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2008 Water Quality Monitoring Program for the Mill Creek Sub-Estuarine System Located in Southern Calvert County, Maryland

Final Report

Prepared for the Calvert County Board of County Commissioners

By

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Figures and Tables

Acknowledgements

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1. The Calvert County Board of County Commissioners provided funds and maintains interest in supporting research to better understand and preserve one of southern Calvert County's important natural resources.

2. The administration of the Chesapeake Biological Laboratory (CBL) consistently releases this grant from overhead charges and absorbs the operating costs of the research vessel. This substantial reduction in costs greatly enhances the scope of work that can be preformed for this yearly study.

3. Field sampling was completed with assistance from Nancy Kaumeyer (CBL-NASL) plus a summer intern from Saint Mary's College.

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5. Mr. Buddy Millsaps (CBL) provided daily precipitation data recorded at the Chesapeake Biological Laboratory for the National Oceanographic and Atmospheric Administration (NOAA).

6. The United States Geological Survey (USGS) provided river flow data for site number 01594440, Patuxent River near Bowie, MD, on the web at:
http://waterdata.usgs.gov/nwis/inventory/

Executive Summary

Yearly Monitoring Measurements

The 2008 Mill Creek monitoring program followed the scaled-down format used in recent years for station locations, sampling frequencies and analytical methodologies. Water column temperature, salinity, dissolved oxygen, clarity and chlorophyll-*a* concentrations were measured at 10 fixed stations on 8 cruises.

The effects and long-term trends of Patuxent River flow, local precipitation, Mill Creek system chlorophyll-*a* concentrations and water column stratification on bottom water dissolved oxygen levels were examined. We have also included the local MDE fecal coliform data from this area.

Temperature, Salinity and Dissolved Oxygen

Both surface and bottom water temperatures increased significantly from the 17-20°C measured on the late May cruise up to 24-28 °C recorded during the early June cruise. Temperatures then remained in that range for the rest of the sampling season. As in the past, neither surface nor bottom temperatures exhibited any significant different trends.

All salinities gradually increased over the sampling season with bottom salinities slightly greater than or equal to surface salinities.

Seventeen percent (17%) of the bottom water dissolved oxygen levels were below 2.0 mg L^{-1} during the 2008 study. Levels below 2.0 mg L^{-1} are considered hypoxic and are stressful to organisms. Bottom water dissolved oxygen saturation levels less than 50% saturation were observed 54% of the time (39 out of 72 observations), similar to observations made during 2004 (51%).

Water Column Stratification

In general, stratification (or the layering of different densities of water) in these tributaries is weak and highly variable, driven by wind and freshwater inflow. Heavy rains/discharge in May and early June of 2008 appear to have increased stratification at the stations in Mill and Saint John’s Creek with the confluence station (station 4) exhibiting the most consistent stratification over the summer. The weakest stratification in the system (more mixing of the surface and bottom layers) was recorded on the September 11 cruise, right after a tropical storm event that brought high winds and tides.

Water Column Clarity

Water column clarity and light penetration are very important parameters contributing to the growth of submerged aquatic vegetation (SAV). SAV not only provides food, oxygen, nursery areas and shelter for Bay animals, but can trap sediment and slow erosion, thus, further clearing the water. The Maryland Department of Natural Resources (DNR) has set a goal to restore SAV to about 185,000 acres in Chesapeake Bay by 2010. In 2008, 42% of the goal was reached. The Mill Creek sub estuary is located in the mesohaline portion (5.0 to 18.0 salinity) of the Bay. This one-meter restoration goal established for this area requires a seasonal light attenuation coefficient of ≤ 1.5.

Over the 2008 sampling season, the 30% light penetration needed for submerged aquatic vegetation growth averaged 0.8 meters, well short of the average water depth. Thus, light sufficient for SAV growth at 1.5 light attenuation coefficient was not present on the sampling dates.

Shellfish and Swimming Safety Review

We reviewed available 2007 and 2008 MDE fecal coliform data for this drainage basin. The Sandy point reference station and the Mill Creek station met the water quality standards for shellfish harvesting, not greater than 70 MPN per 100 mls of water (MPN = most probable number). In Back Creek, the average measurements for 2007 and 2008 were twice as high as the other 3 stations (excepting a spike at the Boat Shop station) with two sampling dates peaking at 93 MPN/100 ml, thus, slightly exceeding the standards.

Even though the bacteria standards are being met, MDE will keep this area closed to shellfish harvesting due to shoreline activities and the intensity of boating activities, increasing the potential for overboard discharge of untreated sewage.

The U.S.EPA regulatory concentration for closure of swimming areas is greater than 200 MPNfecal coliforms per 100 ml. The highest concentration measured in the Mill Creek system in 2008 was one spike in July at 360 MPN/100 mls measured at the harbor entrance. The next highest were in Back Creek (93 MPN/100 mls).

Precipitation and River Flow/Discharge

Precipitation and river discharge patterns exert substantial influence on water quality conditions.

The March through September local average precipitation of 0.14 inches day^{-1} , was just above the 25-year average of 0.13 inches per day (Fig 4.1B). May and June received 0.21 and 0.25 inches per day respectively with 7.6 inches falling in June. Below-average precipitation fell in March, April, August and September.

The January-May 2008 mean flow of 468 cubic feet per second or cfs (measured at Bowie, MD) was just below the twenty-two year average of 501 cfs. Like most of the

Chesapeake Bay region, the Patuxent river watershed mainly experienced a dry winter and spring during 2008 (with the exception of the record-breaking average May discharge of 928 cfs – one day recorded 6000 cfs - all months were at or below average).

However, except for a short pulse of chorophyll that may be observed directly after a rain event, the systems in Chesapeake Bay appear to be driven by the rainfall and river discharge including associated nutrients occurring earlier in the year (March/April) when leaves are not yet on the trees and evapotranspiration is low.

Long-Term Trends for Dissolved Oxygen and Chorophyll-a

As in 2007, at the long-term trend stations, the 2008 bottom-water dissolved oxygen concentrations again decreased, indicating a possible worsening trend in bottom water quality. Even though anoxic conditions (dissolved oxygen concentrations of zero milligrams per liter) have never been observed, hypoxic conditions (less than 2.0 mg L^{-1}) are observed frequently enough to continue monitoring these trends.

Concentrations of active chlorophyll-*a* serve as a measure of the size of the algal populations in the water column. The surface mean active chlorophyll-*a* concentration for the five inter-annual comparison stations (2, 6, 7, 9 and 15) decreased slightly from last year's average (22.3) to 19.5 µg L^{-1} . However, this yearly average is still greater than the total 1987-2008 average concentration of ~17.2 µg L^{-1}.

During the 2008 sampling season, 13 small plankton blooms and one substantial (91.4) surface bloom were observed at the 5 inter-annual comparison stations; the full dataset average is 10 blooms per year.

Conclusions

- Monitoring of Mill Creek estuarine system has been conducted for the past twenty-two years. The overall water quality of the system in terms of oxygen and cholorphyll is again degraded.

- After a 3-year trend of improving bottom-water dissolved oxygen conditions, both 2007 and 2008 average concentrations have decreased.

- Interannual variability in precipitation and river flow greatly influences water quality trends. However, it appears that winter and spring conditions tend to affect overall water quality more so than ephemeral storm events.

Recommendations

- Continue to monitor this system so that both negative and positive trends in the system's health can be recognized in a timely fashion.

- Continue to support planning and eventual implementation of sewer upgrades, BMPs, installation of ENR septic systems, riparian and other vegetative buffer zones, and encourage the use of pump-out facilities by boaters within the Mill Creek system.

- Encourage MDE to continue its current fecal coliform monitoring program in the Mill Creek System.

- Continue to support the local county and state environmental educational programs as an educated person is our hope for a cleaner future.

1. Introduction

As development adjacent to coastal and estuarine waters increases so does the risk that water quality of these areas will degrade. Water quality degradation is a concern not only in the large estuaries, such as Chesapeake Bay, but also in the smaller coves and tributary rivers adjoining these estuaries. In many cases these areas can be considered small estuaries or sub-estuaries. They are subjected to similar natural and anthropogenic influences as the larger estuaries. However, due to their smaller size and restricted flushing, the potential for dilution of pollutants is limited and the potential for algal blooms and general water quality deterioration is enhanced.

Located within the Dowell, Drum Point, Lusby, Olivet and Solomons portion of southern Calvert County, Maryland, the Mill Creek sub-estuarine system includes St. John's Creek, Mill Creek, Back Creek, The Narrows and Solomons Harbor. It is identified as a smaller sub-estuarine system. The number of houses and town houses surrounding the Mill Creek system is increasing, as are the numbers of boat slips and the amount of shore-line hardening within the Mill Creek system. Additionally, many forms of recreation enjoyed by the local population and by visitors are becoming increasingly popular.

The aquatic resources and the population growth in this area must be managed to preserve this system for the use and enjoyment of future generations. In response to these management concerns, the Calvert County Board of County Commissioners provides the University of Maryland System, Center for Environmental Science, Chesapeake Biological Laboratory (UMCES CBL) with funding to monitor water quality conditions in the Mill Creek system. Past monitoring grants were awarded in 1987-1988 and 1990-2007. The focal point of these studies was to measure the variables that best indicate stress to an estuarine system due to increased development and recreational activity. In the early years of this program, variables measured included particulate and dissolved nutrients, chlorophyll-*a*, fecal coliform concentrations, temperature, water column clarity, dissolved oxygen concentrations and salinity.

The 2008 Mill Creek study followed the scaled-down format used in recent years, focusing on water column temperature, salinity, dissolved oxygen, water clarity and chlorophyll-*a* concentrations. The effects and long-term trends of Patuxent River flow, precipitation, Mill Creek system chlorophyll-*a* concentrations and water column stratification on bottom water dissolved oxygen levels were also examined.

2. Sampling Procedures

2.1 Station Locations and Sampling Frequency

Figure 2.1 and Table 2.1

Water column data were collected at ten fixed stations in the Mill Creek system on eight different cruises beginning May 20 and ending on September 11, 2008. The data from these eight cruises characterized the water quality of the Mill Creek system during the spring and summer periods of 2008 and were compared to findings of all previous monitoring studies.

As in previous years, sampling stations were distributed throughout the Mill Creek system to ensure coverage of the area. Four stations were positioned along Mill Creek (stations 3, 4, 6 and 7); two along St. John's Creek (stations 8 and 9) and two located in Back Creek (stations 15 and 17). One station was located in The Narrows (station 11) and one at the mouth of the Mill Creek system (station 2). Data from stations 2 and 11 provide insight into main stem Patuxent River / Mill Creek System interactions.

Each sampling cruise was conducted aboard the R/V Pisces, a 25-ft CBL research vessel, between the hours of 0600 and 1200 (with the exception of the May cruise which was in the afternoon).

2.2 Water Quality Observations

Appendix 1

Water column temperature, conductivity, salinity and dissolved oxygen were measured at each station using a submersible water quality monitoring instrument (YSI model 6600, 6920 or 600). Surface (0.5 meters) and bottom (0.5 meters above the sediment surface) measurements were taken at each site. At station 9 (ave. depth = 1 meter) only surface measurements were recorded. However, bottom water measurements are checked and recorded if significantly different from the surface measurements. Water column turbidity was measured using a Secchi disk. Chlorophyll readings were recorded when possible. Weather and sea-state conditions including air temperature, percent cloud cover, wind speed and direction, total water depth and wave height were recorded.

2.3 Chlorophyll-*a* Analyses

Samples of near-surface and near-bottom water were collected for chlorophyll-a in separate, sample rinsed, one-liter polyethylene jugs using a small submersible pump (Rule model 1500). For each depth, aliquots of 25 to 100 ml were immediately filtered through a 0.7 μm glass fiber filter, wrapped in a labeled foil packet, then stored in a dark, iced cooler. After the cruise, the samples were immediately transported to the CBL Nutrient Analytical Services Laboratory (NASL) and frozen. Analyses of all samples were conducted by NASL using the standard operating protocols described in Keefe et al. (2004).

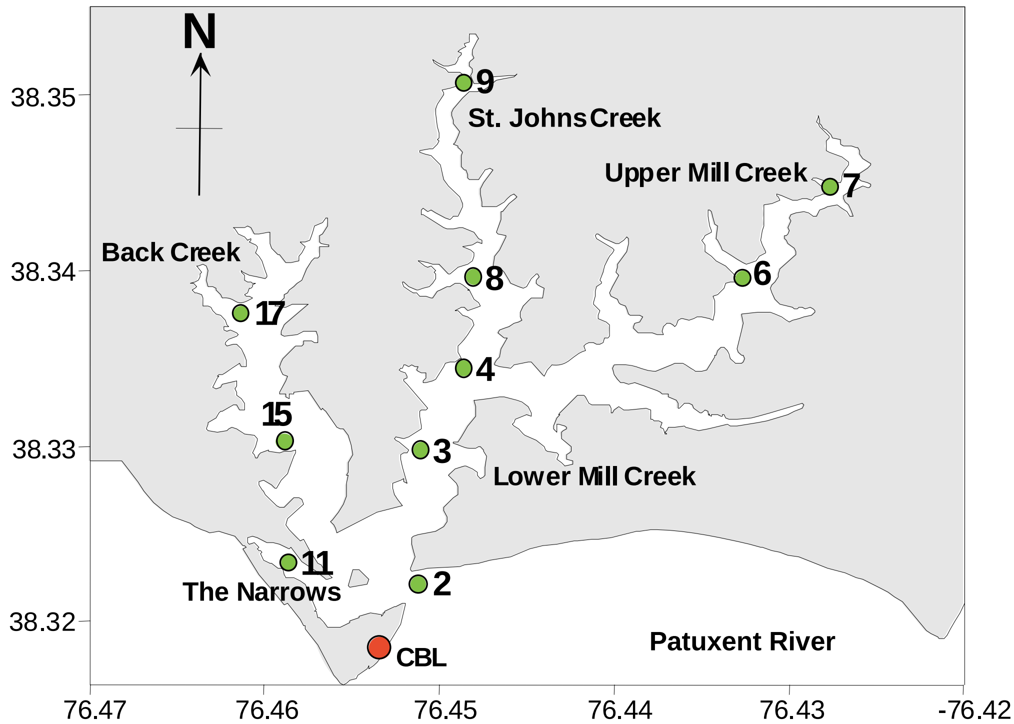


Figure 2.1. Map of the sampling sites within the Mill Creek system.

Table 2-1. Location and average depth of sampling sites within the Mill Creek system.

Station Number	Station Name	Average Depth (meters)	Latitude (degrees - decimal minutes)	Longitude
2	Boat Shop	5.68	38° 19.43'	76° 26.16'
3	Bow Cove	4.56	38° 19.61'	76° 27.13'
4	Pancake Point	4.52	38° 20.10'	76° 27.01'
6	Cole's Creek	2.30	38° 20.40'	76° 26.03'
7	Ranch Club	1.33	38° 20.77'	76° 25.70'
8	Hutchin's Cove	2.80	38° 20.46'	76° 26.92'
9	Lore's Creek	1.05	38° 21.13'	76° 26.98'
11	Pilot Transfer Station	3.61	38° 19.50'	76° 27.58'
15	Calvert Marina	3.75	38° 19.95'	76° 27.53'
17	Solomon's Landing	2.95	38° 20.34'	76° 27.71'

3. Water Quality Results and Discussion

Water quality data collected during the 2008 Mill Creek System monitoring study are listed by station and date in Appendix I.

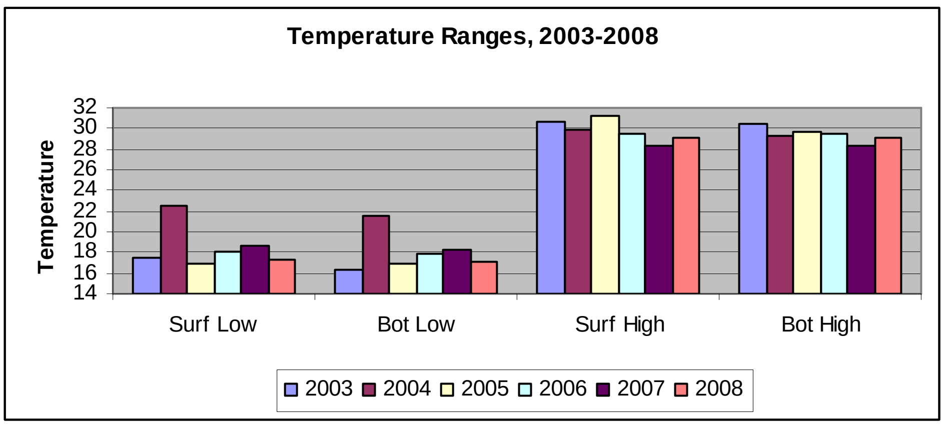
3.1 Temperature and Salinity

Temperature, Figure 3.1

Surface temperatures ranged from 17.21°C (station 2, May 20) to 29.09°C (station 9, June 30). The bottom temperature ranged from 17.08 °C (station 2, May 20) to 29.12°C (station 7, June 30).

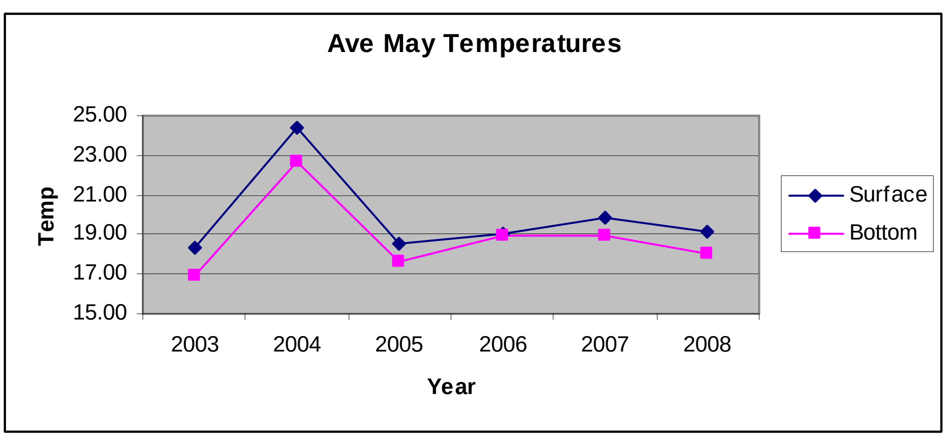
Historical Surface and Bottom Temp Ranges (°C)

Year	2003	2004	2005	2006	2007
Surface	17.57-30.71	22.6-29.88	16.93–31.20	18.07-29.52	18.66-28.27
Bottom	16.27-30.38	21.62-29.21	16.93-29.64	17.90-29.54	18.18-28.26



Average May Surface and Bottom Temperatures (°C)

Date	16May03	22May04	26May05	23May06	22May07	20May08
Surface	18.35	24.44	18.57	19.07	19.83	19.18
Bottom	16.94	22.64	17.67	18.89	18.91	18.06



Both surface and bottom water temperatures increased significantly from the 17-20°C measured on the late May cruise up to 24-28 °C recorded during the early June cruise. Temperatures then remained in that range for the rest of the sampling season. As in the past, neither surface nor bottom temperatures exhibited any significant spatial trends.

Warmer water temperatures encourage epiphytic growth on SAV and increased respiration (oxygen consumption) in both the water column and in the sediments.

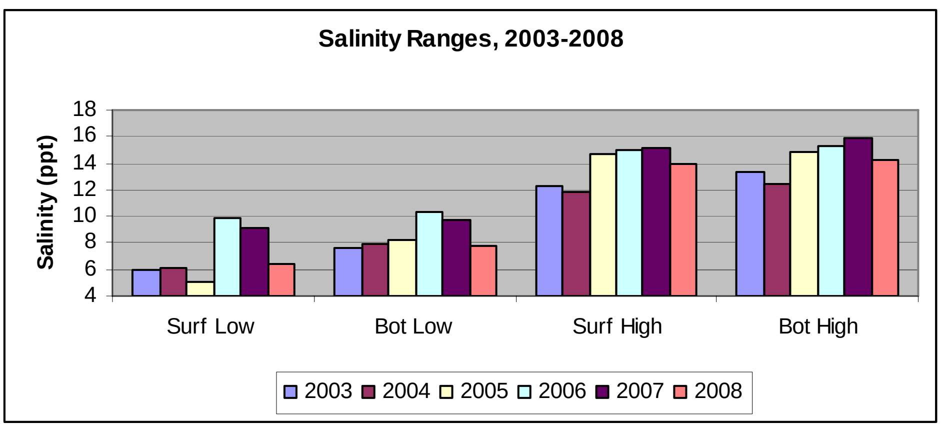
Salinity, Figure 3.2

All salinities gradually increased during the sampling season with bottom salinities slightly greater than or equal to surface salinities. The average difference between the two depths was small and similar among years (<0.5 ppt).

Surface water salinity ranged from 6.37 ppt (station 7 on May 20) to 14.01 ppt (station 2 on September 11). Bottom water salinity ranged from 7.76 ppt (station 11, May 20) to 14.27 (Station 6, September 11).

Surface and Bottom Salinity Ranges (ppt):

Year	2003	2004	2005	2006	2007	2008
Surface Ranges	6.00-12.21	6.12-11.89	5.05-14.66	9.8-14.93	9.07-15.16	6.37-14.01
Bottom Ranges	7.59-13.34	7.93-12.42	8.29-14.84	10.35-15.28	9.74-15.93	7.76-14.27



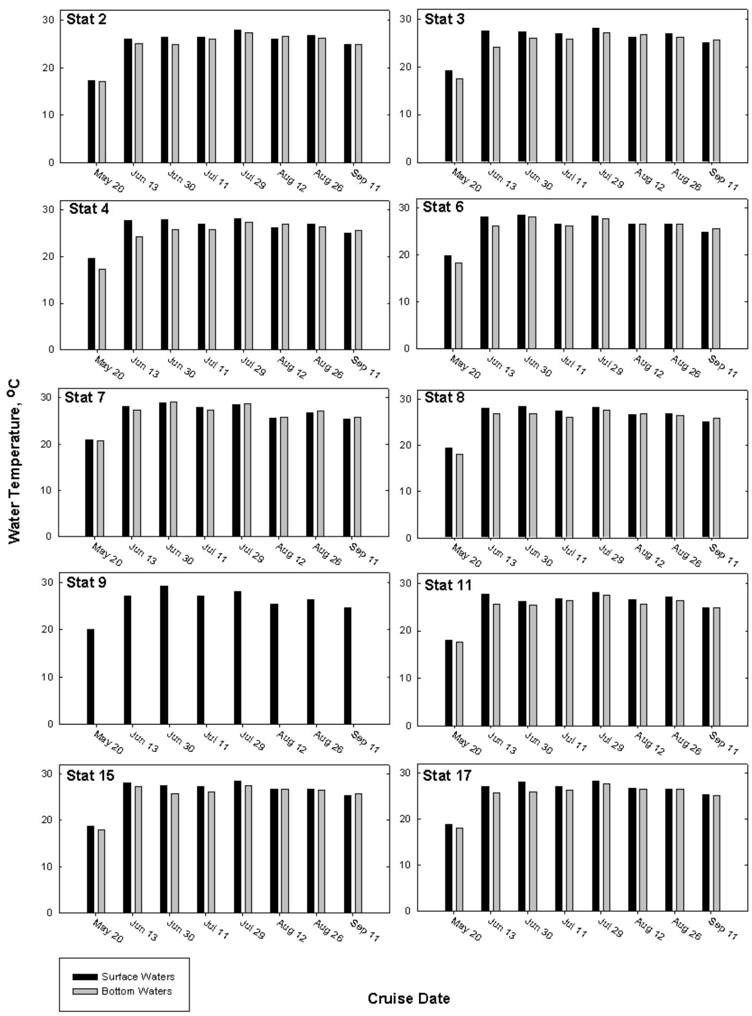


Figure 3.1. Bar graphs of surface and bottom water temperature measured at each station from May 20 through September 11, 2008.
No bottom water temperatures were measured at station 9.

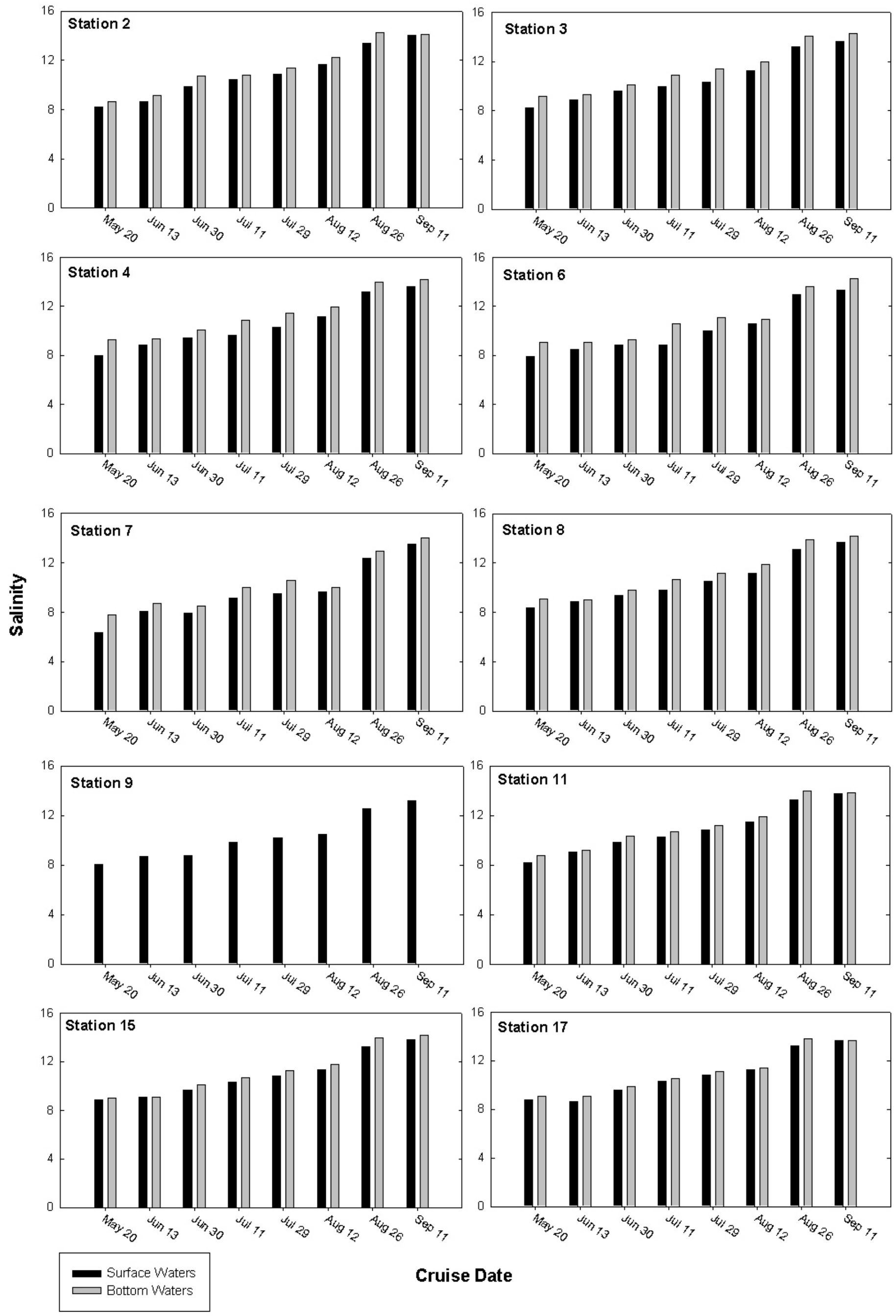


Figure 3.2. Bar graphs of surface and bottom water salinity values measured at each station from May 20 through September 11, 2008. No bottom water salinities were measured at station 9.

Stratification Strength, Figure 3.3

Sigma-t (specific gravity of water computed using water temperature and salinity) of the surface and bottom waters was calculated for each station and sampling date. The difference between surface and bottom sigma-t values provides an indication of the stratification strength of the water column. In general, stratification in these tributaries was weak and highly variable, driven by wind and freshwater inflow.

In the 2008 season, bottom water sigma-t was higher than surface water sigma-t at all stations. The lowest numbers were recorded on the September 11 cruise which was right after a tropical storm event that brought high winds and tides. Heavy rains/discharge in May and early June appear to have increased stratification at the stations in both Mill Creek and Saint John's Creek with the confluence station (station 4) exhibiting the most consistent stratification during the summer. Station 9 rarely shows any stratification due to its shallow, one-meter depth; thus, bottom readings at this station are checked but only recorded if stratification is present..

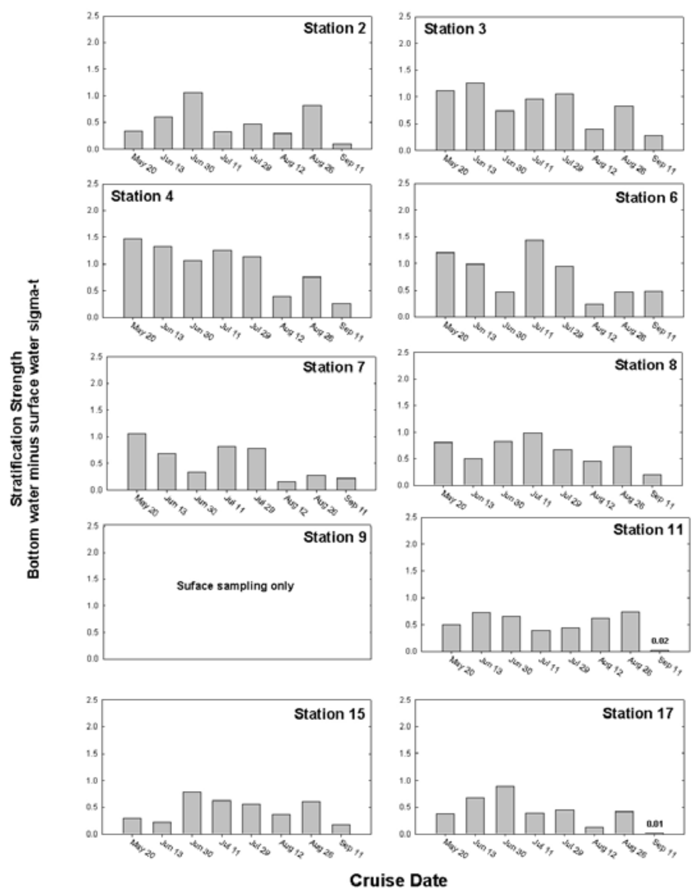


Figure 3.3. Bar graphs of water column stratification represented as the difference between surface and bottom water sigma-t values calculated for each station from May 20 through September 11, 2008. No bottom water measurements were taken at station at station 9.

3.2 Dissolved Oxygen

Figure 3.4 and 3.5A

The dissolved oxygen concentration of surface waters ranged from 2.77 milligrams per liter (mg L^{-1}) at station 7 (August 26) to 8.89 mg L^{-1} at station 2 (May 20). Bottom water dissolved oxygen concentrations ranged from 0.98 mg L^{-1} (station 17, June 30) to 8.17 mg L^{-1} (station 2, May 20).

Historic surface water oxygen concentration ranges (mg/l):

2003	2004	2005	2006	2007	2008
1.96-12.59	0.79-10.10	1.86-11.92	2.10-9.47	2.12-8.32	2.77-8.89

Historic bottom water oxygen concentration ranges (mg/l):

2003	2004	2005	2006	2007	2008
0.30-11.40	0.18-7.31	0.3-9.56	1.18-7.91	0.88-6.99	0.98-8.17

Seventeen percent (17%) of the bottom water dissolved oxygen levels were below 2.0 mg L^{-1} during the 2008 study (see figure 3.5A for historical comparisons). Levels below 2.0 mg L^{-1} are considered hypoxic and are stressful to organisms. The percent of hypoxic readings during the drier years (e.g. 2002) was low relative to the wetter years (e.g. 2003).

Percent Hypoxic Readings in the Bottom Water (<2.0 mg/l)

2002	2003	2004	2005	2006	2007	2008
8%	31%	25%	24%	10%	11%	17%

True anoxic conditions (0.00 mg L^{-1} dissolved oxygen) have not been recorded on the sampling dates of any Mill Creek system cruise. It may be that only high frequency monitoring will record any short-term (less than 2 weeks in duration) anoxic events. During the 2008 sampling season, only 1 of the bottom water observations was less than 1.0 mg L^{-1}.

3.2.1 Dissolved Oxygen Saturation Levels

Figure 3.5B

Oxygen from the air dissolves in the water column in proportion to water temperature and salinity. When oxygen dissolved in water is in equilibrium with that in air, the water is 100% saturated with dissolved oxygen. Oxygen is replenished in water by direct exchange with air at the surface and through the efforts of photosynthesizing phytoplankton in the water column. Respiration by organisms in the water and in the mud, as well as some chemical processes, consumes oxygen in the water, causing the oxygen content to fall below the 100% saturation level.

Bottom water dissolved oxygen saturation levels less than 50% saturation were observed 54% of the time (39 out of 72 observations) similar to those observed during 2004 (51%). Wetter years ranged from 44% in 2001 to 65% in 2003.

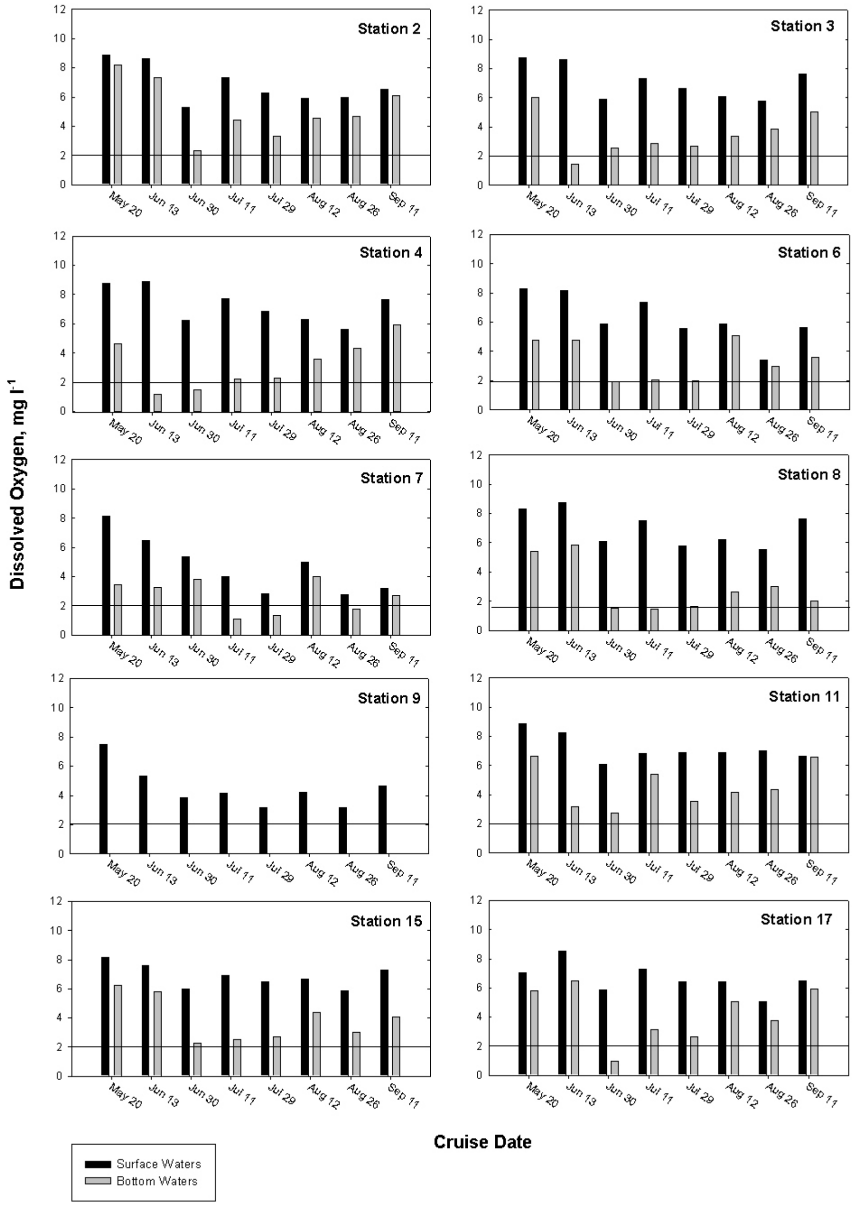


**Figure 3.4. Bar graphs of surface and bottom water dissolved oxygen concentrations measured at each station from May 20 through September 11, 2008.
No bottom water measurements were taken at station at station 9.**

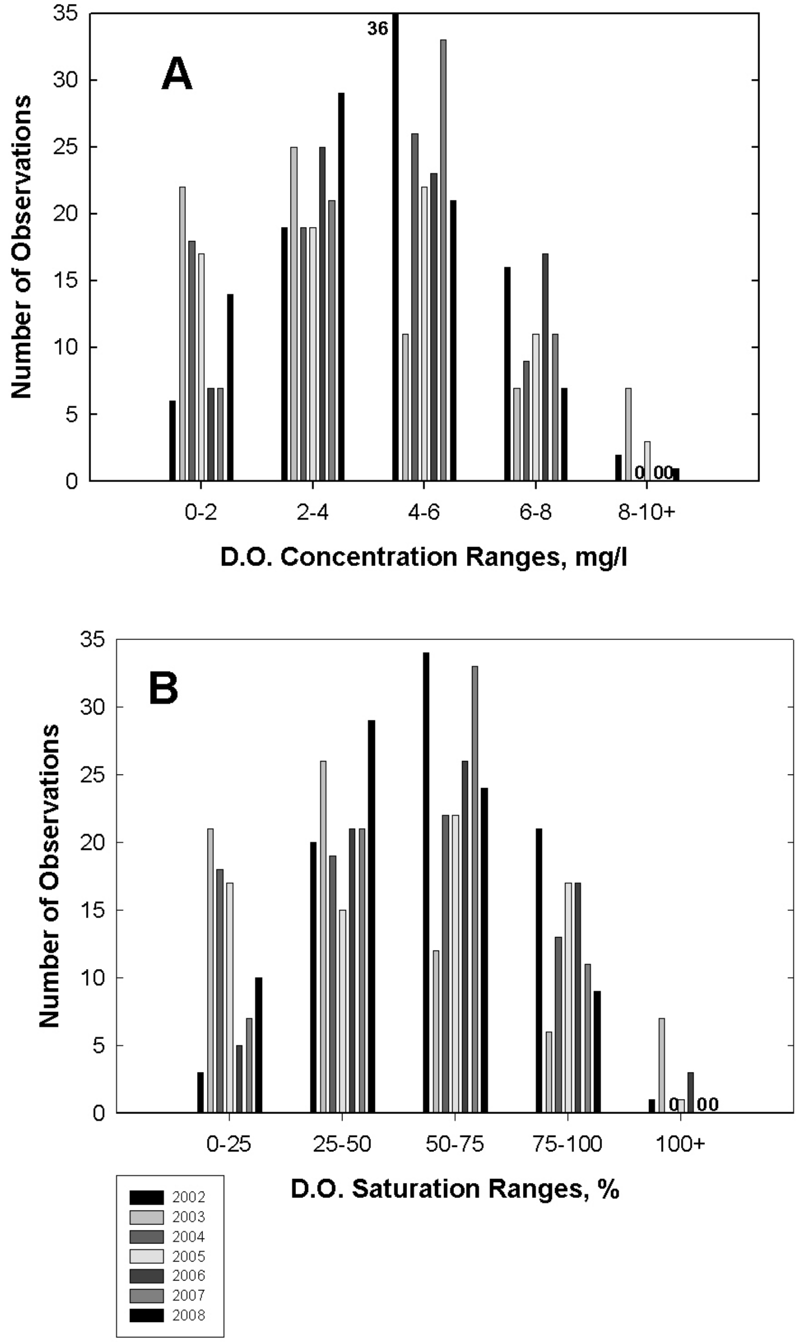


Figure 3.5.A&B. Bar graphs comparing the distribution of bottom water dissolved oxygen (A) and bottom water percent oxygen saturation (B) observations (2002 through 2008).

3.3 Active Chlorophyll-*a*

Figure 3.6

Active chlorophyll-*a* concentrations serve as a measure of water-column algal population densities. Total chlorophyll measurements include phaeophytin, a chlorophyll degradation product. Active chlorophyll-*a* concentrations in surface waters ranged from 4.70 micrograms per liter (µg L^{-1}) at station 17 on May 20 to 91.38 µg L^{-1} at station 9 on Sept. 11. Bottom water concentrations ranged from 3.48 µg L^{-1} (station 15, June 11) to 52.96 µg L^{-1} (station 8, July 29).

Historical surface active chlorophyll-*a* ranges:

2003	2004	2005	2006	2007	2008
8.65-411.61	5.47-88.39	3.54-224.88	4.96-57.10	3.75-63.83	4.70-91.38

Historical bottom active chlorophyll-*a* ranges:

2003	2004	2005	2006	2007	2008
3.23-90.25	3.45-41.48	2.69-42.17	2.15-68.07	5.26-46.49	3.48-52.96

Concentrations of greater than 20 µg L^{-1} indicate the presence of an algal bloom (severe bloom concentrations in the Patuxent River have exceeded 300 µg L^{-1}).

Average surface active chlorophyll-*a* concentrations:

2004	2005	2006	2007	2008
20.46	17.64	16.69	19.97	15.63

During the 2008 sampling season, 13 small blooms and one substantial (91.38) surface bloom were observed at the 5 inter-annual comparison stations; the full dataset average is 10 blooms per year. See also chapter 5, Figure 5.2.

At Station 7 in upper Mill Creek, significant differences in surface and bottom chlorophyll-*a* readings in past years point to the importance of shallow water stratification. In 2008, surface-water blooms were measured on 6 out of the 8 cruises (June 30 through September 11). The significant bloom measured on September 11 at Station 9 (upper St. John's Creek) is likely tied to nutrients (nitrogen and phosphorus) in run-off from the tropical storm.

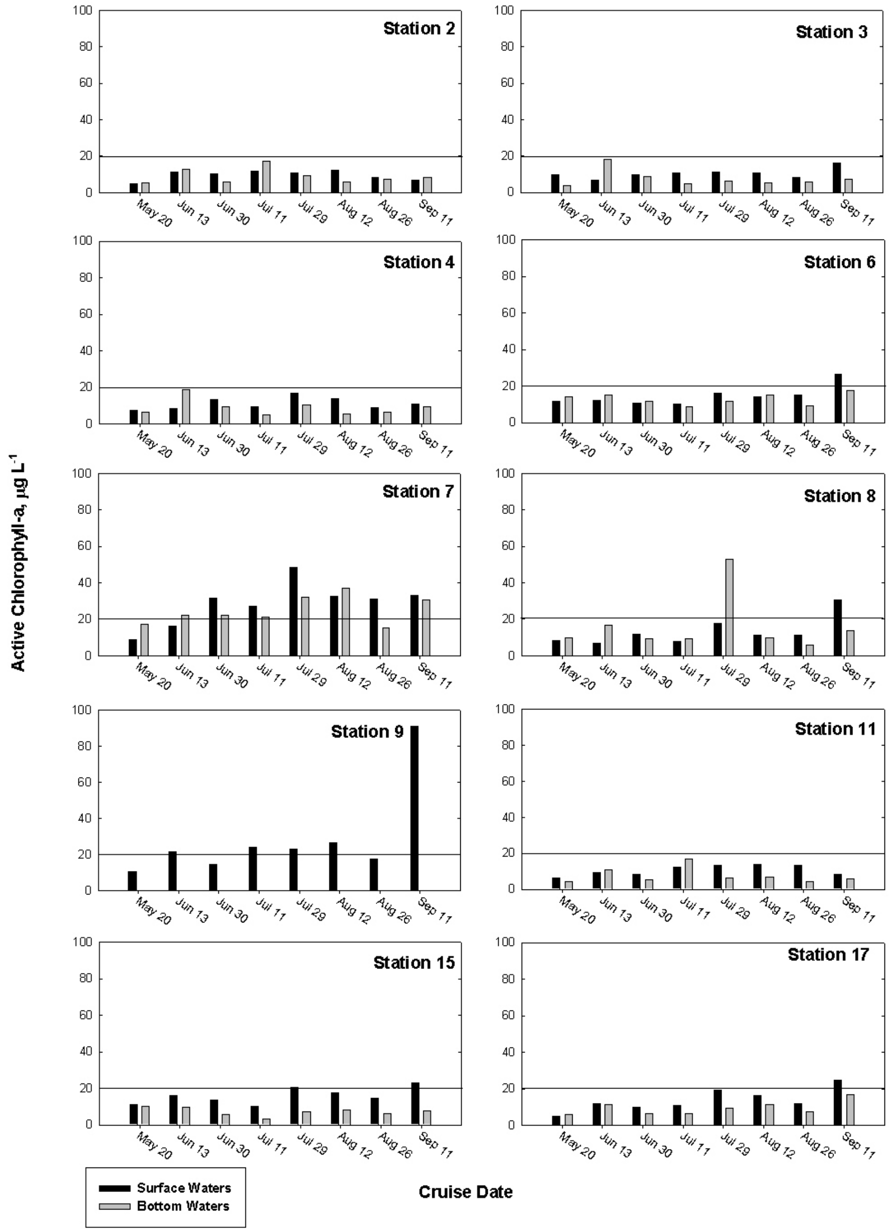


**Figure 3.6. Bar graphs of surface and bottom water active chlorophyll-*a* values for each station from May 20 through September 11, 2008.
No bottom water measurements were taken at station at station 9.**

3.4 Water Column Clarity

Figure 3.7

Water clarity was measured using a Secchi disc. The highest 2008 Secchi measurement (indicating the clearest water) was 2.2 meters (m) measured on May 20 at station 2 (in 2006 = 1.7 m, 2005 = 2.0 m). The highest Secchi readings at all stations were in May with an average of 1.65 meters. The lowest 2008 recording was 0.3 meters at Station 7 on June 30. Station 7 (upper Mill Creek) had the lowest readings on each cruise. The lowest Secchi readings at all other stations were on July 29.

Historical Secchi Ranges (lowest to highest clarity)

2003	2004	2005	2006	2007	2008
0.3-1.6	0.5-2.0	0.2-2.0 m	0.4-1.7 m	0.4-1.8 m	0.3-2.2

Light Penetration using Light Attenuation (Kd), Figure 3.8

Water column clarity and light penetration are very important parameters contributing to the growth of submerged aquatic vegetation (SAV). SAV not only provides food, oxygen, nursery areas and shelter for Bay animals, but can trap sediment and slow erosion, thus, further clearing the water. The Maryland Department of Natural Resources (DNR) has set a goal to restore SAV to about 185,000 acres in Chesapeake Bay by 2010. In 2008, 42% of the goal was reached. The Mill Creek sub estuary is located in the mesohaline portion (5.0 to 18.0 salinity) of the Bay. The goal in this area is to restore SAV to depths of one meter, requiring a light attenuation coefficient of ≤ 1.5.

This extinction or light attenuation coefficient (kd) is calculated based on the Secchi depth using the following equation: kd = 1.45/ Secchi. We can use this calculation to determine the depth that sufficient light penetrates for both algal growth (1% of surface radiation) and submerged aquatic vegetation or SAV (at 30% of surface radiation).

Light penetration sufficient for algal growth ranged from 0.81 meters (June) to 4.5-5 meters (May). The seasonal average Secchi depth of 1.08 meters allowed for 1% light penetration to 3 meters. Since the average mean depth of the Mill Creek system is about 2.0 meters, light for algal growth was present throughout most of the water column on most sampling dates as in past years.

During the sampling season, the 30% light penetration sufficient for submerged aquatic vegetation growth ranged from 0.21 meters (June) to 1.6 meters (May) with an average penetration of 0.8 meters. Thus, light sufficient for SAV growth at the 1.5 light attenuation coefficient was not present on the sampling dates. Note that the average depth of the Mill Creek estuarine system is about 2 meters.

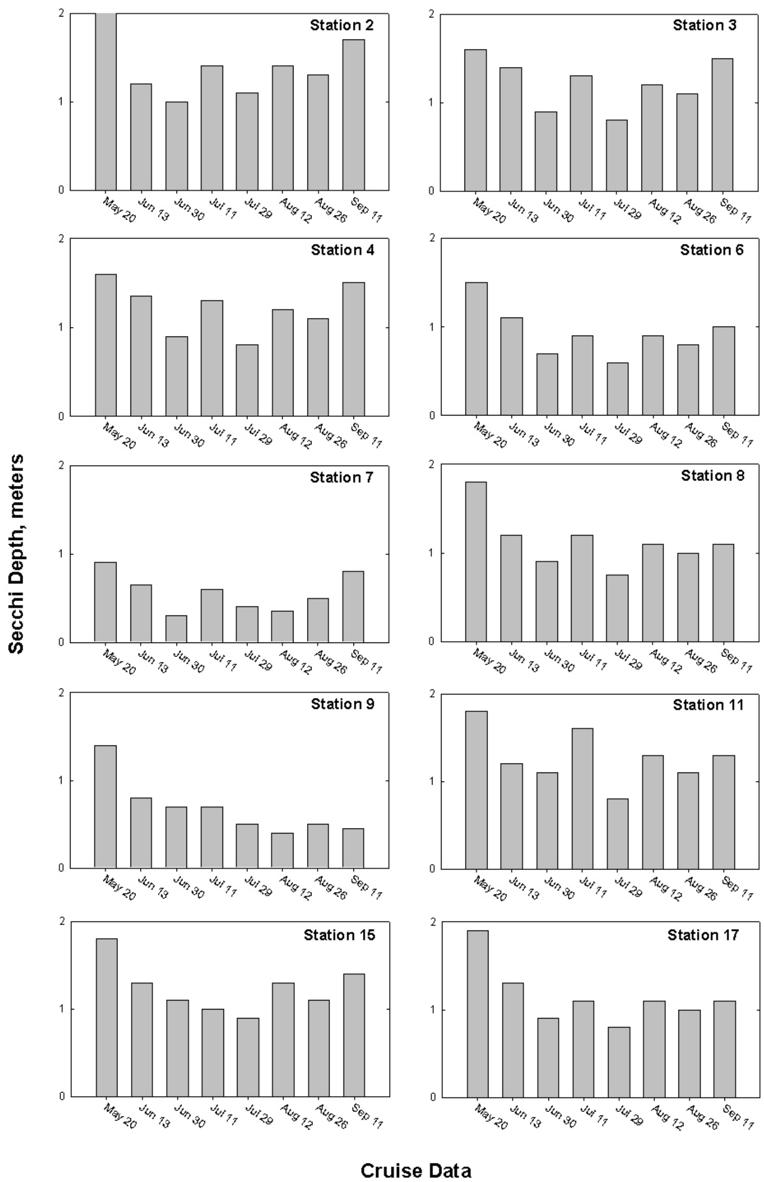


Figure 3.7. Bar graphs of water column Secchi disk measurements for each station from May 20 through September 11, 2008.

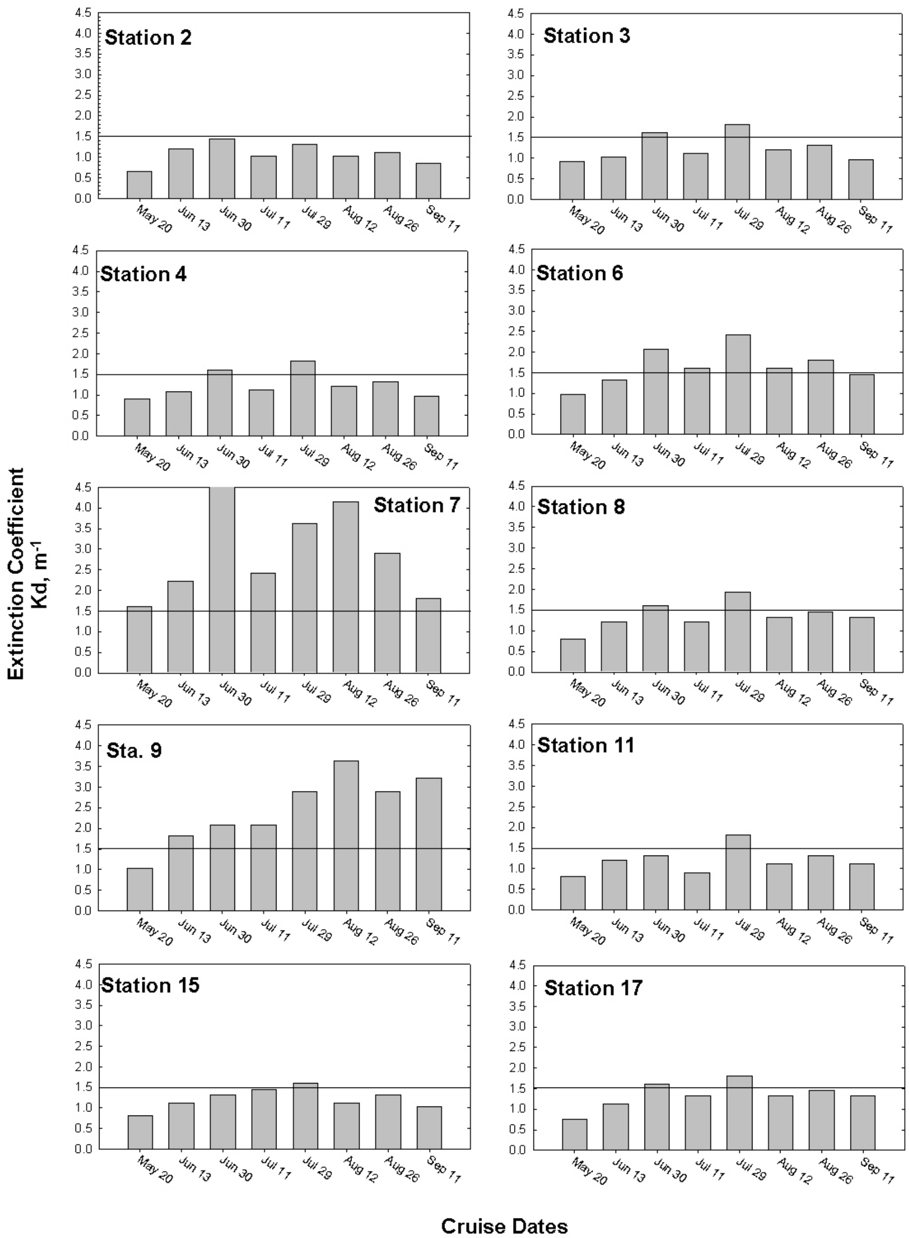


Figure 3.8. Bar graphs of light attenuation measurements (Kd) for each station from May 20 through September 11, 2008..
Line in each graph indicates the CBP restoration goal of KD = 1.5 at one meter.

3.5 Seafood and Swimming Safety Monitoring - update for 2008

Figures 3.9 and 3.10

During the presentation of the 2006 report to the Calvert County Board of County Commissioners the issue was raised concerning bacterial contamination of waters in the creek system. Additionally, the question was raised regarding seafood consumption advisories in the Solomons vicinity. Our water quality monitoring program does not make coliform measurements. However, the Maryland Department of Environment (who monitor bacteria for shellfish waters in the vicinity of Solomons) has supplied data since 2007.

MDE has three monitoring stations in the creek system for classifying shellfish (oyster/clam) harvesting waters along with a sanitary survey. Figure 3.9 depicts a total of 4 stations of interest: Station 005B, a reference Station located off of Sandy Point in the Patuxent River; Station 015A, near the SHS station 2 (Boat Shop); Station 109A, in Mill Creek at the mount of Saint John's Creek near the SHS station 4 (Pancake Point), and station 104 in Back Creek, near SHS station 15 (Calvert Marina).

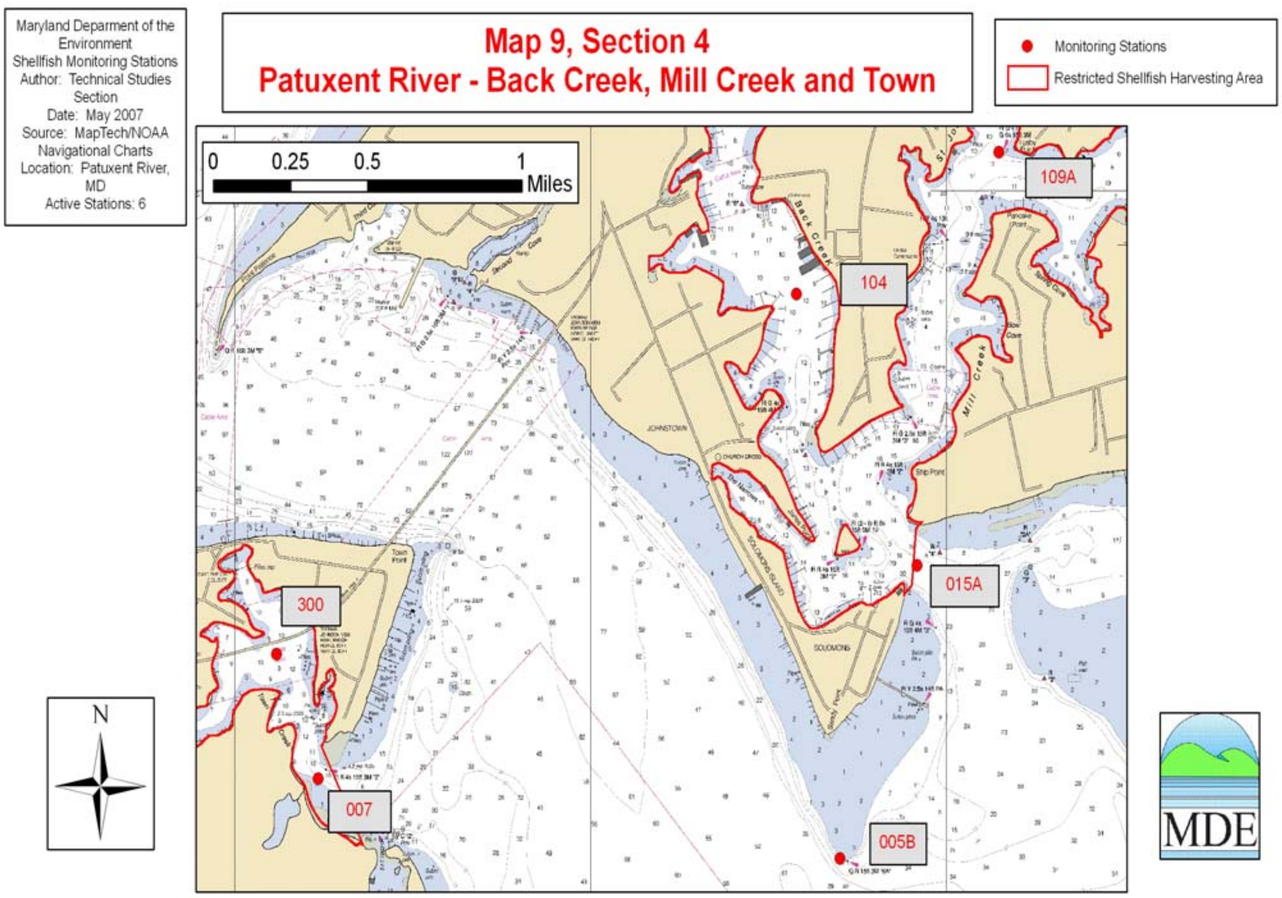


Figure 3.9. Map of the Maryland Department of the Environment (MDE) shellfish monitoring stations in the Mill Creek System

Fecal coliform is the indicator used for classifying shellfish waters. Water quality standards for shellfish harvesting require that fecal coliform numbers be ≤ 70 MPN/100 ml. (MPN = most probable number per 100 milliliters of water.)

The charts and graphs in figure 3.10A and B display the January - October 2008 fecal coliform sample analyses. Numbers greater than 70 MPN/100 ml are highlighted.

The Reference Station, 005B located at Sandy Point, remained very low all summer (in general lower than in 2007) with counts ranging from 1 MPN/ml to 9.1 MPN/ml. Station 015A, at the SHS Boat Shop station met the water quality standards except for a very large peak on July 15 of 360 MPN/100 ml. Minimal rain fell over July 14 and 15 (0.2 inches); thus, this spike was probably not due to run-off. The 2008 average without using the spike count was 13.2 - only slightly (but not significantly) higher than the 2007 count of 8.1 MPN/100ml. Including the spike, the 2008 average rose to 44.8 MPN/100ml.

All of the Mill Creek station samples, (109A) met water quality standards with a range of 1 to 43 MPN/100 ml. The 2008 average count of 11.7 MPN/100ml was essentially the same as for 2007 (10.7 MPN/100ml). The Back Creek station failed twice, in August and September. This station was not sampled in May of 2008 although it failed in May of 2007. The 2008 average count was 36.5 MPN/100ml - a bit higher (but not significantly) than the 2007 average count of 27.4 MPN/100 ml.

Even though the bacteria standards are largely achieved, MDE will keep the entire area closed to shellfish harvesting due to shoreline activities and the intensity of boating activities, increasing the potential for overboard discharge of untreated sewage.

MDE does monitor for contaminants in fish and shellfish. There are no advisories for Solomon's Harbor for eating crab meat. However, the advisory does mention that the "mustard" should be eaten sparingly. Further details regarding crab or fish advisories can be obtained by contacting John Backus at MDE (410-537-3965).

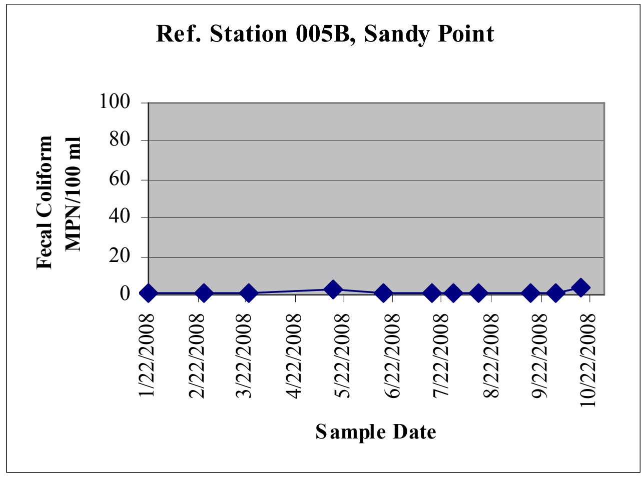
Swimming Safety

MDE does not monitor for swimming safety, but they do work closely with the local health departments who determine where beach monitoring should occur. No beaches in the Mill Creek system are monitored by Calvert County. They do monitor a beach at Drum Point on the Chesapeake Bay side. The bacteria indicator used for beach monitoring in estuarine waters is *enterococci*. U.S. EPA regulations state that waters used for Class 1 primary contact (including such activities as swimming, rafting, and kayaking) shall not have fecal coliform counts above 200 fecal coliforms per 100 ml. Waters used for Class 2 secondary contact (non-primary contact waters, including, but not limited to, fishing and other streamside or lakeside recreation) should not have fecal coliform counts above 2000 fecal coliforms per 100 ml.

To read a layman's discussion of factors affecting fecal coliform, please refer to the following web site:
http://bcn.boulder.co.us/basin/data/BACT/info/FColi.html

Station ID	Sample Date	Fecal Coliform MPN/ 100 ml
09-04-005B	1/22/2008	1
	2/25/2008	1
	3/24/2008	1
	5/15/2008	3
	6/16/2008	1
	7/15/2008	1
	7/29/2008	1
	8/13/2008	1
	9/15/2008	1
	9/30/2008	1
	10/16/2008	3.6

2007 Ave 4.5
2008 Ave 1.4



Station ID	Sample Date	Fecal Coliform MPN/ 100 ml
09-04-015A	1/22/2008	1
	2/25/2008	1
	3/24/2008	1
	5/15/2008	9.1
	6/16/2008	43
	7/15/2008	360
	7/29/2008	15
	8/13/2008	9.1
	9/15/2008	1
	9/30/2008	9.1
	10/16/2008	43

2007 Ave 8.1
2008 Ave 44.8 (13.2) without 360

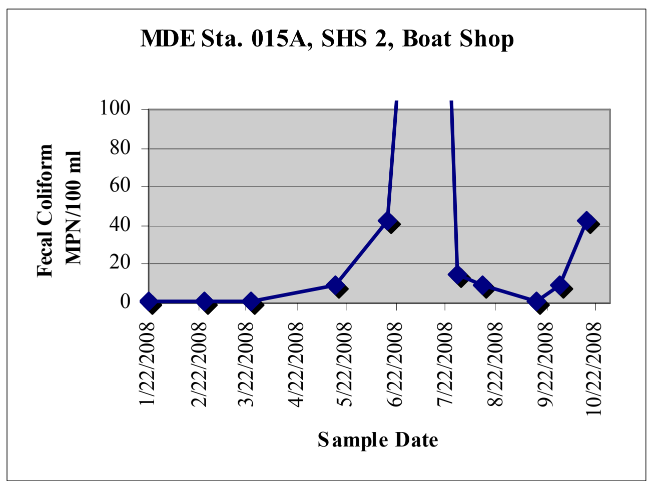
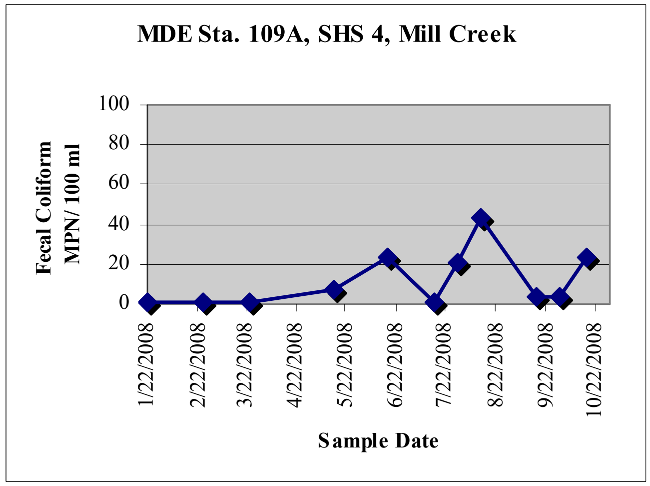


Figure 3.10A. Fecal coliform counts from a reference station located in the Patuxent River and one station at the mouth of the Mill Creek System in 2008. The averages for each station for 2007 and 2008 are listed.

Station ID	Sample Date	Fecal Coliform MPN/ 100 ml
09-04-109A	1/22/2008	1
	2/25/2008	1
	3/24/2008	1
	5/15/2008	7.3
	6/16/2008	23
	7/15/2008	1
	7/29/2008	21
	8/13/2008	43
	9/15/2008	3.6
	9/30/2008	3.6
	10/16/2008	23

2007 Ave 10.7
2008 Ave 11.7



Station ID	Sample Date	Fecal Coliform MPN/ 100 ml
09-04-104	1/22/2008	1
	2/25/2008	1
	3/24/2008	36
	5/15/2008	
	6/16/2008	23
	7/15/2008	23
	7/29/2008	9.1
	8/13/2008	93
	9/15/2008	43
	9/30/2008	93
	10/16/2008	43

2007 Ave 27.4
2008 Ave 36.5

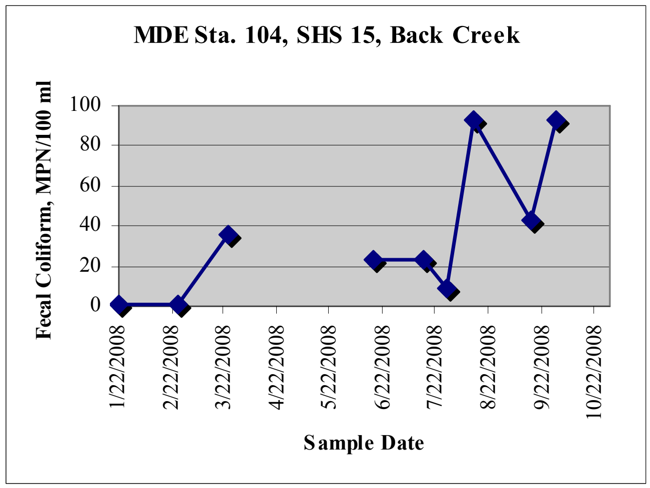


Figure 3.10B. Fecal coliform counts from 2 stations in the Mill Creek System in 2008. The averages for each station for 2007 and 2008 are listed. No sample was taken in Back Creek on 15 May.

4. Precipitation Patterns and River Flow

4.1 Precipitation (*Figures 4.1 A&B)*

To understand the water quality in the Mill Creek system it is critical to consider spring and summer precipitation. This section describes when and how materials enter the system from the surrounding land and from the Patuxent River, then notes the 2008 and the long-term trends.

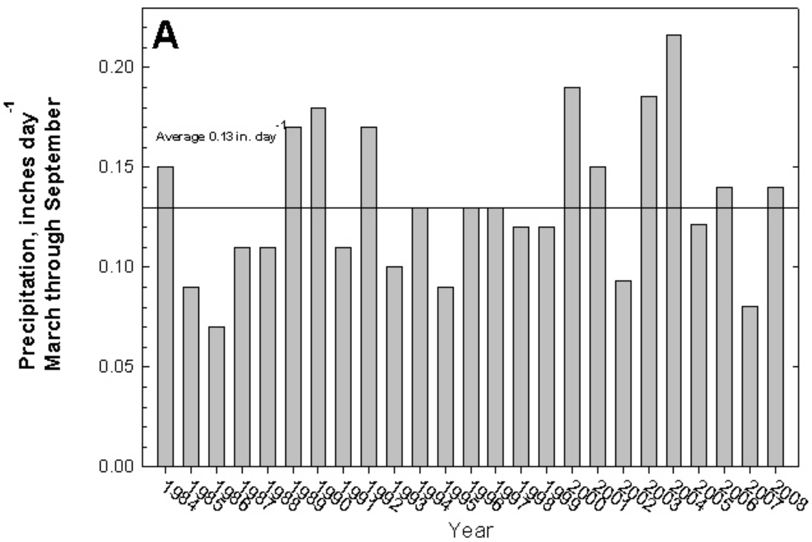
In general, the level of precipitation provides an index of the potential amount of nitrogen and phosphorus (as well as other materials), which could enter the Mill Creek system as diffuse source run-off. While there is not a simple relationship between precipitation and diffuse source nutrient loading (Summers 1989), loading generally increases in proportion to precipitation. As a result, nutrient loads to the Mill Creek system can be expected to be larger in wet than in dry years. The magnitude of spring river flow reflects the intensity of spring rainfall. Since river water is ultimately of terrestrial origin, it is responsible for the import of a significant amount of nutrients to the estuary (Kemp and Boynton, 1992). This supply of nutrients can then generate spring algal blooms.

This relationship between river flow and algal biomass has been documented in a number of estuaries (Nichols and Cloern, 1985; Malone *et al.*, 1988; Christian *et al.*, 1991; Kemp and Boynton, 1992). Typically, with increased river input in the spring, the amount of nutrients imported to the system increases and therefore the potential for more intense algal blooms increase. Furthermore, decay of an algal bloom and its subsequent sinking to the bottom can stimulate bacteria which draw down dissolved oxygen and decrease habitat quality for fish, seagrass, and other organisms.

Average daily precipitation in the Mill Creek system (measured at a NOAA station located at CBL) for the period of March through September has been collected during the past twenty-five years (1984 – 2008). This time interval corresponds with sampling dates of the present and previous Mill Creek system studies.

The March through September average precipitation of 0.14 inches day^{-1} , is just above the 25-year average of 0.13 inches per day (Fig 4.1B). May and June received 0.21 and 0.25 inches per day respectively, with 7.6 inches falling in June. Below-average precipitation fell in March, April, August and September.

However, except for a short pulse of chorophyll that may be observed directly after a rain event, the systems in Chesapeake Bay appear to be driven by the rainfall (and river discharge (including associated nutrients) occurring earlier in the year (March/April) when leaves are not yet on the trees and evapotranspiration is low and temperatures are still cool.



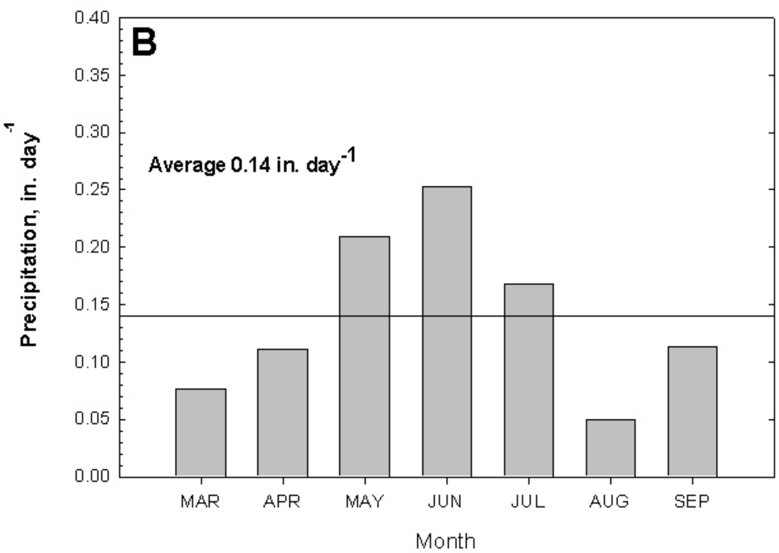


Figure 4.1.A&B. **Bar graphs showing (A) the mean daily seasonal precipitation (March through September) for 1984 to 2008 and the mean daily precipitation for these same months during 2008. The solid horizontal line in both graphs indicates the average daily precipitation.**

4.2 River Flow (*Figures 4.2 A&B)*

Mean Patuxent River flow for each month from January through May for 2008 was obtained from a discharge gauge at station 01594440 Patuxent River at Bowie, MD. It is maintained by the United States Geological Survey (USGS).

The January-May 2008 mean flow for the year, 468 cubic feet per second (cfs), is just below the twenty-two year average of 501 cfs. Like most of the Chesapeake Bay region, the Patuxent river watershed mainly experienced a dry winter and spring during 2008 (with the exception of the record-breaking average May discharge of 928 cfs – one day recorded 6000 cfs) all months were at or below average).

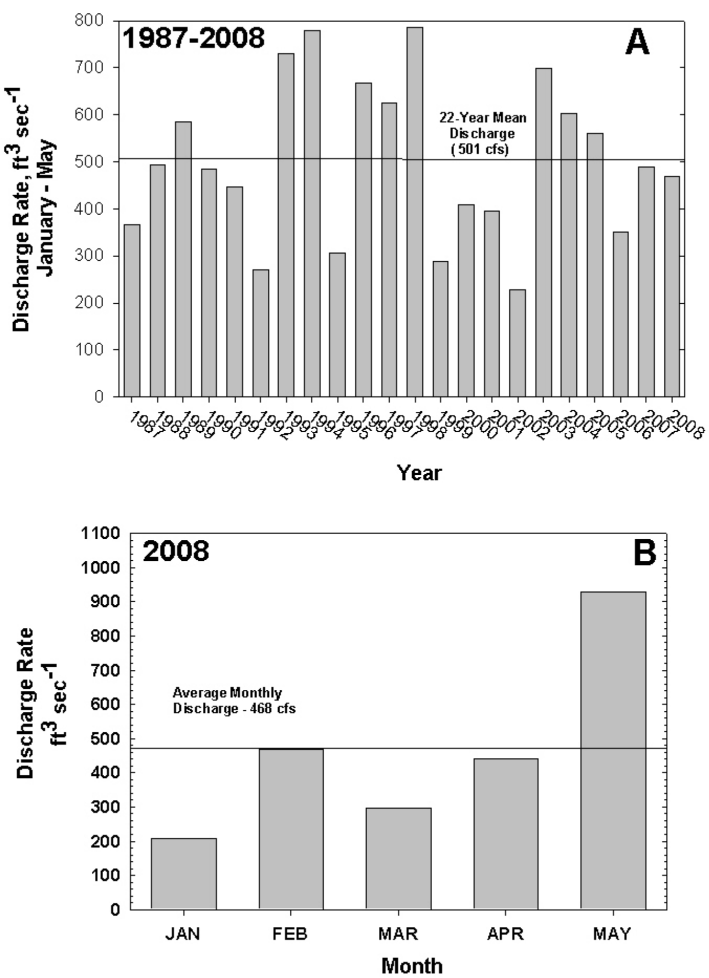


Figure 4.2.A&B. Bar graphs showing (A) Patuxent River mean winter-spring flow (January through May) for 1987 to 2008 and the (B) mean monthly winter-spring flow for 2008. Average flows during the history of the study are indicated.

5. Long Term Water Quality Trends

To determine if trends were evident in Mill Creek system water quality conditions. We examined data from 5 representative stations: 2 Boat Shop (Mill Creek system mouth), 6 Coles Creek (mid Mill Creek), 7 Ranch Club (upper Mill Creek), 9 Lore's Creek (upper St. John's Creek), and 15 Calvert Marina (mid Back Creek). Two variables were examined, bottom water dissolved oxygen concentrations and surface water active chlorophyll-*a* concentrations. These variables are good indicators of the water quality status of estuarine systems.

5.1. Dissolved Oxygen Trends

Figure 5.1A

The average mean bottom water dissolved oxygen concentrations for these stations (except for station 9) for the summer periods for 1987, 1990-2008 are summarized in Figure 5.1A. The average long-term bottom water dissolved oxygen concentration is 4.29 mg L^{-1}. As in 2007, bottom-water dissolved oxygen concentrations in 2008 again decreased, indicating a possible worsening trend in bottom water quality. Even though anoxic conditions (dissolved oxygen concentrations of zero milligrams per liter) have never been observed, hypoxic conditions (less than 2.0 mg L^{-1}) are observed frequently enough to continue monitoring these trends. Ranking mean bottom water dissolved oxygen concentrations for all years with existing data (20 out of 22) creates the following pattern from high (better) to low (worse):

1991>1997>2002>1992>1994>2001>1998>1996>2000>2006
>1999>1995>1990>1987>2005>1993>2007>2004>**2008**>2003

5.2. Chlorophyll and Algal Bloom Trends

Figures 5.1B & 5.2

Surface active chlorophyll-*a* concentration means for stations 2, 6, 7, 9, and 15 from 1997 through 2008 are depicted in Figure 5.1B. Ranking mean bottom water dissolved oxygen concentrations for all years with existing data (20 out of 22) creates the following pattern from low (better) to high (worse):

1991<1992<1995<1999<2002<2000<1997<1993<1987<2001
<1994<2006<2005<1990<**2008**<1996<2004<2007<1998<2003

The surface mean active chlorophyll-*a* concentration decreased slightly from last year's average (22.3) to 19.5 μg L^{-1} , but is still in the highest third of all years. This yearly average is still greater than the 1987-2008 average concentration of ~17.2 μg L^{-1}. The highest observed average yearly concentration, in 2003, was twice as high as the average at 45.21 μg L^{-1} which skews the multi-year average.

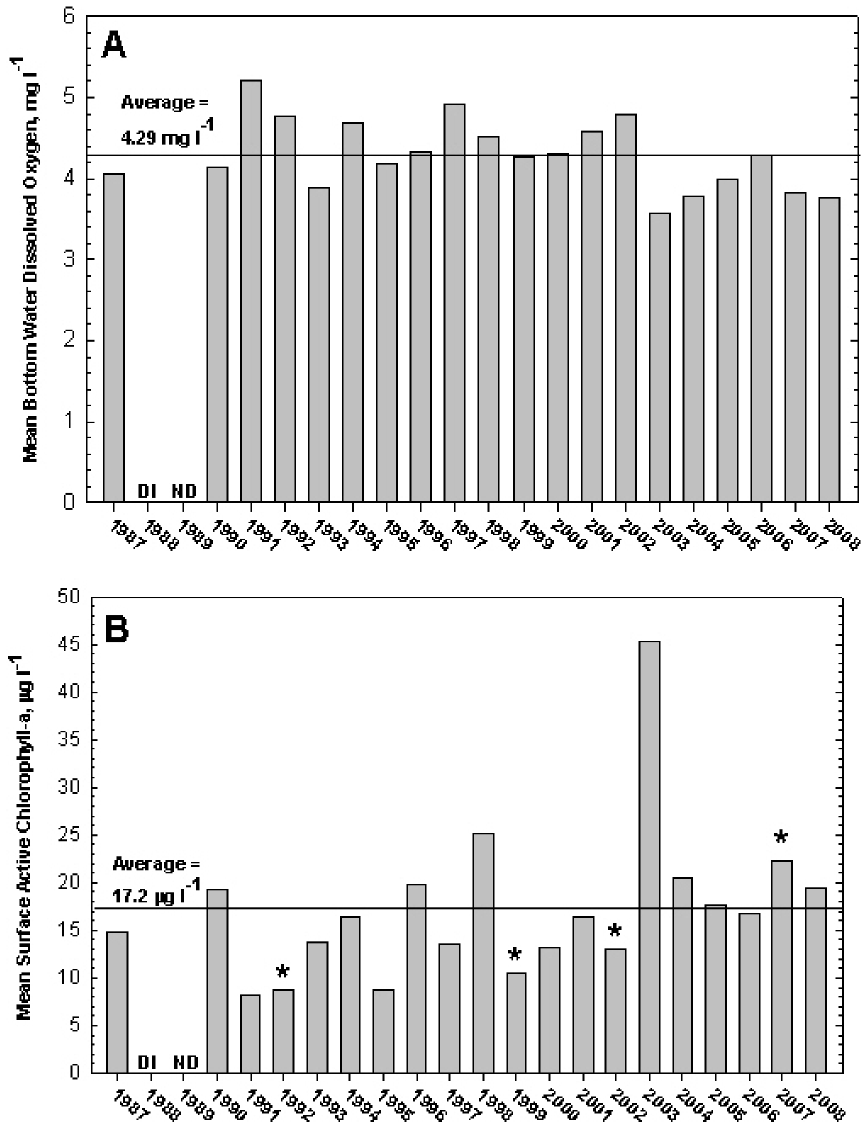


Figure 5.1.A&B. Bar graphs of (A) bottom water mean dissolved oxygen concentrations at the inter-annual comparison sites (stations 2, 6, 7, 9(historical) and 15) from 1987 through 2008, and (B) mean surface water active chlorophyll-*a* concentrations at the inter-annual comparison sites (stations 2, 6, 7, 9 and 15) from 1987 through 2008.
***In graph B, the drought years (1992, 1999, 2002 and 2007) are starred.**
DI = Data set for 1988 was incomplete. ND = Study was not funded 1989.

For this program, an algal bloom is defined as any concentration of active chlorophyll-*a* greater than 20 µg L^{-1}. Occurrences of algal blooms at the five inter-annual comparison stations were tallied using the norm of eight cruises per year (Figure 5.2). This year produced 14 blooms dropping it to the fifth highest year. In comparison, no blooms occurred during 1999, while 2003 produced the maximum of 29 blooms. Ranking occurrences of algal blooms since 1987 gives the following pattern from lowest (better) to highest (worse) number of blooms:

1999<1995<2002<1991=1992<2005<1993=1997=2000<1987=1990
<2006<1994=2001<1996=2008<2004<1998<2007<2003

In general, algal blooms rankings are similar to active chlorophyll-*a* rankings.

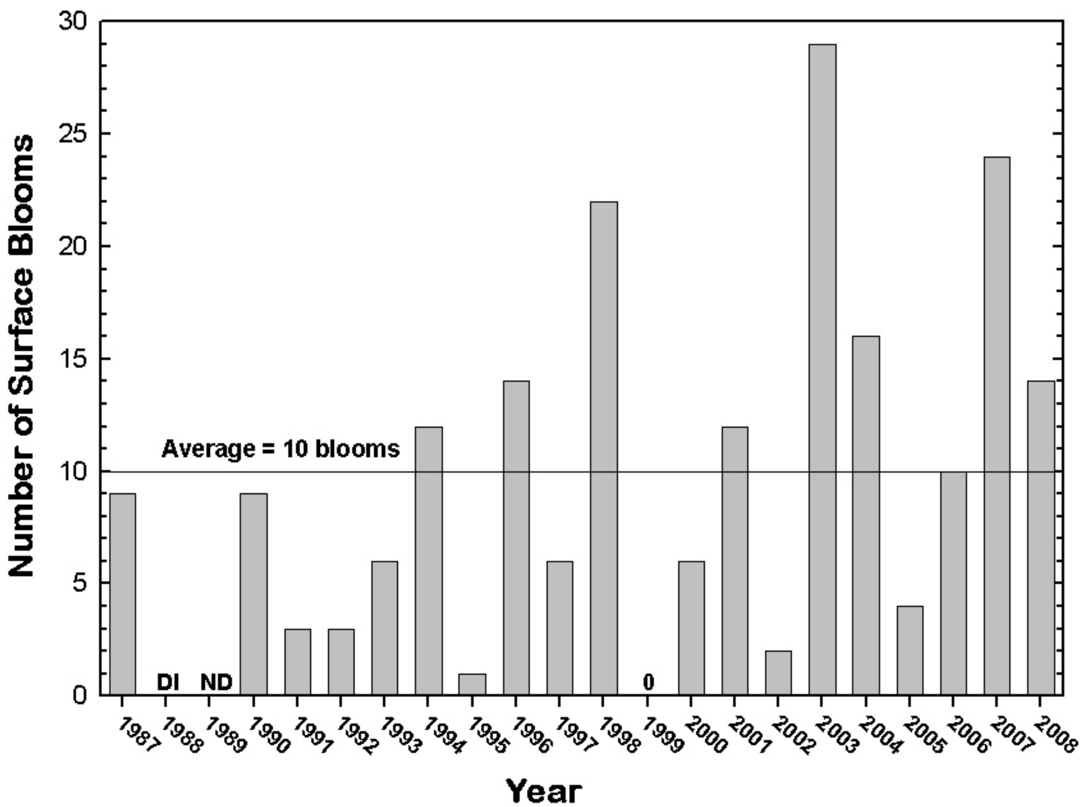


Figure 5.2. Bar graph of surface chlorophyll-*a* blooms at the inter-annual comparison stations 2, 6, 7, 9 and 15 from 1987 through 2008. Note that chlorophyll-a concentrations measuring greater than 20 µg L^{-1} were defined as blooms. DI = Data set for 1988 was incomplete. ND = No study was funded in 1989.

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