Piscataqua River-Portsmouth Harbor Water Transparency Field Study

Field Sampling & Monitoring Report

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Submitted by

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INTRODUCTION

At the request of the Great Bay Municipal Coalition, a research team from the University of New Hampshire's Jackson Estuarine Laboratory (JEL) conducted a short-term field and laboratory program to generate water quality data for water column nitrogen, dissolved oxygen and particle concentrations in the Piscataqua River and Portsmouth Harbor (Figure 1). The data consist of near-continuous datasonde measurements at three sites, along with water column measurements and analyses of water samples obtained from the study sites during the sonde deployment period, as detailed in the following text.

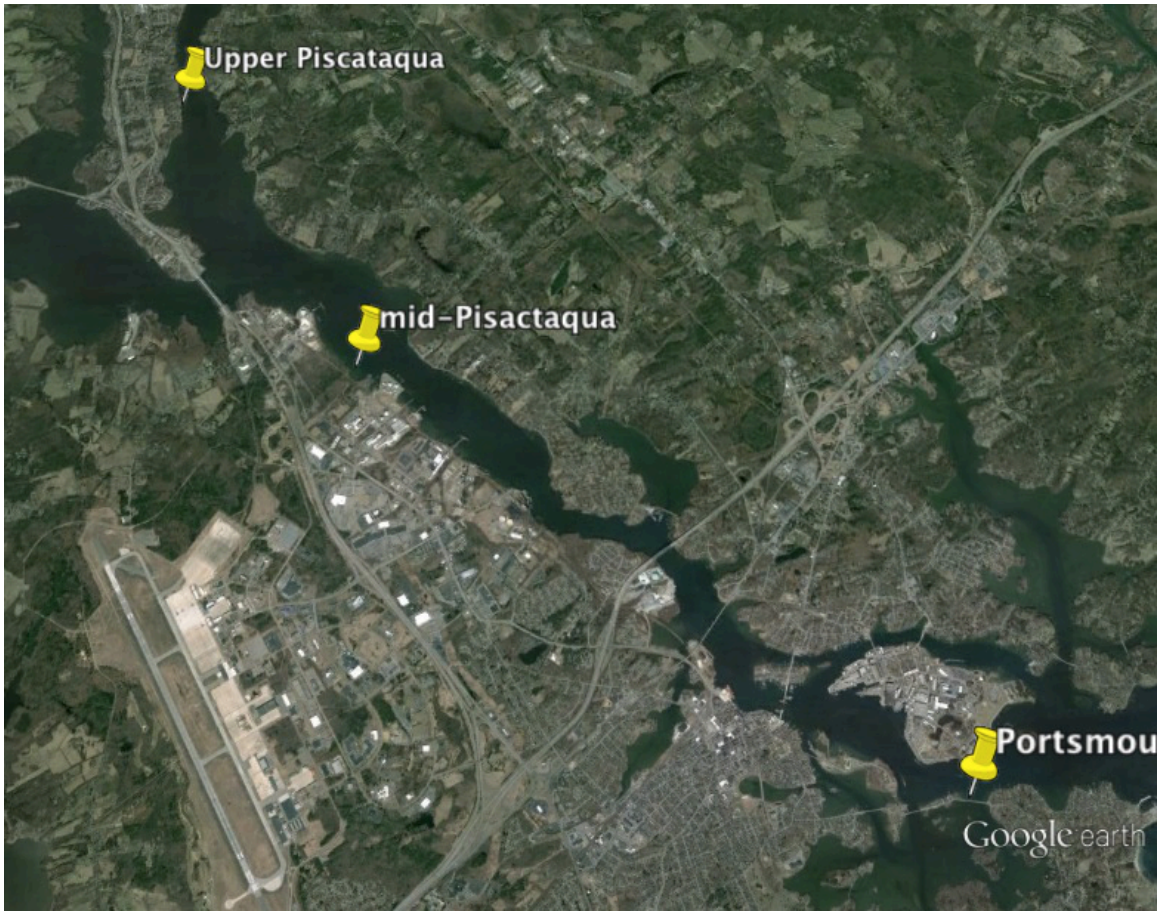

Figure 1. Piscataqua River and Portsmouth Harbor sonde deployment sites. Site #1-Portsmouth Harbor, Site #2-mid-Piscataqua, Site #3-Upper Piscataqua.

The deliverables for this study include a QAPP (modified existing QAPP from 2011 study) for all field and laboratory tasks and a data report. The study results have been compiled into electronic data files in Microsoft Excel format and in hard copy.

This final report describes field and laboratory methods, QA/QC procedures and results, observations, and analysis of data and sample analysis results.

METHODS

Sampling and Field Measurements

There were two main field-based tasks involved with this project:

1) Datasondes were used for temporally intensive monitoring of temperature, depth, salinity, conductivity, turbidity, pH, chlorophyll *a* and dissolved oxygen. Three Eureka Manta2 sondes were deployed along the western shoreline of the Piscataqua River at three sites: just south of the mouth of Sturgeon Creek, near the natural gas facility south of the General Sullivan bridge, and in Portsmouth Harbor. The three Eureka datasondes were deployed continuously for 4 weeks with brief weekly interruptions to clean sensors and change batteries.

2) At deployment and once per week for 4 weeks, measurements were made of water column conditions and light attenuation. Grab samples were collected for analyzing chlorophyll *a* and phaeophytin at the 3 deployed sonde locations, in part to help calibrate the chlorophyll probe readings and to provide water quality data over the full 4 week study period. Suspended solids (TSS & VSS) analyses were conducted on grab samples collected at deployment and after 2 and 4 weeks. During deployment and recovery of the sondes on the first day and after 4 weeks, grab samples were also collected for analysis of total and dissolved nitrogen. Meteorological data were downloaded from the UNH Weather Statistics web site. All sonde and field data time readings are in Standard Time.

Lab And Field Data

The results of lab analyses and field measurements are summarized in the following electronic files:

-" **2013 Piscataqua River Chlorophyll and Nutrient database"** includes the results of lab analyses for dissolved and total nitrogen, chlorophyll *a*/phaeophytin, light attenuation and TSS/VSS data.

-"**2013 PiscRiver Sample visit Sonde readings**" has all of the data for YSI 6600 water column readings taken during site visits.

-"**PiscRiver sonde data Summary by SITE & rainfall**" summarizes the sonde data from all of the Eureka data sondes by site.

Datasonde Deployment

Eureka Manta 2 datasondes were deployed at three different locations for the full 4 week duration of the study-from 8/28/13 to 9/25/13. The datasondes were deployed with anchors and buoys on August 28 following probe calibration at JEL. Sondes were attached to main deployment lines with hose clamps held at the top and bottom of the sonde, with small lines threaded through the main lines and through the eye at the top of the sonde. Sondes were checked for fouling on a weekly basis, and de-fouled according

to manufacturer's recommended procedures, using the provided wiper for the turbidity probe and carefully using a small toothbrush on the other probe tips. Data were downloaded as described below. The chlorophyll probes were calibrated using manufacturer standardization cubes and the maximum values depended on initial settings made by the manufacturer. Initial deployment settings were initially set for 2-minute readings. The frequency for readings was changed to 15 minutes on September 4.

Table 1. Locations and deployment depths for Eureka datasondes in the Piscataqua River: August-September, 2013.

Datasonde Location	Latitude	Longitude
Portsmouth Harbor	43°00288'	70°93973'
Mid-Piscataqua River	43°00281'	70°93792'
Upper Piscataqua River	43°03108'	70°93627'

The deployment histories of the three Eureka datasondes are as follows:

Table 2. Sonde #1 deployment history

Sonde #1 was deployed at the Portsmouth Harbor site (Site #1) near the western shoreline along Rt 1B/Portsmouth Ave. near the Kittery Point Yacht Club in New Castle.

Date	Time (local time)	Deployment condition
8/28/13	14:01	Datasonde turned on and then deployed
9/4/13	9:45	Datasonde removed from water for de-fouling, turned off, data downloaded, batteries replaced and re-set for readings every 15 minutes
	10:15	Datasonde turned back on; first reading at 10:30
9/12/13	11:48	Datasonde removed from water for de-fouling
9/18/13	13:15	Datasonde removed from water for de-fouling, turned off, batteries replaced
	13:35	Datasonde turned back on; first reading at 13:45
9/25/13	10:17	Datasonde removed from the water and turned off; last reading at 10;15

Table 3. Sonde #2 deployment history

Sonde #2 was deployed off bottom near the western shoreline of the mid-Piscataqua River near the terminus of Patterson Lane in Newington (Site #2)

Date	Time (local time)	Deployment condition
8/28/13	14:52	Datasonde turned on and then deployed
9/4/13	10:50	Datasonde removed from water for de-fouling, turned off, data downloaded, batteries replaced and re-set for

		readings every 15 minutes
	11:15	Datasonde turned back on; first reading at 11:30
9/12/13	12:52	Datasonde removed from water for de-fouling
9/18/13	12:23	Datasonde removed from water for de-fouling, turned off, batteries replaced
	12:35	Datasonde turned back on; first reading at 13:00
9/25/13	11:12	Datasonde removed from the water and turned off; last reading at 11:00

Table 4. Sonde #3 deployment history

Sonde #3 was deployed from a private dock on the western shoreline of the upper Piscataqua River.

Date	Time (local time)	Deployment condition
8/28/13	15:24	Datasonde turned on and then deployed
	15:34	Sonde depth was lifted from 6-8" off bottom to ~2' off bottom
	15:37	Because the turbidity at the deployment site was visibly greater than that in the channel, a second sonde reading and grab sample were conducted at the 'MCKENNA' mooring ball off the end of the dock
9/4/13	12:05	Datasonde removed from water for de-fouling, turned off, data downloaded, batteries replaced and re-set for readings every 15 minutes
	12:25	Datasonde turned back on; first reading at 12:45
9/12/13	13:06	Datasonde removed from water for de-fouling
9/18/13	11:52	Datasonde removed from water for de-fouling, turned off, batteries replaced
	12:10	Datasonde turned back on; first reading at 12:15
9/25/13	11:30	Datasonde removed from the water and turned off; last reading at 11:30

Sonde and Grab Sample Data for Water Quality and Condition

The datasondes were deployed at three sites to help address concerns about water quality in the upper Piscataqua River and in Portsmouth Harbor. Grab sample analytical data and water column measurement data from this transect of three sites were collected weekly to help interpret the 2-15 minute sonde data. Weather conditions (precipitation conditions, cloud cover) and site conditions (presence of birds, trash, types of organisms and changes from original conditions) were recorded on standard field sheets. The daily rainfall amounts recorded at the UNH weather station in Durham, NH (Figure 2) show three significant rainfall events occurred on 9/1-2 (2.01"), 9/12-13 (4.44") and 9/22 (0.8"). Water profile information was measured using a YSI 6600 datasonde. Water samples

were collected according to the US EPA National Coastal Condition Assessment field sampling Standard Operating Procedures (USEPA 2009). All samples were transported in coolers back to JEL for processing and/or analysis.

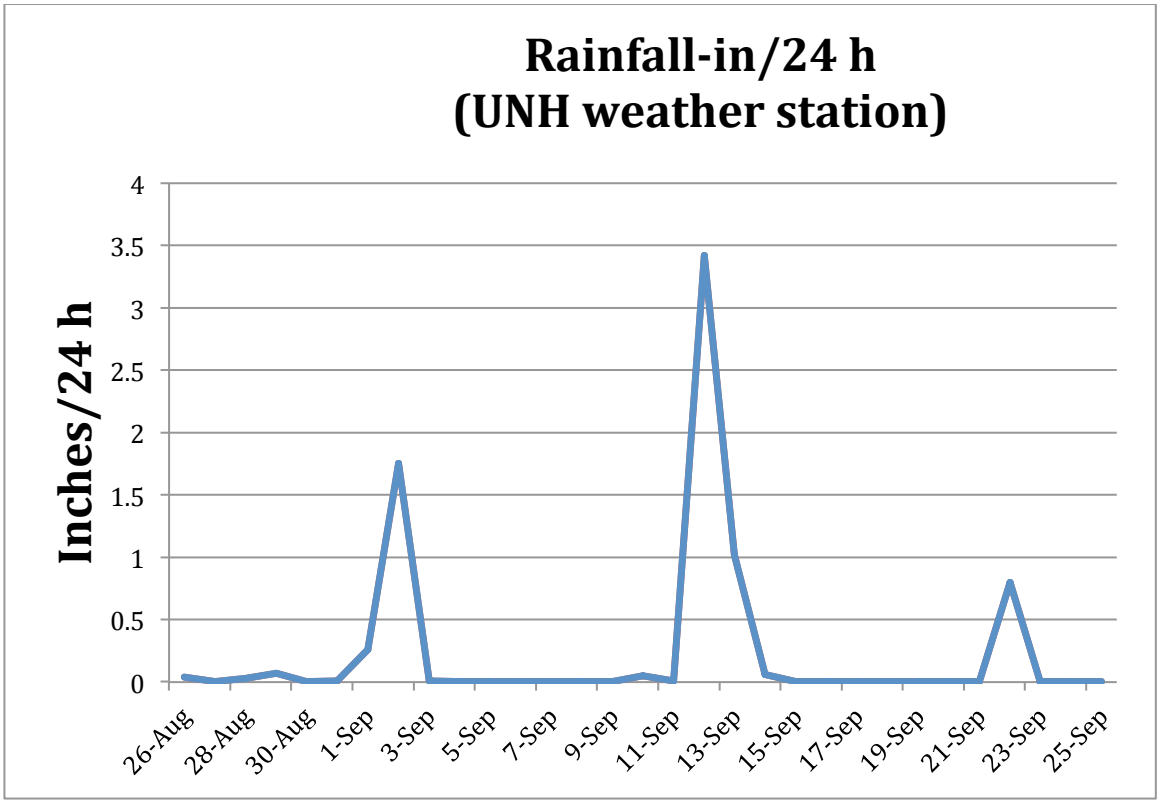

Figure 2. Daily rainfall amounts recorded at the UNH Weather Station.

The timing of the sampling occurred during midday each week to enable sampling during different tidal stages.

Table 5. Sampling details for each analytically determined water quality parameter.

Parameter	Sample Method	Depth interval
Dissolved nutrients	Niskin Bottle transferred to 2 L Nalgene bottle	mid-depth
Total nutrients	Niskin Bottle transferred to 250 brown Nalgene bottle	mid-depth
TSS & VSS	Niskin Bottle transferred to 2 L Nalgene bottle	mid-depth
Chlorophyll *a* & phaeophytin	Niskin Bottle transferred to 2 L Nalgene bottle	mid-depth

RESULTS

The sondes were relatively reliable most of the time at all three sites, although there were distinct findings for each site. There was a clear latitudinal trend for conditions at the three sites, with Site 1, then Site 2 then Site 3 having the highest to the lowest average salinity, DO and pH, and the lowest to highest temperature (Table 6). Site 2, however, had the lowest average turbidity and chlorophyll, reflecting more stable conditions that include having the deepest sonde depth and the least disruptive conditions in the surrounding area. Site 1 is in a small shallow area near a mooring area and next to the main channel in Portsmouth Harbor, Site 3 is a private dock in an even shallower area just off the main channel, while Site 2 is at a location with apparently less disturbance in the mid-river area. The sonde at Site 1 was in deeper water than at the private dock at Site 3 and showed less variability than at Site 3, although the data were more variable than at Site 2.

Table 6. Average readings for all data from datasondes deployed at the three study sites.

	Site 1	Site 2	Site 3
Temperature	16.6	18.2	20.2
Specific Conductivity	47.1	46.2	39.8
Salinity	30.7	30.0	25.6
Dissolved oxygen (% Saturation)	105.1	103.5	98.9
Dissolved oxygen (mg/l)	8.5	8.2	7.7
Depth	1.5	2.3	1.0
pH	8.1	7.9	7.9
Turbidity	3.4	3.3	5.6
Chlorophyll	8.4	6.9	14.0

It also appears that pH readings at Site 3 increased ~0.2 pH units following the site visits when probe tips were de-fouled, while the same was not true at the other two sites.

Rainfall events had the greatest impact on salinity at Site 3, as expected because this is the site furthest away from the ocean and closest to freshwater tributaries. The salinity varied most between low and high tides also at Site 3.

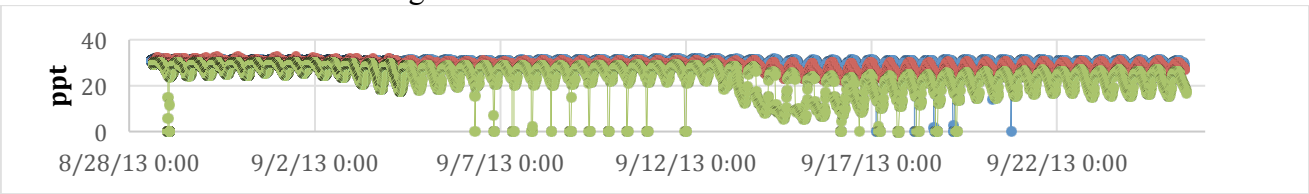

Figure 3. Water salinity from datasonde readings at the three study sites. BLUE is site 1, RED is Site 2, GREEN is Site 3.

The sondes gave false readings at times, based on existing knowledge and the conditions at the time of the questionable readings. The data for these readings have been highlighted in yellow in the attached '**PiscRiver sonde data Summary by SITE & rainfall'** file. For example, there were times for all three sondes where the DO concentration and % saturation would drop to 0 for one time reading, then return to the levels found prior to the single-time reading. This happened 16 times at Site 1, 6 times at Site 2 and 8 times at Site 3 (Table 7). Otherwise, all other DO readings were >79.7 % saturation and 6.55 mg/L (both lows at Site 3). These readings suggest non-limiting DO at all times during the study period. Water temperature and salinity readings also dropped to abnormal low levels at Sites 1 and 3, but only during low depth conditions, and less frequently at Site 1 than at Site 3 (Site 3 was the only site where there were negative depth readings); low pH readings were also associated with low depth events.

Table 7. Evaluation of datasonde readings.

	Parameter	QC check	Explanatory comments
Site #1	Temp	6 < 10.04 °C	all associated with low depth events
	Salinity/SpCond		all associated with low depth events
	HDO_%Sat	16; <83.7	never > 1 time point
	HDO_mg/l	16< 7.45	never > 1 time point
	Depth	all normal range	x
	pH	all normal range	x
	Turb	13 > 68	11 occurred when depth <0.5 m
	Chl	95 > 100	all but 3 were single time points
			3 events: 8/30 event of 2:28 h (72 time pts); 9/2 event of 0:04 h, 9/4 event of 0:20 h (8 time pts)
	Parameter	QC check	Explanatory comments
Site #2	Temp	all normal range	x
	Salinity/SpCond	all normal range	x
	HDO_%Sat	6<85.4	never > 1 time point
	HDO_mg/l	6<7.32	never > 1 time point
	Depth	all normal range	x
	pH	all normal range	x
	Turb	all normal range	x
	Chl	13 > 100	all but one were single time points; on 9/22 discontinuous event of 3 h
	Parameter	QC check	Explanatory comments
Site #3	Temp	26 below 14°C	25/26 at depth <0.12 m and between 9 PM & 8 AM
	Salinity/SpCond	102 < 2.32	99/102 at depth <0.12 m
	HDO_%Sat	8 < 79.7	never > 1 time point
	HDO_mg/l	8 < 6.55	never > 1 time point
	Depth	96 < 0	all at low tide; 8/29 event 1:20 h (41 time pts)
	pH	34 < 7 (7.3)	33/34 during low depth event
	Turb	27 > 100	12 single time pt.,events of 6, 15, 30 & 45 minutes
	Chl**	416 > 74.4	chlorophyll peaks at this site correspond to a consistent condition on almost a daily basis
		49 <0	1 single time pt, 5 events (as follows):
			8/30 event 14 time pts (>-0.81) 0:30 ebb early PM
			8/31 event 11 time pts.(>-1.37) 0:26 ebb early PM
			9/1 5 time pts. (>-0.92) 0:08 ebb
			9/18 12 time pts. (>-5.44) 3:00 hi-ebb early PM
			9/23 6 time pts. (>-2.99) 1:30 flooding midday

**Chl from 9/5 thru 9/19, there would be a maximum CHL event on the fallling tides twice a day, except for 1 tide on 9/13 and 9/15
9/5 to 9/12 were most striking and regular

The turbidity readings were abnormally high at some times at Sites 1 and 3. At Site 1, 11 of the 13 high (> 68 NTU) readings occurred when the depth of the sonde was <0.5 m. At Site 3, 12 of the 27 high (>100 NTU) readings were single time events and the rest were associated with relatively short turbidity events of 6, 15, 30 and 45 minutes. Turbidity levels ranged only from 0.5 to 45.4 NTU at Site 2, while at Site 1 the range was 0 to 6253 and at Site 3 the range was 0 to 862 NTU. We suspect that the turbidity probe occasionally became momentarily fouled at Sites 1 and 3 where the sondes were deployed in shallower areas that are more prone to disturbance of sediments.

The chlorophyll *a* data from the datasonde are the most complicated, especially at Site 3. For Site 1, there were 95 high 'maximum' (>100) readings, however, all but three were events of single time point readings. The other high readings were associated with events lasting 4 min., 20 min. and 2:28 h. At Site 2, there were only 13 high 'maximum' (>100) readings and all were associated with single time points, except for one discontinuous event of 3 h. At Site 3, there were many more (416 times) high 'maximum' (>74.4) readings, many of which occurred in a striking pattern, during events of 1-5 h on falling tides twice each day from September 5-19, with a few exceptions. This site was the only site with chlorophyll readings (49 times) that were <0; many of these occurred during ebb tides in early afternoon just before low tide from August 30-September 1 for periods of 8-30 minutes. The other low readings were 5 single time events and two longer events lasting 1:30 and 3 h. Although there is little plausible reason for the negative readings, the high chlorophyll readings suggest consistent periodic events where either high chlorophyll containing water passed by the sonde or chlorophyll containing detritus or re-suspended benthic algae fouled the probe. The latter explanation is quite plausible, as solid chlorophyll-containing detritus introduced into a container with the probe causes the probe to spike to high readings (data not shown).

Chlorophyll Concentrations, Light Meter Readings & Suspended Solids Concentrations

Grab samples were analyzed (UNH-OPAL lab) for chlorophyll *a*, phaeophytin, and total and volatile suspended solids (UNH-WQAL lab). Duplicate field samples were analyzed for chlorophyll *a* at each of the 5 site visits, and field duplicates for nutrient analyses at the first and last site visits. All relative percent differences for field duplicate analytical results were <20%, except for one pair of chlorophyll *a* analyses where the RPD was 34%, and 4 of the 5 phaeophytin pairs had RPD values >20%. The average chlorophyll *a* concentration at Site 3 (3.96 µg/L) was twice the values at other sites, with levels at Site 2 (2.04 µg/L) only slightly higher than at Site 1 (1.95 µg/L); phaeophytin concentrations followed a similar trend. The linearity of Kd values are acceptable, except where noted, based on high regression coefficient values.

Table 8. Chlorophyll *a*, phaeophytin, total suspended solids (TSS) and volatile suspended solids (VSS) concentrations for collected grab samples and light attenuation coefficients (Kd) at the three study sites.

Sample name	Site #	Date of sampling	Chorophyll	Phaeophytin	TSS	VSS	Kd	Kd regression coefficient
			(ug/L)	(ug/L)	(mg N/L)	(mg N/L)	(/m)	R2
1A*	1	8/28/13	3.34	1.46	4.88	2.93	0.445	0.75
1B	1	8/28/13	3.24	1.41	6.15	3.08	0.601	0.95
2	2	8/28/13	3.02	1.24	15.4	3.90	NR**	
3	3	8/28/13	7.22	1.46	46.9	9.27	NR	
3M†	3	8/28/13					0.735	0.98
1	1	9/4/13	1.62	0.72			0.561	0.79
2A	2	9/4/13	1.53	0.71			0.581	0.97
2B	2	9/4/13	1.49	0.92			0.498	0.95
3	3	9/4/13	2.77	1.51			0.568	0.92
3M	3	9/4/13					0.519	0.97
1	1	9/12/13	1.44	0.67	66.8	3.57	0.57	0.90
2	2	9/12/13	2.55	0.88	39.6	4.29	0.52	0.92
3A	3	9/12/13	7.21	3.45	25.0	19.3	0.87	0.99
3B	3	9/12/13	6.02	2.03	22.5	16.4	NR	
3M	3	9/12/13	2.37	0.96	18.2	16.4	0.709	0.98
1A	1	9/18/13	2.79	0.87			0.55	0.85
1B	1	9/18/13	1.98	0.66			0.601	0.83
2	2	9/18/13	1.85	0.84			0.945	0.90
3	3	9/18/13	1.40	0.65			0.828	0.99
3M	3	9/18/13					0.866	0.88
1	1	9/25/13	1.00	0.37	20.4	3.57	NR	
2A	2	9/25/13	1.16	0.41	8.21	2.14	0.945	0.90
2B	2	9/25/13	1.36	0.55	2.14	1.43	0.93	0.75
3	3	9/25/13	1.76	0.72	40.7	3.57	1.474	0.98
3M	3	9/25/13					1.302	0.96

*A & B denote duplicate field samples

** NR denotes data 'Not Reported' due to operator error in making the readings or poor quality of water column readings (low regression coefficient)

†M denotes data from mooring ball in main river channel off shore from Site 3 dock

Secchi depths were determined to augment light attenuation information (Table 9). All readings but one were 'on bottom', reflecting visibility of the Secchi disk through the full water column.

Table 9. Secchi disk depth readings for all sites and sample dates.

Date	Site	Secchi depth (m)	On bottom?	If "No" Total depth (m)
8/28/13	1	2.4	Yes	
8/28/13	2	2.2	Yes	
8/28/13	3	1.6	Yes	
9/4/13	1	3.2	Yes	
9/4/13	2	2.4	Yes	
9/4/13	3	2.2	Yes	
9/12/13	1	1.2	Yes	
9/12/13	2	1.25	Yes	
9/12/13	3	1.2	Yes	
9/18/13	1	2.2	Yes	
9/18/13	2	3	Yes	
9/18/13	3	2	No	2.6
9/25/13	1	0.6	Yes	
9/25/13	2	1.2	Yes	
9/25/13	3	0.5	Yes	

Chlorophyll *a* Probe and Grab Sample Comparison

Previous work with Eureka/Manta (YSI) chlorophyll *a* probes in the Great Bay estuary showed that they yielded readings that were reasonably comparable to chlorophyll *a* concentrations determined by lab analysis (Jones and Gregory, 2011). In the previous study, the relationship between paired readings was highly correlated ($r^2 = 0.95$) once one outlier pair of data was excluded. As part of this study, weekly calibration visits to the sonde locations included collection of water samples for analysis of chlorophyll *a* by wet chemistry for comparison to measurements for chlorophyll *a* by the probes on the Eureka sondes. Concentrations of chlorophyll *a* determined by the probes at all three sites were related to the concentrations determined by wet chemistry with a correlation coefficient of $r^2 = 0.34$ (Figure 4). The sonde probe data used in these comparisons include the values recorded immediately after the sonde was recovered for defouling, and the chlorophyll probe was cleaned of fouling material. The relationships between probe and lab values were also calculated for each site. Site 1 and Site 3 showed poor ($r^2 < 0.24$) relationships while for Site 2 the readings were highly correlated ($r^2 = 0.95$). This trend of similar conditions being present at Sites 1&3, and what appears to be more straightforward conditions at Site 2 is consistent with other results.

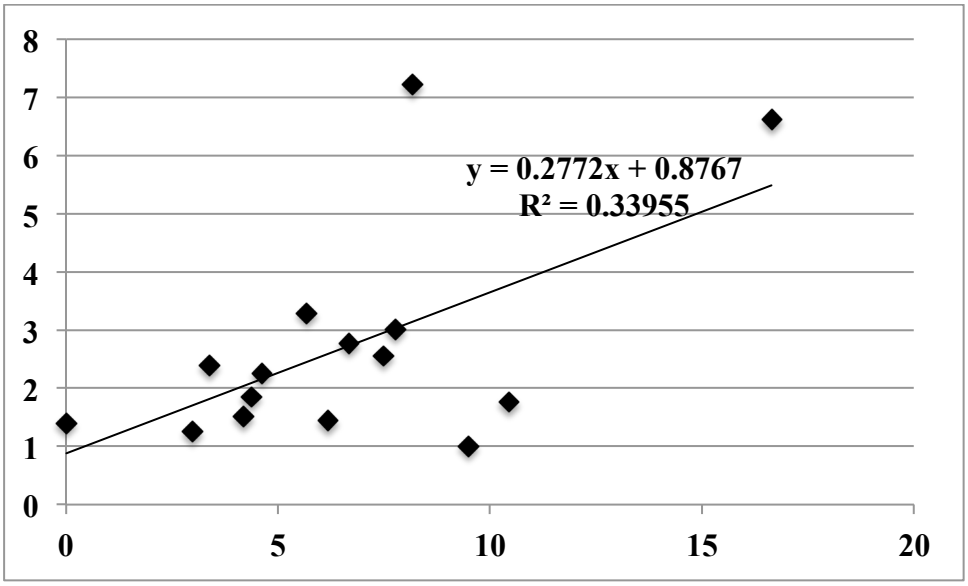

Figure 4. Comparison of chlorophyll *a* concentrations measured by wet chemistry lab analysis and *in situ* probe.

Total and Dissolved Nitrogen Concentrations

In addition to lab analysis for photosynthetic pigments and suspended solids, grab samples were also analyzed (UNH-WQAL) for total dissolved nitrogen, nitrate/nitrite, ammonium and total nitrogen (Table 10). The highest average TN, TDN, nitrate/nitrite and ammonium concentrations were at Site 3, followed by Site 2 and then Site 1. Concentrations of all four nitrogen species were higher on September 25th compared to August 28th.

All relative percent differences for field duplicate analytical results were <20%. On 8/28/13, the TDN included a low (≤3%) fraction of nitrate/nitrite and of ammonium (≤6%) at all three sites, while TDN constituted 50-82% of the TN. Somewhat different results were observed on 9/25/13. All nitrogen species were present at higher concentrations than observed on 8/28/13, and nitrate (27-48%) and ammonium (14-17%) constituted greater fractions of the TDH. TDH was still a significant fraction (68-82%) of the TN.

Table 10. Dissolved and total nitrogen concentrations for grab samples collected at the three study sites.

Sample name	Site #	Date of sampling	Total nitrogen TN	Total dissolved nitrogen TDN	Nitrate & nitrite NO3+NO2	Ammonium NH4
			(mg N/L)	(mg N/L)	(mg N/L)	(mg N/L)
1A*	1	8/28/13	0.170	0.140	0.003	0.008
1B	1	8/28/13	0.169	0.122	0.003	0.007
2	2	8/28/13	0.236	0.164	0.005	0.003
3	3	8/28/13	0.280	0.141	0.003	0.004
3M†	3	8/28/13				
1	1	9/4/13				
2A	2	9/4/13				
2B	2	9/4/13				
3	3	9/4/13				
3M	3	9/4/13				
1	1	9/12/13				
2	2	9/12/13				
3A	3	9/12/13				
3B	3	9/12/13				
3M	3	9/12/13				
1A	1	9/18/13				
1B	1	9/18/13				
2	2	9/18/13				
3	3	9/18/13				
3M	3	9/18/13				
1	1	9/25/13	0.288	0.196	0.059	0.027
2A	2	9/25/13	0.348	0.235	0.063	0.034
2B	2	9/25/13	0.313	0.214	0.062	0.035
3	3	9/25/13	0.464	0.380	0.184	0.064
3M	3	9/25/13				

*A & B denote duplicate field samples
†M denotes data from mooring ball in main river channel off shore from Site 3 dock

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Jones, S.H. and T. K. Gregory. 2011. Piscataqua River-Portsmouth Harbor Water Transparency Field Study: Field Sampling & Monitoring Report. Final Report submitted to the Great Bay Municipal Coalition.

USEPA. 2009. National Coastal Condition Assessment: Field Operations Manual. EPA-841-R-09-003. U.S. Environmental Protection Agency, Washington, DC.

APPENDIX A:

EUREKA DATASONDE MEASUREMENT SPECIFICATIONS

Parameters Monitored with Datasondes

Parameter	Unit of Measure	Instrument	Depth interval
Temperature	°Centigrade	30k ohm thermistor temperature sensor on a Manta2 multiprobe 3.0 in. Datasonde	Site-specific deployment depths
Salinity	ppt (from conductivity and temperature)	Conductivity sensor on a Manta2 multiprobe 3.0 in. Datasonde	Site-specific deployment depths
Turbidity	NTU	Turbidity sensor on a Manta2 multiprobe 3.0 in. Datasonde	Site-specific deployment depths
Dissolved oxygen	mg/L & % saturation	Optical dissolved oxygen sensor on a Manta2 multiprobe 3.0 in. Datasonde	Site-specific deployment depths
Chlorophyll *a*	µg/L	Manta2 chlorophyll *a* sensor on a Manta2 multiprobe 3.0 in. Datasonde	Site-specific deployment depths
Depth	meters	Depth sensor on a Manta2 multiprobe 3.0 in. Datasonde	Site-specific deployment depths
pH	pH units	pH sensor on a Manta2 multiprobe 3.0 in. Datasonde	Site-specific deployment depths

Eureka sensor specifications

Temperature sensor; Range: -5 to +50°C; Resolution: 0.01°C; Accuracy: ±0.1°C

Conductivity sensor; Range: 0 to 100 mS/cm; Accuracy- 1.0% of reading ±1 count

Salinity sensor; Range: 0 to 70 ppt; Resolution: 4 digits; Accuracy: ±1% of reading or 0.1 ppt, whichever is greater

Depth: Range- varies; Resolution: 0.01 m; Accuracy: ± 0.1% full scale

Turbidity sensor; Range: 0 to 3,000 NTU; Resolution: 0.1 NTU; Accuracy: <1% of reading for 0-100 NTU, <3% of reading for 100-400 NTU and <5% of reading for >400 NTU

Dissolved oxygen optical sensor; Range: 0 to 200% saturation and 0 to 25 mg/L; Resolution: 0.1% saturation and 0.01 mg/L; Accuracy: 0 to 200% ± 1% of reading or ±0.02 mg/L, whichever is greater.

Chlorophyll *a* sensor; Range: 0.03 to 50 µg/L; Resolution: 0.01 µg/L; Accuracy: ±3%

pH sensor: Range: 0 to 14 units; Resolution: 0.01 units; Accuracy: ±0.02 units

APPENDIX B:

YSI DATASONDE AND LICOR SENSOR SPECIFICATIONS

Water Profiling Datasonde Measurements

Parameter	Unit of Measure	Instrument	Depth interval
Temperature	°Centigrade	YSI 6560 sensor on a 6600 Datasonde	0.25 m below surface, mid depth and 0.25 m above bottom
Salinity	ppt (from conductivity and temperature)	YSI 6560 sensor on a 6600 Datasonde	0.25 m below surface, mid depth and 0.25 m above bottom
Turbidity	NTU	YSI 6236 sensor on a 6600 Datasonde	0.25 m below surface, mid depth and 0.25 m above bottom
Light attenuation	PAR	LI-COR LI-193 Underwater Quantum Sensor & LI-1400 data logger	0.25 m, 0.5 m, 1.0 m, 1.5 m, 2.0m*
Solar irradiance	W m^{-2}	LI-COR LI-190 Quantum Sensor & LI-1400 data logger	Above surface
Dissolved oxygen	mg/L & % saturation	6150 ROX optical oxygen sensor on a 6600 Datasonde	0.25 m below surface, mid depth and 0.25 m above bottom
pH	pH unit	6561 field pH sensor on a 6600 Datasonde	0.25 m below surface, mid depth and 0.25 m above bottom
Depth	meter	YSI medium depth pressure sensor on a 6600 Datasonde	All depths

* These depths are as water depth allows, and approximate depths. Actual depths will be according to the light attenuation profile to capture adequate intervals for calculating kd.

YSI sensor specifications

Temperature 6560 Sensor; Range: -5 to +50°C; Resolution: 0.01°C; Accuracy: ±0.15°C

Conductivity 6560 Sensor; Range: 0 to 100 mS/cm; Resolution: 0.001 to 0.1 mS/cm (range dependent); Accuracy: ±0.5% of reading + 0.001 mS/cm

Salinity from conductivity and temperature; Range: 0 to 70 ppt, Resolution: 0.01 ppt; Accuracy: ±1% of reading or 0.1 ppt, whichever is greater

Depth; Range: 0 to 61 m; Resolution: 0.001 m; Accuracy: ± 0.12 m

Turbidity 6136 sensor; Range: 0 to 1,000 NTU; Resolution: 0.1 NTU; Accuracy: ±2% of reading or 0.3 NTU, whichever is greater

Dissolved oxygen 6150 ROX sensor; Range: 0 to 500% saturation and 0 to 50 mg/L; Resolution: 0.1% saturation and 0.01 mg/L; Accuracy: 0 to 200% saturation: ± 1% of reading or 1% of air saturation, whichever is greater and for 0 to 20 mg/L: ±0.1 mg/L or 1% of reading, whichever is greater.

pH sensor; Range: 0 to 14 units; Resolution: 0.01 units; Accuracy: ±0.02 units

LI-COR sensor specifications

LI-COR LI-193

Absolute Calibration: ± 5% in air traceable to NIST.
Sensitivity: Typically 7 µA per 1000 µmol s^{-1} m^{-2} in water.
Linearity: Maximum deviation of 1% up to 10,000 µmol s^{-1} m^{-2}.
Stability: < ± 2% change over a 1 year period.
Response Time: 10 µS.
Temperature Dependence: ± 0.15% per °C maximum.
Angular Response: < ± 4% error up to ± 90° from normal axis (see Angular Response chart).
Azimuth: < ± 3% error over 360° at 90° from normal axis.
Detector: high stability silicon photovoltaic detector (blue enhanced).

LI-COR LI 190

Absolute Calibration: ± 5% traceable to the National Institute of Standards and Technology (NIST).
Sensitivity: Typical 5µA per 1000 µmol s^{-1} m^{-2}.
Linearity: Maximum deviation of 1% up to 10,000 µmol s^{-1} m^{-2}.
Stability: Typically < ± 2% change over a 1 year period.
Response Time: 10 µs.
Temperature Dependence: 0.15% per °C maximum.
Cosine Correction: Cosine corrected up to 80° angle of incidence.
Azimuth: < ± 1% error over 360° at 45° elevation.
Tilt: No error induced from orientation.
Operating Temperature: -40 to 65 °C.
Relative Humidity: 0 to 100%.