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Water Quality Monitoring Program for Mill Creek and its Tributaries Located in Southern Calvert County

Summer 2007

Final Report
Prepared for the Calvert County Board of County Commissioners

By

Janet Barnes, Senior Faculty Research Assistant
Dr. Walter R. Boynton, Professor

University of Maryland Center for Environmental Science
Chesapeake Biological Laboratory
P.O. Box 38
Solomons, Maryland 20688-0038

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Table of Contents

Figures and Tables

Acknowledgements

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1. The Calvert County Board of County Commissioners provides 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 and Bryan Stuller (summer teacher intern).

4. The Nutrient Analytical Services Laboratory (NASL) based at CBL, provides valuable guidance and assistance with sample collection techniques and performs the laboratory analyses, ensuring the integrity of the results presented in this report.

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

Executive Summary

Overall, the year 2007 represented relatively poor water quality conditions, despite the summer being a dry period. For example, both mean surface chlorophyll and bottom dissolved oxygen concentrations were slightly above and slightly below, respectively, the 20 year average. In the context of the past few years, these conditions in Mill Creek and its surrounding tributaries illustrate less favorable water quality conditions.

Yearly Monitoring Measurements

As in all years of this monitoring study, measurements included water column temperature, salinity, dissolved oxygen, clarity and chlorophyll-*a* concentrations. These variables were measured at 10 fixed stations on 8 occasions during 2007 (once in May, bimonthly in June, July, August, and once in September). Station locations, sampling frequencies and analytical methodologies were identical to those used in previous years.

Water Column Clarity

Water clarity, measured using a Secchi disc, is affected by runoff, resuspension of bottom sediment, algal blooms and submerged aquatic vegetation. The minimum light necessary for algal growth is estimated to be 1% of surface radiation, while the minimum light necessary for SAV growth is estimated to be 30% of the surface radiation. At the lowest Secchi reading of 0.4 meters (kd = 3.62), light sufficient for algal growth penetrates to 1.3 meters; for SAV sufficient light penetrates to only 0.33 meters. At the highest Secchi reading of 1.8 meters (kd = 0.83), 1% of the surface radiation penetrates to 5.4 meters and 30% surface radiation penetrates to 1.4 meters. Since the average mean depth of the system is about 2.0 meters, light sufficient for algal growth throughout most of the water column was present on most sampling dates. However, light sufficient for SAV growth throughout an average depth of 2 meters was not present on the sampling dates.

Shellfish and Swimming Safety Review

We reviewed available 2007 MDE fecal coliform data for this drainage basin. Two of the stations meet the water quality standards for shellfish harvesting (not greater than 70 MPN per 100 ml). In general, Back Creek samples were higher 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 fecal coliforms per 100 ml. The highest concentration measured in the Mill Creek system in 2007 was 93 MPN/ 100 mls.

Precipitation and River Flow/Discharge

Precipitation and river discharge patterns exert substantial influence on water quality conditions. Average precipitation within the Mill Creek system drainage basin during the 2007 sampling season (March through September) was 0.08 inches day^{-1}, among the lowest observed average precipitation for the past 20 years of monitoring. The lowest average recorded during the monitoring program was 0.07 inches day^{-1} in 1986, and the highest was 0.22 inches day^{-1} in 2004.

The January-May 2007 mean discharge measured at Bowie, Maryland, at 490 cfs, is just below the nineteen year average of 503 cfs. Like most of the Chesapeake Bay region, the Patuxent river watershed experienced a drier than normal winter and spring during 2007.

Long-Term Trends for Dissolved Oxygen and Chorophyll-a

In the context of the past five years, dissolved oxygen concentrations in the bottom waters at the long-term trend stations decreased for the first time since 2003, indicating a possible decrease 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, increased to 22.3 µg L^{-1} - the third highest average in 11 years. This is an increase from the past 3 years and above the average concentration of ~17 µg L^{-1}. Twenty four (24) algal blooms (concentrations of active chlorophyll-*a* greater than 20 µg L^{-1}) were measured at these same five inter-annual comparison stations. This is the second highest number since 1997.

Conclusions

- Monitoring of Mill Creek and its surrounding tributaries has been conducted for the past twenty-one years. During 2007, the water quality of the system was below average. Algal blooms and the resulting bottom water hypoxia are common, especially in late summer.

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

- In the context of the past several years (2005 and 2006), it appeared that the system was slowly improving after two very wet years (2003 and 2004) produced suboptimal conditions.

  However, conditions were sub-optimal during 2007 despite dry conditions. Why? Since there is little surface run-off, the nutrients fueling increased algal biomass may be coming from near-surface groundwater. As the basin develops (which it has), we would expect increasing level of nitrogen in this groundwater.

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, BNR, installation of ENR septic systems, riparian and vegetative buffer zones, and encourage the use of pump-out facilities by boaters within the Mill Creek system.

- Encourage MDE to continue or intensify its 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.

Mill Creek, St. John Creek, Back Creek, The Narrows and Solomons Harbor located within the Dowell, Drum Point, Lusby, Olivet and Solomons portion of southern Calvert County, Maryland (referred to as the ***Mill Creek system*** in this report), is one of these smaller sub-estuarine systems. 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 1990-2006. 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 2007 Mill Creek study followed the scaled-down format used in recent years that focuses on water column temperature, salinity, dissolved oxygen, clarity and chlorophyll-*a* concentrations. The effects and long-term trends of Patuxent River flow/discharge, precipitation, Mill Creek system chlorophyll-*a* concentrations and water column stratification on bottom water dissolved oxygen levels were 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 22, 2007 and ending on September 12, 2007. The data from these eight cruises characterized the water quality of the Mill Creek system during the spring and summer periods of 2007 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 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.

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 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 (depth of 1 meter) only surface measurements were recorded. Evidence for water column stratification was checked on each cruise. Water column turbidity was measured using a Secchi disk. 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).

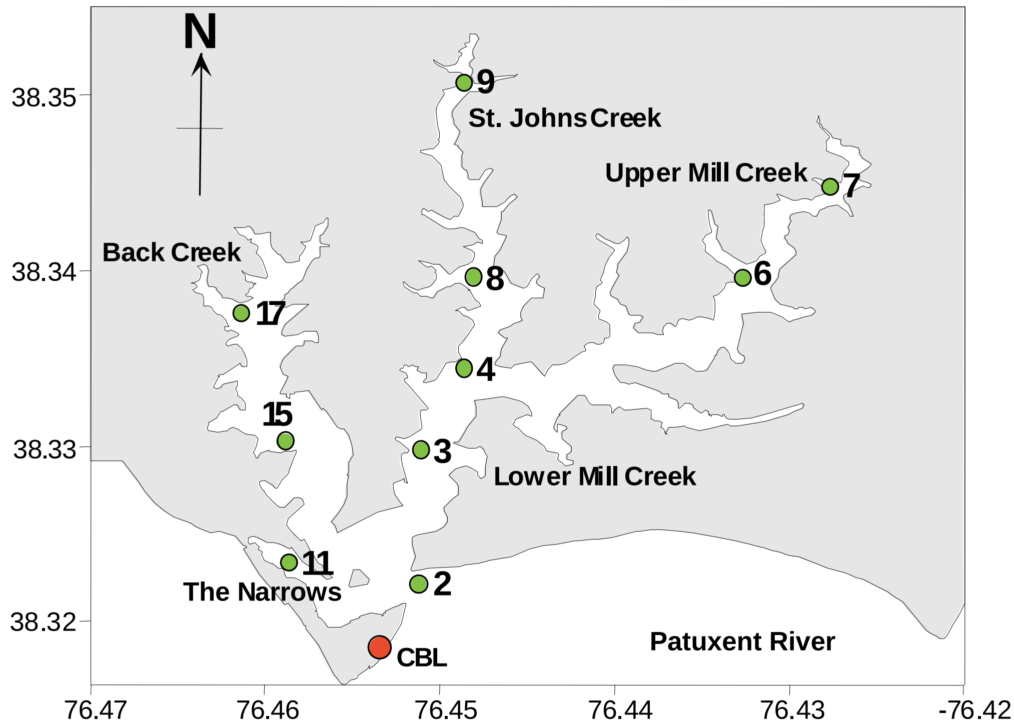

Figure 2.1. Map of the sampling sites within the Mill Creek system.

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 Transport 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 2007 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 18.66°C (station 2, May 22) to 28.27°C (station 7, July 13). The 2006 range = 18.07°C to 29.52°C; 2005 range = 16.93°C to 31.20°C.

May Surface Temperatures:

May 22, 2004	May 26, 2005	May 23, 2006	May 22, 2007
24.44°C	18.57°C	19.07°C	19.83°C

The bottom temperature range of 18.18 °C (station 4, May 22) to 28.26°C (station 4, August 15) was slightly smaller than in 2006 (17.9°C to 29.54°C).

May Bottom Temperatures:

May 22, 2004	May 26, 2005	May 23, 2006	May 22, 2007
22.64°C	17.67°C	18.89°C	18.91°C

Warmer water temperatures encourage epiphytic growth on SAV and increased respiration (oxygen consumption). Both surface and bottom water temperature increased from May to June, then remained at about the same level throughout the sampling season. The average June through early September temperatures were 26.89 (surface) and 26.44 (bottom). As in the past, neither surface nor bottom temperatures exhibited any significant spatial trends within this system.

Salinity, Figure 3.2
All salinities gradually increased over the sampling season with bottom salinities slightly greater than or equal to surface salinities. The average difference between the two depths, 0.4 ppt, was small and similar to most years (<0.5 ppt).

Surface water salinity ranged from 9.07 ppt (station 7 on May 22) to 15.16 ppt (station 11 on September 12).

Surface Salinity Ranges (ppt):

2003	2004	2005	2006	2007
6.00-12.21	6.12-11.89	5.05 - 14.66	9.8 - 14.93	9.07 - 15.16

Bottom water salinity ranged from 9.74 ppt (station 7, May 22) to 15.93 (Station 3, September 12).

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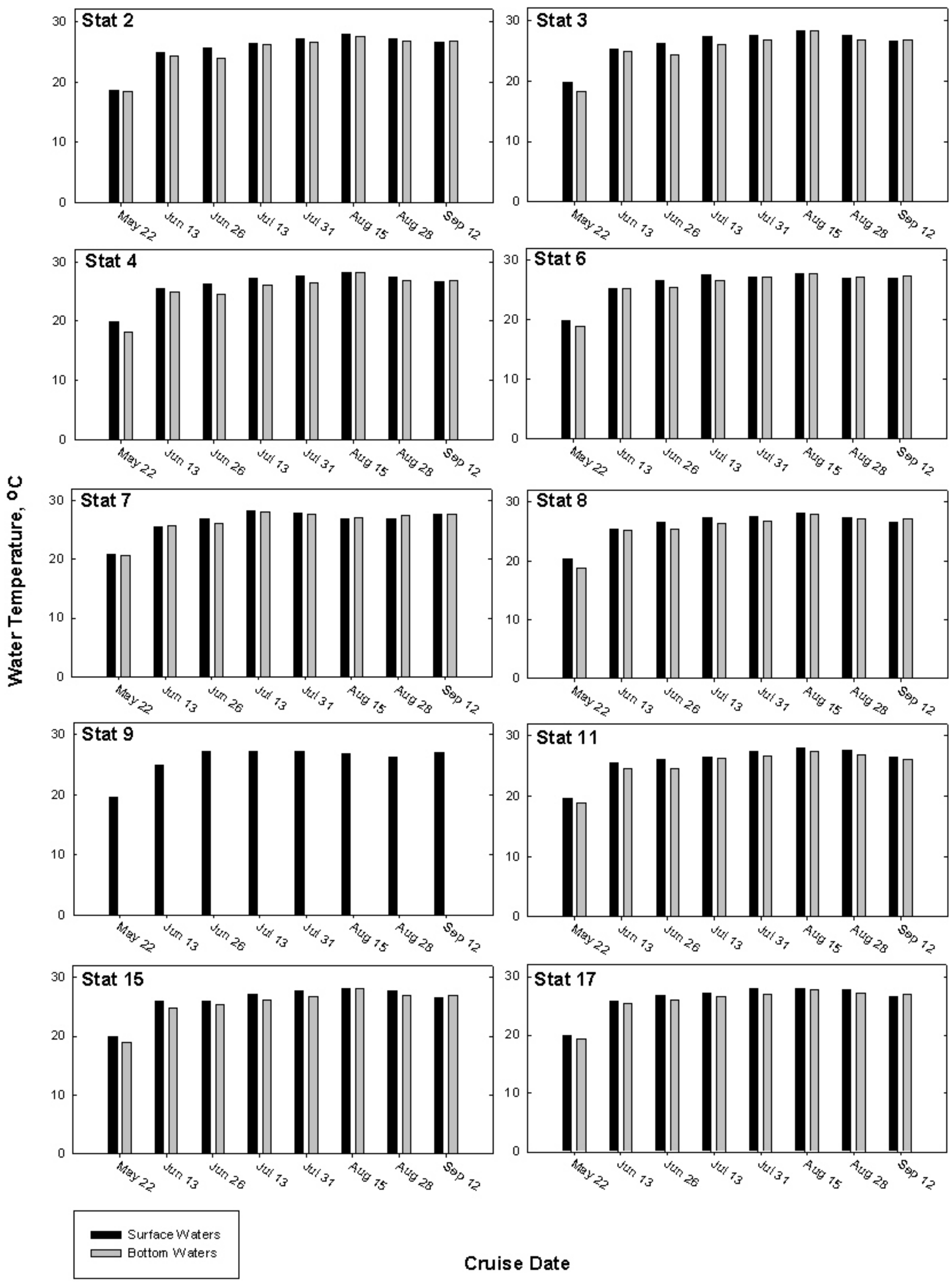


Figure 3.1. Bar graphs of surface and bottom water temperature measured at each station from May 22 through September 12, 2007. No bottom water temperatures were measured at station 9.

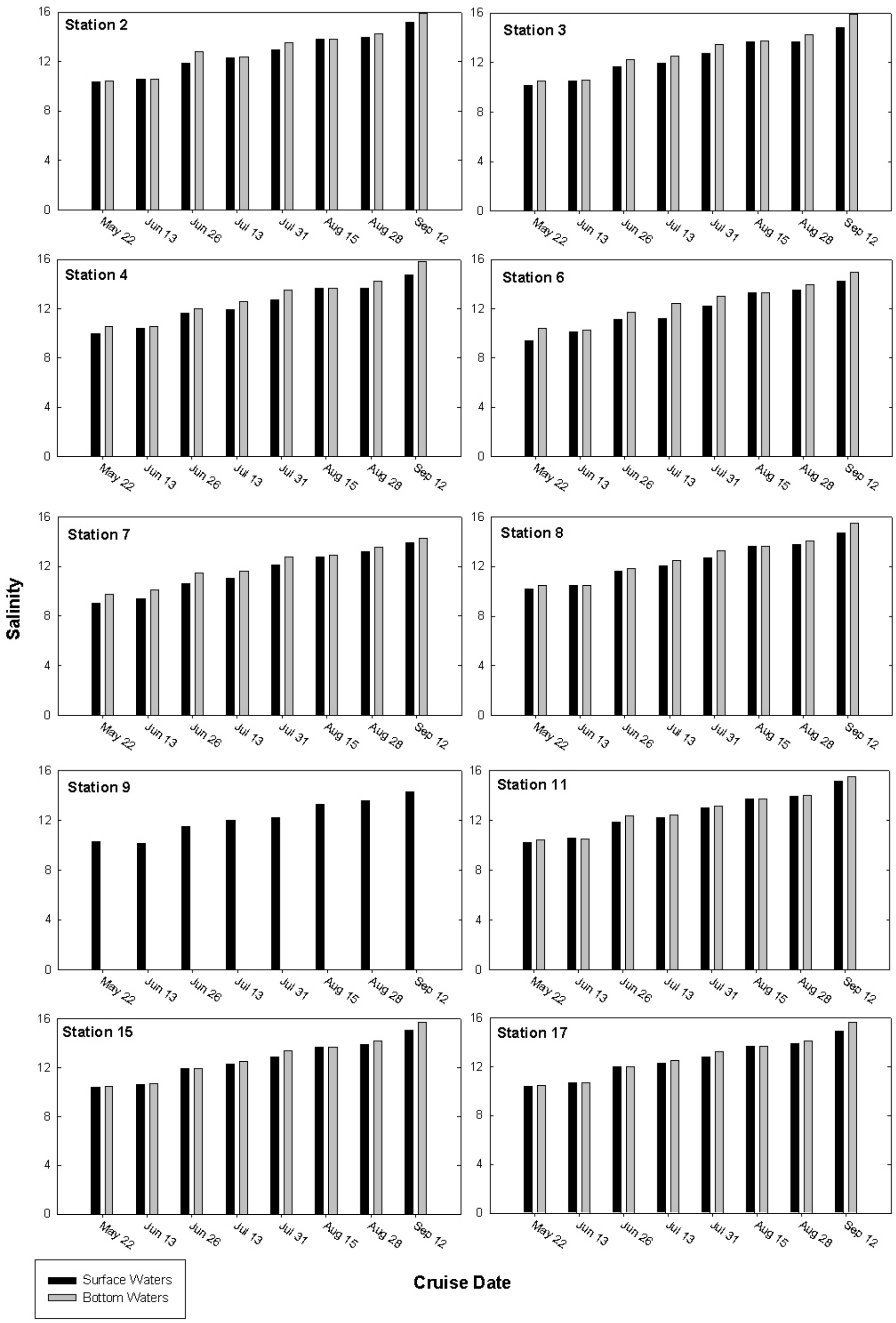


Figure 3.2. Bar graphs of surface and bottom water salinity values measured at each station from May 22 through September 12, 2007. No bottom water salinities were measured at station 9.

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 producing a measure of stratification strength. In general, stratification in these tributaries is weak, driven by wind and freshwater inflow. Bottom water sigma-t was higher than surface water sigma-t at all stations except on August 15 at stations 3, 4 and 6 where sigma-t was 0.00 - 0.01. The difference between surface and bottom sigma-t values provides an indication of the stratification strength of the water column. As in past years, stratification strength was highly variable. Four of the nine stations peaked on June 26. However peaks for the remaining 5 stations occurred during different times during the season. Station 9 rarely shows any stratification due to its shallow, one-meter depth. (Bottom readings at station 9 are checked but not recorded.)

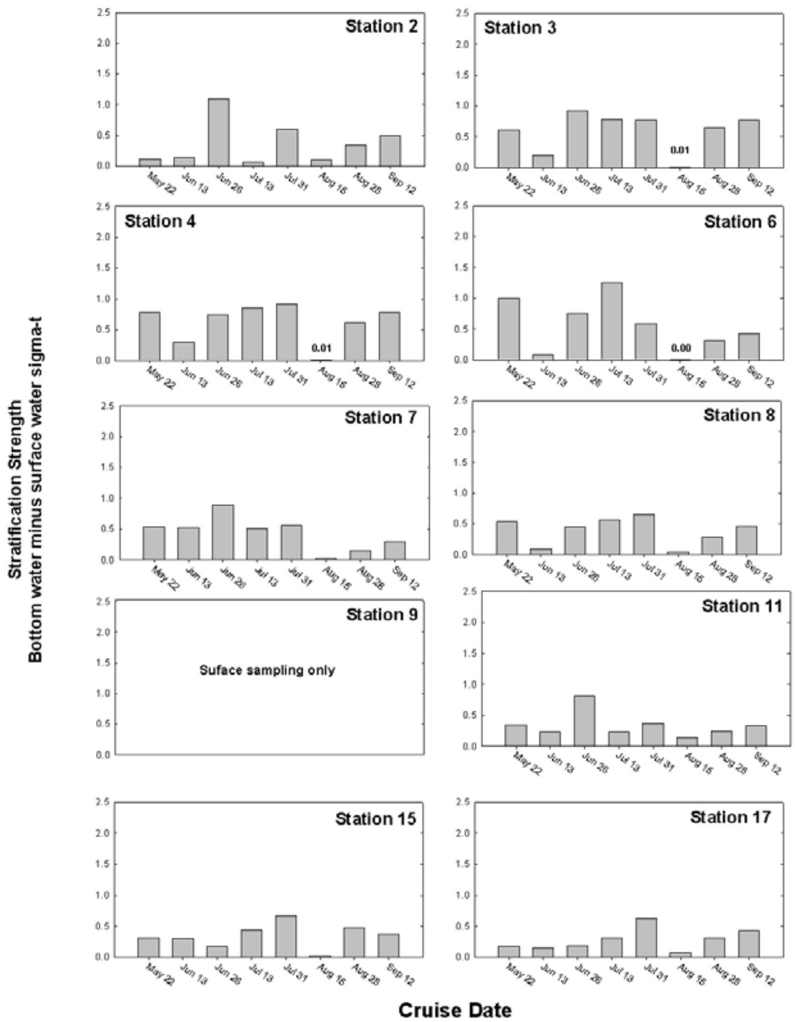


Figure 3.3. Bar graphs of water column stratification represented as the difference between surface and bottom water sigma-t values calculated for each station from May 22 through September 12, 2007. No bottom water measurements were taken at station at station 9.

3.2 Dissolved Oxygen

Figure 3.4 and 3.5A

The dissolved oxygen concentration of surface waters ranged from 2.12 milligrams per liter (mg L^{-1}) at station 7 (July 31) to 8.32 mg L^{-1} (station 8, May 22). Bottom water dissolved oxygen concentrations ranged from 0.88 mg L^{-1} (station 7, July 31) to 6.99 mg L^{-1} (station 2, May 22).

Surface water oxygen concentration ranges (mg/l):

2004	2005	2006	2007
0.79 - 10.10	1.86 - 11.92	2.10 - 9.47	2.12 - 8.32

Bottom water oxygen concentration ranges (mg/l):

2004	2005	2006	2007
0.18 - 7.31	0.3 - 9.56	1.18 - 7.91	.88 - 6.99

Eleven percent (11%) of the bottom water dissolved oxygen levels were below 2.0 mg L^{-1} during the 2007 study as compared to 10% in 2006, 24% in 2005, 30.6% of 2003, and 8% of the 2002 readings (Figure 3.5A). Levels below 2.0 mg L^{-1} are considered hypoxic and are stressful to organisms. The percent of hypoxic readings during the drier years is low relative to the wetter years.

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

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

True anoxic conditions (0.0 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 2007 sampling season, only 1% of the bottom water observations were less than 1.0 mg L^{-1}.

3.2.1 Percent Saturation of Dissolved Oxygen

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 36% of the time (26 out of 72 observations) similar to 2002 at 32%. Wetter years ranged from 44% in 2001 and 2005, 50% in 2004 and 65% in 2003.

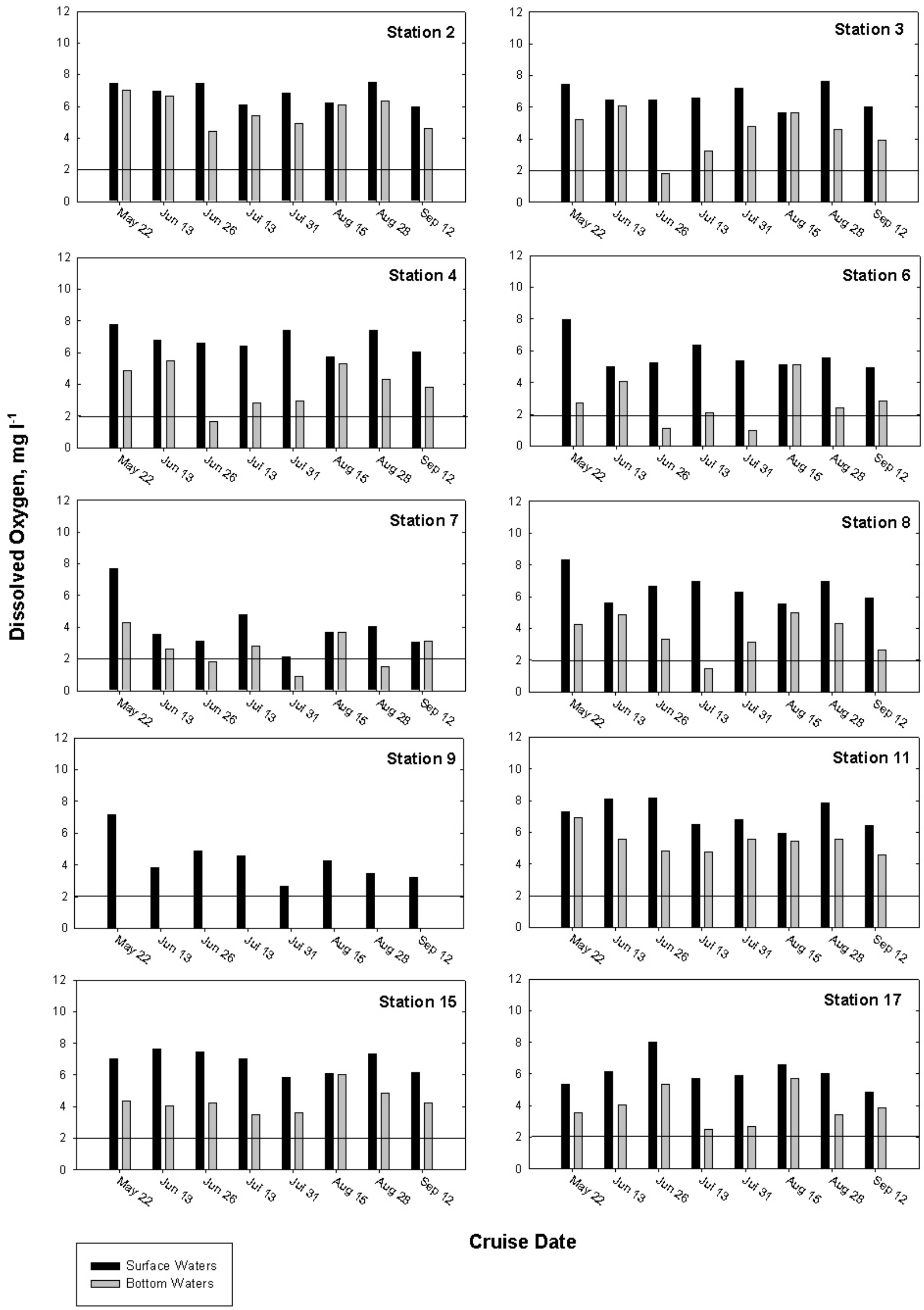


Figure 3.4. Bar graphs of surface and bottom water dissolved oxygen concentrations measured at each station from May 22 through September 12, 2007.
No bottom water measurements were taken at station at station 9.

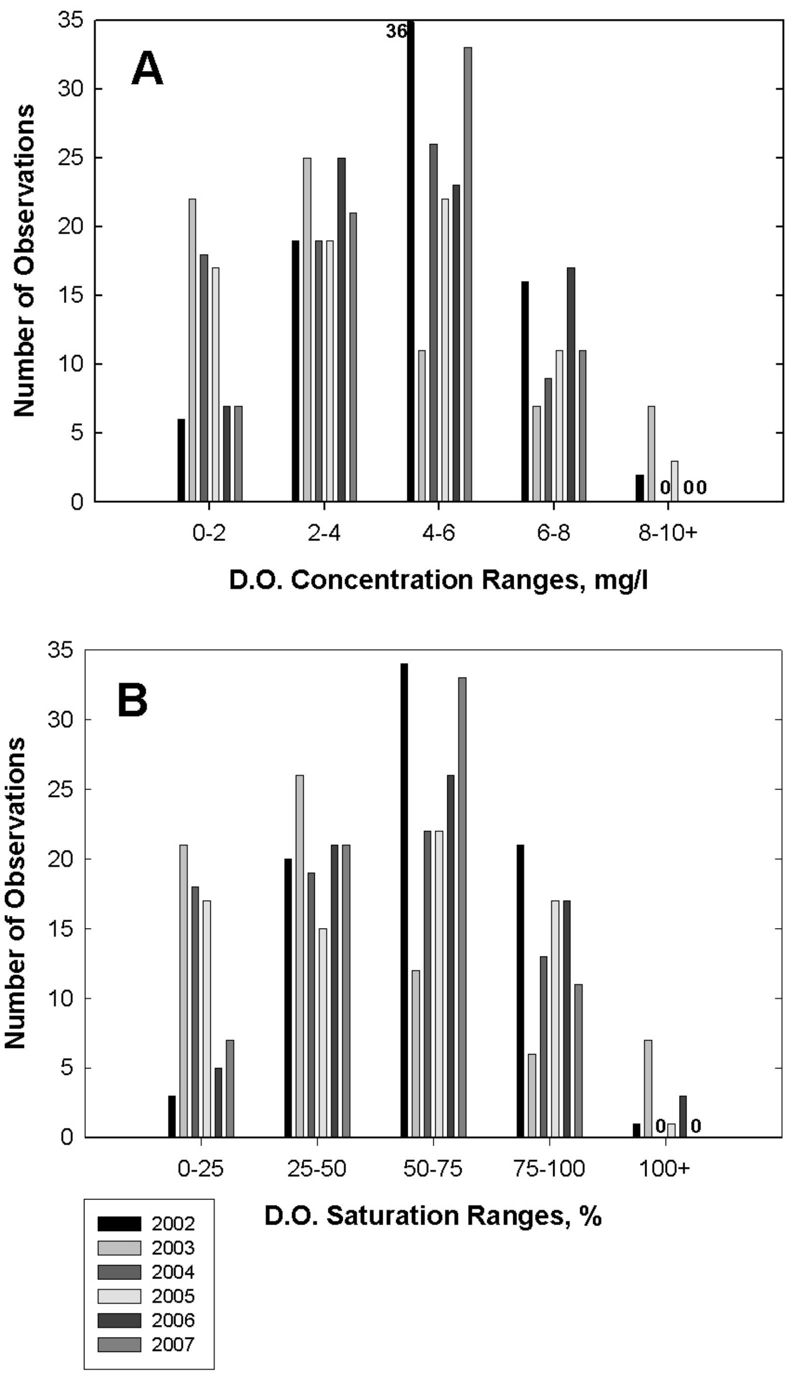


Figure 3.5.A&B. Bar graphs comparing the distribution of bottom water dissolved oxygen (A) and bottom water percent oxygen saturation (B) observations (2002 through 2007).

3.3 Active Chlorophyll-*a*

Figure 3.6

Concentrations of active chlorophyll-*a* serve as a measure of the size of algal populations in the water column. (Total chlorophyll measurements include phaeophytin. These degraded pigments that do not affect the algae concentration.) Active chlorophyll-*a* concentrations in surface waters ranged from 3.75 micrograms per liter (µg L^{-1}) (station 9, May 22) to 63.83 µg L^{-1} (station 4, May 22). Bottom water concentrations ranged from 5.26 µg L^{-1} (station 2, May 22 and Sept 12) to 46.49 µg L^{-1} (station 4, July 31).

Surface active chlorophyll-*a* ranges:

2004	2005	2006	2007
5.47 - 88.39	3.54 - 224.88	4.96 - 57.10	3.75 - 63.83

Bottom active chlorophyll-*a* ranges:

2004	2005	2006	2007
3.45 - 41.48	2.69 - 42.17	2.15 - 68.07	5.26 - 46.49

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
20.46	17.64	16.69	19.97

During the 2007 sampling season, 24 small surface blooms were observed; (the full dataset average is 10). 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. Thus, we will continue to monitor both surface and bottom readings at this station (1.4 meters depth). As stated, we also monitor surface and bottom readings at station 9 (1.0 meter depth), but only record data if stratification is observed.

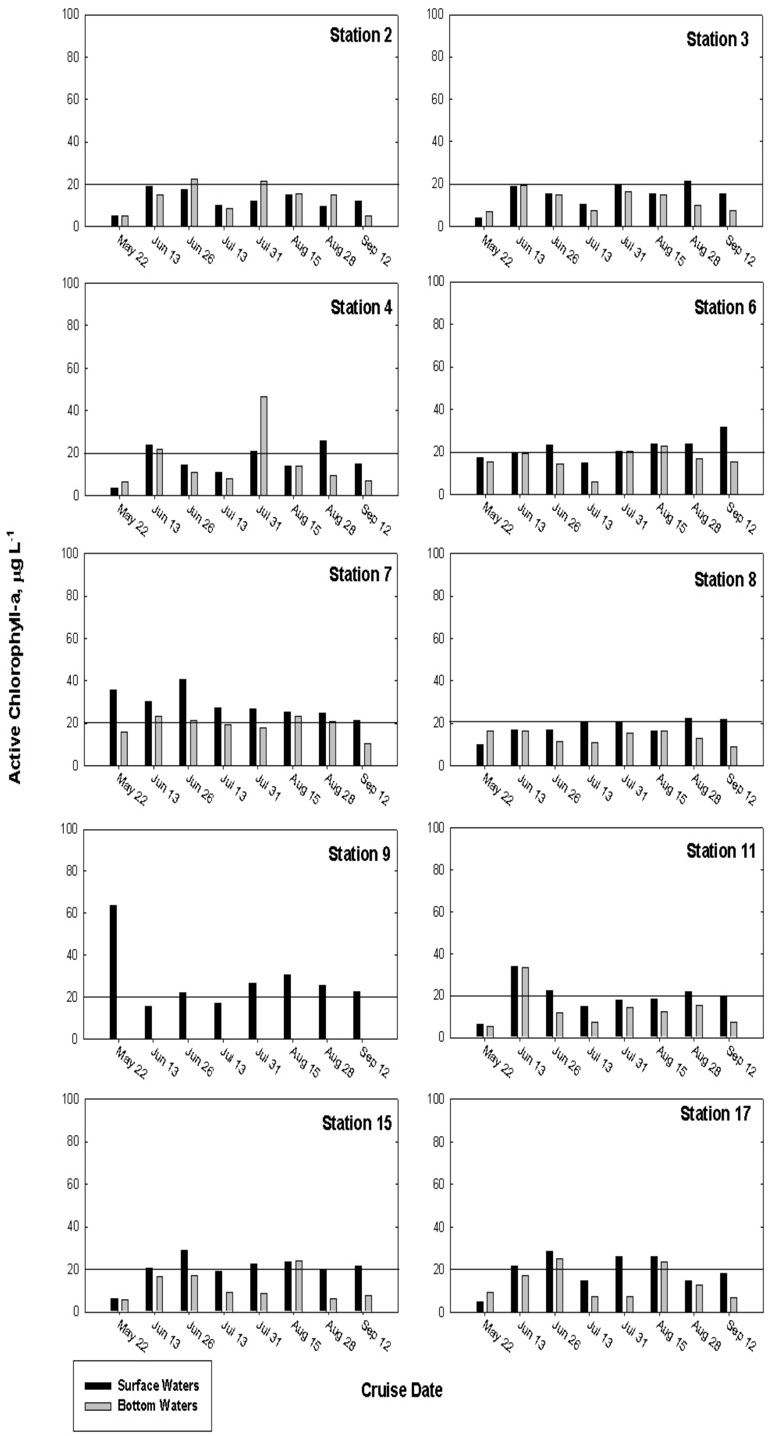


Figure 3.6. Bar graphs of surface and bottom water active chlorophyll-*a* values for each station from May 22 through September 12, 2007.
No bottom water measurements were taken at station at station 9.

3.4 Water Column Clarity

Figure 3.7

Water clarity was measured using a Secchi disc. The highest 2007 Secchi measurement (indicating the clearest water) was 1.8 meters (m) measured on May 22 at station 2 (in 2006 = 1.7 m, 2005 = 2.0 m). The lowest 2007 recording was 0.4 meters for the last 3 cruises at station 9 and at Station 7 on Sept. 12 (2006 = 0.4 m, 2005 = 0.2 m).

Secchi Ranges (low clarity to high clarity)

2005	2006	2007
0.2 - 2.0 m	0.4 - 1.7 m	0.4 - 1.8 m

Light Penetration using Kd, Figure 3.8

The extinction coefficient (kd) is calculated based on the Secchi depth using the following equation: kd = 1.5/ 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).

At the lowest Secchi reading of 0.4 meters (kd = 3.62), light sufficient for algal growth penetrates to 1.3 meters; for SAV sufficient light penetrates to only 0.33 meters. At the highest Secchi reading of 1.8 meters (kd = 0.83), 1% of the surface radiation penetrates to 5.4 meters and 30% surface radiation penetrates to 1.4 meters. Since the average mean depth of the system is about 2.0 meters, light sufficient for algal growth throughout most of the water column was present on most sampling dates. However, light sufficient for SAV growth throughout an average depth of 2 meters was not present on the sampling dates.

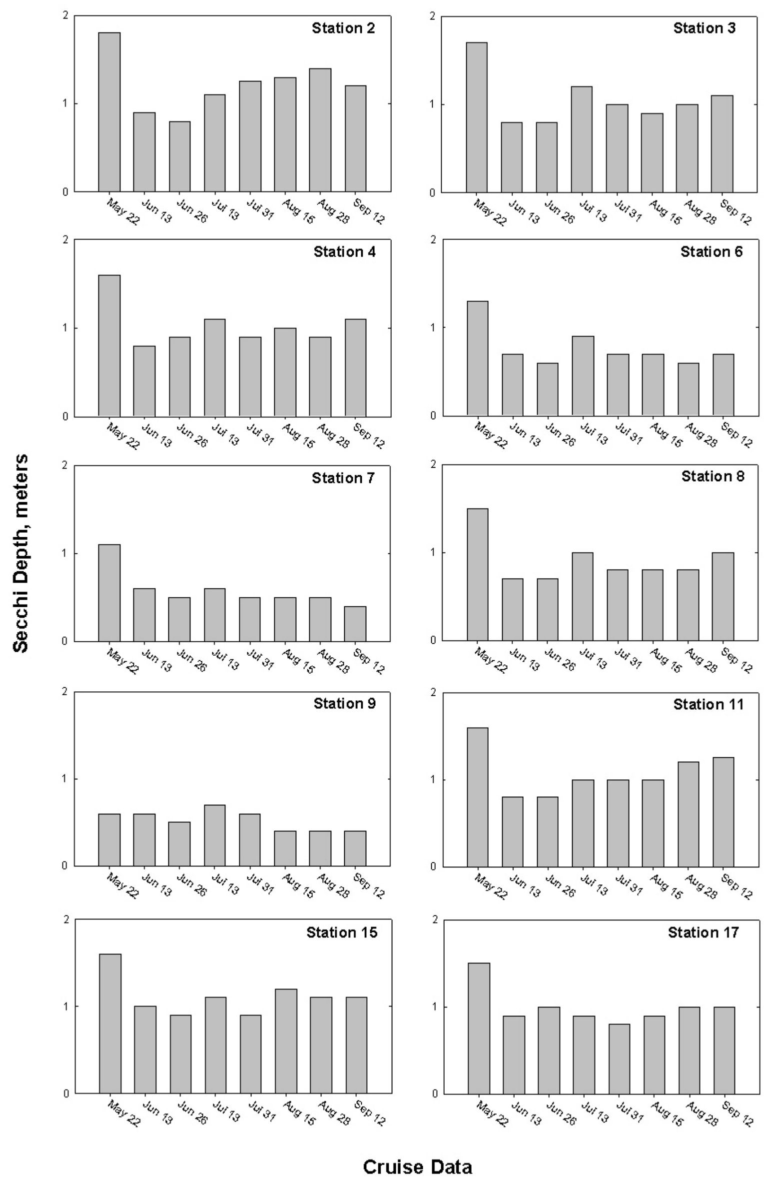


Figure 3.7. Bar graphs of water column Secchi disk measurements for each station from May 22 through September 12, 2007.

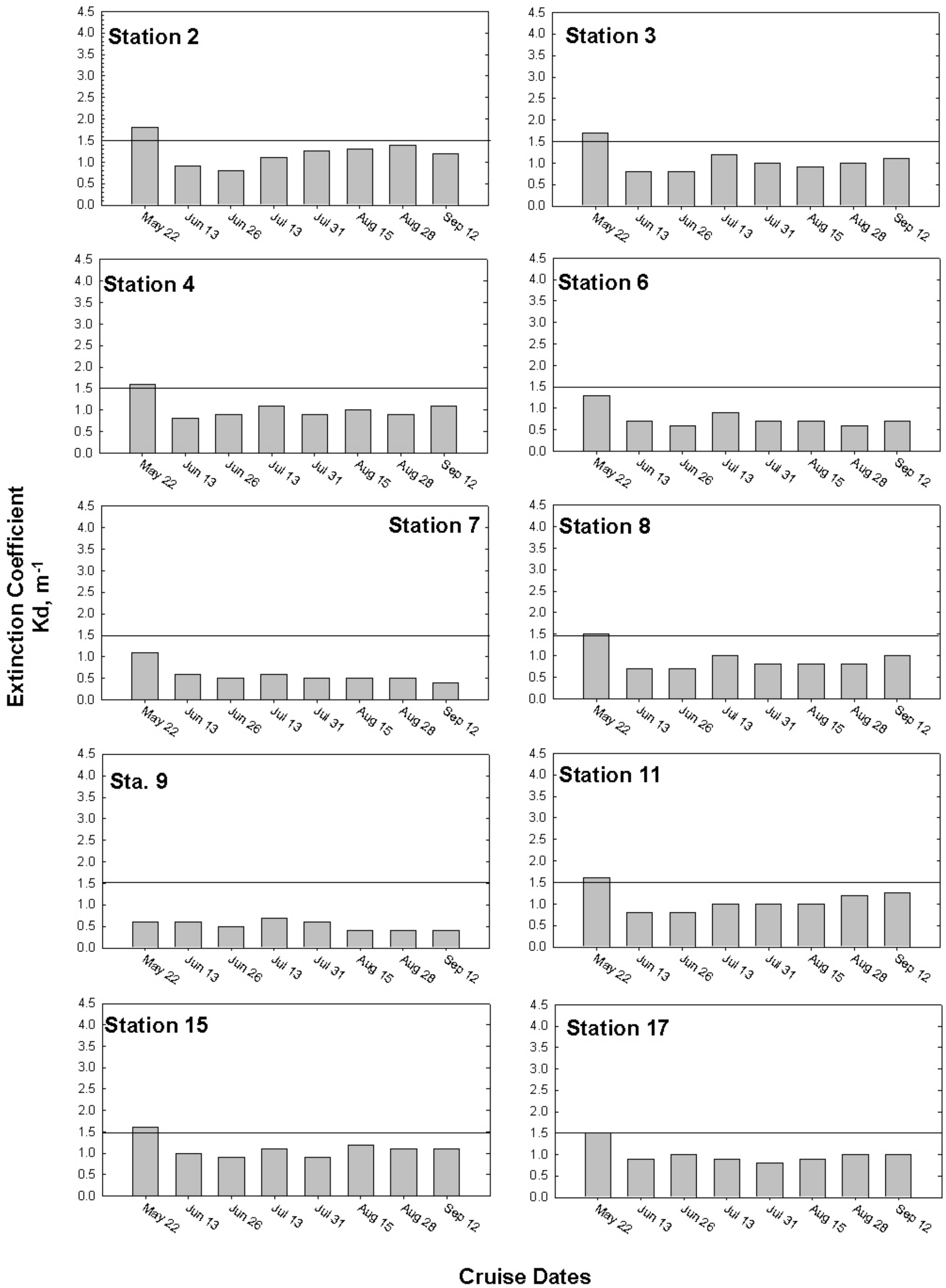


Figure 3.8. Bar graphs of light attenuation measurements (Kd) for each station from May 22 through September 12, 2007.
Line in each graph indicates Tier I SAV restoration goal of 1.5 meters.

3.5 Seafood and Swimming Safety Monitoring

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, we contacted the Maryland Department of Environment and found that there is bacterial monitoring for shellfish waters in the vicinity of Solomons.

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).

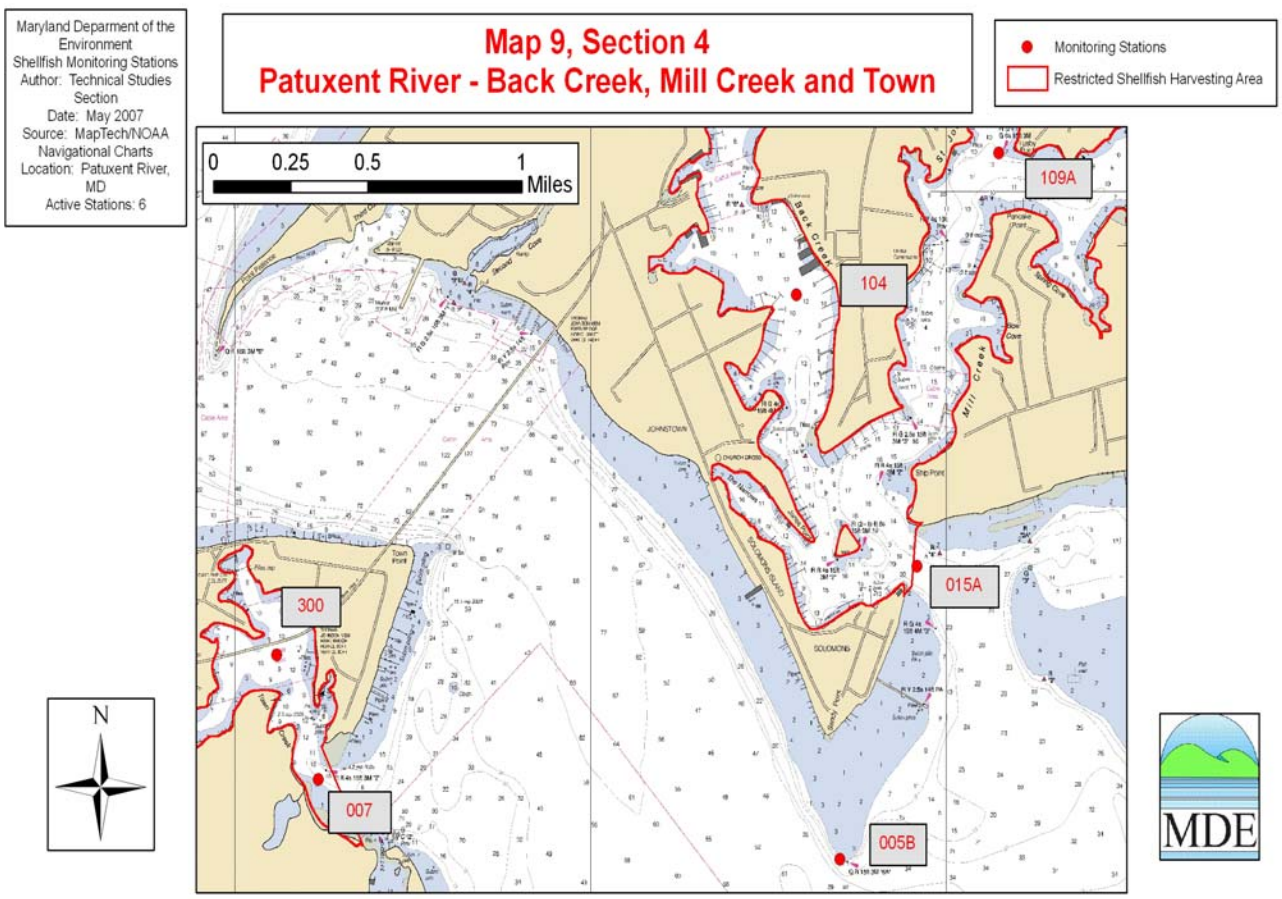


Figure 3.9. Map of the Maryland Department of the Environment (MDE) shellfish monitoring stations in the Mill Creek System

The indicator used for shellfish waters is fecal coliform. The charts and graphs in figure 3.10A and B display the January - October 2007 fecal coliform sample analyses as MPN (most probable number) per 100 milliliters of water. The Reference Station, 005B peaks once at 23 MPN/100 ml on August 20. Two of the stations meet the water quality standards for shellfish harvesting (not greater than 70 MPN/ 100 ml): Station 015A, at the SHS Boat Shop station, peaks twice on August 20 and on October 1 at 23 MPN/100 ml. The Mill Creek station, 109A had 3 peaks at 23 MPN/100 ml on January 4, May 15 and October 9. In general, Back Creek samples are higher with two samples peaking at 93 MPN/100 ml on May 15 and October 9, thus, slightly exceeding the standards.

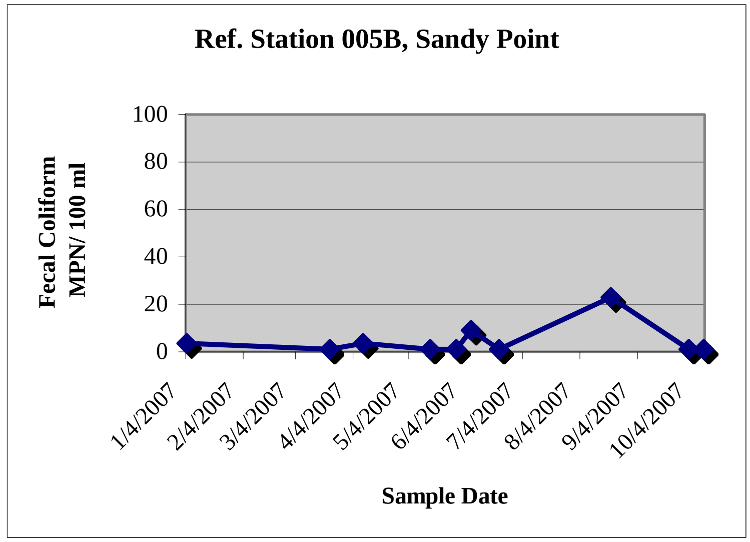
Even though the bacteria standards are being met, MDE will keep this area closed to shellfish harvesting due to shoreline activities and the intensity of boating activities, increasing the potential for overboard discharge of untreated sewage.

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 are monitored by Calvert County in the Mill Creek system. 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	1/4/2007	3.6
	3/22/2007	1
	4/9/2007	3.6
	5/15/2007	1
	5/29/2007	1
	6/6/2007	9.1
	6/21/2007	1
	8/20/2007	23
	10/1/2007	1
	10/9/2007	1



Station ID	Sample Date	Fecal Coliform MPN/ 100 ml
09-04-015A	1/4/2007	1
	3/22/2007	3.6
	4/9/2007	3
	5/15/2007	1
	5/29/2007	9.1
	6/6/2007	4.3
	6/21/2007	4.3
	8/20/2007	23
	10/1/2007	23
	10/9/2007	9.1

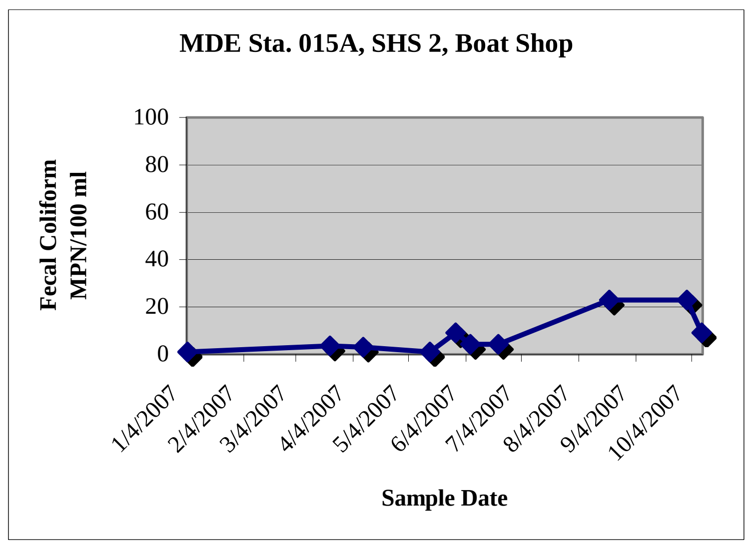
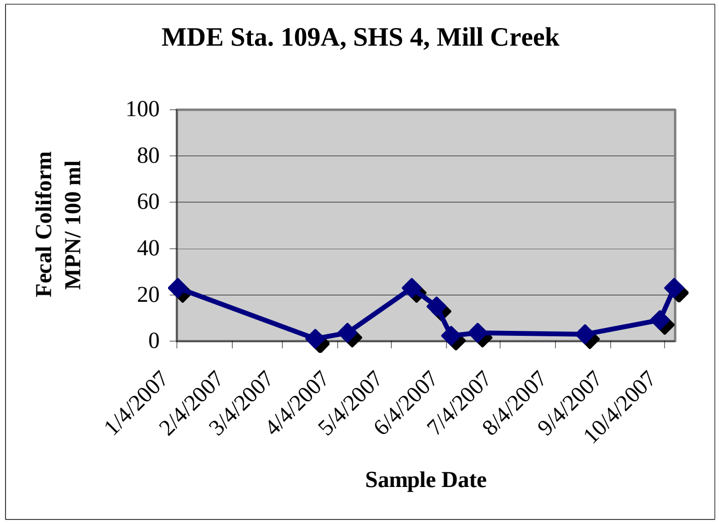


Figure 3.10A. Fecal coliform counts from a reference station and one station in the Mill Creek System in 2007.

Station ID	Sample Date	Fecal Coliform MPN/ 100 ml
09-04-109A	1/4/2007	23
	3/22/2007	1
	4/9/2007	3.6
	5/15/2007	23
	5/29/2007	15
	6/6/2007	2.3
	6/21/2007	3.6
	8/20/2007	3
	10/1/2007	9.1
	10/9/2007	23



Station ID	Sample Date	Fecal Coliform MPN/ 100 ml
09-04-104	1/4/2007	9.1
	3/22/2007	3.6
	4/9/2007	14
	5/15/2007	93
	5/29/2007	9.1
	6/6/2007	1.5
	6/21/2007	4.3
	8/20/2007	23
	10/1/2007	23
	10/9/2007	93

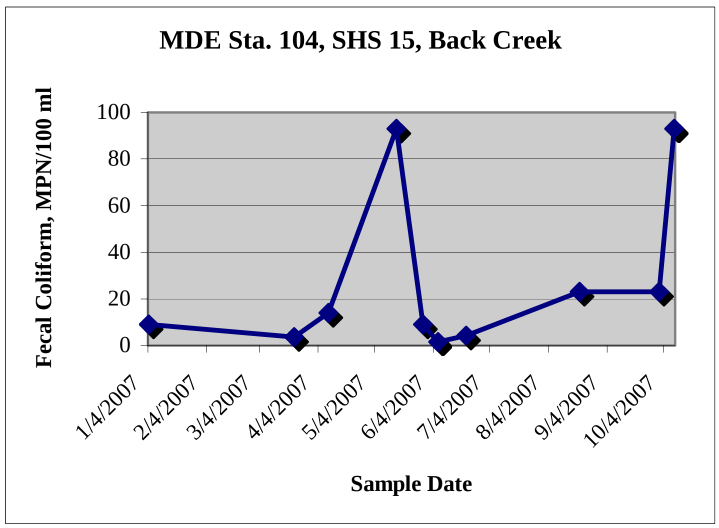


Figure 3.10B. Fecal coliform counts from 2 stations in the Mill Creek System in 2007.

4. Precipitation Patterns and River Flow

4.1 Precipitation

Figure 4.1 A&B

To understand the water quality in the Mill Creek system one must 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 2007 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.

For the Mill Creek system, average daily precipitation for the period of March through September has been collected over the past twenty-four years (1984 – 2007) from a precipitation monitoring station located at CBL. This time interval was chosen to correspond with sampling dates of the present and previous Mill Creek system studies.

Average precipitation within the Mill Creek system drainage basin during the 2007 sampling season (March through September) was 0.08 inches day^{-1} (Fig 4.1B), lower than in any year since 1986 (Fig 4.1A, 1985, 1995 and 2002 averaged 0.09 inches per day).

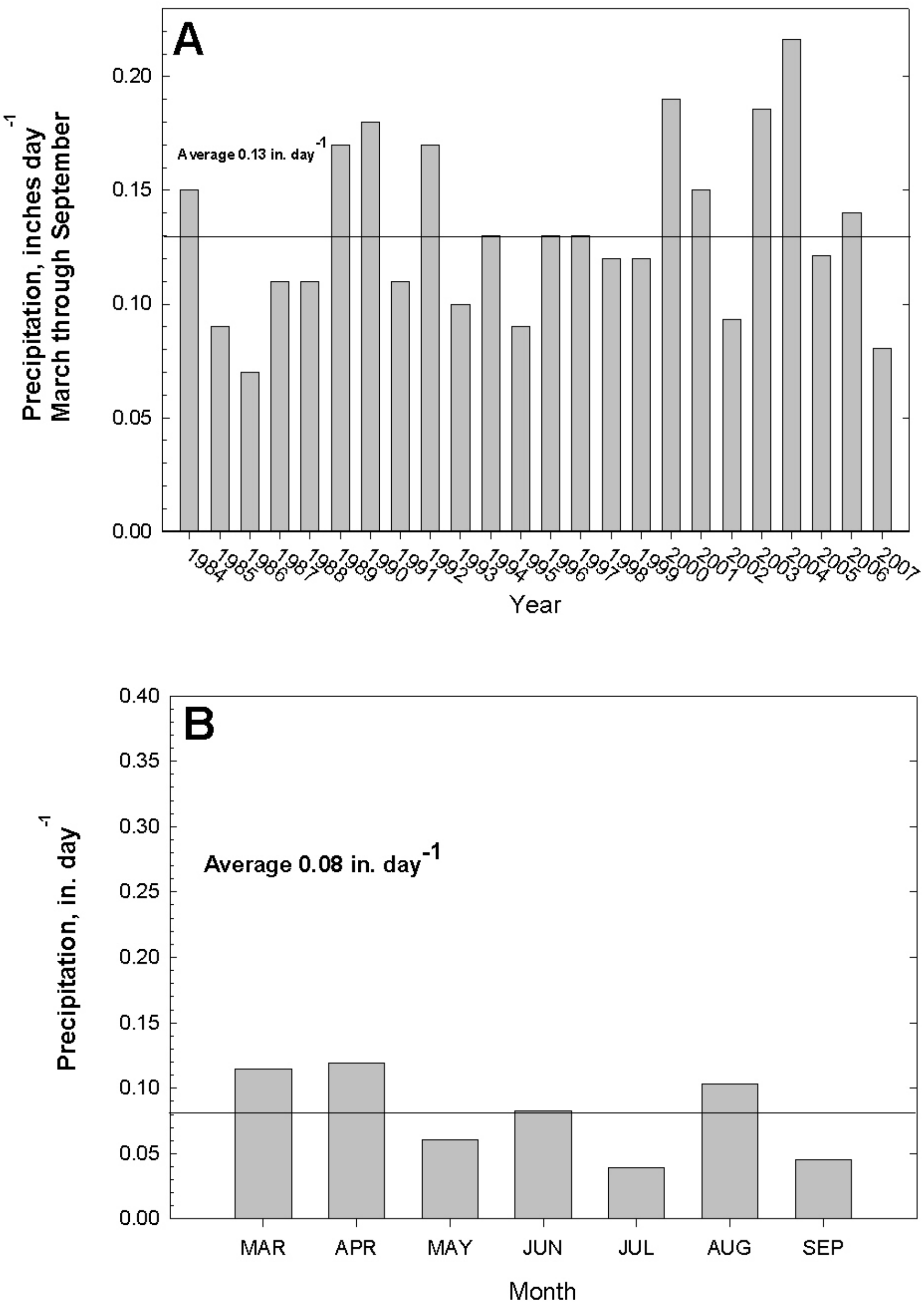


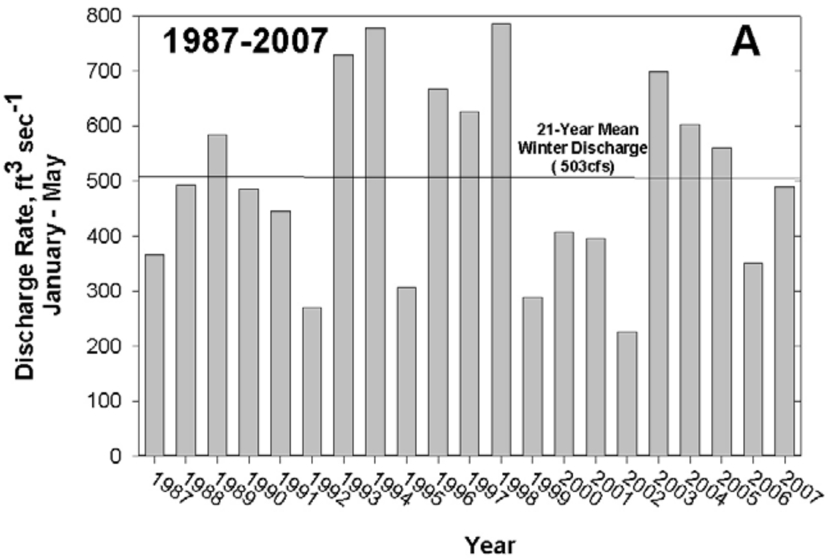
Figure 4.1.A&B. Bar graphs showing (A) the mean daily seasonal precipitation (March through September) for 1984 to 2007 and the mean daily precipitation for these same months during 2007. The solid horizontal line in both graphs indicates the average daily precipitation for these months during the period of 1984 to 2007.

4.2 River Flow

Figure 4.2 A&B

Mean Patuxent River flow for each month from January through May for 2007 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 2007 mean flow for the year, 490 cfs, is just below the twenty-one year average of 503 cfs. Like most of the Chesapeake Bay region, the Patuxent river watershed experienced a drier than normal winter and spring during 2007.



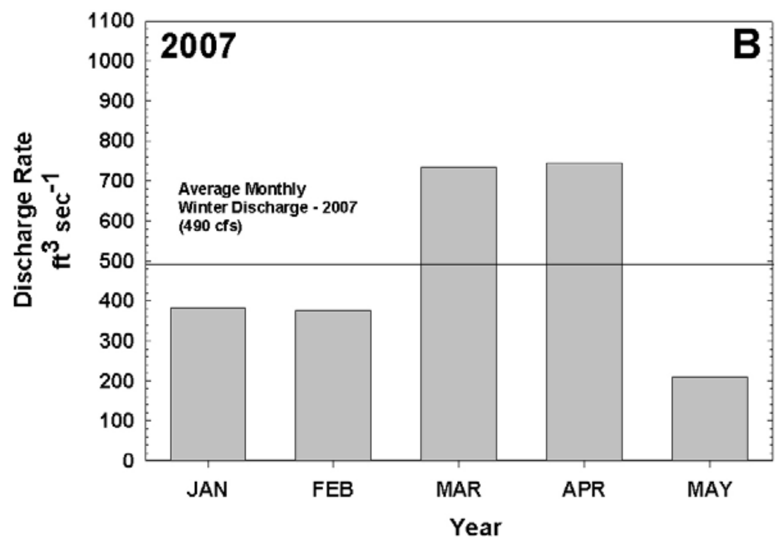


Figure 4.2.A&B. Bar graphs showing (A) Patuxent River mean winter-spring flow (January through May) for 1987 to 2007 and the (B) mean monthly winter-spring flow for 2007. Average flows during the history of the study are indicated.

5. Long Term Water Quality Trends

Data from the following representative stations were examined to determine if trends were evident in water quality conditions: stations 2 (Mill Creek system mouth), 6 (mid Mill Creek), 7 (upper Mill Creek), 9 (upper St. John's Creek), and 15 (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, 1990-2007 are summarized in Figure 5.1A. The average long-term bottom water dissolved oxygen concentration is 4.32 mg L^{-1}. In the context of the past five years, dissolved oxygen concentrations in the bottom waters decreased for the first time since 2003, indicating a possible decrease 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.

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 1987 through 2007 are depicted in Figure 5.1B. Ranking the past 11 years according to mean surface chlorophyll-*a* concentration gives the following pattern:

1999<2002<2000<1997<2001<2006<2005<2004<**2007**<1998<2003

The surface mean active chlorophyll-*a* concentration increased to 22.3 µg L^{-1} - the third highest average in 11 years and an increase from the past 3 years and above the average concentration of ~17 µg L^{-1}). However, the highest average yearly concentration, observed in 2003, was twice as high at 45.21 µg L^{-1}.

An algal bloom is being 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 24 blooms. In comparison, no blooms occurred during 1999, while 2003 produced the maximum of 29 blooms. Ranking occurrences of algal blooms since 1997 gives the following pattern:

1999<2002<2005<1997<2000<2006<2001<2004<1998<**2007**<2003

In general the trends of numbers of algal blooms between years follow the same trends as active chlorophyll-*a*. That is, if the mean active chlorophyll-*a* concentration rose or fell, so did the number of blooms.

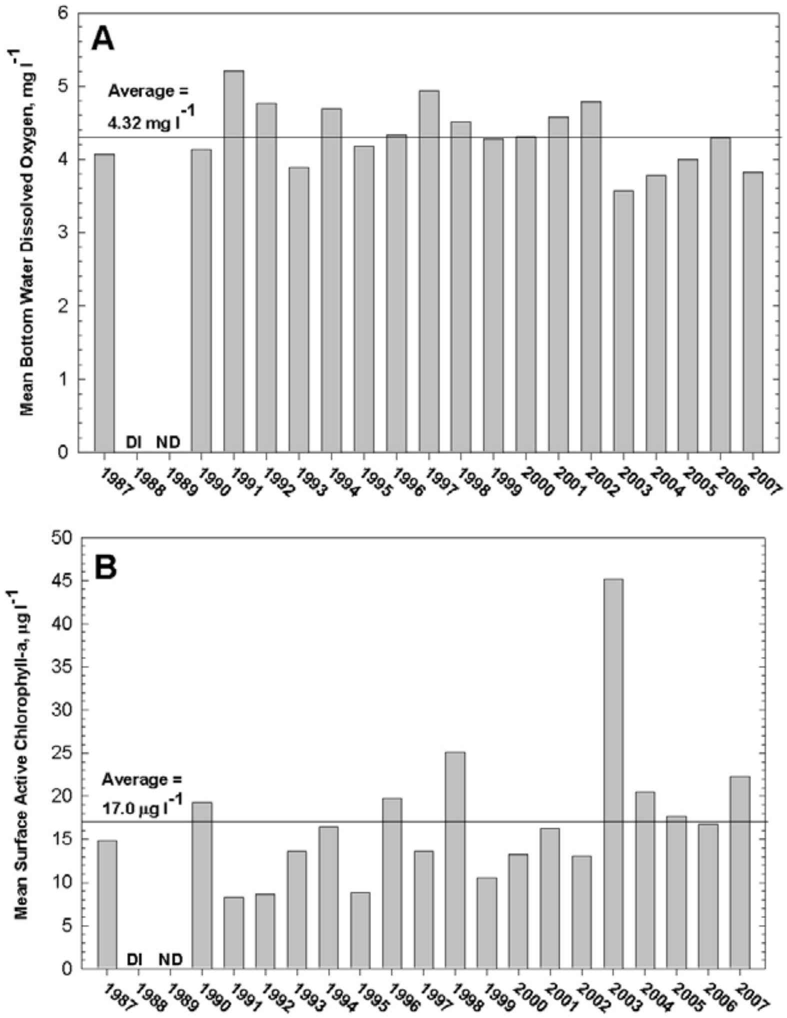


Figure 5.1.A&B. Bar graphs of (A) bottom water mean dissolved oxygen concentrations at the inter-annual comparison sites (stations 2, 6, 7, 9 and 15) from 1987 through 2007, and (B) mean surface water active chlorophyll-*a* concentrations at the inter-annual comparison sites (stations 2, 6, 7, 9 and 15) from 1987 through 2007.
***In graph B, the drought years (1992, 1999, 2002, 2005 and 2007) are starred.**
DI = Data set for 1988 was incomplete.
ND = Study was not funded 1989.

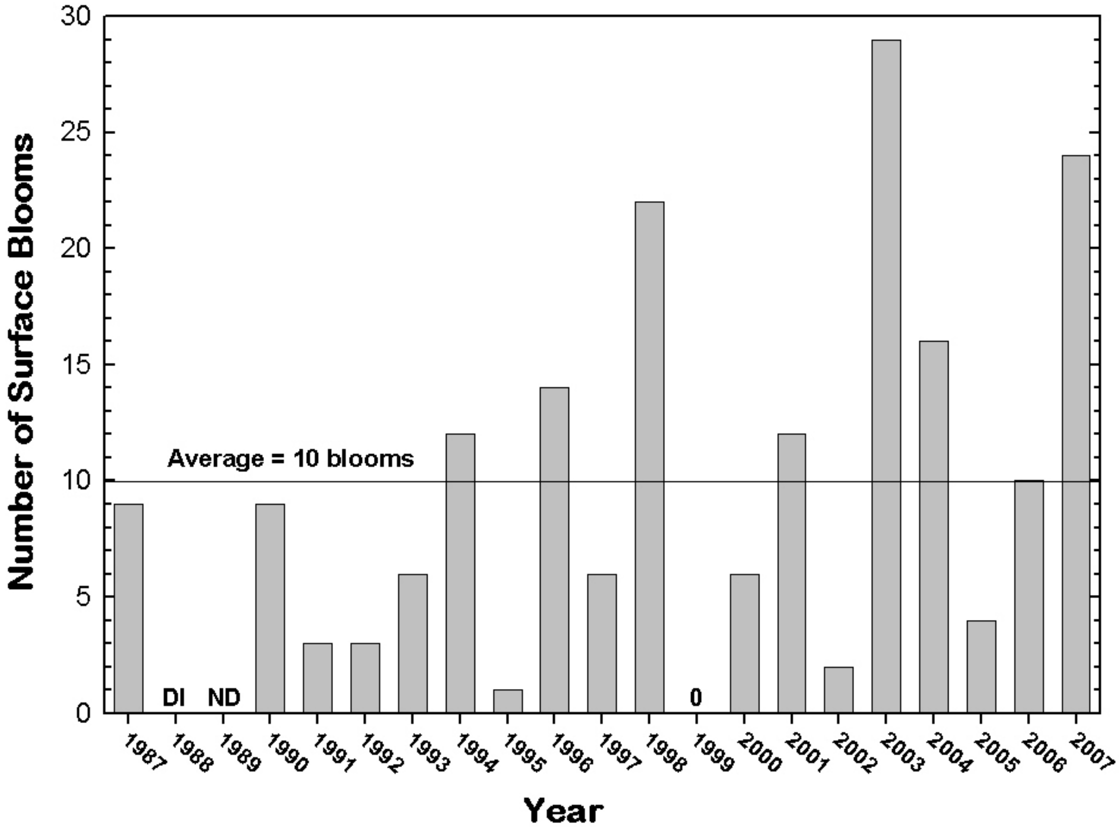


Figure 5.2. Bar graph of surface chlorophyll-*a* blooms at the inter-annual comparison stations 2, 6, 7, 9 and 15 from 1987 through 2007. Note: chlorophyll-a concentrations greater than 20 µg L^{-1} were defined as blooms.
DI = Data set for 1988 was incomplete.
ND = No study was funded in 1989.

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