Chapter 4.2

Status and trends of phytoplankton abundance in the Maryland Coastal Bays

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Abstract
High concentrations of phytoplankton can lead to a reduction in water clarity and dissolved oxygen, creating unsuitable conditions for living resources (fish, shellfish, and seagrasses). Algae abundance was monitored in the Coastal Bays by measuring water column chlorophyll concentrations using fixed station and continuous monitor data. Phytoplankton abundance in Assawoman, Isle of Wight, Sinepuxent, and Chincoteague bays was generally low enough to allow for seagrass growth during 2007-2013. The St. Martin River and tributaries of Newport Bay demonstrated high chlorophyll levels (20.5% of sites) and failed the thresholds established for seagrass growth and dissolved oxygen. Many tributaries with failing nutrient thresholds also had elevated water column chlorophyll levels, while the open bays generally had lower chlorophyll levels more suitable for seagrasses. Continuous monitoring estimates of chlorophyll suggest possible improvement over time. Chlorophyll attainment related to the Total Maximum Daily Load analyses showed improvement in Sinepuxent and Isle of Wight bays. Many areas show improving trends in chlorophyll *a*, scientists anticipate that seagrasses will respond positively in time.

Introduction
Phytoplankton are an important food source to many living resources (shellfish and fish) in the Coastal Bays. However, large algae blooms in the water column can have detrimental effects on water quality. Blooms may lead to oxygen depletion that stresses or kills fish and shellfish. High levels of water column algae can also limit the amount of light available to seagrasses.

The concentration of chlorophyll, the green pigment in algae, is often used to represent the amount of algae in the water column. These amounts are affected by a number of factors, including temperature, light, nutrient levels, and grazing by zooplankton, planktivorous fish, and shellfish. Persistent efforts to reduce the amount of nutrients entering the watershed are expected to reduce chlorophyll levels and thus improve water clarity and oxygen levels, particularly in tributaries that have continued to fail management objectives.

Data Sets
A wealth of information is available on phytoplankton abundance through monthly monitoring of water column chlorophyll *a* at numerous **fixed stations** throughout the Coastal Bays. The National Park Service at Assateague Island National Seashore (ASIS) has conducted monthly chlorophyll *a* monitoring at 18 fixed stations in the southern bays since 1987. The Maryland

Department of Natural Resources (DNR) has monitored chlorophyll *a* monthly at 28 fixed sites in the St. Martin River and Newport Bay since 1998 and at 17 fixed sites in Assawoman, Isle of Wight, and Chincoteague Bays since 2001. The Maryland Coastal Bays Program (MCBP) implemented a volunteer water quality monitoring program in 1997 and has monitored chlorophyll at 26 fixed stations since 2007. Samples were sent to laboratories at the Maryland Department of Health and Mental Hygiene (DNR 2007-08) or the University of Maryland (DNR 2009-13, ASIS and MCBP) for extractive spectrophotometric (DNR and MCBP) or High-performance liquid chromatography (ASIS) analysis of chlorophyll *a* concentration. All three programs collect data in accordance with EPA-approved quality assurance project plans. An additional five sites were sampled during August 2010, as part of EPA's National Coastal Condition Assessment and associated supplementary sampling for benthic conditions (Fig 4.3.1).

While monthly sample collection provides important information on spatial patterns of phytoplankton variation, it misses events occurring on smaller time scales (days/weeks) or at times of the day or year when it is impractical to deploy field crews. Moreover, monthly sampling efforts are snapshot events, and cannot provide data on the duration of poor water quality episodes. To assess chlorophyll concentrations at these finer time scales, **continuous monitors** have been deployed in the Coastal Bays – five by DNR and two by ASIS (Figure 4.2.1). These monitors measure a suite of water quality parameters every 15 minutes. At four sites data are telemetered to a website for near real-time viewing (Maryland Department of Natural Resources 2004). Continuous monitors estimate total chlorophyll *in situ* u sing a built-in fluorometer. Although this method cannot distinguish between the various forms of chlorophyll, the dominant form found in surface water samples is typically chlorophyll *a*. Continuous monitoring data allows scientists to learn more about the ecosystem by tracking daily fluctuations in chlorophyll and linking them to real-time events, such as fish kills or harmful algae blooms.

Management Objective: Maintain suitable fisheries habitat.

Algae Indicator 1: 50 µg/L for dissolved oxygen effects
Algae Indicator 2: 15 µg/L for effects on seagrasses

Analyses

Status:

1) Fixed stations: For each fixed monitoring station (Figure 4.2.1), a median chlorophyll *a* concentration was determined for the seagrass growing season (March - November) for rolling three-year periods from 2007-2013. Threshold values developed by the Maryland Coastal Bays Scientific and Technical Advisory Committee (STAC), based on living resources indicators (see Management Objective above) (Table 4.2.1), were used as the basis for a 5-category attainment series. Each median value was compared to its category cut-off values using the non-parametric Wilcoxon sign-rank test. Those medians that were significantly different at p=0.01 from both category cutoffs were considered statistically significant overall.

2) Continuous monitoring: Frequency of threshold failure was determined using temporally intensive continuous monitoring data from 2007 and 2013. DNR continuous monitoring data were compared to monthly and biweekly laboratory data from grab samples collected simultaneously with sonde changeover, using a regression that includes a temperature component. (Figures 4.2.2 through 4.2.8). The calibration equation is determined by calculating a log-ratio ($log_{grab} - log_{sonde}$) for each event, regressing it over concomitant temperature to determine a predicted log-ratio, and multiplying the backtransformed predicted log-ratio by the sonde chlorophyll value to predict the grab chlorophyll value.

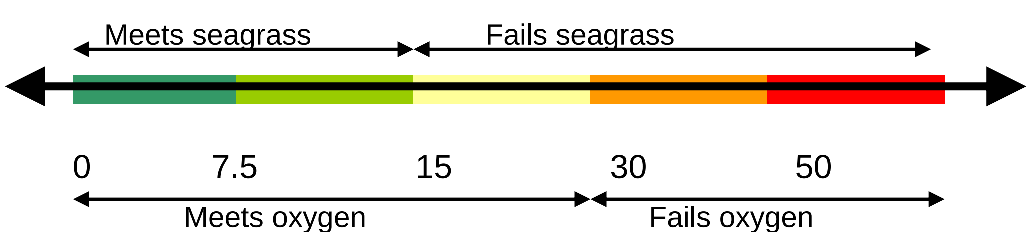
3) National Coastal Condition Assessment, NCCA, 2010: Samples were collected at five sites during August 2010 as part of an US EPA program that assess our nation's waters. One visit was made to four stations and the fifth site was visited twice, providing a snapshot of water quality conditions. Chlorophyll *a* values were placed into STAC attainment categories (Table 4.2.1).

4) Total Maximum Daily Load (TMDL) comparisons: Chlorophyll criteria for TMDL analyses use a different metric for chlorophyll than those reported above (Maryland Department of the Environment, 2014). The Maryland Department of the Environment (MDE) calculates a percent of time chlorophyll levels exceed a threshold (either 15ug/L for seagrasses and within 250 foot buffer from submerged aquatic vegetation or 50 µg/L threshold) to determine if the TMDL is met. Results are presented for comparison to STAC status analyses. Chlorophyll endpoints for the TMDL analyses have been approved by the EPA.

Table 4.2.1 Attainment category values for chlorophyll *a* in the Maryland Coastal Bays. Upper cutoff values are shown; lower cutoff values are the values from the previous category, forming category bounds for hypothesis testing. Bolded criteria and values are living resources and dissolved oxygen indicators developed by scientific and technical advisory committee.

Threshold criteria	Chlorophyll *a* cutoff values for category
Better than SAV (seagrass) objective	<7.5 µg/L
Meets SAV (seagrass) objective	**<15 µg/L**
Does not meet SAV (seagrass) objective	<30 µg/L
Dissolved oxygen concentration threatened	<50 µg/L
Threatened - does not meet any objectives	**>50 µg/L**

Chlorophyll *a* (µg/L) Threshold categories



Trends:
Trend analyses were used to compare the effect of time on chlorophyll *a* concentrations at fixed stations. These analyses detect changes over time that may be related to management actions. Linear and non-linear analyses were performed on all stations that have been sampled continuously since 1999 (2001 for a subset of DNR stations, and 2000 for a subset of MCBP stations), in order to make comparisons among all programs using comparable data. At least 10 continuous years of data are required for trend analyses. The Seasonal Kendall test was used to identify linear trends, and Sen's slope estimator was used to estimate the magnitude of change over time when a significant trend was present (Ebersole et al. 2002, Hirsch et al. 1982; Van Belle and Hughes 1984). At sites when no linear trend was detected, non-linear trends were evaluated to identify whether reversals in trend direction had occurred, and their corresponding inflection points, during the analysis period. For all trend tests, a significance level of $p<0.01$ was used to achieve the highest possible power.

Results: Status of Algae Abundance
The status of chlorophyll concentrations in each Coastal Bays segment is discussed below. Please refer to Figure 4.2.1 for place names and station locations. (Table 4.2.2). Comparison of monthly values to predicted values for continuous data shows relatively poor relationships during the summer months (Figure 4.2.2 through 4.2.13). This is most likely because monthly sampling is concurrent with sonde exchange, occurring when the fluorescence probe is most likely to be fouled. Chlorophyll status for the most recent 3-year analysis period (2011-13) is mapped in Figure 4.2.2.

Figure 4.2.1 Water quality monitoring station locations.

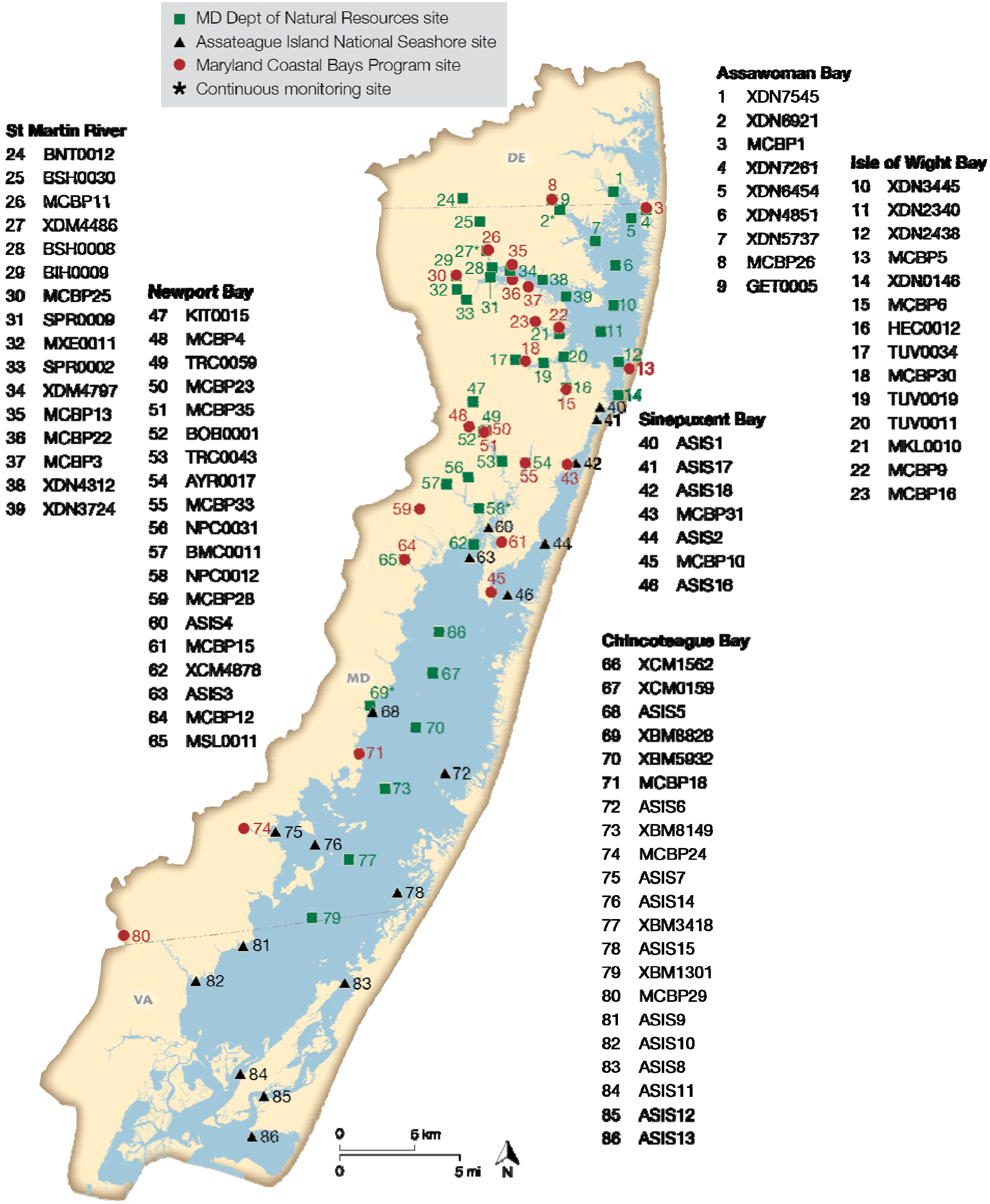
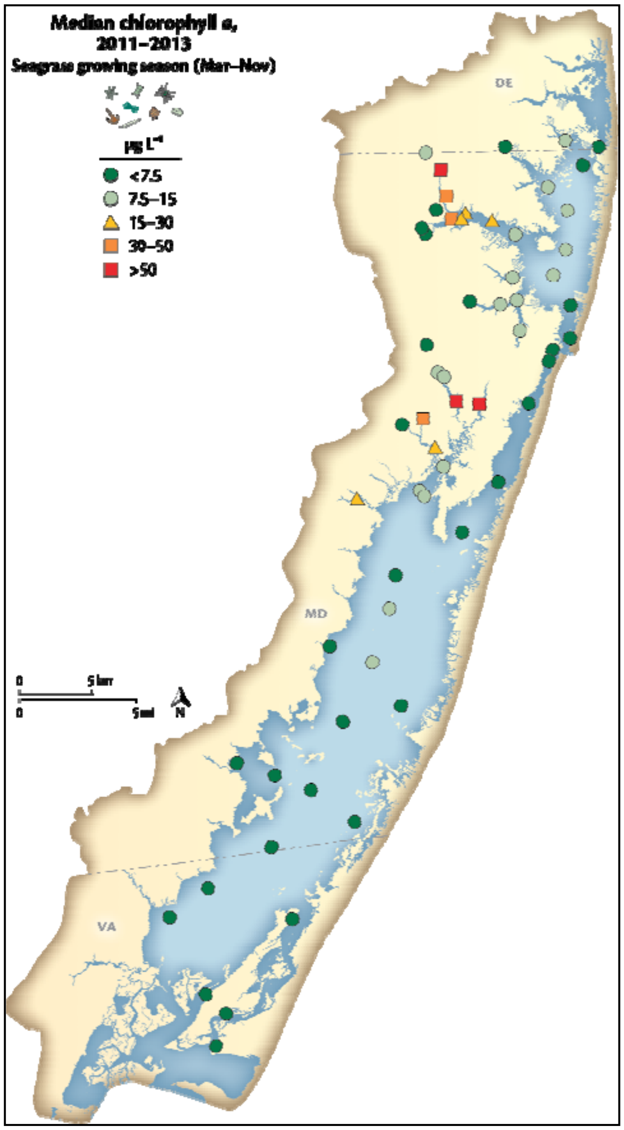


Figure 4.2.2 a) Median chlorophyll *a* concentrations (µg/L) during the seagrass growing season (March – November) at fixed stations during 2001-13. Colors indicate thresholds from Table 4.2.1. **b)** Map of 2010 National Coastal Condition Assessment chlorophyll a.

a.



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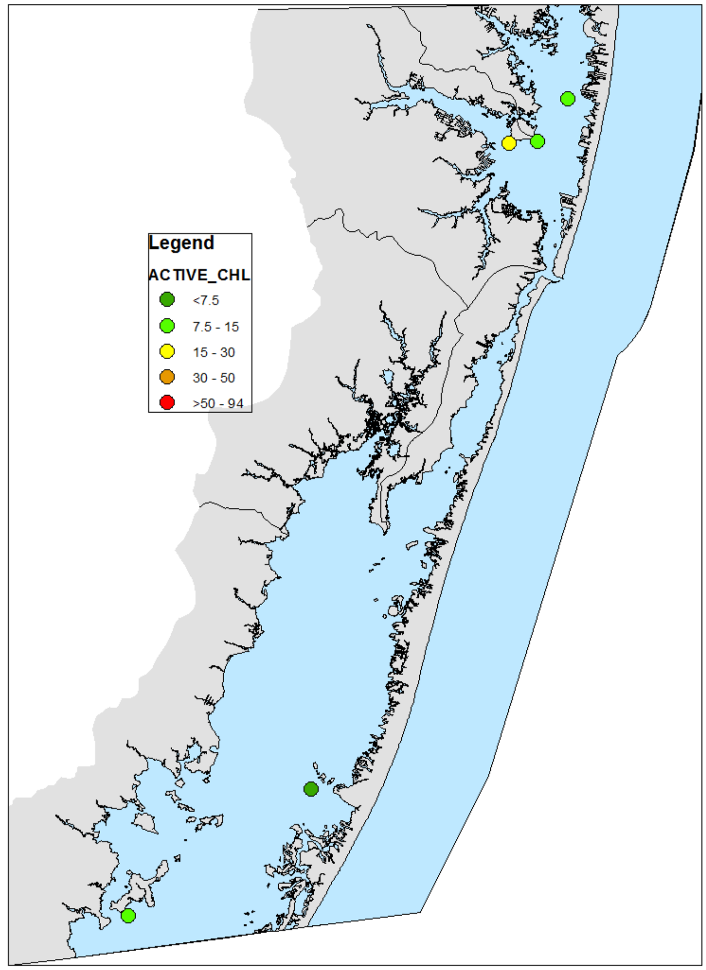
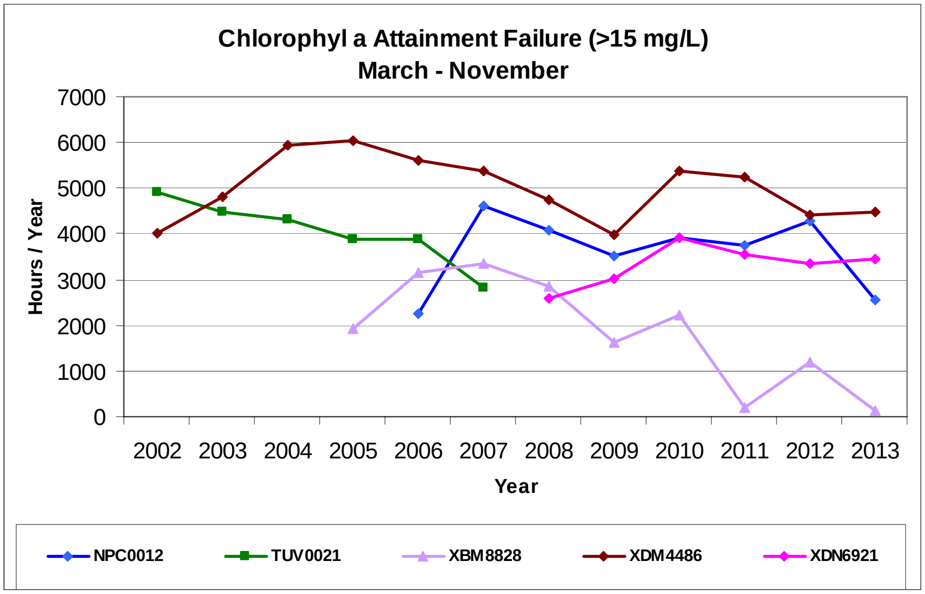


Figure 4.2.3 Total hours per year that chlorophyll *a* exceeded the 15µg/L threshold during the seagrass growing season (March – November, ~6480 max hours) at DNR continuous monitoring stations. Site locations are as follows: NPC0012 – Newport Creek TUV0021 – Turville Creek, XBM8828 – Public Landing, XDM4486 – Bishopville Prong and XDN6921 - Greys Creek.



Assawoman Bay

Fixed Station Status: All fixed stations met or exceeded seagrass thresholds during all five status timeframes (Table 4.2.2). However, at four sites (XDN4851, XDN5737, XDN7261, XDN7545), the median chlorophyll values were highest during the most recent analysis period, 2011-13.

Table 4.2.2 Rolling three year medians of chlorophyll *a* (µg/L) for stations in the Assawoman Bay watershed during seagrass growing season (March – November).

3-year medians of chlorophyll *a* (µg/L) in Assawoman Bay						
	Station	07-09	08-10	09-11	10-12	11-13
Greys Creek	MCBP 26[a]					6.3
	GET0005[a]	9.6	8.0	6.4	6.4	5.6
Fenwick Ditch	XDN7261	5.4	6.2	4.3	5.3	6.9
	MCBP 1	4.9	5.0	4.9	5.0	5.0
Roys Creek	XDN7545	8.0	9.6	6.6	9.8	11.2
Assawoman Bay	XDN6454	6.8	7.0	5.4	5.8	6.4
	XDN5737	9.7	9.0	8.1	9.9	11.7
	XDN4851	5.3	5.1	5.6	8.5	8.7

bold values are significantly different from boundary values in all tables
grey cells have insufficient data for analysis blank cells have no data for that timeframe
[a] stations are co-located

NCCA status: One station was sampled for NCCA during August 2010, and chlorophyll *a* met the seagrass objective (15 µg/L) at 8.61 µg/L.

Continuous monitoring Status: Despite all of the fixed stations in Assawoman Bay passing the seagrass threshold (15 µg/L), the Greys Creek continuous monitor showed that total chlorophyll measurements were seldom below the seagrass objective (7.5 µg/L) over the course of six years, with failure occurring between 88 and 98% of the time. This site also fared poorly in meeting the seagrass objective (15 µg/L), with failure occurring between 70 and 81% of the time. These data show that this area is poor seagrass habitat, however, this site rarely failed the DO threshold (>50 µg/L). There is no clear pattern of improvement or decline in performance over the 6-year monitoring period (Figure 4.2.3).

Table 4.2.3 Annual percent failure of chlorophyll criteria in Greys Creek (2007-2013).

Site	Threshold	2007	2008	2009	2010	2011	2012	2013
Greys Creek XDN6921	**CHLt > 50**	not sampled	**10.2%**	**20.6%**	**19.1%**	**9.4%**	**4.8%**	**10.5%**
	CHLt > 30		25.3%	39.8%	42.0%	31.8%	24.1%	40.5%
	CHLt > 15		**70.1%**	**70.3%**	**80.7%**	**71.7%**	**78.6%**	**75.4%**
	CHLt > 7.5		92.6%	87.7%	97.9%	91.3%	92.3%	97.0%

During the seagrass growing season, extracted values for chlorophyll *a* at Greys Creek consistently exceeded measured fluorescent and predicted values, suggesting that percent failure for chlorophyll criteria may actually have been higher during most years.

Figure 4.2.3 Comparison of extracted chlorophyll *a* vs fluorescence and predicted temperature-corrected fluorescence chlorophyll values in Greys Creek.

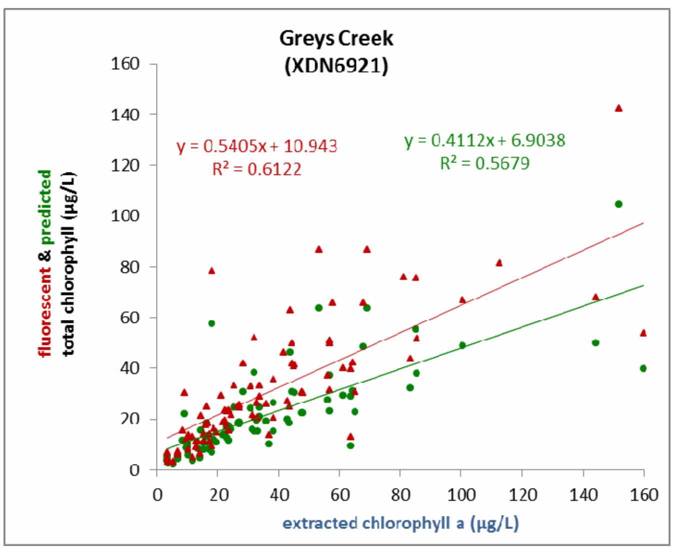
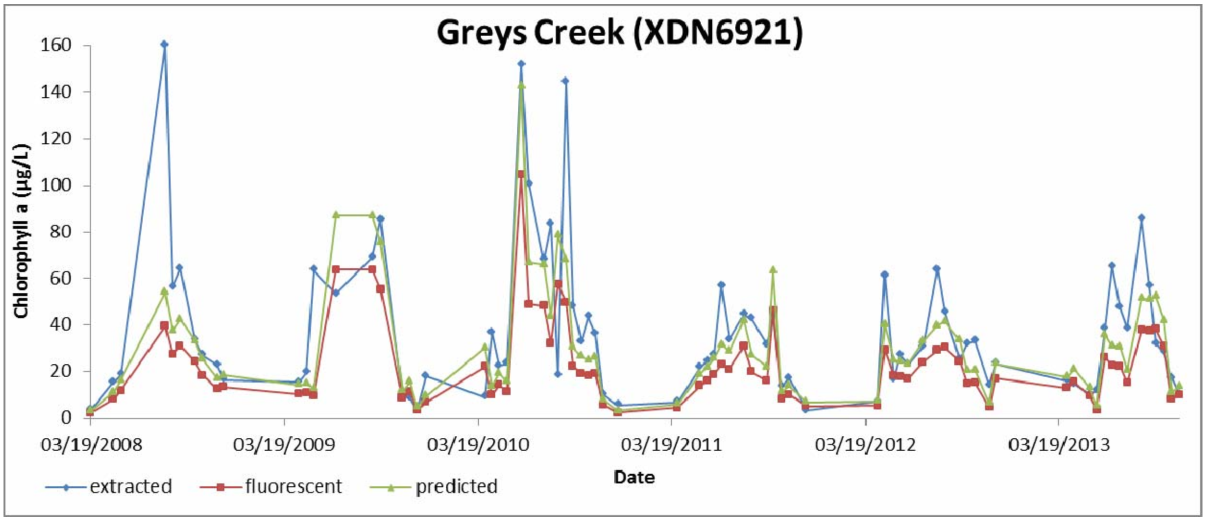


Figure 4.2.4 Comparison of chlorophyll *a* values measured by fluorescence probe, extracted and temperature corrected predicted values in Greys Creek.



<u>TMDL Status</u>: Achievement of the TMDL endpoints was achieved at all three long term monitoring sites in Assawoman Bay (Table 4.2.16). No site had values above 50 µg/L chlorophyll *a* although the continuous monitor at Greys Creek showed exceedance of 50 µg/L chl in 2008 and 2010 (Table 4.2.16).

St. Martin River

<u>Fixed Station Status</u>: Four sites consistently met or exceeded the seagrass threshold of 15 µg/L: Birch Branch and Middle Branch, a station located mid-river (MCBP 3), and the farthest downstream station (XDN3724). Spring Branch continues to struggle, with medians well above the 15 µg/L threshold. With the exception of XDN4312 in mid-river, there is little evidence of change across the rolling 3-year medians at these sites. Although during the first two 3-year analysis intervals beginning in 2007, the upstream Bishopville Prong site (XDM4486) did pass the 50 µg/L threshold, it has since failed to pass and was therefore considered eutrophic. As with Greys Creek in Assawoman Bay, the chlorophyll thresholds were not applicable to non-tidal sites on Bishopville and Shingle Landing prongs (Figure 4.2.2).

Table 4.2.4 Rolling three year medians of chlorophyll *a* (µg/L) for stations in the St. Martin River watershed during seagrass growing season (March – November).

3-year medians of chlorophyll *a* (µg/L) in St. Martin River						
	STATION	07-09	08-10	09-11	10-12	11-13
Bishopville Prong	MCBP 11	13.7			25.9	25.5
	XDM4486*	47.0	35.9	51.3	58.7	58.7
	BSH0008	30.9	29.0	36.6	42.0	42.0
Shingle Landing Prong	MXE0011	**4.4**	**2.7**	**4.0**	**3.7**	**3.2**
	BIH0009	**3.6**	**2.8**	**2.7**	**3.2**	**2.7**
	MCBP 25					**1.8**
	SPR0009	31.3	31.0	31.3	35.8	35.6
	SPR0002	31.0	26.2	31.0	33.6	28.8
St Martin River	MCBP 13	19.7	19.7	17.9	16.6	17.3
	XDM4797	**23.4**	**24.6**	22.3	**24.6**	21.7
	MCBP 22	18.9	18.9	16.6	16.6	16.8
	MCBP 3	14.3	13.7	14.2	13.2	13.7
	XDN4312	14.6	**23.4**	16.2	16.8	15.8
	XDN3724	8.5	13.5	**9.9**	**9.4**	**11.4**

*also a continuous monitoring station

NCCA status: One station was sampled twice during 2010. During August chlorophyll *a* passed the seagrass objective (7.5 µg/L) at 4.57 µg/L; however, during September the value failed the seagrass objective (15 µg/L) at 24.73 µg/L. These results demonstrate the high variability of chlorophyll *a* in highly eutrophic areas, and thus the difficulty in using snapshots and measures of central tendency (mean=14.7 µg/L meets seagrass objective) to characterize status.

Continuous monitoring Status: During March through November of all seven years, the Bishopville Prong continuous monitor showed that total chlorophyll concentrations failed the seagrass threshold (15 µg/L) over 80% of the time. Performance was somewhat better at higher concentration thresholds (30 and 50 µg/L thresholds respectively), with failure between 55 and 77%, and 20 and 43% of the time (Table 4.2.5). This is a marked improvement from 2002 when failures occurred 84 and 94 percent of the time, but similar to 2003 (46 and 68 percent of the time).

Table 4.2.5 Annual percent failure rate of chlorophyll criteria from 2007-2013.

Site	Threshold	2007	2008	2009	2010	2011	2012	2013
Bishopville Prong XDM4486	**CHL > 50**	**32.5%**	**20.4%**	**33.2%**	**31.4%**	**26.2%**	**28.0%**	**43.5%**
	CHL > 30	76.0%	54.9%	58.6%	69.7%	69.4%	69.6%	77.3%
	CHL > 15	**95.2%**	**93.1%**	**82.1%**	**97.0%**	**92.7%**	**91.4%**	**94.7%**
	CHL > 7.5	99.1%	99.7%	93.2%	100.0%	99.8%	95.5%	99.8%

During the seagrass growing season, extracted values for chlorophyll *a* at Bishopville Prong frequently exceeded measured fluorescent and predicted values during 2009-2013, suggesting that percent failure for the higher concentration chlorophyll criteria may actually have been greater during those years.

Figure 4.2.5 Comparison of extracted chlorophyll *a* vs fluorescence and predicted temperature-corrected fluorescence chlorophyll values in Bishopville Prong (2007-2013).

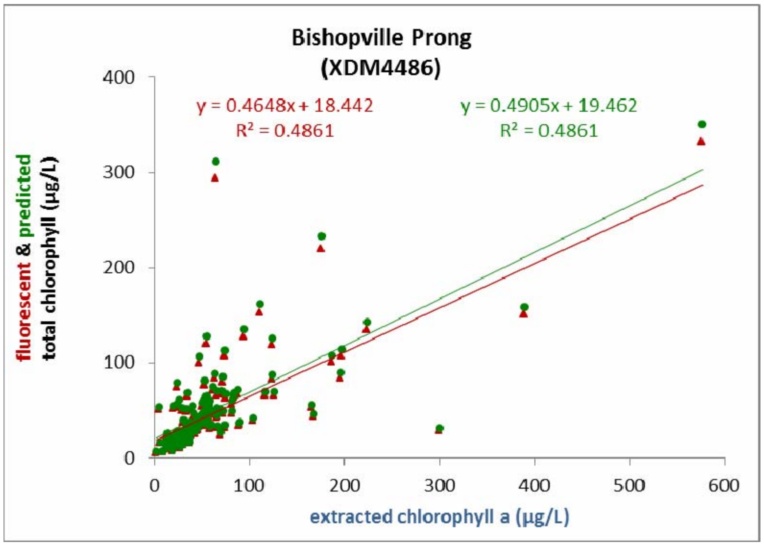
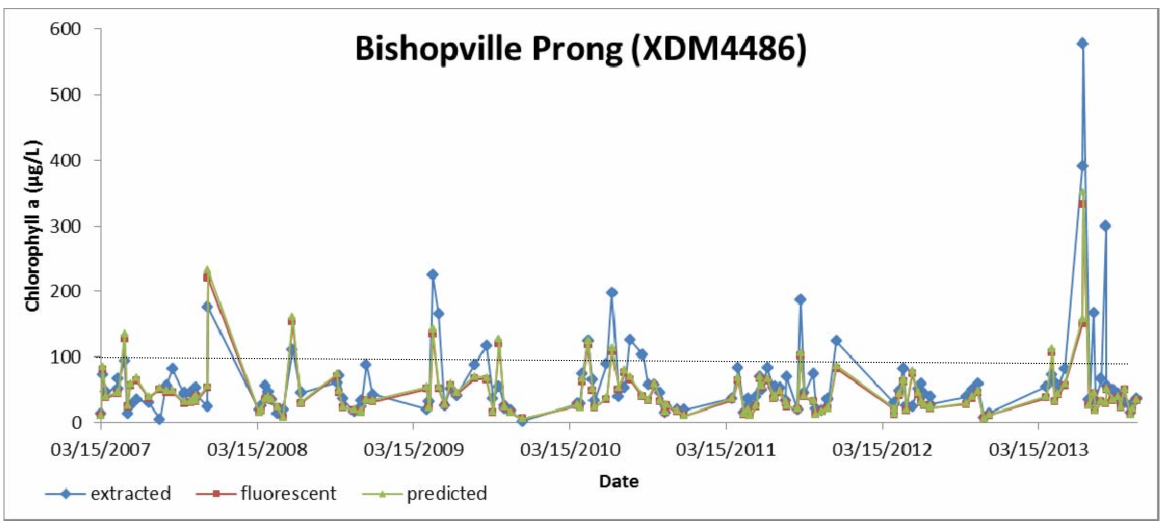


Figure 4.2.6 Comparison of chlorophyll *a* values measured by fluorescence probe, extracted and temperature corrected predicted values in Bishopville Prong.



<u>TMDL Status</u>: Achievement of the total maximum daily load endpoints in the St Martin River ranged from 0% (downstream) to 70.6% (upper river) of chlorophyll levels above 50 µg/L (Table 4.2.16). Only three stations had values above 100 µg/L (BSH008-8.3%; SPR0009 – 5.6% and SPR0002 – 2.8%). Additionally, the continuous monitor at Bishopville Prong showed nearly annual exceedances (Table 4.2.16).

Isle of Wight Bay

Fixed Station Status: All fixed stations except MCBP 30 met or exceeded seagrass thresholds during all years (Figure 4.2.1). Sites nearest the inlet had the lowest chlorophyll concentrations (likely influenced by clear water coming in from the ocean). Sites in the tributaries typically had the highest concentrations.

Table 4.2.6 Rolling three year medians of chlorophyll *a* (µg/L) at stations in the Isle of Wight Bay watershed during seagrass growing season (March – November).

3-year medians of chlorophyll *a* (µg/L) in Isle of Wight Bay						
	STATION	07-09	08-10	09-11	10-12	11-13
Manklin Creek	MCBP 16	4.7	8.2	10.7	11.6	8.9
	MKL0010[a]	12.5	12.5	12.8	13.9	12.1
	MCBP 9[a]	6.3	7.2	7.4	7.1	5.7
Turville Creek	TUV0034	**1.5**	**1.8**	2.1	**1.8**	**1.2**
	MCBP 30	15.8	14.2	17.5	17.2	17.2
	TUV0019	13.0	12.7	13.0	13.8	12.5
	TUV0011	9.8	10.0	10.3	12.7	**11.2**
Herring Creek	HEC0012[b]	14.0	15.0	15.0	10.5	10.7
	MCBP 6[b]				9.5	9.3
Isle of Wight Bay	XDN3445	5.3	5.4	5.6	9.6	10.0
	XDN2340	**5.3**	**5.5**	6.7	9.1	8.6
	MCBP 5	**1.2**	**1.3**	**1.4**	**2**	**1.5**
	MCBP 34	**2.0**	**1.9**			
	XDN2438	**4.8**	6.0	6.0	6.8	6.4
	XDN0146	4.6	**5.1**	5.1	5.7	5.8

[a, b] stations with the same letter are co-located

NCCA status: One station was sampled for National Coastal Condition Assessment during August 2010, and chlorophyll *a* met the seagrass objective (15 µg/L) at 12.71 µg/L.

Continuous monitoring Status: A continuous monitor was deployed on Turville Creek during only one year of this report's time period (2007). It shows the seagrass threshold failed 54% of the time from March – November (1.4% and 10.0 percent for 50 and 30 µg/L thresholds, respectively).

Table 4.2.7 Annual percent failure of chlorophyll endpoints.

Site	Threshold	2007
Turville Creek TUV0021	**CHL > 50**	**1.4%**
	CHL > 30	10.0%
	CHL > 15	**53.6%**
	CHL > 7.5	86.9%

The calibration data from the Turville Creek continuous monitor show the predicted value exceeded the extracted value in nearly all instances, particularly during June and September, when the sonde was left in place for more than two weeks.

Figure 4.2.7 Comparison of extracted chlorophyll *a* vs fluorescence and predicted temperature-corrected fluorescence chlorophyll values in Turville Creek (2007).

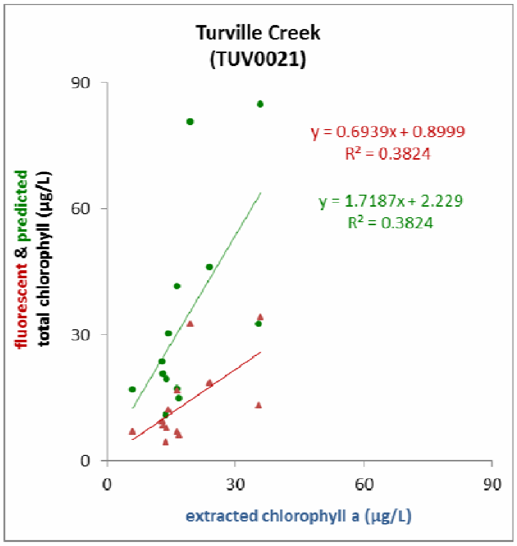
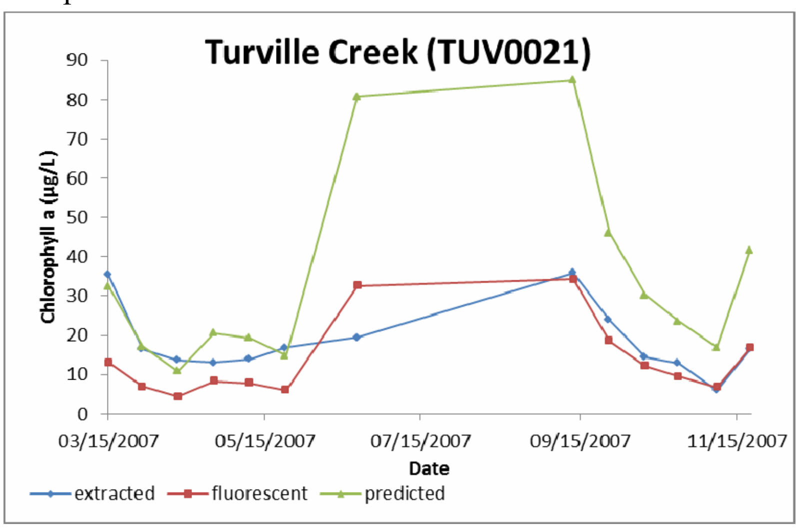


Figure 4.2.8 Comparison of chlorophyll *a* values measured by fluorescence probe, extracted and temperature corrected predicted values in Turville Creek.



TMDL Status: Achievement of the total maximum daily load endpoints in Isle of Wight Bay ranged from 0-5.6% in tributaries with a 50 µg/L threshold and 11-44% failure in open bay sites with a 15 µg/L threshold (Table 4.2.16). Exceedance of the 50 µg/L endpoint did not occur at any of the fixed stations (Table 4.2.16).

Sinepuxent Bay
Fixed Station Status: All fixed stations met seagrass thresholds (Table 4.2.8 and Figure 4.2.2).

Table 4.2.8 Rolling three year chlorophyll *a* status at stations in the Sinepuxent Bay watershed (2007-2013).

3-year medians of chlorophyll *a* (µg/L) in Sinepuxent Bay						
	STATION	2007-09	2008-	2009-11	2010-12	2011-13
West OC Harbor	ASIS 1	**4.9**	**3.9**	4.6	**4.6**	**4.6**
Sinepuxent Bay	ASIS 17	**4.7**	**4.6**	5.4	**5.7**	**5.9**
	ASIS 18	**4.1**	**3.2**	4.4	**4.9**	**5.5**
	MCBP 31	**2**	**2.7**	**4.3**	**4.3**	**3.1**
	ASIS 2	**4.1**	**3.9**	4.1	**4.6**	**4.6**
	MCBP 10	6.2	4.3	**4.2**	**4.5**	5.3
	ASIS 16	7.6	5.2	5.2	**3.7**	**3.7**

NCCA status: There were no stations located in Sinepuxent Bay.

Continuous monitoring Status: ASIS maintains a continuous monitor at a tide gauge station near the Verrazano Narrows Bridge (TS1). Data available from 2009-13 shows that total chlorophyll increased dramatically after 2010. 2012 was a particularly poor year, where total chlorophyll failed the threatened threshold (50 µg/L) nearly 30% of the time and the seagrass threshold (15 µg/L) nearly 90% of the time. Performance improved in 2013, but failure rates remained elevated relative to 2009-2010.

Table 4.2.9 Annual percent failure of chlorophyll endpoints in Sinepuxent Bay (2007-2013).

Site	Threshold	2007	2008	2009	2010	2011	2012	2013
Verezzano Narrows Bridge ASIS TS1	**CHL > 50**	**No Data**	**No Data**	**4.1%**	**2.1%**	**3.6%**	**29.9%**	**1.1%**
	CHL > 30			5.7%	3.1%	25.7%	57.1%	17.9%
	CHL > 15			**25.7%**	**8.7%**	**44.1%**	**87.8%**	**65.9%**
	CHL > 7.5			49.9%	51.1%	59.1%	96.0%	96.7%

Simultaneous grab samples for chlorophyll *a* extraction were not collected at TS1, therefore calibration was not done to predict extracted chlorophyll *a* using continuous monitor fluorescent total chlorophyll and temperature data.

TMDL Status: Achievement of the total maximum daily load 15 µg/L endpoint was achieved at 100% of sites and an improvement from the 2001-2004 assessment (Table 4.2.16). There were no exceedences of the 50 µg/L chlorophyll *a* target (Table 4.2.16).

Newport Bay
Fixed Station Status: In the lower, open bay, the seagrass threshold was met at three sites (ASIS3, ASIS4, XCM4878). While many tributary stations did meet this threshold, many of these are far upstream above the turbidity/chlorophyll maximum and low chlorophyll concentrations are to be expected.

Table 4.2.10 Rolling three year medians of chlorophyll *a* (µg/L) at stations in the Newport Bay watershed during seagrass growing season (March – November).

3-year medians of chlorophyll *a* (µg/L) in Newport Bay						
	STATION	2007-09	2008-10	2009-11	2010-12	2011-13
Trappe Creek	KIT0015	3.3	3.6	**3.9**	**4.1**	**4.5**
	BOB0001	6.3	7.1	7.2	8.3	8.0
	MCBP 4					**3.9**
	MCBP 23	6.9	5.9	4.5	5.1	4.5
	TRC0059[a]	11.7	9.3	13.2	8.7	12.0
	MCBP 35[a]	**4.4**	**5.5**	6.9	6.9	6.8
	TRC0043	43.0	44.9	48.1	56.1	56.1
Ayres Creek	AYR0017[b]	44.7	43.8	38.3	39.3	50.2
	MCBP 33[b]	24.7	22.6	17.3	33.4	31.7
Newport Creek	BMC0011	**0.9**	**0.9**	0.8	**1.2**	**0.9**
	NPC0031	32.6	19.9	33.1	32.4	30.3
	NPC0012	22.4	25.6	18.2	25.6	22.4
Newport Bay	ASIS 4	16.3	14.6	11.9	11.2	10.2
	MCBP 15	13.5	8.1	6.3	6.8	10.2
	XCM4878	11.7	13.4	14.3	13.4	**11.0**
	ASIS 3	12.9	**11.4**	9.5	9.5	8.6
Bassett Creek	MCBP 28	**0.9**	**1.0**	**1.4**	**1.7**	**1.4**
Marshall Creek	MSL0011[c]	32.6	34.4	32.0	28.1	29.6
	MCBP 12[c]	22.0	19.8	16.1	19.0	18.0

[a, b, c]: stations with the same letter are co-located

<u>NCCA status</u>: No stations in Newport Bay were sampled during NCCA 2010.

<u>Continuous monitoring Status</u>: During March through November of 2007, 2008, and 2012, the Newport Creek continuous monitor showed total chlorophyll concentrations failing the SAV threshold (15 µg/L) over 80% of the time. Performance was somewhat better at higher concentration thresholds (30 and 50 µg/L thresholds). Failure of the 30 µg/L threshold ranged from 12 to 50%, with the highest rate in 2008 and the lowest in 2013. Percent failure at 50 µg/L was relatively low compared to Bishopville Prong, ranging from 0.5 to 17.5% of the time (Table 4.2.11).

Table 4.2.11 Annual percent failure of chlorophyll criteria in Newport Creek (2007-13)

Site	Threshold	2007	2008	2009	2010	2011	2012	2013
Newport Creek NPC0012	**CHL > 50**	**4.7%**	**12.5%**	**10.3%**	**8.1%**	**7.6%**	**17.5%**	**0.5%**
	CHL > 30	25.4%	55.1%	22.8%	27.9%	33.1%	39.1%	12.5%
	CHL > 15	**86.4%**	**88.2%**	**61.9%**	**73.8%**	**61.6%**	**85.0%**	**51.4%**
	CHL > 7.5	99.3%	99.5%	92.9%	99.4%	93.2%	97.8%	93.3%

Figure 4.2.9 Comparison of extracted chlorophyll *a* vs fluorescence and predicted temperature-corrected fluorescence chlorophyll values in Newport Creek (2007-2013).

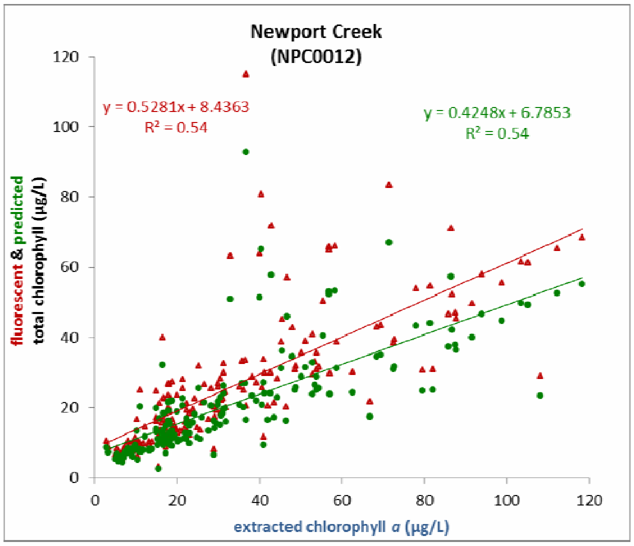
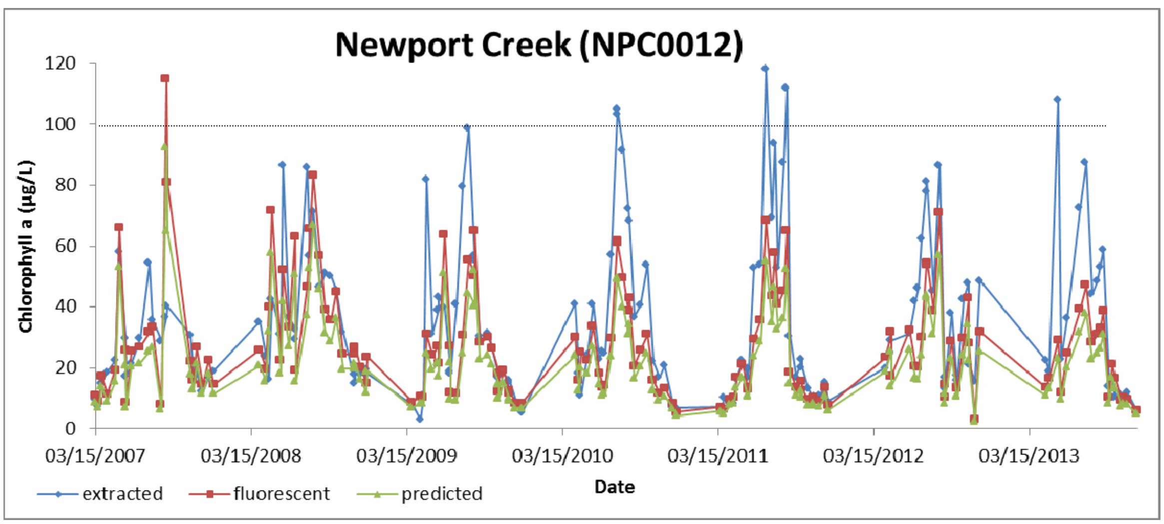


Figure 4.2.10 Comparison of chlorophyll *a* values measured by fluorescence probe, extracted and temperature corrected predicted values in Newport Creek.



TMDL Status: Achievement of the total maximum daily load endpoints in Newport Bay ranged from 0-3% at sites with 50 µg/L threshold and 19% at the one site with a 15 µg/L threshold (Table 4.2.16). The continuous monitor at Newport Creek showed 50 µg/L was exceeded most years (Figure 4.2.10).

Chincoteague Bay

Fixed Station Status: All sites met seagrass threshold of 15 µg/L, with almost all sites less than 7.5 µg/L (Figure 4.2.2).

Table 4.2.12 Rolling three year medians of chlorophyll *a* (µg/L) at stations in the Chincoteague Bay watershed during seagrass growing season (March – November).

3-year medians of chlorophyll *a* (µg/L) in Chincoteague Bay							
		STATION	2007-09	2008-10	2009-11	2010-12	2011-13
Maryland	Open Bay	XCM1562	8.8	6.4	9.2	8.8	6.2
		XCM0159	7.2	7.5	9.8	8.5	7.7
		ASIS 5	9.3	7.6	7.5	7.5	**4.7**
		XBM5932	6.6	5.9	8.9	7.5	6.4
		MCBP 18	6.4	4.9	**3.5**	**3.8**	**3.2**
		ASIS 6	6.8	7.7	**6.5**	**6.1**	**3.3**
		XBM8149	8	9.2	7.8	8.2	8.1
	Johnson Bay	ASIS 7	6.4	5.8	5.2	6.4	**5.2**
		ASIS 14	**4.7**	**3.1**	**4.8**	**4.2**	**2**
	Open Bay	XBM3418	**5.6**	**4.5**	**6.3**	**5.9**	**2.5**
		ASIS 15	**4.4**	**4.8**	**3.9**	**3.9**	**2.6**
	Johnson	MCBP 24				5.4	5.4
	Open bay	XBM1301	**3.1**	**2.9**	**3.8**	**4.6**	**2.2**
Virgina		ASIS 9	**3.1**	**3.1**	**2.9**	**2.9**	**2.9**
		MCBP 29				4.9	4.9
		ASIS 10	**2.5**	**3**	**2.7**	**2.9**	**2.7**
		ASIS 8	**2.8**	**2.3**	**2.5**	**2.6**	**2.5**
		ASIS 11	**4.6**	**4.2**	**5.2**	**5.2**	**5.2**
		ASIS 12	**4.3**	**3.2**	**4.4**	**4.7**	**4.7**
		ASIS 13	5.6	5.4	**5.4**	**4.7**	**5**
	Parker Bay	MCBP 27	**4.4**	**4**	**2.3**	**3.1**	**3.1**

NCCA status: Two stations were sampled for Natioanl Coastal Condition Assessment during 2010. Chlorophyll *a* met the seagrass objective (15 µg/L) at NCCA10-1629 (12.71 µg/L). At NCCA10-1633, chlorophyll *a* (3.7 µg/L) was better than the seagrass objective (7.5 µg/L).

Continuous monitoring status: Continuous monitoring data collected at Public Landing and Green Run Bay showed more chlorophyll failures, with the percent failure of the seagrass threshold (15 µg/L) as much as 94% of the time in 2012. The best attainment rate occurred during 2013 at Public Landing, with a failure rate of 2%. Failure at the 50 µg/L threshold was a rare event (<12%) at that location, and did not occur during 2011 or 2013.

Table 4.2.13 Annual failure of chlorophyll criteria at Public and Tingles Landings

Site	Threshold	2007	2008	2009	2010	2011	2012	2013
Public Landing XBM8828	**CHL > 50**	**11.1%**	**4.9%**	**5.7%**	**2.0%**	**0.0%**	**0.3%**	**0.0%**
	CHL > 30	31.8%	19.5%	11.6%	6.2%	0.0%	3.3%	0.0%
	CHL > 15	**57.1%**	**52.9%**	**30.6%**	**37.5%**	**4.0%**	**21.6%**	**2.2%**
	CHL > 7.5	81.2%	80.7%	58.0%	69.7%	47.7%	63.1%	34.3%
Tingles Landing ASIS TS2	**CHL > 50**	**No Data**	**No Data**	1.2%	0.5%	1.4%	63.0%	0.6%
	CHL > 30			7.9%	0.7%	5.8%	83.5%	2.1%
	CHL > 15			48.5%	17.3%	24.3%	93.8%	17.4%
	CHL > 7.5			67.7%	73.1%	50.7%	99.2%	65.2%

Figure 4.2.11 Comparison of extracted chlorophyll *a* vs fluorescence and predicted temperature-corrected fluorescence chlorophyll values in Chincoteague Bay (2007-2013).

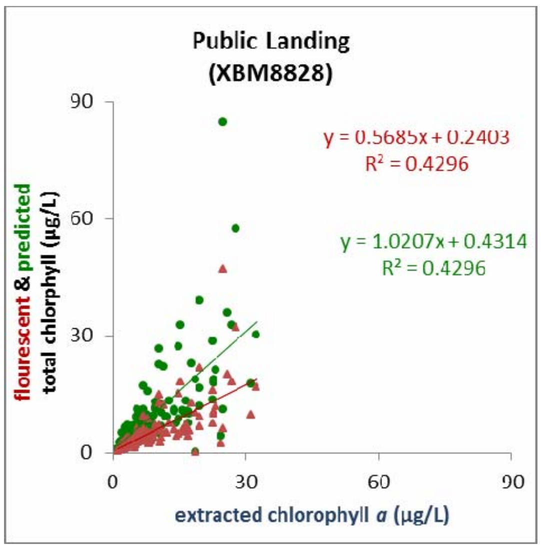
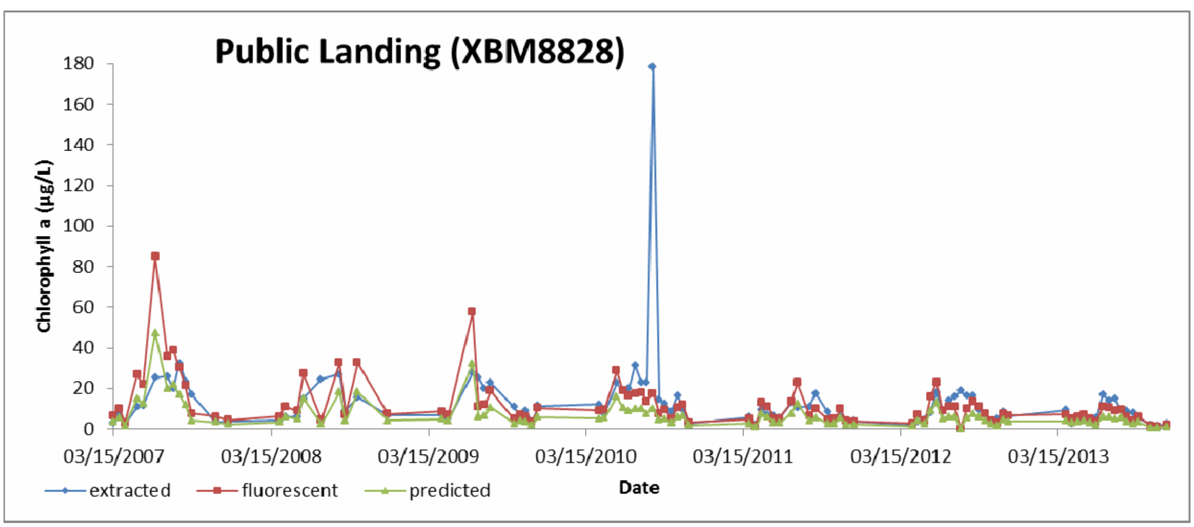


Figure 4.2.12 Comparison of chlorophyll *a* values measured by fluorescence probe, extracted and temperature corrected predicted values in Greys Creek.



TMDL Status: Achievement of the total maximum daily load thresholds and the 50 µg/L endpoint in Chincoteague Bay were met at all sites (Table 4.2.16).

Results: Trends in algae abundance
Few linear trends were observed in chlorophyll *a* concentration in any Coastal Bays segment. Among those, improving trends were found at four Assawoman Bay open bay stations and one in St. Martin River, while declining trends were found at one Newport Bay (Bottle Branch) and two Chincoteague Bay stations located in the Virginia portion of the bay near Chincoteague Island (Table 4.2.14). Many significant non-linear trends were found, and all were changing from degrading to improving during the analysis timeframe (Table 4.2.15).

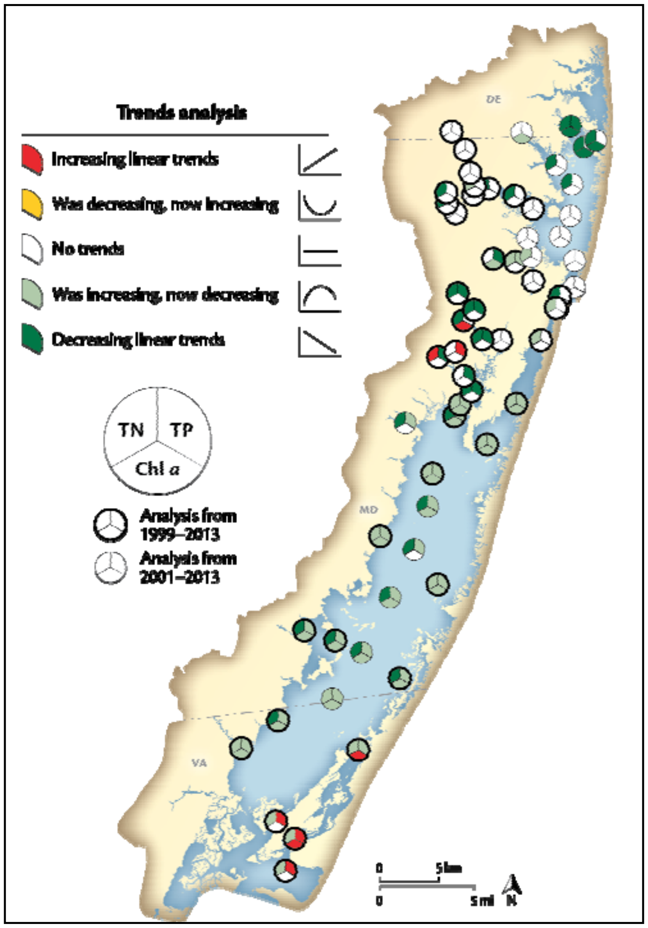
Table 4.2.14 Significant linear trend results for chlorophyll *a*. Cells shaded green are significantly improving while cells shaded pink are significantly degrading.

Station	p-value	slope	parameter	segment
XDN7261	0.0000	-0.769	CHLA	Assawoman Bay
XDN6454	0.0000	-0.6022	CHLA	
XDN7545	0.0073	-0.5696	CHLA	
MCBP 1	0.0000	-0.735	CHLA	
ASIS 8	0.0050	0.1148	CHLA	Chincoteague Bay
ASIS 12	0.0009	0.1753	CHLA	
BOB0001	0.0024	0.2783	CHLA	Newport Bay
MCBP 11	0.0000	-3.1343	CHLA	St. Martin R

Table 4.2.15 Significant non-linear trend results for chlorophyll *a*. Cells shaded green are significantly improving while cells shaded pink are significantly degrading.

Station	trend type	critical date	segment
GET0005	inverted U	18Jul2007	Assawoman Bay
MCBP 13	inverted U	29Sep2004	St. Martin River
TUV0034	inverted U	12Nov2004	Isle of Wight
ASIS 2	inverted U	18Jul2007	Sinepuxent Bay
MCBP 10	inverted U	24Jul2007	
ASIS 16	inverted U	26Oct2006	
XCM4878	inverted U	03Feb2007	Newport Bay
ASIS 3	inverted U	10Jan2006	
MCBP 12	inverted U	05Aug2007	
XCM1562	inverted U	24Mar2007	Chincoteague Bay
XCM0159	inverted U	05Jun2007	
ASIS 5	inverted U	21Jan2006	
MCBP 18	inverted U	17Jan2006	
ASIS 6	inverted U	20Sep2005	
XBM8149	inverted U	02Apr2007	
ASIS 7	inverted U	25May2005	
ASIS 14	inverted U	17Aug2005	
XBM3418	inverted U	08Sep2005	
ASIS 15	inverted U	22Sep2005	
XBM1301	inverted U	16Jan2006	
ASIS 9	inverted U	09May2006	
ASIS 10	inverted U	29Dec2005	

Figure 4.2.13 Chlorophyll *a* trends at Marylan Department of Natural Resources and Assateague Island National Seashore stations (1999-2013 or 2001-2013). Linear trends are primary, if there was no linear trend detected then non-linear trend analyses were checked for significant trends.



Assawoman Bay
Four linearly improving trends and one non-linear improving chlorophyll trend (Greys Creek, GET0005) were detected is Assawoman Bay (Figure 4.2.13).

St. Martin River
One linear improving (MCBP 11) and one non-linear chlorophyll trend was detected at the mouth of Bishopville Prong (MCBP 13), otherwise no chlorophyll trends were detected (Figure 4.2.13).

Isle of Wight Bay
One improving non-linear trend was found in the upper reach of Turville Creek (TUV0034), otherwise no chlorophyll trends were detected (Figure 4.2.13).

Sinepuxent Bay

Two improving non-linear chlorophyll trends were found in the southern part of the bay while no significant trends were detected in northern areas (Figure 4.2.13).

Newport Bay

Improving non-linear trends were found at two open bay sites (XCM4878, ASIS 3), and at 1 tributary site (MCBP 12 – Marshall Creek). A degrading linear trend was found at one upper tributary station (BOB0001 – Bottle Branch). (Figure 4.2.13)

Chincoteague Bay

Two degrading linear, chlorophyll trends were found near Chincoteague Island (ASIS 8 and 11) and 12 significantly improving, non-linear trends in chlorophyll were found in Chincoteague Bay (Figure 4.2.13).

Summary

Current status analyses show chlorophyll levels are suitable for seagrasses in the bays (79.5% of sites passed seagrass chlorophyll threshold) and elevated in many tributaries. Overall, trends show improving chlorophyll concentrations or no trend at all.

The seagrass chlorophyll threshold (15ug/L) was met at a majority of sites in Assawoman, Isle of Wight, Sinepuxent and Chincoteague bays; while the St. Martin River and tributaries of Newport Bay failed during the most recent assessment period (2011-2013). The STAC chlorophyll threshold (>50ug/L) showed eutrophic conditions are present in Bishopville Prong, Trappe Creek and Ayres Creek. Surprisingly the August 2010 snapshot of chlorophyll by the National Coastal Assessment showed similar results.

The relationships of measured fluorescent and predicted values, suggesting that percent failure for chlorophyll criteria may actually have been higher during most years. Intensive temporal monitoring shows the duration of blooms can be very long in these areas. Even Chincoteague Bay showed intense blooms when 30-57% of samples were >15 µg/L at Public Landing and 17-94% of values at Taylor's Landing. Continuous monitors should be placed in all bay segments to better understand duration of blooms; at present only Isle of Wight Bay does not have a deployed continuous monitor.

Chlorophyll criteria for TMDL analyses use a different metric than the MCBP STAC analyses. Applying this analysis to the same dataset used to determine if STAC thresholds were achieved, a different picture emerges of areas meeting or failing objectives (Figure 4.2.16). The TMDL analyses show that chlorophyll endpoints are not met (≥5% of values above threshold) at 44% of the sites in the Coastal Bays. This analysis relates better to areas with oxygen problems (see Chapter 4.3).

Trend analyses show significantly improving trends at 27 of 79 sites (34%), throughout the Coastal Bays system. Improving linear trends were found mostly in Assawoman Bay, while non-linear trends showed improvements in many areas, especially Chincoteague Bay. Three significant degrading chlorophyll trends were found – two in southern Chincoteague Bay and the third in Bottle Branch, a tributary of Newport Bay suggesting nutrient sources need to be reduced in these areas.

Despite many areas failing nutrient thresholds in the Coastal Bays, chlorophyll values were generally good in the open bays. This could be because much of the algal biomass (organic matter) produced in the tributaries is deposited within these areas (see Chapter 5.1). Another explanation may be that nutrients are sequestered in or utilized by other forms such as benthic planktonic algae, macroalgae, and seagrasses instead of water column phytoplankton. We recommend that all primary producers be monitored in a coordinated program in order to best understand the total impacts of nutrient inputs.

Table 4.2.16 Total maximum daily load, TMDL, chlorophyll analysis (2001-2004 vs 2011-2013) indicating the percent of time chlorophyll *a* levels are not meeting thresholds for TMDL endpoint. Red box indicates greater failure rate in more recent period (2011-2013) compared with baseline analysis (2001-2004).

Sub-basin	Station Name	Threshold (Endpoint)	Growing season % > Threshold		Annual % > Threshold	
			2001-2004	**2011-2013**	2001-2004	**2011-2013**
Assawoman Bay	XDN4851	>15	45.83	**33.3**	27.97	**17.1**
	XDN5737	>50	0	**5.6**	0	**2.9**
	XDN6454	>15	70.83	**27.8**	41.86	**14.3**
St. Martin River	BSH0008	>50	39.13	**55.6**	26.19	**33.3**
	SPR0002	>50	25	**11.1**	15.56	**8.3**
	SPR0009	>50	43.48	**33.3**	27.91	**19.4**
	XDM4486	>50	50	**70.6**	41.86	**48.5**
	XDM4797	>50	8.33	**22.2**	11.11	**16.7**
	XDN3724	>50	0	**0.0**	4.55	**0.0**
	XDN4312	>50	4.17	**2.8**	6.67	**1.4**
Isle of Wight Bay	TUV0011	>50	4.17	**0.0**	2.22	**0.0**
	TUV0019	>50	8.33	**5.6**	4.26	**2.8**
	MKL0010	>50	4.17	**0.0**	2.22	**0.0**
	XDN0146	>15	8.33	**11.1**	6.67	**11.1**
	XDN2340	>15	20.83	**22.2**	13.33	**13.9**
	XDN2438	>15	12.50	**11.1**	8.89	**11.1**
	XDN3445	>15	29.17	**44.4**	17.78	**22.2**
Newport Bay	AYR0017	>50	37.5		25	
	XCM4878	>50	4	**0**	2.33	**0**
	ASIS 3	<15	50	**19.4**	27.66	**33.3**
	ASIS 4	>50	4.17	**2.8**	2.17	**5.6**
Sinepuxent Bay	ASIS 1	<15	8.33	**2.8**	4.26	**5.6**
	ASIS 2	<15	12.5	**5.6**	6.38	**11.1**
	ASIS 16	<15	20.83	**0**	10.64	**0**
	ASIS 17	<15	12.5	**8.3**	6.38	**11.1**
	ASIS 18	<15	12.5	**5.6**	6.38	**0**
Chincoteague Bay, MD	XBM1301	>50	4.35	**0.0**	2.27	**0.0**
	XBM3418	>50	0	**0.0**	0	**0.0**
	XBM5932	>50	0	**0.0**	0	**0.0**
	XBM8149	>15	56.52	**13.9**	29.55	**7.1**
	XCM0159	>15	39.13	**19.4**	20.45	**10.0**
	XCM1562	>50	0	**0.0**	0	**0.0**
Chincoteague Bay, VA	ASIS 5	<15	33.33	**2.8**	16.67	**5.6**
	ASIS 6	<15	12.5	**0**	6.25	**0**
	ASIS 7	<15	37.5	**5.6**	19.15	**11.1**
	ASIS 8	<15				
	ASIS 14	<15	4.35	**0**	2.17	**0**
	ASIS 15	<15	0	**0**	0	**0**

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