MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Robert L. Ehrlich, Jr., *Governor*
Michael S. Steele, *Lt. Governor*
C. Ronald Franks, *Secretary*

2004 Upper Patuxent River Shallow Water Monitoring Data Report

September, 2005

Tawes State Office Building • 580 Taylor Avenue • Annapolis, Maryland 21401
410.260.8DNR or toll free in Maryland 877.620.8DNR • TTY users call via Maryland Relay

2004 Upper Patuxent River Shallow Water Monitoring Data Report

Prepared by:
Becky Raves, Christopher Heyer, Mark Trice, Chris Trumbauer, John Zimmerelli
and Bruce Michael
Resource Assessment Service/Tidewater Ecosystem Assessment
Maryland Department of Natural Resources
Tawes Building, D-2
580 Taylor Avenue
Annapolis, MD 21401

Website Address:
http://dnr.maryland.gov

Toll Free in Maryland:
1-877-620-8DNR, ext: 8630
Out of state call: 410-260-8630
TTY users call via the MD Relay:
711 (within MD)
Out of state call: 1-800-735-2258

Robert L. Ehrlich, Jr., Governor Michael S. Steele, Lt. Governor

Printed on Recycled Paper

1. Introduction

The Maryland Department of Natural Resources (DNR) maintained three shallow water continuous monitoring stations, including one weather station, within the Chesapeake Bay National Estuarine Research Reserve (CBNERR-MD) system, through funding provided by the NOAA National Estuarine Research Reserve System (NERRS) program in 2004. These continuous monitoring stations, located in Jug Bay in the upper Patuxent River, included Iron Pot Landing, Railroad Bridge and Mataponi Creek (Figures 2-1 and 2-2). DNR has been maintaining shallow water monitoring technologies over the last several years in cooperation with the University of Maryland's Chesapeake Biological Laboratory, EPA and NOAA and implemented a Maryland-wide program in 2003. In 2004, Maryland DNR deployed and maintained 34 continuous monitoring stations in the Chesapeake and Coastal Bays and 13 tributaries. These shallow water monitoring technologies have been extremely successful, providing a wealth of physical and nutrient information that supply the necessary data to evaluate new water quality criteria for dissolved oxygen, water clarity and chlorophyll, assess potential submerged aquatic vegetation (SAV) restoration sites and determine if areas are meeting their designated use.

The Jug Bay project's aim was to monitor ambient water quality parameters, nutrient concentrations and meteorological conditions in order to characterize water quality and habitat conditions. Water quality measurements were collected every 15 minutes from January 1st to November 22nd 2004 using YSI 6600 data loggers approximately 0.3 m from the river bottom. Real-time data (updated hourly) for the Railroad Bridge site and near-time data (updated biweekly) for the Iron Pot Landing and Mataponi Creek stations are available on DNR's "Eyes on the Bay" web site (http://www.eyesonthebay.net) and through the NERRS national database (http://cdmo.baruch.sc.edu/).

Nutrient grab samples were collected by Maryland DNR on a monthly basis from February to December at all three sites (Table 1-1). Duplicate samples were taken once monthly and analyzed for chlorophyll a, nitrate, nitrite, ammonium and orthophosphate. An additional round of sampling (not in duplicate) was conducted each month at each site in collaboration with Maryland DNR's Continuous Monitoring Program. Diel nutrient sampling was conducted once monthly at the Railroad Bridge station from March through December 2004 and included the core NERRS nutrients. Unattended samplers were programmed to collect water samples every two and one half hours, over a 24-hour period. Weather data (air temperature, relative humidity, barometric pressure, rainfall, wind speed, wind direction and photosynthetically active radiation) was collected from January 1 through December 31, 2003; however, only data collected after July 22 was reported due to calibration and time coding concerns. Water quality, nutrient and meteorological data are available through the NERRS national database (http://cdmo.baruch.sc.edu/).

Table 1-1. Dates of 2004 Sample Collection.

Dates	Iron Pot Landing	Railroad Bridge	Mataponi Creek	Other Events and Details
02/10/04	X	X		Duplicate Grab Samples Collected
03/11/04	X	X	X	Duplicate Grab Samples Collected
03/25/04				Railroad Bridge Diel Grab Sampling
04/06/04	X	X		
04/08/04			X	
04/20/04	X	X	X	Duplicate Grab Samples Collected
04/28/04				Railroad Bridge Diel Grab Sampling
05/04/04	X	X	X	
05/18/04	X	X	X	Duplicate Grab Samples Collected
05/27/04				Railroad Bridge Diel Grab Sampling
06/03/04	X	X	X	
06/15/04	X	X	X	Duplicate Grab Samples Collected
06/29/04	X	X	X	
06/30/04				Railroad Bridge Diel Grab Sampling
07/13/04	X	X	X	
07/27/04		X	X	Railroad Bridge Diel Grab Sampling; Duplicate Grab Samples Collected
07/29/04	X			Duplicate Grab Samples Collected
08/10/04	X	X	X	
08/24/04	X	X	X	Railroad Bridge Diel Grab Sampling; Duplicate Grab Samples Collected
09/07/04	X	X	X	
09/21/04	X	X	X	Duplicate Grab Samples Collected
09/28/04				Railroad Bridge Diel Grab Sampling
10/05/04	X	X	X	
10/20/04	X	X	X	Railroad Bridge Diel Grab Sampling; Duplicate Grab Samples Collected
11/01/04	X	X	X	
11/22/04	X	X	X	Railroad Bridge Diel Grab Sampling; Duplicate Grab Samples Collected
12/08/04	X	X	X	
12/21/04	X	X	X	Railroad Bridge Diel Grab Sampling; Duplicate Grab Samples Collected

2. Site Locations and Descriptions

Mataponi Creek 38° 44.599’N, 76° 42.446’W (NAD83)

The Mataponi Creek site is located in a small tributary (Mataponi Creek) off the upper tidal headwaters of the Patuxent River (Figures 2-1 and 2-2). The site is 2.4 km upstream from the mouth and located in the midchannel of the creek, which is approximately 7 m wide. Average depth at the site is 0.7 m with a mean tidal fluctuation of approximately 0.6 m. The bottom habitat is soft sediment, with submerged aquatic vegetation (SAV) abundant and dense during the summer months. Because of the dense SAV and limited degree of anthropogenic activities occurring within the watershed of this site, Mataponi Creek is thought to be a “reference” water quality site for the Jug Bay Reserve.

Railroad Bridge 38° 46.877'N, 76° 42.822'W (NAD83)
Railroad Bridge site is located slightly upstream (0.3 km) from Jackson's Landing at the Patuxent River Park. The site is roughly 1 km downstream of the confluence of the Western Branch tributary and the Patuxent River Mainstem (Figures 2-1 and 2-2). This section of the Patuxent River is approximately 70 m wide, with an average depth at the site of 1.4 m. Mean tidal fluctuation is approximately 0.6 m. The bottom habitat is characterized by soft sediment, with SAV evident in the shallow areas during the summer.

Iron Pot Landing 38° 47.760'N, 76° 43.248'W (NAD83)
Iron Pot Landing is located 2.09 km from the mouth of the Western Branch. The monitoring site is attached to a small pier near midchannel of the river and has an average depth of 1.6 m. The site is roughly 1 km downstream of a large (10-20 mgd) wastewater treatment plant effluent discharge site (Figures 2-1 and 2-2). The river is approximately 15 m wide at this site and flows through extensive riparian buffers. Tides are semi-diurnal and mean tidal fluctuation is approximately 0.6 m. Bottom habitat is soft sediment, with narrow SAV beds occasionally evident in the summer. Because of the proximity of this site to the discharge location for the wastewater treatment plant, this site is considered "impacted".

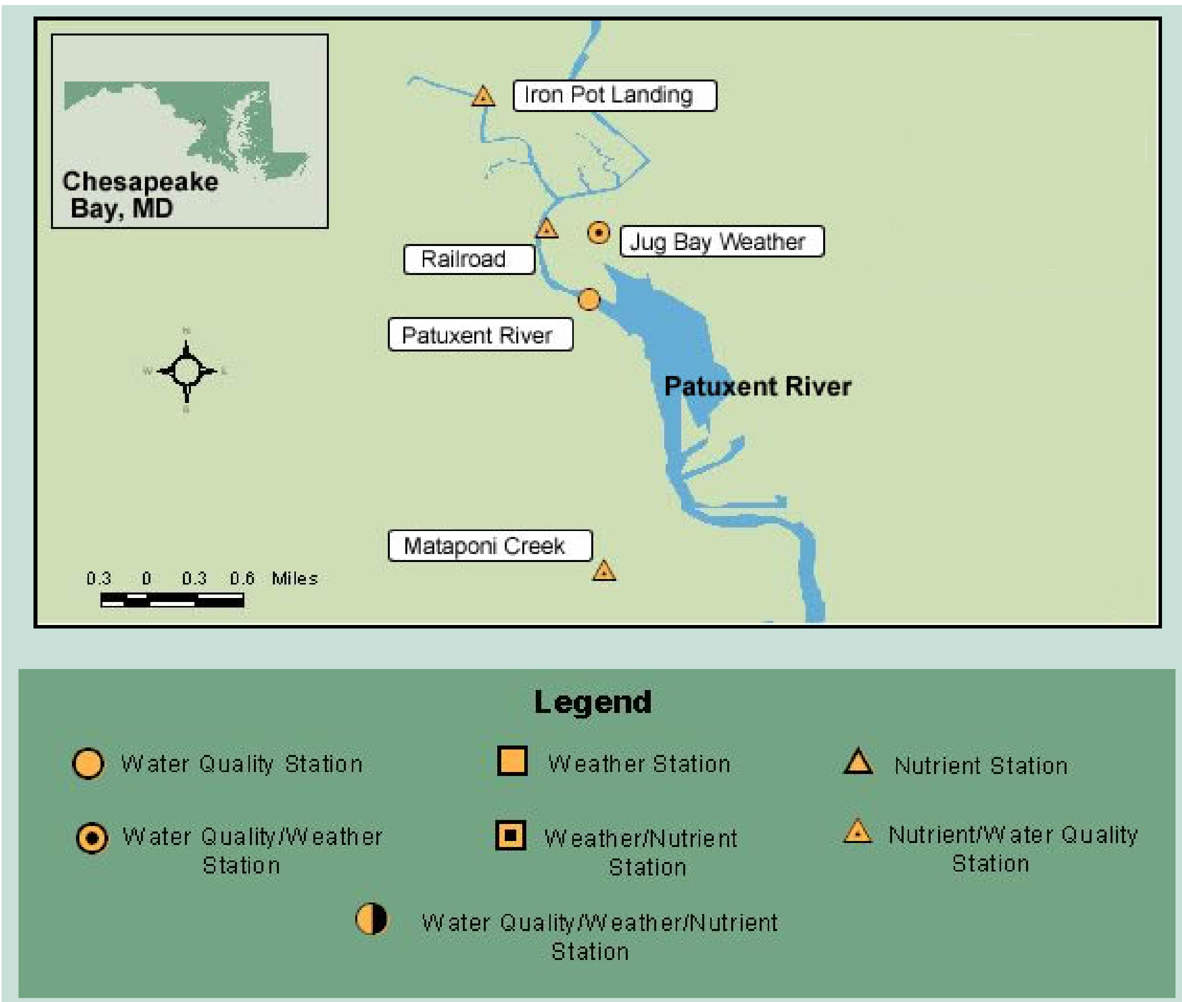


Figure 2-1. Map of Jug Bay NERR in the upper Patuxent River (Courtesy of NOAA NERRS).

Iron Pot Landing **Railroad Bridge** **Mataponi Creek**

Figure 2-2. Map of continuous monitoring stations in Jug Bay NERR.

3. Continuous Monitoring Results

The purpose of the water quality monitoring program was to conform to the NERRS System Wide Monitoring Program (SWMP) and to identify trends in water quality (water temperature, salinity, pH, dissolved oxygen, chlorophyll and turbidity) over both temporal and spatial scales. Water quality measurements were collected every 15 minutes from February 10^{th} to December 21^{st}, 2004 at Railroad Bridge and Iron Pot Landing and from March 11^{th} to December 21^{st}, 2004 at Mataponi Creek using YSI 6600 data loggers. Water quality conditions at each of the three stations exhibited temporal and spatial trends in response to a variety of biological, oceanographic and meteorological conditions that occurred in 2004. Missing data resulted from the rejection of "bad" data during quality assurance and quality control checks.

3.1 Temperature

As expected, water temperatures varied over the course of deployment, with highest temperatures occurring during the summer (June –September), followed by a decline in early September (Figure 3-1, Table 3-1). Railroad Bridge experienced both the lowest winter median temperature (3.08 °C) and the highest median summer temperature (24.04 °C) compared to the other two stations. All three stations experienced highest median temperatures in summer, followed by similar temperatures in the spring and fall, and lowest temperatures in winter (Table 3-1).

Table 3-1. Description of median temperatures for winter (Jan.-Feb.), spring (Mar.-May), summer (Jun.-Sep.) and fall (Oct.-Nov.) at upper Patuxent River stations in 2004.

Season	Iron Pot Landing	Railroad Bridge	Mataponi Creek
Winter	5.77 °C	3.08 °C	6.51 °C
Spring	14.43 °C	16.14 °C	14.36 °C
Summer	22.79 °C	24.04 °C	22.17 °C
Fall	15.51 °C	13.73 °C	12.63 °C

3.2 Salinity

All three stations experienced relatively stable salinity readings except for excursions due to tidal fluctuations (Figure 3-2, Table 3-2). Mataponi Creek experienced more frequent fluctuations in salinity throughout the deployment period, with a maximum occurring on November 5th, 2004. Iron Pot Landing and Railroad Bridge both experienced peaks in salinity in late January 2004. The maximum recorded salinity at the Iron Pot Landing site (0.79 ppt) occurred on January 19th, several days before the maximum recorded salinity (0.37 ppt) occurred at Railroad Bridge. The datasondes were removed shortly after these salinity spikes due to ice concerns (the Mataponi Creek datasonde was removed two weeks earlier). It is possible that the spikes in salinity were due to ice formation when salt was expelled from the freezing water, thus increasing the salinity of the underlying waters.

Table 3-2. Description of salinity at upper Patuxent River stations in 2004.

Site	mean	median	minimum	maximum	variance
Iron Pot Landing	0.17 ppt	0.18 ppt	0.05 ppt	0.79 ppt	0.00
Railroad Bridge	0.13 ppt	0.13 ppt	0.00 ppt	0.37 ppt	0.00
Mataponi Creek	0.11 ppt	0.10 ppt	0.03 ppt	0.42 ppt	0.00

3.3 pH

Median pH values ranged from 6.50 at the Mataponi Creek site to 7.15 at the Iron Pot Landing site (Figure 3-3, Table 3-3). Railroad Bridge and Mataponi Creek experienced periods of elevated pH during the summer (Figures 3-3b and c). Maximum pH levels at the Railroad Bridge site (8.59) occurred on June 30th while maximum pH readings (8.34) were recorded on July 3 at Mataponi Creek. Elevated pH levels are often found during alga1 blooms due to chemical processes associated with photosynthesis. Periods of high pH at the Railroad Bridge station corresponded to periods of high oxygen saturation and chlorophyll concentrations. The elevated pH levels at the Mataponi Creek site corresponded with high dissolved oxygen saturation, but not chlorophyll concentrations, suggesting the presence of a blue-green algal bloom (Figure 3-9). The chlorophyll concentrations presented were calculated from fluorescence values. At the time of datasonde deployment, blue-green algae, such as *Microcystis*, fluorescence was outside the range of the continuous monitor probes. Therefore, blue-green algae blooms were not likely to show significant chlorophyll concentrations, but exhibited elevated pH and oxygen saturation concentrations.

Table 3-3. Description of pH at upper Patuxent River stations in 2004.

Site	mean	median	minimum	maximum	variance
Iron Pot Landing	7.13	7.15	6.47	7.48	0.01
Railroad Bridge	7.02	7.00	6.44	8.59	0.05
Mataponi Creek	6.51	6.50	5.94	8.34	0.03

3.4 Dissolved Oxygen

Dissolved oxygen (DO) concentrations varied diurnally and seasonally at all stations (Figures 3-4 and 3-5, Tables 3-4 and 3-5). Maximum median dissolved oxygen concentrations corresponded to lower winter water temperatures, which can hold more oxygen than warmer waters (Table 3-4). Median summer dissolved oxygen concentrations ranged from 3.77 mg/l at Mataponi Creek to 6.85 mg/l at Railroad Bridge. The frequency of dissolved oxygen concentrations below 5 mg/l was greatest at Mataponi Creek (41%), followed by Railroad Bridge (8.7%) and Iron Pot Landing (<1%). Oxygen concentrations below 5 mg/l exceed the threshold of the Bays' more sensitive organisms, such as fish, especially if exposed to these conditions for prolonged periods. The Mataponi Creek site was shallow (0.6m MLW) compared to Iron Pot Landing (1.6m MLW) and Railroad Bridge (1.3m MLW), and increased water temperatures and oxygen demand during the summer may have contributed to the steep drop in DO concentrations in May and subsequent low concentrations throughout the summer (Figures 3-4c and 3-5c) at this site.

Table 3-4. Description of median dissolved oxygen for winter (Jan.-Feb.), spring (Mar.-May), summer (Jun.-Sep.) and fall (Oct.-Nov) at upper Patuxent River stations in 2004.

Season	Iron Pot Landing	Railroad Bridge	Mataponi Creek
Winter	12.10 mg/l	12.97 mg/l	11.24 mg/l
Spring	8.43 mg/l	9.29 mg/l	9.09 mg/l
Summer	6.85 mg/l	6.31 mg/l	3.77 mg/l
Fall	8.23 mg/l	7.75 mg/l	5.43 mg/l

DO saturation exhibited similar seasonal trends as dissolved oxygen concentrations, with higher values during the winter and lowest values during the summer (Table 3-5). Mataponi Creek had lower saturation values overall, compared to Iron Pot Landing and Railroad Bridge. Railroad Bridge and Mataponi Creek both experienced periods of supersaturation during the spring and summer (Figures 3-5b and c). Supersaturation (over 100% DO saturation) can occur when there is a large algal bloom. During the daylight, when the algae are photosynthesizing, they can produce oxygen so rapidly that it is not able to escape into the atmosphere, thus leading to short-term saturation levels of greater than 100%. These periods of supersaturation at Railroad Bridge and Mataponi Creek corresponded to periods of high chlorophyll concentrations and elevated pH.

Table 3-5. Description of median dissolved oxygen saturation for winter (Jan.-Feb.), spring (Mar.-May), summer (Jun.-Sep.) and fall (Oct.-Nov) at upper Patuxent River stations in 2004.

Season	Iron Pot Landing	Railroad Bridge	Mataponi Creek
Winter	96.40%	98.70%	88.70 %
Spring	83.90%	92.10 %	82.50 %
Summer	79.60%	74.00 %	42.90 %
Fall	84.30%	74.10 %	51.50 %

3.5 Chlorophyll

Several algal blooms were observed at Railroad Bridge, with smaller spikes in chlorophyll occurring at Iron Pot Landing and Mataponi Creek (Figure 3-6). Maximum chlorophyll values ranged from 28 μg/l at Mataponi Creek to 139 μg/l at Railroad Bridge. Highest median chlorophyll concentrations occurred in the spring and summer with lowest concentrations occurring in the winter (Table 3-6). Spring and early summer algal blooms are typical due to increases in nutrients (made available by winter mixing) and increased sunlight, both of which are necessary for algal growth. Chlorophyll concentrations at Railroad Bridge were greater throughout the deployment period when compared to Iron Pot Landing and Mataponi Creek. The Patuxent River and several creeks flow into Jug Bay and during the low-flow periods of the summer months, increased water temperatures and excessive nutrient levels resulted in frequent algal blooms in the area (Figure 3-6b). These bloom events corresponded with periods of elevated pH and DO concentrations.

Overall, the frequency of bloom events was very low compared to the total number of chlorophyll observations at the continuous monitoring stations. Chlorophyll concentrations exceeding 50 μg/l occurred less than 1% of the time at all stations. Median chlorophyll concentrations at all stations during the entire deployment period were well below the 15 μg/l SAV habitat limit. Chlorophyll concentrations exceeding this limit reduce the light reaching SAV and inhibit its growth.

Table 3-6. Description of median chlorophyll for winter (Jan.-Feb.), spring (Mar.-May), summer (Jun.-Sep.) and fall (Oct.-Nov) at upper Patuxent River stations in 2004.

Season	Iron Pot Landing	Railroad Bridge	Mataponi Creek
Winter	1.30 μg/l	2.70 μg/l	1.40 μg/l
Spring	2.10 μg/l	6.40 μg/l	2.90 μg/l
Summer	2.00 μg/l	6.30 μg/l	2.70 μg/l
Fall	1.60 μg/l	3.31 μg/l	2.00 μg/l

3.6 Turbidity

Maximum turbidity values ranged from 304 NTU at Railroad Bridge to 948 NTU at Iron Pot Landing (Figure 3-7). Maximum turbidity occurred on June 18th, 2004 at Iron Pot Landing and Railroad Bridge, and on November 10th at Mataponi Creek. Based on meteorological data observed at the weather station, these dates also experienced a series of thunderstorms and periods of high winds, which may have contributed to these spikes in observed turbidity.

Turbidity was highest in the summer at Iron Pot Landing and Railroad Bridge and during the spring at Mataponi Creek. Turbidity values at the Railroad Bridge site exceeded turbidity threshold limits (15 NTU) during the spring, summer and fall, while turbidity concentrations at the Mataponi Creek site exceeded threshold values during the winter and spring. Turbidity levels greater than 15 NTU have been shown to negatively impact SAV. The majority of high turbidity values; however, were short-lived and corresponded with high chlorophyll values (Figure 3-10a), suggesting that most periods of high turbidity were the result of algal biomass, rather than suspended solids. However, USGS discharge data for the Patuxent River near Upper Marlboro shows periods of increasing discharge in the fall, which also correspond to increases in turbidity (Figure 3-10b).

Table 3-7. Description of median turbidity for winter (Jan.-Feb.), spring (Mar.-May), summer (Jun.-Sep.) and fall (Oct.-Nov) at upper Patuxent River stations in 2004.

Season	Iron Pot Landing	Railroad Bridge	Mataponi Creek
Winter	6.50 NTU	14.10 NTU	15.10 NTU
Spring	13.40 NTU	17.20 NTU	17.60 NTU
Summer	14.70 NTU	22.00 NTU	10.90 NTU
Fall	11.90 NTU	18.20 NTU	9.60 NTU

3.7 Water Depth

Water depth was tidally influenced at all three stations during the 2004 monitoring period (Figure 3-8). Median water depth was greatest at Iron Pot Landing (2.0 m) and shallowest at Mataponi Creek (1.4 m). Water depth also varied by season at each site. Water depths were lowest during the spring at all stations and highest during the fall at Iron Pot Landing and Mataponi Creek and during the summer at Railroad Bridge (Table 3-8).

Table 3-8. Description of median water depth for spring (Mar.-May), summer (Jun.-Sep.) and fall (Oct.-Nov) at upper Patuxent River stations in 2004.

Season	Iron Pot Landing	Railroad Bridge	Mataponi Creek
Spring	1.72	1.49	0.89
Summer	1.76	1.57	1.15
Fall	1.80	1.53	1.17

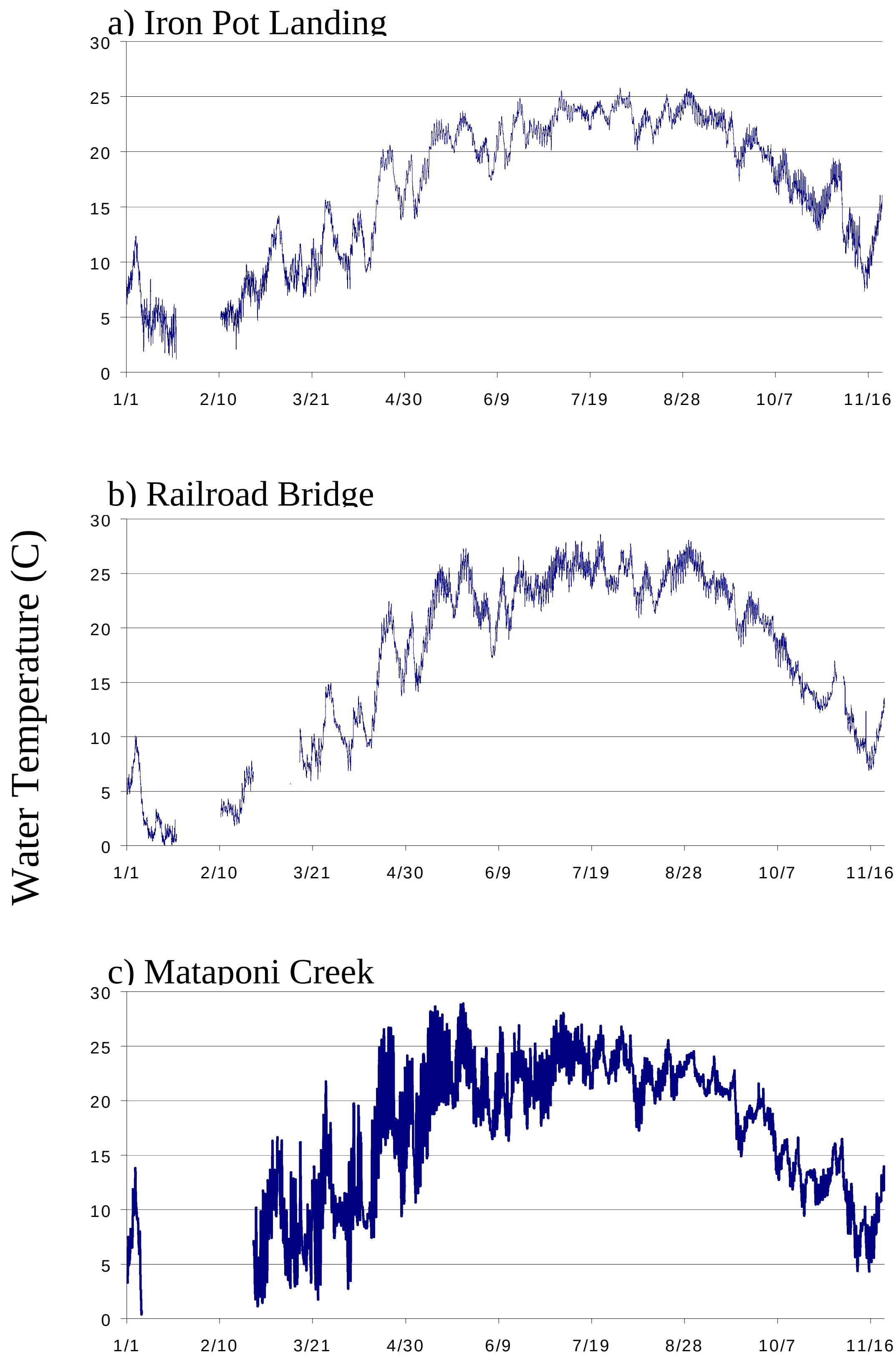


Figure 3-1. Time series of continuous monitoring temperature data at a) Iron Pot Landing, b) Railroad Bridge and c) Mataponi Creek from January through November 2004.

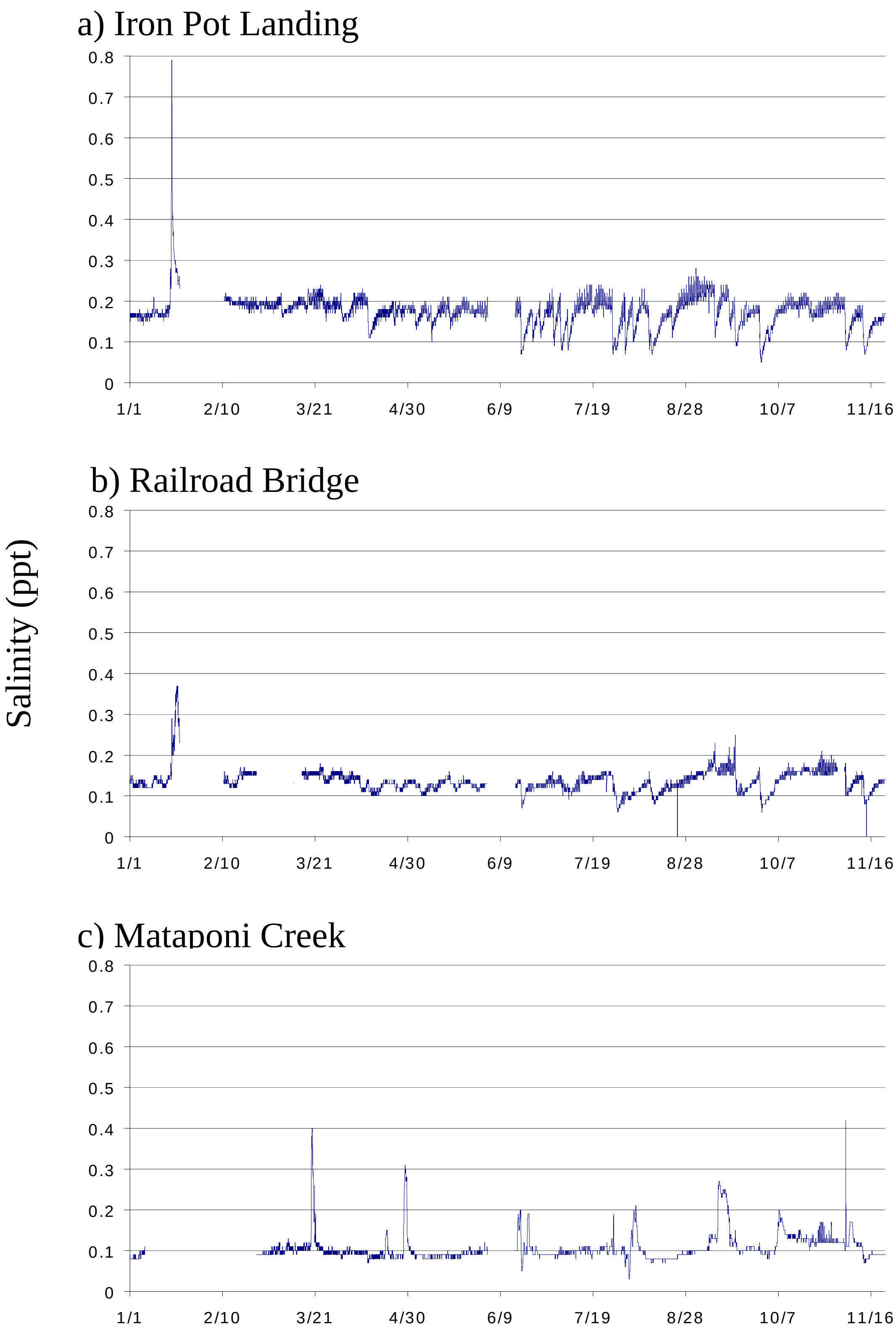


Figure 3-2. Time series of continuous monitoring salinity data at a) Iron Pot Landing, b) Railroad Bridge and c) Mataponi Creek from January through November 2004.

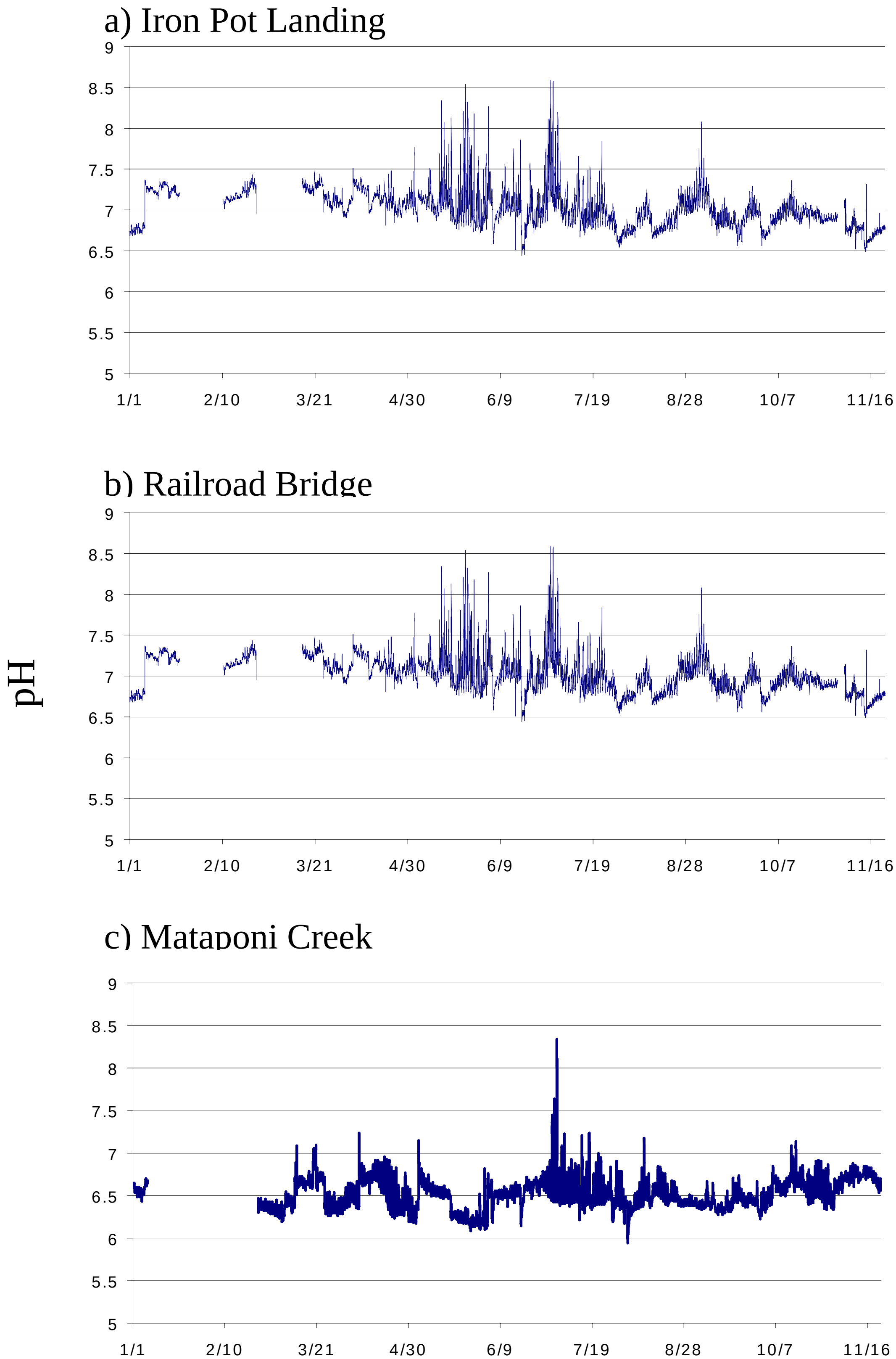


Figure 3-3. Time series of continuous monitoring pH data at a) Iron Pot Landing, b) Railroad Bridge and c) Mataponi Creek from January through November 2004.

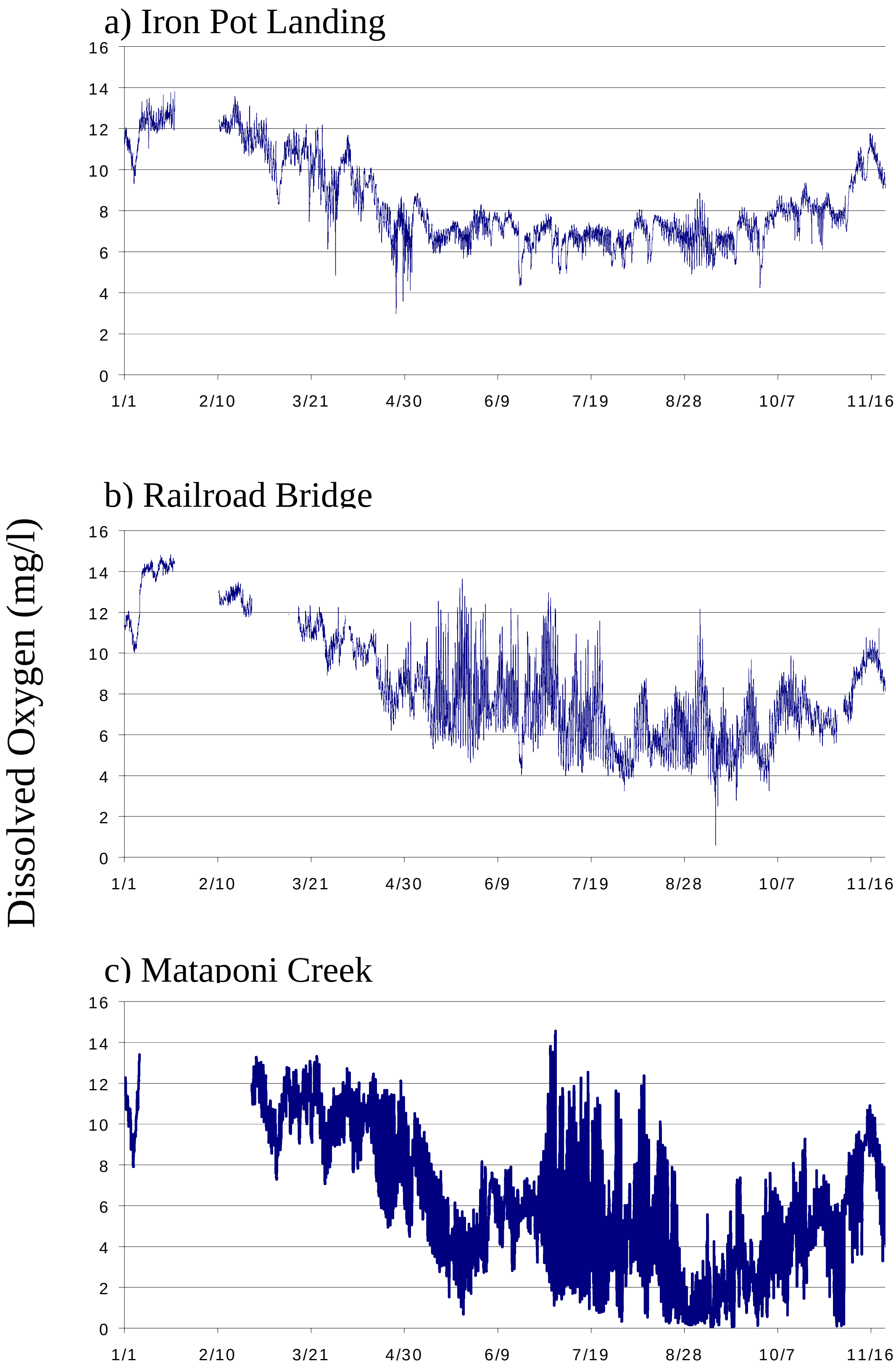


Figure 3-4. Time series of continuous monitoring dissolved oxygen data at a) Iron Pot Landing, b) Railroad Bridge and c) Mataponi Creek from January through November 2004.

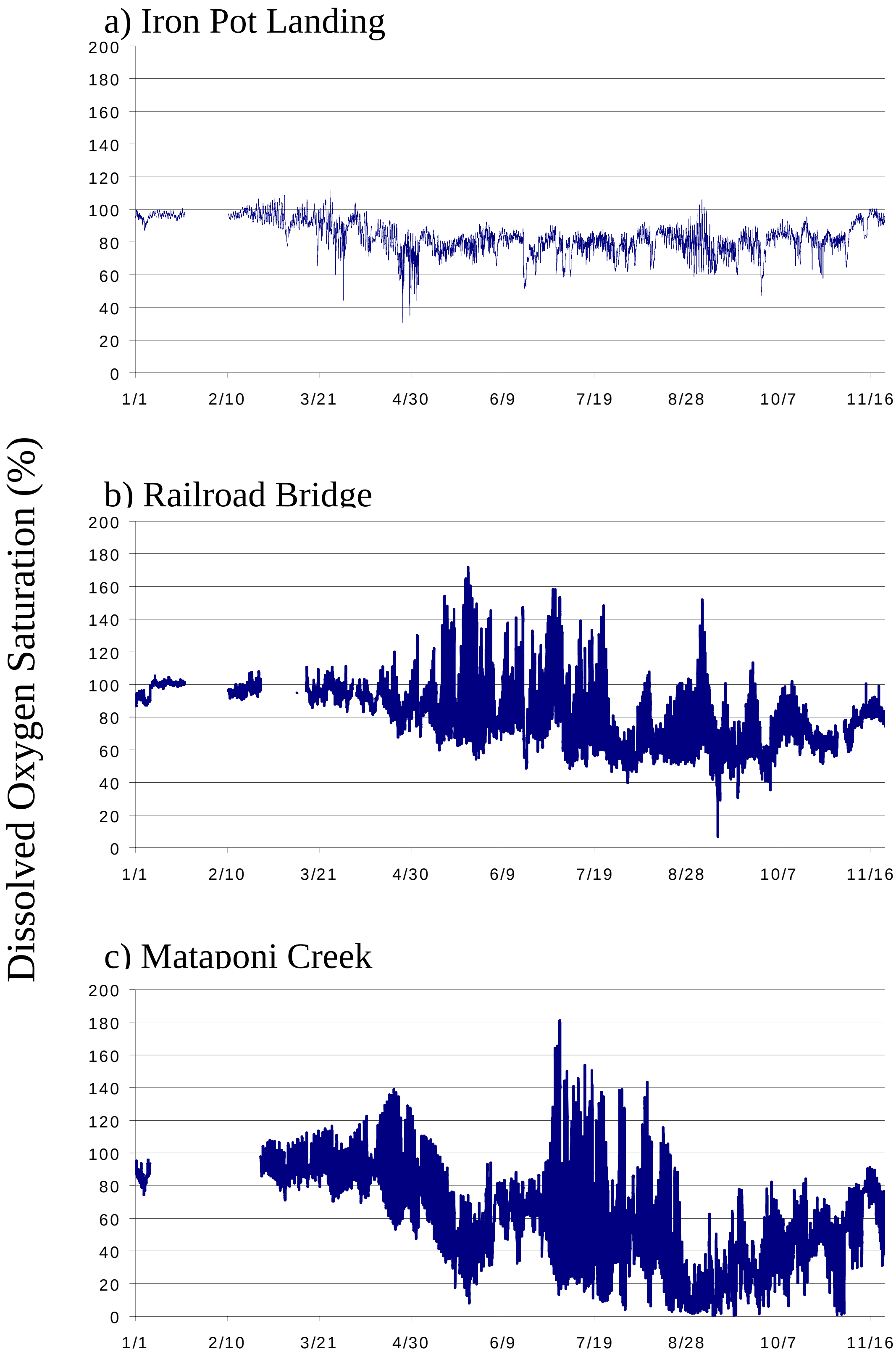


Figure 3-5. Time series of continuous monitoring dissolved oxygen saturation data at a) Iron Pot Landing, b) Railroad Bridge and c) Mataponi Creek from January through November 2004.

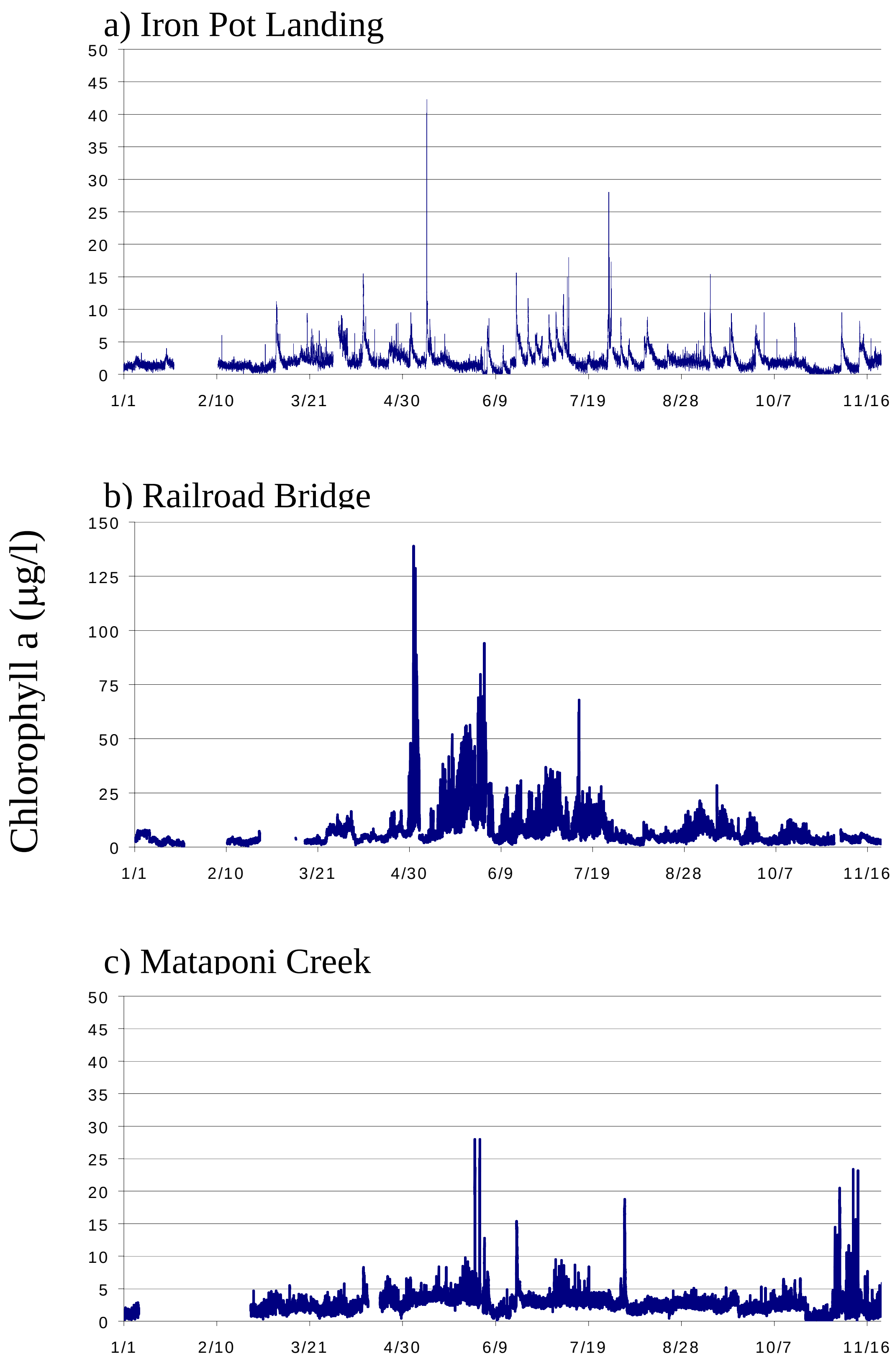


Figure 3-6. Time series of continuous monitoring chlorophyll a data at a) Iron Pot Landing, b) Railroad Bridge and c) Mataponi Creek from January through November 2004.

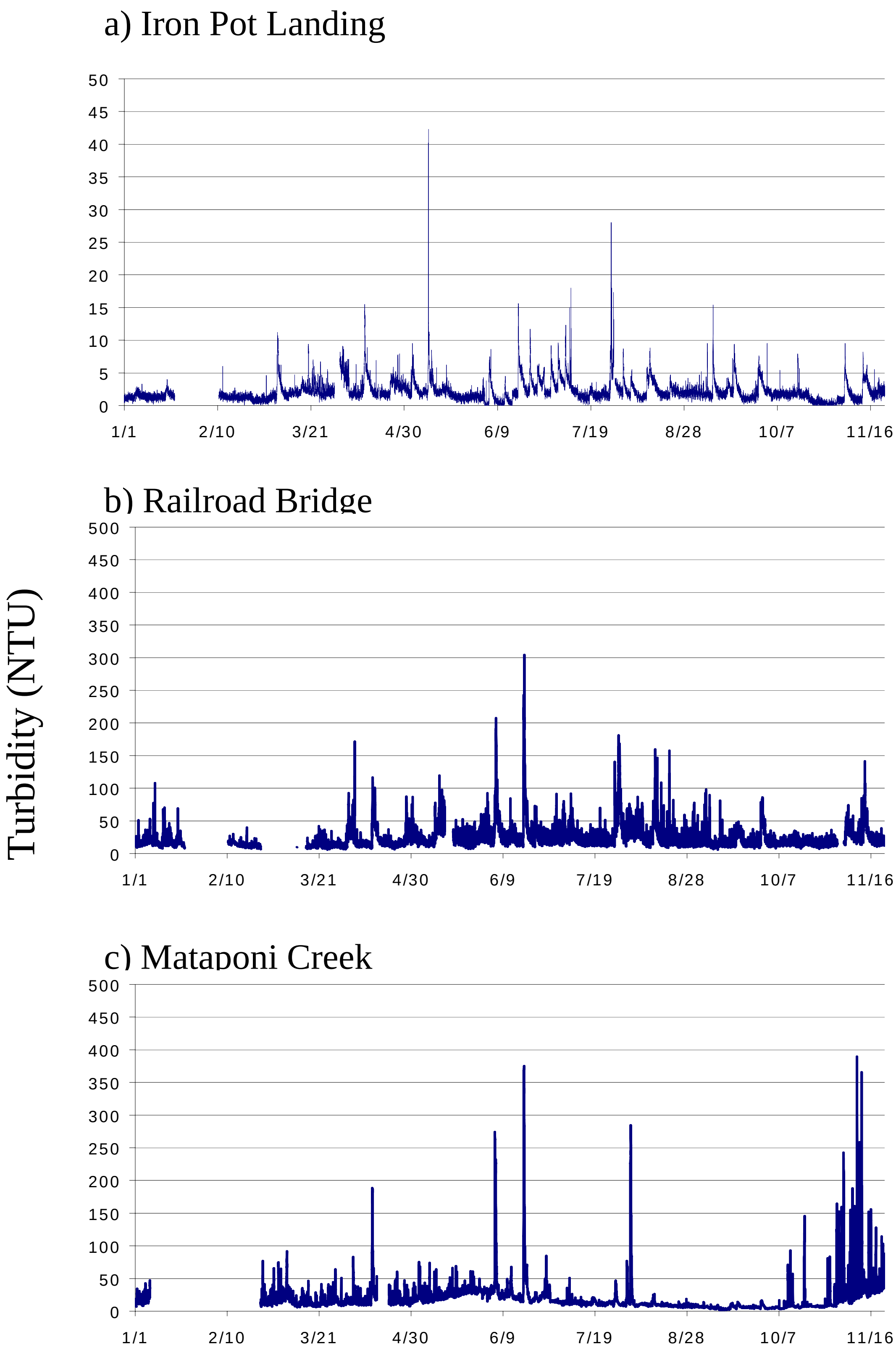


Figure 3-7. Time series of continuous monitoring turbidity data at a) Iron Pot Landing, b) Railroad Bridge and c) Mataponi Creek from January through November 2004.

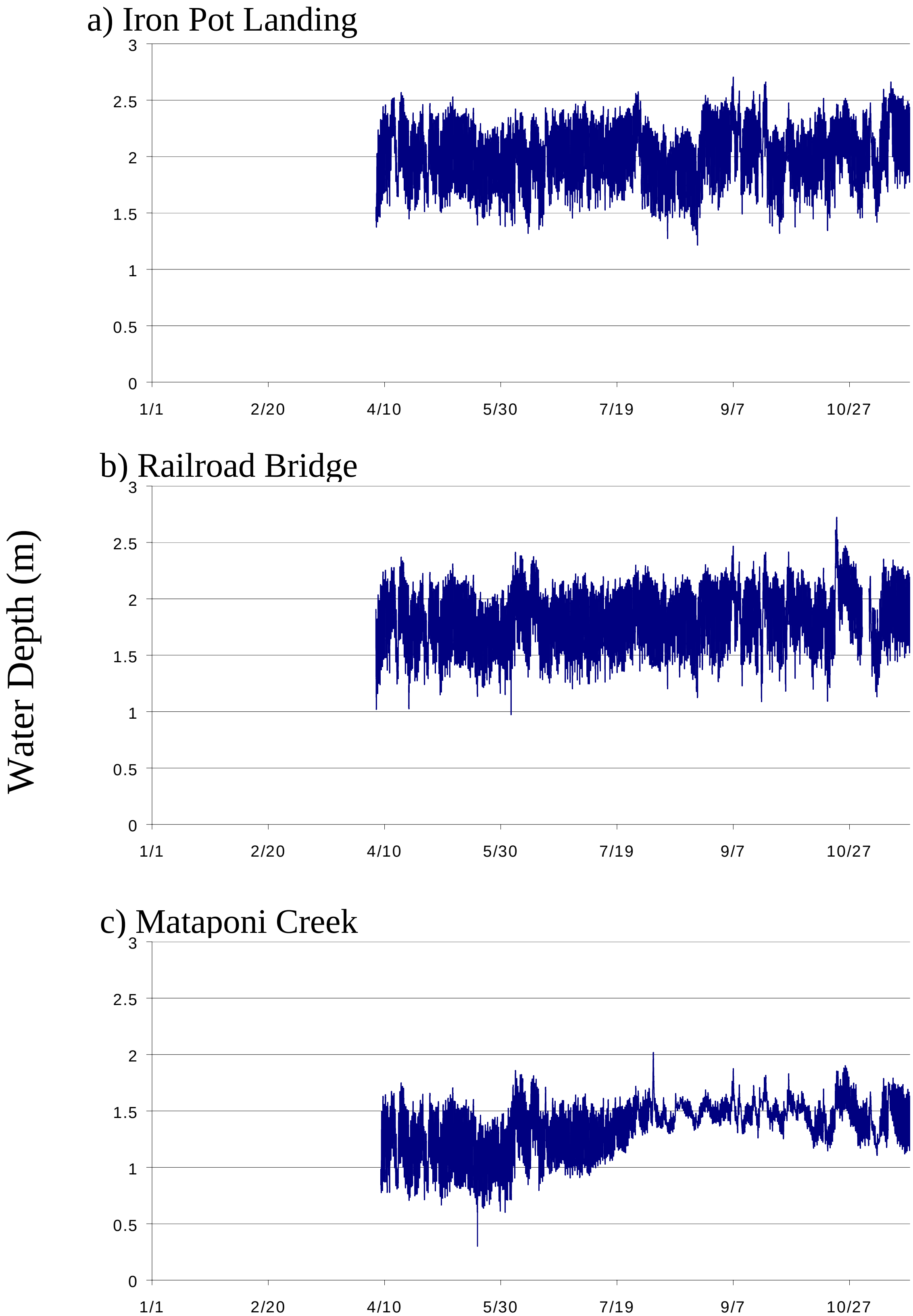


Figure 3-8. Time series of continuous monitoring water depth data at a) Iron Pot Landing, b) Railroad Bridge and c) Mataponi Creek from January through November 2004.

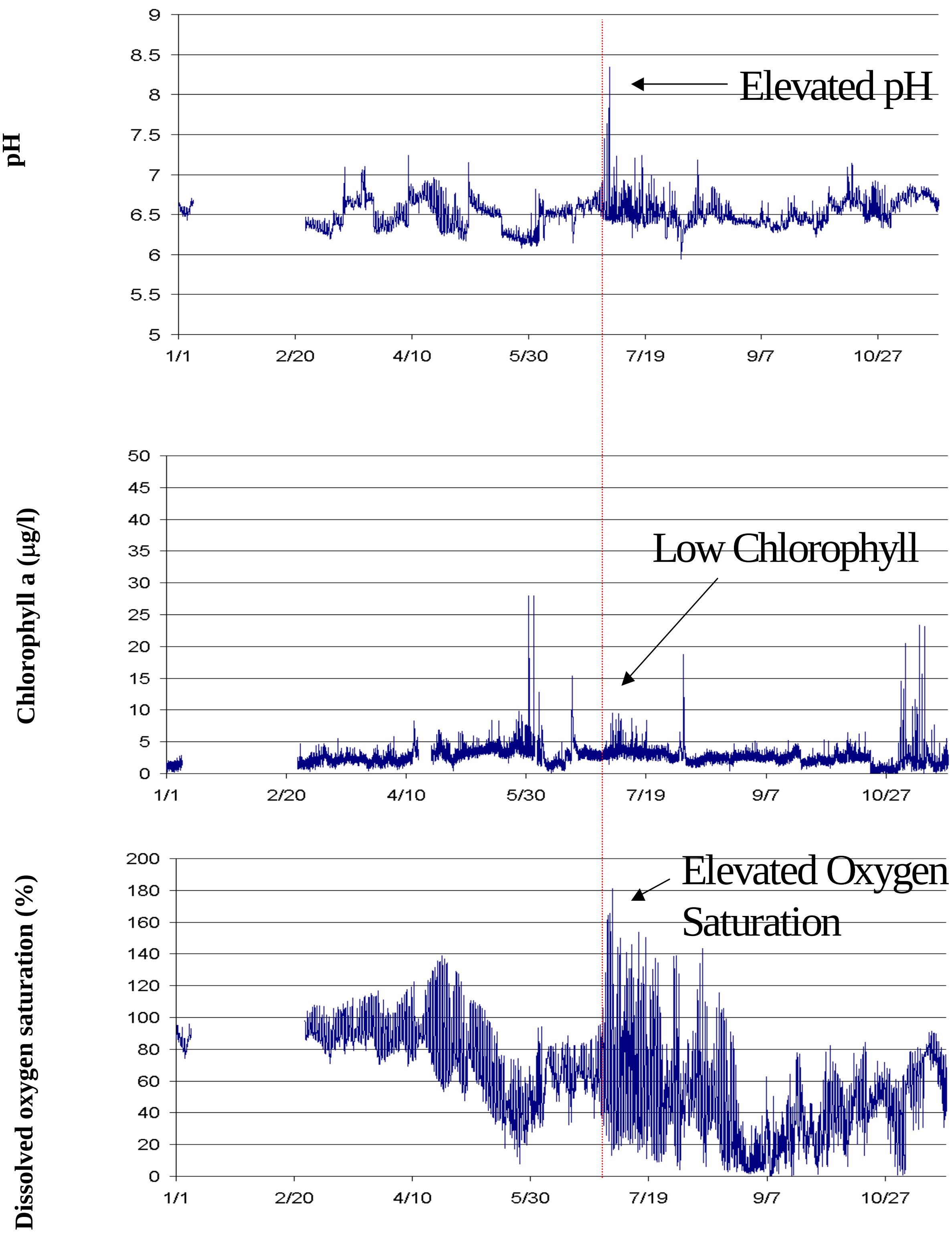
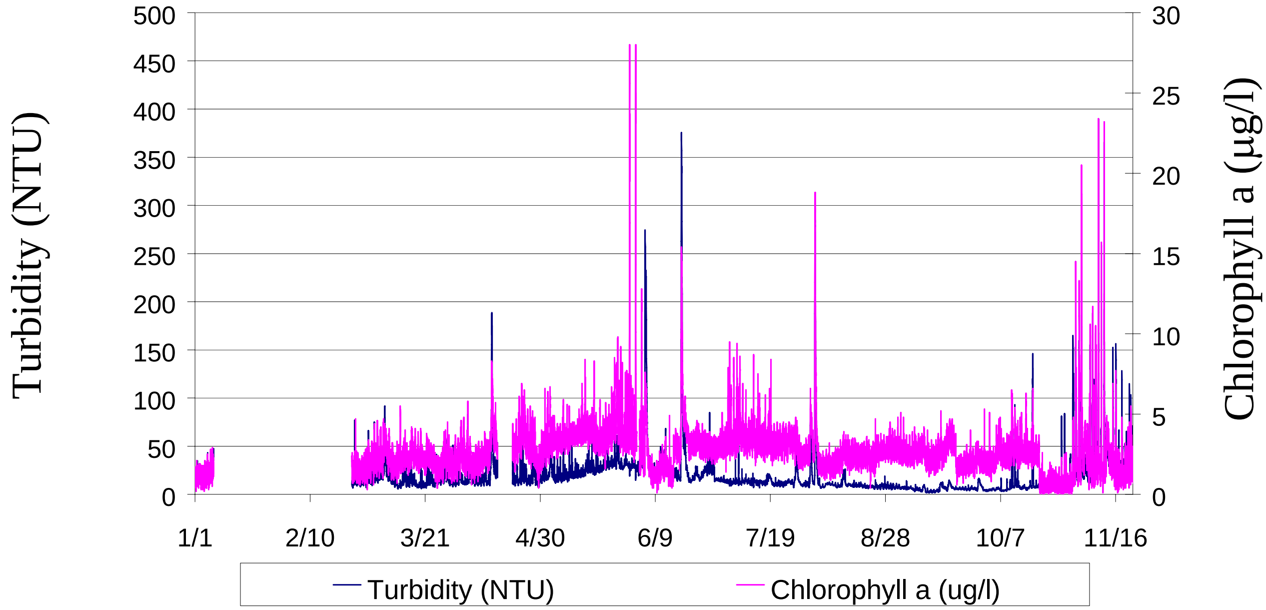


Figure 3-9. Example of elevated pH, high dissolved oxygen saturation and low chlorophyll concentrations during a possible cyanobacteria bloom at the Mataponi Creek site in 2004.

a)



b)

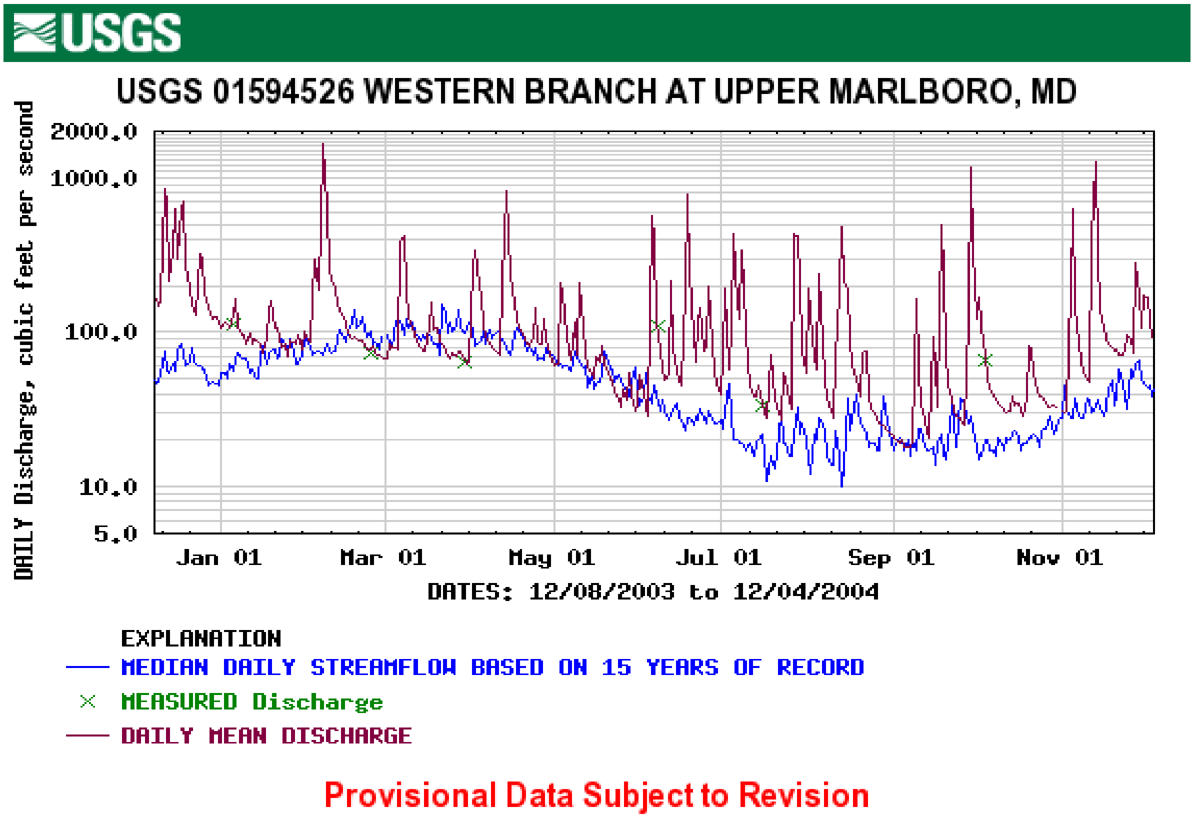


Figure 3-10. Comparison of turbidity and chlorophyll (a) values and Patuxent River discharge data (b) for Mataponi Creek in 2004.

3.8 Monthly Grab Sampling Results

The goals of the monthly nutrient sampling were to create a long-term database of nutrient information at each site for the purpose of detecting changes over time and across sites. Samples for nutrient analyses were collected monthly at each site during the continuous monitoring deployment period. Nutrient grab samples were collected by Maryland DNR on a monthly basis from February to December at all three sites (Table 1-1). Duplicate samples were taken once monthly and analyzed for chlorophyll a, nitrate, nitrite, ammonium and orthophosphate. An additional round of sampling (not in duplicate) was conducted each month at each site in collaboration with Maryland DNR's Continuous Monitoring Program. Diel nutrient sampling was conducted once monthly at the Railroad Bridge station from March through December 2004 and included the core NERRS nutrients. Unattended samplers were programmed to collect water samples every two and one half hours, over a 24 hour period. Nutrient samples were analyzed by the Nutrient and Analytical Services Laboratory (NASL) at Chesapeake Biological Laboratory. Missing data was rejected and deleted through QA/QC procedures.

Highest mean chlorophyll a concentrations occurred in the spring at Iron Pot Landing and Railroad Bridge, with lowest concentrations occurring in the fall at both sites (Tables 3-9, 3-10 and 3-11). This trend was reversed at Mataponi Creek where highest chlorophyll a concentrations were present in the fall. Overall, chlorophyll a concentrations at Railroad Bridge were greater throughout the deployment period when compared to Iron Pot Landing and Mataponi Creek (Tables 3-9, 3-10 and 3-11). 75% (24/32) of chlorophyll a observations exceeded the 15 μg/l SAV habitat limit at the Railroad Bridge site during the time of deployment. Mataponi Creek and Iron Pot Landing exceeded the 15 μg/l SAV habitat limit 31% and 32% of the deployment period, respectively.

Nutrient concentrations also varied by season and site (Tables 3-9, 3-10 and 3-11). Orthophosphate and ammonium concentrations were highest at Iron Pot Landing and lowest at Mataponi Creek. Highest nitrite and nitrate concentrations occurred at Railroad Bridge, while lowest nitrite and nitrate levels were present at Mataponi Creek. Ammonium and nitrite concentrations were greater in the spring, while orthophosphate concentrations were greatest in the summer. Nitrate levels were highest in the summer at Iron Pot Landing, but were greatest in the spring at Mataponi Creek and Railroad Bridge.

Chlorophyll concentrations exhibited responses to diel and tidal cycles (Figures 3-11 through 3-20). Peaks in chlorophyll corresponded with high tide and generally occurred a few hours after sunrise. Orthophosphate and nitrate concentrations showed the greatest response to tidal cycle and chlorophyll concentration (Figures 3-11 through 3-20). The greatest concentrations of orthophosphate and nitrate occurred during periods of low tide and were inversely proportional to chlorophyll concentrations. Nitrite and ammonium concentrations were low throughout the diel sampling period and did not show significant fluctuations due to tidal or diel cycles.

Table 3-9. Iron Pot Landing 2004 monthly Orthophosphate (PO_4), Ammonium (NH_4), Nitrite (NO_2), Nitrate (NO_3) and Chlorophyll a (CHLA) data.

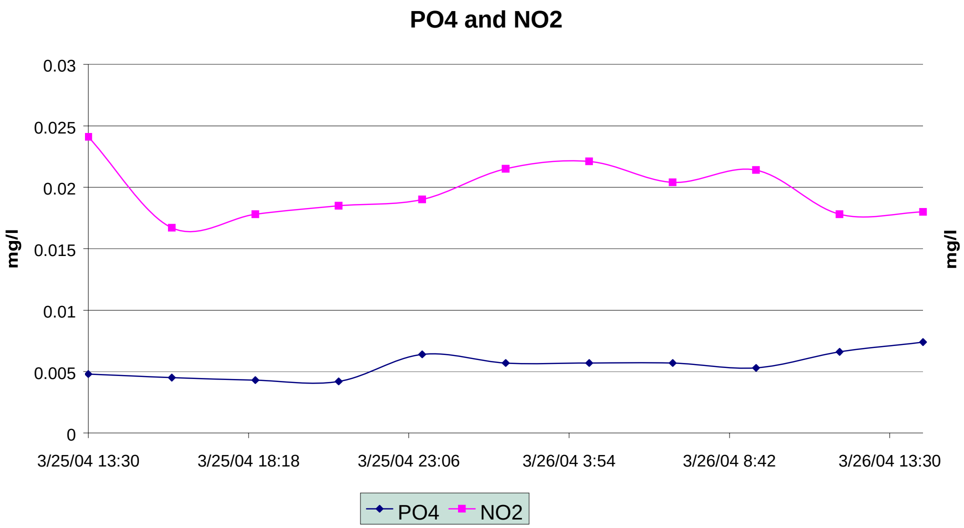
	Date	Time	Replicate	PO4F	NH4F	NO2F	NO3F	CHLA
	mm/dd/yy	**hh:mm**		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**μg/L**
	02/10/04	13:45	1	0.0283	0.168	0.0094	0.844	
	02/10/04	13:47	2	0.0101	0.162	0.0092	0.832	
Spring	03/11/04	10:45	1	0.0109	0.445	0.0185	0.537	39.2
	03/11/04	10:45	2	0.0122	0.462	0.0177	0.528	7.5
	04/06/04	9:00	1	0.0155	2.335	0.0057	0.308	15.0
	04/20/04	9:45	1	0.0164	1.730	0.0093	0.198	11.2
	04/20/04	9:45	2	0.0256	1.617	0.0101	0.238	11.2
	05/04/04	9:00	1	0.0219	0.529	0.0204	0.278	26.2
	05/18/04	10:45	1	0.0553	0.154	0.0229	0.325	17.4
	05/18/04	10:45	2	0.0540	0.170	0.0240	0.364	15.0
Mean				**0.0265**	**0.930**	**0.0161**	**0.347**	**17.8**
Median				**0.0192**	**0.496**	**0.0181**	**0.317**	**15.0**
St. Dev.				**0.0180**	**0.835**	**0.0068**	**0.125**	**10.3**
Summer	06/03/04	11:45	1	0.1310	0.0830	0.0143	0.850	10.0
	06/15/04	10:00	1	0.2660	0.1140	0.0121	0.508	12.5
	06/15/04	10:01	2	0.2520	0.0740	0.0120	0.424	7.5
	06/29/04	10:30	1	0.1360	0.0580	0.0082	0.406	7.5
	07/13/04	9:30	1	0.1180	0.0580	0.0082	0.409	5.6
	07/29/04	9:30	1	0.0317	0.0530	0.0112	0.269	18.7
	07/29/04	9:30	2	0.0331	0.0570	0.0108	0.282	18.7
	08/10/04	12:15	1	0.2240	0.0540	0.0105	1.110	
	08/24/04	10:00	1	0.1410	0.0690	0.0054	0.655	22.4
	08/24/04	10:00	2	0.1340	0.0670	0.0060	0.654	27.4
Mean				**0.147**	**0.0687**	**0.0099**	**0.557**	**14.5**
Median				**0.135**	**0.0625**	**0.0107**	**0.466**	**12.5**
St. Dev.				**0.081**	**0.0186**	**0.0028**	**0.265**	**7.6**
Fall	09/07/04	9:30	1	0.1950	0.0640	0.0056	0.810	11.2
	09/21/04	9:30	1	0.1050	0.0450	0.0059	0.561	9.3
	09/21/04	9:30	2	0.1080	0.0410	0.0059	0.569	9.3
	10/05/04	10:00	1	0.2040	0.0370	0.0070	0.344	4.5
	10/20/04	9:30	1	0.1450	0.0230	0.0036	0.529	3.7
	10/20/04	9:30	2	0.1480	0.0140	0.0036	0.515	
	11/01/04	12:45	1	0.1638	0.0150	0.0043	0.214	15.0
	11/22/04	11:00	1	0.0807	0.0330	0.0067	0.307	12.0
	11/22/04	11:00	2	0.0851	0.0360	0.0064	0.307	12.0
Mean				**0.137**	**0.0342**	**0.0054**	**0.462**	**9.6**
Median				**0.145**	**0.0360**	**0.0059**	**0.515**	**10.3**
St. Dev.				**0.045**	**0.0157**	**0.0013**	**0.185**	**3.9**
	12/08/04	11:30	1	0.0161	0.0650	0.0086	0.364	15.0
	12/21/04	11:15	1	0.1260	0.1140	0.0066	0.801	7.5
	12/21/04	11:15	2	0.1280	0.1150	0.0063	0.803	5.6
Annual								
Mean				**0.102**	**0.273**	**0.0097**	**0.522**	**13.0**
Median				**0.113**	**0.072**	**0.0082**	**0.512**	**11.2**
St. Dev.				**0.073**	**0.535**	**0.0053**	**0.236**	**7.8**

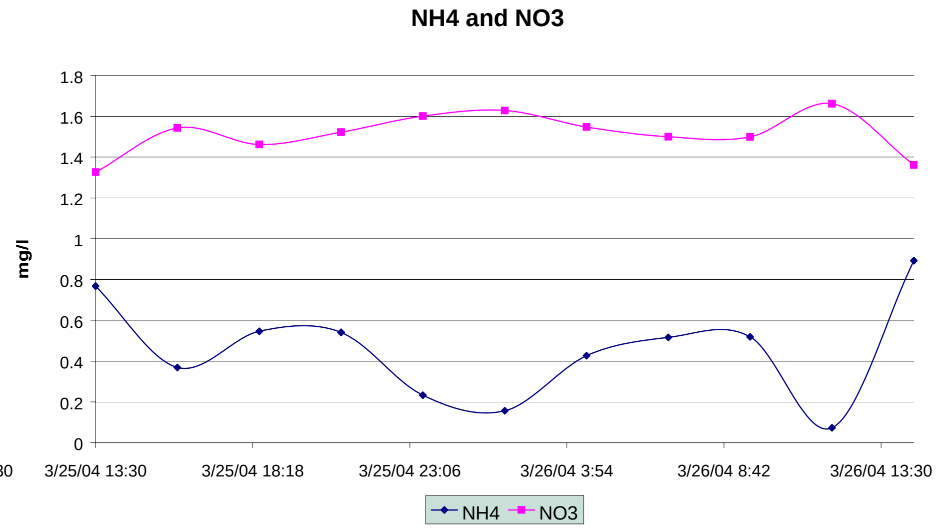
Table 3-10. Railroad Bridge 2004 monthly Orthophosphate (PO_4), Ammonium (NH_4), Nitrite (NO_2), Nitrate (NO_3) and Chlorophyll a (CHLA) data.

	Date	Time	Replicate	PO4F	NH4F	NO2F	NO3F	CHLA
	mm/dd/yy	**hh:mm**		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**μg/L**
	02/10/04	12:15	1	0.0089	0.177	0.0145	1.556	12.5
	02/10/04	12:15	2	0.0095	0.182	0.0146	1.565	12.5
Spring	03/11/04	9:15	1	0.0115	0.112	0.0156	1.394	27.4
	03/11/04	9:15	2	0.0108	0.115	0.0136	1.376	27.4
	04/06/04	7:30	1	0.0151	0.322	0.0120	1.188	15.0
	04/20/04	11:15	1	0.0293	0.476	0.0189	1.061	17.4
	04/20/04	11:15	2	0.0412	0.496	0.0185	1.062	19.9
	05/04/04	7:30	1	0.0392	0.129	0.0236	1.156	19.9
	05/18/04	8:00	1	0.0204	0.107	0.0319	1.018	299.0
	05/18/04	8:00	2	0.0150	0.112	0.0324	0.928	284.1
Mean				**0.0228**	**0.234**	**0.0208**	**1.148**	**88.8**
Median				**0.0178**	**0.122**	**0.0187**	**1.109**	**23.7**
St. Dev.				**0.0122**	**0.172**	**0.0078**	**0.167**	**125.3**
Summer	06/03/04	9:45	1	0.0168	0.0180	0.0232	1.017	256.7
	06/15/04	11:15	1	0.0401	0.0400	0.0174	0.932	44.8
	06/15/04	11:16	2	0.0402	0.0760	0.0172	0.754	49.8
	06/29/04	8:30	1	0.0312	0.0410	0.0143	0.962	94.7
	07/13/04	8:15	1	0.0447	0.0410	0.0143	0.522	109.6
	07/27/04	8:45	1	0.0467	0.0640	0.0192	0.632	47.3
	07/27/04	8:45	2	0.0447	0.0640	0.0189	0.645	62.3
	08/10/04	10:30	1	0.0274	0.0470	0.0114	0.742	59.8
	08/24/04	8:00	1	0.0403	0.0680	0.0116	0.719	67.3
	08/24/04	8:00	2	0.0383	0.0530	0.0119	0.717	39.2
Mean				**0.0370**	**0.0512**	**0.0159**	**0.764**	**83.2**
Median				**0.0402**	**0.0500**	**0.0158**	**0.731**	**61.1**
St. Dev.				**0.0093**	**0.0173**	**0.0039**	**0.159**	**65.0**
Fall	09/07/04	8:00	1	0.0321	0.0290	0.0075	0.382	114.0
	09/21/04	8:00	1	0.0451	0.0530	0.0097	0.522	29.9
	09/21/04	8:00	2	0.0404	0.0540	0.0095	0.542	44.8
	10/05/04	8:45	1	0.0424	0.0550	0.0102	0.439	22.4
	10/20/04	8:15	2	0.0407	0.0780	0.0079	0.790	44.8
	10/20/04	8:15	S	0.0412	0.0960	0.0084	0.790	37.4
	11/01/04	14:15	1	0.0369	0.0500	0.0099	0.690	12.5
	11/22/04	9:45	2	0.0228	0.0950	0.0120	0.889	12.5
	11/22/04	9:45	S	0.0203	0.0970	0.0131	0.893	10.0
Mean				**0.0358**	**0.0674**	**0.0098**	**0.660**	**36.5**
Median				**0.0404**	**0.0550**	**0.0097**	**0.690**	**29.9**
St. Dev.				**0.0089**	**0.0247**	**0.0018**	**0.194**	**32.1**
	12/08/04	10:00	1	0.0096	0.1500	0.0115	0.889	5.0
	12/21/04	9:45	1	0.0104	0.1870	0.0105	1.150	7.5
	12/21/04	9:45	2	0.0118	0.1850	0.0117	1.158	5.0
Annual								
Mean				**0.0289**	**0.1209**	**0.0149**	**0.909**	**59.8**
Median				**0.0317**	**0.0865**	**0.0134**	**0.891**	**33.7**
St. Dev.				**0.0135**	**0.1144**	**0.0061**	**0.307**	**77.5**

Table 3-11. Mataponi Creek 2004 monthly Orthophosphate (PO_4), Ammonium (NH_4), Nitrite (NO_2), Nitrate (NO_3) and Chlorophyll a (CHLA) data.

	Date	Time	Replicate	PO4F	NH4F	NO2F	NO3F	CHLA
	mm/dd/yy	hh:mm		mg/L	mg/L	mg/L	mg/L	µg/L
Spring	03/11/04	12:00	1	0.0151	0.0670	0.0082	0.598	9.0
	03/11/04	12:00	2	0.0103	0.0910	0.0098	0.611	6.0
	04/08/04	11:00	1	0.0149	0.0490	0.0059	0.384	13.4
	04/20/04	8:30	1	0.0111	0.0470	0.0085	0.389	10.0
	04/20/04	8:30	2	0.0108	0.1110	0.0086	0.391	12.5
	05/04/04	10:30	1	0.0335	0.1010	0.0135	0.394	17.4
	05/18/04	9:30	1	0.0370	0.2620	0.0220	0.358	12.5
	05/18/04	9:30	2	0.0387	0.3000	0.0246	0.319	12.5
Mean				**0.0214**	**0.1285**	**0.0126**	**0.431**	**11.7**
Median				**0.0150**	**0.0960**	**0.0092**	**0.390**	**12.5**
St. Dev.				**0.0126**	**0.0974**	**0.0069**	**0.110**	**3.4**
Summer	06/03/04	13:00	1	0.0159	0.1960	0.0195	0.355	15.0
	06/15/04	8:45	1	0.0206	0.0650	0.0153	0.357	5.0
	06/15/04	8:46	2	0.0397	0.0620	0.0154	0.399	10.0
	06/29/04	12:00	1	0.0287	0.0120	0.0046	0.385	12.5
	07/13/04	10:45	1	0.0251	0.0120	0.0046	0.134	12.5
	07/27/04	10:45	1	0.0259	0.0200	0.0075	0.171	56.1
	07/27/04	10:45	2		0.0310	0.0062		37.4
	08/10/04	13:30	1	0.0244	0.0320	0.0101	0.317	
	08/24/04	11:00	1	0.0274	0.0510	0.0032	0.116	7.5
	08/24/04	11:00	2	0.0226	0.0260	0.0028	0.141	9.3
Mean				**0.0256**	**0.0507**	**0.0089**	**0.264**	**18.4**
Median				**0.0251**	**0.0315**	**0.0069**	**0.317**	**12.5**
St. Dev.				**0.0065**	**0.0545**	**0.0059**	**0.120**	**17.0**
Fall	09/07/04	10:45	1	0.0167	0.0030	0.0045	0.027	49.8
	09/21/04	10:45	1	0.0187	0.0330	0.0025	0.091	6.0
	09/21/04	10:45	2	0.0160	0.0200	0.0029	0.082	7.5
	10/05/04	13:00	1	0.0224		0.0062	0.094	35.5
	10/20/04	11:00	1	0.0234	0.0180	0.0045	0.209	7.5
	10/20/04	11:00	2	0.0251	0.0120	0.0044	0.206	29.9
	11/01/04	11:00	1	0.0166	0.0190	0.0073	0.131	7.5
	11/22/04	12:15	1	0.0144	0.0720	0.0088	0.393	15.0
	11/22/04	12:15	2	0.0130	0.0670	0.0088	0.349	26.2
Mean				**0.0185**	**0.0305**	**0.0055**	**0.176**	**20.5**
Median				**0.0167**	**0.0195**	**0.0045**	**0.131**	**15.0**
St. Dev.				**0.0042**	**0.0255**	**0.0024**	**0.126**	**15.6**
	12/08/04	12:45	1	0.0113	0.0530	0.0092	0.463	13.1
	12/21/04	12:30	1	0.0089	0.1420	0.0094	0.769	1.5
	12/21/04	12:30	2	0.0090	0.1400	0.0095	0.767	3.0
Annual								
Mean				**0.0206**	**0.0729**	**0.0089**	**0.324**	**15.9**
Median				**0.0187**	**0.0510**	**0.0084**	**0.355**	**12.5**
St. Dev.				**0.0089**	**0.0735**	**0.0056**	**0.195**	**13.5**





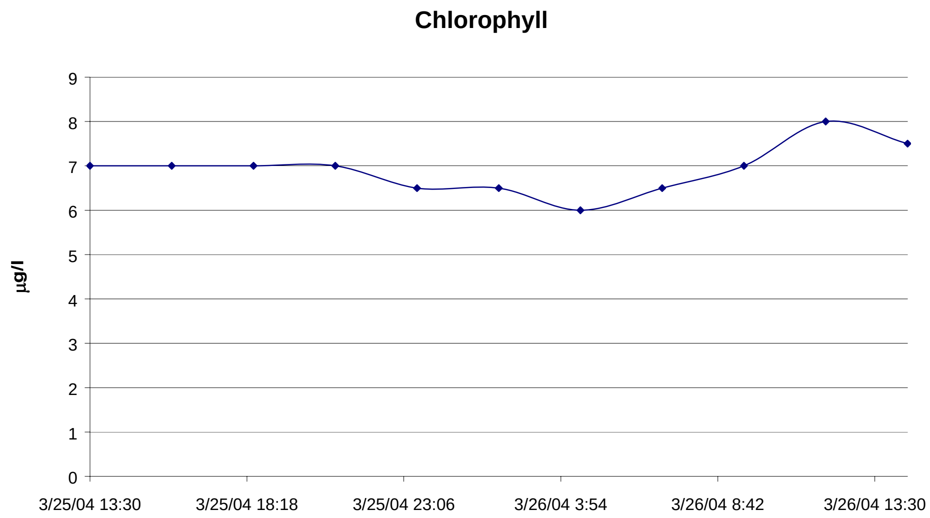


Figure 3-11. March 2004 Diel Nutrient and Chlorophyll Data.

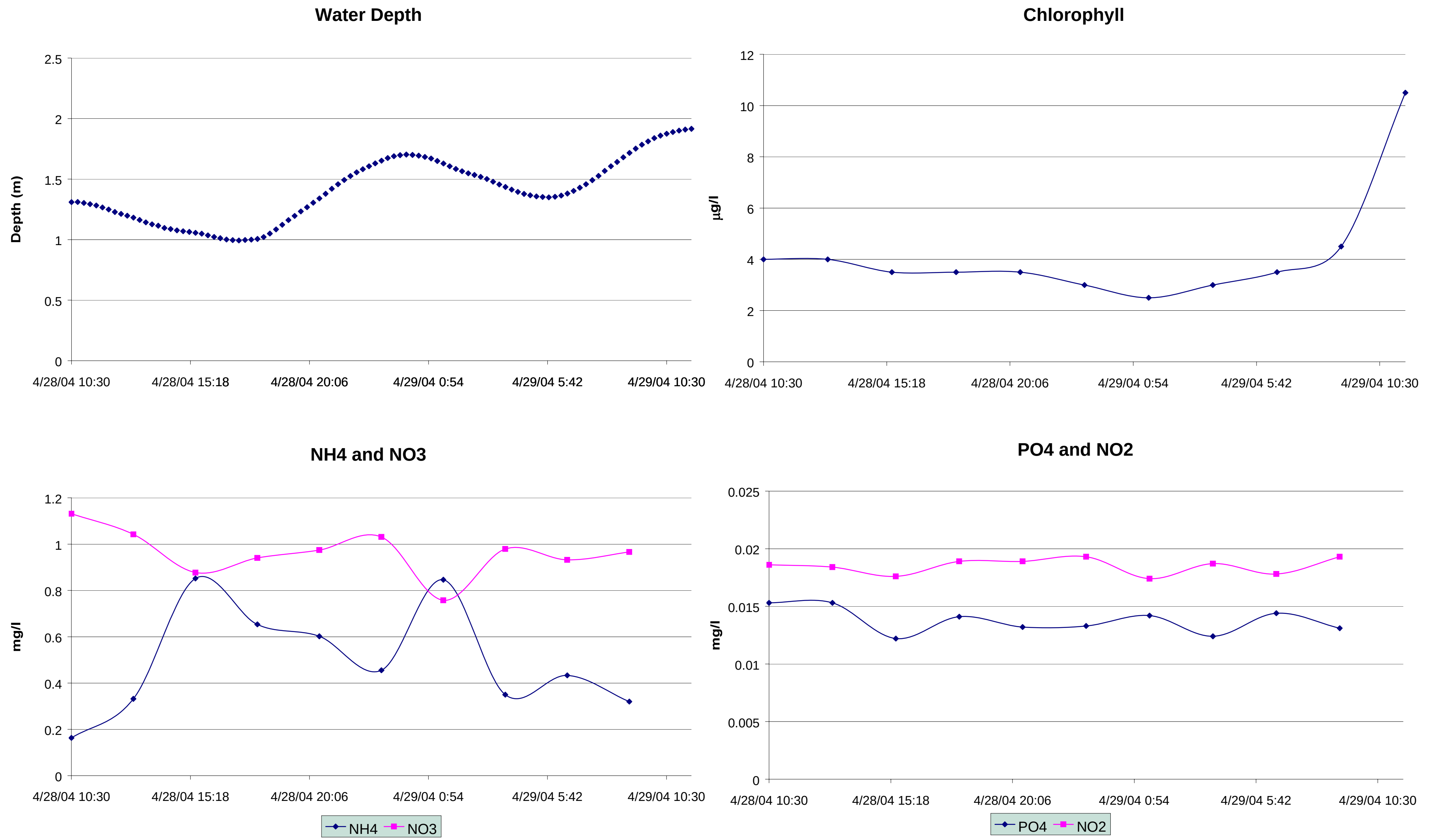


Figure 3-12. April 2004 Diel Water Depth, Chlorophyll and Nutrient Data. (Water Depth data from continuous monitoring data).

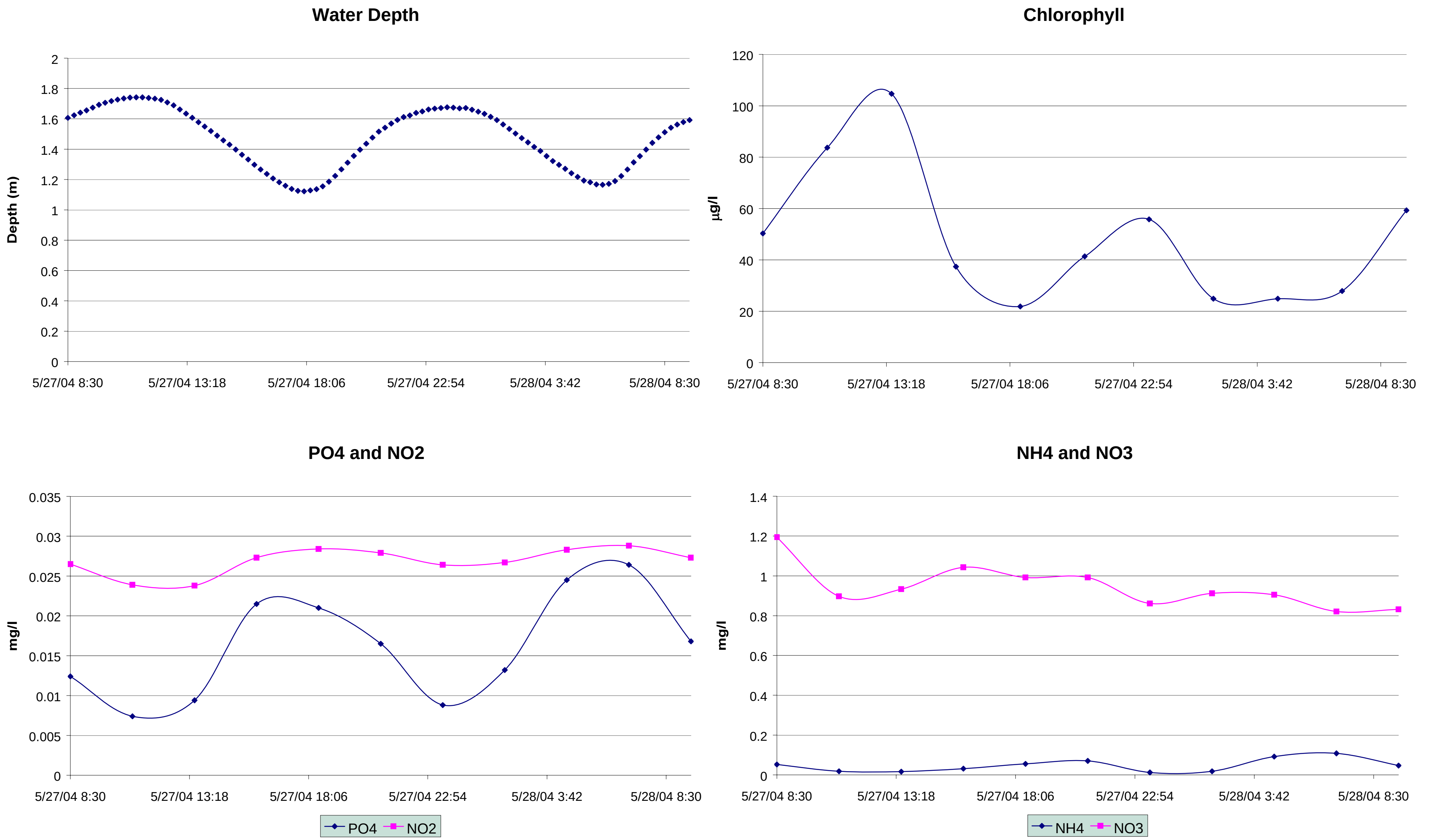


Figure 3-13. May 2004 Diel Water Depth, Chlorophyll and Nutrient Data. (Water Depth data from continuous monitoring data).

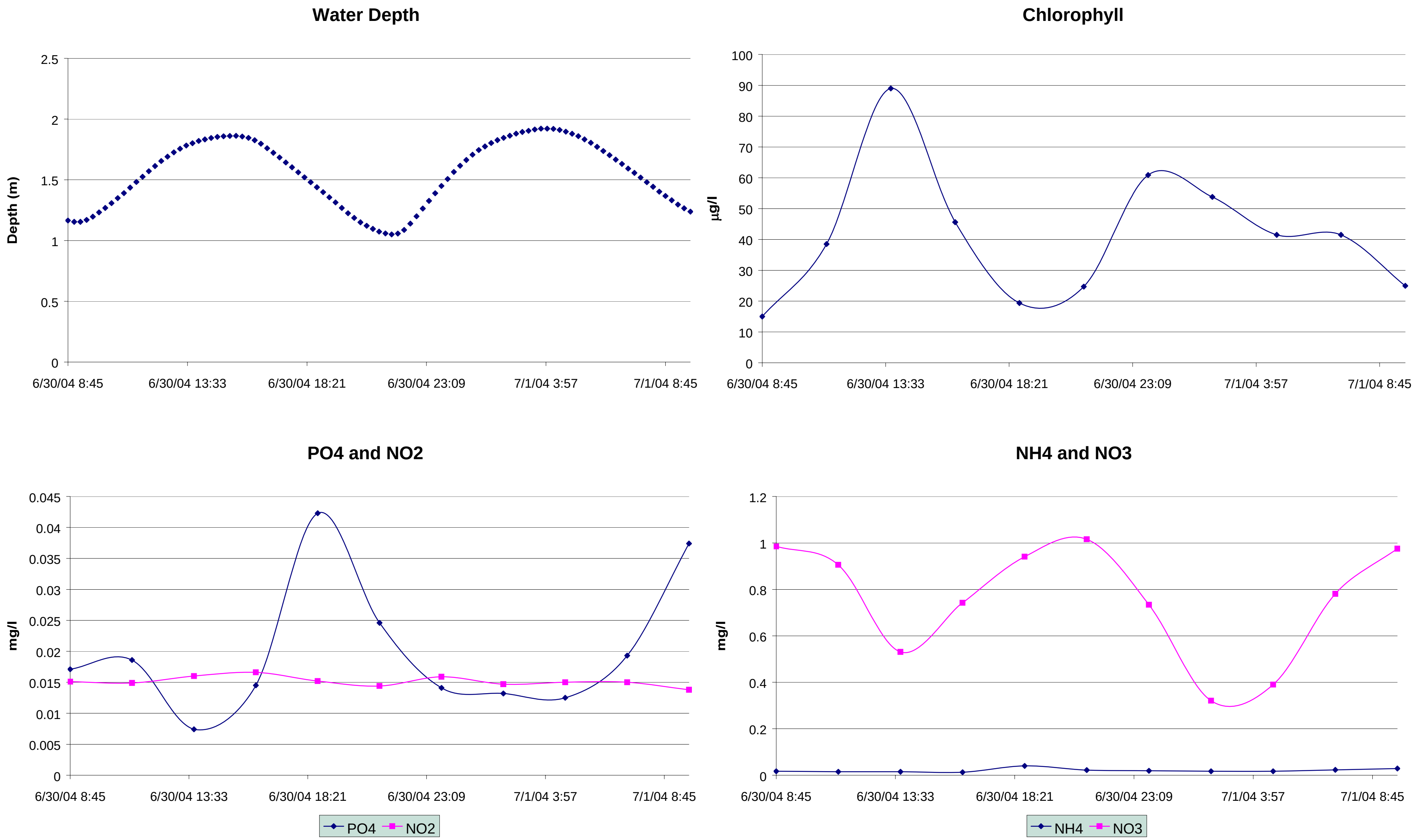


Figure 3-14. June 2004 Water Depth, Chlorophyll and Nutrient Data. (Water Depth data from continuous monitoring data).

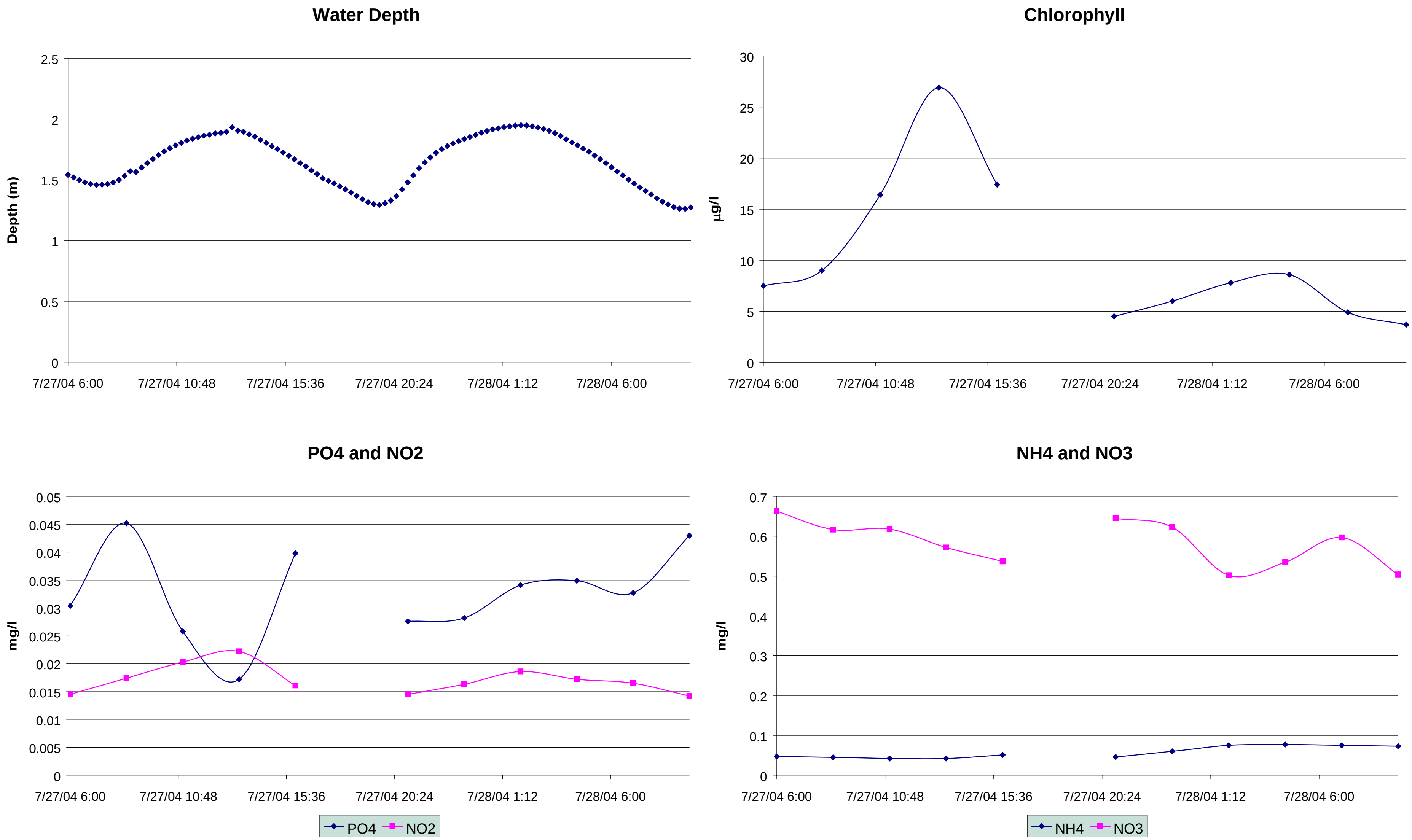


Figure 3-15. July 2004 Diel Water Depth, Chlorophyll and Nutrient Data. (Water Depth data from continuous monitoring data).

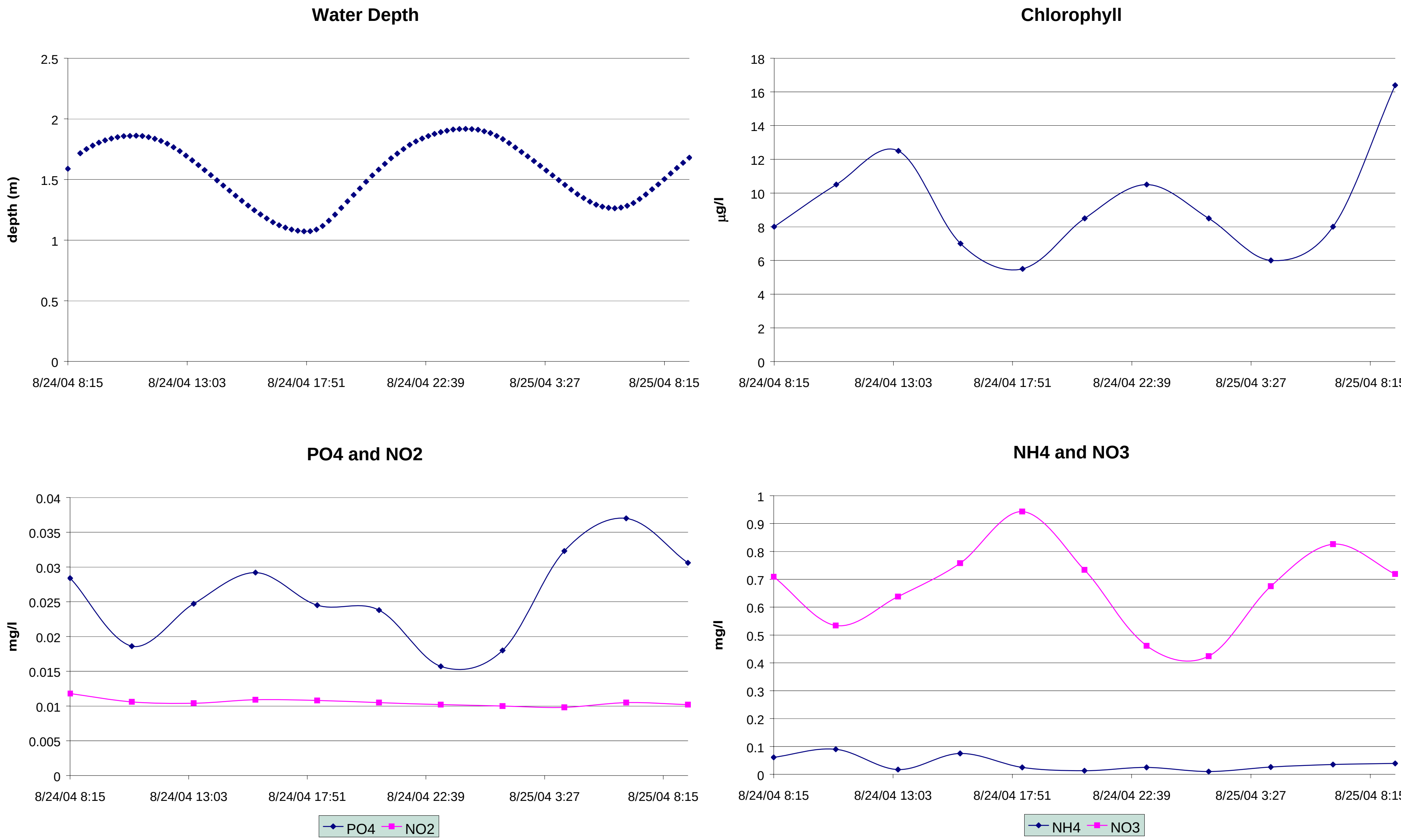


Figure 3-16. August 2004 Diel Water Depth, Chlorophyll and Nutrient Data. (Water Depth data from continuous monitoring data).

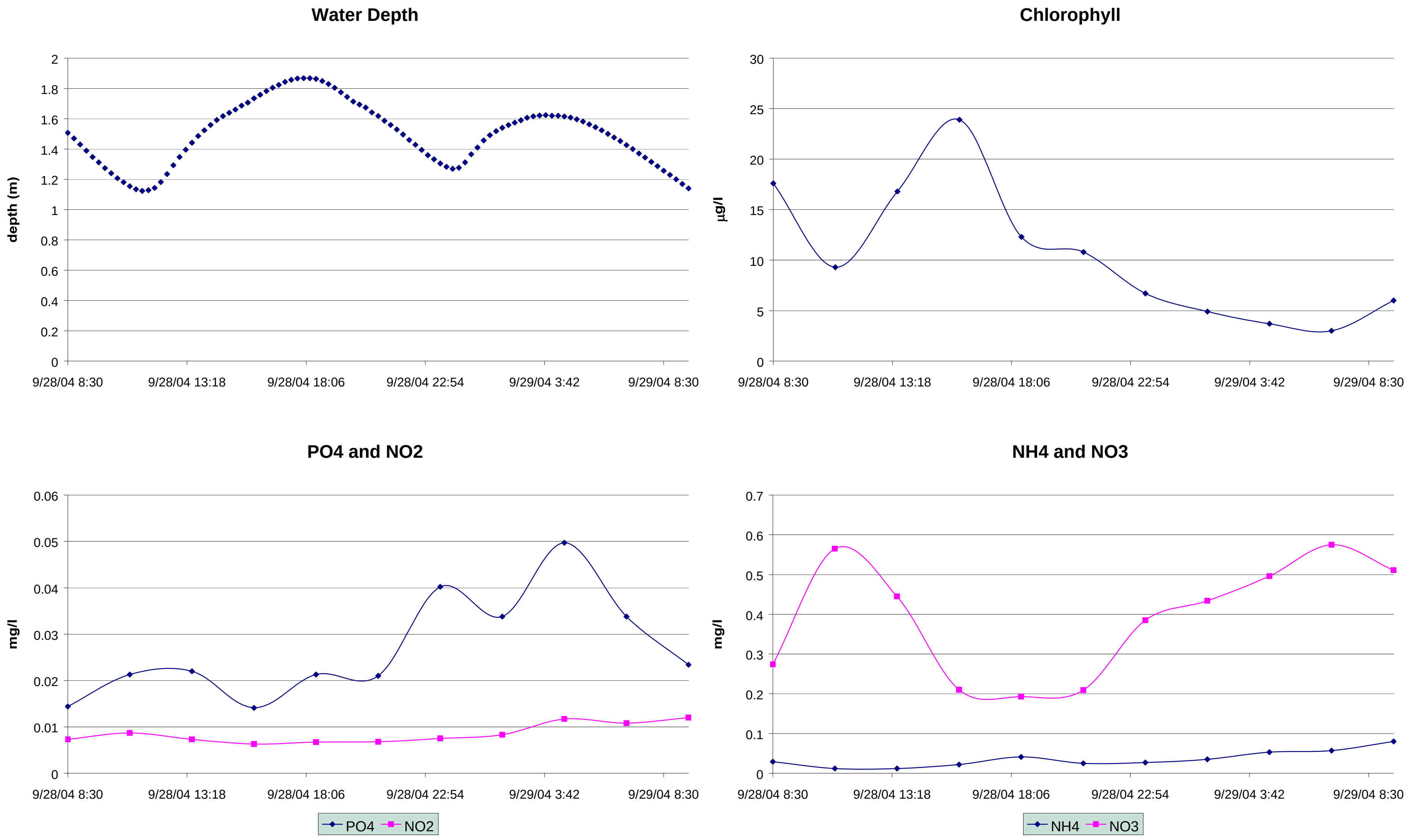


Figure 3-17. September 2004 Diel Water Depth, Chlorophyll and Nutrient Data. (Water Depth data from continuous monitoring data).

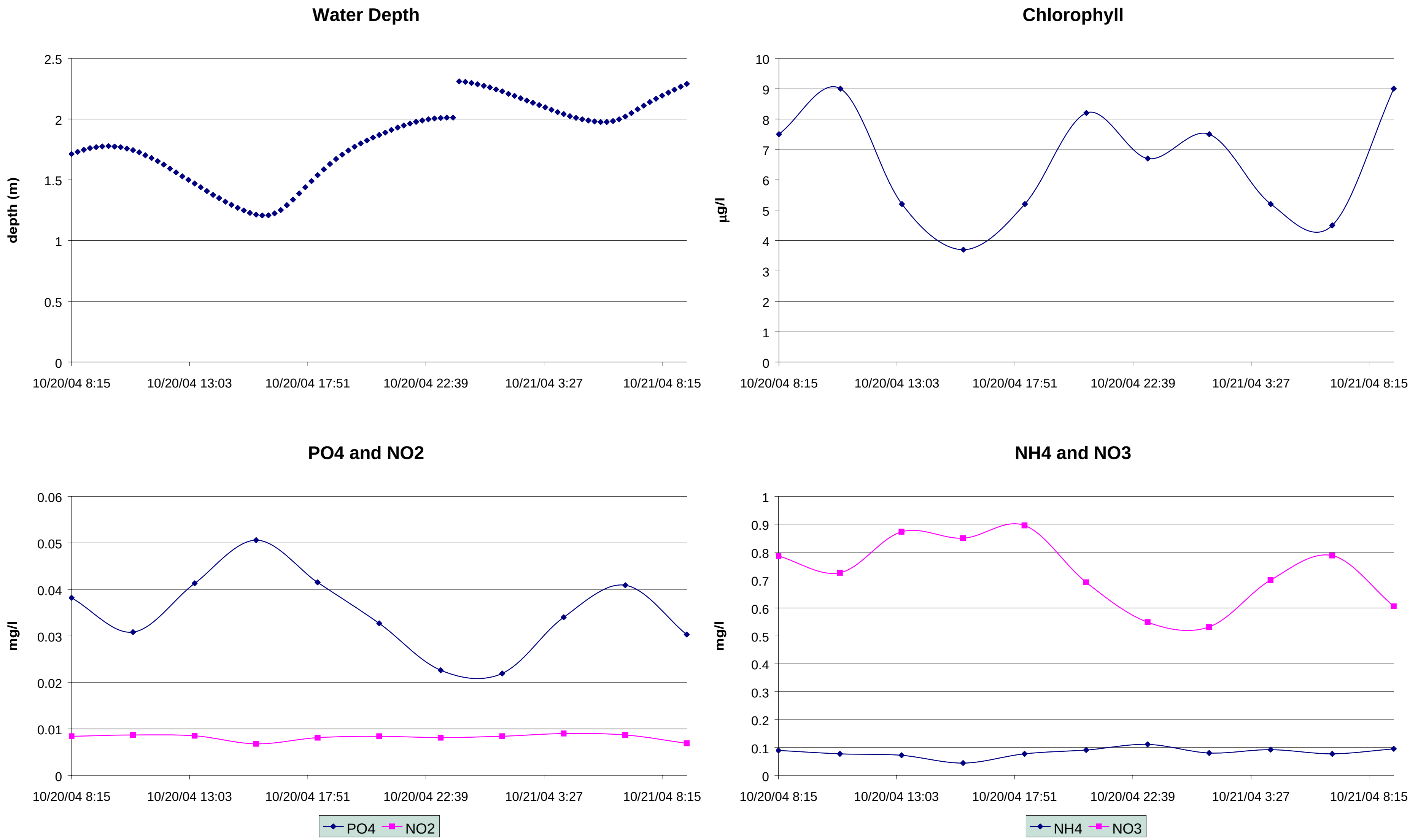
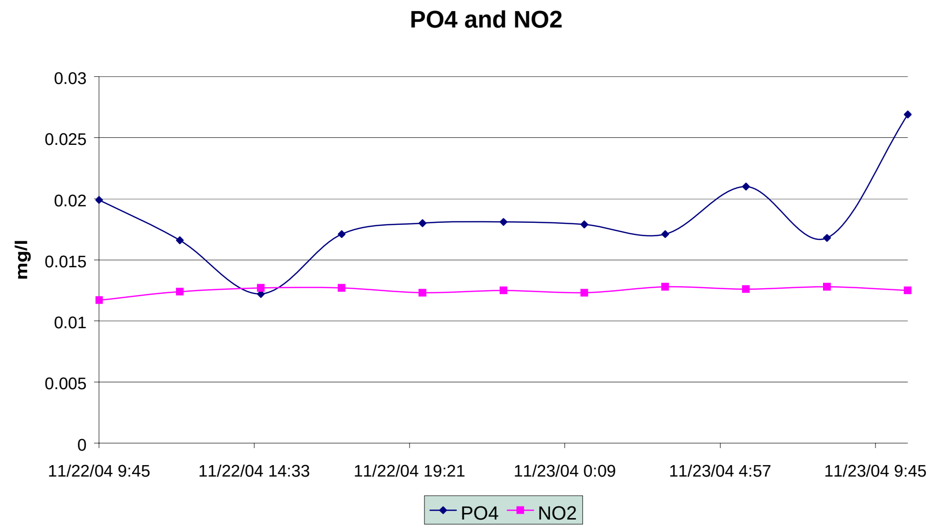
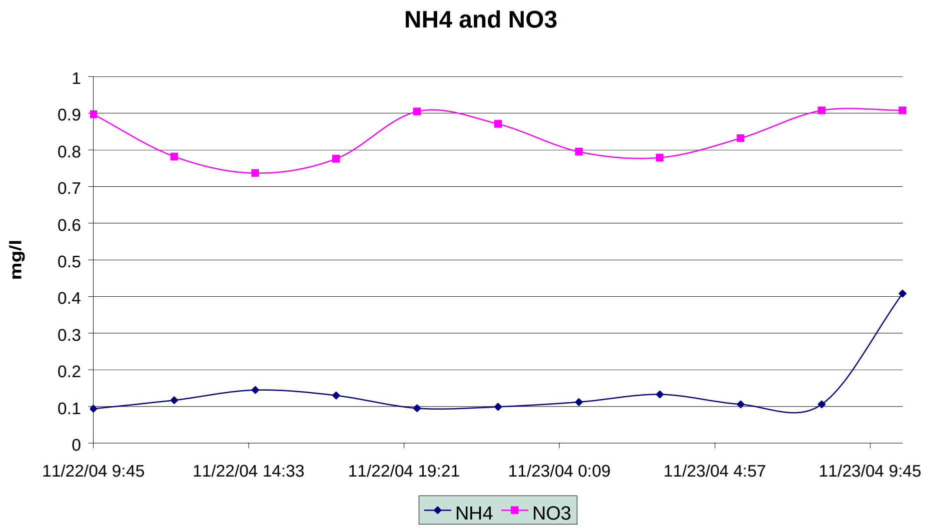


Figure 3-18. October 2004 Diel Water Depth, Chlorophyll and Nutrient Data. (Water Depth data from continuous monitoring data).





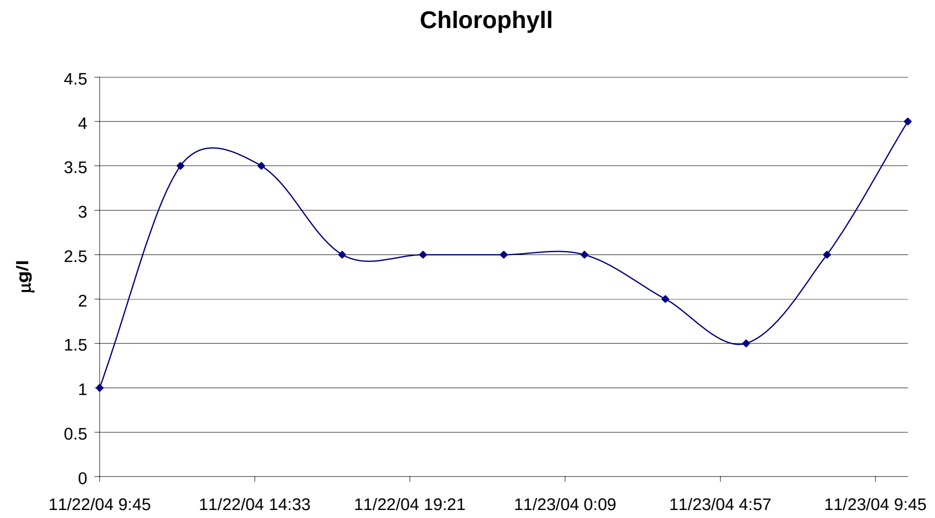


Figure 3-19. November 2004 Diel Nutrient and Chlorophyll Data.

Figure 3-20. December 2004 Diel Nutrient and Chlorophyll Data.

3.9 Metrological Results

The principle objectives of the meteorological information was to track and record atmospheric and meteorological conditions, create a database capable of detecting long-term changes in weather patterns, and to record and identify the impact of storms, hurricanes, heavy rain and other episodic weather events capable of influencing other environmental conditions, such as water quality. The Campbell Scientific weather station was located on the north end of the Jug Bay marsh, along a tidal creek that feeds the Patuxent River. Meteorological data was collected every 5 seconds and stored on a Campbell Scientific CR10X data logger. The data was then used by the CR10X to produce 15 minute averages, maximum and minimums, hourly averages, maximums and minimums and daily averages, maximums and minimums of air temperature, relative humidity, barometric pressure, rainfall, wind speed, wind direction and light. Due to instrumentation errors, only data from January 1st through October 14th, 2004 was analyzed (Table 3-11). Data quality assurance and control was conducted using either the NERRS WDMP or EQWin programs. All other missing data were rejected and deleted through QA/QC procedures.

Air temperatures ranged from –13.70 ^{o}C on January 11th to 34.30 ^{o}C on June 2nd, with a median temperature of 17.70 ^{o}C. Median relative humidity was 78%, while median barometric pressure was 1019 mm Hg. The median wind speed observed at the Railroad Bridge weather station was 1.5 m/s, with 27% of the winds coming from the northwest and 23% from the southeast (Figure 3-21).

Table 3-11. Description of meteorological data from the Railroad Bridge weather station from January-October, 2004.

	Air Temperature (C)	Relative Humidity (%)	Barometric Pressure (mm Hg)	Wind Speed (m/s)
mean	14.95	73	1019	1.8
median	17.70	78	1019	1.5
minimum	-13.70	14	997	0.2
maximum	34.30	114	1111	8.6
variance	110	401	48.55	2.3

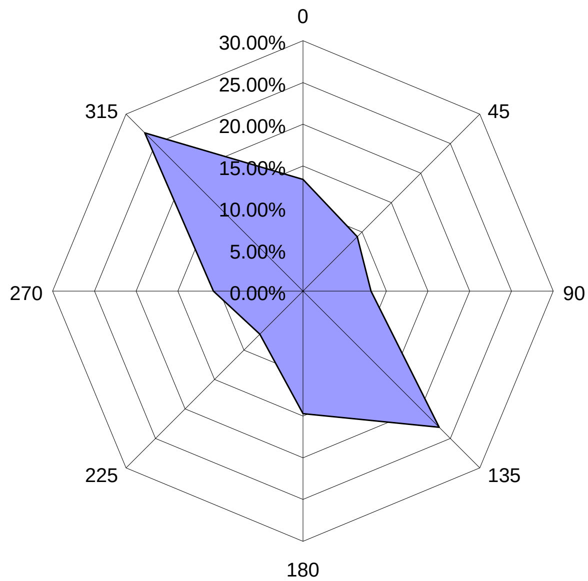


Figure 3-21. Percentage of wind direction observations for each compass heading (0 = North, 135 = Southeast, 180 = South, 315 = Northwest).

4. Discussion

A variety of biological, oceanographic and meteorological conditions were responsible for the variability in spatial and temporal trends in water quality data occurring in the Jug Bay Research Reserve in 2004. Water temperatures and dissolved oxygen concentrations varied seasonally, with lower temperatures and higher dissolved oxygen in the winter months. Chlorophyll concentrations (algae) peaked in the spring and summer due to increased nutrients and sunlight available for photosynthesis. Increases in pH, dissolved oxygen saturation and turbidity were largely the result of phytoplankton, and possibly blue-green algal, blooms. Turbidity and salinity were controlled by increased precipitation and run-off associated with the increased frequency of tropical storms and hurricanes affecting the northeastern United States in 2004. However, the Patuxent River was not severely impacted by the increased run-off due to Hurricane Ivan, as were other riverine systems, including the Susquehanna River.

Compared to water quality conditions experienced in 2003, water quality at the Jug Bay Reserve remained relatively constant. Median summer dissolved oxygen values remained stable at Iron Pot Landing and Railroad Bridge and were above the 5 mg/l threshold, indicating good oxygen levels in these areas. Median summer dissolved oxygen values at Mataponi Creek also remained stable compared to 2003 levels; however, dissolved oxygen fell below the 5 mg/l threshold in 2003 and 2004, which indicated poor oxygen levels at Mataponi Creek during the summer months in both years. Median fall dissolved oxygen values were lower in 2004 than in 2003, possibly due to higher fall water temperatures in 2004 (warmer waters hold less dissolved oxygen than cooler waters). 2003 was an extremely wet year, with increased precipitation and run-off entering the watershed. Salinity and summer turbidity at Iron Pot Landing and Mataponi Creek were lower in 2004, suggesting these stations were not as influenced by precipitation and river discharge as in the previous year. However, fall and spring median turbidity values were higher at all stations in 2004 compared to 2003. Chlorophyll concentrations were lower at Iron Pot Landing and Mataponi Creek in 2004, while Railroad Bridge experienced higher chlorophyll concentrations in the spring and summer of 2004. Lower salinities and higher chlorophyll values in Railroad Bridge suggest that increased run-off, and subsequent nutrient supply, into Jug Bay may have contributed to summer algal blooms and low dissolved oxygen concentrations during 2004. Further data analysis and monitoring of water quality in the Jug Bay Research Reserve will allow for continued comparisons between stations, years and other systems.