MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Martin O'Malley, Governor
Anthony G. Brown, Lt. Governor
John R. Griffin, Secretary
Joseph P. Gill, Deputy Secretary

2010 Bush River Shallow Water Monitoring Data Report

27 September, 2011

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

2010 Bush River
Shallow Water Monitoring Data Report

DNR publication #12-9272011-528

Prepared by:
Brian Smith, Diana Domotor, Mark Trice, and Tom Parham
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

Martin O'Malley, Governor John R. Griffin, Secretary

Printed on Recycled Paper

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

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Bush River watershed drains 117 square miles of land in Harford County, Maryland. This watershed is becoming increasingly urbanized as approximately 35% of the land has been developed and impervious surface area (roads, rooftops, parking lots) has increased to around 11%. All three major subwatersheds of the Bush River have been listed by the State of Maryland as impaired waterways, and the watershed as a whole is considered a high priority for restoration. Causes of impairment include elevated levels of nutrients, suspended sediments, and toxic substances that are harmful to aquatic organisms and degrade the ecosystem. The Maryland Department of Natural Resources (DNR), in partnership with the Harford County Government and the National Oceanic and Atmospheric Administration (NOAA), therefore, began a water quality criteria assessment of the Bush River in 2003 as part of its Shallow Water Monitoring Program. Two fixed Continuous Monitoring stations, configured to record measurements every fifteen minutes, were set up in the Bush River watershed to quantify the effects of nutrient and sediment pollution and associated algal blooms on water clarity and the living resources within the waterways. The stations were located at Church Point (39.4582°, -76.2323°) and Otter Point Creek (39.4508°, -76.2746°).

This report contains the results of Continuous Monitoring for the Bush River during 2010, which was the final year of the partnership between DNR and Harford County. (Results from previous years may be found in the 2003-2009 Bush River Shallow Water Monitoring Data Reports, available online at DNR's searchable publication page - http://mddnr.chesapeakebay.net/eyesonthebay/stories.cfm).

A summary of the 2010 Bush River report is as follows:

- Salinity levels remained low during the year peaking at 3.4 parts per thousand (ppt) at Church Point and 2.6 ppt at Otter Point Creek.
- Dissolved oxygen levels generally remained at healthy levels during 2010, although the rate of dissolved oxygen criteria failure at Otter Point Creek more than doubled as compared to 2009.
- Algal blooms were infrequent and short in duration, although bloom conditions at Church Point increased significantly during the spring as compared to 2009.
- Water clarity continued a declining trend as approximately 100% of all measurements were beyond thresholds considered optimal for underwater grass growth.
- Submerged aquatic vegetation (SAV) total area (236 acres) has decreased 63% since 2007 and dropped below the restoration goal for the first time since 2001.

Introduction

Temporally Intensive Monitoring

In 2010, Maryland DNR was contracted by Harford County, Maryland to conduct temporally intensive water quality monitoring on the Bush River. The Continuous Monitoring component of the Shallow Water Monitoring Program is designed to acquire temporal records of water quality data at shallow water stations throughout the Chesapeake and Maryland Coastal Bays. The purpose of the program is to characterize water quality and habitat conditions for assessing compliance with the Environmental Protection Agency's (EPA) Chesapeake Bay ambient water quality criteria for dissolved oxygen, water clarity, and chlorophyll (US EPA, 2003). Maryland DNR deployed and maintained YSI 6600™ datasondes (multi-parameter logging instruments), at 29 Continuous Monitoring sites in 2010 spread across 14 segments of the Chesapeake Bay watershed. Four Coastal Bay sites were also monitored during 2010. The following water quality data parameters were collected at 15-minute intervals during deployment: water temperature, salinity, dissolved oxygen, fluorescence (used to estimate chlorophyll concentration), pH, and turbidity, which is a measure of water clarity. Data from salinity, chlorophyll, and turbidity readings were also used to calculate an additional measure of water clarity called the coefficient of light attenuation (K_d; US EPA, 2007), which estimates how far light travels through the water column.

Pigment, Nutrient, Suspended Solids, and Secchi Samples

Data concerning pigments, nutrients, and suspended solids were obtained by DNR staff during deployment of Continuous Monitoring datasondes. Discrete whole water samples were collected to measure chlorophyll *a*, pheophytin, total suspended solids, volatile suspended solids, ammonium, nitrite, nitrate, total dissolved nitrogen, particulate nitrogen, total nitrogen, phosphate, particulate phosphorus, total phosphorus, total dissolved phosphorus, and particulate carbon. Datasondes were removed and replaced with freshly calibrated instruments on a biweekly basis. At the time of each instrument replacement, Secchi disk depth and photosynthetically active radiation (PAR) measurements were recorded for use in additional calculations of K_d.

Bush River Continuous Monitoring

In 2010, Continuous Monitoring data were collected at two sites in the Bush River: Church Point (XJG7461) and Otter Point Creek (XJG7035) (Figure 1). The Church Point Continuous Monitor was deployed from March 25th to November 3rd (Table 1), and was suspended from a float, 1m below the water's surface. The Continuous Monitor at Otter Point Creek was fixed 0.3m above the bottom sediments and was deployed from March 11th to December 16th (Table 1).

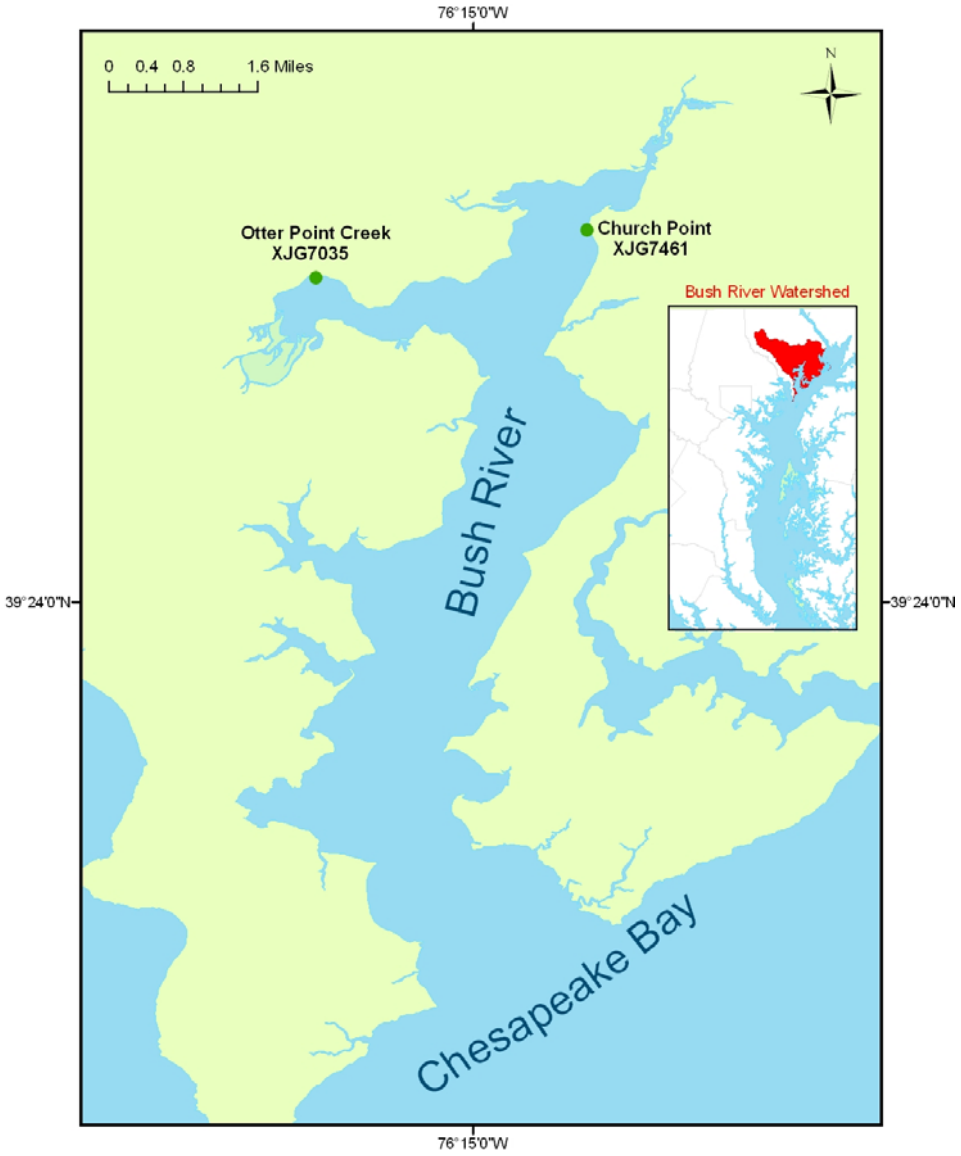


Figure 1. Map of Bush River Continuous Monitoring sites for 2010.

Several gaps in collected data occurred during 2010 due to mechanical problems. Dates and causes of data gaps at both Bush River Continuous Monitoring sites are found in Table 2.

The Harford County Government provided funding for the Continuous Monitoring equipment, nutrient analyses, and maintenance of the Church Point site. The Otter Point Creek site was funded through a cooperative agreement with NOAA's National Estuarine Research Reserve System (NERRS) Program.

Bush River Continuous Monitoring data are archived on DNR's "Eyes on the Bay" website, www.eyesonthebay.net. The interface allows users to view and download data and graphs of current and archived water quality measurements. Table 1 displays a 2010 timeline for the Bush River Continuous Monitoring sites, including related weather events and sanitary sewer overflows in the watershed that were reported to the Maryland Department of the Environment (http://www.mde.state.md.us/programs/Water/OverFlow/Pages/ReportedSewerOverflow.aspx).

	Dates	Events and Details
2010	17-Jan	Sanitary sewer overflow due to mechanical failure; 100 gallons; Bel Air; Winters Run drainage area
	5-6-Feb	Winter Storm impacts Mid-Atlantic region
	9-10-Feb	Heavy snow and blizzard conditions across northeast Maryland
	23-Feb	Sanitary sewer overflow due to a tripped breaker; 1,800 gallons; Fallston; Winters Run drainage area
	11-Mar	Continuous Monitoring begins at Otter Point Creek
	13-Mar	Sanitary sewer overflow due to precipitation; 6,000 gallons; Bel Air; Bynum Run drainage area
	25-Mar	Continuous Monitoring begins at Church Point
	4-Apr	Sanitary sewer overflow due to grease clog; 600 gallons; Bel Air; Bynum Run drainage area
	6-Jun	Presence of potentially harmful cyanobacteria detected at Otter Point Creek
	6-Jul	Presence of potentially harmful cyanobacteria detected at Church Point
	10-Jul	Heavy rain and flooding across northeast Maryland
	10-Jul	Sanitary sewer overflow due to precipitation; 2.5 million gallons; Aberdeen Proving Ground, Edgewood Area; King's Creek & Bush River
	20-Jul	Presence of potentially harmful cyanobacteria detected at Otter Point Creek
	12-Aug	Heavy rain and flooding across northeast Maryland
	17-Sep	Presence of potentially harmful cyanobacteria detected at Otter Point Creek
	30-Sep	Remnants of Tropical Storm Nicole impacts Mid-Atlantic region and leads to heavy rain and flooding across northeast Maryland
	30-Sep	Collection of real-time data ends at Church Point due to telemetry equipment damage from Tropical Storm Nicole
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 10,000 gallons; Bel Air; Plumtree Run drainage area
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 7,650 gallons; Edgewood; Bush River
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 1,792 gallons; Aberdeen; Romney Creek
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 2,960 gallons; Aberdeen; Romney Creek
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 18,700 gallons; Aberdeen; Romney Creek
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 2,832 gallons; Aberdeen; Romney Creek
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 17,490 gallons; Aberdeen; Romney Creek
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 5,500 gallons; Aberdeen; Romney Creek
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 7,480 gallons; Aberdeen; Romney Creek
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 4,680 gallons; Aberdeen; Romney Creek
	30-Sep	Sanitary sewer overflow due to Tropical Storm Nicole; 4,335 gallons; Aberdeen; Romney Creek
	30-Sep - 1-Oct	Sewer bypass due to Tropical Storm Nicole; 93,611 gallons; Aberdeen Proving Ground; Spesutie Narrows
	1-Oct	Sanitary sewer overflow due to Tropical Storm Nicole; 750 gallons; Havre de Grace; Chesapeake Bay
	3-Nov	Continuous Monitoring stopped at Church Point
	16-Dec	Continuous Monitoring stopped at Otter Point Creek due to threat of icing

Table 1. Timeline of 2010 Continuous Monitoring related events.

	Dates	Details
Church Point	9-26 Apr	Turbidity probe wiper malfunction
	13-26 Apr	pH data did not meet post-calibration thresholds
	14-26 Apr	Chlorphyll probe wiper malfunction
	15-29 May	Turbidity probe wiper malfunction
	31 May - 1 Jun	Turbidity probe wiper malfunction
	15-19 Aug	Chlorphyll probe wiper malfunction
	28-30 Sep	Datasonde power failure
Otter Point Creek	19-26 Apr	Turbidity probe wiper malfunction
	22-26 Apr	Chlorphyll probe wiper malfunction
	3-6 May	Turbidity data failed quality control checks
	24 Oct - 3 Nov	Turbidity probe wiper malfunction
	15-16 Dec	Temperature probe failure caused all measured parameters to fail quality control checks

Table 2. Data gaps at Bush River Continuous Monitoring sites during 2010.

(There were also several occasions during which the datasonde at Otter Point Creek was not submerged due to low tidal conditions and did not collect valid data.)

Yearly Precipitation and Discharge Events

Precipitation increases run off into waterways, which can lead to a higher discharge of nutrients that fuels algal blooms, decreases water clarity, and suppresses SAV growth. In 2010, precipitation at Baltimore Washington International (BWI) Thurgood Marshall Airport was approximately normal, totaling 1.5-inches above the 139-year average (Figure 2). Fueled by precipitation from the remnants of Tropical Storm Nicole (Table 1), September was the wettest month and exhibited the greatest departure from average. Daily mean flow of discharge at the USGS Gaging Station on Otter Point Creek was also four times higher during this storm event than any other day in 2010 (Figure 3). Overall, total mean flow of discharge was higher in 2010 (90.1 cubic feet per second – cfs) as compared to the previous three years (2007: 65.0 cfs; 2008: 53.4 cfs; 2009: 85.6 cfs). Average discharge during the growing season of April through October was 76.7 cfs, a time when discharge events can have the greatest effect on SAV growth.

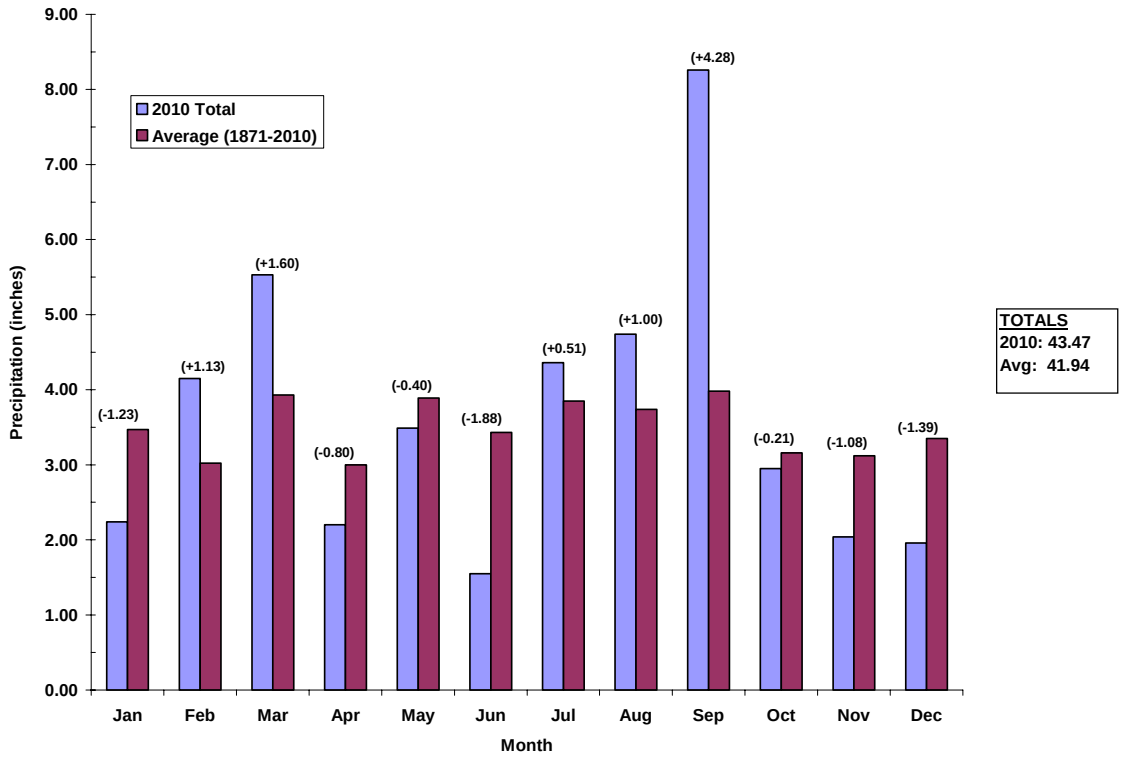


Figure 2. Total 2010 monthly precipitation at BWI Marshall Airport compared to 139-year averages. (Values in parentheses indicate departures from average.)

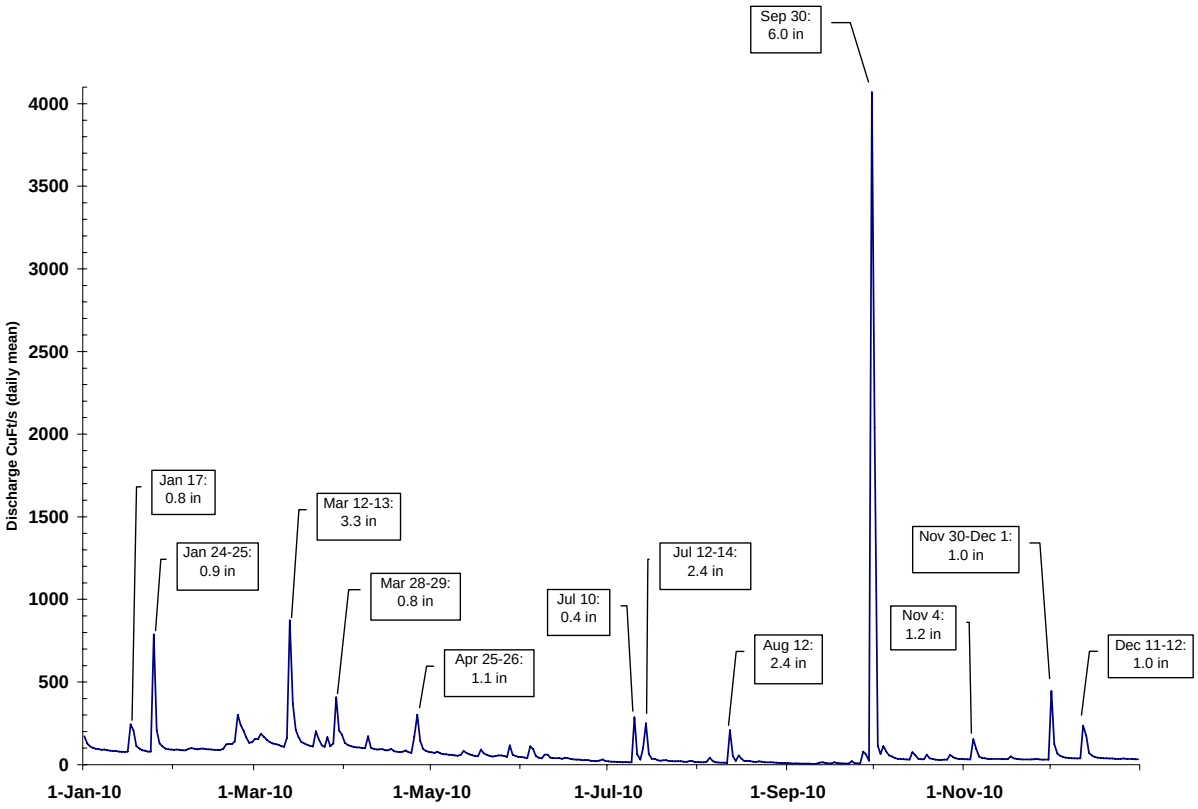
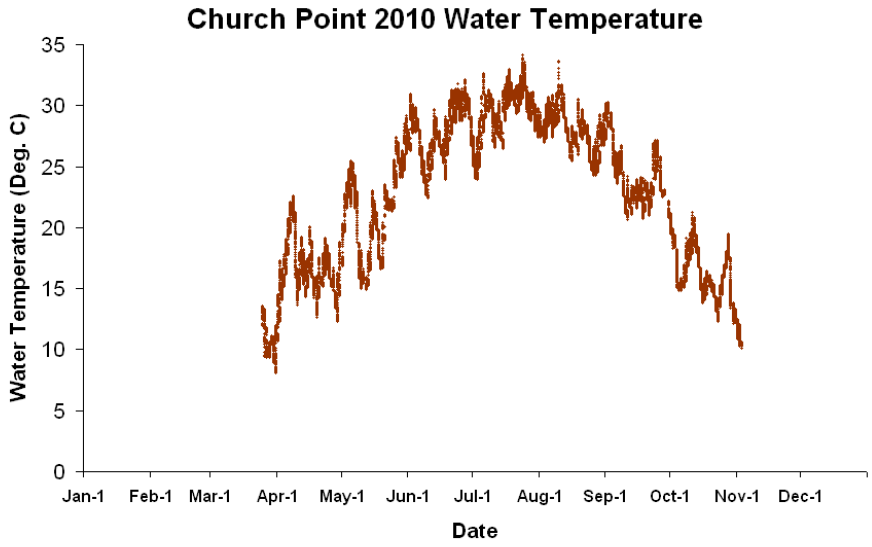


Figure 3. Daily discharge in cubic feet per second measured at USGS Gaging Station 01581757 on Otter Point Creek near Edgewood, MD in 2010. (Boxes indicate precipitation events at BWI Marshall Airport that coincided with spikes in discharge.)

Continuous Monitoring Data

Water Temperature

Water temperature at both Bush River Continuous Monitoring sites rose predictably as air temperatures increased during the summer months and peaked in August (Figure 4). Church Point reached a peak of approximately 34°C, while Otter Point Creek peaked at 35°C.



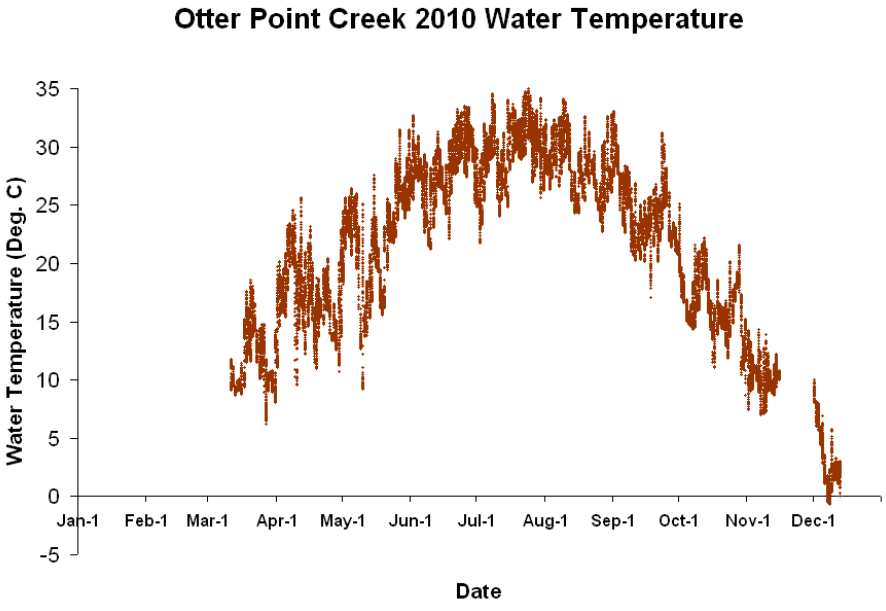


Figure 4. Water temperature at Bush River Continuous Monitoring sites during 2010.

Salinity

Salinity levels for both the Church Point and Otter Point Creek Continuous Monitoring sites remained low for most of the spring and summer (Figure 5). Levels then increased during the late summer and early fall, before dropping off on in late September following the influx of fresh water from the remnants of Tropical Storm Nicole. Church Point salinity levels peaked at 3.4 parts per thousand (ppt) and Otter Point Creek levels peaked at 2.6ppt.

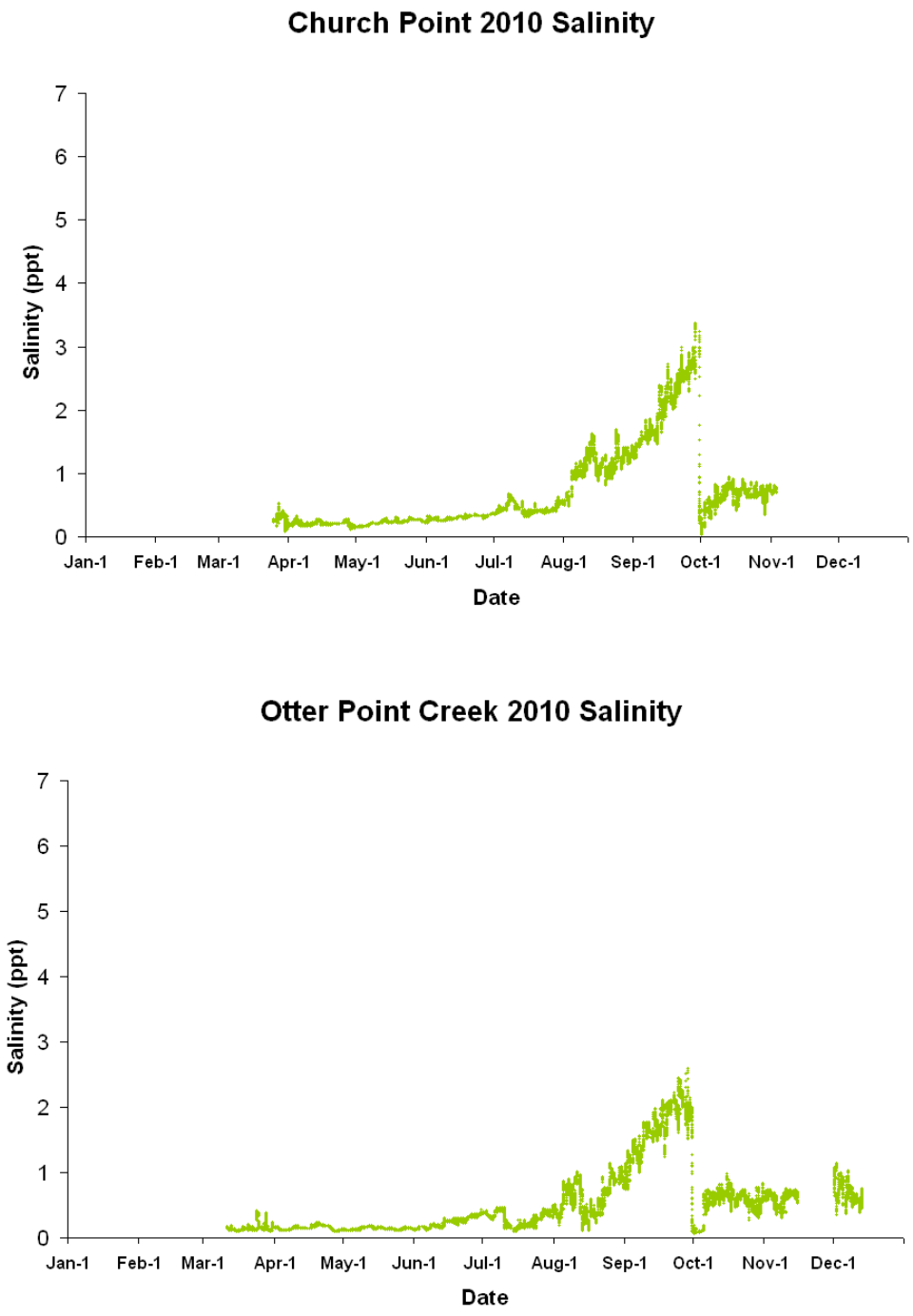


Figure 5. Salinity levels at Bush River Continuous Monitoring sites during 2010.

Dissolved Oxygen

In 2010, both Continuous Monitoring sites were located closer to the head waters than the mouth of the Bush River (Figure 1) and exhibited similar variability in dissolved oxygen levels (Figure 6). Both sites also experienced relatively few days of dissolved oxygen concentrations below 5 milligrams per liter (mg/l), although the rate of dissolved oxygen criteria failure at Otter Point Creek more than doubled as compared to 2009 (Table 3). This criteria threshold as been set by the US Environmental Protection Agency (EPA) because dissolved oxygen levels below 5mg/l can be detrimental to the survival of juvenile fish (US EPA, 2003).

The highest dissolved oxygen concentration measured at Church Point was 19.27mg/l on July 6th, and the lowest was 1.84mg/l on August 12th. In general, dissolved oxygen levels were concentrated around 6-10mg/l during the summer months and 4.8% of 8,655 valid readings between July and September were below 5mg/l (Table 3). At Otter Point Creek, dissolved oxygen concentrations reached a high of 18.27mg/l on August 28th and a low of 1.60mg/l on July 11th. 8.3% of 8,818 valid readings at Otter Point Creek between July and September were below 5mg/l, which represents an approximately 110% increase in criteria failure rate since 2009 (Table 2).

Algal blooms in waterways are identified by measuring chlorophyll concentrations and dissolved oxygen levels often drop following the death and decomposition of algal blooms and associated decreases in chlorophyll levels. The decomposition process can consume significant amounts of dissolved oxygen in the water and can lead to conditions harmful to aquatic organisms. For example, decreases in dissolved oxygen levels at Church Point to 4.76mg/l on June 30th, 3.95mg/l on July 11th, 4.36mg/l on September 3rd, and 3.31mg/l on September 13th coincided with drops in chlorophyll levels (Figure 7). Decreases in dissolved oxygen levels at Otter Point Creek to 1.60mg/l on July 11th and 5.50mg/l on October 3rd also coincided with drops in chlorophyll levels (Figure 7).

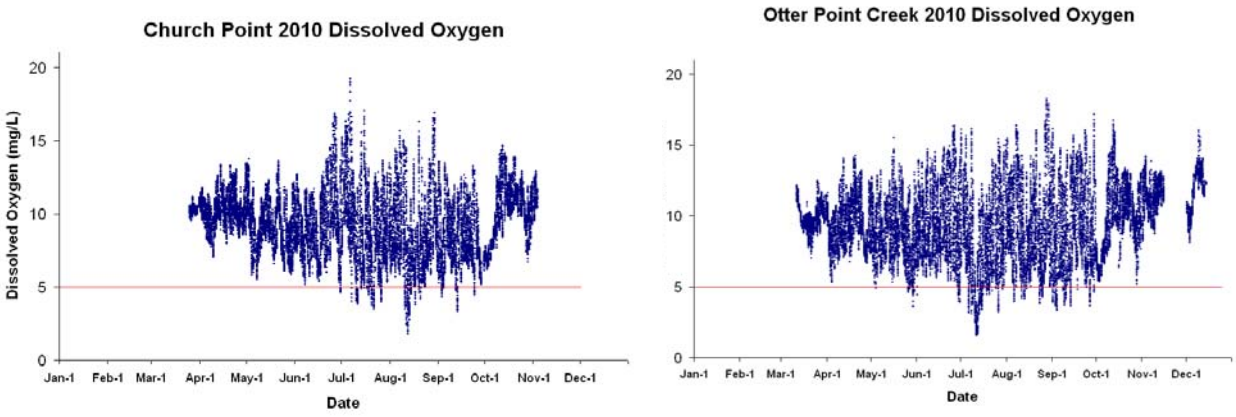


Figure 6. Dissolved oxygen levels at Bush River Continuous Monitoring sites during 2010.

(Red line indicates threshold below which levels can lead to ecosystem stress.)

Continuous Monitoring Site	2003	2004	2005	2006	2007	2008	2009	2010
Church Point								
Dissolved Oxygen less than 5 mg/l	N/A	N/A	N/A	N/A	N/A	5.46%	5.81%	4.83%
Dissolved Oxygen less than 3.2 mg/l	N/A	N/A	N/A	N/A	N/A	0.37%	0.52%	0.31%
Otter Point Creek								
Dissolved Oxygen less than 5 mg/l	3.78%	31.82%	23.17%	5.04%	10.33%	10.01%	3.96%	8.28%
Dissolved Oxygen less than 3.2 mg/l	0.43%	9.70%	8.40%	0.10%	1.62%	1.17%	0.15%	1.45%

Table 3. Dissolved Oxygen criteria failure at Church Point and Otter Point Creek during July through September, 2003 to 2010. *(5mg/l is the 30-day mean and 3.2mg/l is the instantaneous EPA threshold for shallow-water habitat; US EPA, 2003.)*

Chlorophyll

At both Continuous Monitoring sites in 2010, there were very few chlorophyll readings greater than 50 micrograms per liter (µg/l), which are indicative of significant algal blooms, or 100µg/l, which indicates severe blooms (Figure 7 and Table 4). However, algal bloom conditions during March through May increased significantly at Church Point as compared to 2009 (Table 4). Furthermore, a substantial proportion of chlorophyll readings during the spring and summer were greater than 15µg/l (Table 4), a threshold above which detrimental effects on aquatic ecosystems may occur.

At Church Point, chlorophyll levels briefly spiked above 100µg/l in mid-May and again following the SAV growing season in early November. During the remainder of the year, chlorophyll readings were greater than 50 µg/l in mid- to late April, mid-August, late September, and mid-October. Of 4,040 valid readings between March and May and 7,709 valid readings between July and September, 75.9% and 93%, respectively, were greater than 15µg/l (Table 4).

At Otter Point Creek, chlorophyll levels briefly spiked above 50µg/l several times throughout the year, but never went above 65µg/l. Of 3,341 valid readings between March and May and 7,834 valid readings between July and September, 45.5% and 89.1%, respectively, were greater than 15µg/l (Table 4). The former represents a 36% decrease in chlorophyll criteria failure rate as compared to 2009, while the later represents an 89% increase.

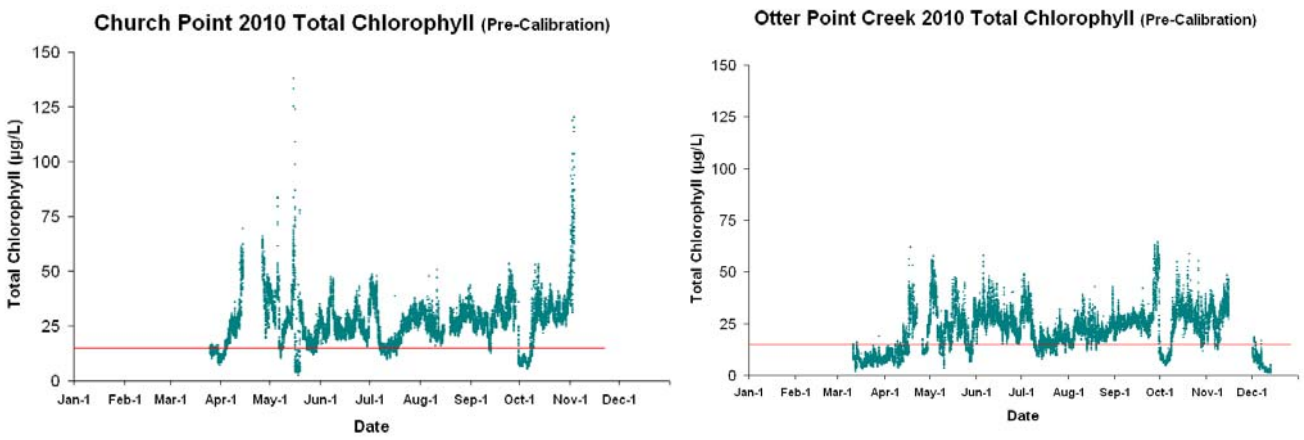


Figure 7. Total chlorophyll levels at Bush River Continuous Monitoring sites during 2010.

(Red line indicates threshold above which levels may have harmful effects on aquatic ecosystems.)

Continuous Monitoring Site	Months	2010
Church Point		
Readings greater than 15µg/l	Mar - May	75.93%
	July - Sept	92.98%
Readings greater than 50µg/l	Mar - May	5.11%
	July - Sept	0.08%
Readings greater than 100µg/l	Mar - May	0.21%
	July - Sept	0%
Otter Point Creek		
Readings greater than 15µg/l	Mar - May	45.49%
	July - Sept	89.13%
Readings greater than 50µg/l	Mar - May	0.74%
	July - Sept	1.92%
Readings greater than 100µg/l	Mar - May	0%
	July - Sept	0%

Table 4. Chlorophyll criteria failure at Church Point and Otter Point Creek in 2010.

pH

Church Point and Otter Point Creek displayed similar variability in pH levels (Figure 8). Both sites displayed a dip in pH in early April, which followed the second wettest month at BWI Marshall Airport in 2010 (Figure 2), and another dip in mid-July, which coincided with a heavy rain event across Maryland (Table 1). Of note, pH at both sites dropped dramatically in late September following an influx of fresh water into the system from heavy rain and a discharge event associated with the remnants of Tropical Storm Nicole (Table 1; Figure 3). pH at Church Point dropped from 7.7 on September 28th to 6.6 on October 1st, and then rebounded to 8.9 on October 8th. At Otter Point Creek, pH dropped from 7.3 on September 28th to 6.7 on October 1st, and rebounded to 7.6 on October 8th.

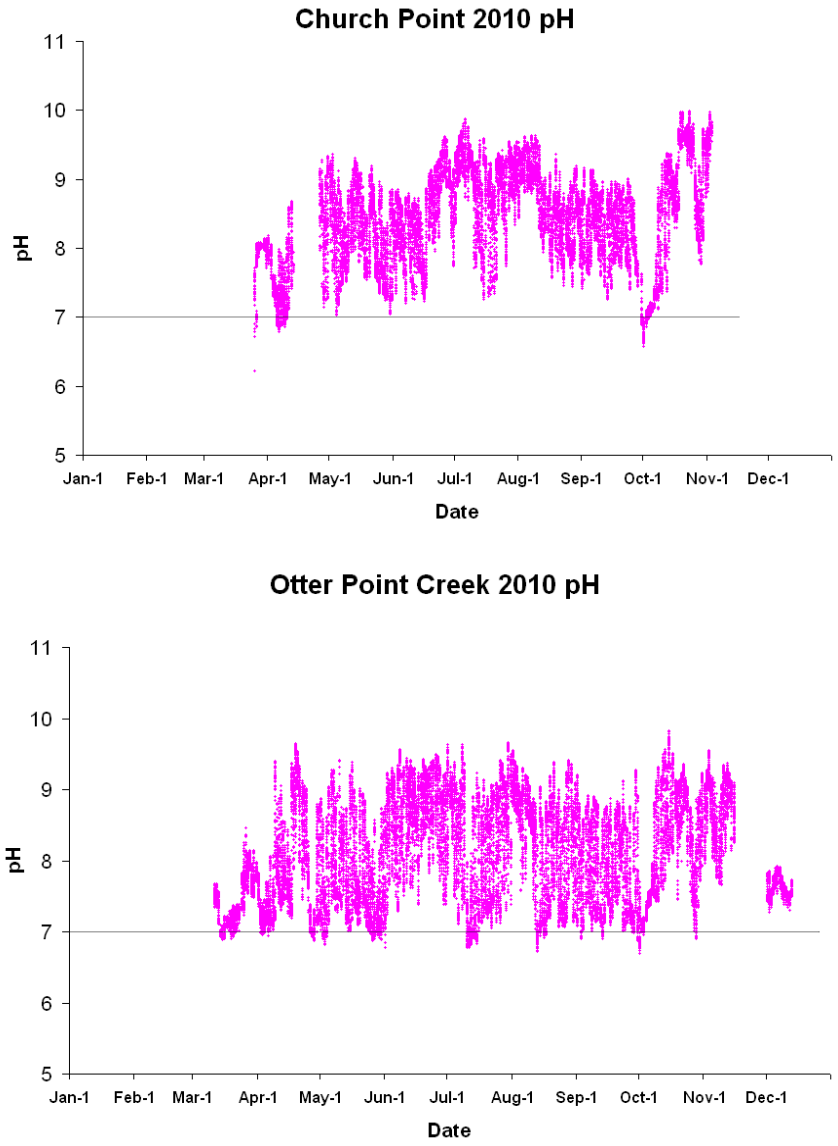


Figure 8. pH levels at Bush River Continuous Monitoring sites during 2010.

(Line indicates neutral pH.)

Turbidity and Coefficient of Light Attenuation (K_d)

Turbidity is one measure of water clarity and is quantified by measuring how much light is reflected from suspended particles in the water. Lower turbidity values indicate less reflection and, therefore, clearer water, while values over 15 nephelometric turbidity units (NTUs) are considered to be detrimental to bay grass growth.

2010 was an average year for precipitation (Figure 2). However, a few storm events, particularly the heavy rain that was associated with the remnants of Tropical Storm Nicole, led to several spikes in daily discharge into Otter Point Creek (Figure 3). Thus, both Continuous Monitoring sites on the Bush River experienced spikes and declines in turbidity levels following weather patterns and chlorophyll levels and the vast majority of turbidity readings were above 15 NTU (Figure 9). Turbidity levels at Church Point spiked above 200 NTU in early May and to almost 400 NTU in early June, which coincided with chlorophyll levels greater than 80µg/l and 40µg/l respectively (Figure 7), above 300 NTU in mid-August during a storm event that impacted northeast Maryland, and above 100 NTU in early October following Tropical Storm Nicole and the associated sanitary sewer overflows in the watershed. At Otter Point Creek, elevated chlorophyll levels above 50µg/l (Figure 7) also coincided with turbidity levels above 150 NTU in early May. Turbidity levels also spiked to 254 NTU in mid-July following a sanitary sewer overflow and heavy rain (Table 1) in the watershed, and above 380 NTU on September 30th during the heavy rain event associated with Tropical Storm Nicole (Table 1).

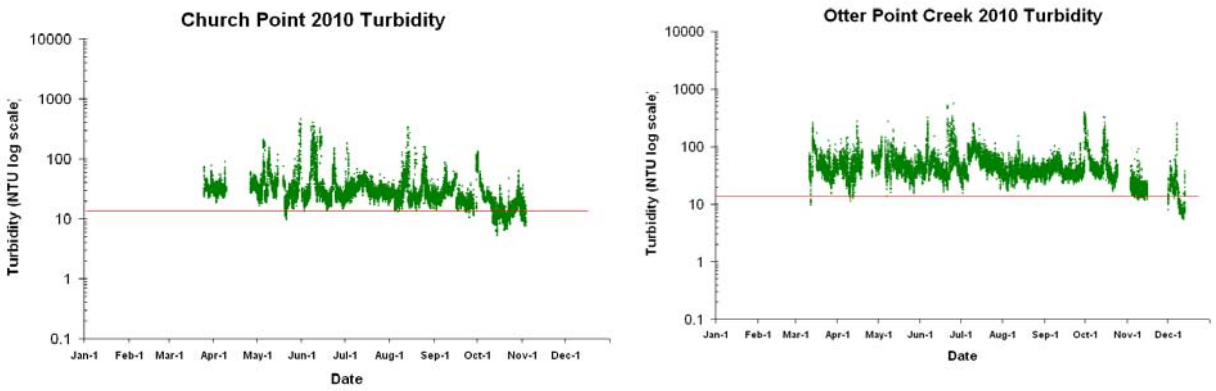


Figure 9. Turbidity levels at Bush River Continuous Monitoring sites during 2010.

(Red line indicates threshold above which levels are considered detrimental to bay grass growth.)

Another measure of water clarity is the coefficient of light attenuation (K_d). This coefficient quantifies how far light can travel down the water column and is calculated using salinity, chlorophyll, and turbidity data (US EPA, 2007). Clearer water has lower K_d values while murky or cloudy water has higher values. For the Continuous Monitoring sites on the Bush River, K_d values less than or equal to 2.1 are considered optimal for SAV growth. During the SAV growing season (April through October) in 2010, water clarity continued a declining trend as the vast majority of K_d values were greater than 2.1 (Table 5). Almost 100% of 17,741 valid readings at Church Point and all of the 18,657 valid readings at Otter Point Creek resulted in K_d values greater than 2.1.

Continuous Monitoring Site	2009
Church Point	
K_d greater than 2.1	99.93%
Otter Point Creek	
K_d greater than 2.1	100%

Table 5. Coefficient of light attenuation failure (K_d) at Church Point and Otter Point Creek during April through October, 2010.

Submerged Aquatic Vegetation (SAV) in the Bush River

SAV, or underwater grasses, are an important component of estuarine ecosystems. They provide habitat for juvenile fish and shellfish, supply food for waterfowl, oxygenate the water, and help stabilize bottom sediments. Since 1984, SAV total area and density within the Bush River has been quantified annually (with the exception of 1988) by the Virginia Institute of Marine Science (VIMS).

SAV acreage continued a three year decline in the Bush River in 2010 and dropped below the restoration goal for the first time since 2001. Total area of SAV in 2010 was 236 acres, which is 33% lower than the restoration goal for the Bush River (Figure 10). SAV acreage decreased by 38% in the Bush River from 2009 and 63% since the current declining trend began in 2008. Acreage of high density beds has also decreased by 81% since 2007 and measured at 35% of total acreage in 2010. VIMS did not conduct ground survey observations on the Bush River in 2010 so SAV species diversity could not be determined.

The decrease in SAV acreage in the Bush River follows the patterns seen in discharge events and water clarity. There were numerous spikes in daily discharge and runoff events into waterways in 2010 (Figure 3). Water clarity was also poor (Figure 9) and K_d values (Table 5) indicate that light conditions within the water column were not optimal to facilitate SAV growth.

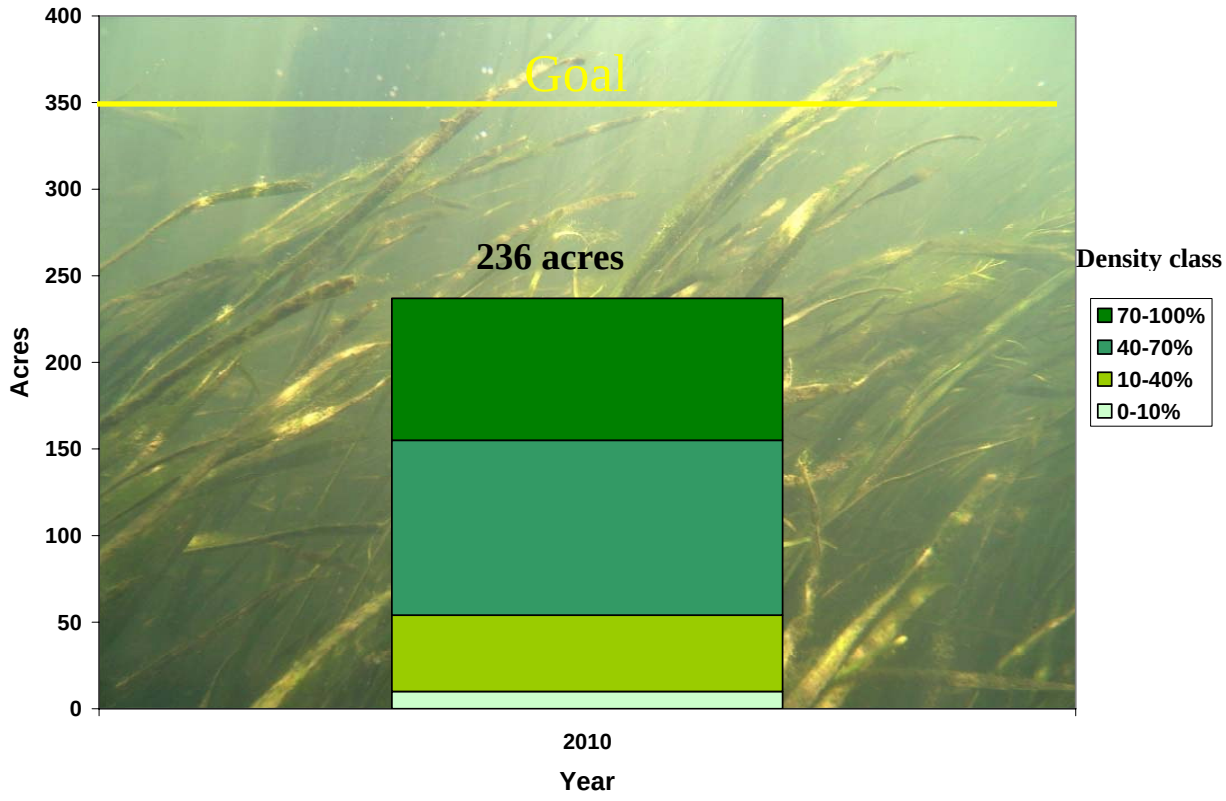


Figure 10. Total area and density of SAV in the Bush River in 2010.

Pigments, Nutrients, Suspended Solids, and Secchi Data

Bi-weekly grab samples of water were taken at each of the two Continuous Monitoring stations on the Bush River when the YSI meters were exchanged. Secchi depth, a measure of water clarity, was also recorded at the time of the grab sample.

For the grab samples, the water was processed in the field using vacuum filtration, and the resulting particulate and filtrate samples were delivered to the laboratory for analysis of pigments, nutrients, and suspended solids. All analyses were performed by the University of Maryland's Chesapeake Biological Laboratory (CBL) Nutrient Analytical Services Laboratory (NASL). For details on methods, procedures, analysis and detection limits, refer to the Quality Assurance Project Plan (QAPP) for the Shallow Water Monitoring Program. This document can be found at http://mddnr.chesapeakebay.net/eyesonthebay/documents/SWM_QAPP_2011_2012_Final.pdf. Results of the nutrient analyses, suspended sediments, and pigments are presented graphically in Appendix A (Figures A-1a through A-16b). If replicate grab samples were taken at a single depth, the graph depicts the average of these samples.

Ambient water quality data (dissolved oxygen, pH, salinity, and water temperature) were collected concurrently with the grab samples. These values, along with those for secchi depth, are presented in Figures A-17a to A-21b in Appendix A. These water quality parameters are measured at multiple depths at each station. In the graphs, the data range for each parameter is represented by a vertical bar for each sample date. The connecting line intersects each bar at the average value for the station on that date.

Examination of the data revealed some interesting results. Hot, dry conditions in early summer facilitated the growth of algae in the Bush River as evidenced by high chlorophyll *a* concentrations at both Otter Point Creek and Church Point (Figures A-15a and A-15b). High chlorophyll values began in May and remained elevated throughout the summer. Lack of concordance between chlorophyll values extracted from grab samples and those measured by the datasondes (Figure 7) during this period may be due to the presence of blue-green algal blooms, which cannot be measured by standard chlorophyll probes deployed with the datasondes. DNR reported blue-green algal blooms at Church Point in early July and at Otter Point Creek in early June, late July, and mid-September (Table 1). More details on these events can be found at DNR's Harmful Algal Bloom webpage: http://mddnr.chesapeakebay.net/eyesonthebay/habs.cfm. Concentrations of pheophytin and volatile suspended solids also rose through the months of May-July and remained elevated through September.

Some of the nutrient values for 2010 show spikes in concentrations which coincide with high rainfall events. For example, ammonium (Figures A-4a and A-4b) and phosphate (Figures A-9a and A-9b) values spike in July following the first significant rainfall in months (Figure 3). Surprisingly, the effects of Tropical Storm Nicole are not apparent in the nutrient sampling data, likely because the sampling date for October occurred more than two weeks after the storm hit on September 30.

An irregularity observed in the 2010 nutrient data was unusually high values of total dissolved phosphorus (TDP) at the Otter Point Creek station (Figure A-11a). Summer peak values of around 0.15 mg/l TDP are approximately five times higher than the values observed at Church Point (Figure A-11b) and some of the highest values of TDP recorded at this station since 2003. Summer values of TDP at Otter Point Creek typically range from 0.01 mg/l to 0.05 mg/l.

For the Otter Point Creek station, the data record extends back to 2003. Plots of the available pigment, nutrient, and suspended solids variables over this extended time period are presented in Appendix B (Figures B1 through B16). The aqua shaded areas in the figures in Appendix B represent the range of values that have occurred from 2003 through 2009. The blue line depicts the mean values over that same time period and the red line shows 2010 measurements.

Conclusion

Shallow water monitoring, consisting of temporally intensive Continuous Monitoring, provides a critical function for assessing the health of Maryland's tidal waters in areas historically lacking water quality information. Not only is this information used for characterizing the health of shallow water habitats, but it is also useful for: 1) assessing Chesapeake Bay water quality criteria for dissolved oxygen, water clarity and chlorophyll in shallow water habitats; 2) determining attainment or non-attainment of shallow water habitats for their designated uses; 3) assessing SAV habitats and identifying potential SAV restoration sites, 4) providing information to better understand ecosystem processes and the impact of extreme events (e.g. hurricanes, high flows, sanitary sewer overflows) in shallow water and open water environments; 5) providing data for calibrating the Bay Eutrophication and Watershed Model.

References

U. S. Environmental Protection Agency. 2003. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries.* EPA 903-R-03-002. Region III Chesapeake Bay Program Office, Annapolis, Maryland.

U. S. Environmental Protection Agency. 2007. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries – 2007 Addendum.* EPA 903-R-07-003. CBP/TRS 285/07. Ambient Water Quality Criteria for Dissolved Oxygen Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tributaries Region III Chesapeake Bay Program Office, Annapolis, Maryland.

Appendix A

Results of laboratory and ambient water quality analyses for:
Church Point (Station XJG7461)
Otter Point Creek (Station XJG7035)

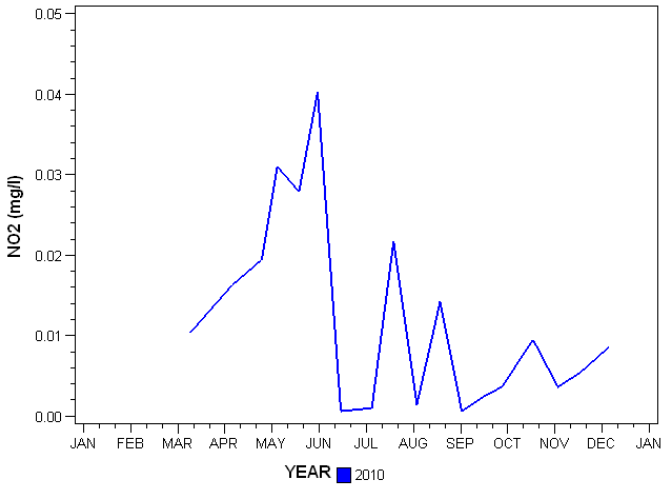


Figure A-1a. Nitrite concentrations at Otter Point Creek.

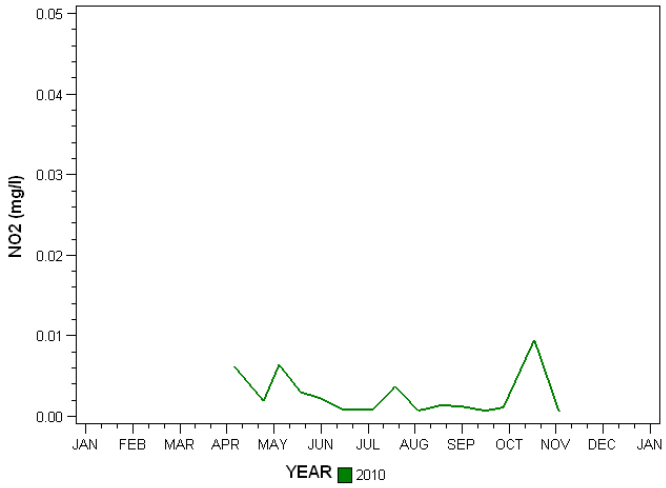


Figure A-1b. Nitrite concentrations at Church Point.

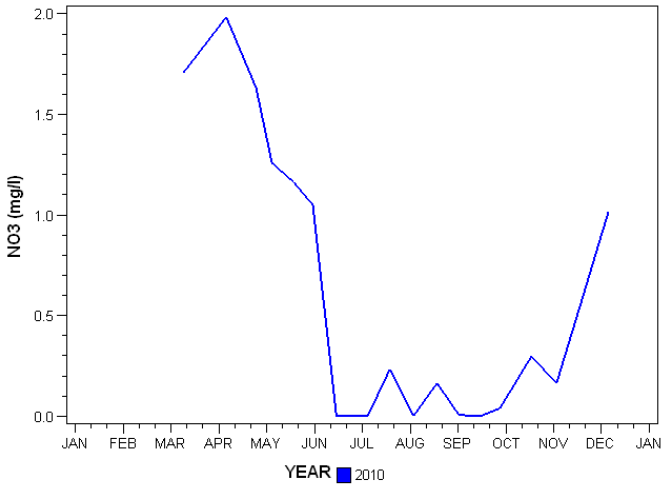


Figure A-2a. Nitrate concentrations at Otter Point Creek.

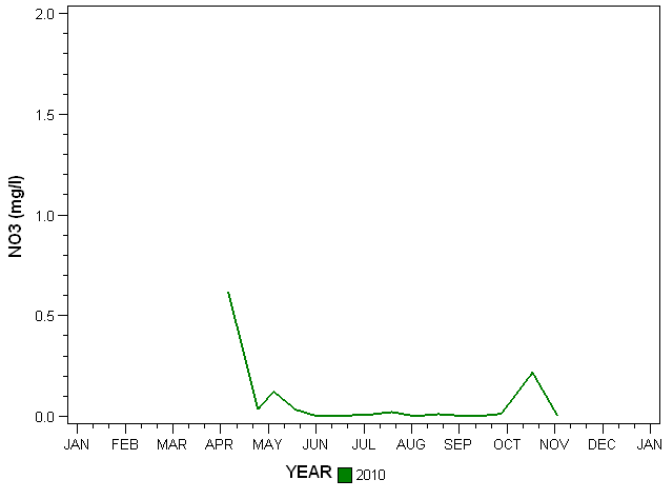


Figure A-2b. Nitrate concentrations at Church Point.

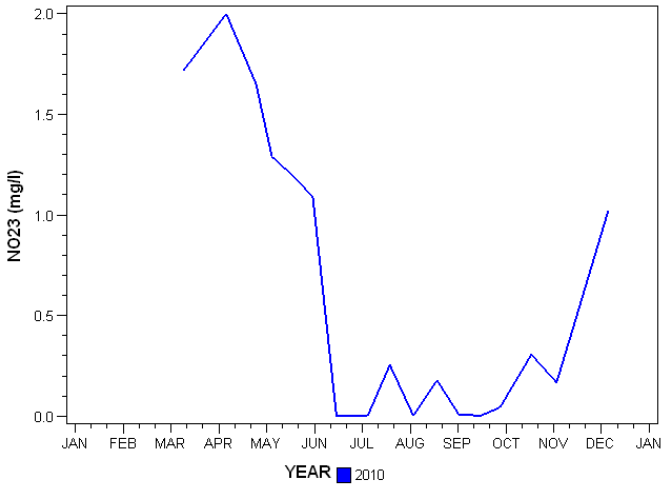


Figure A-3a. Nitrite + Nitrate concentrations at Otter Point Creek.

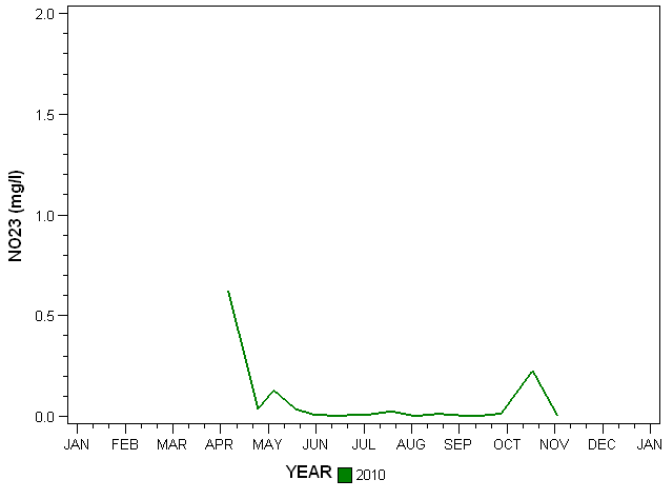


Figure A-3b. Nitrite + Nitrate concentrations at Church Point.

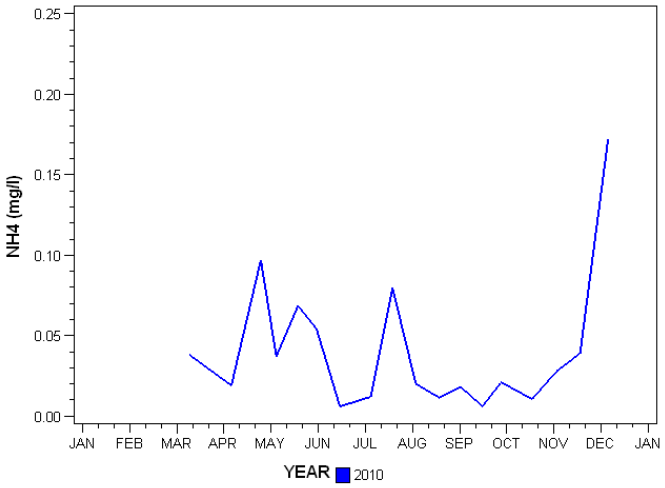


Figure A-4a. Ammonium concentrations at Otter Point Creek.

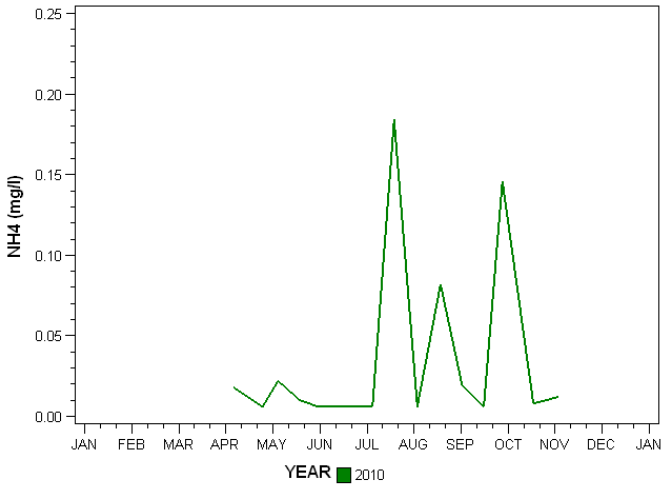


Figure A-4b. Ammonium concentrations at Church Point.

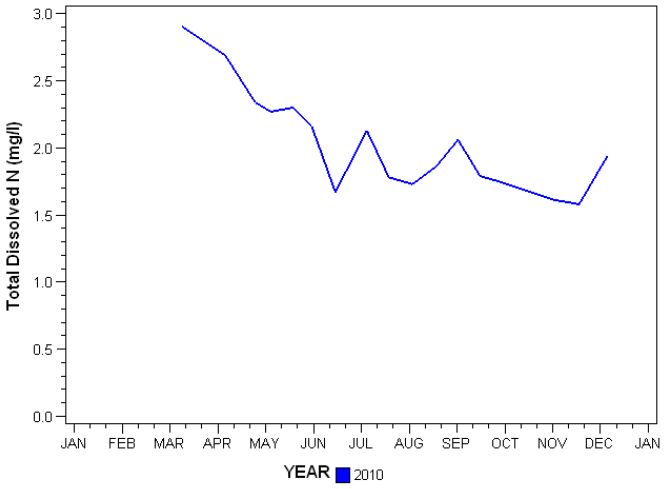


Figure A-5a. Total dissolved nitrogen concentrations at Otter Point Creek.

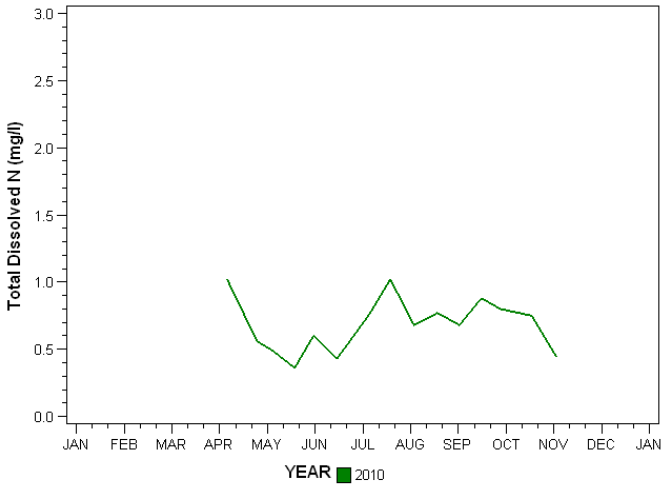


Figure A-5b. Total dissolved nitrogen concentrations at Church Point.

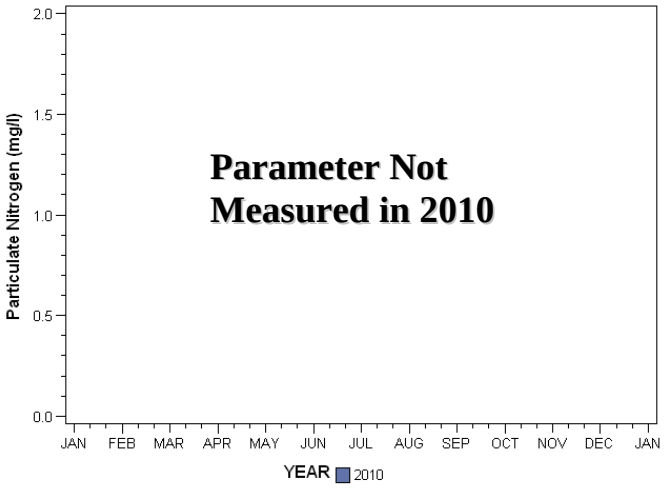


Figure A-6a. Particulate nitrogen concentrations at Otter Point Creek.

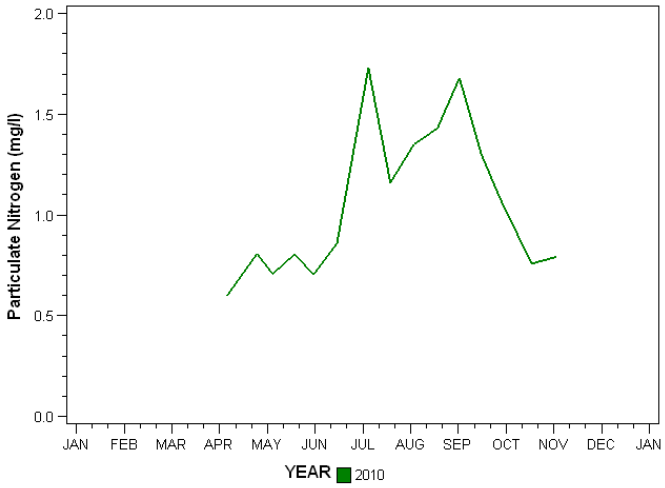


Figure A-6b. Particulate nitrogen concentrations at Church Point.

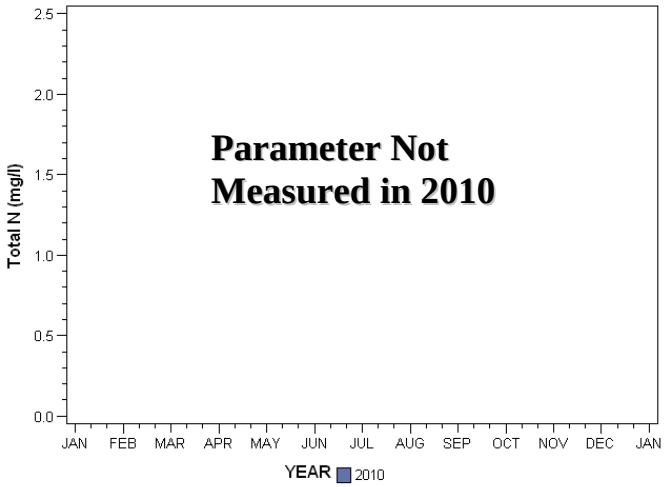


Figure A-7a. Total nitrogen concentrations at Otter Point Creek.

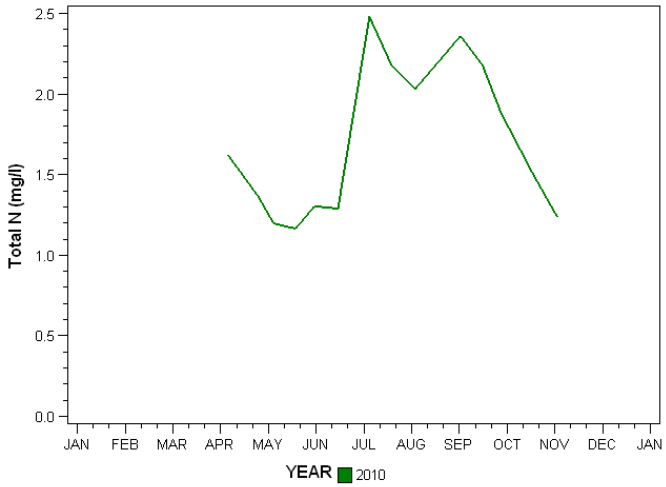


Figure A-7b. Total nitrogen concentrations at Church Point.

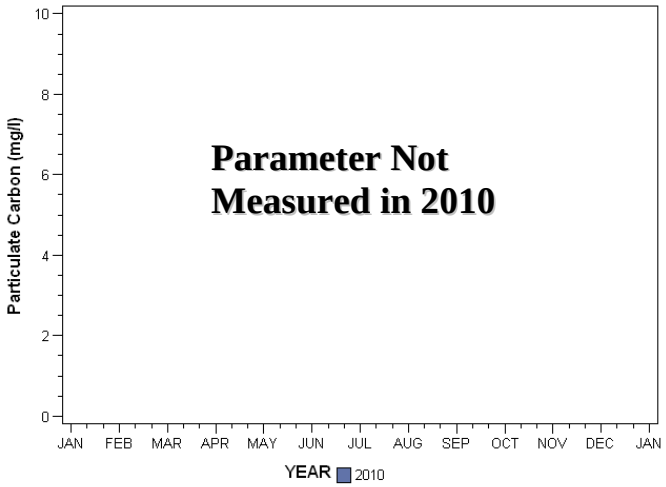


Figure A-8a. Particulate carbon concentrations at Otter Point Creek.

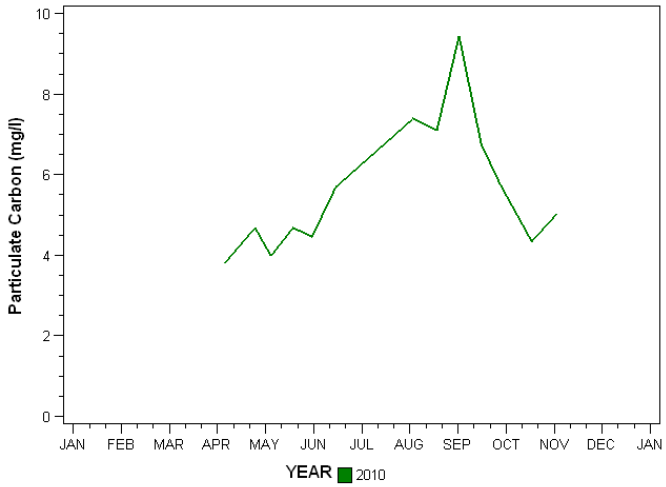


Figure A-8b. Particulate carbon concentrations at Church Point.

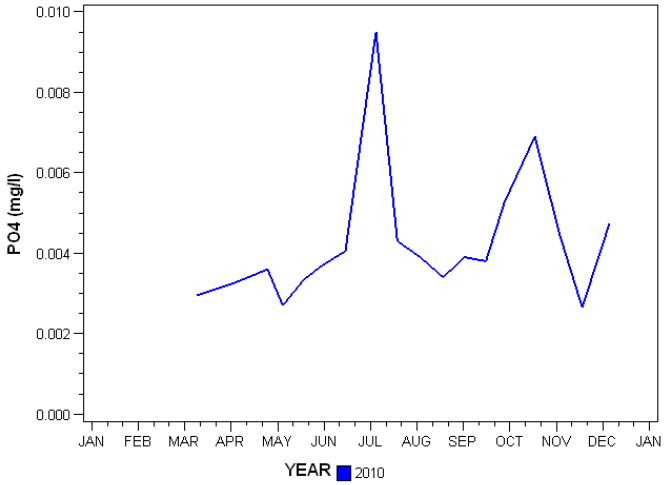


Figure A-9a. Phosphate concentrations at Otter Point Creek.

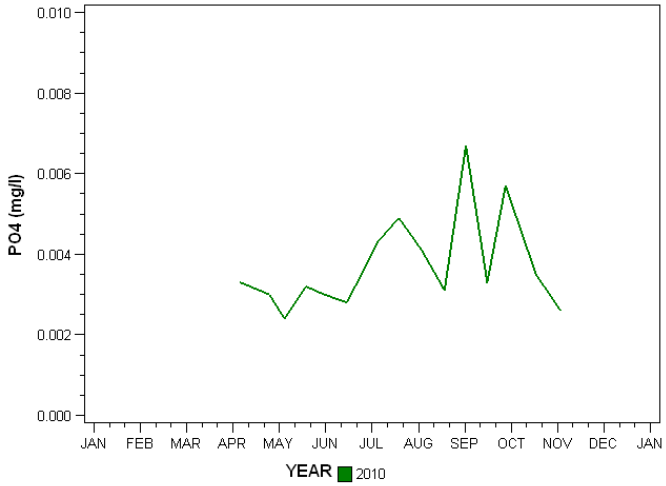


Figure A-9b. Phosphate concentrations at Church Point.

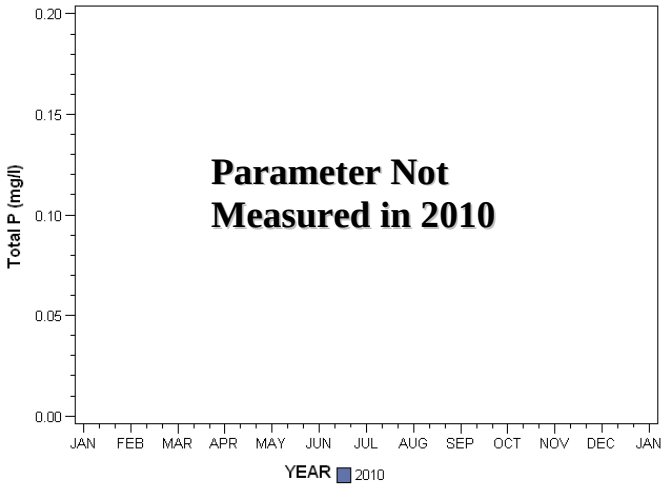


Figure A-10a. Total phosphorus concentrations at Otter Point Creek.

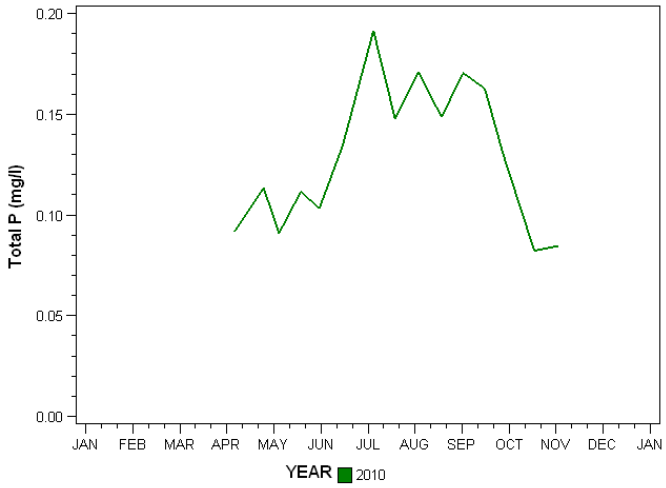


Figure A-10b. Total phosphorus concentrations at Church Point.

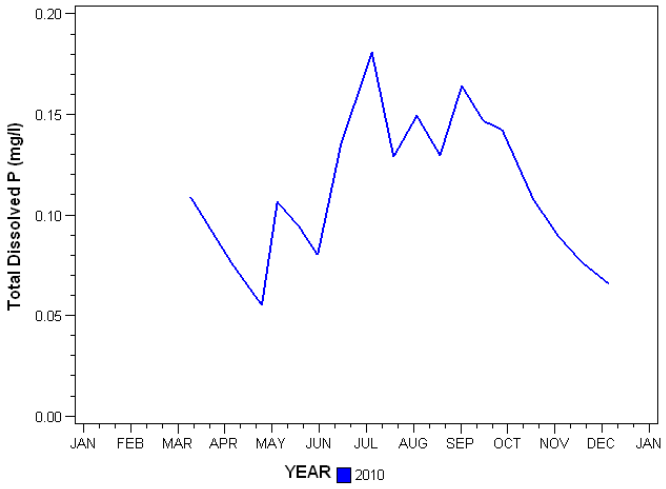


Figure A-11a. Total dissolved phosphorus concentrations at Otter Point Creek.

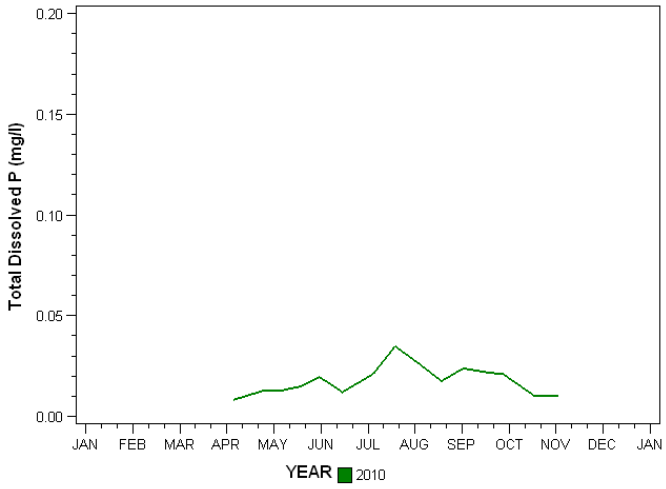


Figure A-11b. Total dissolved phosphorus concentrations at Church Point.

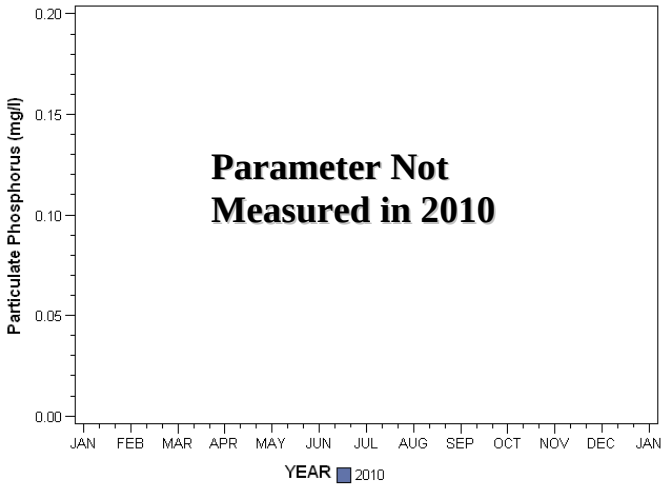


Figure A-12a. Particulate phosphorus concentrations at Otter Point Creek.

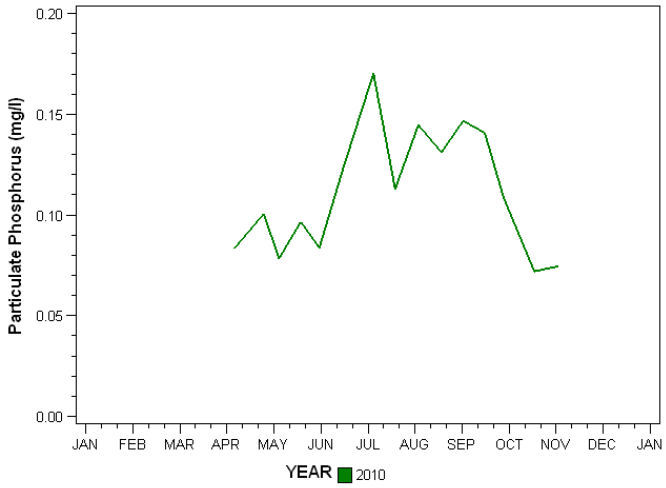


Figure A-12b. Particulate phosphorus concentrations at Church Point.

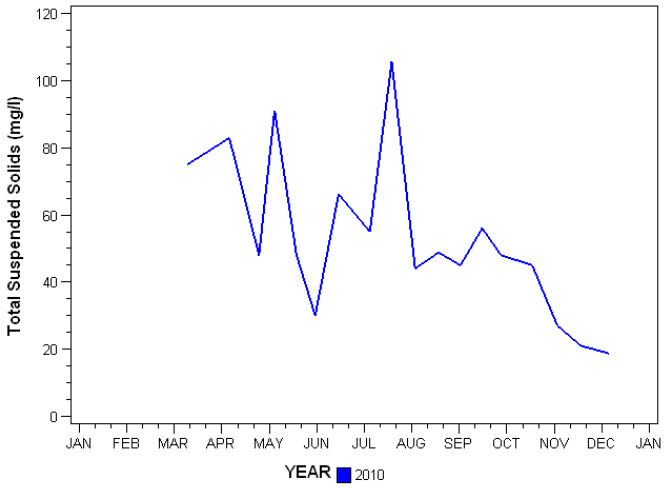


Figure A-13a. Total suspended solids concentrations at Otter Point Creek.

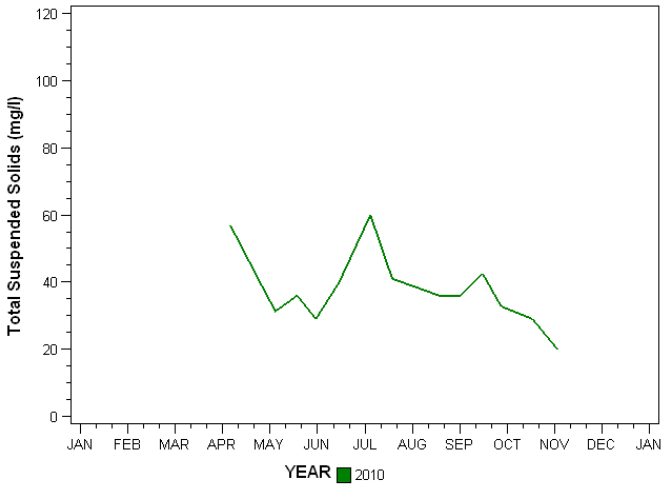


Figure A-13b. Total suspended solids concentrations at Church Point.

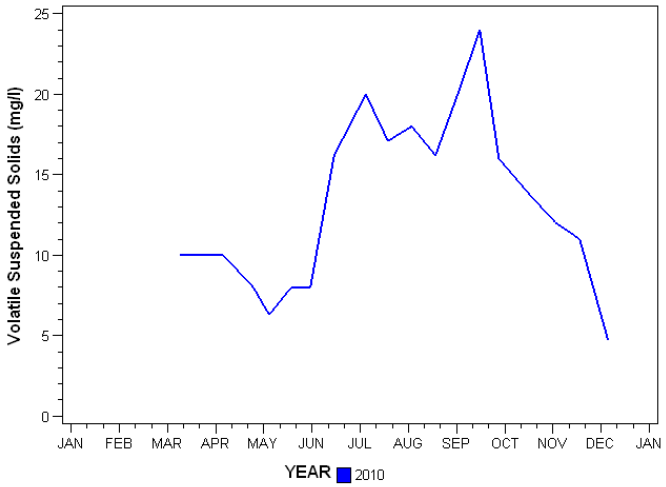


Figure A-14a. Volatile suspended solids concentrations at Otter Point Creek.

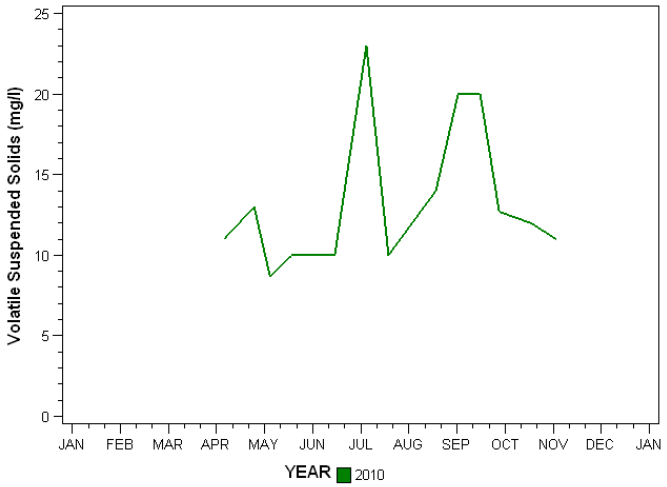


Figure A-14b. Volatile suspended solids concentrations at Church Point.

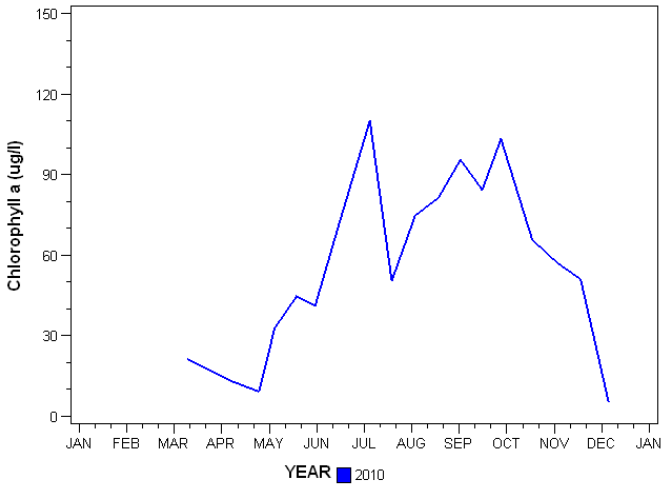


Figure A-15a. Chlorophyll *a* concentrations at Otter Point Creek.

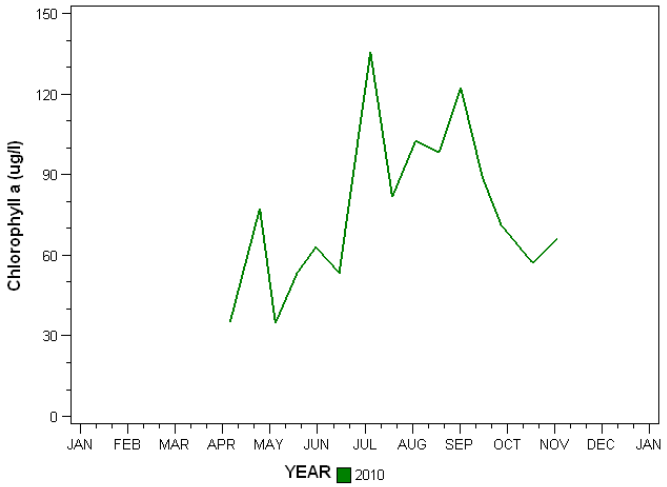


Figure A-15b. Chlorophyll *a* concentrations at Church Point.

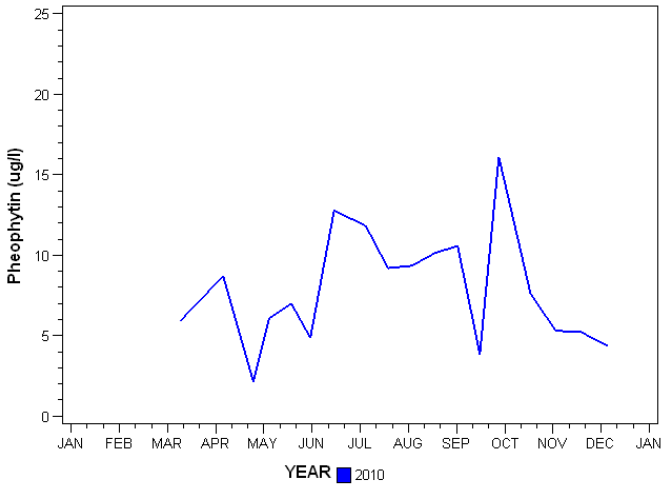


Figure A-16a. Pheophytin concentrations at Otter Point Creek.

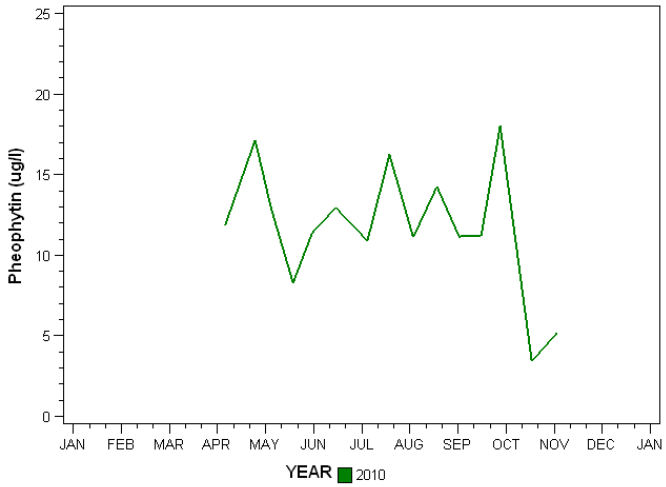


Figure A-16b. Pheophytin concentrations at Church Point.

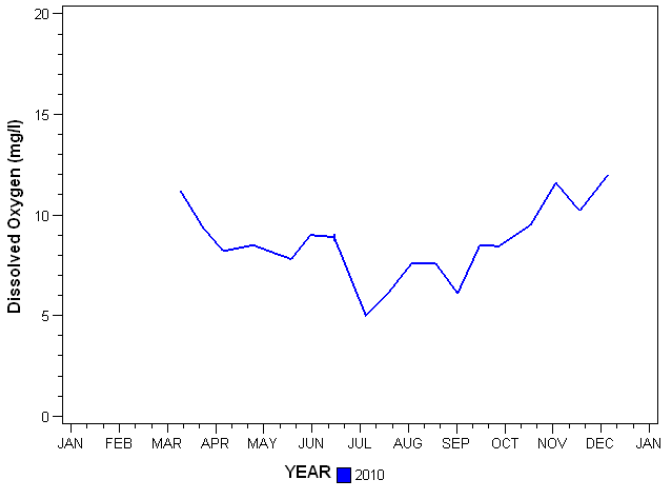


Figure A-17a. . Dissolved oxygen concentrations at Otter Point Creek.

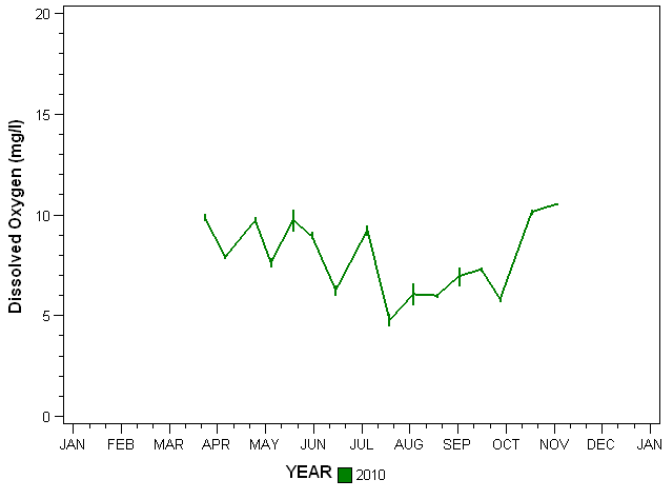


Figure A-17b. Dissolved oxygen concentrations at Church Point.

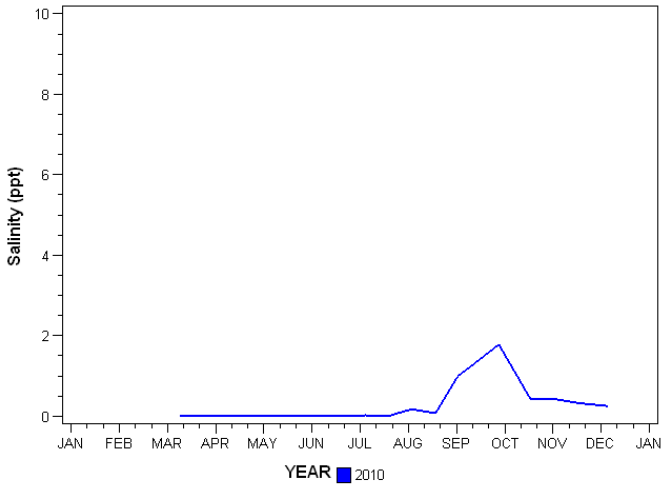


Figure A-18a. Salinity values at Otter Point Creek.

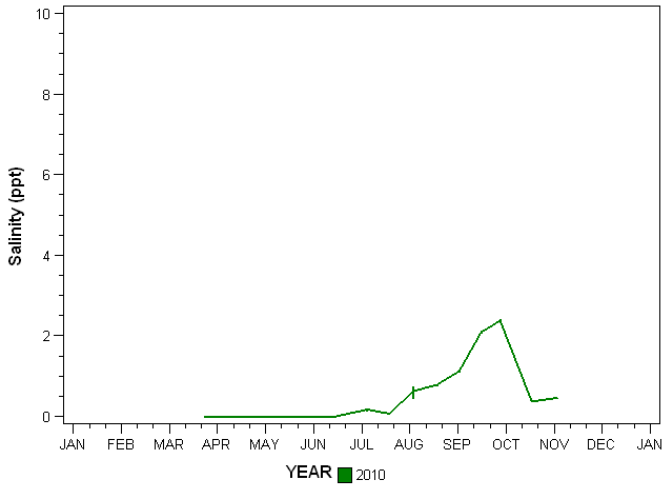


Figure A-18b. Salinity values at Church Point.

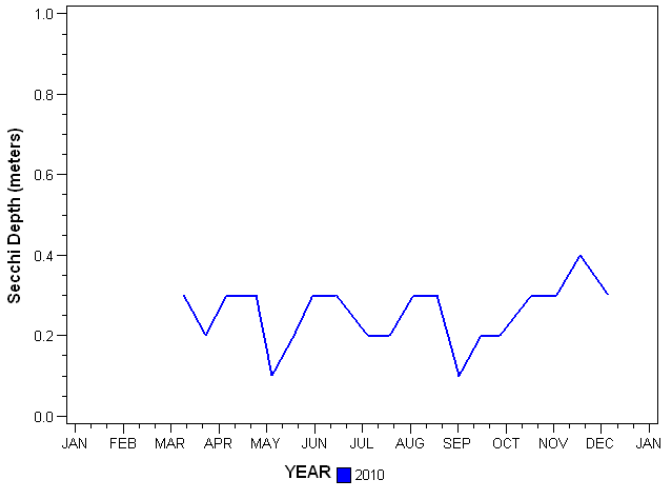


Figure A-19a. Secchi depth at Otter Point Creek.

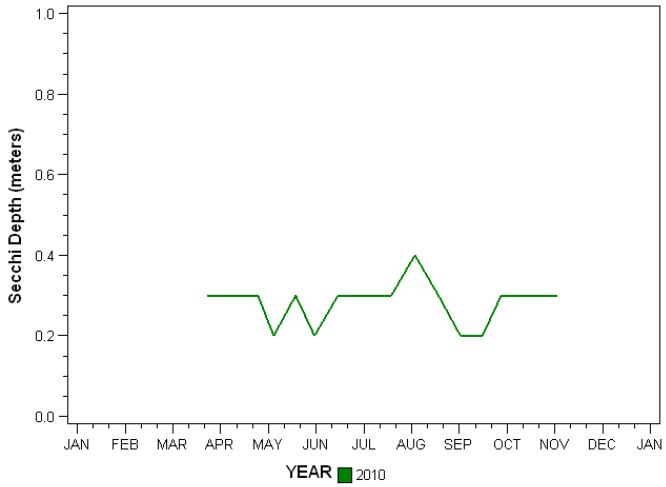


Figure A-19b. Secchi depth at Church Point.

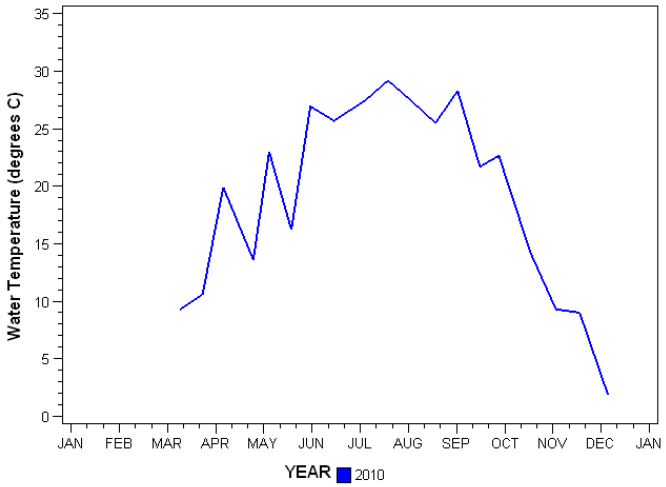


Figure A-20a. Water temperatures at Otter Point Creek

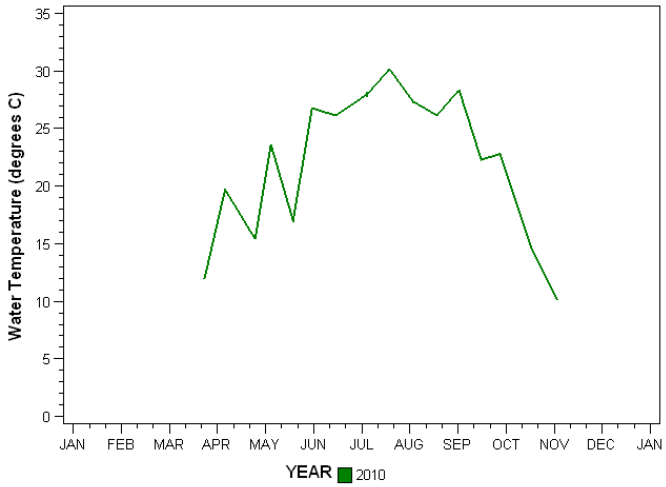


Figure A-20b. Water temperatures at Church Point.

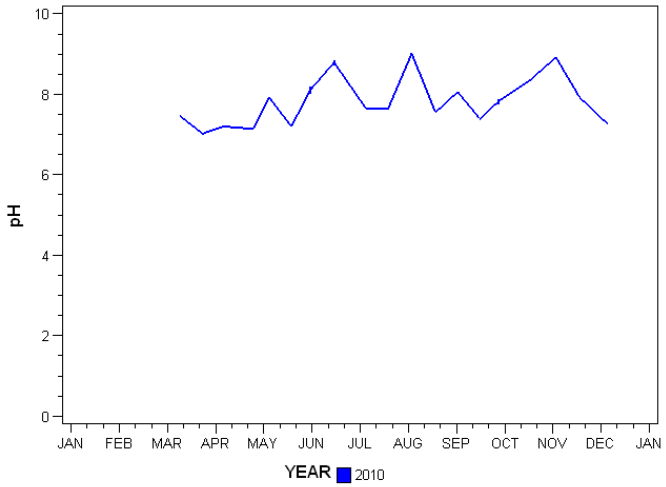


Figure A-21a. Values of pH at Otter Point Creek.

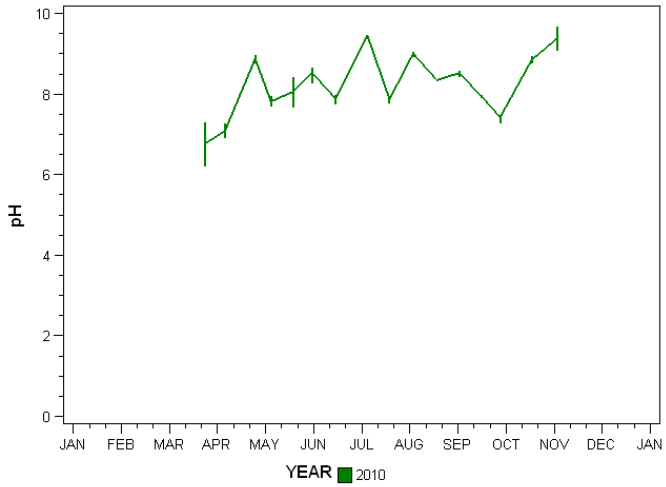


Figure A-21b. Values of pH at Church Point.

Table A1. Discrete Continuous Monitoring Data for Otter Point Creek (XJG7035) in 2010; ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), nitrite + nitrate (NO23), total dissolved nitrogen (TDN), particulate nitrogen (PN), total nitrogen (TN), phosphate (PO_4), total dissolved phosphorus (TDP), particulate phosphorus (PP), total phosphorus (TP), and particulate carbon (PC).

Date	Depth (m)	Replicate	NH_4 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	NO23 (mg/L)	TDN (mg/L)	PN (mg/L)	TN (mg/L)	PO_4 (mg/L)	TDP (mg/L)	PP (mg/L)	TP (mg/L)	PC (mg/L)
03/11/10	0.7	1	0.036	0.0103	1.7197	1.7300	2.90			0.0032	0.1089			
03/11/10	0.7	2	0.040	0.0105	1.6995	1.7100				0.0027				
04/07/10	0.5	1	0.019	0.0163	1.9837	2.0000	2.69			0.0033	0.0755			
04/26/10	0.6	1	0.099	0.0196	1.6204	1.6400	2.34			0.0034	0.0551			
04/26/10	0.6	2	0.095	0.0193	1.6407	1.6600				0.0038				
05/06/10	0.7	1	0.037	0.0310	1.2590	1.2900	2.27			0.0027	0.1065			
05/20/10	0.4	1	0.067	0.0300	1.1600	1.1900	2.30			0.0031	0.0942			
05/20/10	0.4	2	0.070	0.0258	1.1642	1.1900				0.0036				
06/01/10	1.0	1	0.054	0.0403	1.0497	1.0900	2.16			0.0037	0.0800			
06/16/10	1.1	1	0.006	0.0006	0.0029	0.0033	1.67			0.0029	0.1349			
06/16/10	1.1	2	0.006	0.0006	0.0039	0.0043				0.0052				
07/06/10	0.5	1	0.012	0.0010	0.0018	0.0028	2.13			0.0095	0.1809			
07/20/10	0.5	1	0.079	0.0221	0.2259	0.2480	1.78			0.0043	0.1289			
07/20/10	0.5	2	0.080	0.0213	0.2387	0.2600				0.0043				
08/04/10	0.7	1	0.020	0.0014	-0.0002	0.0012	1.73			0.0039	0.1493			
08/19/10	0.5	1	0.011	0.0140	0.1640	0.1780	1.86			0.0035	0.1296			
08/19/10	0.5	2	0.012	0.0144	0.1626	0.1770				0.0033				
09/02/10	0.5	1	0.018	0.0006	0.0050	0.0056	2.06			0.0039	0.1641			
09/16/10	0.7	1	0.006	0.0024	0.0005	0.0029	1.79			0.0038	0.1467			
09/28/10	1.1	1	0.022	0.0021	0.0419	0.0440	1.75			0.0048	0.1424			
09/28/10	1.1	2	0.020	0.0052	0.0359	0.0411				0.0057				
10/18/10	0.5	1	0.012	0.0092	0.2828	0.2920	1.67			0.0046	0.1080			
10/18/10	0.5	2	0.009	0.0098	0.3102	0.3200				0.0092				
11/03/10	0.5	1	0.028	0.0036	0.1634	0.1670	1.61			0.0045	0.0897			
11/18/10	0.2	1	0.038	0.0061	0.5379	0.5440	1.58			0.0022	0.0768			
11/18/10	0.2	2	0.040	0.0049	0.5601	0.5650				0.0031				
12/06/10	0.3	1	0.185	0.0087	1.0413	1.0500	1.94			0.0054	0.0656			
12/06/10	0.3	2	0.159	0.0085	0.9915	1.0000				0.0041				

Table A2. Discrete Continuous Monitoring Data for Church Point (XJG7461) in 2010; ammonium (NH_4), nitrite (NO_2), nitrate (NO_3), nitrite + nitrate (NO23), total dissolved nitrogen (TDN), particulate nitrogen (PN), total nitrogen (TN), phosphate (PO_4), total dissolved phosphorus (TDP), particulate phosphorus (PP), total phosphorus (TP), and particulate carbon (PC).

Date	Depth (m)	Replicate	NH_4 (mg/L)	NO_2 (mg/L)	NO_3 (mg/L)	NO23 (mg/L)	TDN (mg/L)	PN (mg/L)	TN (mg/L)	PO_4 (mg/L)	TDP (mg/L)	PP (mg/L)	TP (mg/L)	PC (mg/L)
04/07/10	1.0	1	0.018	0.0062	0.6198	0.6260	1.0200	0.600	1.620	0.0033	0.0083	0.0833	0.0916	3.81
04/26/10	1.0	1	0.006	0.0019	0.0349	0.0368	0.5600	0.807	1.367	0.0030	0.0128	0.1005	0.1133	4.68
05/06/10	1.0	1	0.022	0.0064	0.1236	0.1300	0.4900	0.707	1.197	0.0024	0.0126	0.0784	0.0910	3.98
05/20/10	1.0	1	0.010	0.0030	0.0332	0.0362	0.3600	0.805	1.165	0.0032	0.0149	0.0966	0.1115	4.68
06/01/10	1.0	1	0.006	0.0023	0.0050	0.0073	0.6000	0.704	1.304	0.0030	0.0196	0.0837	0.1033	4.46
06/16/10	1.0	1	0.006	0.0009	0.0029	0.0038	0.4300	0.859	1.289	0.0028	0.0120	0.1221	0.1341	5.69
07/06/10	1.1	1	0.006	0.0009	0.0084	0.0093	0.7500	1.730	2.480	0.0043	0.0212	0.1703	0.1915	
07/20/10	1.0	1	0.184	0.0037	0.0215	0.0252	1.0200	1.160	2.180	0.0049	0.0348	0.1128	0.1476	
08/04/10	1.0	1	0.006	0.0007	0.0015	0.0022	0.6800	1.350	2.030	0.0041	0.0264	0.1446	0.1710	7.39
08/19/10	1.0	1	0.082	0.0014	0.0112	0.0126	0.7700	1.430	2.200	0.0031	0.0175	0.1311	0.1486	7.10
09/02/10	1.0	1	0.019	0.0012	0.0034	0.0046	0.6800	1.680	2.360	0.0067	0.0238	0.1467	0.1705	9.44
09/16/10	1.0	1	0.006	0.0007	0.0035	0.0042	0.8800	1.300	2.180	0.0033	0.0220	0.1407	0.1627	6.76
09/28/10	1.0	1	0.146	0.0011	0.0125	0.0136	0.8000	1.080	1.880	0.0057	0.0209	0.1089	0.1298	5.76
10/18/10	1.0	1	0.008	0.0095	0.2175	0.2270	0.7500	0.758	1.508	0.0035	0.0102	0.0720	0.0822	4.34
11/03/10	1.0	1	0.012	0.0006	0.0007	0.0013	0.4400	0.792	1.232	0.0026	0.0101	0.0746	0.0847	5.03

Table A3. Discrete Continuous Monitoring Data for Chlorophyll-a, Pheophytin, Total Suspended Solids, Volatile Suspended Solids, and Secchi Disk Depth for Otter Point Creek (XJG7035) in 2010.

Date	Sample Depth (m)	Replicate	Chlorophyll-a (ug/L)	Pheophytin (ug/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Secchi Depth (m)
03/11/10	0.7	1	21.894	7.262	75.0	10.0	0.3
03/11/10	0.7	2	20.826	4.592			
03/25/10	0.2	1					0.2
04/07/10	0.5	1	13.350	8.704	83.0	10.0	0.3
04/26/10	0.6	1	9.612	3.097	48.0	8.0	0.3
04/26/10	0.6	2	8.544	1.175			
05/06/10	0.7	1	32.708	6.074	91.2	6.3	0.1
05/20/10	0.4	1	45.390	7.316	48.0	8.0	0.2
05/20/10	0.4	2	43.788	6.675			
06/01/10	1.0	1	41.118	4.859	30.0	8.0	0.3
06/16/10	1.1	1	70.755	15.219	66.2	16.2	0.3
06/16/10	1.1	2	71.423	10.346			
07/06/10	0.5	1	110.138	11.815	55.0	20.0	0.2
07/20/10	0.5	1	53.400	9.612	105.7	17.1	0.2
07/20/10	0.5	2	47.297	8.773			
08/04/10	0.7	1	74.760	9.345	44.0	18.0	0.3
08/19/10	0.5	1	90.780	12.950	48.8	16.2	0.3
08/19/10	0.5	2	72.090	7.343			
09/02/10	0.5	1	95.586	10.573	45.0	20.0	0.1
09/16/10	0.7	1	84.372	3.845	56.0	24.0	0.2
09/28/10	1.1	1	103.062	16.554	48.0	16.0	0.2
09/28/10	1.1	2	103.596	15.646			
10/18/10	0.5	1	68.085	8.077	45.0	13.7	0.3
10/18/10	0.5	2	63.412	7.142			
11/03/10	0.5	1	57.138	5.287	27.0	12.0	0.3
11/18/10	0.2	1	51.264	5.554	21.0	11.0	0.4
11/18/10	0.2	2	50.730	4.966			
12/06/10	0.3	1	4.984	4.486	18.7	4.7	0.3
12/06/10	0.3	2	4.984	4.236			

Table A4. Discrete Continuous Monitoring Data for Chlorophyll-a, Pheophytin, Total Suspended Solids, Volatile Suspended Solids, and Secchi Disk Depth for Church Point (XJG7461) in 2010.

Date	Sample Depth (m)	Replicate	Chlorophyll-a (ug/L)	Pheophytin (ug/L)	Total Suspended Solids (mg/L)	Volatile Suspended Solids (mg/L)	Secchi Depth (m)
03/25/10	0.10	1					0.3
03/25/10	0.25	1					0.3
03/25/10	0.50	1					0.3
03/25/10	0.75	1					0.3
03/25/10	0.80	1					0.3
04/07/10	1.00	1	35.244	11.855	57.0	11.0	0.3
04/26/10	1.00	1	77.430	17.141	40.0	13.0	0.3
05/06/10	1.00	1	34.710	12.949	31.3	8.7	0.2
05/20/10	1.00	1	53.400	8.277	36.0	10.0	0.3
06/01/10	1.00	1	63.012	11.374	29.0	10.0	0.2
06/16/10	1.00	1	53.400	12.950	40.0	10.0	0.3
07/06/10	0.10	1					0.3
07/06/10	0.25	1					0.3
07/06/10	0.50	1					0.3
07/06/10	1.10	1	135.636	10.894	60.0	23.0	0.3
07/20/10	1.00	1	81.702	16.234	41.0	10.0	0.3
08/04/10	1.00	1	102.528	11.107			0.4
08/19/10	1.00	1	98.256	14.258	36.0	14.0	0.3
09/02/10	1.00	1	122.286	11.161	36.0	20.0	0.2
09/16/10	1.00	1	88.778	11.214	42.5	20.0	0.2
09/28/10	1.00	1	71.200	18.014	32.7	12.7	0.3
10/18/10	1.00	1	57.138	3.418	29.0	12.0	0.3
11/03/10	1.00	1	66.216	5.180	20.0	11.0	0.3

Table A5. Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Otter Point Creek (XJG7035) in 2010.

Date	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (^{o}C)
03/11/10	0.7	11.2	7.45	0.00	9.3
03/25/10	0.2	9.4	7.02	0.00	10.6
04/07/10	0.5	8.2	7.20	0.00	19.9
04/26/10	0.6	8.5	7.14	0.00	13.6
05/06/10	0.7	8.2	7.92	0.00	23.0
05/20/10	0.4	7.8	7.20	0.00	16.2
06/01/10	0.5	9.0	8.20	0.00	27.0
06/01/10	1.0	9.0	8.02	0.00	26.9
06/16/10	0.5	8.7	8.86	0.00	25.7
06/16/10	1.1	9.1	8.72	0.00	25.7
07/06/10	0.5	5.0	7.65	0.02	27.5
07/20/10	0.5	6.1	7.63	0.00	29.2
08/04/10	0.7	7.6	9.01	0.17	27.4
08/19/10	0.5	7.6	7.55	0.07	25.5
09/02/10	0.5	6.1	8.06	0.99	28.3
09/16/10	0.7	8.5	7.39	1.41	21.7
09/28/10	0.5	8.4	7.76	1.77	22.8
09/28/10	1.1	8.5	7.90	1.79	22.5
10/18/10	0.5	9.5	8.36	0.42	14.2
11/03/10	0.5	11.6	8.92	0.42	9.3
11/18/10	0.2	10.2	7.92	0.32	9.0
12/06/10	0.3	12.0	7.25	0.25	1.8

Table A6. Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Church Point (XJG7461) in 2010.

Date	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (^{o}C)
03/25/10	0.5	9.7	7.30	0.00	12.0
03/25/10	0.8	10.1	6.22	0.00	12.0
04/07/10	0.5	7.8	7.28	0.00	19.8
04/07/10	1.0	8.0	6.90	0.00	19.6
04/26/10	0.5	9.7	8.98	0.00	15.4
04/26/10	1.0	9.9	8.78	0.00	15.4
04/26/10	1.4	9.6	8.87	0.00	15.4
05/06/10	0.5	7.6	7.78	0.00	23.6
05/06/10	1.0	7.9	7.97	0.00	23.7
05/06/10	1.3	7.4	7.70	0.00	23.5
05/20/10	0.5	10.3	8.44	0.00	17.1
05/20/10	1.0	9.2	7.67	0.00	16.9
06/01/10	0.5	8.8	8.65	0.00	26.8
06/01/10	1.0	9.2	8.28	0.00	26.7
06/01/10	1.6	8.8	8.65	0.00	26.8
06/16/10	0.5	6.3	7.99	0.00	26.2
06/16/10	1.0	6.5	7.76	0.00	26.1
06/16/10	1.7	6.0	7.89	0.00	26.1
07/06/10	0.5	9.0	9.48	0.14	28.2
07/06/10	1.1	9.5	9.43	0.20	27.8
07/20/10	0.5	4.7	7.87	0.06	30.2
07/20/10	1.0	5.1	7.97	0.08	30.2
07/20/10	1.3	4.5	7.78	0.06	30.1
08/04/10	0.5	6.6	9.05	0.44	27.4
08/04/10	1.0	6.1	9.03	0.74	27.2
08/04/10	1.3	5.5	8.93	0.70	27.4
08/19/10	0.5	6.1	8.33	0.77	26.1
08/19/10	1.0	5.9	8.36	0.80	26.2
09/02/10	0.5	7.0	8.54	1.10	28.4
09/02/10	1.0	7.4	8.58	1.16	28.4
09/02/10	1.2	6.5	8.44	1.09	28.3
09/16/10	0.5	7.4	7.99	2.05	22.3
09/16/10	1.0	7.2	7.92	2.13	22.3
09/28/10	0.5	5.9	7.48	2.36	22.8
09/28/10	1.0	5.9	7.27	2.42	22.8
09/28/10	1.5	5.8	7.47	2.36	22.8
09/28/10	1.9	5.7	7.47	2.36	22.8
10/18/10	0.5	10.0	8.76	0.36	14.6
10/18/10	1.0	10.3	8.94	0.38	14.5
11/03/10	0.5	10.6	9.07	0.45	10.1
11/03/10	1.0	10.5	9.69	0.47	10.1

Appendix B

Water quality data for 2003-2010 at the Otter Point Creek Continuous Monitoring station (XJG7035)

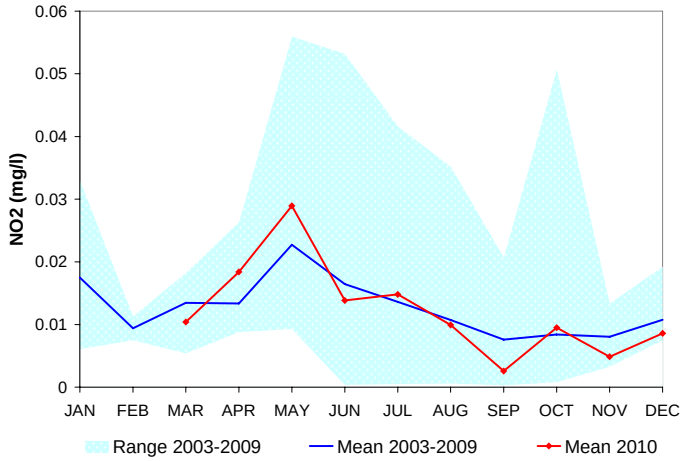


Figure B-1. Nitrite concentrations at Otter Point Creek.

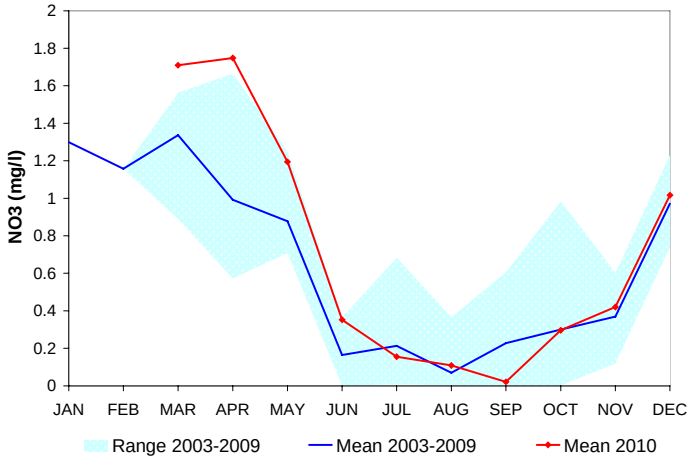


Figure B-2. Nitrate concentrations at Otter Point Creek.

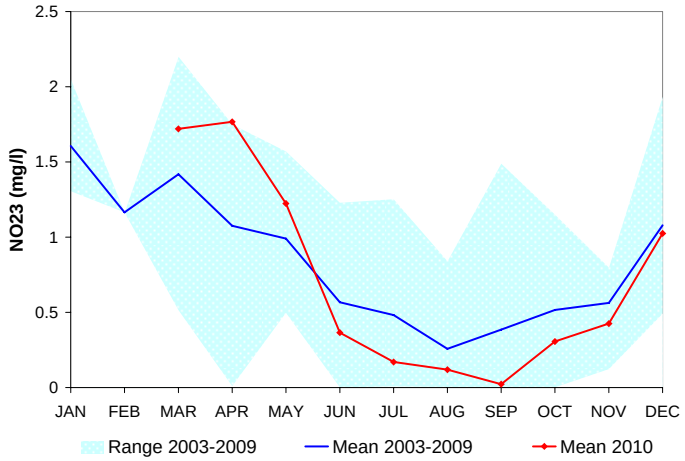


Figure B-3. Nitrite + nitrate concentrations at Otter Point Creek.

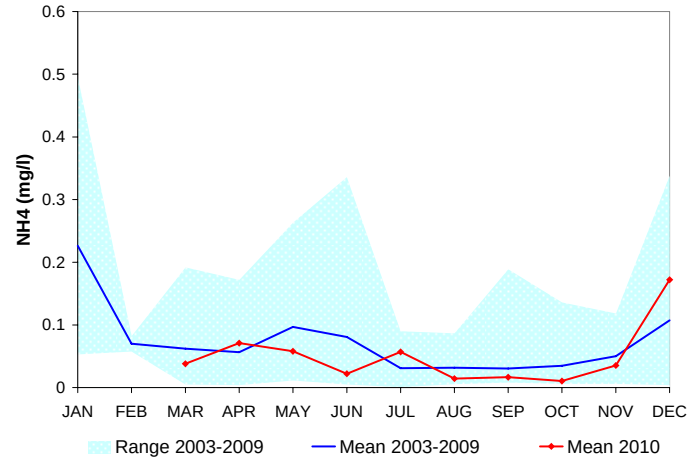


Figure B-4. Ammonium concentrations at Otter Point Creek.

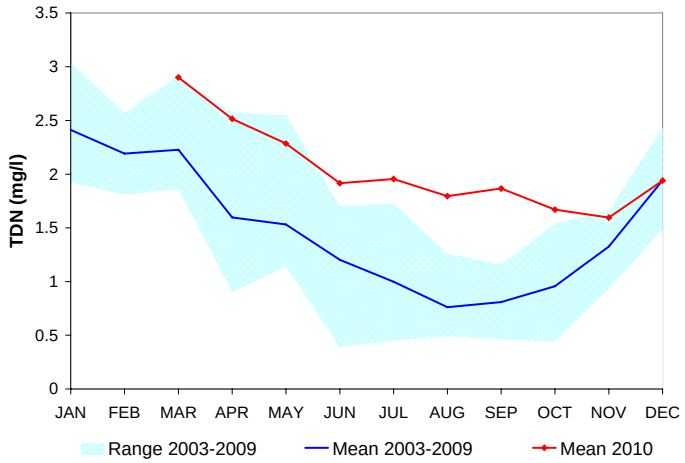


Figure B-5. Total dissolved nitrogen concentrations at Otter Point Creek.

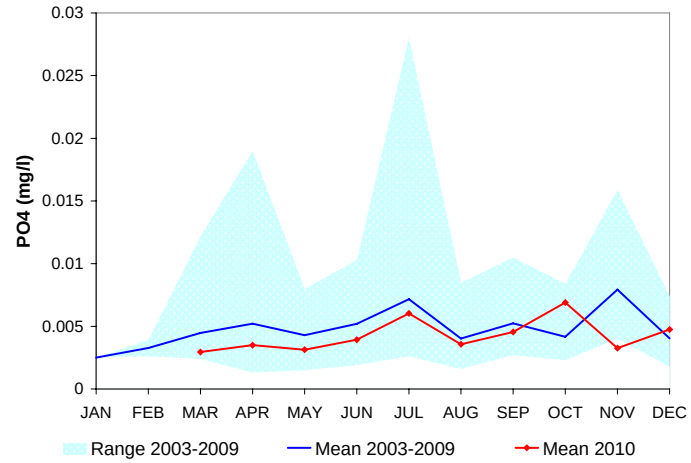


Figure B-6. Phosphate concentrations at Otter Point Creek.

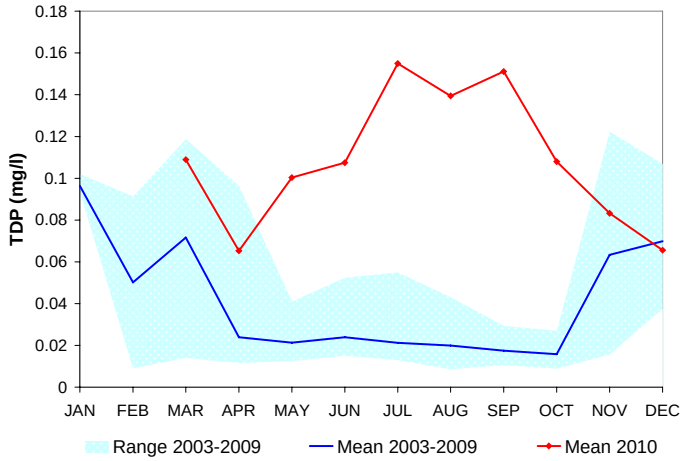


Figure B-7. Total dissolved phosphorus concentrations at Otter Point Creek.

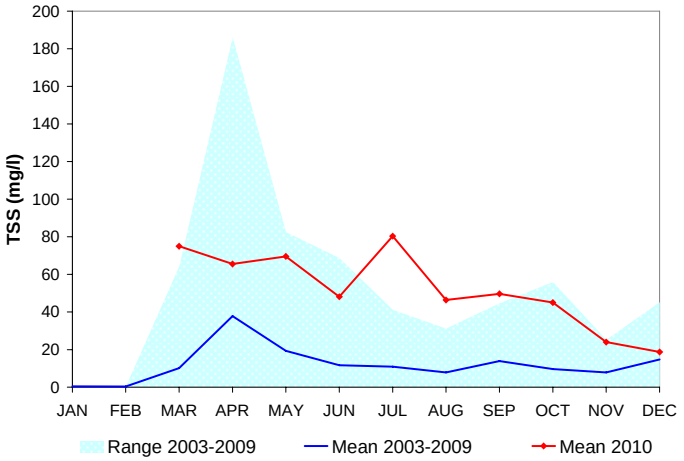


Figure B-8. Total suspended solids concentrations at Otter Point Creek.

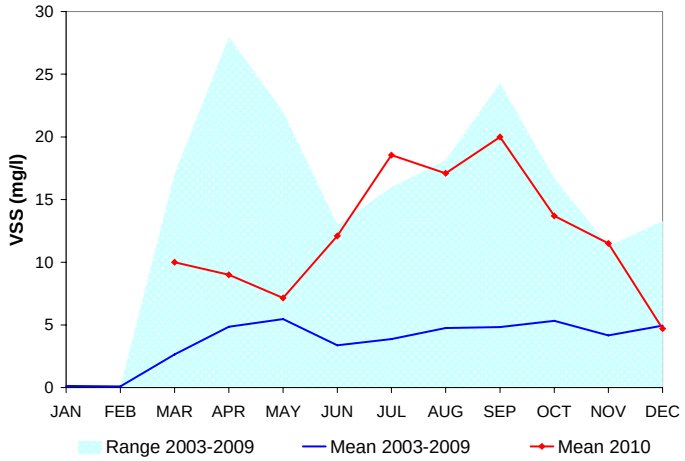


Figure B-9. Volatile suspended solids concentrations at Otter Point Creek.

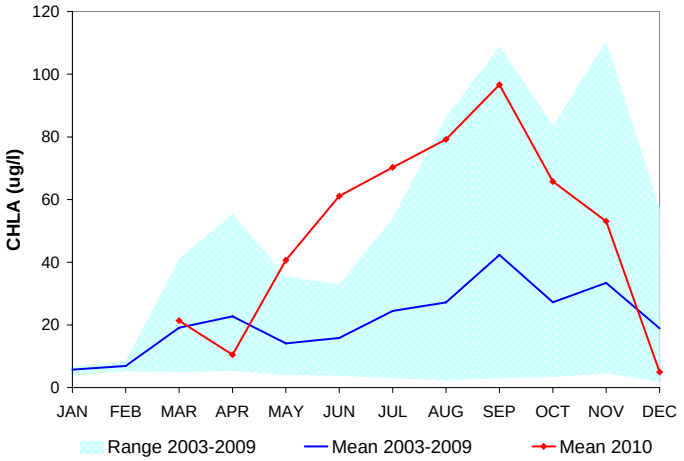


Figure B-10. Chlorophyll *a* concentrations at Otter Point Creek.

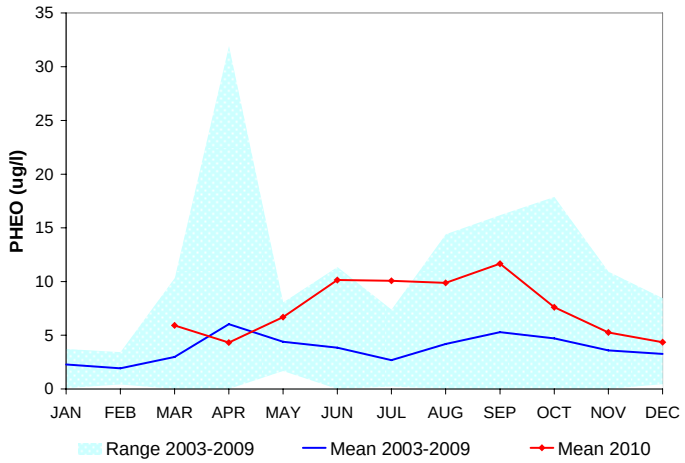


Figure B-11. Pheophytin concentrations at Otter Point Creek.

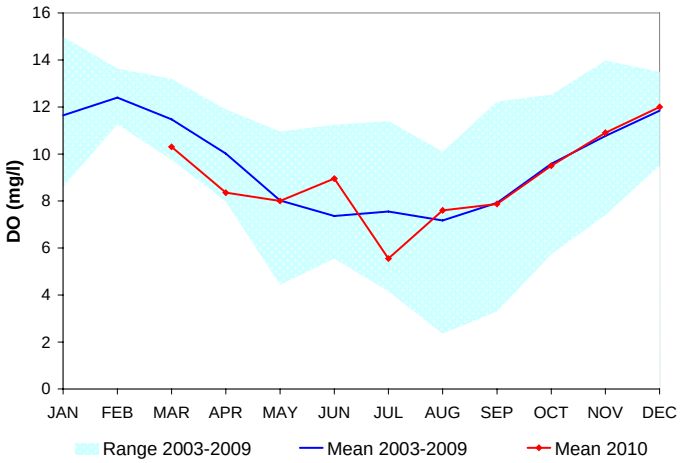


Figure B-12. Dissolved oxygen concentrations at Otter Point Creek.

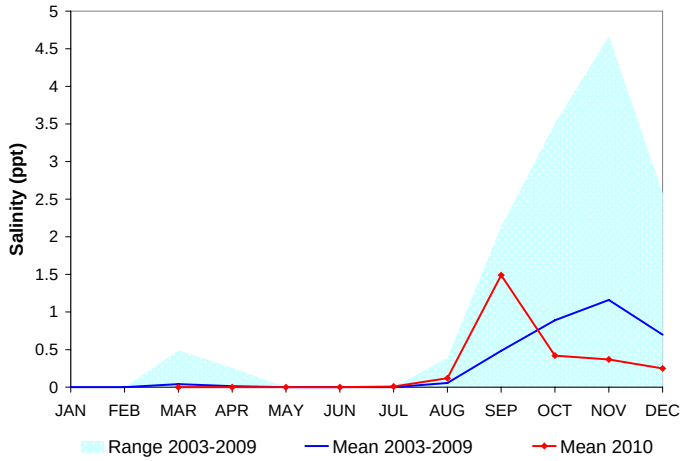


Figure B-13. Salinity concentrations at Otter Point Creek.

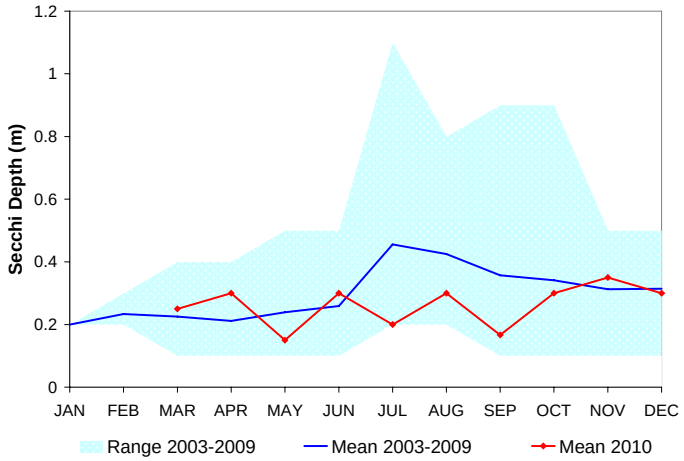


Figure B-14. Secchi depth values at Otter Point Creek.

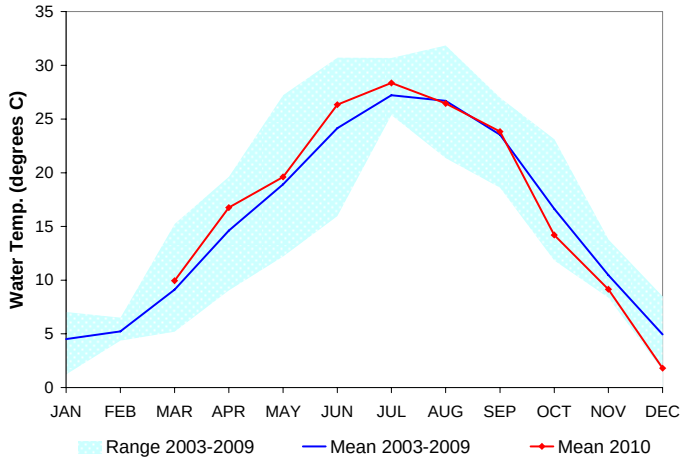


Figure B-15. Water temperatures at Otter Point Creek.

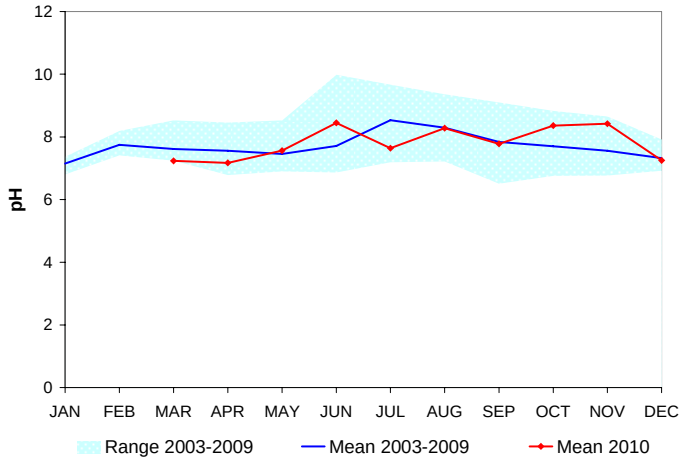


Figure B-16. pH values at Otter Point Creek.