USE OF SUBMERGED AQUATIC VEGETATION HABITAT REQUIREMENTS AS TARGETS FOR WATER QUALITY IN MARYLAND AND VIRGINIA COASTAL BAYS

ASSATEAGUE ISLAND NATIONAL SEASHORE MARYLAND AND VIRGINIA

Chris Lea
Rebecca L. Pratt
Tamara E. Wagner
Elden W. Hawkes, Jr.
Alejandro E. Almario

Technical Report NPS/NRWRD/NRTR-2003/316

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
Fort Collins - Denver - Washington

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Chris Lea[1]
Rebecca L. Pratt
Tamara E. Wagner
Elden W. Hawkes, Jr.
Alejandro E. Almario

Division of Resource Management
Assateague Island National Seashore
7206 National Seashore
Berlin, MD 21811
(410) 641-1443

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August, 2003

[1]- present address: National Park Service Natural Resources Information Division, Lakewood, CO

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EXECUTIVE SUMMARY

The National Park Service (NPS) has conducted long term estuarine water quality monitoring in the Maryland and Virginia Coastal Bays since 1987. One purpose of water quality monitoring is to determine whether water quality is high enough to maintain beds of submerged aquatic vegetation (SAV), which serve as important habitat to other organisms and provide other ecological services to the bays. Water column light attenuation coefficient and water column concentrations of chlorophyll a, total suspended solids, dissolved inorganic nitrogen, and dissolved inorganic phosphorus are parameters that have been determined to be good predictors of the ability of an area to maintain SAV in the nearby Chesapeake Bay system. Of the current 18 NPS monitoring stations in the Coastal Bays, 17 are located at sites with non-vegetated bottoms, and only one is located within a bed of SAV. An experiment was conducted for two purposes: (1) to determine how much the habitat parameters identified as important for SAV in the Chesapeake Bay varied from otherwise similar stations in the Coastal Bays (i.e., how well the current NPS monitoring program captured the values of these parameters as they would be measured in SAV beds) and (2) to estimate the values of these parameters within SAV beds in the Coastal Bays as empirical evidence of minimum possible values for threshold levels of the Chesapeake Bay parameters for the Coastal Bays.

Median values for light attenuation and for dissolved inorganic phosphorus in non-vegetated (NPS long term) monitoring stations were not found to differ significantly from those of vegetated (SAV) stations. Median values for dissolved inorganic nitrogen and for chlorophyll a were found to be slightly higher at non-vegetated stations, but the differences were relatively small, so that there can be reasonable confidence that monitoring at non-vegetated stations represents conditions in SAV beds for these parameters. Median values for total suspended solids were higher in vegetated stations, suggesting that the current water quality monitoring program may overestimate this parameter relative to that experienced by SAV in the Coastal Bays.

Median values of the SAV habitat parameters developed for the Chesapeake Bay were estimated for Coastal Bay SAV beds. If the Chesapeake Bay threshold limits for the polyhaline regime are applicable to the Coastal Bays, then light attenuation levels appears to be high enough to be possibly limiting SAV growth at the one meter depth, with the levels of the other parameters well below growth and maintenance limiting thresholds.

ACKNOWLEDGEMENTS

Many individuals contributed to field data collection, including Bianca McIntyre, Rebecca Anderson, Helen Hamilton, Frank Hudson, and Bethany Caruso. Much appreciation is extended to Laura Murray (Horn Point Laboratory) and Bob Stankelis (Chesapeake Biological Laboratory) for assistance in developing methods. Lois Lane, Laurie Van Heukelem, and other staff of the Horn Point Laboratory provided laboratory analysis of water samples. Jim Tilmant (National Park Service Water Resources Division) provided review and helpful suggestions for the project design and report. Leslie Krueger, Mark Flora, John Karish, and Carl Zimmerman (all National Park Service) facilitated administrative assistance. This project was funded by the National Park Service Water Resources Division, the National Park Service Northeast Region Science Fund, and Assateague Island National Seashore.

INTRODUCTION

The role of submerged aquatic vegetation (SAV) as an important component of estuarine ecosystems, serving as a food source and nursery for a variety of organisms, contributing to water quality, and indicating ecosystem health has been well recognized (Orth and Moore 1984) (Bohlen et al. 1997). The decline of SAV due to attenuation of light in the water column has been observed in many estuaries worldwide, with anthropogenically induced increases in suspended solids and/or phytoplankton responding to nutrient enrichment often implicated (Orth and Moore 1983; Short and Burdick 1996; Tomasko et al. 1996).

The understanding of the relationship between water quality and persistence of SAV prompted efforts to quantify habitat parameters necessary for SAV growth. Through data collection in four different salinity regimes in the Chesapeake Bay estuary system, Batiuk et al. (1992) developed maximum values (applied as median values over the critical growing season for SAV for the applicable salinity regime) for five water quality parameters deemed most significant to SAV maintenance and restoration at a depth of one meter. These are: (1) water column light attenuation coefficients (K_d), and concentrations of (2) chlorophyll a (CHLA), (3) total suspended solids (TSS), (4) dissolved inorganic nitrogen (DIN), which is the sum of nitrogen contributed by ammonium, nitrate, and nitrite, and (5) dissolved inorganic phosphorus (DIP).

The Maryland and Virginia Coastal Bays contain large and apparently healthy beds of SAV (Figure 1), which have increased in area from 2,134 hectares in 1986 (Orth et al. 1987) to 5,598 hectares in 1997 (Orth et al. 1998). Within the Maryland part of the Coastal Bays, over 90% of SAV bed area occurs within Assateague Island National Seashore. The National Park Service (NPS), which manages the National Seashore, recognizes SAV beds in the Coastal Bays as a significant natural resource that is crucial to the maintenance of regional biological diversity and ecosystem health (National Park Service 1994). Accordingly, the NPS has conducted a long term monitoring program of parameters pertinent to the maintenance of estuarine water quality in the Bays (National Park Service 1991; Sturgis 2001). Presently, there are 18 monitoring stations in Chincoteague, Sinepuxent, and Newport Bays.

The applicability of the habitat requirements for SAV in the polyhaline regime of the Chesapeake Bay (Batiuk et al. 1992) to the situation in the Coastal Bays is somewhat uncertain. Until this can be adequately tested, these requirements have been generally regarded as reasonable interim requirements for the Coastal Bays, since the same SAV species, eelgrass (*Zostera marina* L.), is dominant in both areas. Regardless of what values are used as minimal SAV requirements, the question of how well water quality data for parameters important to SAV that are collected in non-vegetated [usually deeper channel] areas represents what SAV [which usually grows in shallower embayments] experiences. This uncertainty prompted the National Park Service to conduct a three year comparison study to determine the reliability of current long-term water quality monitoring data for assessing habitat conditions for SAV in the Maryland and Virginia

Coastal Bays (Chincoteague, Sinepuxent, Newport, Isle of Wight, and Assawoman Bays.

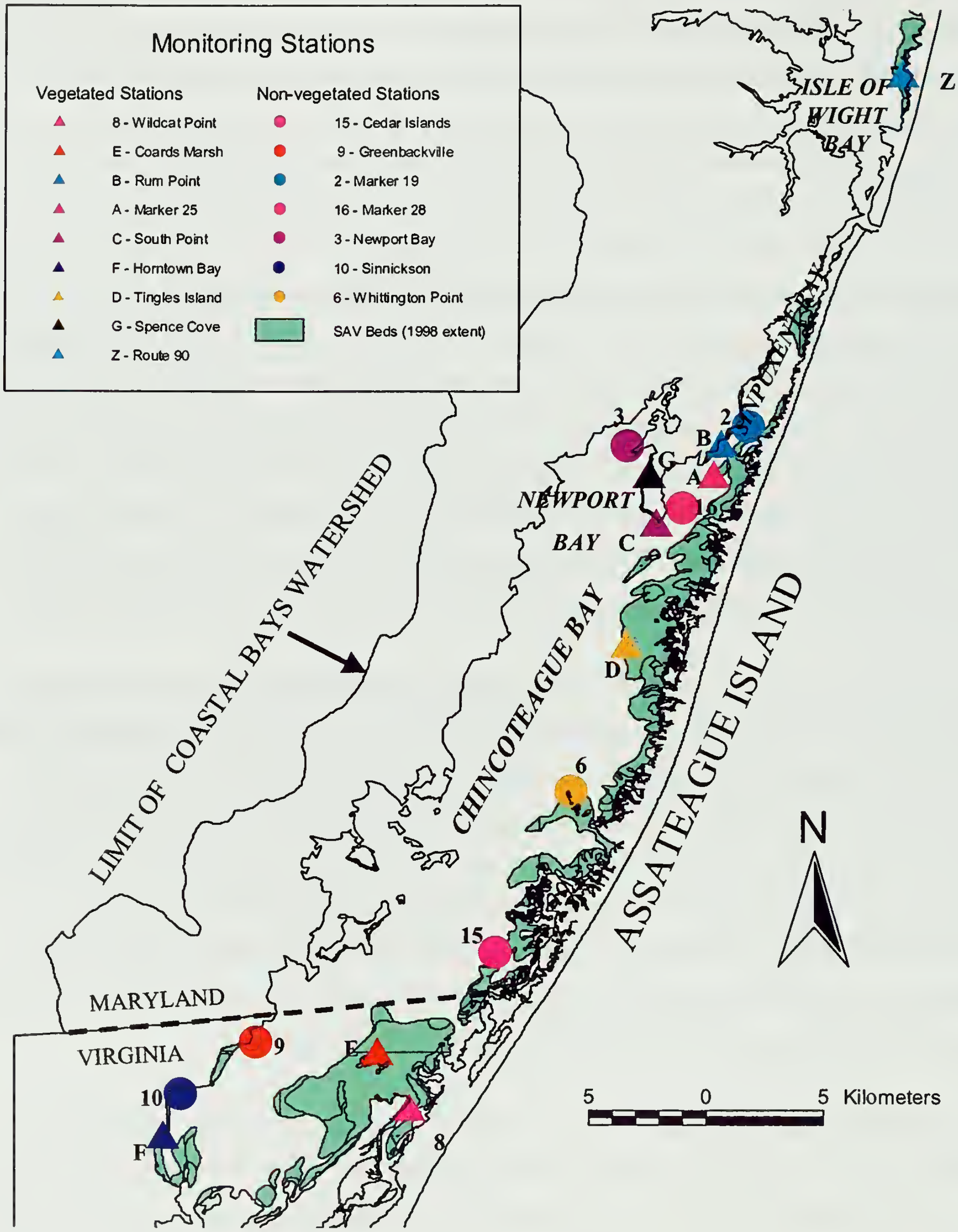

Figure 1. SAV habitat requirement water quality monitoring stations, Maryland-Virginia Coastal Bays, 1998-2000. Pairs of stations used for comparing vegetated and non-vegetated sites are of like color (stations G and Z were not used for paired comparions).

METHODS

In 1998, six temporary monitoring stations were established in SAV beds (vegetated stations), each near an existing long term monitoring station (non-vegetated stations) to create spatial pairs of vegetated and non-vegetated monitoring stations. The only long term monitoring station located in an SAV bed (Wildcat Point), was paired with the closest non-vegetated long term monitoring station (Cedar Islands) to create a seventh pair (Table 1, Figure 1).

Table 1. Water quality monitoring stations for investigations of parameters establishing SAV habitat requirements in Maryland-Virginia Coastal Bays, 1998-2000.

Vegetated Station of pair (station name and number)	Non-vegetated Station of pair (station name and number)	Location of Pair
Channel Marker 25 (A)	Channel Marker 28 (16)	Sinepuxent Bay
Rum Point (B)	Channel Marker 19 (2)	Sinepuxent Bay
South Point (C)	Newport Bay (3)	Newport Bay
Tingles Island (D)	Whittington Point (6)	Chincoteague Bay
Coards Marsh (E)	Greenbackville (9)	Chincoteague Bay
Horntown Bay (F)	Sinnickson (10)	Chincoteague Bay
Wildcat Point (8)	Cedar Island (15)	Chincoteague Bay
Spence Cove (G)	N/A	Newport Bay
Route 90 (Z)	N/A	Isle of Wight Bay

Measurements of the five SAV habitat parameters defined by Batiuk et al. (1992) were made at both the established stations and the paired SAV bed stations during monthly sessions of the park's long-term water quality monitoring program from March to October in 1998, 1999, and 2000. Usually both stations of a pair were visited on the same day; occasionally, they were visited from 1 to 2 days apart. Field and laboratory methods for parameter measurement are specified in Appendix 1. Occasional sessions or parameters were missed due to logistical problems. The value of an individual variable representing a measurement of a parameter at a vegetated station during a sampling session was subtracted from the value of the variable representing the same parameter measured during the same sampling session at the corresponding non-vegetated station of the pair to derive a difference (between paired stations) for the variable. Median values and 80%, 90%, and 95% confidence intervals (CI) for the entire sample of individual differences (all years, all stations) and for the subsamples representing individual year data were derived for each habitat parameter using methods derived from the binomial and sign tests described by Zar (1996). Exclusion of the value zero within a confidence interval was considered to represent a significant differences between medians of samples from paired stations at a value less than the corresponding p value for a two-tailed sign test (e.g., $p < 0.2$, for 80% CI, $p < 0.1$, for 90% CI, $p < 0.05$, for 95% CI). Median values and confidence intervals were also derived for the subsamples representing vegetated stations only and non-vegetated stations only by year for all years.

In 1999 and 2000, the parameters were measured at the Channel Marker 25 (A), Rum Point (B), Tingles Island (D), and Coards Marsh (E) stations and were monitored twice monthly, as were two new stations (Spence Cove (G) and Route 90 (Z)). These additional data were not collected as paired observations with non-vegetated stations, but were combined with the paired comparison data for vegetated stations A-F to more precisely determine the levels of the five critical habitat parameters for SAV beds in the Coastal Bays, and to evaluate their proximity to critical values for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992). Because the critical values of the parameters are expressed as median values (Batiuk et al. 1992), tests of the median (rather than the mean), with 80, 90, and 95% confidence limits, were calculated. For the tests of the medians, only data collected in the periods from March to June and from mid-September to October were used (i.e., July, August, and early September observations were omitted from the analysis) to confine observations to the growing season for polyhaline regimes (and *Zostera marina*) (Batiuk et al. 1992).

RESULTS AND DISCUSSION

Results of tests of the median differences between paired treatments (non-vegetated, vegetated) and the individual treatment medians and summary statistics are summarized for each of the five habitat parameters (plus the individual contributions of nitrate-nitrite and of ammonium to dissolved inorganic nitrogen) for each of the three years and for all years in Tables 2-4 and Tables 7-15 (Appendix 2).

Results for the estimation of median values of the 5 habitat parameters at vegetated stations A, B, C, D, E, F, G, and Z, with confidence intervals for the median are summarized for the entire data set (Table 5) and by year (Tables 16-18, Appendix 3) and by year (Tables 19-26, Appendix 4) and are graphically depicted in Figures 2-11.

The paired-station water quality study showed differences between the (non-vegetated) stations currently included in the NPS long-term water quality program and comparable stations located in SAV beds (Table 2). Among paired station sample means showing differences significant at $p < 0.05$, non-vegetated stations had greater concentrations of water column chlorophyll a (median difference between paired observations: 0.90 µg/L), total suspended solids (median difference paired observations: 2.90 mg/L), and dissolved inorganic nitrogen (median difference paired observations: 0.13 µM).).

For Table 2, statistics represent results of subtraction of value for the vegetated member of pair from the non-vegetated member of pair; thus, positive values indicate that the variable is greater for non-vegetated stations; negative values indicate that the variable is greater for vegetated stations.

For confidence interval (CI) limits in Table 2, bold-faced values indicate that confidence interval for that variable does not include zero – indicating significant differences at that level of confidence.

Table 2. Differences Between Stations – All Years (1998-2000)

	CHLA (μg/L)	TSS (mg/L)	DIP (μM)	K_d	DIN (μM)	NH_4^+ (μM)	NO_2^-/NO_3^- (μM)
N (of cases)	153	147	147	168	147	147	147
Minimum	-25.68	-36.80	-1.28	-3.36	-8.23	-7.85	-2.39
Maximum	17.97	77.18	0.95	4.24	14.73	7.70	9.02
Median	0.90	2.90	0.00	0.02	0.13	0.04	0.01
95% CI Upper Limit	**1.46**	**4.76**	0.04	0.11	0.28	0.18	0.04
95% CI Lower Limit	**0.23**	**0.78**	-0.06	-0.08	0.00	-0.10	0.00
90% CI Upper Limit	**1.39**	**4.69**	0.03	0.10	**0.26**	0.12	0.04
90% CI Lower Limit	**0.33**	**1.48**	-0.06	-0.03	**0.02**	-0.06	0.00
80% CI Upper Limit	**1.31**	**4.20**	0.03	0.09	**0.20**	0.09	0.03
80% CI Lower Limit	**0.58**	**1.81**	-0.05	-0.03	**0.03**	-0.04	0.00

Table 3. Non-Vegetated Stations – All Years (1998-2000)

	CHLA (μg/L)	TSS (mg/L)	DIP (μM)	K_d	DIN (μM)	NH_4^+ (μM)	NO_2^-/NO_3^- (μM)
Minimum	0.40	2.31	0.01	0.15	0.11	0.07	0.01
Maximum	28.16	93.50	1.39	6.39	20.93	16.90	14.90
Median	5.97	12.70	0.17	1.41	1.23	0.97	0.14
95% CI Upper Limit	7.32	14.40	0.20	1.55	1.48	1.17	0.21
95% CI Lower Limit	4.86	10.70	0.13	1.29	0.98	0.80	0.08
90% CI Upper Limit	7.04	14.00	0.20	1.54	1.43	1.14	0.18
90% CI Lower Limit	4.96	11.00	0.13	1.29	0.98	0.82	0.09
80% CI Upper Limit	6.69	13.59	0.19	1.50	1.32	1.09	0.18
80% CI Lower Limit	5.03	11.30	0.14	1.32	1.01	0.83	0.11

Table 4. Vegetated Stations – All Years (1998-2000)

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
Minimum	0.49	0.97	0.01	0.37	0.05	0.02	0.01
Maximum	35.80	61.20	1.82	4.93	16.00	14.60	5.88
Median	3.95	8.80	0.20	1.44	1.21	1.01	0.11
95% CI Upper Limit	5.34	9.92	0.25	1.56	1.57	1.24	0.13
95% CI Lower Limit	2.45	7.90	0.13	1.26	0.96	0.85	0.08
90% CI Upper Limit	4.94	9.90	0.24	1.54	1.51	1.23	0.13
90% CI Lower Limit	2.50	8.11	0.15	1.29	0.98	0.87	0.08
80% CI Upper Limit	4.26	9.41	0.24	1.51	1.40	1.18	0.12
80% CI Lower Limit	2.87	8.16	0.17	1.32	1.02	0.89	0.09

Table 5. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Stations A,B,C,D,E,F,G,Z – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	154	147	149	167	148
Minimum	0.07	1.87	0.01	0.35	0.02
Maximum	35.80	61.20	1.54	5.30	18.72
Median	4.22	8.83	0.10	1.38	1.03
95% CI* Upper	5.42	10.20	0.15	**1.52**	1.34
95% CI* Lower	2.87	7.95	0.06	**1.20**	0.78
90% CI* Upper	5.23	9.92	0.14	**1.51**	1.23
90% CI* Lower	2.97	8.03	0.07	**1.26**	0.85
80% CI* Upper	4.96	9.90	0.13	1.48	1.21
80% CI* Lower	3.07	8.16	0.07	1.30	0.94
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Chlorophyll a (CHLA)

The median difference in water column CHLA concentrations between all paired stations, for all years, of 0.90 µg/L (Table 2) is significantly greater than zero at $p < 0.05$, but is relatively small, compared to treatment medians for non-vegetated (5.97 µg/L) and vegetated stations (3.95 µg/L) (Tables 3 and 4) and compared to the Chesapeake Bay habitat limits for the parameter median of 15.00 µg/L. The cause for the difference may be greater competition for nutrients occurring in SAV beds, where autotrophs other than phytoplankton (SAV, macroalgae, SAV epiphytes) are likely to be responsible for a greater percentage of total primary production. Whatever the cause, these results suggest that the current water quality monitoring program may slightly overestimate levels of this parameter, compared to what SAV experiences.

For the habitat parameter evaluation for vegetated stations, the median value for CHLA for all pooled sample units for all eight stations for all three years (Table 5, Figures 3 and 4) was well below the habitat requirement of < 15 µg/L established for SAV growth at one meter depth in the polyhaline section of the Chesapeake Bay (Batiuk et al., 1992). The pooled median for all stations for all years was 4.22 µg/L (95% CI: 2.87-5.42), with all individual stations across years and all individual years across stations having 95% confidence intervals for estimated median values below the threshold. This suggests that, for most areas of the Maryland and Virginia Coastal Bays at or less than this depth, water column CHLA a is not limiting SAV growth.

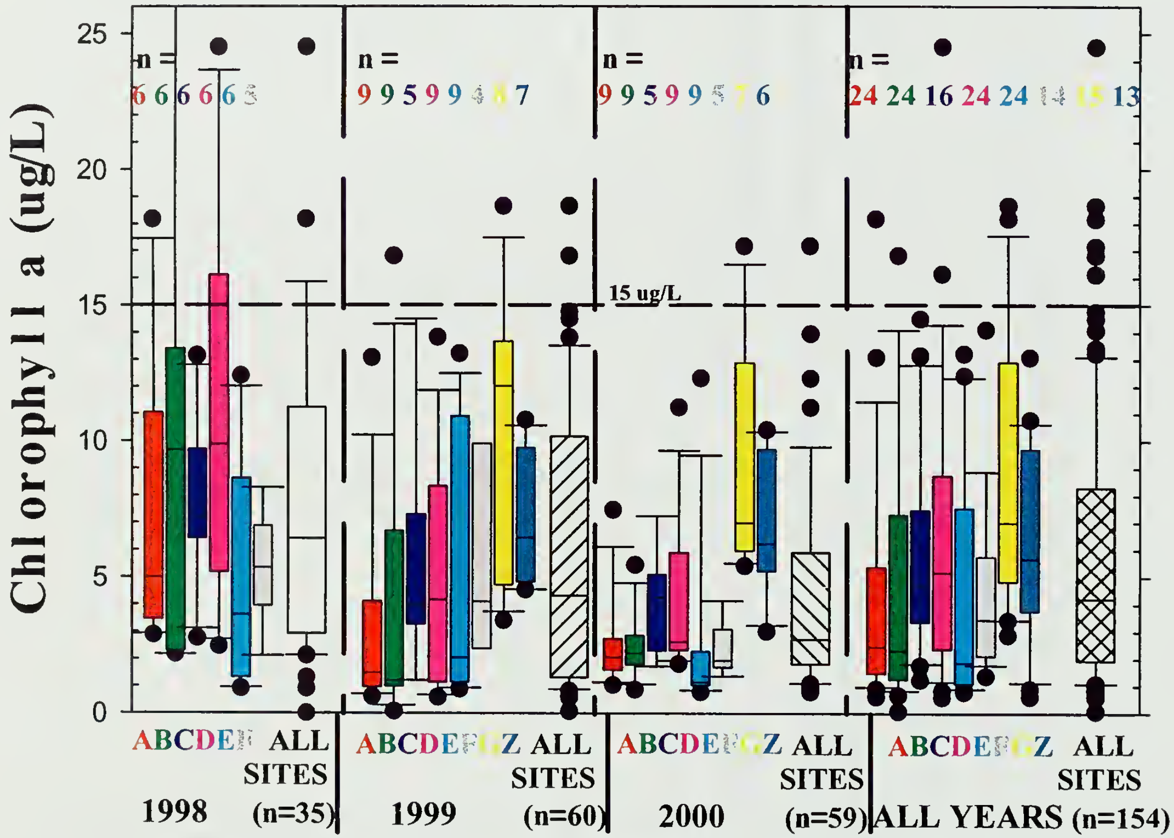

Figure 2. Water column chlorophyll a during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by years. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

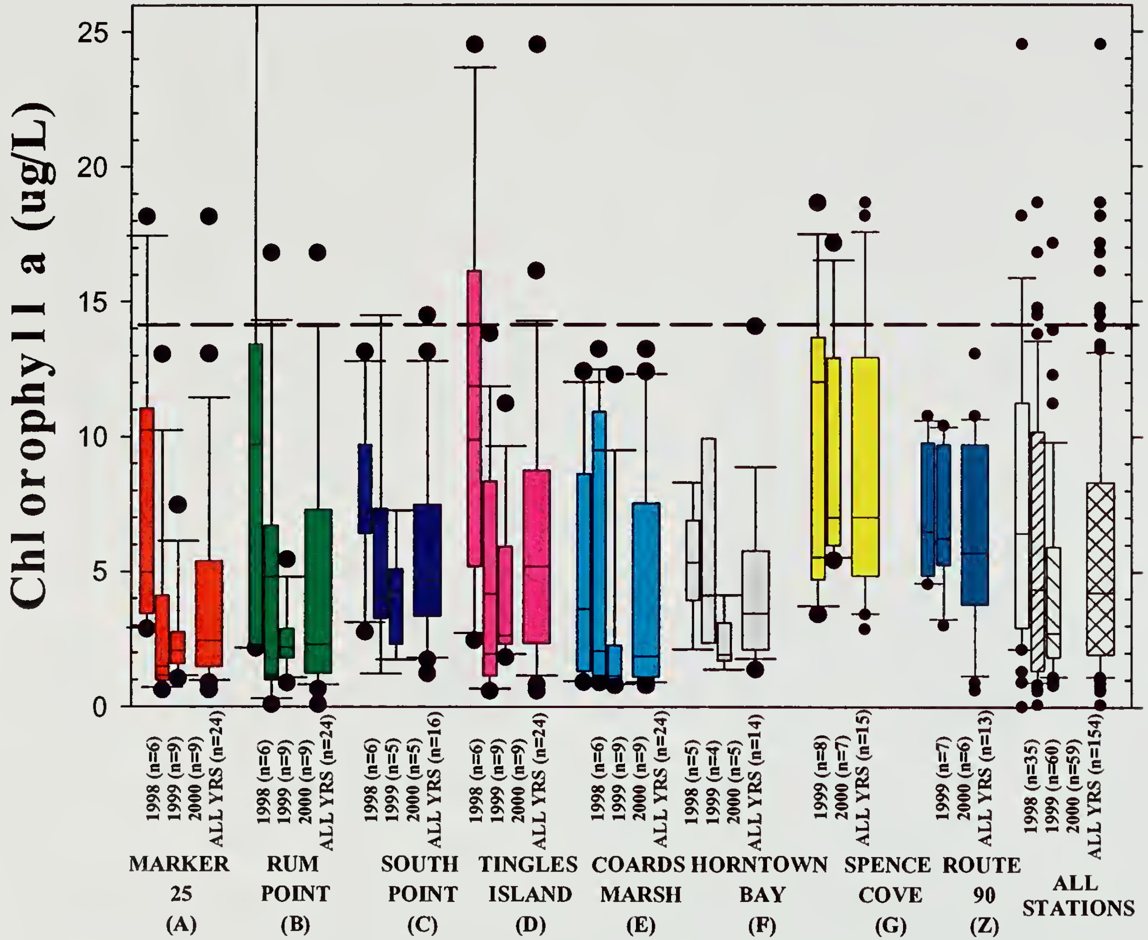

Figure 3. Water column chlorophyll a during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by stations. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

Total Suspended Solids (TSS)

The median difference in TSS concentrations between paired stations is 2.90 mg/L and is significantly greater than zero at $p < 0.05$ (Table 2). While this difference is similar in proportion to the non-vegetated (12.70) and vegetated (8.80) station medians (Tables 3 and 4) as the difference measured for chlorophyll a is to the individual treatment medians, it and the treatment medians are proportionally larger compared to the corresponding Chesapeake Bay habitat requirement value of 15.00 mg/L, making the differences between non-vegetated and vegetated station median values more of a concern for attempts to apply the Chesapeake Bay habitat parameters to the Coastal Bays under current conditions. The difference between treatments is not surprising, given that (1) SAV grows in more protected shoals and coves and (2) the plants likely trap suspended sediment and inhibit resuspension. These results suggest that the current water quality monitoring program may overestimate levels of this parameter, compared to what SAV experiences.

For the habitat parameter evaluation for vegetated stations, the median value for TSS for all pooled sample units for all eight stations for all three years (Table 5, Figures 4 and 5) was well below the habitat requirement of < 15 mg/L established for SAV growth at 1 meter depth in the polyhaline section of the Chesapeake Bay (Batiuk et al., 1992), with a pooled median for all stations for all years of 9.73 mg/L (95% CI: 8.03-11.09). At the southernmost stations, Coards Marsh (E) and Horntown Bay (F), the median value for all years data pooled was below 15 mg/L, but 80% confidence intervals included this threshold. Overall, this suggests that, for most areas of the Maryland and Virginia Coastal Bays at or less than this depth, TSS are not limiting SAV growth.

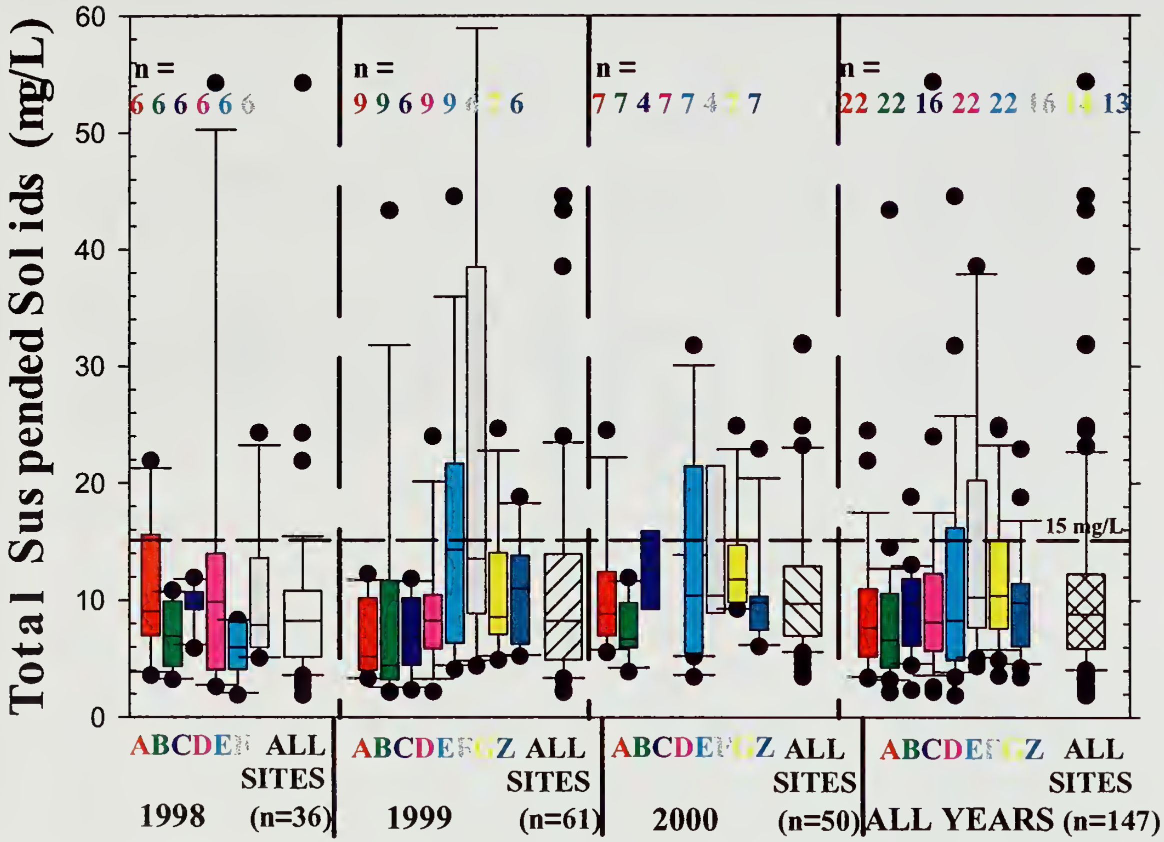

Figure 4. Water column total suspended solids during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by years. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

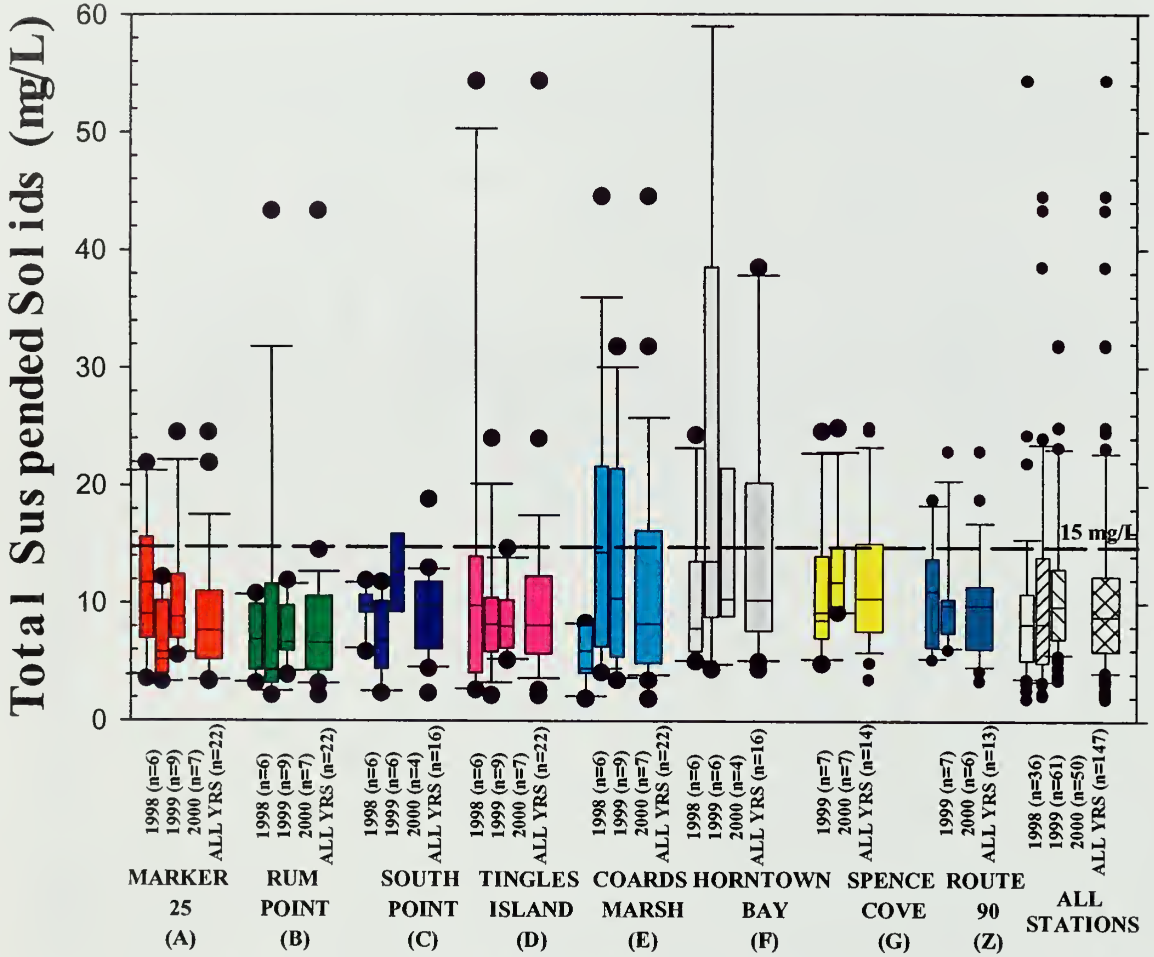

Figure 5. Water column total suspended solids during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by station. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

Dissolved Inorganic Phosphorus (DIP)

The median difference in DIP concentrations between paired stations is 0.00 µM, and is significantly greater than zero at $p > 0.2$ (Table 2), with vegetated stations having slightly greater concentrations of DIP than non-vegetated stations (median of 0.20 µM at vegetated stations vs. 0.17 µM at non-vegetated stations (Tables 3 and 4)). These results suggest that the current water quality monitoring program probably estimates levels of this parameter that are comparable to that which SAV experiences.

For the habitat parameter evaluation for vegetated stations, the median value for DIP for all pooled sample units for all eight stations for all three years (Table 5, Figures 6 and 7) was well below the habitat requirement of < 0.65 µM established for SAV growth at one meter depth in the polyhaline section of the Chesapeake Bay (Batiuk et al., 1992), with a pooled median for all stations for all years of 0.09 µM (95% CI: 0.05-0.20), with all individual stations across years and all individual years across stations having 95% confidence intervals for estimated median values below the threshold. This suggests that, for most areas of the Maryland and Virginia Coastal Bays at or less than this depth, DIP is not limiting SAV growth.

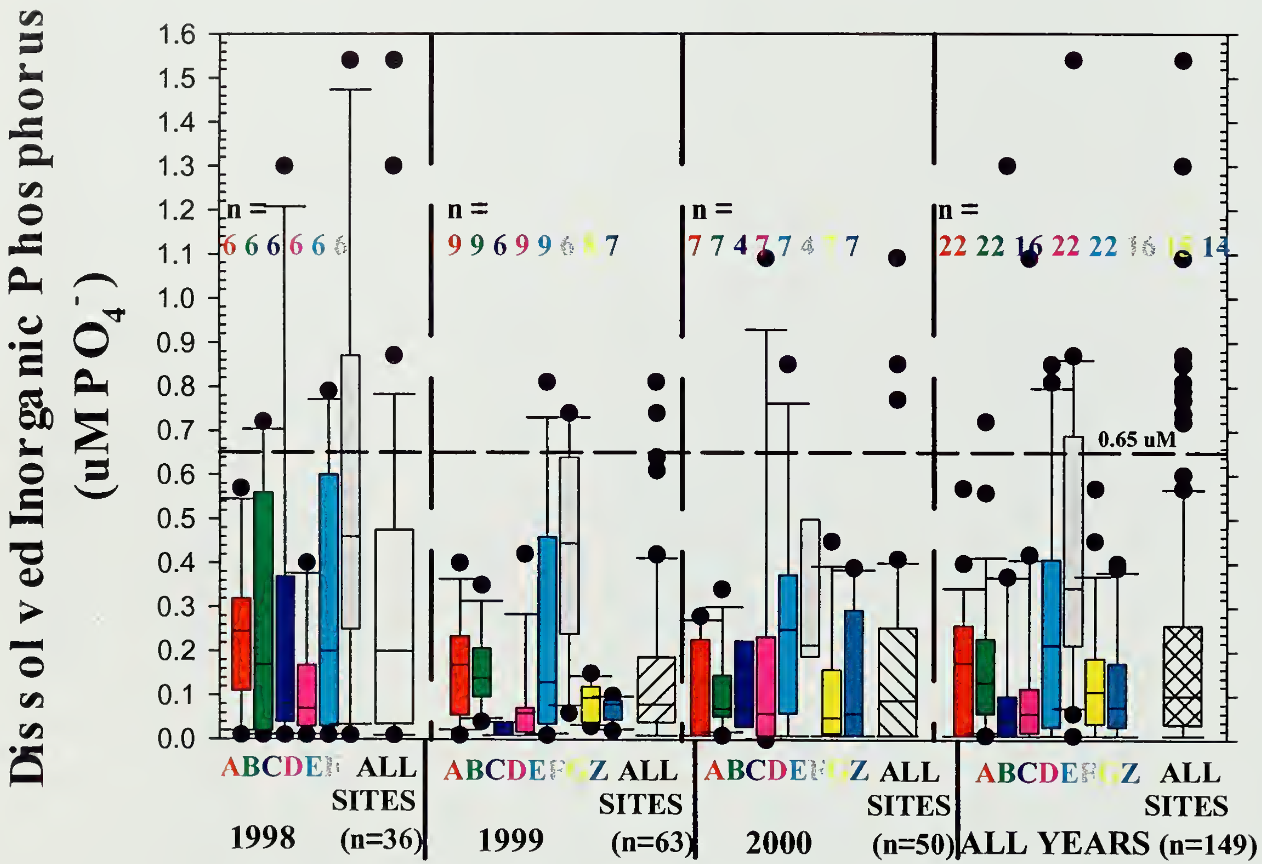

Figure 6. Dissolved inorganic phosphorus during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by years. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

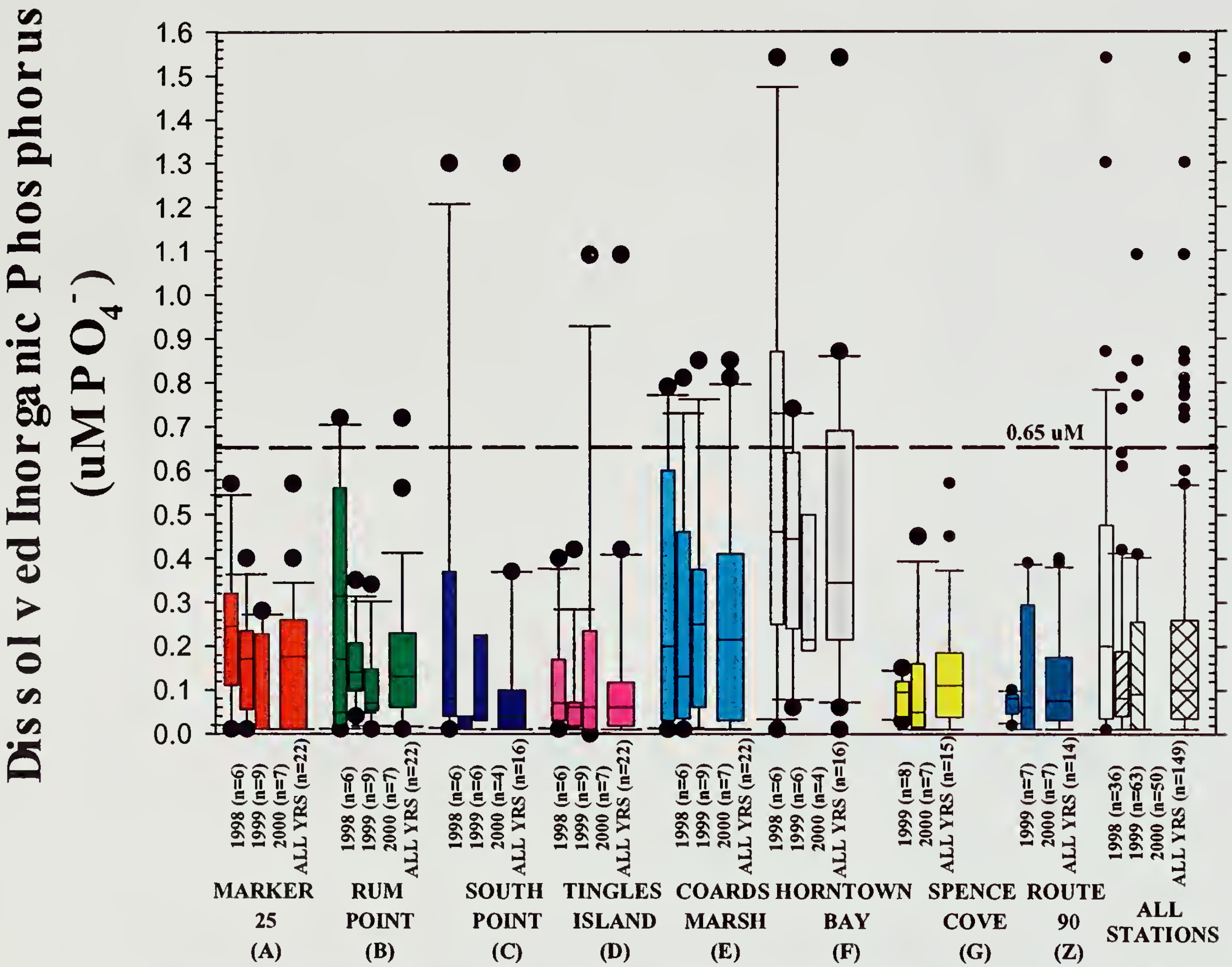

Figure 7. Dissolved inorganic phosphorus during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by station. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

Dissolved Inorganic Nitrogen (DIN)

The median difference in water column DIN concentrations between all paired stations, for all years, is 0.13 µM (Table 2) and, although significantly greater than zero at $p < 0.10$, it is relatively small compared to the treatment median values for non-vegetated stations (1.23 µM) and vegetated stations (1.21 µM) (Tables 3 and 4) and the Chesapeake Bay habitat limits for the parameter median of 10.71 µM. The relative contribution of ammonium and of nitrate-nitrite to DIN is similar for non-vegetated and vegetated stations (Tables 2-4). From the small scale of the [significant] difference between treatments, it appears that water quality sampling at non-vegetated stations adequately represents DIN concentrations in SAV beds.

For the habitat parameter evaluation for vegetated stations, the median value for DIN for all pooled sample units for all eight stations for all three years (Table 5, Figures 8 and 9; see also Figures 12-15, Appendix 5) was well below the habitat requirement of < 10.71 µM established for SAV growth at one meter depth in the polyhaline section of the Chesapeake Bay (Batiuk et al., 1992), with a pooled median for all stations for all years of 1.03 µM (95% CI: 0.63-1.34), with all individual stations across years and all individual years across stations having 95% confidence intervals for estimated median values below the threshold. This suggests that, for most areas of the Maryland and Virginia Coastal Bays at or less than this depth, DIN is not limiting SAV growth.

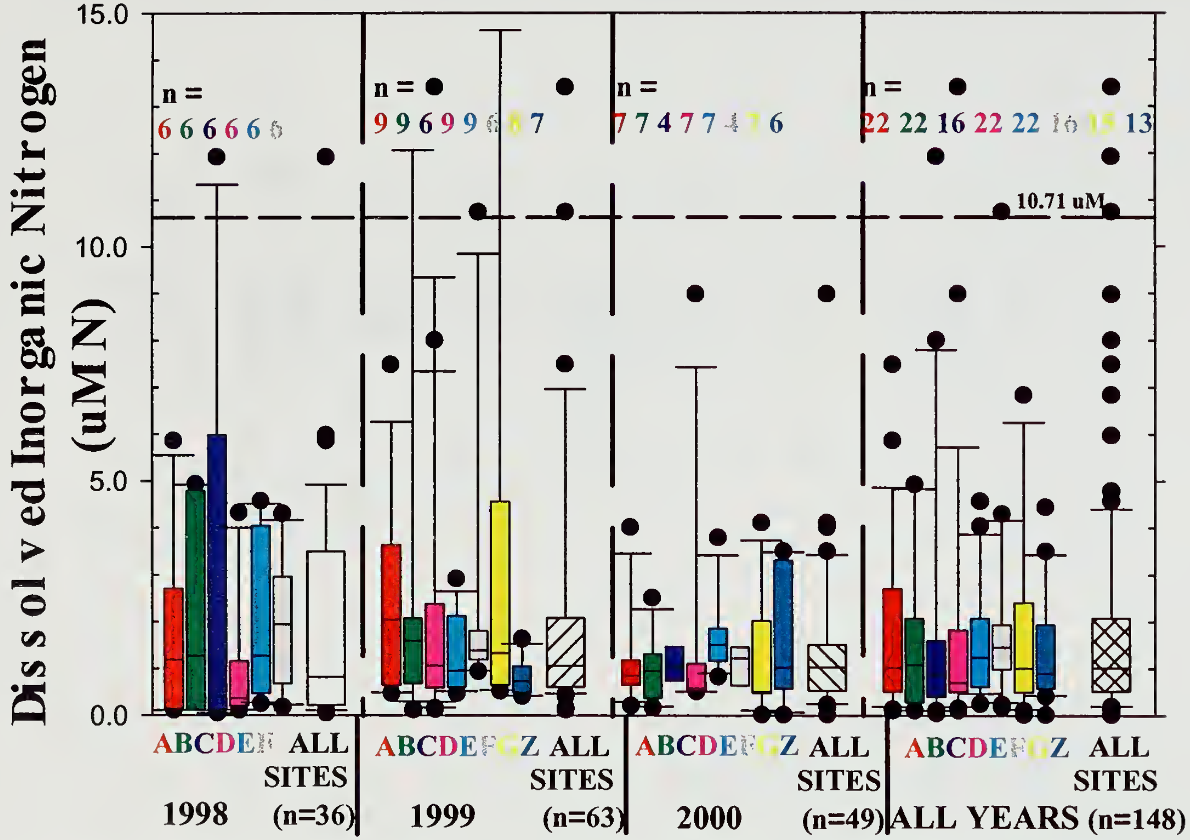

Figure 8. Dissolved inorganic nitrogen during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by years. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

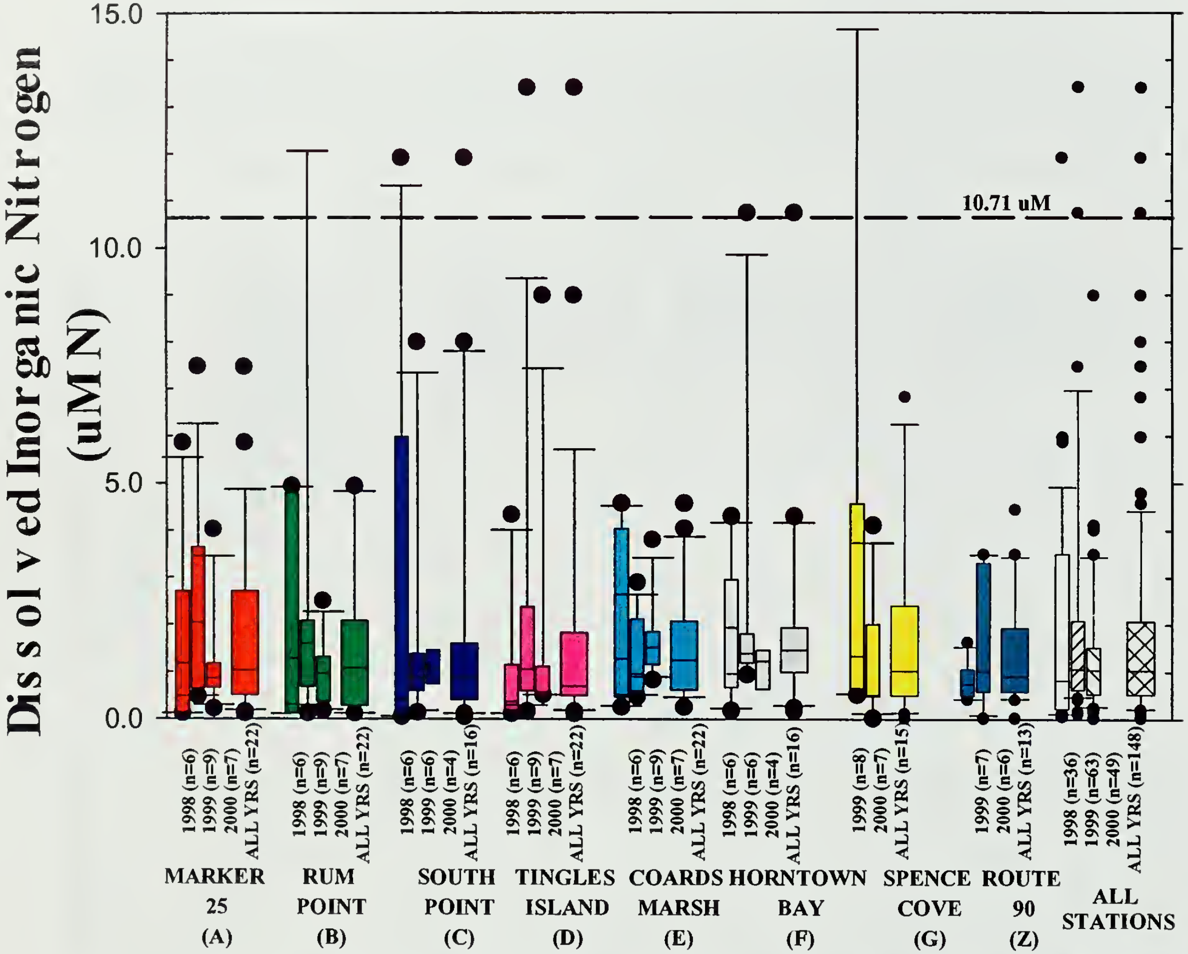

Figure 9. Dissolved inorganic nitrogen during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by station. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

Light Attenuation Coefficient (K_d)

The data suggest little difference in the K_d between paired stations (Tables 2-4).

For the habitat parameter evaluation for vegetated stations, the median value for K_d for all pooled sample units for all eight stations for all three years (Table 5, Figures 10 and 11) was below the habitat requirement of 1.50 established for SAV growth at one meter depth in the polyhaline section of the Chesapeake Bay (Batiuk et al., 1992), with a pooled median for all stations for all years of 1.38 µM (95% CI: 1.20-1.52). The median value for pooled sample units for all three years exceeded 1.50 at South Point (1.70 (95% CI: 0.97-1.97) (Table 21, Appendix 4), Spence Cove (1.58 (95% CI: 1.19-1.98) (Table 25, Appendix 4), and Route 90 (1.52 (95% CI: 1.13-1.73) (Table 26, Appendix 4) and was very close to 1.50 at Tingles Island (1.49 (95% CI: 1.19-1.83) (Table 22, Appendix 4), and Coards Marsh (1.47 (95% CI: 0.87-2.29) (Table 23, Appendix 4). This suggests that K_d may be limiting SAV growth in some areas of the Coastal Bays.

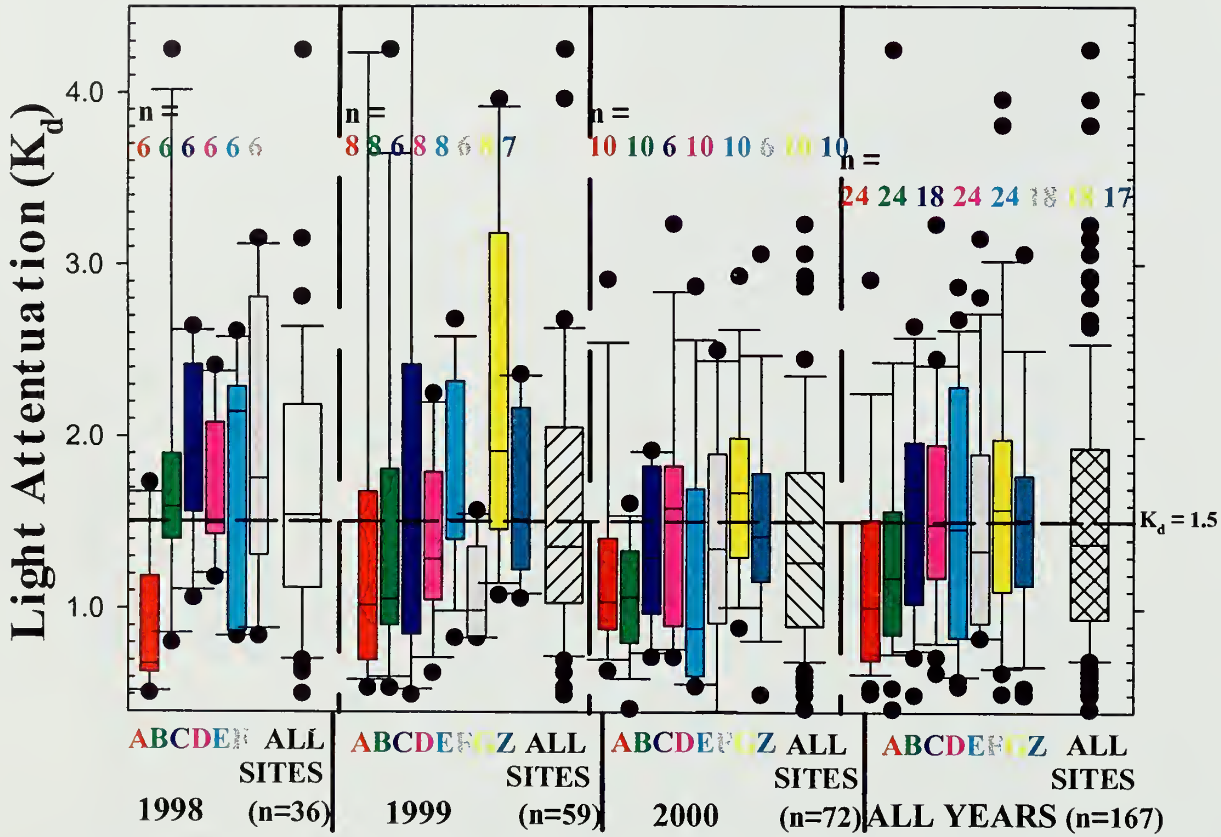

Figure 10. Water column light attenuation during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by years. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

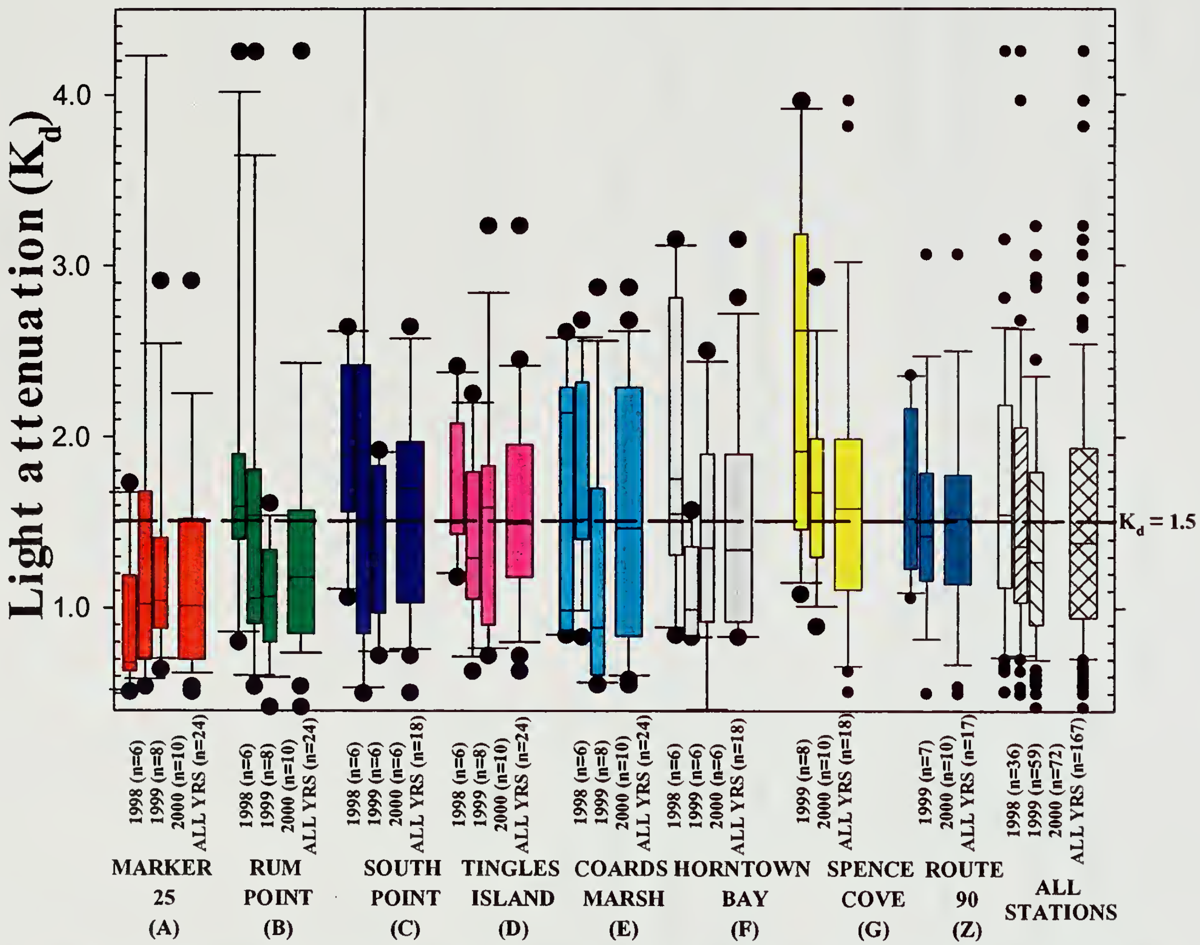

Figure 11. Water column light attenation during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by stations. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles. Dash horizontal line across chart indicates water quality requirements for SAV at one meter depth for Chesapeake Bay polyhaline regimes (Batiuk et al. 1992).

To further investigate the possible limiting effects of K_d, the [modified] equation expressing the relationship between minimal light requirements, light attenuation coefficient, and maximum depth limits of SAV growth (Dennsion et al. 1993),

$$MLQ = e^{-Kd*Zmax}$$

Where,

MLQ = minimal light requirement for *Zostera marina* (in %) (19.4, the median of calculated minima from five studies (Dennison et al. 1993) of *Zostera marina* was used) (MLQ = 100 x I_z/I_o of Dennison et al. 1993)

Kd = light attenuation coefficient

Z_{max} = maximum depth of growth

was solved for Z_{max} for each of the eight Coastal Bay monitoring stations (the median value of pooled sample units over all three years was used for each Coastal Bay monitoring station). Results are presented in Table 6.

Table 6. Theoretical maximum depths (Z_{max}) for SAV growth at monitoring stations, compared to observed depths (Z_O) at monitoring stations in SAV beds, Maryland-Virginia Coastal Bays. Median values (1998-2000) observed for stations are used for K_d, mean depths observed are used for Z_O, median minimal light coefficient of five studies on *Zostera marina* cited by Dennison et al. (1993) was used for minimal light requirement.

STATION	*Estimated Z_{max}*	*Z_O mean (95% confidence interval for mean) (# of observations)*
Marker 25 (A)	1.62	0.97 (0.94-1.01) (n=57)
Rum Point (B)	1.39	0.62 (0.59-0.65) (n=57)
South Point (C)	0.96	0.62 (0.57-0.67) (n=25)
Tingles Island (Dd)	1.10	**1.19 (1.14-1.25) (n=36)***
Coards Marsh (Ed)	1.12	**1.29 (1.25-1.34) (n=37)***
Horntown Bay (F)	1.22	0.77 (0.69-0.85) (n=25)
Spence Cove (G)	1.04	0.98 (0.93-1.03) (n=49)
Route 90 (Z)	1.08	0.89 (0.85-0.93) (n=48)

* - values are for deeper of paired stations. Values for shallow stations are:

Tingles Island (Ds) 0.86 (0.81-0.92) (n=34)

Coards Marsh (Es) 0.89 (0.82-0.96) (n=34)

It would be interesting to measure the maximum depths of SAV growth at each of these stations (Z_{Omax}), since Z_O here represents the depth at the monitoring station, not the depth limits of SAV in the vicinity of the station. Nevertheless, it is interesting to note that the depths at the Tingles Island and Coards Marsh monitoring stations are clearly greater than their respective [hypothetical] Z_{max} and the depth at the Spence Cove monitoring station is very close to this value. It is possible that the relationship between light attenuation and depth limits for *Zostera marina* at five other sites established by Dennison et al. (1993) is not applicable to the Coastal Bays. The situation seems more paradoxical when it is considered that median values of chlorophyll a and TSS, the parameters that would be expected to contribute most to K_d, are well below maximum growing season median values established by Batiuk et al. (1992) for the Chesapeake Bay. It suggests further investigation into the use of water column K_d as an indicator of suitable SAV habitat. Field measurement methods for light attenuation should also be reviewed to ascertain whether some aspects, particularly as used in very shallow water, or as measured during the middle hours of the day, when K_d may be higher than in the early morning hours, might introduce bias toward overly high or overly low calculations of K_d.

LITERATURE CITED:

Batiuk, R.A., R.J. Orth, K.A. Moore, W.C. Dennison, J.C. Stevenson, L.W. Staver, V. Carter, N.B. Rybicki, R.E. Hickman, S. Kollar, S. Bieber, and P. Heasly. 1992. Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A Technical Synthesis. U.S. Environmental Protection Agency, Annapolis, MD.

Bohlen, C., C. Stokes, D. Goshorn, and W. Boynton. 1997. Today's treasures for tomorrow: an environmental report on Maryland's coastal bays. Maryland Department of Natural Resources, Annapolis, MD.

Dennison, W. C., R. J. Orth, K. A. Moore, J. C. Stevenson, V. Carter, S. Kollar, P. W. Bergstrom, and R. A. Batiuk. 1993. Assessing water quality with submersed aquatic vegetation: habitat requirements as barometers of Chesapeake Bay health. BioScience 43: 86-94.

D'Elia, C.F., E.E. Connor, N.L. Kaumeyer, C.W. Keefe, K.V. Wood, and C.F. Zimmermann. 1997. Nutrient Analytical Services Laboratory Standard Operating Procedures. Technical Report Series No. 158-97. Chesapeake Biological Laboratory, Solomons, MD.

National Park Service. 1991. Assateague Island National Seashore water quality monitoring 1987-1990 data summary and report. Technical report NPS/NRWRD/NRTR-91/06. Fort Collins, CO and Berlin, MD.

National Park Service. 1994. Resource management plan - Assateague Island National Seashore. Unpublished report. Berlin, MD.

Orth, R. J. and K. A. Moore. 1983. Chesapeake Bay: an unprecedented decline in submerged aquatic vegetation. Science 222: 51-53.

Orth, R. J. and K. A. Moore. 1984. Distribution and abundance of submerged aquatic vegetation in Chesapeake Bay: an historical perspective. Estuaries 7: 531-540.

Orth, R. J., J. F. Nowak, D. J. Wilcox, J. R. Whiting, and L. S. Nagey. 1998. Distribution of submerged aquatic vegetation in the Chesapeake Bay and tributaries and the coastal bays -1997. Virginia Institute of Marine Science Special Report No. 138. Report to the U. S. Environmental Protection Agency. Gloucester Point, VA.

Orth, R. J., J. Simons, J. Capelli, V. Carter, A. Fritsch, L. Hindman, S. Hodges, K. Moore, and N. Rybicki. 1987. Distribution of submerged aquatic vegetation in the Chesapeake Bay and tributaries and Chincoteague Bay -1986. Report to the U. S. Environmental Protection Agency. Virginia Institute of Marine Science, Gloucester Point, VA.

Short, F. T. and D. M. Burdick. 1996. Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries 19: 730-739.

Sturgis, B. 2001. Assateague Island National Seashore water quality monitoring program chemical and physical properties: 2000 annual report. National Park Service, Berlin, MD. Unpublished report.

Tomasko, D. A., C. J. Dawes, and M. O. Hall. 1996. The effects of anthropogenic nutrient enrichment on turtle grass (*Thalassia testudinum*) in Sarasota Bay, Florida. Estuaries 19: 448-456.

U.S. Environmental Protection Agency. 1979. Methods for chemical analysis of water and wastes. Report No. EPA-600/4-79-020. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH.

VanHeukelem, L. et al. 1994. Improved separations of phytoplankton phaeopigments using temperature controlled high performance liquid chromatography. Mar. Ecol. Prog. Ser. 114: 303-313.

Zar, J. H. 1996. Biostatistical analysis, 3rd ed. Prentice Hall, Upper Saddle River, NJ.

Appendix 1. Field and laboratory data collection methods

Total Suspended Solids (TSS): A 250 ml bottle was filled from just under the water's surface. It was placed in a cooler of ice, transported to a refrigerator within 8 hours, and transported in a cooler of ice to the analytical laboratory within five days of collection. At the laboratory, TSS is calculated in mg/L using methods described in D'Elia et al. (1997), which is a slight modification of Method No. 160.2 (U.S. Environmental Protection Agency, 1979).

Dissolved Inorganic Nitrogen (DIN) and Dissolved Inorganic Phosphorus (DIP): For each of the two components of DIN (Ammonium and nitrate-nitrite) and DIP (orthophosphate), 20 ml of water were collected in a syringe from just below the water surface. The water in the syringe was pushed, using moderate hand pressure, through a 1.5 μm fiberglass filter. The filtrate was stored, buried in ice, in a cooler and transported to a freezer (-15 °C) within 8 hours of collection, and transported, buried in ice in a cooler, to the analytical laboratory within 5 days of collection.

> **Dissolved Inorganic Nitrogen (DIN):** Ammonium was measured in μM by Berthelot Reaction method (D'Elia, et al., 1997), followed by colorimetric analysis. Nitrite and nitrate were measured by reduction of nitrate to nitrite through a copper-cadmium column, with original nitrite plus reduced nitrate concentration in μM determined by colorimetric analysis of an azo dye formation formed by addition of sulfanilamide and N-1-naphthylethylenediamine dihydrochloride (D'Elia, et al., 1997). DIN was measured as the sum of ammonium plus nitrite-nitrate in μM.
>
> **Dissolved Inorganic Phosphorus (DIP):** DIP was measured as the orthophosphate concentration in μM, as determined by initial reaction of the phosphorus in the sample with ammonium molybdate/antimony potassium tartrate, with the resulting complex subsequently reduced by ascorbic acid to a color whose intensity is proportional to phosphorus concentration, as determined by colorimeter.

Chlorophyll a (CHLA): On site, staff extracted 200 ml of water from just below the surface in a syringe, and filtered it through a 1.5 μm fiberglass filter, using moderate hand pressure. The filter was stored in aluminum foil buried in ice in a cooler and was transported to a (-15 °C) freezer. Within 5 days, it was transported to the analytical laboratory. Pigments were extracted from the filter by acetone and grinding and concentration of chlorophyll a in μg was made by high performance liquid chromatography (Van Heukelem et al. 1994).

Light attenuation (K_d): Variables required for the calculation of K_d were measured *in situ* by first lowering a Li-Cor LI-192SA [cosine] underwater sensor to depths of 0.1meters and 1.1 meters and recording radiation in µE, as averaged over 15 1-second intervals by a LI-1400 datalogger. Simultaneous readings were made with a deck sensor (LI-190SA) in order to correct for the available ambient radiation. If water depth prevented the sensor from being lowered to 1.1 m, radiation was recorded at 0.1 m and at 0.6 m.

Light attenuation (K_d) was calculated as:

$$K_d = (\mathrm{Ln}\,[(2000/D_1)*U_1)] - \mathrm{Ln}\,[(2000/D_2)*U_2)]) / (Z_2 - Z_1)$$

Where, D_1 = the deck sensor reading (µE), at the underwater sensor depth 1

U_1 = the underwater sensor reading (µE), at depth 1

D_2 = the deck sensor reading (µE), at the underwater sensor depth 2

U_2 = the underwater sensor reading (µE), at depth 2

Z_1 = depth 1 (m) (0.1)

Z_2 = depth 2 (m)

Appendix 2. Summary statistics for hypothesis tests of medians – differences between vegetated and non-vegetated stations by individual year of study (Tables 7-15).

For Tables 7, 10, and 13, statistics represent results of subtraction of value for the vegetated member of pair from the non-vegetated member of pair; thus, positive values indicate that the variable is greater for non-vegetated stations; negative values indicate that the variable is greater for vegetated stations.

For confidence interval (CI) limits in Tables 7, 10, and 13, bold-faced values indicate that confidence interval for that variable does not include zero – indicating significant differences at that level of confidence.

Table 7. Differences Between Stations -1998.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
N (of cases)	48	49	49	56	49	49	49
Minimum	-25.68	-28.90	-1.28	-3.36	-7.85	-7.85	-1.74
Maximum	11.85	77.18	0.46	1.06	14.73	5.71	9.02
Median	-0.48	1.90	-0.06	-0.01	0.00	0.00	0.00
95% CI Upper Limit	1.46	4.91	0.05	0.13	0.40	0.37	0.00
95% CI Lower Limit	-2.07	-0.86	-0.16	-0.28	-1.00	-1.00	0.00
90% CI Upper Limit	1.36	4.76	0.05	0.12	0.31	0.31	0.00
90% CI Lower Limit	-1.89	-0.70	-0.16	-0.27	-0.95	-0.96	0.00
80% CI Upper Limit	0.86	4.69	0.03	0.11	0.27	0.27	0.00
80% CI Lower Limit	-1.00	-0.60	-0.12	-0.26	-0.90	-0.82	0.00

Table 8. Non-Vegetated Stations – 1998.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
Minimum	0.40	2.53	0.02	0.54	0.11	0.10	0.01
Maximum	19.29	93.50	1.06	3.50	20.71	8.05	14.90
Median	7.77	11.10	0.20	1.66	0.88	0.83	0.01
95% CI Upper Limit	9.54	14.70	0.30	1.85	1.31	1.22	0.04
95% CI Lower Limit	5.97	8.83	0.13	1.19	0.45	0.41	0.01
90% CI Upper Limit	9.23	14.40	0.27	1.79	1.29	1.14	0.03
90% CI Lower Limit	6.24	8.96	0.13	1.39	0.47	0.43	0.01
80% CI Upper Limit	9.14	13.30	0.25	1.77	1.20	1.13	0.02
80% CI Lower Limit	6.54	9.28	0.14	1.40	0.50	0.46	0.01

Table 9. Vegetated Stations – 1998.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
Minimum	0.49	2.15	0.01	0.51	0.05	0.04	0.01
Maximum	35.80	57.10	1.54	4.87	9.15	8.85	5.88
Median	7.37	8.53	0.26	1.62	1.16	0.95	0.01
95% CI Upper Limit	9.18	10.10	0.45	2.03	1.94	1.93	0.04
95% CI Lower Limit	5.34	7.08	0.11	1.41	0.47	0.42	0.01
90% CI Upper Limit	8.63	9.91	0.44	2.03	1.94	1.92	0.03
90% CI Lower Limit	5.57	7.20	0.13	1.43	0.50	0.45	0.01
80% CI Upper Limit	8.29	9.90	0.37	1.99	1.94	1.84	0.02
80% CI Lower Limit	5.78	7.24	0.17	1.47	0.58	0.48	0.01

Table 10. Differences Between Stations -1999.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
N (of cases)	56	56	56	56	56	56	56
Minimum	-10.13	-20.10	-1.00	-1.97	-5.50	-5.25	-1.41
Maximum	12.70	35.59	0.95	4.24	11.59	7.70	8.48
Median	1.37	3.95	0.00	0.06	0.26	0.05	0.07
95% CI Upper Limit	**2.96**	5.79	0.04	0.27	0.51	0.29	**0.16**
95% CI Lower Limit	**0.33**	-0.62	-0.10	-0.07	-0.25	-0.33	**0.00**
90% CI Upper Limit	**2.86**	5.25	0.04	0.25	0.48	0.28	**0.15**
90% CI Lower Limit	**0.58**	-0.35	-0.06	-0.03	-0.13	-0.28	**0.00**
80% CI Upper Limit	**2.33**	5.00	0.04	0.21	0.43	0.25	**0.14**
80% CI Lower Limit	**0.59**	-0.10	-0.06	-0.02	-0.06	-0.22	**0.01**

Table 11. Non-Vegetated Stations – 1999.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
Minimum	0.40	2.53	0.02	0.54	0.11	0.10	0.01
Maximum	19.29	93.50	1.06	3.50	20.71	8.05	14.90
Median	7.77	11.10	0.20	1.66	0.88	0.83	0.01
95% CI Upper Limit	6.86	15.16	0.20	1.55	2.20	1.58	0.48
95% CI Lower Limit	3.81	9.00	0.07	1.10	0.98	0.73	0.22
90% CI Upper Limit	6.77	14.00	0.20	1.54	2.14	1.54	0.42
90% CI Lower Limit	4.24	9.05	0.09	1.11	0.98	0.75	0.22
80% CI Upper Limit	6.51	13.72	0.20	1.54	1.90	1.47	0.42
80% CI Lower Limit	4.30	9.22	0.10	1.14	1.15	0.80	0.22

Table 12. Vegetated Stations – 1999.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
Minimum	0.49	2.15	0.01	0.51	0.05	0.04	0.01
Maximum	35.80	57.10	1.54	4.87	9.15	8.85	5.88
Median	7.37	8.53	0.26	1.62	1.16	0.95	0.01
95% CI Upper Limit	3.95	9.92	0.34	1.46	2.08	1.72	0.32
95% CI Lower Limit	1.48	6.11	0.06	1.03	0.95	0.78	0.11
90% CI Upper Limit	3.95	8.89	0.32	1.45	2.07	1.72	0.32
90% CI Lower Limit	1.64	6.15	0.08	1.04	0.96	0.81	0.14
80% CI Upper Limit	3.68	8.86	0.26	1.45	2.04	1.70	0.31
80% CI Lower Limit	1.90	6.47	0.11	1.05	0.96	0.85	0.14

Table 13. Differences Between Stations – 2000.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
N (of cases)	49	42	42	56	42	42	42
Minimum	-5.20	-36.80	-1.13	-2.08	-8.23	-5.84	-2.39
Maximum	17.97	35.08	0.48	1.92	3.85	2.69	3.45
Median	0.97	2.40	0.04	-0.02	0.12	0.07	0.03
95% CI Upper Limit	**2.47**	6.21	0.06	0.18	**0.35**	0.32	**0.10**
95% CI Lower Limit	**0.18**	-2.23	-0.07	-0.37	**0.00**	-0.10	**0.01**
90% CI Upper Limit	**2.22**	5.75	0.06	0.18	**0.26**	0.22	**0.10**
90% CI Lower Limit	**0.21**	-1.01	-0.07	-0.37	**0.02**	-0.04	**0.01**
80% CI Upper Limit	**2.21**	5.70	0.06	0.13	**0.20**	0.19	**0.09**
80% CI Lower Limit	**0.22**	-0.41	-0.07	-0.36	**0.02**	-0.02	**0.01**

Table 14. Non-Vegetated Stations – 2000.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
Minimum	0.85	3.70	0.01	0.46	0.14	0.07	0.01
Maximum	28.16	65.00	0.78	3.84	5.82	5.40	3.92
Median	4.80	14.52	0.16	1.33	1.25	0.99	0.15
95% CI Upper Limit	6.69	16.46	0.24	1.50	1.65	1.37	0.24
95% CI Lower Limit	2.77	11.74	0.10	1.22	0.85	0.75	0.08
90% CI Upper Limit	6.09	15.89	0.23	1.44	1.63	1.33	0.21
90% CI Lower Limit	3.12	12.31	0.10	1.22	0.93	0.76	0.09
80% CI Upper Limit	5.82	15.63	0.20	1.44	1.53	1.30	0.18
80% CI Lower Limit	3.49	12.99	0.11	1.23	0.96	0.81	0.11

Table 15. Vegetated Stations – 2000.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)	NH_4^+ (µM)	NO_2^-/NO_3^- (µM)
Minimum	0.61	2.15	0.01	0.55	0.14	0.07	0.01
Maximum	16.25	57.20	1.33	3.83	9.19	6.65	2.54
Median	2.42	10.58	0.19	1.36	1.08	0.93	0.11
95% CI Upper Limit	3.52	13.00	0.23	1.61	1.40	1.05	0.14
95% CI Lower Limit	1.82	8.26	0.06	1.08	0.89	0.76	0.07
90% CI Upper Limit	3.39	12.33	0.23	1.61	1.35	1.04	0.13
90% CI Lower Limit	1.86	8.73	0.08	1.08	0.91	0.85	0.07
80% CI Upper Limit	3.07	11.90	0.23	1.58	1.23	1.02	0.13
80% CI Lower Limit	1.92	9.17	0.09	1.15	0.95	0.85	0.07

Appendix 3. Estimated values and confidence intervals for medians for Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime), as measured in Maryland and Virginia Coastal Bay submerged aquatic vegetation beds, all stations by individual growing season (Tables 16-18).

Table 16. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Stations A,B,C,D,E,F,G,Z – 1998 Growing Season.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	35	36	36	36	36
Minimum	0.91	1.87	0.01	0.51	0.05
Maximum	35.80	54.30	1.54	4.25	11.92
Median	6.42	8.21	0.20	**1.55**	0.82
95% CI* Upper	8.63	9.91	0.37	**1.99**	2.30
95% CI* Lower	3.44	5.86	0.05	**1.19**	0.25
90% CI* Upper	8.29	9.90	0.32	**1.97**	1.94
90% CI* Lower	4.18	5.95	0.06	**1.31**	0.29
80% CI* Upper	8.09	9.50	0.26	**1.90**	1.94
80% CI* Lower	4.26	6.96	0.08	**1.40**	0.40
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 17. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Stations A,B,C,D,E,F,G,Z – 1999 Growing Season.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	60	61	63	59	63
Minimum	0.07	2.13	0.01	0.50	0.12
Maximum	18.65	61.20	0.81	5.30	18.72
Median	4.33	8.25	0.08	1.36	1.06
95% CI* Upper	5.98	10.20	0.12	**1.63**	1.63
95% CI* Lower	2.14	6.24	0.06	**1.06**	0.78
90% CI* Upper	5.43	9.99	0.11	**1.61**	1.59
90% CI* Lower	2.34	6.74	0.06	**1.08**	0.90
80% CI* Upper	5.43	9.92	0.11	**1.55**	1.57
80% CI* Lower	2.44	6.76	0.06	**1.20**	0.94
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 18. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Stations A,B,C,D,E,F,G,Z – 2000 Growing Season.

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	59	50	50	72	49
Minimum	0.78	3.44	0.01	0.35	0.02
Maximum	17.15	31.90	1.09	3.23	8.98
Median	2.71	9.73	0.09	1.27	1.03
95% CI* Upper	4.38	11.09	0.20	1.47	1.34
95% CI* Lower	2.07	8.03	0.05	1.08	0.63
90% CI* Upper	4.25	10.99	0.19	1.44	1.23
90% CI* Lower	2.24	8.16	0.05	1.10	0.67
80% CI* Upper	3.31	10.60	0.18	1.38	1.22
80% CI* Lower	2.32	8.26	0.05	1.13	0.72
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Appendix 4. Estimated values and confidence intervals for medians for Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime), as measured in Maryland and Virginia Coastal Bay submerged aquatic vegetation beds, all growing seasons, by individual station (Tables 19-26).

Table 19. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Station A (Marker 25) – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	24	22	22	24	22
Minimum	0.61	3.30	0.01	0.51	0.11
Maximum	18.16	24.50	0.57	5.30	7.48
Median	2.44	7.63	0.18	1.01	1.03
95% CI* Upper	4.18	12.90	0.31	1.41	4.01
95% CI* Lower	1.47	4.49	0.01	0.70	0.50
90% CI* Upper	3.50	12.20	0.28	1.19	3.37
90% CI* Lower	1.49	5.17	0.01	0.77	0.51
80% CI* Upper	3.50	11.00	0.26	1.15	2.71
80% CI* Lower	1.49	5.53	0.04	0.88	0.63
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 20. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Station B (Rum Point) – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	24	22	22	24	22
Minimum	0.07	2.13	0.01	0.42	0.11
Maximum	35.80	43.30	0.72	4.25	18.72
Median	2.30	6.61	0.13	1.18	1.08
95% CI* Upper	5.44	10.80	0.34	**1.53**	2.50
95% CI* Lower	1.19	3.87	0.05	**1.03**	0.24
90% CI* Upper	5.43	10.70	0.26	1.47	2.30
90% CI* Lower	1.40	4.25	0.06	1.05	0.28
80% CI* Upper	5.43	10.60	0.23	1.40	2.08
80% CI* Lower	1.40	4.30	0.06	1.05	0.57
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 21. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Station C (South Point) – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	16	16	16	18	16
Minimum	1.22	2.33	0.01	0.50	0.05
Maximum	14.49	18.85	1.30	4.93	11.92
Median	4.66	9.71	0.04	**1.70**	0.86
95% CI* Upper	7.70	11.90	0.11	**1.97**	1.82
95% CI* Lower	2.50	5.86	0.01	**0.97**	0.13
90% CI* Upper	7.26	11.80	0.09	**1.94**	1.38
90% CI* Lower	2.75	6.11	0.01	**1.03**	0.40
80% CI* Upper	7.26	11.80	0.09	**1.94**	1.38
80% CI* Lower	2.75	6.11	0.01	**1.03**	0.40
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 22. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Station D (Tingles Island) – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	24	22	22	24	22
Minimum	0.58	2.16	0.01	0.63	0.11
Maximum	24.51	54.30	1.09	3.23	13.41
Median	5.18	8.13	0.06	1.49	0.70
95% CI* Upper	8.16	14.30	0.10	**1.83**	3.25
95% CI* Lower	2.34	5.15	0.01	**1.19**	0.44
90% CI* Upper	8.09	14.00	0.08	**1.68**	2.09
90% CI* Lower	2.39	5.68	0.02	**1.26**	0.50
80% CI* Upper	8.09	12.30	0.08	**1.66**	1.83
80% CI* Lower	2.39	6.15	0.03	**1.32**	0.51
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 23. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Station E (Coards Marsh) – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	24	22	22	24	22
Minimum	0.78	1.87	0.01	0.55	0.25
Maximum	13.22	44.50	0.85	2.87	4.57
Median	1.86	8.26	0.22	1.47	1.24
95% CI* Upper	4.26	**23.10**	0.61	**2.29**	2.90
95% CI* Lower	1.09	**4.52**	0.02	**0.87**	0.60
90% CI* Upper	2.97	**21.20**	0.60	**2.25**	2.26
90% CI* Lower	1.10	**4.87**	0.03	**0.95**	0.61
80% CI* Upper	2.97	**16.20**	0.41	**1.99**	2.08
80% CI* Lower	1.10	**4.99**	0.04	**1.08**	0.83
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 24. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Station F (Horntown Bay) – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	14	16	16	18	16
Minimum	1.37	4.37	0.01	0.35	0.18
Maximum	14.07	61.20	1.54	3.15	10.74
Median	3.45	10.28	0.35	1.34	1.46
95% CI* Upper	6.42	**24.30**	**0.74**	**1.90**	1.94
95% CI* Lower	1.82	**5.95**	**0.18**	**0.84**	0.68
90% CI* Upper	5.77	**16.20**	**0.64**	**1.57**	1.94
90% CI* Lower	1.94	**7.20**	**0.20**	**0.92**	0.94
80% CI* Upper	5.34	**16.20**	**0.64**	**1.57**	1.94
80% CI* Lower	2.12	**7.20**	**0.20**	**0.92**	0.94
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 25. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Station G (Spence Cove) – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	15	14	15	18	15
Minimum	2.87	3.54	0.01	0.51	0.02
Maximum	18.65	24.90	0.57	3.96	17.98
Median	7.00	10.40	0.11	**1.58**	1.01
95% CI* Upper	12.57	14.73	0.17	**1.98**	2.30
95% CI* Lower	4.49	7.27	0.03	**1.19**	0.50
90% CI* Upper	12.14	14.73	0.15	**1.97**	2.24
90% CI* Lower	4.96	7.27	0.04	**1.30**	0.50
80% CI* Upper	11.91	14.62	0.13	**1.85**	1.85
80% CI* Lower	5.42	7.95	0.04	**1.31**	0.51
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Table 26. Confidence Intervals for the Median Values of Chesapeake Bay SAV 1 meter habitat requirements (polyhaline regime) for Maryland Coastal Bays Vegetated Station Z (Route 90) – All Growing Seasons (1998-2000).

	CHLA (µg/L)	TSS (mg/L)	DIP (µM)	K_d	DIN (µM)
N (of cases)	13	13	14	17	13
Minimum	0.61	3.39	0.01	0.50	0.02
Maximum	13.06	22.90	0.40	5.30	4.44
Median	5.68	9.79	0.08	**1.52**	0.90
95% CI* Upper	9.71	11.60	0.17	**1.73**	2.04
95% CI* Lower	3.01	5.19	0.02	**1.13**	0.51
90% CI* Upper	9.70	11.00	0.17	**1.68**	1.63
90% CI* Lower	3.50	6.04	0.02	**1.16**	0.57
80% CI* Upper	6.78	10.40	0.10	**1.68**	1.36
80% CI* Lower	4.54	6.24	0.04	**1.16**	0.61
Chesapeake Bay SAV Habitat Parameter Median	15.00	15.00	0.65	1.50	10.71

Appendix 5. Ammonium and nitrate-nitrite (components of DIN) concentrations grouped by year and by station (Figures 12-15).

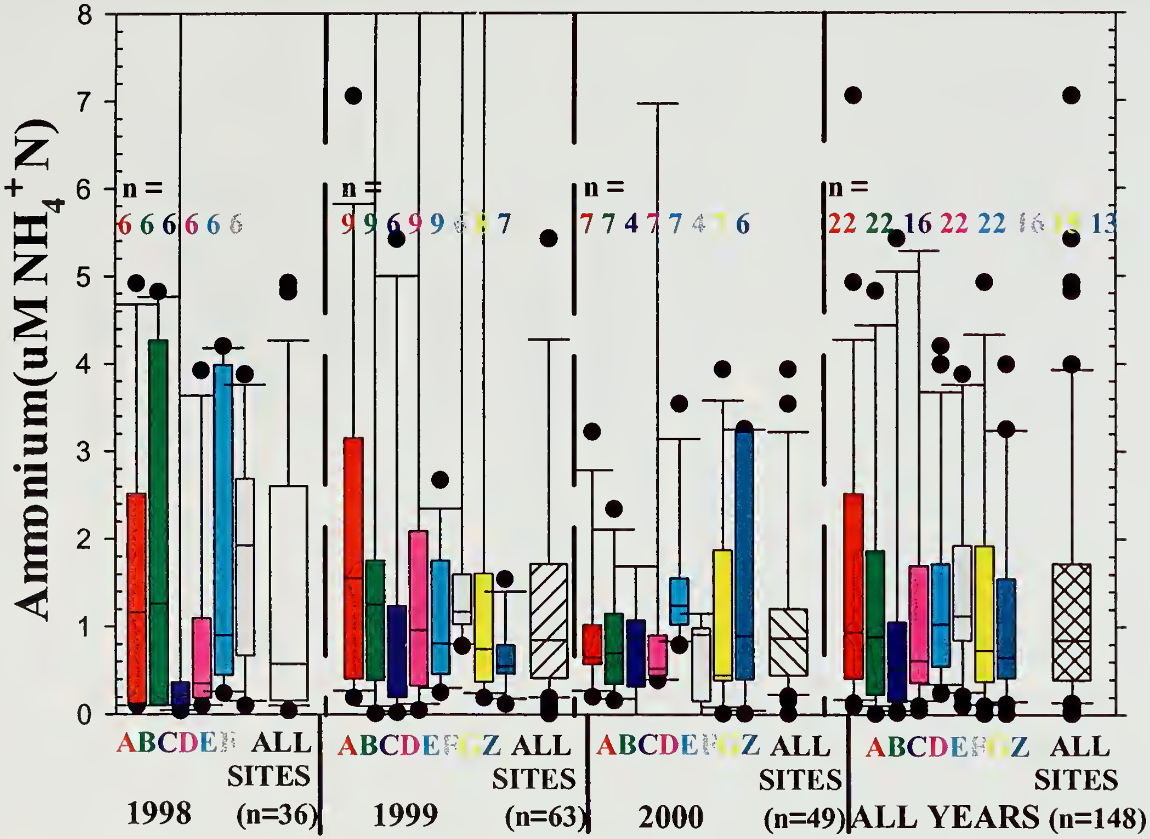

Figure 12. Water column ammonium (NH_4^+) during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by years. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles.

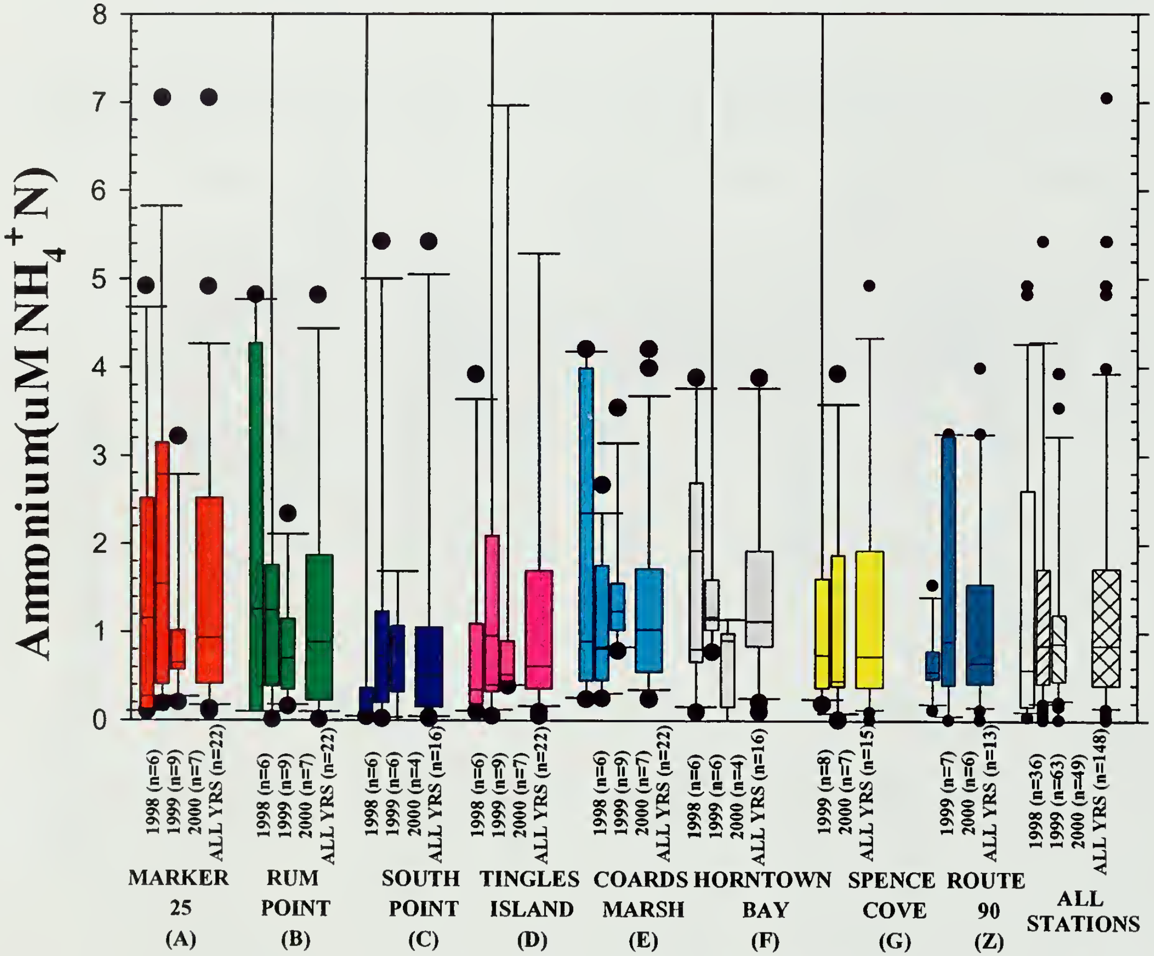

Figure 13. Water column ammonium (NH_4^+) during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by station. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles.

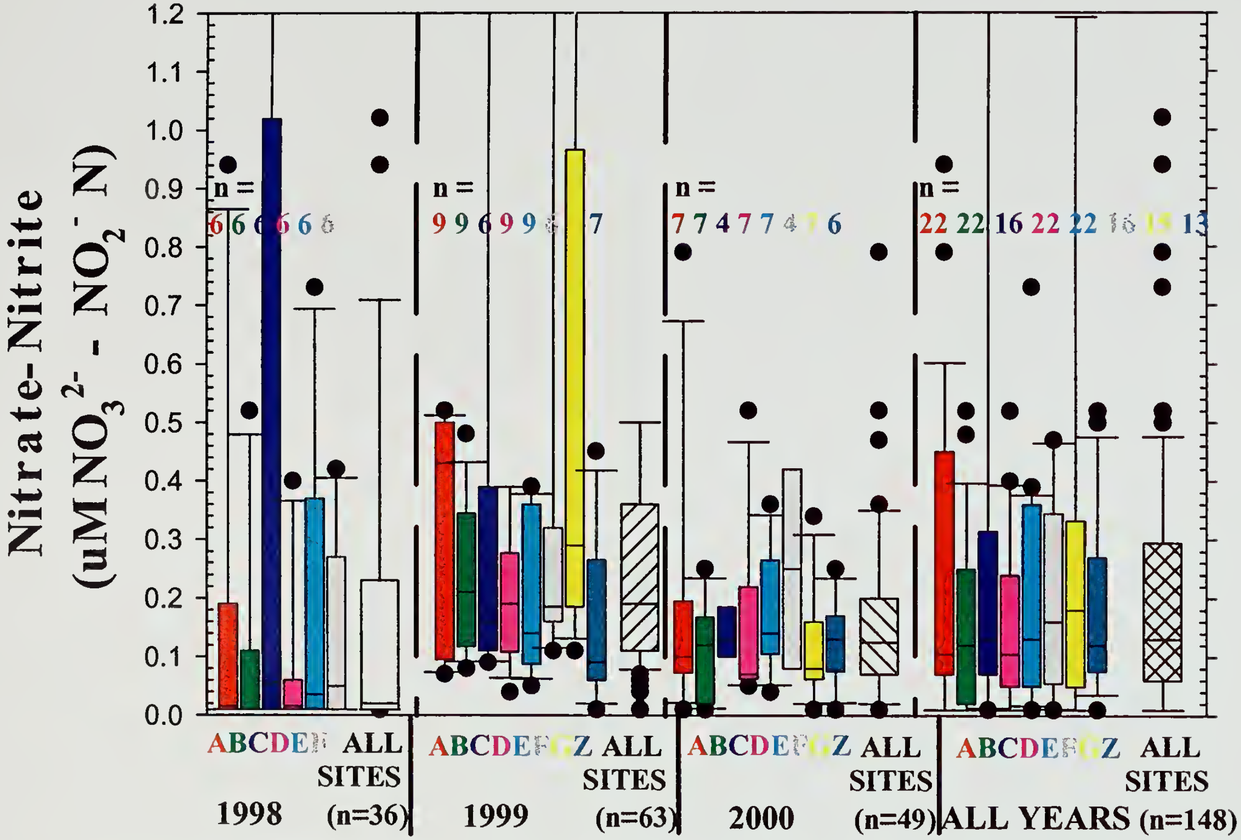

Figure 14. Water column nitrate-nitrite (NO_3^{2-} -NO_2^-) during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by years. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles.

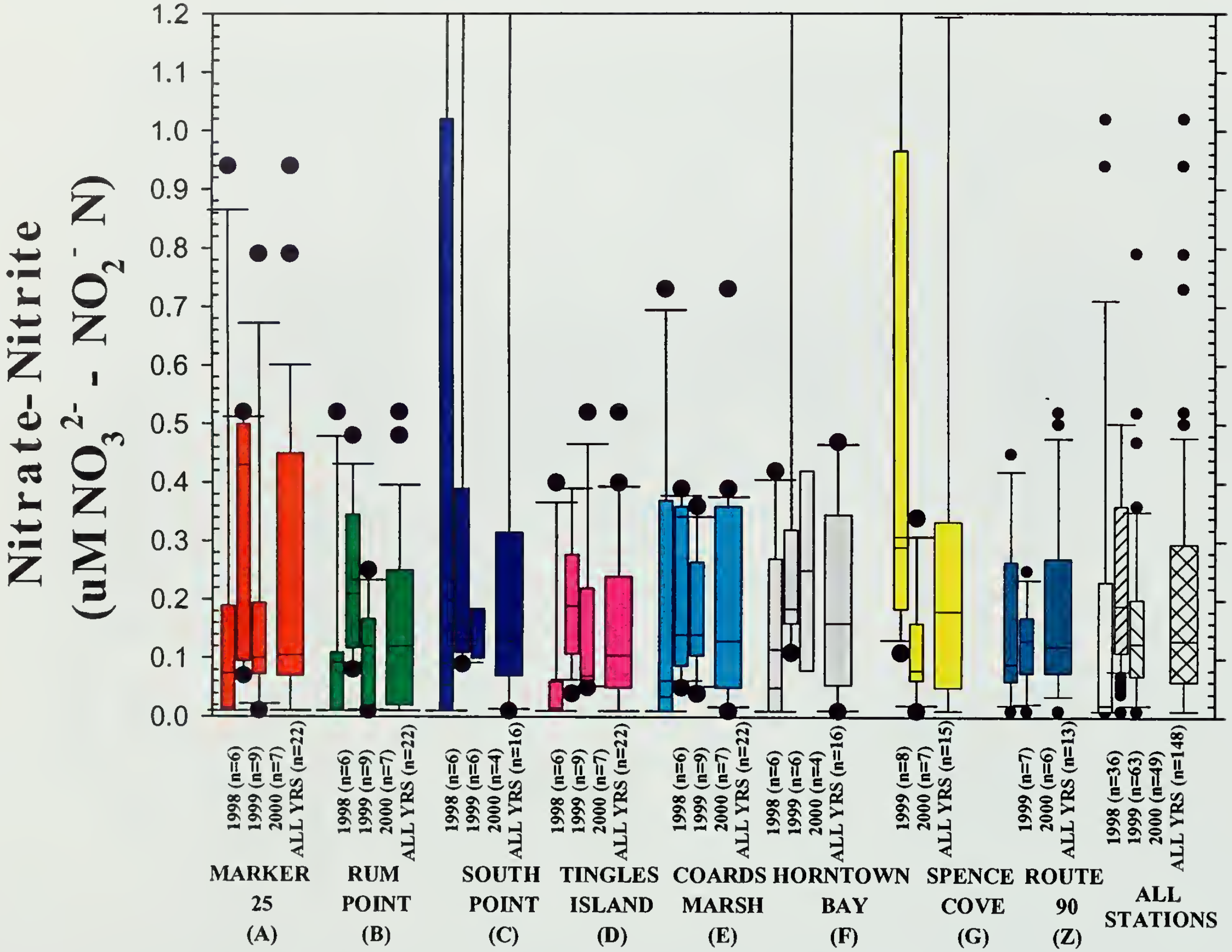

Figure 15. Water column nitrate-nitrite (NO_3^{2-}-NO_2^-) during SAV growing season, Maryland Coastal Bays, 1998-2000, grouped by stations. Horizontal lines through box plots represent median values for parameter. Boxes contain 25th through 75th percentile values. Error bars contain 10th through 90th percentile values. Outliers are represented by black circles.

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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