Chapter 5.2

Development of a seagrass habitat suitability index for the Maryland Coastal Bays

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Abstract
The Coastal Bays submerged aquatic vegetation habitat index (SAVi) was developed to explain differences in seagrass distribution among the major watersheds. The SAVi summarizes the attainment of five habitat criteria (total nitrogen, total phosphorus, chlorophyll, total suspended solids and Secchi depth). When the SAVi was compared to SAV goal attainment in each segment 2011-2013 the relationship was poor ($r^2 = 0.17$). Therefore, three additional indices of SAV habitat were compared to the seagrass goal attainments in each watershed between 2011 and 2013. The water quality index (WQI) presented in Chapter 4.4 used total nitrogen (TN), total phosphorus (TP), chlorophyll a (CHL) and dissolved oxygen (DO) showed the best relationship to SAV goal attainment ($r^2 = 0.78$), followed closely by a new SAV index that used dissolved inorganic nitrogen, dissolved inorganic phosphorus and chlorophyll ($r^2 = 0.75$) and a modified water quality index using TN, TP and chlorophyll ($r^2 = 0.71$).

Introduction

Seagrasses are ecologically important resources which are sensitive to changes in water quality. Certain environmental variables that are measured in standard water quality monitoring programs, may help explain differences in seagrass distribution (Dennison *et al*, 1993). Previous studies in the Maryland Coastal Bays have suggested that seagrass distribution and abundance may be limited by high nutrient loading rates (Boynton *et al*, 1996). Therefore, assessing water quality thresholds based on seagrass habitat criteria provides information about potential maintenance of the ecosystem services associated with aquatic grass meadows.

A seagrass habitat suitability index (**SAVi)** was developed in an attempt to summarize habitat criteria attainment for all five parameters on a bay segment scale which could be compared to the status of seagrasses in each segment. The SAVi was compared to seagrass goal attainment. The Secchi threshold was adapted since Secchi disk readings are often "on the bottom" due to the shallow nature of the seaside lagoons indicating sufficient light for plant growth. In addition, total suspended solids were analyzed as an indicator of light availability. Additionally, the WQI (TN, TP, CHL and DO) used in Chapter 4.4 was also compared to the seagrass goal attainment as well as a new SAV index (DIN, DIP, CHL) and a new water quality index (TN, TP and CHL).

Seagrass Habitat Criteria

Although seagrasses are found in all four major segments of Maryland's Coastal Bays, they are not distributed evenly. Over 90% percent of seagrasses in the coastal lagoons

occur along the Assateague Island shoreline. In the northern bays, seagrass abundance is limited (see chapter 5.1) presumably due to reduced water quality from human activities.

Increased sediment and nutrient inputs from point and non-point sources decrease the amount of sunlight from reaching the seagrasses and are considered the primary threat to their health. Seagrasses in the Coastal Bays may also be damaged by excessive macroalgae, Brown Tide and recreational and commercial boating activity. Natural factors, such as sediment type and wave action also influence the health and location of seagrass beds.

Management Objective: Increase seagrass abundance by maintaining acceptable habitat conditions for seagrass expansion.

Indicator: SAVI = 1.0 (100% attainment)

Seagrass Habitat Indicators:

***Draft* Habitat Indicator 1:**	Chlorophyll *a* < 15 μg/L
***Draft* Habitat Indicator 2:**	Dissolved Inorganic Nitrogen < 0.15 mg/L
***Draft* Habitat Indicator 3:**	Dissolved Inorganic Phosphorus < 0.02 mg/L
***Draft* Habitat Indicator 4:**	Total Suspended Solids < 15 mg/L
***Draft* Habitat Indicator 5:**	Secchi >0.966 m or on bottom (>40% of time)

***Draft* Seagrass Habitat Index:** Index = 1.0

Data Sets

Monthly data from 41 Maryland Department of Natural Resources (DNR) and 18 Assateague Island (ASIS) National Park Service water quality stations was compiled for a 3-year time period (2011-2013). The indicators that were used to determine seagrass habitat criteria followed those adopted for the Chesapeake Bay and included Secchi depth, chlorophyll *a* concentration (chl *a*), total suspended solids (TSS), dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorus (DIP) (Batiuk et al. 2000). Habitat indicators use a median value of a three year period for all parameters during the SAV growing season (March – November).

Analyses

The primary growth of seagrasses in the Coastal Bays occurs from March through November. The growing season is based on the combined temperature requirements for growth of the two species of seagrass species present: *Zostera marina* (March – May and October – November) and *Ruppia maritima* (April - October). Median values for each indicator (except Secchi depth; see below) at each station were evaluated against accepted Environmental Protection Agency (EPA) Chesapeake Bay Program criteria (draft habitat indicators above) over the seagrass growing season for the combined three-year period. Although these were originally established for the Chesapeake Bay, work by Valdez *et al* (1998) and Lea *et al* (2003) suggest that the nutrient thresholds are similar in the Coastal Bays; however, the total suspended solids (TSS) and Secchi may be different.

Because the Secchi disk was frequently visible on the bottom, traditional median values could not be used. Specifically, median Secchi depths would have masked measurements "on bottom" thus suggesting conditions to be worse. For the current analyses, bottom measurements were determined to always indicate adequate seagrass light penetration. Therefore, a percentage of samples exceededing the Secchi threshold over the three-year period was adopted. Samples designated as "on bottom" were always included as meeting the threshold.

Attainment of habitat criteria (except Secchi depth) was tested by comparing the 3-year medians against the individual criteria. Each of the five criteria was determined to either pass or fail the individual criteria. The sum of the indicators that passed was divided by the total number of indicators (five) and an unweighted SAV index was determined for each station. An average of the SAV indices for all the stations in a bay segment was then calculated and compared to SAV goal attainments.

Index Analysis

To summarize SAV habitat criteria attainment, standard water quality variables measured between 2011 and 2013 were compiled into a suitability Index (SAVi). The index was calculated for each station (Figure 5.2.1) and also for each bay segment (Table 5.2.2). This index was based on compliance of measured water quality variables (Chlorophyll *a*, dissolved inorganic nitrogen, dissolved inorganic phosphorus, total suspended solids and Secchi depth) to established thresholds for survival of seagrasses (Table 5.2.1). Index values range from zero (no thresholds for seagrass survival attained) to one (all thresholds for SAV survival met). This approach of summarizing compliance of water quality variables with threshold values has previously been carried out to compare U.S. mid-Atlantic estuaries as well as tributaries within the Chesapeake Bay (Kiddon *et al*, 2003; Jones *et al*, 2003).

Table 5.2.1: Variables and threshold values used in the calculation of an submerged aquatic vegetation, SAV, index for Maryland Coastal Bays (1: Dennison *et al*, 1993; 2: Stevenson *et al*, 1993).

Variable	Threshold value	Reference
Chl a	< 15 μg L^{-1}	1, 2
Dissolved inorganic nitrogen	< 0.15 mg L^{-1} (11 μM)	1, 2
Dissolved inorganic phosphorus	< 0.02 mg L^{-1} (0.64 μM)	1, 2
Total suspended solids	< 15 mg L^{-1}	1, 2
Secchi depth	> 0.96M >40% of the time	1

For each station with greater than 10 records for each variable, medians were calculated for each variable. Only sampling occasions in March through November during 2001 to 2003 were included to represent the growth season of *Zostera marina* and *Ruppia maritima* the dominant seagrass species. Median values for each variable were compared to threshold values and scored as one (meets criteria) or zero (fails to meet criteria). These scores were summed for all variables and divided by the number of variables to result in a unitless index value ranging from zero to one for each sampling location. An index value of zero indicated that a site met none of the criteria, while a score of one indicated a site that met all habitat criteria. Once index values were calculated for each site, means were calculated for all sites within several reporting regions and

are presented by measured variable and index values in tables 5.2.3 and5.2.4. Error associated with mean index values in these cases represents variation between sites, within a reporting region (and does not account for temporal variation).

SAV Index Status

Assawoman Bay

In Assawoman Bay, the open bay station nearest existing seagrass beds (XDN4851) met all but one habitat criteria (Secchi failed) (Table 5.2.2). The majority of stations, 67%, failed the Secchi criteria while all stations but one passed TSS (Table 5.2.4). Assawoman Bay tied for the highest SAVi (0.8) but one of the lowest SAV goal attainments (5%) (Table 5.2.3).

St. Martin River

The St. Martin River shows minimal agreement with the chlorophyll and Secchi seagrass habitat thresholds while DIN and DIP water quality variables failed in only some of the headwater sites (Table 5.2.2). Total suspended solids failed at half the sites, while the Secchi threshold was only achieved at one station. The SAVi was rather high (0.51) given there is currently minimal seagrass growing within this region (2% of SAV goal attainment) (Table 5.2.3).). (Table 5.2.4)

Isle of Wight

In Isle of Wight Bay nutrient thresholds only failed in the headwaters of Turville Creek. Total suspended solids and Secchi conditions failed at two sites (open bay and near the inlet) while light limitation was also indicated by Secchi in Herring and Turville creeks (Table 5.2.2). Isle of Wight Bay had the second highest SAVi (0.80) but met only 7% of the SAV goal (Table 5.2.3). (Table 5.2.4)

Sinepuxent

All stations in Sinepuxent Bay meet all of the water chemistry criteria (chlorophyll, DIN and DIP); however, failed light requirements (both TSS and Secchi) at ASIS 17 and ASIS 18 and Secchi at ASIS 1 (Table 5.2.2). Noticeably absent are seagrass beds around the two stations nearest the Ocean City Inlet (ASIS 1 and ASIS 17). ASIS 1 is the West Ocean City Harbor. The strong currents coming from the inlet probably make the area unsuitable for SAV growth and may also contribute to the elevated TSS levels at site ASIS 17 (Table 5.2.2). Yet, site ASIS 18 sits at the edge of a large bed that may be decreasing slightly in size and density. Sinepuxent Bay had the highest SAVi score (0.80) and met 46% of its seagrass goal (Table 5.2.3). All dissolved nutrient and chlorophyll thresholds were met (Table 5.2.4).

Newport

Stations in the upper tributaries of Newport Bay failed one or more criteria (Table 5.2.2). DIP was met at nearly all stations; however, attainment of Secchi depth criteria was not attained at any of the stations (Table 5.2.4). The two stations in the bay proper (ASIS 3 and 4) met all thresholds (Table 5.2.2). However, they barely met the Secchi attainment. Overall, Newport Bay was only slightly better than St Martin River based on the SAVi (0.62) and SAV goal attainment was 12% (Table 5.2.3).

Chincoteague

Generally, stations with a majority of criteria met were in close proximity to existing seagrass beds (ASIS 6, 8 and 15); however, both ASIS 8 and 15 failed the Secchi threshold. The majority of stations, including those not near seagrass beds, demonstrated generally good conditions for seagrass growth (Table 5.2.2) except that 71% failed to attain Secchi thresholds. Six stations also failed TSS thresholds (35%) and four failed DIP threshold (24%). The bay averaged SAVi for Chincoteague was ranked forth (0.74) yet this bay had the highest SAV goal attainment of 31% (Table 5.2.3). The northern part of Chincoteague Bay passed all of the dissolved nutrient and chlorophyll thresholds but struggled with light (TSS and Secchi) while the southern portion of the bay also struggle with light (Secchi) and dissolved phosphorus (Table 5.2.4).

Seagrass Habitat Criteria Summary

Regressions of four indices of water quality to seagrass goal attainment by segment was completed for 2011-2013. Results show the SAV index (DIN, DIP, CHL, Secchi and TSS) had an r^2 or 0.169. The water quality index, WQI, combines TN, TP, CHL and DO only had a r^2 of 0.7802. The new WQI used TN, TP, light and had an r^2 of 0.7475. The last index tested (yellow triangles) was the WQI with dissolved oxygen removed (TN, TP, CHL) had an r^2 of 0.7097.

However, indicators of water quality (see figure 4.1.3) suggest no trend prior to the 3-year period used for this analysis. Another possible explanation could be that since this SAV habitat analysis only includes water quality and clarity indicators, physical habitat characteristics conducive to seagrass growth, such as sediment characteristics or hydrology are not considered. Sediment type as well as other factors can play roles in the presence of seagrass.

The low proportions of Secchi depth percentages across all stations regardless of seagrass presence serves as a warning that criteria developed for the Chesapeake Bay may not suffice. Secchi depth data was found to be problematic due to the lack of quantitative measure associated with instances of "on bottom" measurements. In fact, at some stations the minimum criterion exceeded the station depth. In response to this issue, a percentage time Secchi passed the criterion was adopted. All "on bottom" measurements were considered to have adequate water clarity for SAV growth and were grouped as passing the criterion. Secchi depth results are reported simply as the percentage of measurements over the three-year period that passed the criterion. Additionally coefficients to convert Secchi to light attenuation (K_d) are thought to be variable in the Coastal Bays based on the dominant sediment material resuspended in the water column.

Summary

The SAV Index by region appears to be less representative than the Water Quality Index (Figures 5.2.1 and 4.4.2). Although both used "seagrass habitat criteria" there was a significant difference between seagrass threshold achievement for total nutrients (see Chapter 4.4, specifically Table 4.4.2) vs. dissolved nutrients (Table 5.2.3). Future evaluation of habitat criteria should include total nutrients, since more stations met the inorganic nutrient criteria (Table 5.2.4) while demonstrating relatively poor status when analyzed for total nutrients (see

Chapter 4.1, specifically Figures 4.1.1 and 4.1.2). However, as a general first iteration of SAV habitat testing, these results tend to follow the spatial pattern of SAV distribution.

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Bay Segment	Station	SECCHI	TSS	CHLA	DIP	DIN
Assawoman Bay	XDN4851	38.5%				
	XDN5737	35.5%				
	XDN6454	35.5%				
	XDN7261	64.5%				
	XDN7545	51.5%				
	GET0005	32%				
St. Martin River	BIH0009	ND				
	BNT0012	ND				
	BSH0008	14.8%				
	BSH0030	0%				
	MXE0011	ND				
	SPR0002	14.8%				
	SPR0009	18.5%				
	XDM4486	13.5%				
	XDN3724	41.4%				
	XDN4312	33.3%				
	XDN4797	25.9%				
Isle of Wight Bay	HEC0012	25.9%				
	MKL0010	31.3%				
	TUV0011	25%				
	TUV0019	59.3%				
	TUV0034	ND				
	XDN0146	37%				
	XDN2340	37%				
	XDN2438	48.1%				
	XDN3445	80%				
Sinepuxent Bay	ASIS 1	33.3				
	ASIS 2	47.2				
	ASIS 16	44.4				
	ASIS 17	36.1				
	ASIS 18	38.9				
Newport Bay	AYR0017	0%				
	MSL0011	0%				
	NPC0012	9.9%				
	NPC0031	0%				
	TRC0043	25.9%				
	TRC0059	36%				
	XCM4878	23.1%				
	BMC0011	ND				
	BOB0001	ND				
	KIT0015	ND				
	ASIS 3					
	ASIS 4					

Bay Segment	Station	SECCHI	TSS	
Chincoteague Bay	XBM1301	48%		
	XBM3418	42.3%		
	XBM5932	23.1%		
	XBM8149	15.4%		
	XCM0159	14.8%		
	XCM1562	18.5%		
	ASIS 5	22.2		
	ASIS 6	22.2		
	ASIS 7	44.4		
	ASIS 8	38.9		
	ASIS 9	47.2		
	ASIS 10	58.3		
	ASIS 11	19.4		
	ASIS 12	27.8		
	ASIS 13	36.1		
	ASIS 14	30.6		
	ASIS 15	38.9		

Met	Not Met	Insufficien
		#####

Table 5.2.2 Coastal Bays seagrass habitat criteria test results for MD Coastal Bays stations 2011-2013 (March-November). The Secchi depth test is the percentage of samples (station per month per year) passing either the 0.966 m criterion or with samples that were "on bottom" which automatically pass (sufficient light on bottom). For all other indicators, medians compared to threshold values are summarized by station using the color-shaded chart (green = threshold met and red = threshold not met).

Table 5.2.3 SAV suitability Index by reporting region calculated from median values (March – November; 2011-2013 vs 2001-2003).

Region	n (sites)	SAVI 11-13	Health	SAVI 01-03
Assawoman	6	**0.80**	Good	0.63
St Martin	11	**0.56**	Poor	0.41
Isle of Wight	9	**0.80**	Good	0.77
Sinepuxent	5	**0.80**	Good	1.00
Newport	12	**0.62**	Poor	0.48
Chincoteague	17	**0.74**	Good	
North Chincoteague	6	**0.67**	Good	0.77
South Chincoteague	11	**0.78**	Good	0.80

Table 5.2.4 SAV suitability Index scores, by measured variable, based on median values (March – November; 2011-2013). Zero means all failed threshold and score of one means mean passed at all sites.

	Secchi	TSS	CHL	DIP	DIN
Assawoman	0.33	0.83	1.0	1.00	0.83
St Martin River	0.36	0.55	0.45	0.82	0.64
Isle of Wight	0.44	0.78	1.0	0.89	0.89
Sinepuxent	0.40	0.60	1.00	1.00	1.00
Newport	0.42	0.58	0.58	0.92	0.58
Chincoteague	0.29	0.65	1.0	0.76	1.0
North Chincoteague	0.00	0.33	1.00	1.00	1.00
South Chincoteague	0.45	0.82	1.00	0.64	1.00

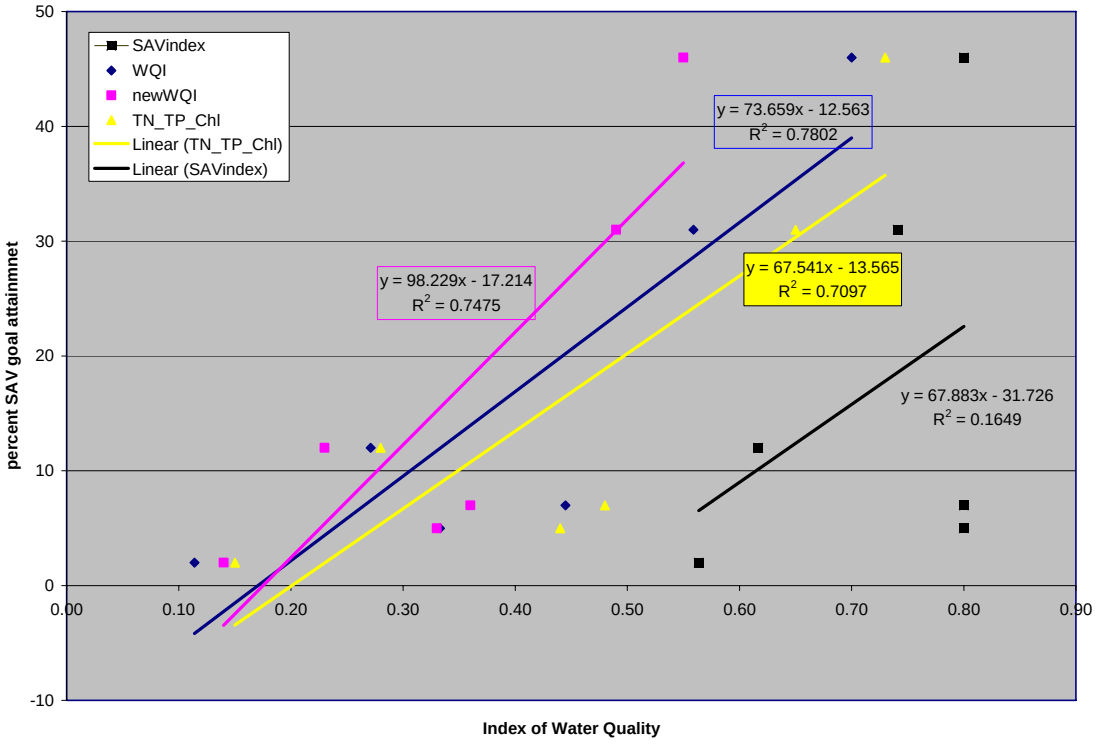

Figure 5.2.1 Regressions of four indices of water quality to SAV goal attainment by segment for 2011-2013. The SAV index (black squares) includes DIN, DIP, CHL, Secchi and TSS. The water quality index, WQI, used in Chapter 4.4 (blue diamonds) combines TN, TP, CHL and DO. The new WQI (pink squares) uses TN, TP, light. The last index tested (yellow triangles) was the WQI with dissolved oxygen removed (TN, TP, CHL).

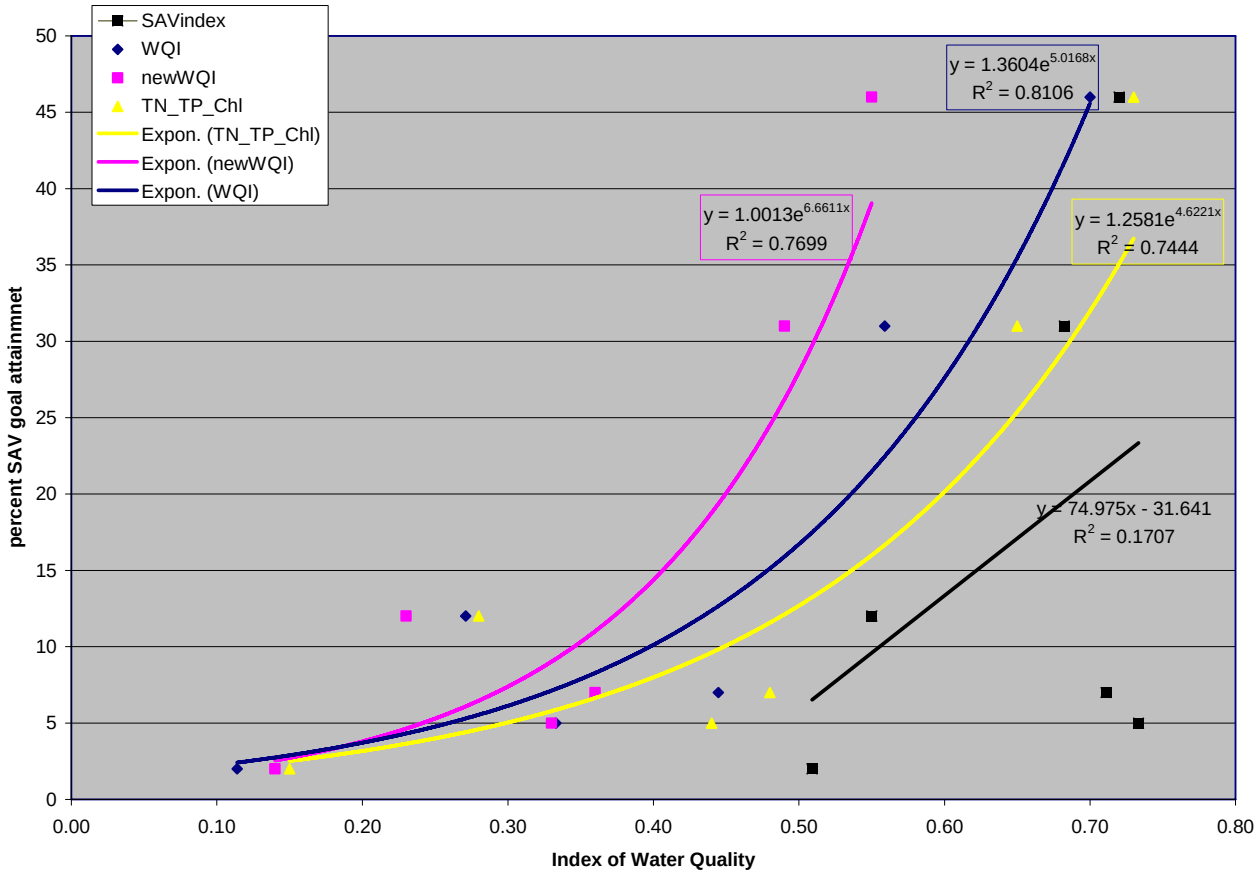

Figure 5.2.2 Exponential regressions improve model fit. The WQI, water quality index, used in chapter 4.4. (TN, TP, CHL, DO); new WQI includes TN, TP and light (from what?) and the last index was the WQI minus DO (TN, TP and CHL). SAVindex includes DIN, DIP, CHL, TSS and Secchi.

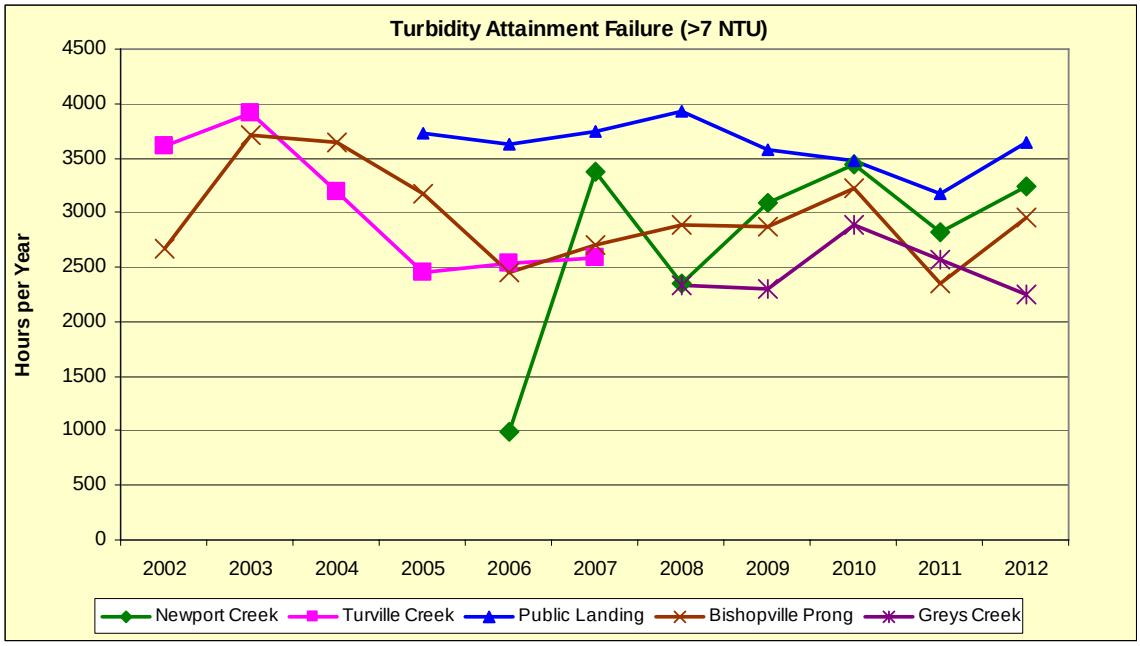

Figure 5.2.3 Failure of turbidity attainment in the coastal bays based on continuous monitoring. Shows highly turbid natural environment (7 NTU ~ 15mg/L TSS- Boyton report).