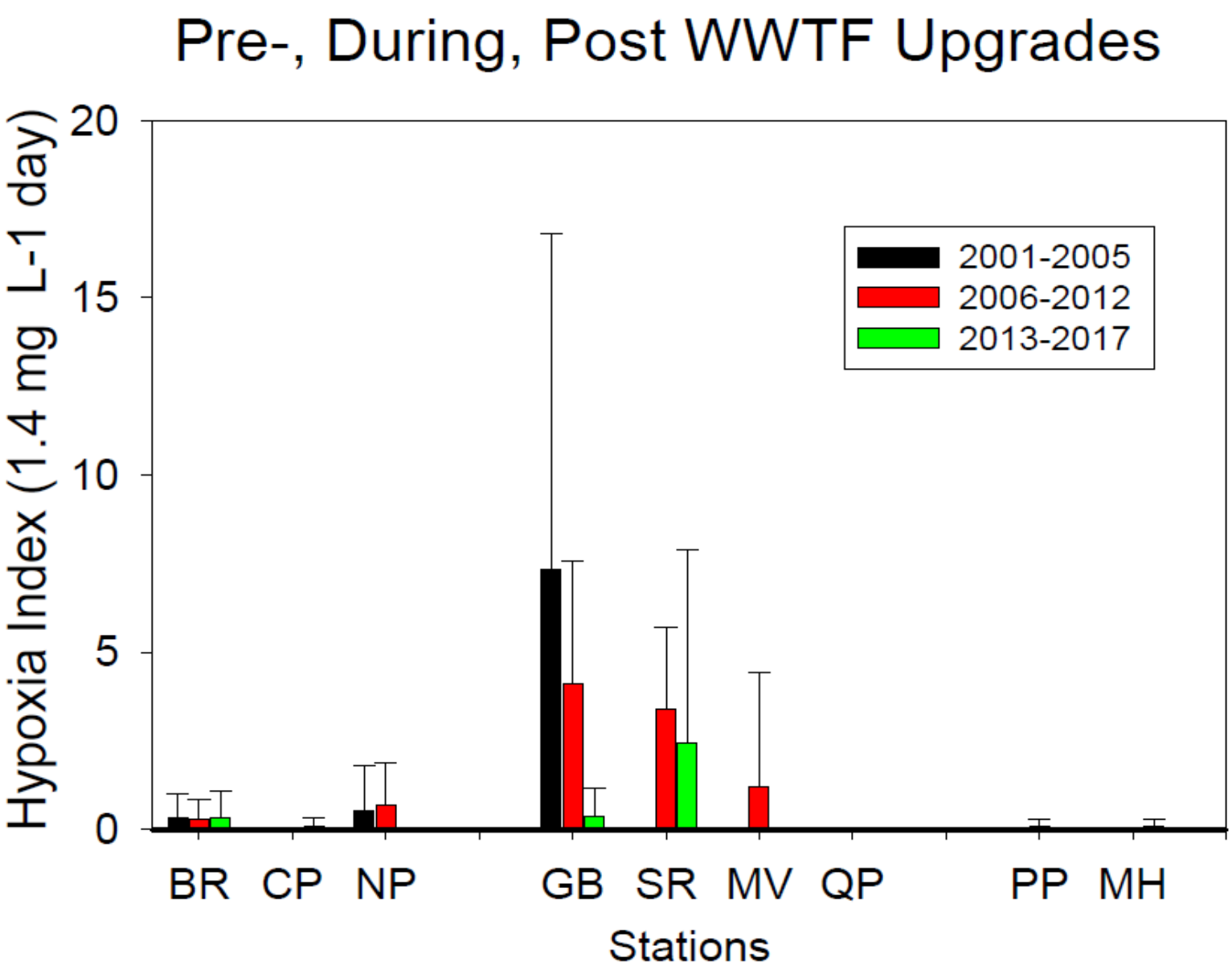
Pre-, During, Post WWTF Upgrades



Pre-, During, Post WWTF Upgrades

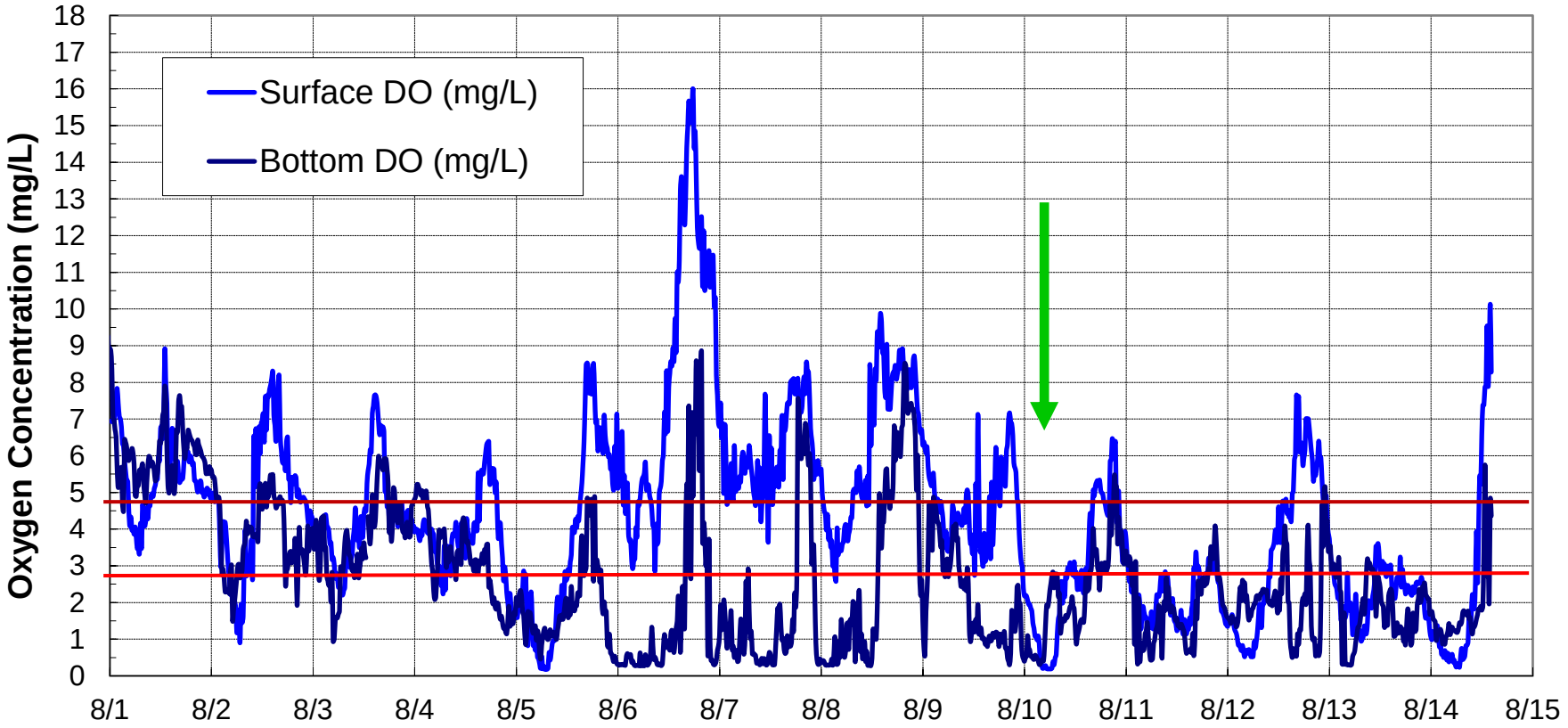


2.9 threshold is consistent with RIDOCS: Decrease of hypoxia



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

Small Fish Kill Event August 2018 in Greenwich Bay



On 8/10/2018, about 75-100 dead fish in an approximately 100 yd2 area. Species noted included juvenile menhaden, river herring, and juvenile weakfish.

Courtesy of RIDEM-F&W

Chlorophyll Levels and Nutrients at Greenwich Bay during Event in August 2018