MARYLAND
DEPARTMENT OF NATURAL RESOURCES

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2011 Masonville Cove – Patapsco River Shallow Water Monitoring Data Report

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Executive summary

Masonville Cove, a small inlet of the upper tidal Patapsco River, figures in local Baltimore lore as a natural respite from the rigors of early twentieth century city life. However, as the Patapsco River was heavily impacted by pollution from centuries of being a center of commerce and population, so too was Masonville Cove. In 2007, the Maryland Port Administration received a permit to build a dredged material containment facility at the Masonville Marine Terminal, adjacent to Masonville Cove. As part of the mitigation agreement for this project, the Maryland Department of Natural Resources (DNR) deployed a continuous water quality monitor in the summer of 2009, ahead of the construction of the dredged material containment facility. The monitor was deployed during most of the year, although it was removed in December to preclude icing damage. Two water quality monitors were deployed in Masonville Cove in the early spring of 2011. As part of its 2011 Shallow Water Quality Monitoring program, DNR also performed monthly water quality mapping cruises of the Patapsco River between April and October.

In 2011, water quality conditions in Masonville Cove, as in the rest of the Chesapeake Bay watershed, were influenced by meteorological events. Heavy rain in the spring, as well as large spikes in precipitation in late-August and early-September, fueled by Hurricane Irene and Tropical Storm Lee, led to massive discharge events that effected salinity and turbidity. Nutrients in storm runoff may also have been factors in the formation of algae blooms, some of which were comprised of potentially harmful algae species. Decaying algae from the blooms also likely caused periods of low dissolved oxygen that were observed in 2011.

Introduction

In 2007, the Maryland Port Administration (MPA) submitted plans to the United States Army Corps of Engineers (USACE) to construct a dredged material containment facility (DMCF) in the vicinity of the Masonville Marine Terminal. The terminal, located on the upper Patapsco River in Baltimore, is a major port for the automotive industry (Figure 1). The design for the DMCF uses sand and clay dikes to contain material dredged from the navigation channels in Baltimore Harbor. The same year, an environmental impact study submitted to USACE suggested mitigation for the project. Mitigation was deemed necessary as the DMCF was to fill 130 acres of tidal open water, cover ten acres of upland habitat, and disturb one acre of vegetated wetland and 0.38 acres of submerged aquatic vegetation (SAV).

In 2011, as continuation of the mitigation plan implemented in 2009, the Resource Assessment Service of the Maryland Department of Natural Resources (DNR) monitored water quality in Masonville Cove adjacent to the DMCF site. In late March, DNR deployed two continuous water quality monitors that collected data every 15 minutes on a suite of water quality parameters, including dissolved oxygen, salinity, temperature, turbidity, pH, and chlorophyll. The two monitors were deployed at the same location, one near the water surface and the other near the bottom. Data from the surface monitor were telemetered to the DNR website (www.eyesonthebay.net) and displayed in near real-time. DNR personnel visited the station every two to four weeks to replace the meters, and to collect water samples for analyses of nutrients, total suspended solids, and chlorophyll *a* concentrations. This project also continued as the final year of DNR's three-year water quality assessment of the Patapsco River. The continuous monitoring site at Masonville Cove was one of four continuous monitoring stations located throughout the tidal Patapsco as part of the three-year assessment. In addition, monthly shallow water quality mapping cruises were conducted throughout the river, including Masonville Cove. Data from these cruises were used to map the spatial extent of water quality conditions.

Description of continuous monitoring

On March 30, 2011, a data collection device known as a sonde was attached to a piling in Masonville Cove (39.2444°, -76.5957°) with its instrumentation one meter below the water surface (see Figure 1 for station location). This 'surface' data sonde, a YSI™ 6600 v2 (Yellow Springs Instruments, Yellow Springs, OH), housed several water quality sensors (Figure 2). The water quality indicator data collected by each sensor are explained in greater detail in the following section. The sonde collected a reading from each sensor simultaneously every 15 minutes for the duration of its deployment. These readings were stored in the sonde's data memory and sent, by attached cellular telemetry equipment, to DNR headquarters in Annapolis. There, the data were posted on DNR's "Eyes on the Bay" website (www.eyesonthebay.net) for easy public access. This website enables the public to access near real-time water quality data for numerous locations throughout Maryland. The data are called "near real-time" since there is a lag of approximately one to one and a half hours between the time that the sonde collects the data and the time that the data are posted on the website.

A second YSI™ 6600 v2 sonde was also attached to the same piling on March 30th, and deployed 1.7m below the water surface. This 'bottom' monitor was part of research project conducted in conjunction with the Smithsonian Environmental Research Center to quantify the relationship between dissolved oxygen levels and the presence of shellfish.

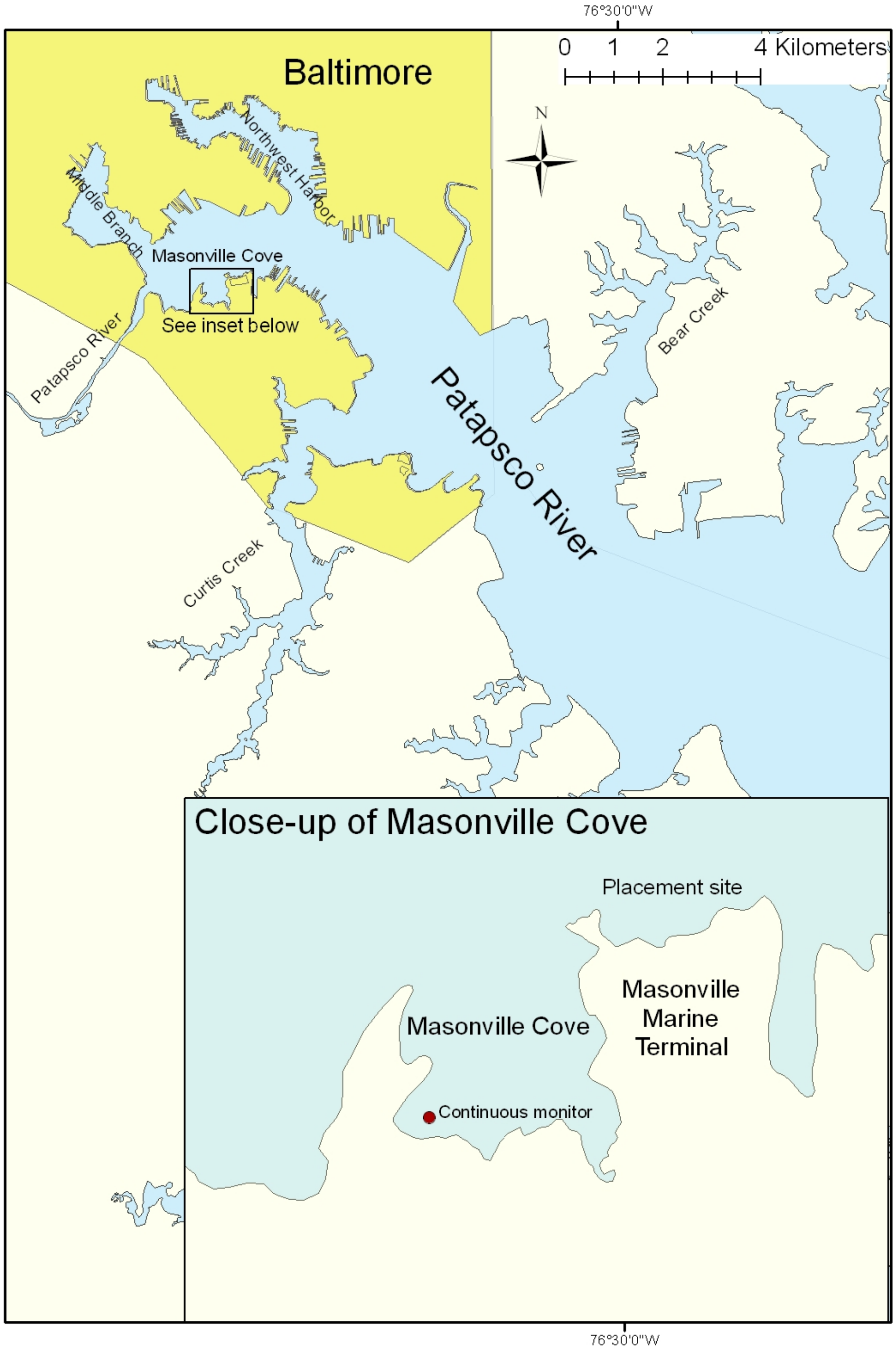


Figure 1. Map of the Patapsco River and Masonville Cove. The inset shows where the continuous monitor is located within the cove as well as the approximate site for dredged material placement.

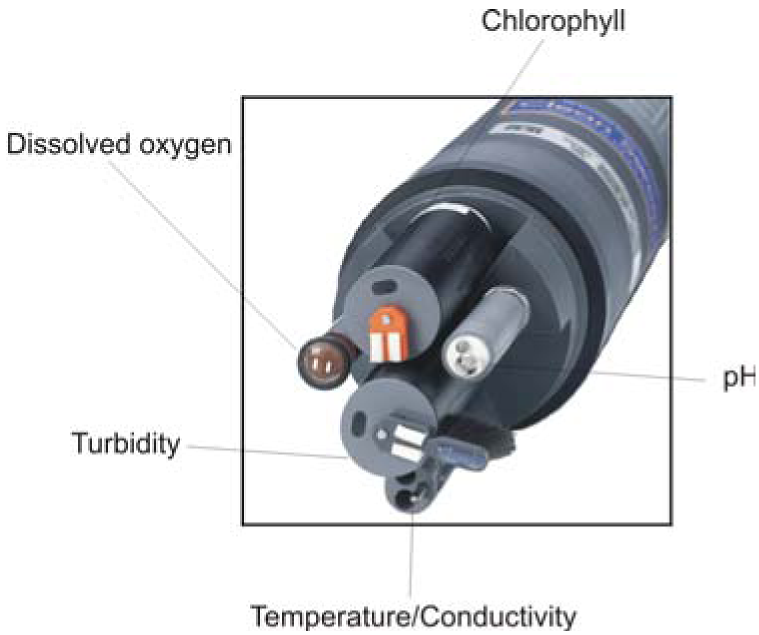


Figure 2. YSI 6600 continuous monitoring sonde showing individual sensors. Image courtesy of YSI, Inc.

Continuous monitoring parameters

The continuous monitors at Masonville Cove, like all continuous monitors in the DNR Shallow Water Monitoring Program, collected data on six water quality parameters:

1. Dissolved oxygen (DO): Fish and other aquatic life require DO to survive. Maryland state water quality criteria require a minimum DO concentration of 5 milligrams per liter (mg/L) (COMAR 1995). This threshold is necessary for the survival of many fish and shellfish species, including hard clams (*Mercenaria mercenaria*) and striped bass (*Morone saxitilis*).
2. Salinity: Salinity, or salt concentration, in the Patapsco River comes from the Chesapeake Bay. Therefore, areas closer to the Bay have higher salinities, except perhaps during large freshwater releases from the Conowingo Dam on the Susquehanna River. During periods of low precipitation and river flow, salinity increases as salty water intrudes further up the river. During wetter periods, salinity decreases. Salinity also cycles in relation to tides, increasing during flood tides and decreasing during ebb tides. Salinity levels are important to aquatic organisms, as some organisms are adapted to live only in brackish or salt water, while others require fresh water.
3. Water temperature: Water temperature is another variable affecting suitability of waterways for aquatic organisms. Many aquatic organisms can tolerate gradual temperature changes associated with changing seasons, but sudden changes can cause stress. Higher water temperatures cause more dissolved oxygen to come out of solution and enter the air, decreasing the amount available to fish and other aquatic organisms.
4. pH: The acidity of water is indicated by pH. A neutral pH is 7; lower values indicate higher acidity, while higher numbers indicate more alkaline conditions. pH is affected by salinity (higher salinities

tend to buffer pH in the 7-8 range) and algae blooms (large algae blooms can raise the pH over 8 in low salinity waters).

5. Turbidity: Turbidity is a measure of water clarity. Events that stir up sediment or cause runoff, such as storms, will increase turbidity. Dense algae blooms will also cause higher turbidities. Relatively clear water (low turbidity) is required for growth and survival of submerged aquatic vegetation (SAV).
6. Chlorophyll: Chlorophyll concentration is a surrogate measure of the amount of algae in the water. Chlorophyll is the main chemical responsible for photosynthesis, the process by which sunlight is converted into food energy. Chlorophyll concentrations are calculated from fluorescence values collected by the sensors. One downside to this method is that certain species of phytoplankton, such as blue-green algae, fluoresce outside the detection range of the chlorophyll fluorescence sensor.

Calibration of continuous monitors and collection of laboratory water samples

Pigments, nutrients, and suspended solids data were obtained by DNR staff during deployment of continuous monitoring data sondes. During the early part of the year, discrete whole water samples were collected to measure chlorophyll *a*, phaeophytin, and total suspended solids. Starting on May 19th, additional samples were also collected to measure ammonium, nitrite, nitrate, total dissolved nitrogen, particulate nitrogen, phosphate, total dissolved phosphorus, and particulate carbon. Data sondes were removed and replaced with freshly calibrated instruments on a biweekly basis. At the time of each instrument replacement, Secchi disk depth was recorded for use in water clarity determination.

Patapsco River Shallow Water Quality Assessment and Water Quality Mapping

The Masonville Cove continuous monitor was part of a network of four continuous monitors deployed throughout the tidal Patapsco River beginning in 2009, the first year of a three-year intensive sampling effort of the Patapsco River. The same network of monitors was re-deployed in 2011 for the third and final year of the assessment. Data from the three-year study will be used to assess water quality conditions and criteria under the auspices of the Chesapeake Bay Program. Aside from the network of continuous monitors, shallow water quality mapping cruises were also conducted. Once per month during April through October, a water quality sonde was deployed from a small watercraft. This boat followed a prescribed path through the Patapsco River while collecting automated data (Figure 3). Parameters were the same as those collected for continuous monitoring, but were collected every four seconds along the cruise path. A Geographic Positioning Satellite (GPS) reading was also collected with each data reading so that the data could be mapped to the waterway. This provided monthly snapshots of the spatial extents of water quality measurements in the Patapsco River, including Masonville Cove.

Masonville Cove continuous monitor deployment

In 2011, both the surface and bottom continuous monitors at Masonville Cove were deployed on March 30th. The bottom sonde was removed on October 31st and collected 20,639 data records in 2011. The surface sonde was removed on December 15th and collected 24,962 data records in 2011. Seventeen nutrient calibration samples were also collected and analyzed in 2011. Automated telemetry generally operated throughout the deployment of the surface sonde, but there were times when telemetry did not work properly, which led to gaps in near real-time web presentation of the data. Telemetry issues did not, however, impede the sonde from collecting the data. The surface monitor did not, however, collect water quality data between November 16th and November 28th due to a failure of the sonde.

Figure 3: Example cruise track for water quality mapping in Masonville Cove.

2011 Precipitation and Discharge Events

Precipitation increases runoff into waterways, which can lead to a higher discharge of nutrients that fuel algal blooms, decrease water clarity, and suppress SAV growth. Though beyond the scope of sampling for this report, precipitation has also been tied to increased loads of contaminants from urban and industrial centers in and around Baltimore (Leffler and Greer 2001).

A near-normal year in monthly precipitation at Baltimore Washington International (BWI) Thurgood Marshall Airport in 2011 was punctuated by a large spike in precipitation in late-August and early-September, fueled by Hurricane Irene and Tropical Storm Lee (Figure 4). Approximately 16-inches of rain fell at BWI Marshall Airport between August and September and the 11-month total for 2011 was more than 10-inches above the 141-year average.

Daily mean discharge at the USGS gaging station in the Gwynns Falls (Figure 5) reflected the pattern of precipitation seen in 2011. Gage data indicate high flows in early spring associated with a wetter than average March and April, followed by a marked decrease in flows in May, June, and July as the region experienced drought conditions. Flows associated with Hurricane Irene and Tropical Storm Lee were approximately 100 and 300 times greater, respectively, than the 46-year mean, reflecting the massive discharge into the Chesapeake Bay from these two storm events.

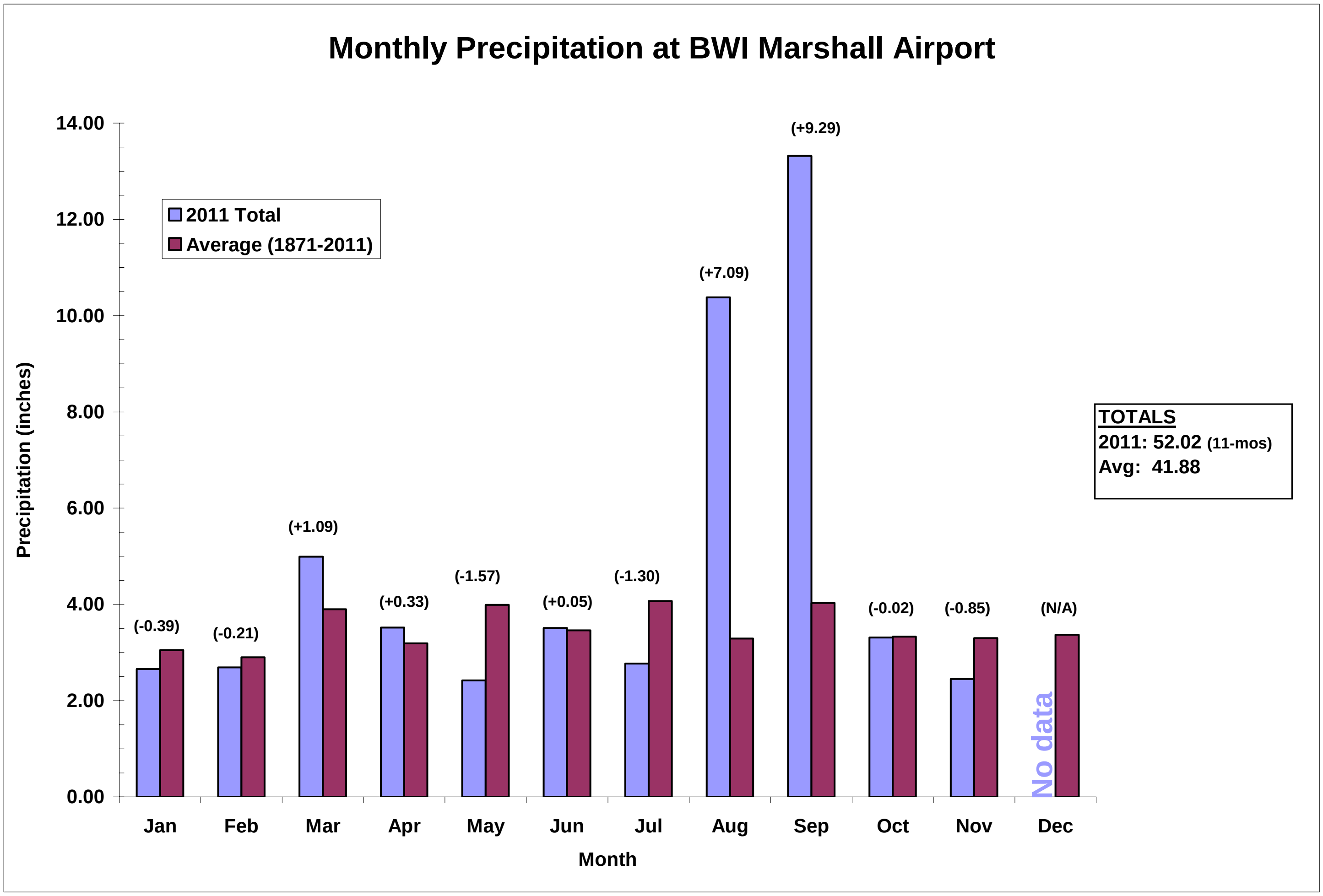


Figure 4. Total monthly precipitation at BWI Thurgood Marshall Airport compared to 141-year averages for 2011. Data for December 2011 were not available at the time of this report. Data source: National Oceanographic and Atmospheric Administration (http://www.erh.noaa.gov/lwx/climate/bwi/bwiprecip.txt).

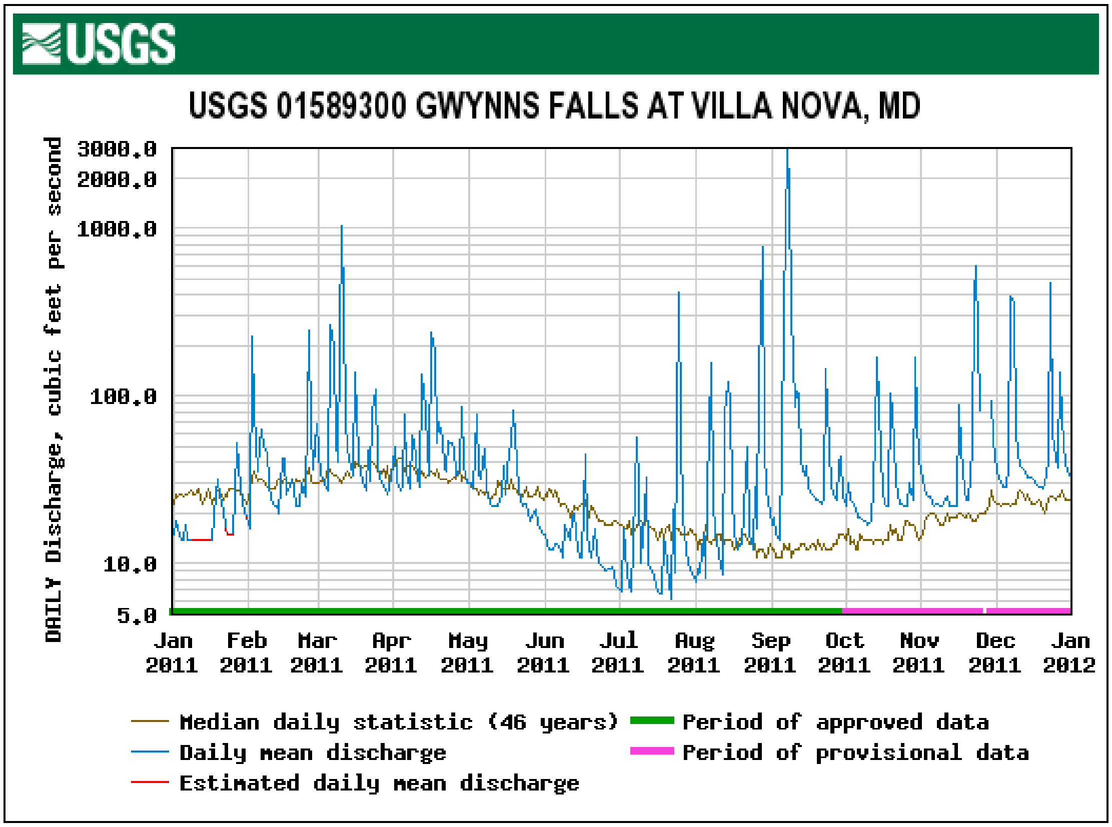
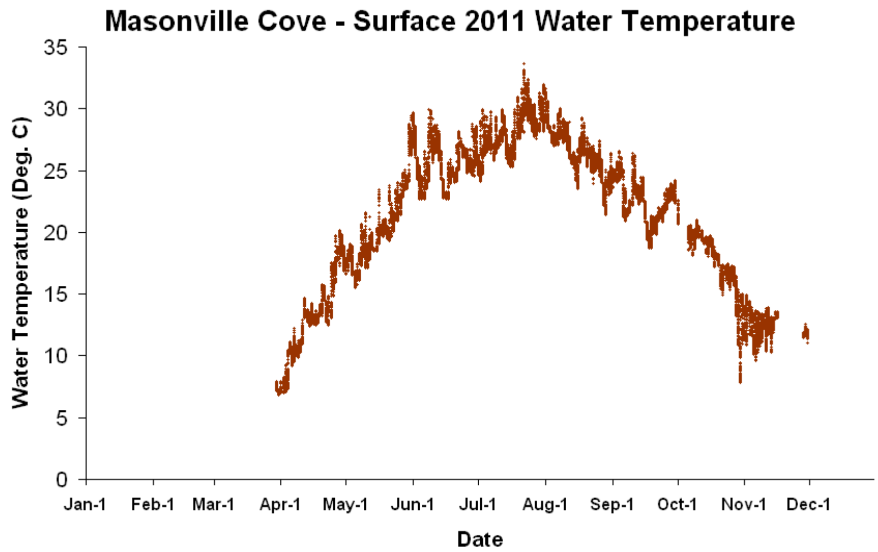


Figure 5. Daily discharge in cubic feet per second measured at a USGS gaging station west of Masonville Cove. The y-axis is in logarithmic scale. Graph courtesy of the United States Geological Survey.

Continuous Monitoring Data

Water Temperature

Water temperature at Masonville Cove rose predictably as air temperatures increased during the summer months and peaked on July 22nd (Figure 6). The surface monitor reached a peak of almost 34°C (93º F), while the bottom monitor peaked at approximately 31°C (~88º F). Following the July peak, temperature gradually declined through the rest of the year. Variability in the plot in Figure 6 was most likely a result of diel variation in temperature (warming temperatures during the day and cooling temperatures during the night). Masonville Cove water temperature was influenced by water temperature in the Patapsco River, as shown during water quality mapping cruises (see Appendix A).



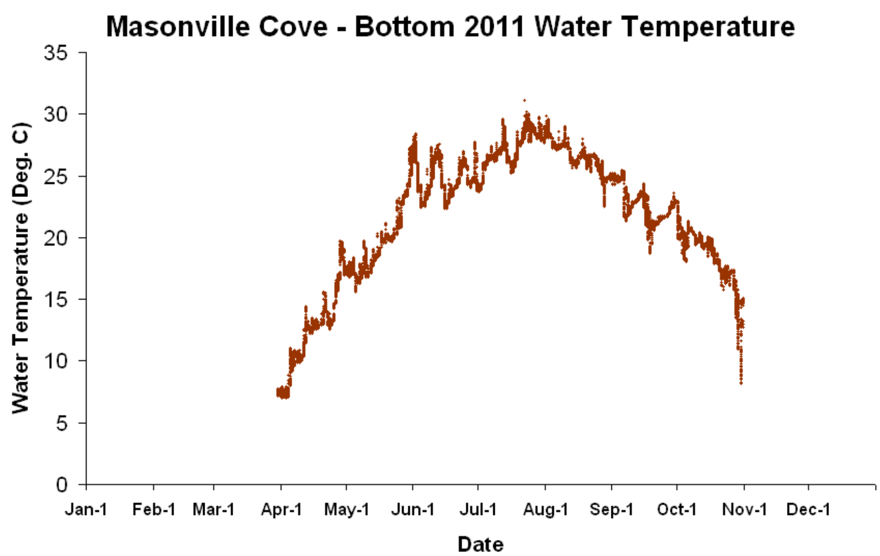


Figure 6. Water temperature at Masonville Cove Surface and Bottom Continuous Monitors during 2011.

Salinity

Salinity tends to vary with precipitation and stream flow. The overall salinity trend in 2011 began with declining salinities in late spring, coinciding with a wetter than average April (Figure 4). Increasing salinity values followed as precipitation and flow declined during the summer drought, until the late summer storm events led to a dramatic decline in salinity (Figure 7).

The highest salinity of the year occurred shortly after initial deployment in the spring. The surface monitor recorded a high of 12.05 part per thousand (ppt) on April 4th, while the bottom monitor peaked at

12.73 ppt on that same day. The lowest salinity of the year occurred immediately after Tropical Storm Lee, and the associated high run-off events, affected the region. The surface monitor recorded a low of 0.16 ppt on September 10th, while the bottom monitor recorded a low of 0.22 ppt on September 9th.

Increasing salinity throughout the summer of 2011 is also evident in the water quality maps, especially between June and July (Figures A3 and A4). Salinity levels then dropped to near 0 during the September cruise (Figure A6), which followed the late-summer storms and associated increased flows into the system.

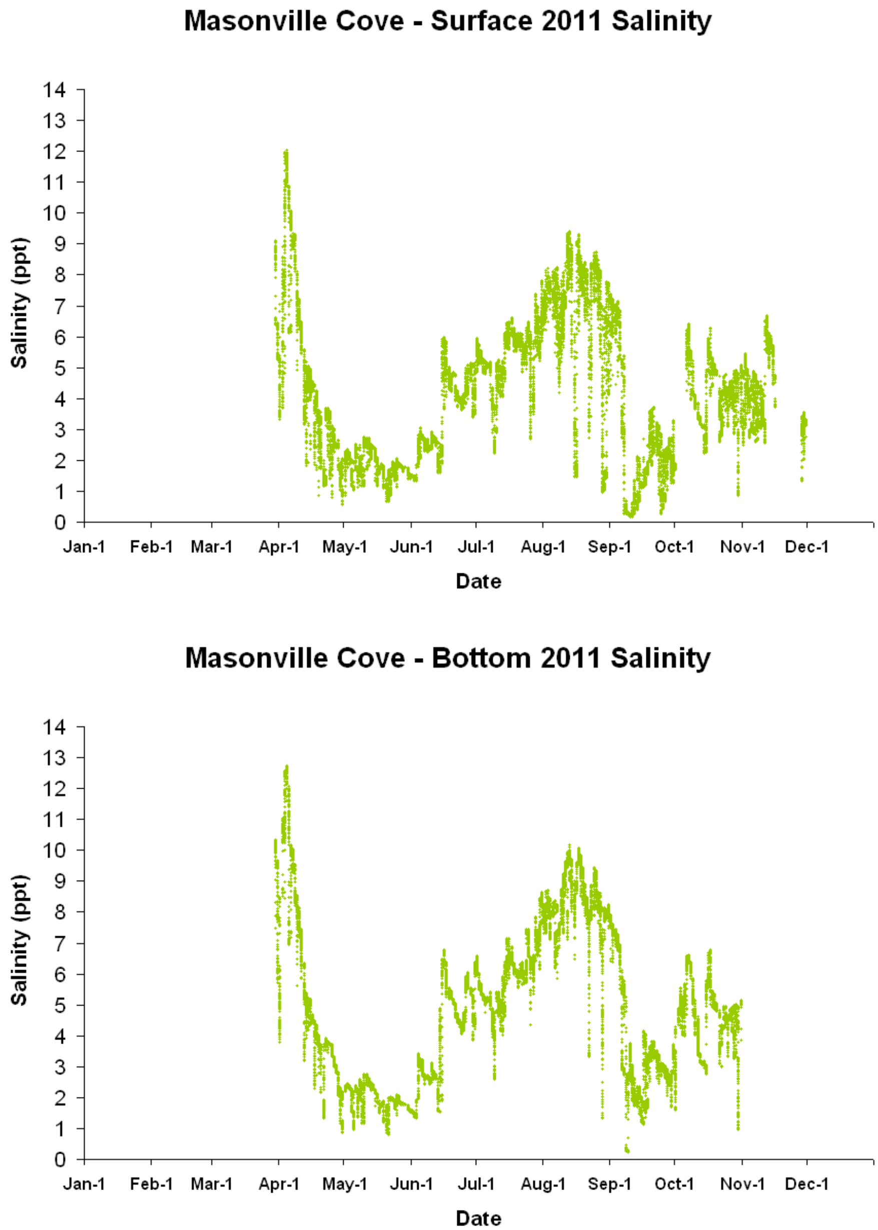
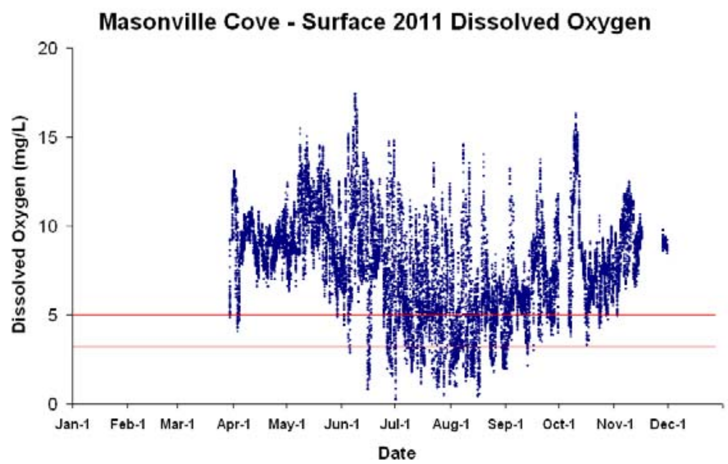


Figure 7. Salinity levels at Masonville Cove Surface and Bottom Continuous Monitors during 2011.

Dissolved Oxygen

Dissolved oxygen (DO) in 2011 showed a downward trend through the late spring, reaching a minimum in the summer, and gradually climbing up during the fall (Figure 8). The summer decrease and fall increase were expected since cooler water can hold more dissolved oxygen. A large number of DO readings throughout the year were below 5 milligrams per liter (mg/L), which can be detrimental to the survival of juvenile fish (US EPA, 2003). The surface monitor recorded a low DO of 0.23 mg/L on July 1st, while the bottom monitor recorded a low of 0.02 mg/L on June 5th. DO also fluctuated on a daily (diel) basis, possibly due to photosynthetic activity and tidal influence.

Algal blooms in waterways are identified by measuring chlorophyll concentrations. Decreases in chlorophyll levels signal the death and decomposition of algal blooms and are often accompanied by a drop in dissolved oxygen 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 the Masonville Cove surface monitor to 2.88 mg/L on June 5th, 0.87 mg/L on June 15th, 0.23 mg/L on July 1st, and 3.66 mg/L on October 16th coincided with drops in chlorophyll levels (Figure 9).



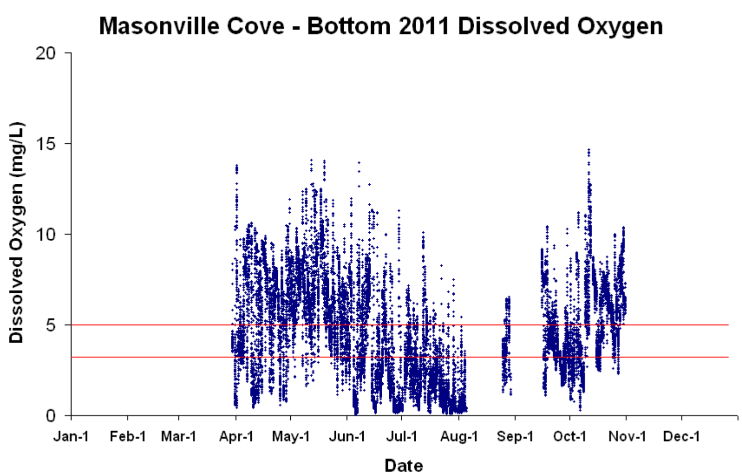


Figure 8. Dissolved oxygen levels at Masonville Cove surface and bottom Continuous Monitors during 2011. Gaps are where data were removed for quality assurance purposes. (*Red lines indicate 5 mg/L and 3.2 mg/L criteria.)*

As part of the goal of the 1987 Chesapeake Bay Agreement, the signatories agreed “to provide for the restoration and protection of living resources, their habitats and ecological relationships.” Further, the Chesapeake Executive Council (CEC) committed to “develop and adopt guidelines for the protection of water quality and habitat conditions necessary to support the living resources found in the Chesapeake Bay system, and to use these guidelines in the implementation of water quality and habitat protection programs.” A document was produced by the Chesapeake Bay Program outlining dissolved oxygen thresholds for various living resources (Jordan et al. 1992). The State of Maryland adopted these dissolved oxygen thresholds as standards in 1995 (COMAR 1995). For shallow water habitats, the criteria are a 30-day average of 5 mg/L DO and an instantaneous minimum of 3.2 mg/L. Table 1 shows the percentage of time the Masonville Cove DO data fell below these criteria values between April and September, which is generally the time of year that DO values are the lowest due to warmer waters.

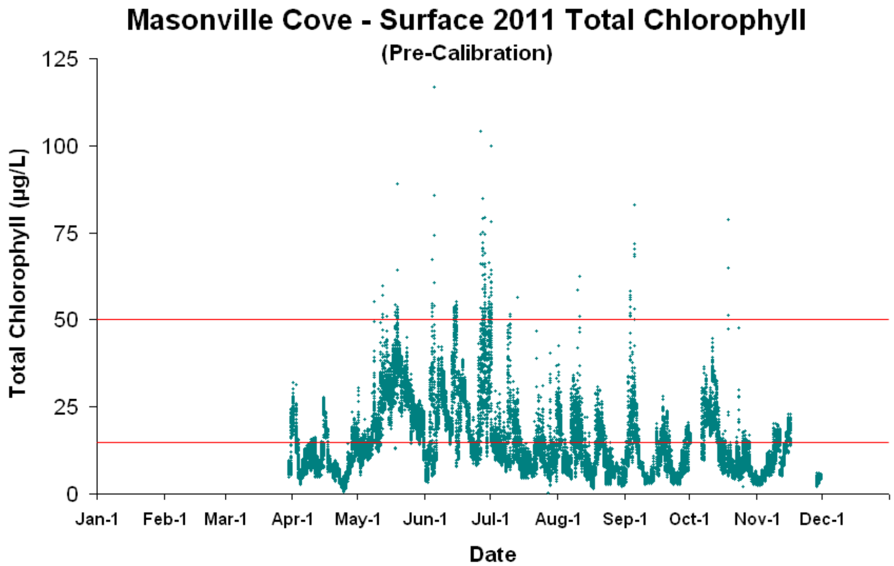
Dissolved oxygen criteria	**Surface**	**Bottom**
Dissolved oxygen less than 5 mg/L	14.32%	54.03%
Dissolved oxygen less than 3.2 mg/L	8.17%	42.67%

Table 1. Dissolved Oxygen criteria failure at Masonville Cove surface and bottom Continuous Monitors during April through September, 2011.

Chlorophyll

Chlorophyll data tended to vary, most likely with algae (phytoplankton) levels. Spikes above 15 micrograms per liter (µg/L) represent algae blooms that can negatively affect living resources. Chlorophyll concentrations above 50 µg/L represent significant algae blooms, and concentrations above 100 µg/L represent severe blooms. At Masonville Cove, few chlorophyll readings were above 50 µg/L in 2011 (Figure 9). However, a substantial proportion of readings during the spring and summer were greater than 15 µg/l, a threshold above which detrimental effects on aquatic ecosystems may occur. The highest prolonged chlorophyll concentrations during the 2011 deployment occurred in late June as levels at the surface reached 104.3 µg/L on June 26th (Figure 9). Bottom chlorophyll levels also rose above 200 µg/L for a brief time on May 18th.

A review of the DNR Harmful Algae Bloom website (http://mddnr.chesapeakebay.net/hab/HAB_maps.cfm) also revealed the presence of potentially harmful blue-green algae (*Aphanocapsa sp.*) in the upper Patapsco in mid-June through mid-August, and again in September.



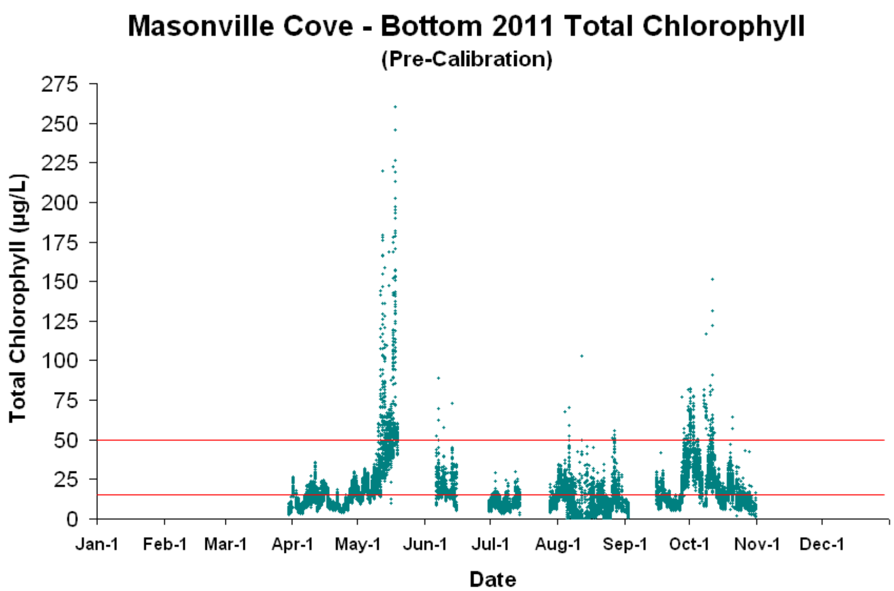


Figure 9. Total chlorophyll levels at Masonville Cove surface and bottom Continuous Monitors during 2011. Gaps are where data were removed for quality assurance purposes. *(Red lines indicate thresholds above which levels may have harmful effects on aquatic ecosystems---15mg/L-- or are considered significant blooms—50mg/L.)*

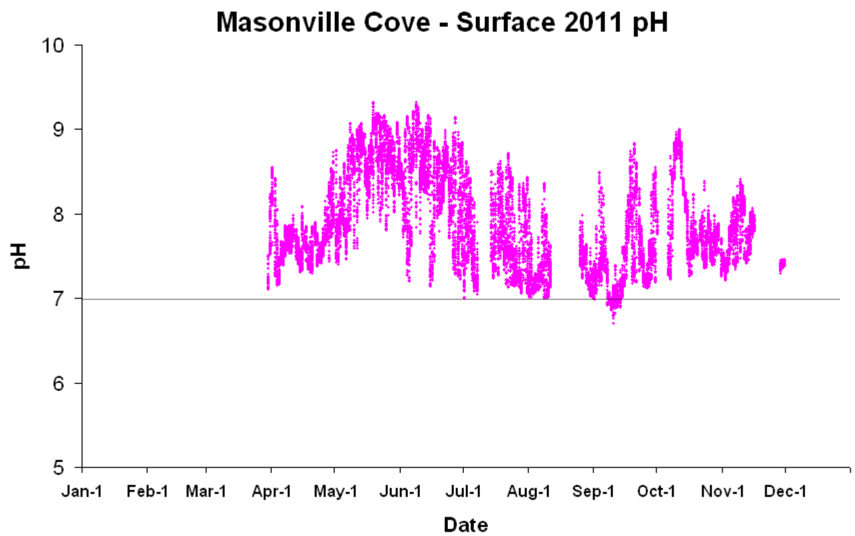
As stated previously, 15 and 50 µg/L represent blooms with potential ecosystem effects and significant blooms respectively. Table 2 indicates the percentage of data readings that violated these thresholds for Masonville Cove during the portion of the 2011 deployment that coincided with SAV growing season (March – October). Algae blooms during this period may impede the ability of SAV to grow and reproduce.

Chlorophyll provisional thresholds	Surface	Bottom
Readings greater than 15 µg/L	38.78%	40.57%
Readings greater than 50 µg/L	0.87%	4.24%

Table 2. Chlorophyll threshold failures at Masonville Cove surface and bottom monitors during March through October, 2011.

pH

pH tends to fluctuate between 7 and 9 in most Chesapeake Bay tidal waters, with spikes above 9 indicating potential algal blooms. High pH in the absence of high chlorophyll can also give some indication that a blue-green algae bloom may have occurred (the chlorophyll probes on the continuous monitors deployed at Masonville Cove were not designed to detect the wavelengths given off by blue-green algae). At Masonville Cove in 2011, pH reached its maximum on May 19th at both the surface (9.32 pH) and bottom (9.27 pH) monitors (Figure 10), corresponding to the date of high dissolved oxygen (Figure 8) and chlorophyll (Figure 9) concentrations. This provides greater evidence that high concentrations of algae were present. Other spikes throughout the season may indicate additional algal blooms, including blue-green algae blooms.



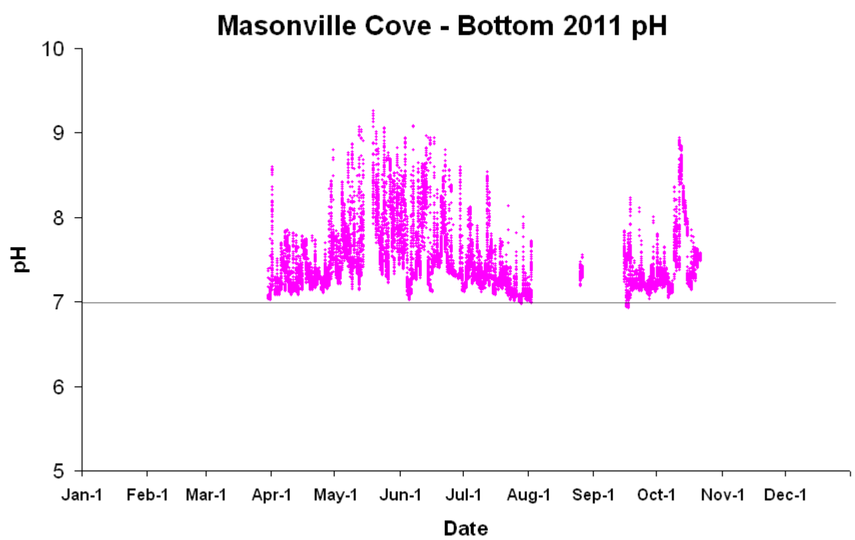
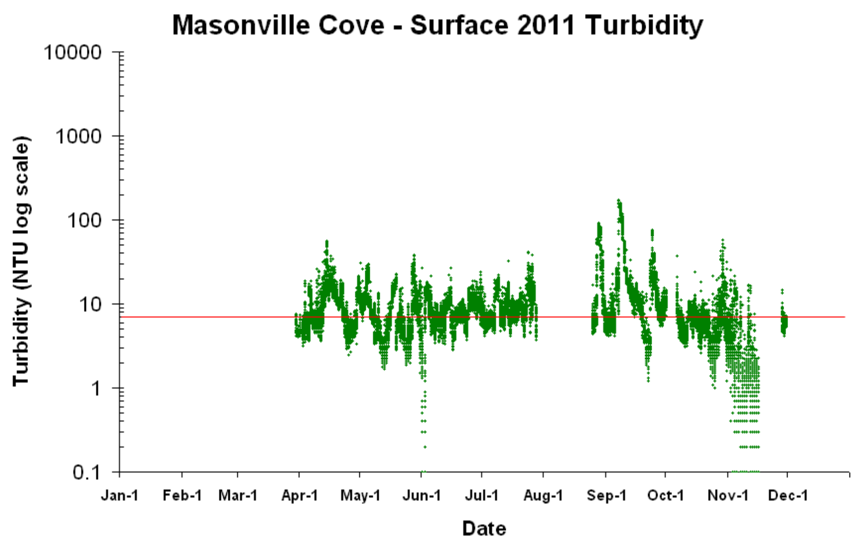


Figure 10. pH levels at Masonville Cove Surface and Bottom Continuous Monitors during 2011. Gaps are where data were removed for quality assurance purposes. *(Line indicates neutral pH.)*

Turbidity

Turbidity is quantified by measuring how much light is reflected from suspended particles in the water and is used to determine water clarity. Lower turbidity values indicate less reflection and, therefore, clearer water, while values above 7 Nephelometric Turbidity Units (NTU) are anecdotally thought to be detrimental to SAV growth (M. Trice, MD DNR, personal communication). Masonville Cove turbidity levels at the surface measured around 7 NTU for much of the year (median value 7.2 NTU), while turbidity levels near the bottom were significantly higher (median value 28.1 NTU). There were several large spikes during the year, with turbidity levels approaching or surpassing 100 NTU at the surface, and one spike surpassing 1000 NTU at the bottom (Figure 11). The highest spike at the surface (174.5 NTU) occurred on September 7th, and coincided with Tropical Storm Lee and the associated discharge event (Figure 5) impacting the region. The largest spike at the bottom (1397.3 NTU) occurred on June 29th, which coincided with the highest prolonged chlorophyll concentrations in Masonville Cove during 2011 (Figure 9).

Additional turbidity spikes on April 14th (surface: 56.7 NTU; bottom 156.4 NTU), August 28th (surface: 91.3 NTU), September 24th (surface: 76.6 NTU; bottom 50.1 NTU), October 29th (surface: 57.3 NTU; bottom 86.4 NTU), and December 8th (surface: 63.4 NTU) coincided with significant discharge events at the Gwynns Falls gaging station west of Masonville Cove (Figure 5). Minor spikes at the surface on May 19th (20.6 NTU), June 15th (26.9 NTU), and June 30th (23.8 NTU), and a large spike at the bottom on September 28th (185.3 NTU) all coincided with significant algal bloom conditions in Masonville Cove (Figure 9).



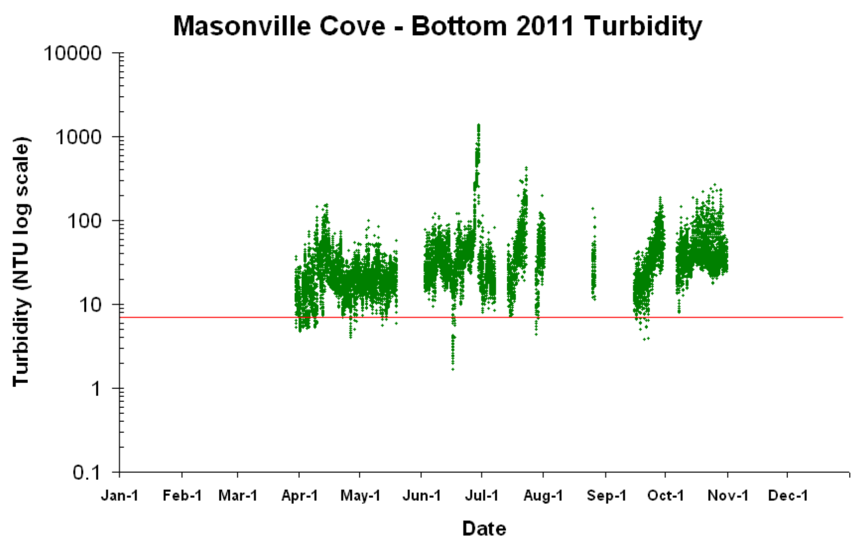


Figure 11. Turbidity levels at Masonville Cove surface and bottom Continuous Monitors during 2011. Gaps are where data were removed for quality assurance purposes. *(Red line indicates threshold above which levels are considered detrimental to bay grass growth.)*

As stated previously, turbidity concentrations above 7 NTU are considered a threshold for detrimental effects on SAV. The surface monitor at Masonville Cove was above this threshold over half the time during 2011 SAV growing season (March through October), and the bottom monitor exceeded this threshold virtually the entire season (Table 3).

Turbidity provisional thresholds	**Surface**	**Bottom**
Readings greater than 7 NTU	51.58%	98.25%

Table 3. Turbidity threshold failures at Masonville Cove surface and bottom monitors during March through October, 2011.

Insights from concurrent shallow water quality mapping cruises

Spatially interpolated maps from the 2011 Patapsco River shallow water quality mapping cruises are included in Appendix A. Seasonal change in water quality conditions, as well as surface water quality events, are evident. Salinity increased throughout the summer of 2011, which is especially evident between June and July (Figures A3 and A4). Salinity levels then dropped to near 0 ppt during the September cruise (Figure A6), which followed the late-summer storms and increased runoff into the system (Figure 5). Water temperature was high throughout 2011 with both Masonville Cove and the adjoining Patapsco River measuring 25° C (77° F) or greater from June through August (Figures A3-A5), and temperatures peaked above 27.5° C (81.5° F) during the July cruise (Figure A4). Turbidity levels were elevated (greater than 22.5 NTU) during the mid-April cruise (Figure A1), which follows the pattern of discharge events at the Gwynns Falls gaging station (Figure 5) and the associated spike seen in the continuous monitoring data (Figure 11) during that same time period. Turbidity levels in Masonville Cove were then generally in the 7.5 to 15 NTU range during the remainder of the 2011 cruises (Figures A2-A7), which are levels indicative of moderate amounts of suspended matter clouding the water. Dissolved oxygen levels were generally in the healthy range (5-10 mg/L) during most of the 2011 cruises. The one exception was in May (Figure A2) when high DO levels (10-12.5 mg/L) coincided with elevated chlorophyll measurements (30-40 µg/L) within Masonville Cove. Algal blooms often lead to saturated DO levels during the day as algal cells are producing oxygen during the process of photosynthesis. At night, however, when photosynthesis is not occurring, cellular respiration can consume large amounts of oxygen and large blooms can, therefore, lead to very low nocturnal DO concentrations. Chlorophyll concentrations the remainder of the 2011 cruises were generally in the 20-30 µg/L range within Masonville Cove.

Sewage treatment overflows affecting the Upper Patapsco River

On March 10th, 2011, the Baltimore City Department of Public Works reported six major sewage overflows (Figure 12) totaling nearly 4.7 million gallons. This total surpasses the combined overflow amount reported by Baltimore City over the previous two years (3.8 million gallons). The largest of these overflows occurred at 401 E. Eager Street and dumped over 4.4 millions gallons of untreated, diluted wastewater into the Jones Falls. Heavy rains which overwhelmed the sanitary lines were the most likely causes of these events. More than 2.6 inches of rain were reported at BWI Marshall Airport on March 10th, with some locations around Baltimore City receiving over 3 inches.

Figure 12. Map of the Patapsco River showing the locations of the six reported sanitary sewer overflows on March 10th, and Maryland DNR's Continuous Monitor at Fort McHenry.

The Jones Falls empties into the upper Patapsco River above Masonville Cove. Unfortunately, the continuous monitors at Masonville Cove were not yet deployed for the 2011 season at the time of the overflows. A year-round continuous monitor near Ft. McHenry, however, was able to capture the effects of the March 10th storm event, and associated sewer overflows, on the Upper Patapsco River. Observations from Fort McHenry show an influx of freshwater as salinity levels dropped from approximately 5 ppt to 1.8 ppt between March 10th and 11th (Figure 13a). Turbidity readings also spiked during this time (Figure 13b), indicating the influx of water brought high concentrations of particles and sediment that clouded the water.

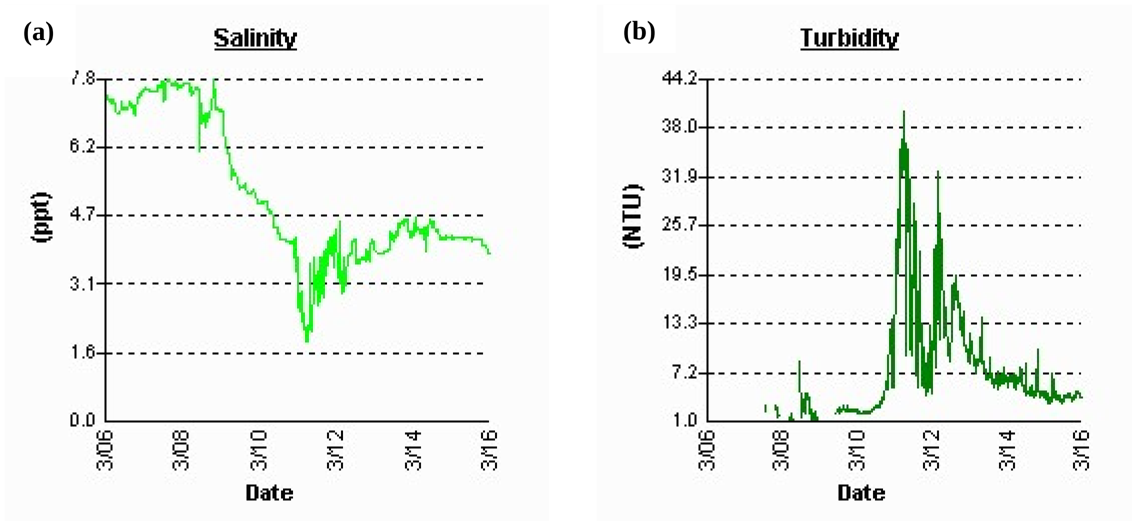


Figure 13. Salinity (a) and turbidity levels (b) recorded between March 6th and March 16th, 2011 at the Maryland DNR Continuous Monitoring site at Fort McHenry on the Patapsco River.

Anti-virus software updated on internet kiosk at Masonville Cove Environmental Education Center

DNR personnel updated anti-virus software installed on the interactive kiosk in the Masonville Cove Environmental Education Center (MCEEC) on March 31st, 2011. The kiosk allows MCEEC staff to display real time water quality data from Masonville Cove, and throughout the Chesapeake Bay, through DNR's "Eyes on the Bay" website. The kiosk features a touch-screen as well as a track ball for easy web navigation. The kiosk is protected by software that prevents users from navigating away from the "Eyes on the Bay" or MCEEC websites. MCEEC staff use the kiosk in their education programs, and it is available to MCEEC visitors. Anti-virus software installed on the kiosk will continue to be updated annually.

Submerged Aquatic Vegetation (SAV) in the Patapsco 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 within the Chesapeake Bay and associated tributaries has been assessed annually (with the exception of 1988) by the Virginia Institute of Marine Science (VIMS). Figure 14 shows total area and density of SAV within the Patapsco beginning in 1994 (the first year SAV was found in the river) through 2011.

Total area of SAV within the Patapsco River remains well below the restoration goal of 389 acres. 2005 was the single best year with 72% of the restoration goal achieved, including SAV beds within Masonville Cove. These beds disappeared in 2006 and total area of SAV within the Patapsco decreased 83% that year. In 2010, there was no SAV in the entire Patapsco River. As of 2011, there continued to be no SAV within Masonville Cove, but total area of SAV in the Patapsco increased to 3.6 acres. These acres occurred in two separate beds, both in Old Road Bay near Sparrows Point.

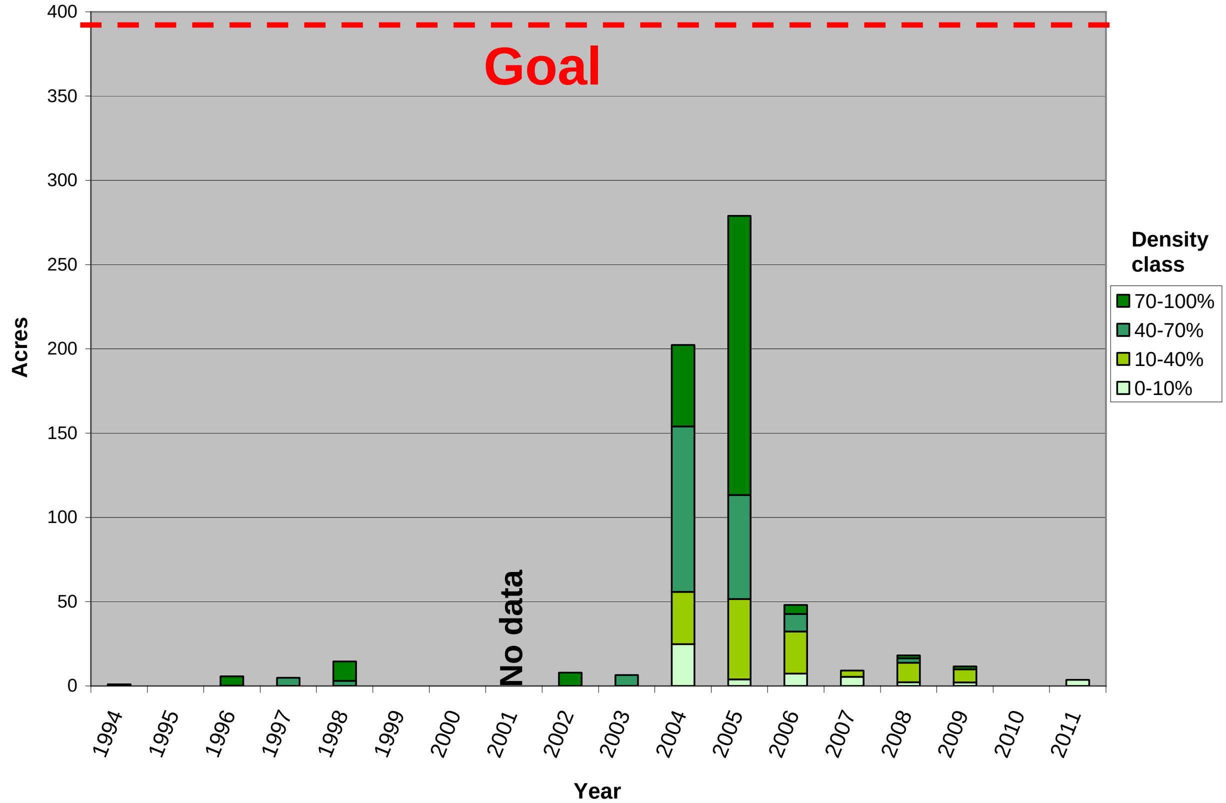


Figure 14. Total area and density of SAV in the Patapsco River. (*Restoration goal is 389 acres)*

Pigments, Nutrients, Suspended Solids, and Secchi Data

Bi-weekly grab samples of water were collected at the Masonville Cove station when the YSI meters were exchanged during Continuous Monitoring cruises. A few samples were collected monthly instead of bi-weekly (Table 4) due to adverse weather conditions that prevented field crews from launching a boat on the scheduled cruise dates. Grab samples were also collected during the monthly Water Quality Mapping cruises. Secchi depth, a measure of water clarity, was also recorded at the time of the grab sample.

The grab samples of water were processed in the field using vacuum filtration, and the resulting particulate and filtrate samples were delivered to the laboratory for analysis. Samples collected during Continuous Monitoring cruises were analyzed for nutrients, pigments, and suspended solids. Samples collected during Water Quality Mapping cruises were analyzed for pigments and suspended solids only. 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 B (Figures B-1 through B-15). Secchi depth measurements are presented in Figure B-16. Masonville Cove was sampled twice on June 2, 2011 when a cruise from each monitoring program visited the site. As a result, two data values are available on this date for chlorophyll *a*, phaeophytin, total suspended solids, and Secchi depth. On the graphs, the data values for this date are represented as endpoints on a vertical bar with the connecting line intersecting the bar at the mean of the two values. Appendix B also includes data tables for the nutrient parameters (Table B-1) and for suspended sediments, pigments, and Secchi depth (Table B-2).

Scheduled calibration date	**Samples collected**	**Comment**
March 30, 2011	Yes	Initial deployment of surface and bottom sondes. Chlorophyll and TSS only.
April 7, 2011	No	Site not visited due to inclement weather.
April 21, 2011	Yes	Chlorophyll and TSS only.
May 5, 2011	Yes	Chlorophyll and TSS only.
May 19, 2011	Yes	Full suite of nutrients collected from this date on.
June 2, 2011	Yes	
June 16, 2011	Yes	
June 30, 2011	Yes	
July 14, 2011	Yes	
July 28, 2011	Yes	
August 11, 2011	No	Site not visited due to inclement weather.
August 25, 2011	Yes	
September 8, 2011	Yes	
September 22, 2011	Yes	
October 6, 2011	Yes	
October 20, 2011	No	Site not visited due to inclement weather.
October 31, 2011	Yes	Bottom sonde removed for 2011 season.
November 16, 2011	Yes	
November 28, 2011	Yes	
December 15, 2011	Yes	Surface sonde removed due to threat of icing.

Table 4: Deployment and calibration record for Masonville Cove continuous monitor 2011.

Ambient water quality data (dissolved oxygen, pH, salinity, and water temperature) were collected concurrently with the grab samples. The data values are presented graphically in Figures B-17 to B-20 in Appendix B. These water quality parameters are measured as a profile, with readings recorded at 0.5 m depth intervals at the station. In the graphs, the data range for each profile is represented by a vertical bar for each sample date. The connecting line intersects each bar at the mean value for the station on that date. All data values for dissolved oxygen, pH, salinity, and water temperature are provided in Table B-3 of Appendix B.

Some of the most significant weather events of 2011 were the two large storms that passed through the region in early fall. Hurricane Irene (August 27-28) was quickly followed by Tropical Storm Lee (Sept.5-8), and brought significant rainfall and flooding to the area. The Continuous Monitoring program sampled the Masonville Cove station on August 25, 2011 and again on September 8, 2011. The timing of these sample dates provides a unique “before” and “after” look at the effects these two storms had on water quality. The turbid waters resulting from the storms caused a sharp increase in suspended solids (Figure B-15) and a corresponding decrease in Secchi disk depth readings (Figure B-16) in early September. The large input of freshwater caused a drop in salinity values (Figure B-18) as well. For algal concentrations, the storms’ initial impact was a decrease in both chlorophyll *a* and phaeophytin (Figures B-13 and B-14), suggesting that the increased flows flushed algal biomass from the system. Total nitrogen, which had been decreasing through June, July, and August, increased sharply in September (Figure B-7). Concentrations of phosphate and total dissolved phosphorus increased in August and remained high in early September before declining sharply at the end of the month (Figures B-9 and B-10).

Conclusion

Shallow water monitoring was conducted in Masonville Cove and the Patapsco River during 2011. Both continuous monitoring and water quality mapping data provide a critical function for assessing the health of Maryland's tidal waters in areas historically lacking water quality information. Shallow water data provide information about the effects of nutrient pollution and weather events on the Patapsco River and in Masonville Cove. In 2011, heavy rain events led to sanitary sewer overflows and massive discharge events that affected salinity and turbidity. Several algal blooms occurred throughout the summer, some including potentially toxic species, which adversely affected dissolved oxygen concentrations. Finally, submerged aquatic vegetation acreage is well below the goal for the Patapsco River. All of these factors likely contributed to overall poor conditions for living resources.

Shallow water monitoring information is not only 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; and 6) assessing mitigation efforts in relation to the dredged material containment facility at the Masonville Marine Terminal.

References

COMAR (Code of Maryland Regulations). 1995. Code of Maryland Regulations: 26.08.02.03 – Water Quality Criteria Specific to Designated Uses. Maryland Department of the Environment. Baltimore, Maryland.

Jordan, S., C. Stegner, M. Olson, R. Batiuk, and K. Mountford. 1992. Chesapeake Bay dissolved oxygen goal for restoration of living resources habitats. Chesapeake Bay Program, Reevaluation Report #7c. CBP/TRS88/93. Annapolis, Maryland.

Leffler, M. and J. Greer. 2001. Taking on toxics in Baltimore Harbor. Maryland Marine Notes 19(2). http://www.mdsg.umd.edu/MarineNotes/Mar-Apr01/

<u>Appendix A</u>

Shallow Water Quality Mapping results for Masonville Cove 2011

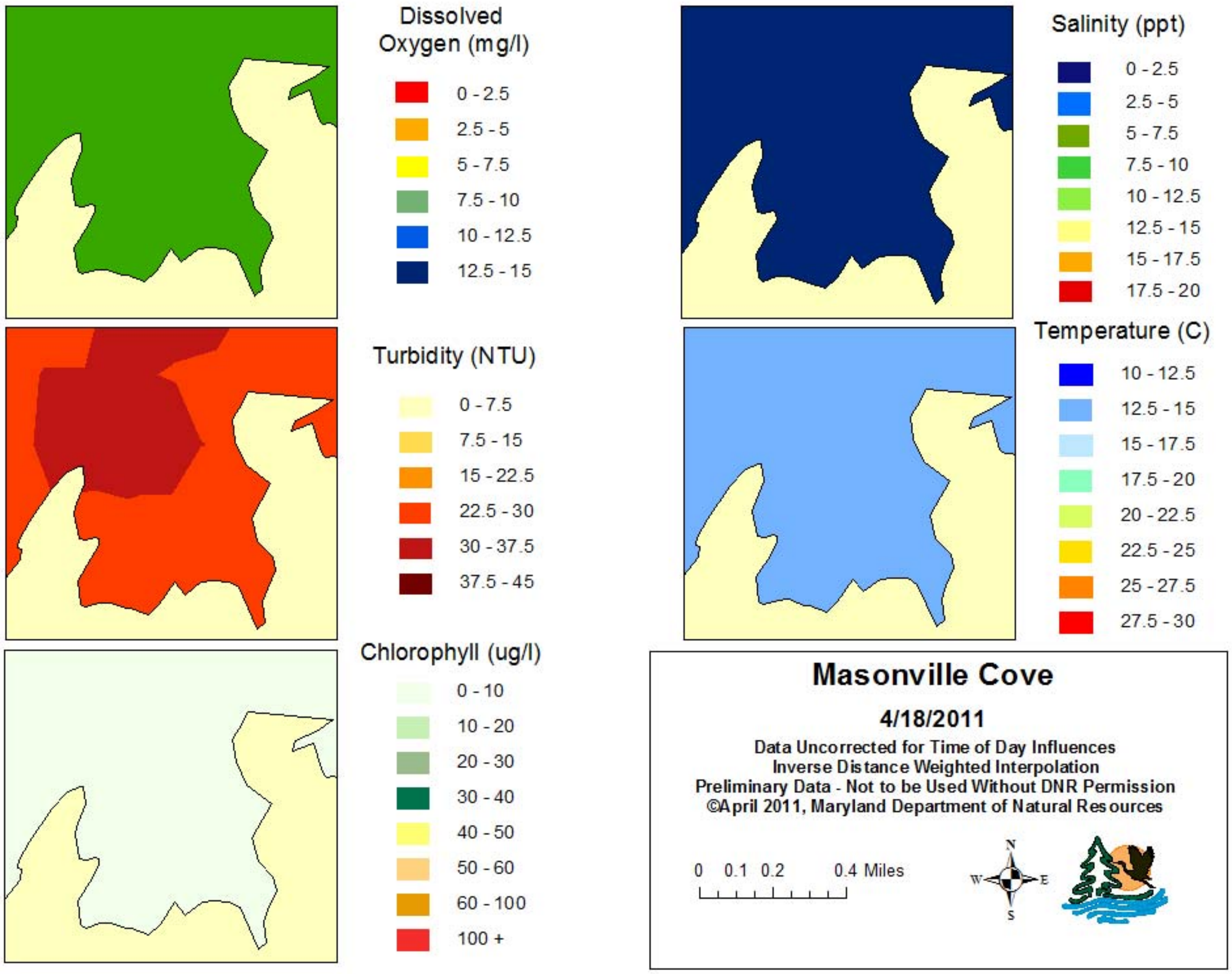


Figure A1: Interpolated April 2011 shallow water quality maps.

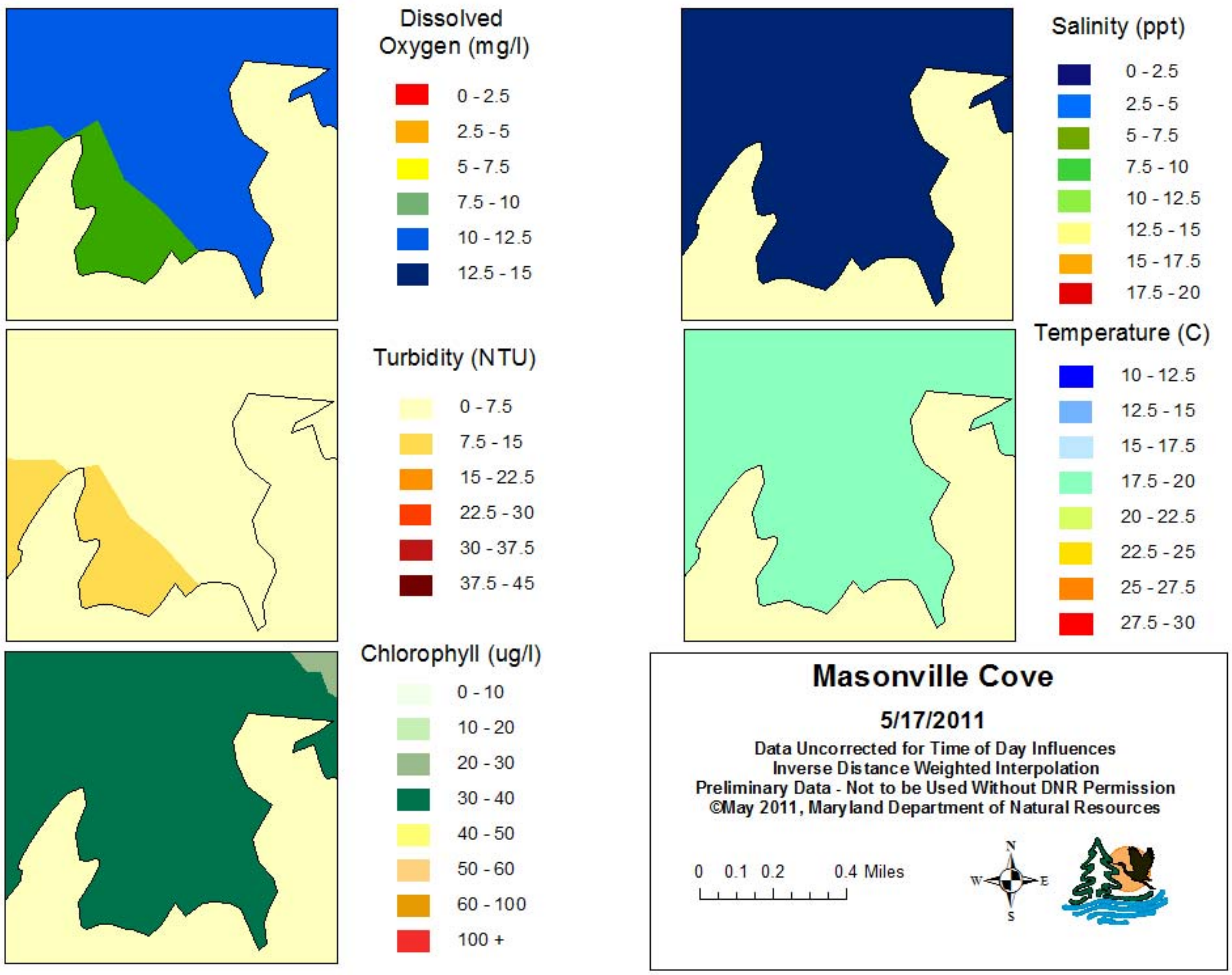


Figure A2: Interpolated May 2011 shallow water quality maps.

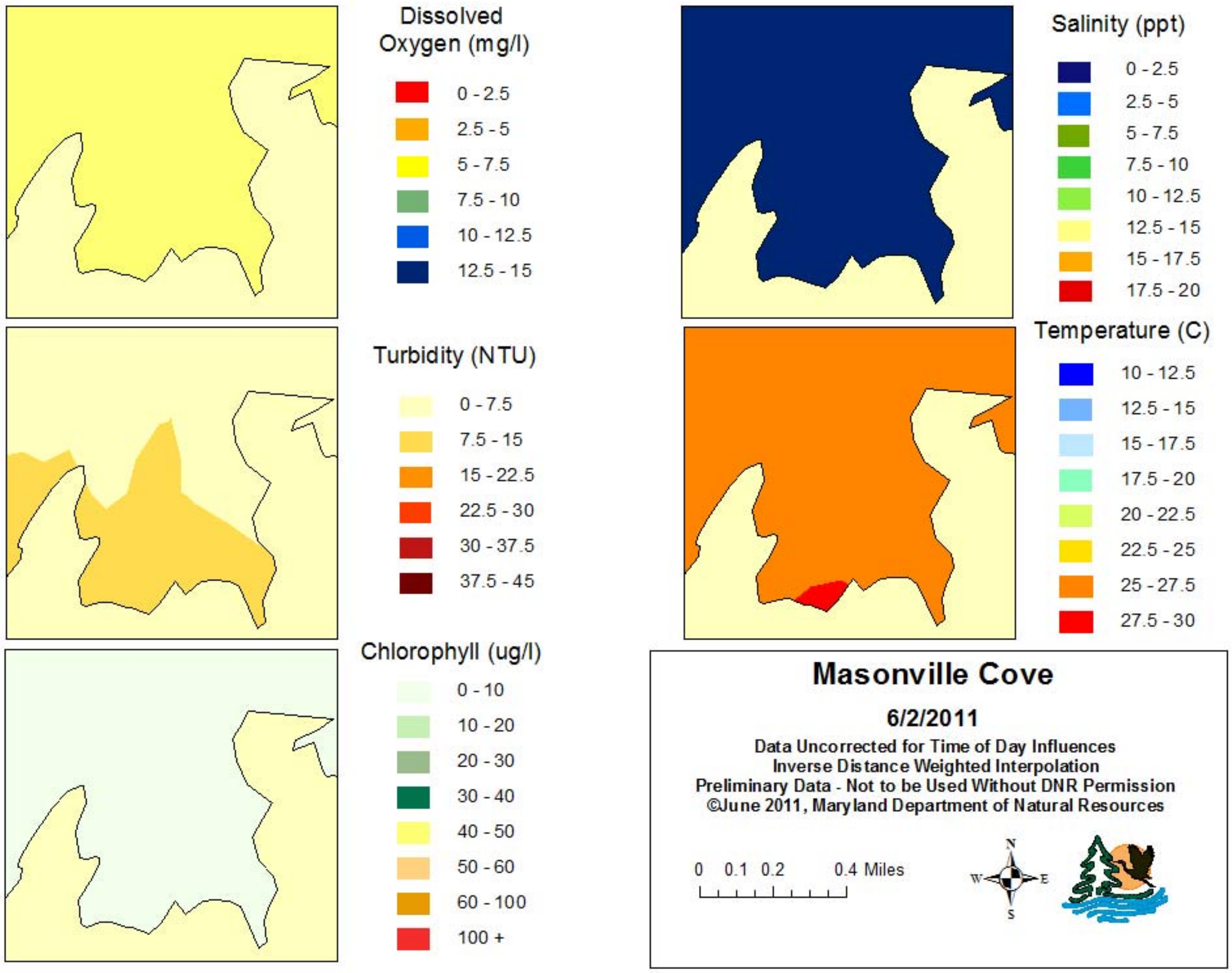


Figure A3: Interpolated June 2011 shallow water quality maps.

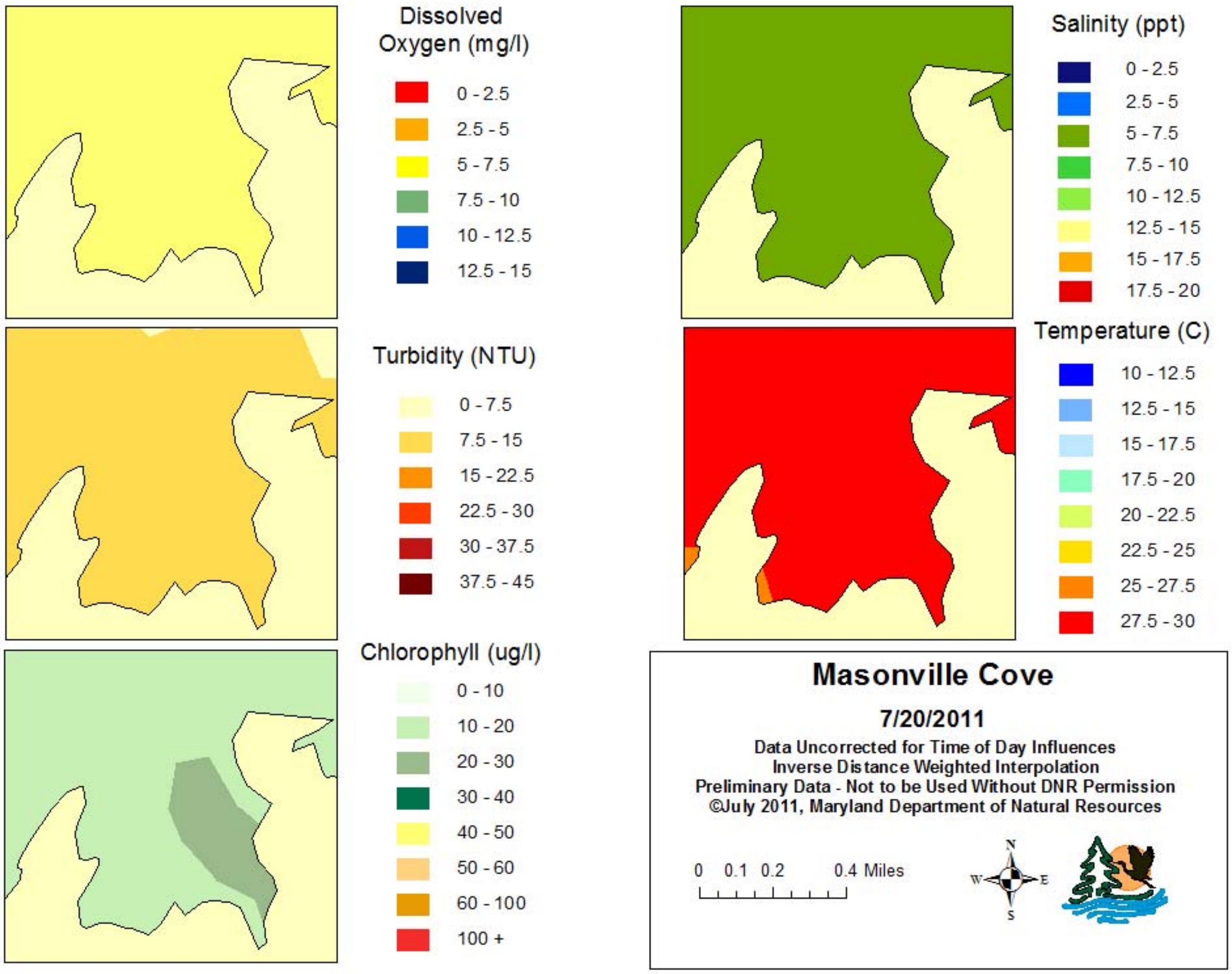


Figure A4: Interpolated July 2011 shallow water quality maps.

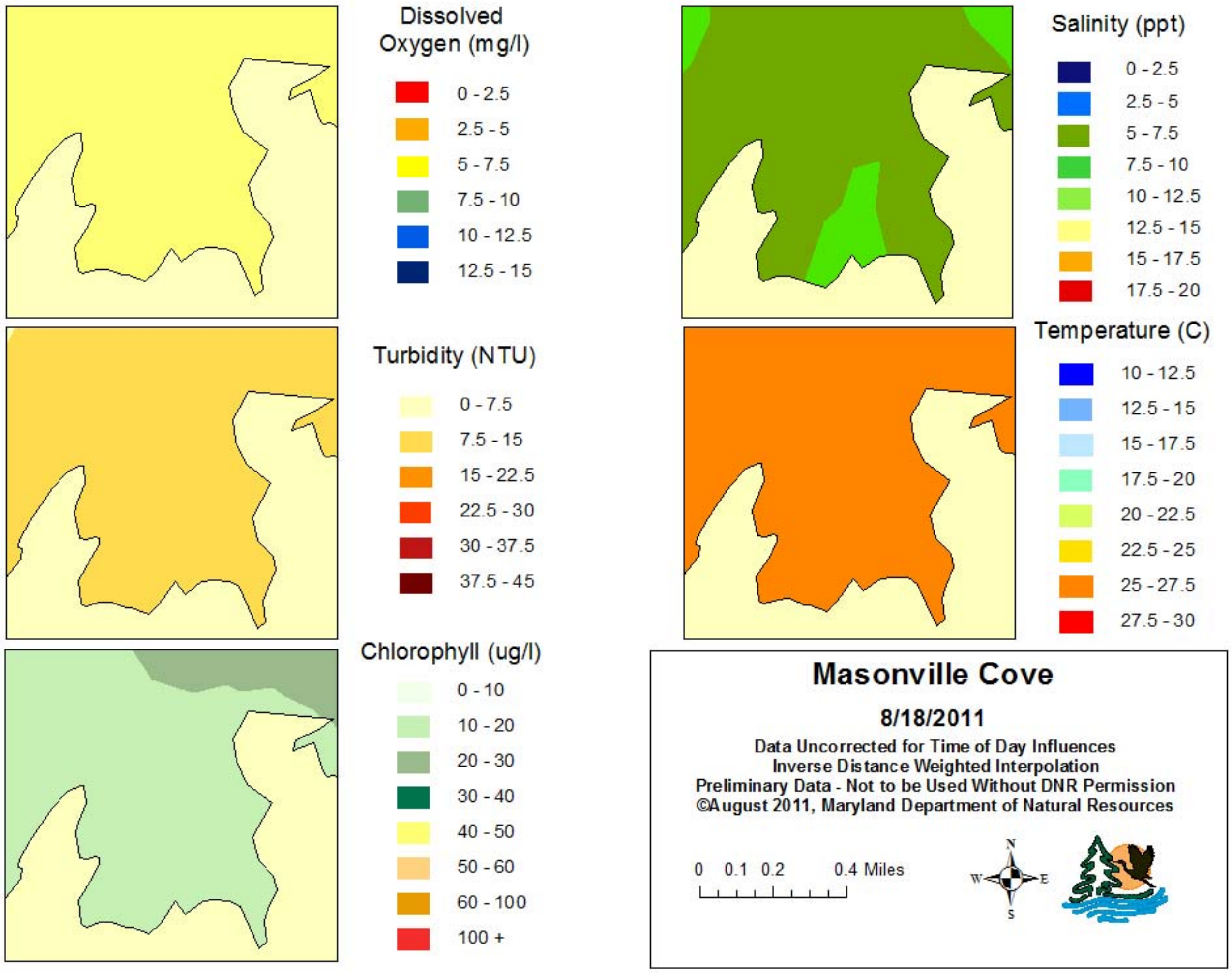


Figure A5: Interpolated August 2011 shallow water quality maps.

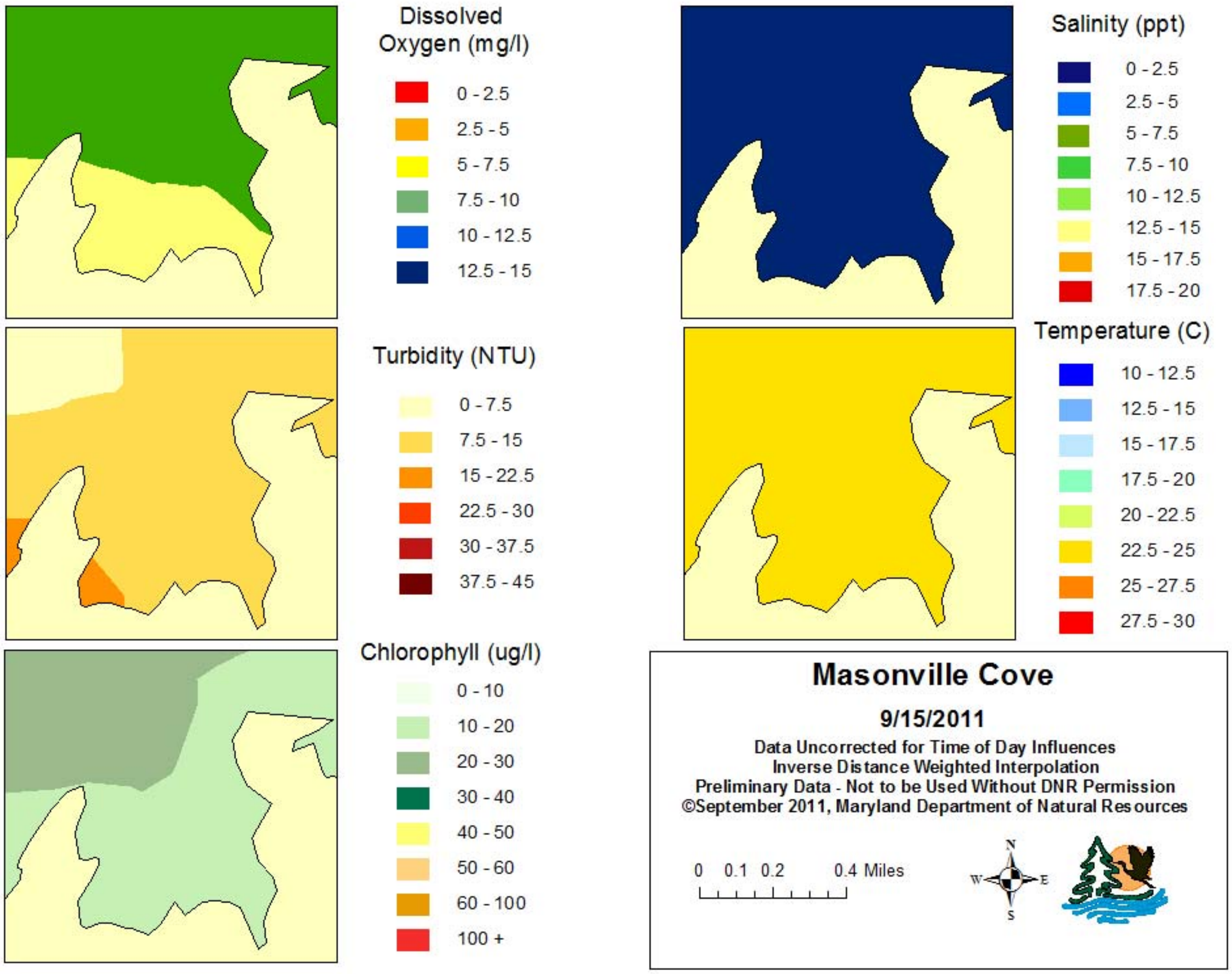


Figure A6: Interpolated September 2011 shallow water quality maps.

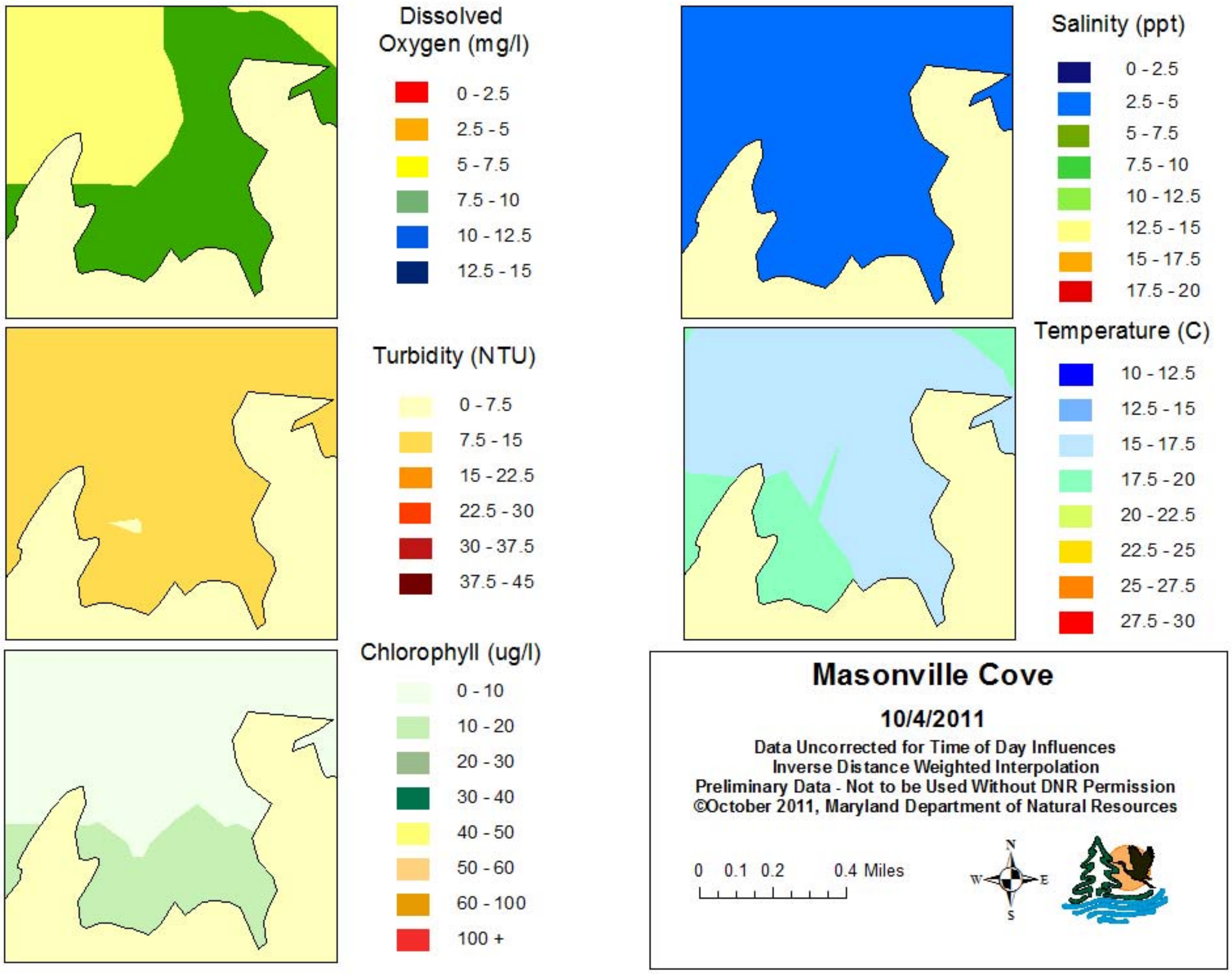


Figure A7: Interpolated October 2011 shallow water quality maps.

Appendix B

Results of laboratory and ambient water quality analyses for:
Masonville Cove (Station XIE4741)

Table B-1. Discrete Continuous Monitoring Data for Masonville Cove (XIE4741) in 2011; 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), dissolved organic carbon (DOC), and particulate carbon (PC).

Date	Project	Depth (m)	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)
05/19/11	CMON	1.0	0.001	0.0168	0.5272	0.544	1.07	0.5640	1.6340	0.0036	0.0107			3.370
06/02/11	CMON	1.0	0.094	0.0189	0.3191	0.338	0.96	0.4030	1.3630	0.0179	0.0349			2.360
06/16/11	CMON	1.0	0.194	0.0146	0.1114	0.126	0.67			0.0054	0.0075	0.0602	0.0677	
06/30/11	CMON	1.0	0.002	0.0075	0.0595	0.067	0.52	0.9600	1.4800	0.0063	0.0150			5.120
07/14/11	CMON	1.0	0.076	0.0184	0.0136	0.032		0.4600		0.0026				2.600
07/28/11	CMON	1.0	0.047	0.1240	0.0740	0.198	0.63	0.4270	1.0570	0.0270	0.0390			2.150
08/25/11	CMON	1.0	0.081	0.0582	0.0568	0.115	0.58	0.3010	0.8810	0.0229	0.0339			1.400
09/08/11	CMON	1.0	0.104	0.0119	0.4111	0.423	1.11	0.4340	1.5440	0.0209	0.0432			3.700
09/22/11	CMON	1.0	0.008	0.1060	0.5070	0.613	0.99	0.3290	1.3190	0.0030	0.0079			1.860
10/06/11	CMON	1.0	0.015	0.0212	0.5738	0.595	1.03	0.3960	1.4260	0.0031	0.0087			2.260
10/31/11	CMON	1.0	0.129	0.0162	0.6268	0.643		0.1670		0.0133				1.400
11/16/11	CMON	1.0	0.026	0.0069	1.0631	1.070	1.30	0.2440	1.5440	0.0028	0.0064			1.310
11/28/11	CMON	1.0	0.154	0.0097	1.0603	1.070	1.62	0.0981	1.7181	0.0098	0.0147			0.662
12/15/11	CMON	1.0	0.130	0.0070	0.8550	0.862	1.45	0.0892	1.5392	0.0075	0.0158			0.557

Table B-2. Discrete Continuous Monitoring Data for Chlorophyll-a, Phaeophytin, Total Suspended Solids, and Secchi Disk Depth for Masonville Cove (XIE4741) in 2011.

Date	Project	Sample Depth (m)	Chlorophyll-a (ug/L)	Phaeophytin (ug/L)	Total Suspended Solids (mg/L)	Secchi Depth (m)
03/30/11	CMON	1.0	8.544	2.296	10.0	0.6
04/18/11	DFLO	0.5	9.345	2.803	16.5	0.3
04/21/11	CMON	1.0	8.544	3.916	14.0	0.5
05/05/11	CMON	1.0	29.192	2.955	19.3	0.4
05/17/11	DFLO	0.5	48.861	4.779	16.5	0.6
05/19/11	CMON	1.0	62.211	4.512	12.5	0.5
06/02/11	DFLO	0.5	20.292	7.182	8.0	0.6
06/02/11	CMON	1.0	21.716	4.201	9.3	0.5
06/16/11	CMON	1.0	48.416	7.156	12.7	0.5
06/30/11	CMON	1.0	66.216	10.538	19.3	0.4
07/14/11	CMON	1.0	30.972	11.392	24.0	0.4
07/20/11	DFLO	0.5	19.491	9.105	17.0	0.4
07/28/11	CMON	1.0	26.433	8.330	10.5	0.5
08/18/11	DFLO	0.5	25.899	6.061	8.5	0.5
08/25/11	CMON	1.0	15.219	7.583	7.5	0.8
09/08/11	CMON	1.0	6.408	0.000	120.0	0.1
09/15/11	DFLO	0.5	15.486	2.270	10.5	0.5
09/22/11	CMON	1.0	24.564	10.947	6.5	0.7
10/04/11	DFLO	0.5	22.695	5.901	7.5	0.7
10/06/11	CMON	1.0	39.516	4.966	20.0	0.3
10/31/11	CMON	1.0	6.141	3.204	27.5	0.7
11/16/11	CMON	1.0	23.229	1.816		0.8
11/28/11	CMON	1.0	4.806	0.801		0.9
12/15/11	CMON	1.0	4.139	0.627		1.3

Table B-3. Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Masonville Cove (XIE4741) in 2011 (continued on next page).

Date	Project	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (°C)
03/30/11	CMON	0.5	11.1	7.86	2.69	5.9
03/30/11	CMON	1.0	5.0	7.11	8.37	7.7
03/30/11	CMON	1.5	4.6	7.14	9.57	7.1
03/30/11	CMON	2.0	4.4	7.14	9.66	7.0
04/18/11	DFLO	0.5	9.5	7.60	1.37	13.2
04/18/11	DFLO	1.0	8.4	7.40	3.25	12.8
04/18/11	DFLO	1.5	8.2	7.40	3.57	12.6
04/18/11	DFLO	2.0	8.3	7.40	3.63	12.9
04/18/11	DFLO	2.5	8.3	7.40	3.76	12.9
04/21/11	CMON	0.5	9.0	7.73	1.04	14.5
04/21/11	CMON	1.0	9.3	7.69	1.08	14.5
04/21/11	CMON	1.5	8.9	7.72	1.05	14.5
04/21/11	CMON	2.0	8.7	7.68	1.21	14.6
04/21/11	CMON	2.3	8.6	7.66	1.27	14.6
05/05/11	CMON	0.5	9.5	8.01	0.70	16.1
05/05/11	CMON	1.0	10.0	8.15	0.87	16.0
05/05/11	CMON	1.5	9.1	7.81	0.75	15.7
05/05/11	CMON	2.2	8.4	7.96	0.83	15.7
05/17/11	DFLO	0.5	9.2	8.60	1.20	19.9
05/17/11	DFLO	1.0	8.5	8.40	1.14	19.8
05/17/11	DFLO	1.5	8.7	8.40	1.14	19.8
05/17/11	DFLO	2.0	8.9	8.50	1.15	19.9
05/17/11	DFLO	2.6	9.0	8.60	1.25	19.9
05/19/11	CMON	0.5	11.5	9.04	1.08	20.3
05/19/11	CMON	1.0	11.5	8.96	1.14	20.0
05/19/11	CMON	2.0	10.8	9.02	1.33	20.2
05/19/11	CMON	2.7	8.5	8.74	1.47	20.0
06/02/11	CMON	0.5	6.5	8.12	1.12	27.8
06/02/11	CMON	1.0	6.7	8.20	1.22	27.7
06/02/11	CMON	1.5	5.4	7.91	1.13	27.6
06/02/11	CMON	2.0	4.4	7.66	1.16	27.5
06/02/11	CMON	2.3	3.9	7.54	1.19	27.3
06/02/11	DFLO	0.5	5.1	7.90	1.15	27.2
06/02/11	DFLO	1.0	4.8	7.80	1.15	27.2
06/02/11	DFLO	1.5	4.2	7.70	1.17	27.0
06/02/11	DFLO	2.0	4.2	7.70	1.19	27.1
06/02/11	DFLO	2.2	4.1	7.70	1.19	27.1
06/16/11	CMON	0.5	5.7	7.89	4.06	23.2
06/16/11	CMON	1.0	2.3	7.33	5.05	23.1
06/16/11	CMON	2.0	2.2	7.31	5.62	22.5
06/16/11	CMON	2.8	0.6	7.17	5.93	22.5
06/30/11	CMON	0.5	8.4	8.53	3.61	26.0
06/30/11	CMON	1.0	6.9	7.71	4.03	25.9
06/30/11	CMON	1.5	5.3	8.00	3.97	25.7
06/30/11	CMON	2.2	1.1	7.40	5.53	24.6

Table B-3 (continued). Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Masonville Cove (XIE4741) in 2011(continued on next page).

Date	Project	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (°C)
07/14/11	CMON	0.5	6.5	7.91	4.40	26.6
07/14/11	CMON	1.0	6.4	7.90	4.53	26.4
07/14/11	CMON	1.5	6.4	7.88	4.40	26.6
07/14/11	CMON	1.9	6.4	7.89	4.40	26.5
07/20/11	DFLO	0.5	5.1	7.60	5.45	27.6
07/20/11	DFLO	1.0	5.0	7.60	5.45	27.7
07/20/11	DFLO	1.5	4.7	7.60	5.45	27.6
07/20/11	DFLO	2.1	4.6	7.60	5.51	27.6
07/28/11	CMON	0.5	5.1	7.44	5.75	28.9
07/28/11	CMON	1.0	5.0	7.51	6.07	28.9
07/28/11	CMON	1.5	1.3	7.16	6.30	28.6
07/28/11	CMON	2.1	1.1	7.21	6.53	28.5
08/18/11	DFLO	0.5	6.9	7.70	7.24	25.9
08/18/11	DFLO	1.0	6.6	7.70	7.62	26.2
08/18/11	DFLO	1.5	5.4	7.40	8.00	26.4
08/18/11	DFLO	2.0	4.4	7.40	8.12	26.5
08/18/11	DFLO	2.3	1.0	7.40	8.76	26.4
08/25/11	CMON	0.5	5.4	7.81	8.00	25.4
08/25/11	CMON	1.0	5.8	7.80	8.37	25.2
08/25/11	CMON	1.5	4.8	7.73	8.02	25.4
08/25/11	CMON	2.0	3.8	7.56	8.26	25.6
08/25/11	CMON	2.3	3.8	7.56	8.29	25.7
09/08/11	CMON	0.5	6.2	7.24	0.00	21.6
09/08/11	CMON	1.0	6.0	6.98	0.02	21.4
09/08/11	CMON	1.5	6.2	7.24	0.00	21.6
09/08/11	CMON	2.0	6.2	7.24	0.00	21.6
09/08/11	CMON	2.6	5.9	7.23	0.02	21.6
09/15/11	DFLO	0.5	6.6	7.40	0.98	23.3
09/15/11	DFLO	1.0	6.5	7.40	0.98	23.3
09/15/11	DFLO	1.5	6.5	7.40	0.98	23.3
09/15/11	DFLO	2.0	6.5	7.40	0.99	23.3
09/15/11	DFLO	2.4	6.5	7.40	0.98	23.3
09/22/11	CMON	0.5	9.3	8.14	2.14	21.4
09/22/11	CMON	1.0	9.7	8.11	2.38	21.2
09/22/11	CMON	1.5	9.3	8.16	2.28	21.2
09/22/11	CMON	2.0	8.2	7.96	2.42	21.3
09/22/11	CMON	2.3	6.3	7.56	2.52	21.1
10/04/11	DFLO	0.5	7.4	7.60	3.89	18.0
10/04/11	DFLO	1.0	7.2	7.50	4.14	19.3
10/04/11	DFLO	1.5	6.0	7.50	4.30	19.2
10/04/11	DFLO	1.8	5.6	7.50	4.33	19.3

Table B-3 (continued). Ambient Water Quality Data for Dissolved Oxygen (D.O.), pH, Salinity, and Water Temperature for Masonville Cove (XIE4741) in 2011.

Date	Project	Sample Depth (m)	D.O. (mg/L)	pH	Salinity (ppt)	Water Temperature (°C)
10/06/11	CMON	0.5	11.1	8.30	3.82	18.5
10/06/11	CMON	1.0	10.5	8.29	3.99	18.5
10/06/11	CMON	1.5	7.8	7.71	4.34	19.0
10/06/11	CMON	2.2	3.2	7.30	5.67	20.7
10/31/11	CMON	0.5	8.9	7.55	1.76	9.1
10/31/11	CMON	1.0	8.8	7.48	2.62	10.9
10/31/11	CMON	1.5	7.6	7.45	3.20	11.8
10/31/11	CMON	2.0	7.3	7.43	3.48	12.4
10/31/11	CMON	2.5	7.6	7.41	3.50	12.4
11/16/11	CMON	0.5	9.9	7.69	3.70	13.1
11/16/11	CMON	1.0	10.5	7.67	3.69	12.1
11/16/11	CMON	1.5	8.7	7.67	4.60	13.4
11/16/11	CMON	2.1	7.7	7.28	5.40	13.4
11/28/11	CMON	1.0	8.8	7.30	2.83	11.5
11/28/11	CMON	1.5	8.4	7.34	3.31	11.3
11/28/11	CMON	2.0	7.9	7.32	3.58	11.3
11/28/11	CMON	2.3	7.9	7.27	4.02	11.4
12/15/11	CMON	0.5	9.1	7.47	3.34	8.6
12/15/11	CMON	1.0	6.7	7.44	3.81	8.7
12/15/11	CMON	1.5	8.3	7.45	3.97	8.8
12/15/11	CMON	2.0	7.1	7.37	4.15	9.2
12/15/11	CMON	2.4	6.4	7.32	4.54	9.8

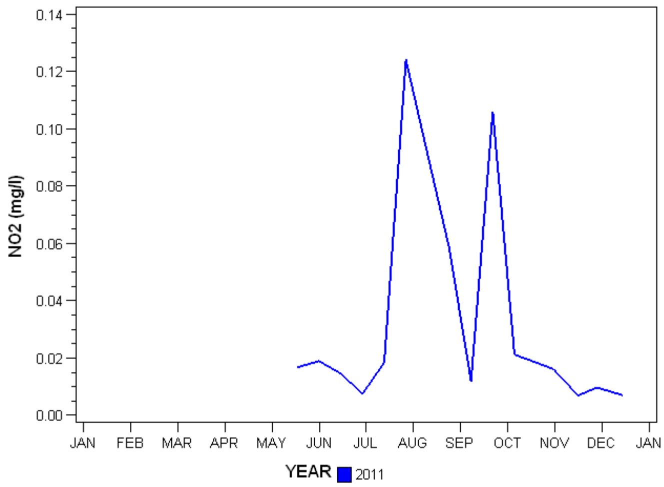


Figure B-1. Nitrite concentrations at Masonville Cove in 2011.

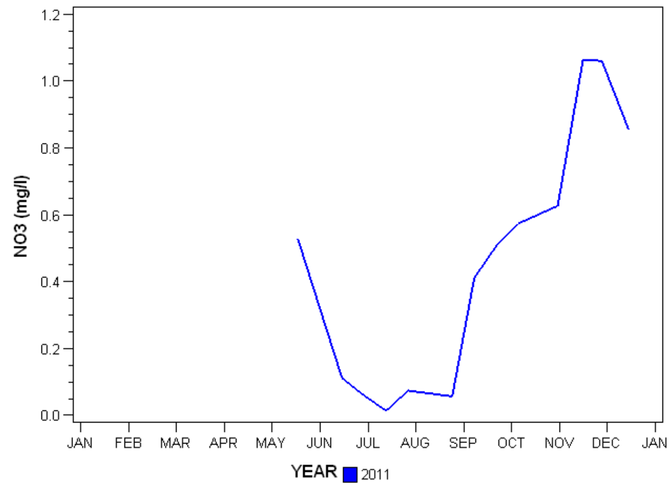


Figure B-2. Nitrate concentrations at Masonville Cove in 2011.

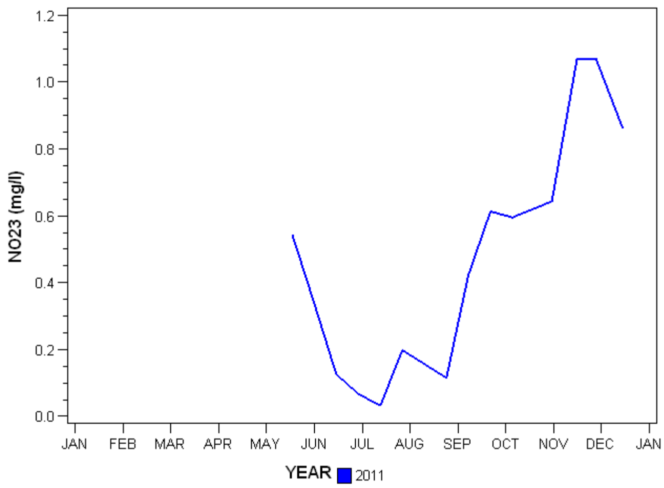


Figure B-3. Nitrite + Nitrate concentrations at Masonville Cove in 2011.

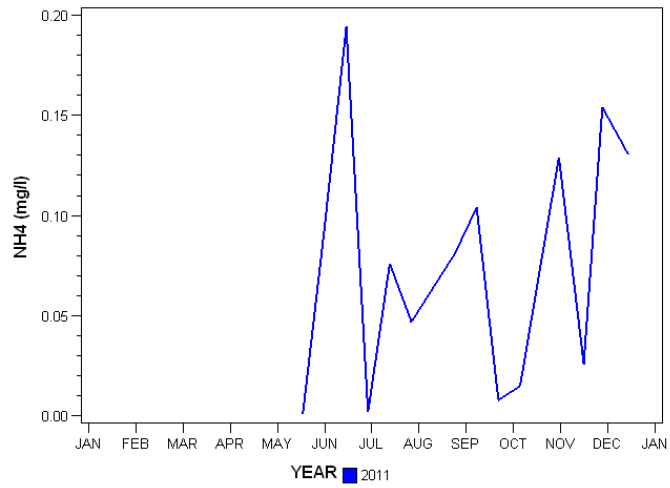


Figure B-4. Ammonium concentrations at Masonville Cove in 2011.

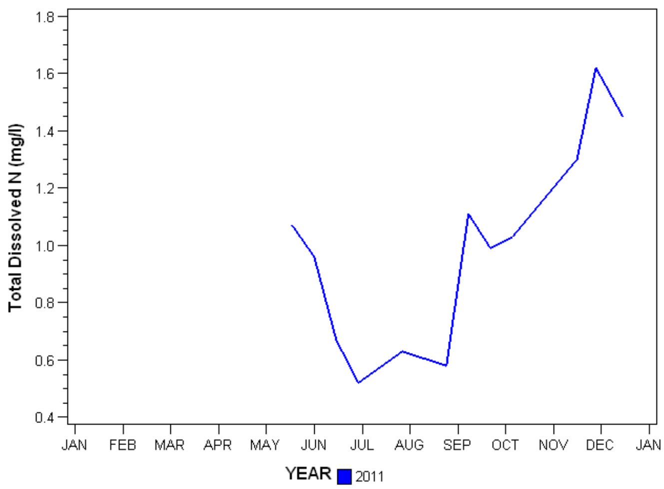


Figure B-5. Total dissolved nitrogen concentrations at Masonville Cove in 2011.

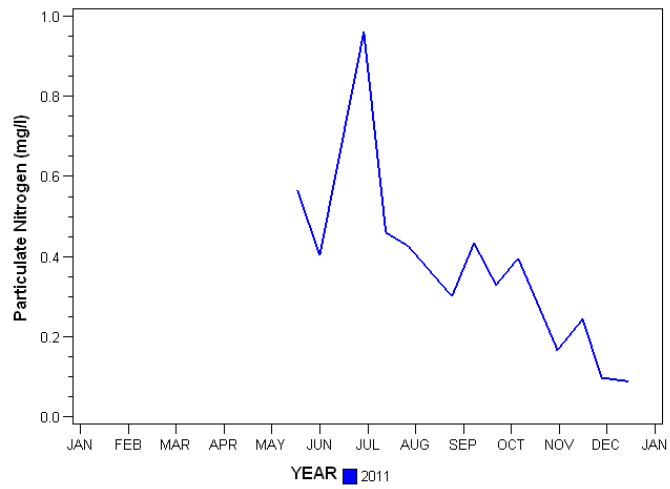


Figure B-6. Particulate nitrogen concentrations at Masonville Cove in 2011.

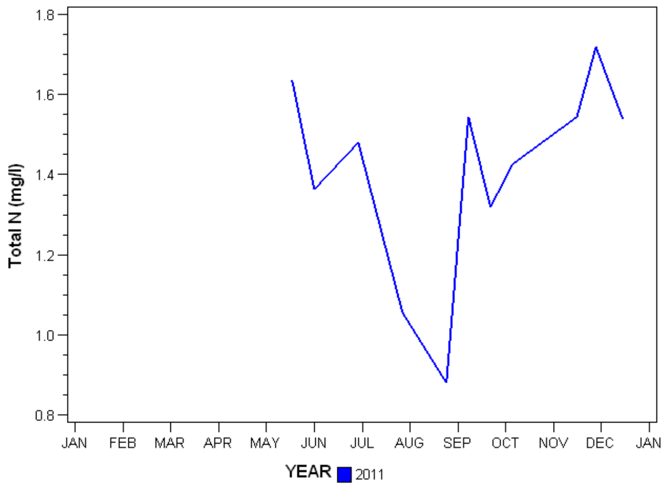


Figure B-7. Total nitrogen concentrations at Masonville Cove in 2011.

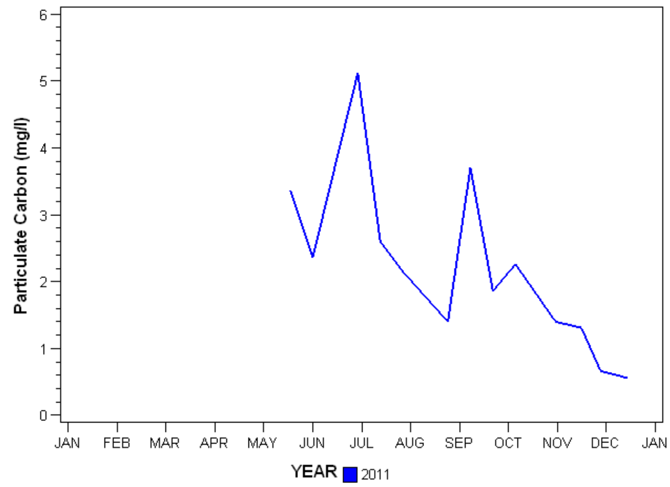


Figure B-8. Particulate carbon concentrations at Masonville Cove in 2011.

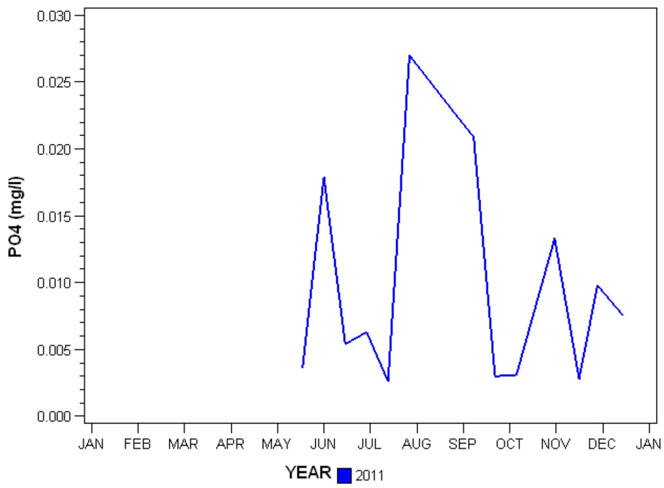


Figure B-9. Phosphate concentrations at Masonville Cove in 2011.

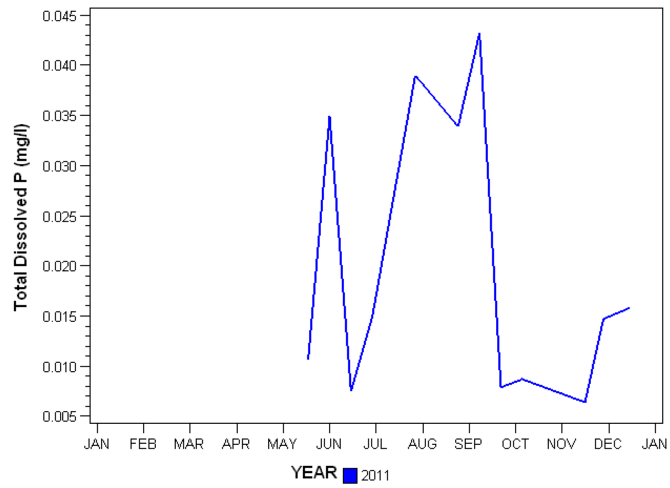


Figure B-10. Total dissolved phosphorus concentrations at Masonville Cove in 2011.

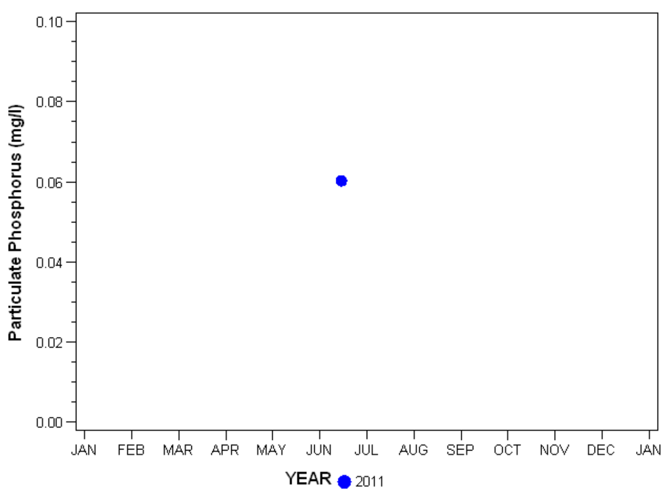


Figure B-11. Particulate phosphorus concentrations at Masonville Cove in 2011.

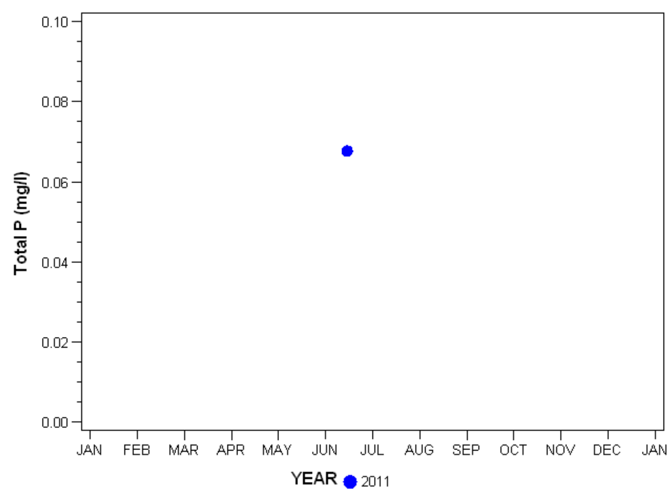


Figure B-12. Total phosphorus concentrations at Masonville Cove in 2011.

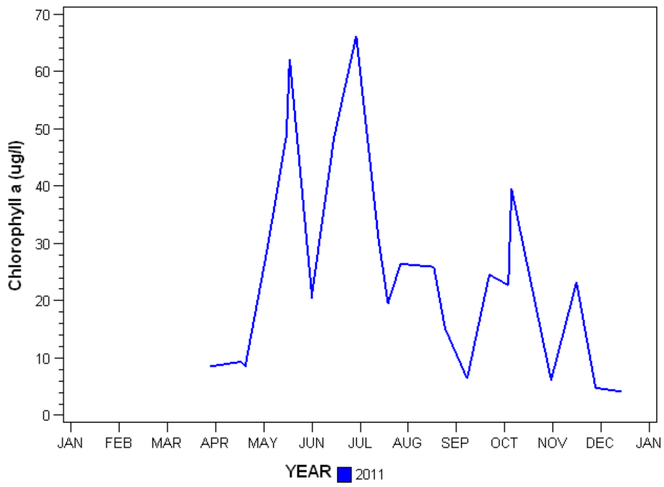


Figure B-13. Chlorophyll *a* concentrations at Masonville Cove in 2011.

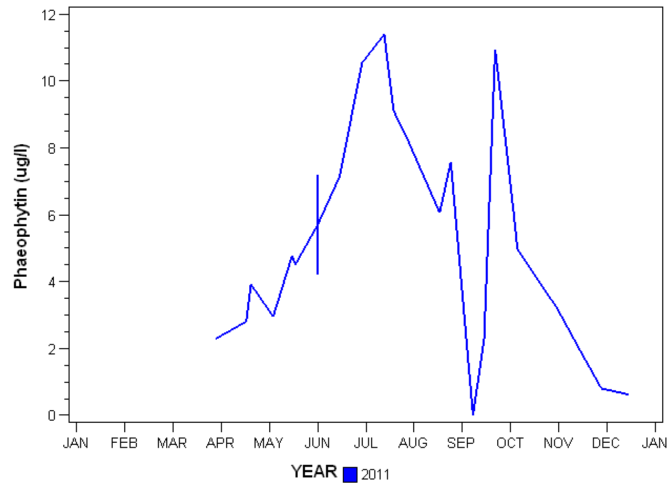


Figure B-14. Phaeophytin concentrations at Masonville Cove in 2011.

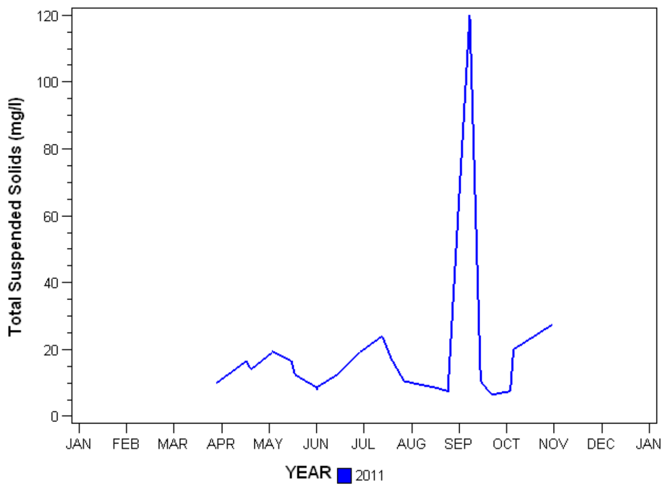


Figure B-15. Total suspended solids concentrations at Masonville Cove in 2011.

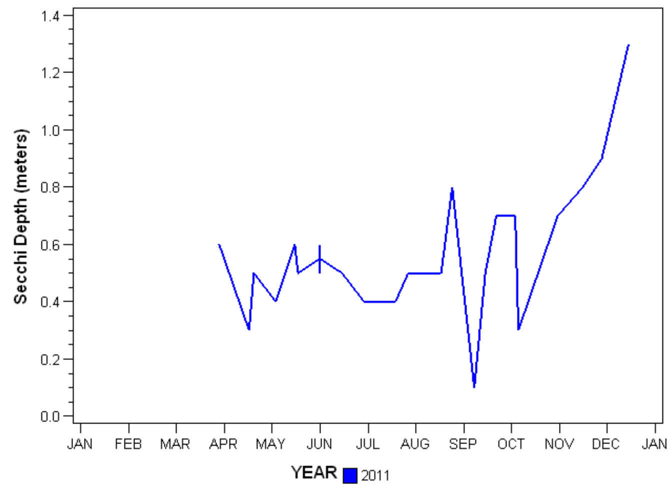


Figure B-16. Secchi depth at Masonville Cove in 2011.

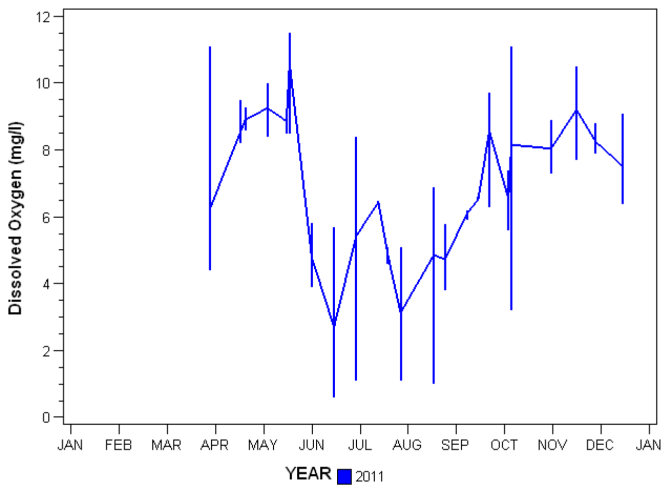


Figure B-17. Dissolved oxygen concentrations at Masonville Cove in 2011.

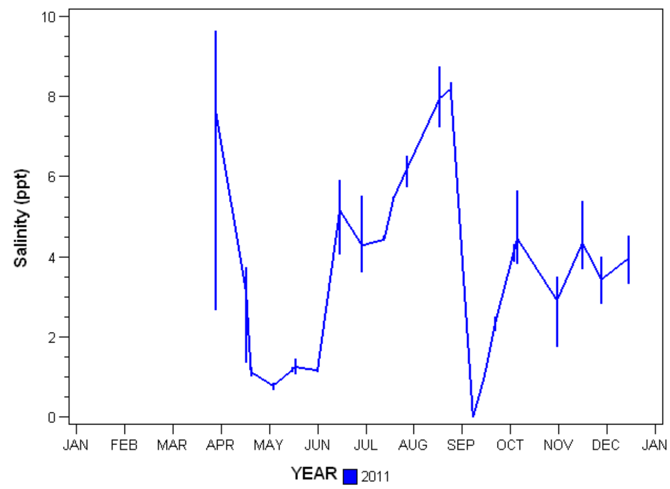


Figure B-18. Salinity concentrations at Masonville Cove in 2011.

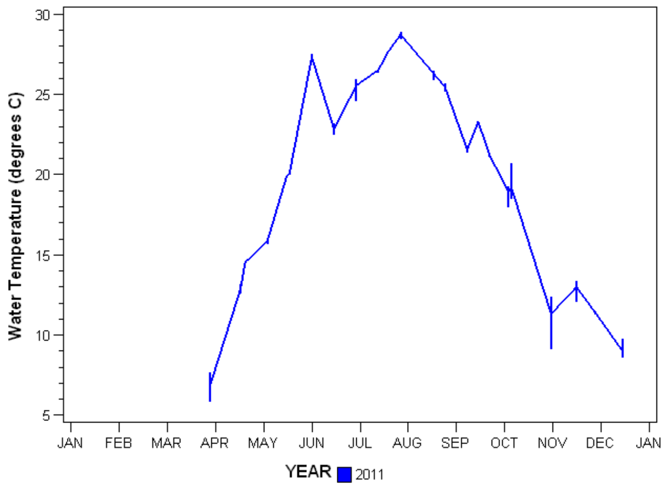


Figure B-19. Water temperature at Masonville Cove in 2011.

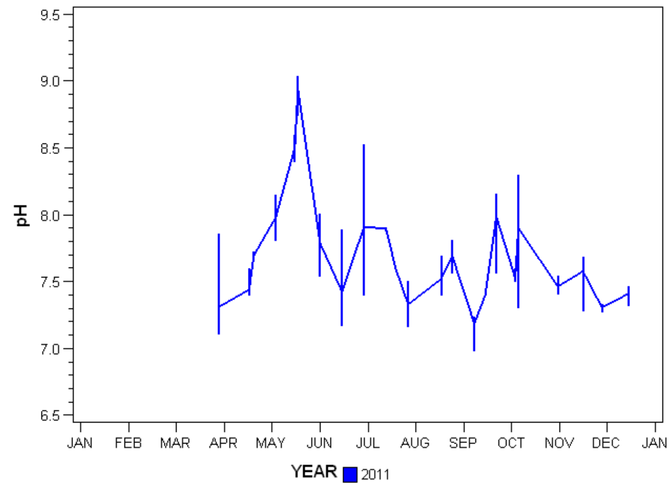


Figure B-20. Values of pH at Masonville Cove in 2011.