Chapter 4.1

Nutrient status and trends in the Maryland Coastal Bays

Catherine Wazniak[1], Carol McCollough[1], Brian Sturgis[2], Carol Cain[3]
[1]Maryland Department of Natural Resources, Tidewater Ecosystem Assessment, Annapolis, MD 21401
[2]US Department of the Interior, National Park Service, Assateague Island National Seashore, Berlin, MD 21811
[3]Maryland Coastal Bays Program, Berlin, MD 21811

Abstract
Nutrient data was analyzed from 87 stations for current status (total nitrogen total phosphorus, and ammonium) and 60 sites for long-term trends (same nutrients as status as well as nitrate-nitrite and orthophosphate). Assawoman Bay, St. Martin River, northern Isle of Wight Bay, and Newport Bay were severely enriched with nitrogen while Sinepuxent and Chincoteague bays had the lowest total nitrogen concentrations. Phosphorus enrichment was widespread, exceeding water quality thresholds at 95% of stations. Ammonium concentrations exceeded seagrass thresholds at 57% of sites and were potentially lethal at 15-22% of sites. Ammonium concentrations were highest in the Virginia portion of Chincoteague Bay and in tributaries watershed-wide. Combined linear and non-linear trends analysis detected 152 unique significant trends among all parameters and stations (50%). Most trends were improving; only 20 significant degrading trends were found (7%). Overall nutrient levels in the Maryland Coastal Bays are fair to poor with generally improving trends since 1999.

Introduction
Nutrient over-enrichment is a major threat to the Coastal Bays. Nutrients can enter the water column from a wide range of point and non-point sources. Non-point sources include agriculture (fertilizer and animal waste), septic systems, legacy groundwater, and natural sources (wetlands, marshes, and forests). Atmospheric deposition is another non-point source that can bring in nutrients from outside the watershed. Some non-point source inputs are often sporadic or ephemeral, as when a storm event causes large amounts of run-off, while others such as groundwater are more constant inputs. Non-point nutrient inputs are the major sources of nitrogen and phosphorus to the Coastal Bays. Point sources, such as sewage treatment plants, are estimated to account for only 4% of the total nutrient inputs. Total nitrogen (TN) and total phosphorus (TP) were used as indicators to reduce variability associated when measuring dissolved nutrients only. Increases in ammonium (NH_4) at relatively low concentrations have been associated with adverse effects on seagrasses (also known as submerged aquatic vegetation or SAV) (van Katwijk et al. 1997; Van der Heide et al. 2008). Van Katwijk showed concentrations of 3µM (9µM application) did not show toxic effects but at a concentration of 10µM (25µM application treatment) plants did exhibit toxic impacts. Ammonium toxicity effects were more pronounced in plants grown on sand and at higher temperatures (20^{o}C) as found in the Coastal Bays.

Data Sets

Three separate but comparable water quality monitoring programs operate in the Coastal Bays (see Chapter 1.1). These programs are conducted by the Maryland Department of Natural Resources (DNR), the National Park Service at Assateague Island National Seashore (ASIS), and the Maryland Coastal Bays Program (MCBP) volunteer monitors. Figure 4.1.1 shows the locations of each station monitored between 2007 and 2013. A number of the same stations are sampled by two different programs (DNR and MCBP); however, the volunteer program samples more frequently. These provide useful quality assurance checks between monitoring programs, and may serendipitously result in better temporal coverage when sampling dates are not simultaneous. A full list of nutrient parameters monitored by ASIS and DNR is reported in the Maryland Coastal Bays Program Eutrophication Monitoring Plan (Wazniak 1999).

Management Objective: To achieve bay water concentrations of nutrients that meet seagrass thresholds.

Nitrogen Indicators:	TN = 0.65 mg/L seagrass health TN = 1.0 mg/L eutrophic
Phosphorus Indicators:	TP = 0.037 mg/L seagrass health TP = 0.1 mg/L eutrophic
Ammonium Indicators:	NH_4 = 2µM = 0.028 mg/L N as NH4 NH_4 = 4µM = 0.056 mg/L N as NH4 seagrass health

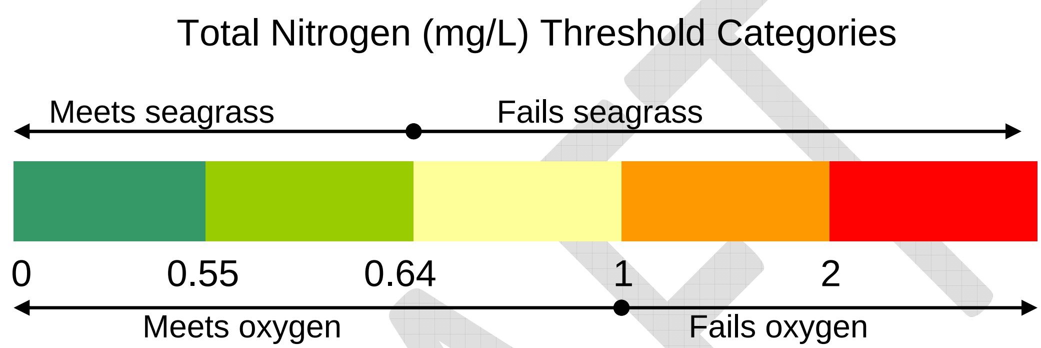
Analyses

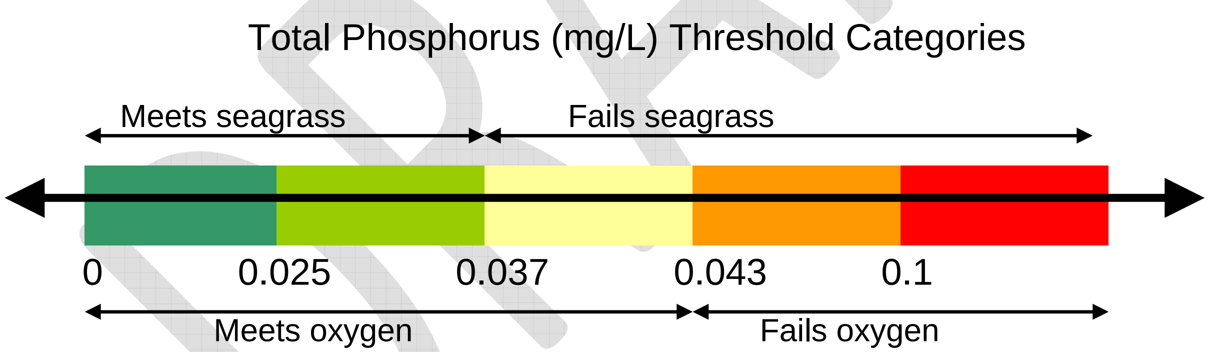
<u>Status</u>

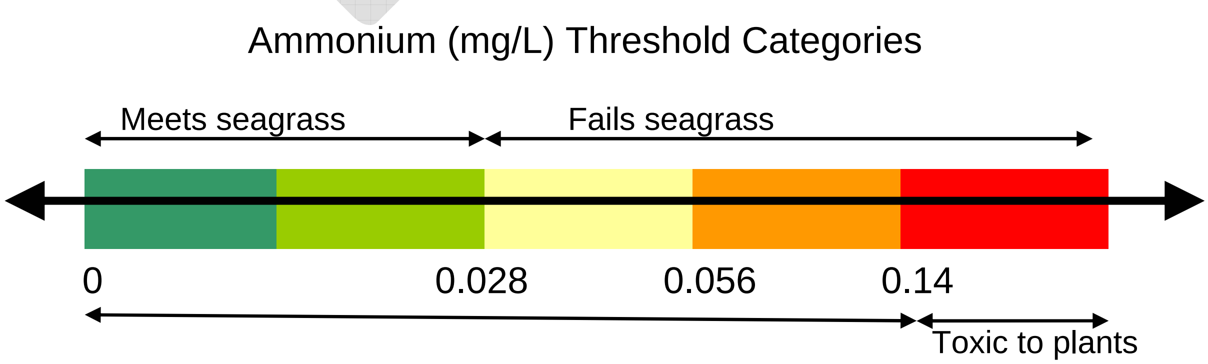
Median concentrations of TN, TP, and NH_4 were determined for rolling three-year periods between 2007-2013 for each DNR and ASIS monitoring station. Where data were available for specific 3-year periods, equivalent analyses were performed for MCBP stations (Figure 4.1.1). The Maryland Coastal Bays Scientific and Technical Advisory Committee (STAC) developed TN and TP threshold categories based on living resources indicators, most notably seagrass (Stevenson et al 1993) (Table 4.1.1). The NH_4 threshold of 4uM was suggested by Pat Glibert (pers. comm.) as harmful to seagrass health. Data from all months were used for TN and TP analyses, while data from only the seagrass growing season (April – October) were used for NH_4 analyses. Using a non-parametric Wilcoxon sign-rank test, median values were compared to threshold upper and lower boundaries. Medians that were significantly different than the boundary values at $p<0.01$ were considered statistically significant overall. Results are presented for all 3-year periods, with discussion focused on the most recent (2011-13).

Table 4.1.1 Threshold category values for TN, TP, and NH_4 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 values are living resources indicator values as mandated by STAC.

Threshold criteria category	TN upper boundary value	TP upper boundary value	NH_4 upper boundary value
Better than seagrass objective	0.55 mg/L	0.025 mg/L	
Meets seagrass objective	**0.64 mg/L**	**0.037 mg/L**	0.028 mg/L
Does not meet seagrass objective	**1 mg/L**	0.043 mg/L	0.056 mg/L
Does not meet STAC objectives	2 mg/L	**0.1 mg/L**	
Does not meet any objectives	> 2 mg/L	> 0.1 mg/L	> 0.126 mg/L







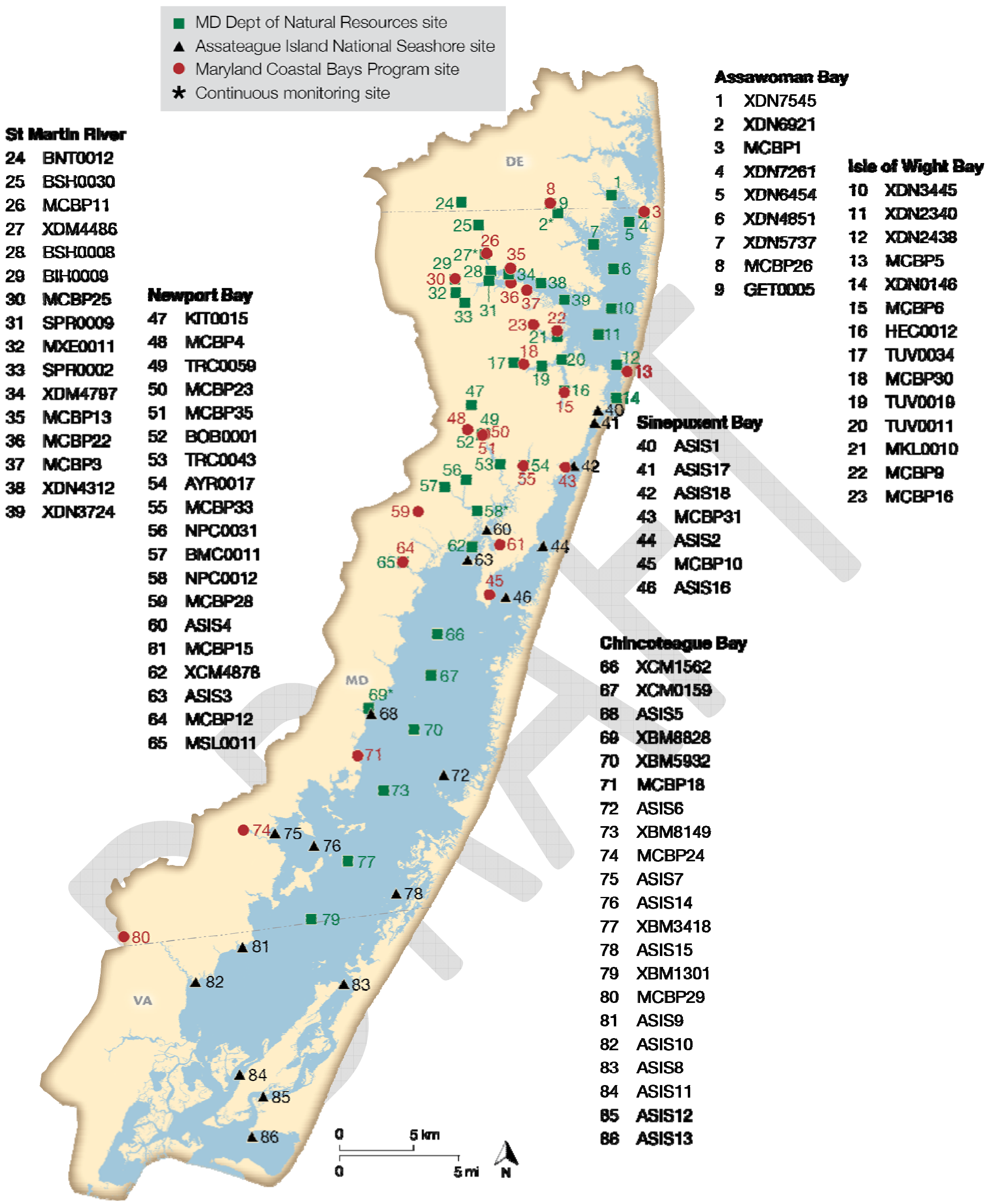


Figure 4.1.1 Water quality monitoring station locations.

<u>*Trends*</u>

Trend analyses were used to compare the effect of time on water quality parameters, including TN and TP, plus the dissolved parameters ammonium (NH_4), nitrate-nitrite (NO_{23}), and orthophosphate (PO_4). Linear and non-linear analyses were performed on all stations that have been sampled continuously since 1999 (since 2001 for a subset of DNR stations). At least 10 continuous years of data are required for trend analyses. No MCBP stations met that criterion, so trends were not determined for those stations. 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). For all trend tests, a significance level of $p<0.01$ was used to achieve the highest possible power. Where no linear trend was detected, non-linear trend analysis was performed to identify if trend direction reversals occurred during the analysis period (Wazniak et al. 2007).

Results: Status of nutrient concentrations

Rolling three year statuses of TN, TP, and NH_4 concentrations in each Coastal Bays segment were examined. Results focus on the most recent time-period (2011-2013). Figure 4.1.2 maps the status of each parameter for the most recent 3-year period, 2011-13. The status of NH_4 was determined to investigate potential impacts on seagrass growth in the bays.

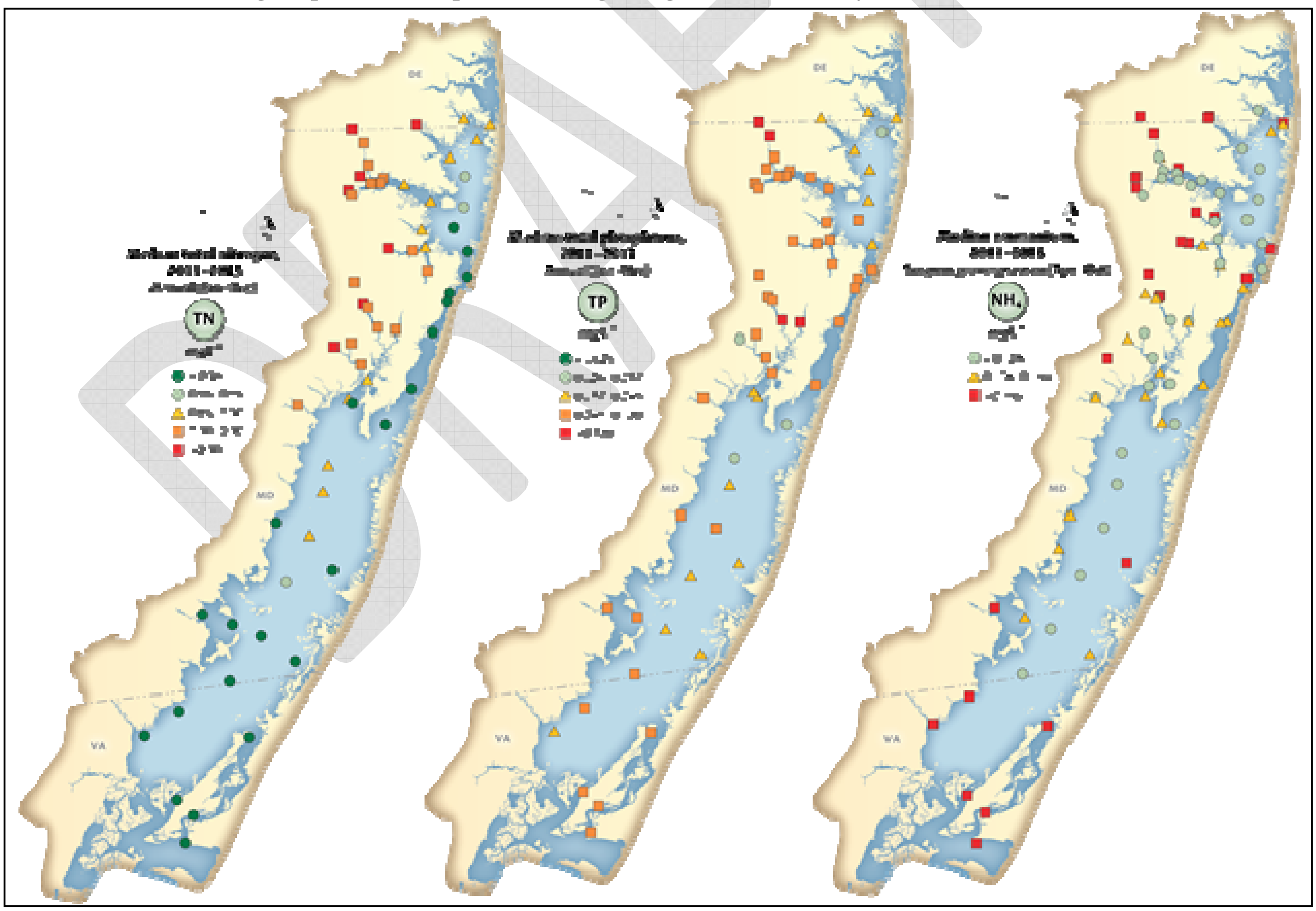


Figure 4.1.2. 2011-13 status for total nitrogen, total phosphorous and ammonium at Maryland Department of Natural Resources and Assateague Island monitoring stations.

Assawoman Bay

Eight stations were monitored in Assawoman Bay. Only three stations met either the TN or TP seagrass thresholds, and their median values were not significantly different from the upper boundary value of the criterion. Two stations met TN thresholds for SAV. One station at the headwaters of Grey's Creek (GET0005) did not meet any STAC TN objective and was classified as eutrophic (Table 4.1.2a). Only one station (XDN6454 at RT 90) passed the TP threshold for SAV (Table 4.1.2b).

Table 4.1.2a: 3-year medians of TN (mg/L) in Assawoman Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Grey's Creek	MCBP26a					1.82
	GET0005[a]	**2.29**	2.15	2.13	2.07	2.35
Fenwick Ditch	XDN7261	1.01	0.96	**0.86**	**0.81**	**0.72**
	MCBP1	**0.67**	**0.67**	0.65	0.56	0.51
Assawoman Bay	XDN7545	0.98	0.99	0.97	**0.82**	**0.75**
	XDN6454	**0.95**	**0.86**	**0.76**	**0.74**	**0.69**
	XDN5737	**0.92**	**0.93**	**0.84**	**0.74**	**0.72**
	XDN4851	0.66	0.66	0.66	0.61	0.56

Table 4.1.2b: 3-year medians of TP (mg/L) in Assawoman Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Grey's Creek	MCBP26a					0.034
	GET0005[a]	**0.058**	**0.059**	**0.051**	**0.056**	0.042
Fenwick Ditch	XDN7261	0.039	0.038	0.037	0.040	0.038
	MCBP1	0.039	0.040	0.040	0.040	0.039
Assawoman Bay	XDN7545	0.041	0.037	0.040	0.040	0.039
	XDN6454	0.036	0.035	0.039	0.039	0.037
	XDN5737	0.042	0.044	0.045	0.045	0.040
	XDN4851	0.037	0.037	0.040	0.040	0.040

Ammonium was at reaching potentially toxic levels at the two stations in Grey's Creek and at sublethal impacts at one station on Fenwick Ditch (Table 4.1.2c). Nutrient data were compatible at the co-located sites on Grey's Creek (TN fell into different categories).
(Figure 4.1.2)

Table 4.1.2c: 3-year medians of NH4 (mg/L) in Assawoman Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Grey's Creek	MCBP26a					**0.096**
	GET0005[a]	0.097	0.069	**0.107**	0.109	**0.115**
Fenwick Ditch	XDN5737	0.025	0.024	0.025	**0.016**	0.020
	MCBP1	**0.124**	**0.178**	**0.155**	**0.138**	**0.111**
Assawoman Bay	XDN6454	0.041	0.049	0.056	0.027	0.035
	XDN7261	0.066	0.086	0.064	0.038	0.038
	XDN7545	0.030	0.029	0.022	0.020	0.021
	XDN4851	0.029	0.019	0.017	**0.014**	0.016

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 with the same letter are co-located

St. Martin River

None of the 16 stations met TN or TP seagrass thresholds during any analytical timeframe. All stations but four were considered eutrophic for TN. The less impacted stations (XDN3724, XDN4312, M3 and M22) were located lower in the river, suggesting positive influence by water exchange with Isle of Wight Bay. Station XDN4312, in the mid St. Martin River, was on the cusp of STAC TN failure during 4 of 5 analytical timeframes (Table 4.1.3a). TP levels showed all sites were eutrophic (Table 4.1.3b)

Table 4.1.3a 3-year medians of TN (mg/L) in St. Martin River

Area	STATION	07-09	08-10	09-11	10-12	11-13
Bishopville Prong	BNT0012	2.42	2.42	3.14	3.16	3.47
	BSH0030	2.58	2.69	2.78	2.77	2.68
	MCBP11					1.64
	XDM4486	2.07	1.97	1.92	1.77	1.84
	BSH0008	1.68	1.69	1.63	1.59	1.58
Shingle Landing Prong	MXE0011	1.50	1.50	1.43	1.39	1.32
	BIH0009	2.55	2.43	2.23	2.14	2.19
	MCBP25					2.31
	SPR0009	1.55	1.56	1.64	1.34	1.35
	SPR0002	1.52	1.43	1.43	1.29	1.30
St. Martin River	MCBP13	1.24	1.24	1.16	1.11	1.19
	XDM4797	1.25	1.20	1.14	1.08	1.15
	MCBP22	1.20	1.13	1.08	0.92	0.92
	MCBP3	0.98	0.86	0.83	0.67	0.66
	XDN4312	0.97	0.98	1.02	0.99	0.95
	XDN3724	0.78	0.78	0.85	0.80	0.76

Table 4.1.3b 3-year medians of TP (mg/L) in St. Martin River

Area	STATION	07-09	08-10	09-11	10-12	11-13
Bishopville Prong	BNT0012	0.067	0.073	0.092	0.092	0.084
	BSH0030	0.130	0.121	0.160	0.146	0.126
	MCBP11					0.121
	XDM4486	0.151	0.129	0.148	0.135	0.119
	BSH0008	0.089	0.082	0.112	0.105	0.096
Shingle Landing Prong	MXE0011	0.100	0.101	0.123	0.120	0.095
	BIH0009	0.085	0.077	0.097	0.100	0.083
	MCBP25					0.057
	SPR0009	0.101	0.094	0.104	0.093	0.084
	SPR0002	0.081	0.089	0.094	0.083	0.068
St. Martin River	MCBP13	0.077	0.091	0.078	0.073	0.083
	XDM4797	0.074	0.078	0.070	0.063	0.066
	MCBP22	0.091	0.089	0.087	0.073	0.073
	MCBP3	0.068	0.067	0.068	0.060	0.060
	XDN4312	0.055	0.058	0.066	0.066	0.059
	XDN3724	0.045	0.046	0.051	0.059	0.055

Median NH_4 concentrations during the SAV growing season passed at nine of the sites and was above concentrations considered to be lethal to seagrasses at five sites (Table 4.1.3c) and moderate at MCBP13. One site (M11) had sub-lethal NH_4 levels that are still harmful to seagrasses. (Figure 4.1.2)

Table 4.1.3c 3-year medians of NH4 (mg/L) in St. Martin River

Area	STATION	07-09	08-10	09-11	10-12	11-13
Bishopville Prong	BNT0012	0.130	0.131	0.159	0.270	0.206
	BSH0030	0.098	0.096	0.138	0.109	0.143
	MCBP11					0.037
	XDM4486	0.016	0.011	0.016	0.010	0.021
	BSH0008	0.013	0.014	0.011	0.015	0.017
Shingle Landing Prong	MXE0011	0.098	0.122	0.131	0.151	0.160
	BIH0009	0.218	0.223	0.221	0.218	0.229
	MCBP25					0.290
	SPR0009	0.016	0.012	0.018	0.011	0.017
	SPR0002	0.011	0.007	0.010	0.010	0.016
St. Martin River	MCBP13	0.045	0.040	0.043	0.061	0.071
	XDM4797	0.013	0.012	0.012	0.012	0.012
	MCBP22	0.028	0.015	0.015	0.015	0.016
	MCBP3	0.034	0.025	0.023	0.018	0.021
	XDN4312	0.017	0.010	0.010	0.010	0.012
	XDN3724	0.024	0.016	0.011	0.010	0.011

Isle of Wight Bay

The five stations in the open bay and one on Manklin Creek consistently met the TN seagrass threshold (6/15 sites=40%) (Table 4.1.4a). Seven stations on Manklin, Turville, and Herring creeks consistently failed the TN seagrass threshold (MKL0010, TUV0011, TUV0019, TUV0034, HEC0012, M16, M30), of which 4 were considered eutrophic (TUV0019, TUV0034, M30, HEC0012) (Table 4.1.4a). Although no stations were considered eutrophic, no station met the TP seagrass threshold (11/15= 73%) (Table 4.1.4b). Stations in the open bay generally showed better TP conditions than stations in tributaries.

Table 4.1.4a: 3-year medians of TN (mg/L) in Isle of Wight Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Manklin Creek	MCBP16	0.99	0.95	**0.86**	**0.87**	0.78
	MKL0010	0.75	**0.76**	**0.76**	0.74	0.68
	MCBP9	0.62	0.61	0.61	0.67	0.55
Turville Creek	TUV0034	**2.63**	**2.65**	**2.58**	**2.55**	**2.58**
	MCBP30	**1.15**	**1.22**	**1.21**	1.19	1.00
	TUV0019	1.11	1.13	**1.23**	1.19	1.04
	TUV0011	**0.75**	**0.75**	**0.77**	**0.77**	0.73
Herring Creek	HEC0012	1.04	1.02	0.97	0.99	1.03
	MCBP6					0.69
Isle Of Wight Bay	XDN3445	0.61	0.62	0.63	0.62	0.56
	XDN2340	0.55	0.56	0.56	0.56	0.50
	MCBP34	0.54	0.56			
	MCBP5	**0.32**	**0.32**	**0.32**	**0.32**	**0.31**
	XDN2438	**0.47**	**0.47**	**0.44**	**0.45**	**0.45**
	XDN0146	**0.46**	**0.46**	**0.47**	**0.47**	**0.46**

Table 4.1.4b: 3-year medians of TP (mg/L) in Isle of Wight Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Manklin Creek	MCBP16	0.095	**0.074**	**0.066**	**0.064**	**0.070**
	MKL0010	0.050	0.052	**0.052**	0.045	0.044
	MCBP9	**0.064**	**0.074**	**0.076**	**0.076**	**0.072**
Turville Creek	TUV0034	**0.079**	**0.075**	**0.075**	**0.075**	**0.066**
	MCBP30	0.085	0.088	0.087	0.065	**0.069**
	TUV0019	**0.063**	**0.057**	**0.058**	**0.057**	**0.057**
	TUV0011	0.050	0.046	**0.047**	**0.046**	0.047
Herring Creek	HEC0012	**0.066**	**0.061**	**0.067**	**0.064**	**0.064**
	MCBP6					**0.064**
Isle of Wight Bay	XDN3445	0.042	0.039	0.042	0.039	0.038
	XDN2340	0.039	0.041	0.046	0.047	0.047
	MCBP34	0.039	0.039			
	MCBP5	0.038	0.042	0.044	0.043	0.041
	XDN2438	0.043	0.042	0.039	0.043	0.041
	XDN0146	0.048	0.041	0.042	0.043	0.046

Table 4.1.4c 3-year medians of NH4 (mg/L) in Isle of Wight Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Manklin Creek	MCBP16	0.049	**0.046**	**0.040**	0.046	0.047
	MKL0010	**0.013**	**0.009**	**0.009**	**0.007**	**0.011**
	MCBP9	**0.072**	**0.066**	0.058	0.058	0.056
Turville Creek	TUV0034	**0.042**	**0.041**	**0.038**	**0.042**	**0.039**
	MCBP30	0.081	0.056	**0.040**	0.040	0.038
	TUV0019	0.034	0.024	0.019	**0.019**	0.022
	TUV0011	**0.019**	**0.013**	**0.013**	**0.008**	**0.009**
Herring Creek	HEC0012	0.020	**0.016**	**0.018**	**0.014**	**0.017**
	MCBP6					0.020
Isle of Wight Bay	XDN3445	0.027	0.020	**0.010**	**0.010**	**0.010**
	XDN2340	0.025	**0.015**	**0.012**	**0.008**	**0.009**
	MCBP34	0.027	0.027			
	MCBP5	0.036	0.037	0.039	0.041	0.045
	XDN2438	**0.014**	**0.008**	**0.011**	**0.012**	**0.013**
	XDN0146	**0.017**	**0.014**	**0.014**	**0.014**	**0.014**

Ammonium levels were generally good (9/14 stations, 64%, met NH4 thresholds), and only considered potentially harmful to seagrass at one station on Manklin Creek (M9) (Table 4.1.1c). No sites were monitored by multiple programs in Isle of Wight Bay. (Figure 4.1.2)

Sinepuxent Bay
TN concentrations were well below the seagrass threshold at all seven stations during all analytical timeframes (Table 4.1.5a). One station (A16) met the TP seagrass threshold during the most recent (2011-13) timeframe. During the same timeframe, most other stations failed the TP seagrass threshold. Five out of seven stations (71%) failed TP ecosystem health threshold and are considered eutrophic. TP status appears to be worsening over time at 4 of these 6 stations (Table 4.1.5b).

Table 4.1.5a: 3-year medians of TN (mg/L) in Sinepuxent Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
West OC Harbor	ASIS1	**0.35**	**0.35**	**0.35**	**0.33**	**0.30**
Sinepuxent Bay	ASIS17	**0.28**	**0.28**	**0.27**	**0.26**	**0.24**
	ASIS18	**0.31**	**0.30**	**0.27**	**0.28**	**0.26**
	MCBP31	**0.37**	**0.37**	**0.32**	**0.32**	**0.31**
	ASIS2	**0.37**	**0.36**	**0.38**	**0.38**	**0.33**
	MCBP10	**0.41**	**0.43**	**0.43**	**0.43**	**0.38**
	ASIS16	0.47	**0.47**	**0.38**	**0.37**	**0.35**

Table 4.1.5b: 3-year medians of TP (mg/L) in Sinepuxent Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
West OC Harbor	ASIS1	0.047	0.046	0.051	**0.050**	**0.048**
Sinepuxent Bay	ASIS17	0.041	0.037	0.040	0.044	**0.050**
	ASIS18	0.038	0.036	0.036	0.042	0.046
	MCBP31	0.041	0.041	0.040	0.038	0.038
	ASIS2	0.036	0.036	0.039	0.045	0.043
	MCBP10	0.031	0.032	0.042	0.043	0.049
	ASIS16	0.039	0.041	0.040	0.039	0.035

Median NH_4 concentrations were consistently high at the two northernmost stations (A1, A17), at levels harmful to seagrasses. The southernmost station (A16) fluctuated between meeting the seagrass objective (Table 4.1.5c). (Figure 4.1.2).

Table 4.1.5c: 3-year medians of NH4 (mg/L) in Sinepuxent Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
West OC Harbor	ASIS1	**0.111**	**0.104**	**0.095**	**0.091**	**0.088**
Sinepuxent Bay	ASIS17	0.065	0.095	0.073	0.073	0.054
	ASIS18	0.053	0.047	0.036	0.042	0.048
	MCBP31	0.060	0.062	0.054	0.054	0.054
	ASIS2	0.031	0.021	0.032	0.082	0.042
	MCBP10	0.035	0.036	0.035	0.046	0.046
	ASIS16	0.027	0.045	0.019	0.034	0.025

Newport Bay

All stations except one in the lower bay (ASIS 3) consistently failed the TN seagrass threshold. Trappe, Ayers, and Marshall creeks and Newport Creek failed the TN threshold and were also classified as eutrophic (Table 4.1.6a). Only one station consistently met the STAC TP threshold, at the head of Beaverdam Creek (BMC0011). During the first and last analysis periods, this station also met the seagrass threshold. All other sites except the two open bay sites failed the STAC TP threshold and were classified as eutrophic. Three stations on Trappe Creek (AYR0017, M33, TRC0043) fell into the most impacted category (Table 4.1.6b).

Results from one station sampled by both DNR and MCBP (TRC0059/M35) were inconsistent for TN and two sites were inconsistent for NH_4 - one on Ayres Creek (AYR0017/M33) and one on Marshall Creek (MSL0011/M12) (Figure 4.1.2a and c). These comparisons suggest possible variation in sample collection times that may have captured sporadic events.

Table 4.1.6a: 3-year medians of TN (mg/L) in Newport Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Trappe Creek	KIT0015	**1.64**	**1.63**	**1.42**	**1.25**	**1.29**
	BOB0001	**3.01**	**2.92**	**3.01**	**2.76**	**2.69**
	MCBP4				2.81	**2.60**
	MCBP23	**1.61**	**1.62**	**1.48**	**1.51**	**1.45**
	TRC0059[a]	**1.81**	**1.78**	**1.74**	**1.74**	**1.74**
	MCBP35[a]	**2.94**	**2.91**	**2.93**	**2.87**	**2.61**
	TRC0043	1.85	**1.76**	**1.74**	**1.70**	**1.68**
Ayers Creek	AYR0017[b]	1.98	1.88	**1.78**	**1.78**	**1.84**
	MCBP33[b]	**1.41**	**1.57**	**1.53**	**1.44**	**1.33**
Newport Creek	BMC0011	**5.78**	**5.55**	**5.55**	**5.50**	**5.91**
	NPC0031	**1.65**	**1.49**	**1.51**	**1.53**	**1.64**
	NPC0012	**1.47**	**1.44**	**1.44**	**1.44**	**1.40**
Newport Bay	MCBP15	0.73	0.76	0.73	**0.80**	0.73
	XCM4878	0.89	0.88	**0.82**	**0.81**	**0.76**
	ASIS4	**0.82**	**0.86**	**0.81**	**0.79**	0.65
	ASIS3	0.63	0.64	0.60	0.60	0.46
Bassett Ck	MCBP28	**3.23**	**2.51**	**2.93**	**2.90**	**2.55**
Marshall Creek	MSL0011[c]	**1.78**	**1.71**	**1.56**	**1.55**	**1.60**
	MCBP12[c]	**1.31**	**1.37**	**1.37**	**1.19**	1.15

Table 4.1.6b: 3-year medians of TP (mg/L) in Newport Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Trappe Creek	KIT0015	0.048	0.050	0.052	**0.052**	0.046
	BOB0001	**0.055**	**0.057**	**0.073**	**0.071**	0.046
	MCBP4				0.092	**0.073**
	MCBP23	0.049	0.046	**0.058**	**0.062**	**0.061**
	TRC0059[a]	**0.073**	**0.073**	0.086	**0.079**	**0.052**
	MCBP35[a]	**0.065**	**0.066**	0.077	**0.071**	**0.052**
	TRC0043	**0.117**	0.114	0.109	0.113	0.108
Ayers Creek	AYR0017[b]	0.113	0.106	0.098	0.106	0.108
	MCBP33[b]	**0.074**	**0.073**	0.101	0.119	0.119
Newport Creek	BMC0011	0.036	0.040	0.040	0.037	0.032
	NPC0031	0.075	**0.069**	**0.070**	**0.073**	**0.075**
	NPC0012	**0.068**	**0.060**	**0.060**	**0.061**	**0.061**
Newport Bay	MCBP15	0.035	0.033	0.051	**0.055**	**0.053**
	XCM4878	**0.050**	**0.044**	0.043	0.041	0.040
	ASIS4	**0.064**	**0.063**	**0.060**	**0.055**	**0.047**
	ASIS3	**0.052**	**0.048**	0.046	0.047	0.040
Bassett Ck	MCBP28	0.030	0.034	0.054	**0.054**	**0.055**
Marshall Creek	MSL0011[c]	**0.075**	**0.070**	**0.070**	**0.070**	**0.072**
	MCBP12[c]	**0.054**	**0.057**	**0.072**	**0.073**	**0.079**

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

Newport Bay met the NH_4 seagrass threshold at seven stations (TRC0043, AYR0017, NPC0031, NPC0012, M15, XCM4878, MSL0011) but failed at 63% of sites (Table 4.1.6c). NH_4 levels were toxic to seagrasses at MCBP23.

Table 4.1.6c: 3-year medians of NH4 (mg/L) in Newport Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Trappe Creek	KIT0015	0.057	0.054	0.056	0.071	0.080
	BOB0001	0.061	0.058	0.058	0.047	0.044
	MCBP4				0.064	0.053
	MCBP23	**0.130**	0.106	0.109	0.114	**0.142**
	TRC0059[a]	**0.112**	0.095	**0.092**	**0.097**	**0.086**
	MCBP35[a]	**0.076**	**0.076**	0.074	0.069	0.056
	TRC0043	**0.014**	**0.011**	**0.009**	**0.009**	**0.015**
Ayers Creek	AYR0017[b]	**0.015**	**0.009**	**0.009**	0.011	0.020
	MCBP33[b]	0.075	0.032	0.026	0.034	0.044
Newport Creek	BMC0011	**0.034**	0.034	0.033	0.039	**0.039**
	NPC0031	0.019	0.019	0.018	0.026	0.027
	NPC0012	0.021	**0.016**	**0.014**	**0.014**	0.018
Newport Bay	MCBP15	0.036	0.027	0.020	0.022	0.023
	XCM4878	**0.012**	**0.009**	**0.008**	**0.011**	**0.016**
	ASIS4	0.052	0.059	0.043	0.056	0.040
	ASIS3	0.064	0.063	0.063	0.063	0.038
Bassett Ck	MCBP28	0.057	0.045	0.056	0.074	**0.083**
Marshall Creek	MSL0011[c]	0.017	0.016	0.014	0.014	0.021
	MCBP12[c]	0.077	0.041	0.028	0.033	0.053

Chincoteague Bay

Three Maryland mainstem stations (XCM1562, XCM0159, and XBM8149) and the Marshall Creek station (MSL0011) consistently did not meet TN seagrass thresholds, while the other 14 stations did meet these thresholds during the most recent two 3-year analysis periods (Table 4.1.7a). Only one station (XCM1562) met the TP seagrass threshold, and only during the most recent (2011-13) 3-year analysis period (Table 4.1.7b). (Figure 4.1.2).

Table 4.1.7a: 3-year medians of TN (mg/L) in Chincoteague Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Maryland	XCM1562	**0.72**	**0.71**	**0.72**	0.70	0.67
	XCM0159	**0.68**	0.68	**0.69**	**0.69**	0.65
	ASIS5	0.99	0.57	0.48	**0.46**	**0.41**
	XBM5932	0.69	0.68	0.67	0.63	0.60
	MCBP18	0.48	0.46	0.49	**0.48**	**0.38**
	ASIS6	0.96	0.47	**0.42**	**0.42**	**0.38**
	XBM8149	**0.72**	0.69	**0.69**	**0.70**	0.67
	ASIS7	1.02	0.52	0.50	0.47	**0.44**
	ASIS14	0.73	**0.47**	**0.40**	**0.40**	**0.35**
	XBM3418	0.60	0.59	0.59	0.58	0.54
	ASIS15	0.79	**0.45**	**0.39**	**0.39**	**0.35**
	M27	0.53				
	XBM1301	0.56	0.56	0.54	0.57	0.54
Virginia	ASIS9	0.58	**0.37**	**0.35**	**0.33**	**0.24**
	ASIS10	0.56	**0.41**	**0.35**	**0.32**	**0.29**
	ASIS8	0.62	**0.37**	**0.36**	**0.33**	**0.32**
	ASIS11	0.39	**0.31**	**0.27**	**0.26**	**0.25**
	ASIS12	0.39	**0.31**	**0.27**	**0.27**	**0.24**
	ASIS13	0.42	**0.30**	**0.26**	**0.25**	**0.23**

Table 4.1.7b: 3-year medians of TP (mg/L) in Chincoteague Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Maryland	XCM1562	0.049	0.047	0.048	0.043	0.035
	XCM0159	**0.047**	**0.049**	**0.050**	0.046	0.038
	ASIS5	**0.052**	**0.054**	**0.049**	**0.047**	0.047
	XBM5932	0.045	0.048	0.048	0.050	0.039
	MCBP18	0.051	0.043	**0.051**	0.048	0.044
	ASIS6	0.040	0.039	0.041	0.044	0.042
	XBM8149	**0.048**	0.047	**0.053**	**0.053**	0.044
	ASIS7	0.049	0.051	**0.052**	0.050	0.049
	ASIS14	0.039	0.040	0.043	0.045	0.043
	XBM3418	0.041	0.041	0.043	0.048	0.042
	ASIS15	0.039	0.040	0.040	0.040	0.038
	M27	**0.056**				
	XBM1301	0.043	0.044	0.049	0.055	0.043
Virginia	ASIS9	0.036	0.043	0.044	0.048	0.046
	ASIS10	0.039	0.041	0.046	0.046	0.040
	ASIS8	0.036	0.040	0.043	0.051	0.045
	ASIS11	0.045	0.047	0.043	0.045	**0.052**
	ASIS12	0.040	0.046	0.042	0.046	**0.047**
	ASIS13	0.043	0.045	0.043	0.043	0.043

Ammonium concentrations during the SAV growing season were very high at the eight stations (six in Virginia) and above concentrations harmful to seagrasses (toxic levels at ASIS 12 and borderline toxic at ASIS 6). An additional four stations had elevated NH_4, for a total of 12 of the 19 sites (63%) failing the seagrass threshold (Table 4.1.7c and Figure 4.1.2). All of the six stations located in Virginia had NH_4 concentrations well above the seagrass threshold during all analysis timeframes. The six open bay stations consistently met the seagrass threshold, but these stations are in deeper waters that are not considered seagrass habitat. One half of the sites located in Maryland failed the seagrass threshold.

Table 4.1.7c: 3-year medians of NH4 (mg/L) in Chincoteague Bay

Area	STATION	07-09	08-10	09-11	10-12	11-13
Maryland	XCM1562	0.018	**0.011**	**0.011**	**0.013**	**0.013**
	XCM0159	**0.013**	**0.010**	**0.010**	**0.010**	**0.014**
	ASIS5	0.066	0.061	0.061	0.068	0.054
	XBM5932	**0.009**	**0.007**	**0.008**	**0.008**	**0.012**
	MCBP18	0.017	0.027	0.029	0.031	0.029
	ASIS6	0.040	0.053	0.084	0.121	0.114
	XBM8149	**0.010**	**0.010**	**0.013**	**0.014**	**0.015**
	ASIS7	0.037	0.062	0.087	0.106	0.062
	ASIS14	0.057	0.042	0.052	0.053	0.045
	XBM3418	**0.010**	**0.012**	**0.015**	**0.015**	**0.014**
	ASIS15	0.042	0.060	0.032	0.065	0.032
	XBM1301	**0.017**	**0.016**	0.017	0.016	0.024
Virginia	ASIS9	0.072	0.098	0.115	0.115	0.073
	ASIS10	0.104	0.113	0.113	0.086	0.070
	ASIS8	0.088	0.090	**0.101**	**0.095**	0.084
	ASIS11	0.068	**0.083**	**0.092**	**0.092**	0.084
	ASIS12	0.081	**0.100**	**0.118**	**0.135**	0.131
	ASIS13	0.062	0.053	0.074	0.112	0.103

Results: Trends in nutrient concentration, 1999 - 2013
Sufficient data were available to perform trend analyses on all DNR and ASIS stations (60 total), but not on any MCBP stations. There were a number of significant linear trends, particularly for total nitrogen and dissolved nutrients. Improving (decreasing) nitrogen trends were found at 25 stations (42%), and only one station showed an increasing (degrading) trend (2%). Fewer linear trends were observed for total phosphorous, with eight decreasing (13%) and four increasing (7%). However, PO_4 showed linear trends at 16 stations, with 15 (25%) improving and only one (2%) degrading. Ammonium showed 17 linear trends, with six (10%) decreasing and 11 (18%) increasing; while 16 linear trends were found for NO_{23} (13 were improving (22%) and three degrading (5%). The results of linear trend analyses are shown in Figure 4.1.3.

Significant non-linear trends for total and dissolved nutrients were also found among stations without significant linear trends. For TN, 17 stations (28%) demonstrated improvement and had significant inverted U-shaped non-linear trends. For TP, 20 stations (33%) had significant inverted U-shaped non-linear trends, while one station (2%) was degrading and showed a significant U-shaped trend. Non-linear trends for dissolved nutrients were found at 34 stations. Significant inverted U-shaped non-linear trends were found at one station for NH_4, 19 for NO_{23}, and 11 for PO_4. Significant U-shaped non-linear trends were found at one station for NH_4 and three stations for PO_4. Most critical inflection values for TN and TP occur during 2005-2007, while those for dissolved nutrients occurred during 2004-2010. The results of these analyses are shown in Figure 4.1.3

When both trend types are considered together, many stations showed improving trends, with 42 (70%) for TN, 28 (47%) for TP, seven (12%) for NH_4, 30 (50%) for NO_{23}, and 26 (43%) for PO_4. (Table 4.1.14). Descriptions of results by embayment follow (refer to Figure 4.1.1 for stations mentioned in text).

Assawoman Bay

Within this northernmost basin, all significant linear trends were improving (Table 4.1.8a). All open bay sites demonstrated improving TN, while the stream station at GET0005 had no trend. A trend in TP was found only at one open bay station (XDN7545). No significant linear trends were found for dissolved nutrients. No significant non-linear trends were found for stations that had no linear trend for total nutrients, however significant improving non-linear trends were found for NO_{23} in Fenwick Ditch (XDN7261) and three stations (XDN545, XDN5737, XDN4851) in the northern portion of the open bay (Table 4.1.8b). (Figure 4.1.3)

Table 4.1.8a Significant linear trends
Assawoman Bay

Area	Station	p value	slope	parameter
Fenwick Ditch	XDN7545	**0.0000**	**-0.0236**	TN
Assawoman Bay	XDN7261	**0.0000**	**-0.0340**	TN
	XDN6454	**0.0000**	**-0.0180**	TN
	XDN4851	**0.0004**	**-0.0114**	TN
	XDN5737	**0.0049**	**-0.0117**	TN
Assawoman Bay	XDN7545	**0.0069**	**-0.0008**	TP

Table 4.1.8b Significant non-linear trends
Assawoman Bay

Area	Station	Trend Type	Critical Date	parameter
Fenwick Ditch	XDN7545	**inverted U**	**6-Nov-05**	NO23
Assawoman Bay	XDN7261	**inverted U**	**12-Jun-07**	NO23
	XDN4851	**inverted U**	**17-Feb-07**	NO23
	XDN5737	**inverted U**	**9-May-06**	NO23
Assawoman Bay	XDN7261	**U-shape**	**16-Jul-08**	PO4

St. Martin River

The two upstream stations on Spring Branch (BIH0009, MXE0011) and the upstream stations on the main river (XDM4797, XDN4312) all had significant improving TN linear trends (Table 4.1.9a). One significant inverted non-linear trend in TN was found at the downstream station of Bishopville Prong (BSH0008), with a critical inflection date in January 2004. All other linear TN trends were not significant. No significant linear trends for TP were found. A significant degrading linear trend for NH_4 was found in Birch Branch (BIH0009). All other linear trends for dissolved nutrients were not significant (Table 4.1.9a). Among stations without significant linear trends, a significant improving non-linear trend for TN was found in Bishopville Prong (BSH0008) (Table 4.1.9b). (Figure 4.1.3)

Table 4.1.9a Significant linear trends
St. Martin River

Area	Station	p value	slope	parameter
Spring Branch	MXE0011	**0.0012**	**-0.0400**	TN
	BIH0009	**0.0100**	**-0.0455**	TN
St. Martin River	XDM4797	**0.0021**	**-0.0203**	TN
	XDN4312	**0.0052**	**-0.0121**	TN
Spring Branch	MXE0011	**0.0004**	**-0.0219**	NO23
	SPR0009	**0.0015**	**-0.0009**	NO23
Spring Branch	BIH0009	**0.0004**	**0.0060**	NH4

Table 4.1.9b Significant non-linear trends
St. Martin River

Area	Station	Trend Type	Critical Date	parameter
Bishopville Prong	BSH0008	**inverted U**	**14-Jan-04**	TN

Isle of Wight Bay

No significant linear trends were found for TN in Isle of Wight Bay. Two stations on Turville Creek (TUV0011, TUV0019) showed significant improving non-linear trends for TN (Table 4.1.10a and Figure 4.1.3).

Only one station had a significant improving trend for TP, the upstream station on Turville Creek (TUV0034). Significant inverted non-linear trends in TN were found in Turville Creek (TUV0019, TUV0034), both with the critical inflection value in December 2005. An inverted trend was also found for TP at TUV0019, with a critical inflection value in March 2006. These inverted trend reversals indicate improving conditions for nutrients that are not reflected by linear trend analysis alone, and provide encouragement although status remains poor.

Significant improving linear trends were also observed for dissolved nutrients. Both the upstream and downstream stations on Turville Creek (TUV0011, TUV0034) showed a significant improving trend in NH_4. All three stations on Turville Creek (TUV0011, TUV0019, TUV0034) also had significant improving trends for PO_4. The station on Herring Creek (HEC0012) showed significant improving trends for both NO_{23} and PO_4. A significant improving trend was also found at the station on Manklin Creek (MKL0010) (Table 4.1.10a and Figure 4.1.3).

Among stations and parameters without significant linear trends, significant non-linear trends were observed for both total and dissolved nutrients. In Turville Creek, significant improving trends were found for both TN and TP at TUV0019, and for TP alone at TUV0011. Significant trends for dissolved nutrients were found only at open bay stations, where an improving trend for NO_{23} was observed at XDN2340, and degrading trends for PO_4 were found at XDN2438 and XDN0146, the closest stations to Ocean City Inlet (Table 4.1.10b and Figure 4.1.3).

Table 4.1.10a Significant linear trends in Isle of Wight Bay

Area	Station	p value	slope	parameter
Turville Creek	TUV0034	**0.0000**	**-0.0023**	TP
Turville Creek	TUV0034	**0.0023**	**-0.0009**	NH4
	TUV0011	**0.0072**	**-0.0008**	NH4
Herring Creek	HEC0012	**0.0011**	**-0.0005**	NO23
Manklin Creek	MKL0010	**0.0085**	**-0.0001**	PO4
Turville Creek	TUV0034	**0.0000**	**-0.0011**	PO4
	TUV0019	**0.0002**	**-0.0002**	PO4
	TUV0011	**0.0019**	**-0.0001**	PO4
Herring Creek	HEC0012	**0.0002**	**-0.0002**	PO4

Table 4.1.10b Significant non-linear trends in Isle of Wight Bay

Area	Station	Trend Type	Critical Date	parameter
Turville Creek	TUV0019	**inverted U**	**5-Dec-05**	TN
	TUV0011	**inverted U**	**6-Dec-05**	TN
Turville Creek	TUV0019	**inverted U**	**25-Mar-06**	TP
Isle of Wight Bay	XDN2340	**inverted U**	**15-Sep-06**	NO23
Isle of Wight Bay	XDN0146	**U-shape**	**2-Jun-08**	PO4
	XDN2438	**U-shape**	**25-Aug-08**	PO4

Sinepuxent Bay

A significant improving TN linear trend was found at the northernmost station (ASIS 1), closest to the Ocean City Inlet. No linear trends were found for TP. All significant linear trends for dissolved nutrients were degrading, with 3 for NH_4 (ASIS 16, ASIS 18, ASIS 17) and one for NO_{23} (ASIS 17) (Table 4.1.11a and Figure 4.1.3).

All ASIS stations besides A1 showed significant improving non-linear trends for TN. Two southern stations (ASIS 2, ASIS 16) showed improving non-linear trends for TP. The southern stations (ASIS 2, ASIS16, ASIS 18) all had significant improving non-linear trends for NO_{23} and PO_4 (Table 4.1.11b and Figure 4.1.3).

Table 4.1.11a Significant linear trends in Sinepuxent Bay

Station	p value	slope	parameter
ASIS1	**0.0029**	**-0.0052**	TN
ASIS18	**0.0091**	**0.0016**	NH4
ASIS17	**0.0011**	**0.0023**	NH4
ASIS16	**0.0038**	**0.0015**	NH4

Table 4.1.11b Significant non-linear trends in Sinepuxent Bay

Station	Trend Type	Critical Date	parameter
ASIS17	**inverted U**	**28-Jul-06**	TN
ASIS18	**inverted U**	**4-Jun-06**	TN
ASIS2	**inverted U**	**2-Jan-07**	TN
ASIS16	**inverted U**	**17-Mar-06**	TN
ASIS2	**inverted U**	**11-Oct-07**	TP
ASIS16	**inverted U**	**24-Jan-07**	TP
ASIS18	**inverted U**	**28-Mar-08**	NO23
ASIS2	**inverted U**	**26-Sep-07**	NO23
ASIS16	**inverted U**	**29-Apr-08**	NO23
ASIS18	**inverted U**	**10-Feb-08**	PO4
ASIS2	**inverted U**	**31-Jan-08**	PO4
ASIS16	**inverted U**	**21-May-08**	PO4

Newport Bay

Significant improving linear trends in TN were found at two of the upstream stations feeding Newport Creek (KIT0015, BOB0001), however the station on Beaverdam Creek (BMC0011), showed a degrading linear tend in TN concentrations. Two stations on the mainstem of Trappe Creek (TRC0043, TRC0059), two stations in Newport Bay (ASIS 3, ASIS 4), and Marshall Creek (MSL0011) also showed significant improving TN linear trends. Significant improving linear trends in NH_4 and NO_{23} were also found at KIT0015 and TRC0059, and in NO_{23} at TRC0043. Encouragingly, four stations that showed improvements in nitrogen also showed significant improving linear trends in phosphorus: both TP and PO_4 concentrations at KIT0015, TRC0043, and TRC0059; and TP at ASIS 4. While BMC0011 had significant degrading linear trends for TN and NO_{23}, it had a significant improving linear trend in TP (Table 4.1.12a and Figure 4.1.3).

Three stations in the open bay (ASIS 3, ASIS 4, XCM4878) showed significant inverted non-linear trends for both TN and TP (Table 4.1.12b and Figure 4.1.3).

Table 4.1.12a Significant linear trends in Newport Bay

Area	Station	p value	slope	parameter
Trappe Creek	KIT0015	**0.0000**	**-0.2536**	TN
	BOB0001	**0.0004**	**-0.0475**	TN
	TRC0059	**0.0000**	**-0.1405**	TN
	TRC0043	**0.0000**	**-0.0550**	TN
Newport Creek	ASIS4	**0.0001**	**-0.0166**	TN
Newport Bay	ASIS3	**0.0097**	**-0.0079**	TN
Marshall Creek	MSL0011	**0.0077**	**-0.0294**	TN
Newport Creek	BMC0011	**0.0000**	**0.0784**	TN
Trappe Creek	KIT0015	**0.0000**	**-0.0139**	TP
	TRC0059	**0.0000**	**-0.0099**	TP
	TRC0043	**0.0000**	**-0.0091**	TP
Newport Creek	BMC0011	**0.0005**	**-0.0011**	TP
Newport Bay	ASIS4	**0.0042**	**-0.0010**	TP
Trappe Creek	KIT0015	**0.0000**	**-0.0132**	NH4
	TRC0059	**0.0000**	**-0.0105**	NH4
Newport Creek	BMC0011	**0.0050**	**-0.0007**	NH4
Marshall Creek	MSL0011	**0.0002**	**-0.0030**	NH4
Trappe Creek	KIT0015	**0.0000**	**-0.1110**	NO23
	BOB0001	**0.0002**	**-0.0401**	NO23
	TRC0059	**0.0000**	**-0.0870**	NO23
	TRC0043	**0.0006**	**-0.0007**	NO23
Ayers Creek	AYR0017	**0.0009**	**-0.0008**	NO23
Newport Bay	XCM4878	**0.0012**	**-0.0003**	NO23
Newport Creek	BMC0011	**0.0000**	**0.0809**	NO23
Trappe Creek	KIT0015	**0.0000**	**-0.0056**	PO4
	BOB0001	**0.0027**	**-0.0006**	PO4
	TRC0059	**0.0000**	**-0.0045**	PO4
	TRC0043	**0.0000**	**-0.0011**	PO4
Ayers Creek	AYR0017	**0.0021**	**-0.0003**	PO4
Newport Creek	BMC0011	**0.0026**	**-0.0004**	PO4
Marshall Creek	MSL0011	**0.0011**	**-0.0003**	PO4
Newport Bay	XCM4878	**0.0005**	**-0.0001**	PO4

Table 4.1.12b Significant non-linear trendsin Newport Bay

Area	Station	Trend Type	Critical Date	parameter
Newport Bay	XCM4878	**inverted U**	**9-Feb-06**	TN
Marshall Creek	MSL0011	**inverted U**	**2-Jun-07**	TP
Newport Bay	XCM4878	**inverted U**	**27-Dec-05**	TP
	ASIS3	**inverted U**	**6-Oct-06**	TP
Newport Creek	ASIS4	**inverted U**	**4-Oct-07**	NH4
	NPC0031	**U-shape**	**2-Jan-07**	NH4
Newport Creek	ASIS4	**inverted U**	**7-Mar-07**	NO23
Newport Bay	ASIS3	**inverted U**	**19-Jun-06**	NO23
Newport Creek	ASIS4	**inverted U**	**30-Jul-07**	PO4
Newport Bay	ASIS3	**inverted U**	**19-Jun-08**	PO4

Chincoteague Bay

All significant linear trends for TN in Chincoteague Bay were improving and were found mainly in the central portion of the bay and Marshall Creek (ASIS 7, ASIS 9, ASIS 14, ASIS 15, MSL0011, XCM0159, XBM3418, XBM5932, XBM8149) (Table 4.1.13a and Figure 4.1.3). In contrast, all significant TP linear trends were degrading, and were concentrated around the town of Chincoteague (ASIS11, ASIS 12, ASIS 13). Significant inverted non-linear trends for TN were found at all open bay stations, only Marshall Creek (MSL0011) did not show a significant trend. Except for the three stations concentrated around the town of Chincoteague (ASIS 11, ASIS 12, ASIS 13), which showed no non-linear trends), all of the stations in Chincoteague Bay showed significant inverted non-linear trends for TP (Table 4.1.13b and Figure 4.1.3).

Table 4.1.13a Significant linear trends Chincoteague Bay

Area	Station	p value	slope	parameter
Maryland	XCM0159	0.0039	-0.0113	TN
	XBM5932	0.0014	-0.0112	TN
	XBM8149	0.0058	-0.0106	TN
	ASIS7	0.0002	-0.0097	TN
	ASIS14	0.0000	-0.0094	TN
	XBM3418	0.0001	-0.0133	TN
	ASIS15	0.0001	-0.0067	TN
Virginia	ASIS9	0.0036	-0.0062	TN
Virginia	ASIS11	0.0001	0.0008	TP
	ASIS12	0.0000	0.0009	TP
	ASIS13	0.0008	0.0006	TP
Maryland	ASIS6	0.0089	0.0017	NH4
	ASIS7	0.0034	0.0015	NH4
	ASIS9	0.0013	0.0025	NH4
Virginia	ASIS8	0.0000	0.0029	NH4
	ASIS10	0.0085	0.0021	NH4
	ASIS12	0.0023	0.0030	NH4
	ASIS13	0.0025	0.0022	NH4
Maryland	XCM0159	0.0002	-0.0003	NO23
	XBM5932	0.0012	-0.0003	NO23
	XBM8149	0.0029	-0.0003	NO23
Maryland	XCM0159	0.0001	-0.0001	PO4
	XBM5932	0.0018	-0.0002	PO4

Table 4.1.13b Significant non-linear trends Chincoteague Bay

Area	Station	Trend Type	Critical Date	parameter
Maryland	XCM1562	inverted U	7-Nov-06	TN
	ASIS5	inverted U	30Oct2005	TN
	ASIS6	inverted U	11Apr2005	TN
	XBM1301	inverted U	12-Sep-06	TN
Virginia	ASIS8	inverted U	16Dec2006	TN
	ASIS10	inverted U	24Jan2006	TN
	ASIS11	inverted U	7-Feb-07	TN
	ASIS12	inverted U	27-Aug-06	TN
	ASIS13	inverted U	22-Jul-06	TN
Maryland	XCM1562	inverted U	24-Aug-06	TP
	XCM0159	inverted U	22-May-07	TP
	ASIS5	inverted U	10-May-07	TP
	XBM5932	inverted U	11-Mar-07	TP
	ASIS6	inverted U	12-Jan-07	TP
	XBM8149	inverted U	25-Jun-07	TP
	ASIS7	inverted U	23-Dec-05	TP
	ASIS14	inverted U	5-Nov-05	TP
	XBM3418	inverted U	18-Sep-06	TP
	ASIS15	inverted U	12-Jun-07	TP
	XBM1301	inverted U	7-Jan-07	TP
Virginia	ASIS9	inverted U	3-Nov-06	TP
	ASIS8	inverted U	28-Jan-07	TP
	ASIS10	inverted U	14-Nov-06	TP
Maryland	XCM1562	inverted U	1-May-06	NO23
	ASIS5	inverted U	29-Jan-06	NO23
	ASIS6	inverted U	16-Nov-06	NO23
	ASIS7	inverted U	11-Aug-07	NO23
	ASIS14	inverted U	3-Oct-06	NO23
	ASIS15	inverted U	10-Jan-07	NO23
Virginia	ASIS8	inverted U	6-Feb-08	NO23
	ASIS13	inverted U	16-Dec-06	NO23
Maryland	XCM1562	inverted U	12-Jul-05	PO4
	ASIS5	inverted U	16-Feb-08	PO4
	ASIS7	inverted U	23-Sep-07	PO4
	ASIS14	inverted U	19-Dec-07	PO4
Virginia	ASIS9	inverted U	8-Nov-07	PO4
	ASIS10	inverted U	13-Jan-08	PO4

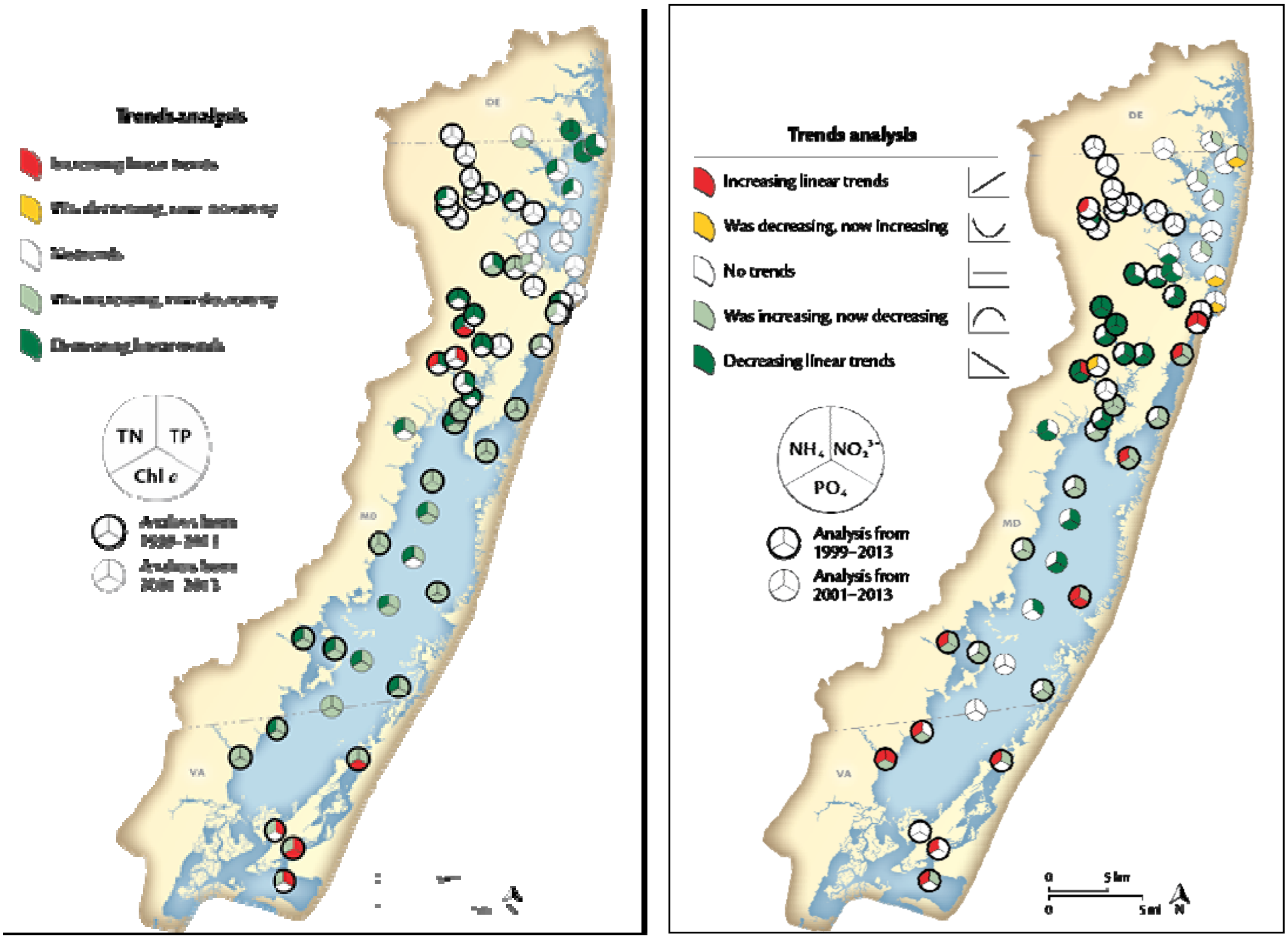


Figure 4.1.3. Nutrient trends at fixed DNR and ASIS stations. Trends were based on between 13 and 15 years of data, depending on the station. Significance in linear trends was calculated using the seasonal Kendall's tau statistic, and directionality (improving or degrading) condition for significant trends was determined by linear regression (p = 0.01 level).

Summary

The entire Coastal Bays watershed continues to be stressed by nutrients. The St. Martin River, Newport Bay, tributaries of Isle of Wight Bay, northern Chincoteague Bay, and most of Assawoman Bay remain enriched with nitrogen. In those areas that meet the seagrass threshold for TN, many stations fail the NH_4 threshold, including Sinepuxent Bay and southern Chincoteague Bay. Phosphorous enrichment is nearly ubiquitous, with only four scattered stations meeting the seagrass threshold during the most recent (2011-13) analysis period. TN and TP are better than dissolved inorganic nutrients as indicators of relative nutrient availability in systems known to have high organic inputs (Glibert et al. 2001). Elevated nutrient levels may be impacting seagrass distribution (see Chapter 5.1).

Although areas of the Coastal Bays continue to fail seagrass thresholds for nitrogen, improving total nitrogen trends were found in Assawoman Bay and at many sites in Newport Bay and Chincoteague Bay.

While the status of phosphorous remains poor throughout the bays, trends analyses indicate that concentrations are declining in recent years in the Maryland and northern Virginia portion of Chincoteague Bay but not in other areas. Legacy groundwater is increasingly understood as a source of phosphorous to the Coastal Bays, which may explain persistent failure of the seagrass threshold. It may take decades for high concentrations to decrease sufficiently to meet the threshold, even in the face of best management practices (BMPs) that improve surface water runoff quality. These BMPs should not be abandoned or scaled back because they mitigate further additions of phosphorus to groundwater and surface water. It is important that declines in phosphorous concentrations continue. In contrast, the area near Chincoteague, Virginia exhibits increasing trends, likely linked to outdated sewage treatment and management practices.

Ammonium concentrations exceeded seagrass thresholds between 32-35% of sites and were potentially lethal at some sites. Ammonium concentrations were highest in the Virginia portion of Chincoteague Bay and in tributaries watershed-wide.

Overall, one site in Assawoman Bay and three in Newport Bay overlapped between DNR and MCBP volunteer monitoring program. Results from co-located sites varied. Differences in the frequency of sample collection (monthly vs twice a month) may be a result of volunteers better capturing sporadic events. These comparisons suggest not eliminating any of the volunteer sites.

Combined linear and non-linear trends analysis detected 152 unique significant trends among all parameters and stations (50%). Out of 60 stations there were 42 significant improving trends for TN, 27 for TP, 7 for NH_4, 30 for NO_{23}, and 26 for PO_4 (Figure 4.1.3). There was one significantly degrading trend for TN, 3 for TP, 12 for NH_4, one for NO_{23}, and three for PO_4 (Table 4.1.14) Improving trends in dissolved nutrients may be one driver for improving trends in total nutrients, where both trends coincide. Declining trends in dissolved nutrients may be early warning of undetected problems, where they coincide with improving trends in total nutrients. Most trends were improving; only 20 significant degrading trends were found (7%)

The improving trends in the St. Martin River are encouraging, because it is one of the most impacted segments within the Coastal Bays watershed. If the degrading trend in NH_4 at Birch Branch continues, it may have a negative impact on the improving trend in TN. Phosphorus and ammonium levels indicate large scale nutrient issues that need to be addressed. Ammonium toxicity effects on Z. marina are expected to be strongest in the fall when irradiance decreases, temperature is still high, and ambient ammonium concentrations rise. Therefore, a different temporal average for ammonium should be investigated to determine potential toxicity impacts.

Table 14.1.14 Summary of significant nutrient trends in each subwatershed (linear and non-linear). Green columns indicate the number of improving trends while the pine columns are degrading trends.

TN

Area	Linear		Non-Linear	
Assawoman Bay	5	0	0	0
St. Martin River	4	0	1	0
Isle of Wight Bay	0	0	2	0
Sinepuxent Bay	1	0	4	0
Newport Bay	7	1	1	0
Chincoteague Bay	8	0	9	0

TP

Area	Linear		Non-Linear	
Assawoman Bay	1	0	0	0
St. Martin River	0	0	0	0
Isle of Wight Bay	1	0	1	0
Sinepuxent Bay	0	0	2	0
Newport Bay	5	0	3	0
Chincoteague Bay	0	3	14	0

NH4

Area	Linear		Non-Linear	
Assawoman Bay	0	0	0	0
St. Martin River	0	1	0	0
Isle of Wight Bay	2	0	0	0
Sinepuxent Bay	0	3	0	0
Newport Bay	4	0	1	1
Chincoteague Bay	0	7	0	0

NO23

Area	Linear		Non-Linear	
Assawoman Bay	0	0	4	0
St. Martin River	2	0	0	0
Isle of Wight Bay	1	0	1	0
Sinepuxent Bay	0	0	3	0
Newport Bay	6	1	2	0
Chincoteague Bay	3	0	8	0

PO4

Area	Linear		Non-Linear	
Assawoman Bay	0	0	0	1
St. Martin River	0	0	0	0
Isle of Wight Bay	5	0	0	2
Sinepuxent Bay	0	0	3	0
Newport Bay	8	0	2	0
Chincoteague Bay	2	0	6	0

References

Ebersole, E., M. Lane, M. Olson, E. Perry, and W. Romano. 2002. Assumptions and procedures for calculating water quality status and trends in tidal waters of the Chesapeake Bay and its tributaries: a cumulative history. Report prepared for Chesapeake Bay Program, Tidal Monitoring and Analysis Workgroup http://mddnr.chesapeakebay.net/eyesonthebay/documents/stat_trend_hist.pdf

Glibert, P.M., R. Magnien, M.W. Lomas, J. Alexander, C. Fan, E. Haramoto, M. Trice, and T.M. Kana. 2001. Harmful algal blooms in the Chesapeake and coastal bays of Maryland, USA: Comparison of 1997, 1998, and 1999 events. Estuaries 24: 875-883.

Hirsch, R.M., J.R. Slack, and R.A. Smith. 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research 18(1): 107-121.

Stevenson, J.C., L.W. Staver, and K.W. Staver. 1993. Water quality associated with survival of submersed aquatic vegetation along an estuarine gradient. Estuaries 16(2): 346-361.

Van Belle, G. and J.P. Hughes. 1984. Nonparametric tests for trend in water quality. Water Resources Research 20(1): 127-136.

van der Heide, T; A. J. P. Smolders; B. G. A. Rijkens; E. H. van Nes; M. M. van Katwijk; J. G. M. Roelofs . 2008. Toxicity of reduced nitrogen in eelgrass (*Zostera marina*) is highly dependent on shoot density and pH. Oecologia: 158:411–419.

van Katwijk, M.M.; L. H.T. Vergeer; G. H. W. Schmitz and J. G. M. Roelofs. 1997. Ammonium toxicity in eelgrass *Zostera marina.* Mar Ecol Prog Ser(157)159- 173.

Wazniak, C.E. 1999. Eutrophication monitoring plan. Appendix A of the Maryland Coastal Bays Comprehensive Conservation Management Plan. Maryland Coastal Bays Program, Berlin, MD.

Wazniak, C. E., M. R. Hall, T. J. B. Carruthers, R. Sturgis, W. C. Dennison, R. J. Orth. 2007. Assessing eutrophication in a mid-Atlantic lagoon system, USA: linking water quality status and trends to living resources. Ecological Applications 07/2007; 17(sp5-5):S64-S78.