Chapter 4.4

Integrated Water Quality Index in the Maryland Coastal Bays

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Abstract
The Water Quality Index synthesizes the status of the four water quality indicators; chlorophyll *a* (algae: Chl *a*), total nitrogen (TN), total phosphorus (TP), and dissolved oxygen (DO) into a single indicator of water quality. This indicator is similar to the Dow Jones Index, which compiles information on multiple stocks and provides a simple number to track over time. The Water Quality Index compares measured variables to values known to maintain fisheries (DO) and submerged aquatic grasses (Chl *a*, TN, and TP). The Index joins these together into one number between zero and one. During the most recent index period of 2011-2013, the chlorophyll threshold was most often achieved while thresholds for dissolved oxygen and total phosphorus were least met. Currently, Assawoman Bay, the St. Martin River, Isle of Wight tributaries and Newport Bay show degraded water quality largely due to high nutrient inputs, while the open bays have fair to excellent water quality.

Introduction
The Water Quality Index (WQI) was designed to synthesize the status of chlorophyll *a*, total nitrogen, total phosphorus, and dissolved oxygen into a single parameter. Three year median values of these variables (see previous water quality chapters) are compared to criteria based on ecosystem function, such as maintaining fisheries (DO threshold) and maintaining submerged aquatic grasses (Chl *a*, TN, and TP threshold). The Index is unitless and is scaled between zero and one, such that a WQI of one indicates habitat suitable for fish and aquatic grass survival, while a value of zero indicates relatively unsuitable habitat for either fish or aquatic grasses. Intermediate values indicate a system in flux, where it might be expected that some ecosystem functions (grass beds or fish) may be present some of the time. This approach of summarizing compliance of water quality variables with threshold values has previously been carried out to compare US mid-Atlantic estuaries as well as tributaries within the Chesapeake Bay (Kiddon *et al*, 2003; Jones *et al*, 2003).

Management Objective: Maintain suitable fisheries and seagrass habitat.

Draft Indicator: Water quality Index >0.6

Data Analyses
For the 60 sampling sites with at least 10 records for all variables between 2011 and 2013, median values for each variable were calculated. Median values were then

compared to established threshold values (Table 4.4.1) and scored as one (meets criteria) or zero (fails to meet criteria). These scores were summed for all four variables and divided by the number of variables to result in an index value ranging from zero to one for each sampling location. An index value of zero indicated that a site met none of the habitat suitability criteria, while a score of one indicated a site that met all habitat suitability criteria. Once an index value had been calculated for each site, the index value for all sites within several reporting regions were averaged and these values are presented by measured variable (Table 4.4.1) and combined regional index values (Table 4.4.3). Standard error associated with mean index values in these cases represents spatial variation between sites, within a reporting region, and does not include temporal variability.

Table 4.4.1 Variables and threshold values used in the calculation of the Water Quality index for Maryland Coastal Bays (1: Dennison *et al*, 1993; 2: Orth *et al.* 2002; 3: Chesapeake 2000, 4: Stevenson *et al*, 1993).

Variable	Threshold value	Reference
WQI		
Chl a	< 15 μg L^{-1}	1, 2
Total nitrogen	< 0.65 mg L^{-1} (46 μM)	4
Total phosphorus	< 0.037 mg L^{-1} (1.2 μM)	4
Dissolved oxygen	> 5 mg L^{-1}	3

Results

Status of the Water Quality Index

Water quality index values in upstream stations that show a better rating than downstream were due to lower chlorophyll values in these areas (above chlorophyll maximum for stream, not really improved water quality in these areas).

Assawoman Bay

None of the sites within Assawoman Bay met the WQI indictor threshold. Four sites were degraded and two sites had fair water quality conditions (Figure 4.4.1). This is largely due to high nutrient inputs (almost all sites failed TN or TP thresholds) and poor oxygen (no sites passed) (Table 4.4.2) since all sites passed chlorophyll thresholds.

St. Martin River

All sites failed TN, TP, and DO thresholds suggesting that high nutrient loading to these regions is reducing water quality. Six sites in St. Martin River had very degraded water quality category (no indicators met threshold values), while the other five stations were destermined to have degraded water quality (typically these sites passed the chlorophyll threshold) (Figure 4.4.1). Broader impacts of these nutrients are becoming evident in this region, with over half the sites failing chlorophyll (Table 4.4.2). There was slightly better water quality upstream due to naturally lower chlorophyll values upstream (Table 4.4.2).

Isle of Wight

Within the Isle of Wight region, a clear distinction occurred between open bay and tributary sites. Three of the four open bay sites had good water quality (only failed the TP threshold); the five tributary sites had degraded water quality conditions (Figure 4.4.1). All sites in Isle of Wight watershed passed the chlorophyll threshold yet failed the TP threshold. The three open bay sites passed the TN threshold; however, all tributary sites exceeded the TN threshold (Table 4.4.2). The station at the Ocean City Inlet was rated as fair because it failed both the TN and DO thresholds. Overall, Isle of Wight had fair conditions.

Sinepuxent

Overall, Sinepuxent Bay had good water quality (Figure 4.4.1). All stations passed the thresholds for chlorophyll, DO, and TN. The slightly reduced water quality in the north resulted from failure to meet the TP threshold at three sites (Table 4.4.2, Figure 4.4.1).

Newport

Most sites in Newport Bay tributaries were degraded or very degraded. Open bay sites had fair to good water quality (Figure 4.4.1). Only the southern bay sites passed TN or TP thresholds and half of all sites failed the chlorophyll threshold (Table 4.4.2). Upper tributary sites categorized as poor, instead of degraded, generally due to chlorophyll and/or oxygen meeting criteria (chlorophyll not always applicable and DO may be supersaturated in headwaters).

Chincoteague

Overall, Chincoteague Bay had fair conditions, yet a few mainstream sites in northern Chincoteague Bay had good water quality (Figure 4.4.1). All sites in Chincoteague Bay met the chlorophyll threshold. In the northern part of Chincoteague, most sites failed TP thresholds but nearly all sites in the southern region of Chincoteague also failed to meet the TP and DO thresholds (Table 4.4.2).

Table 4.4.2 Breakdown of WQI variables by region ($mean_{(se)}$), 2011-2013.

Bay Segment	Chl	TN	TP	DO
Assawoman	$1.00_{(0.00)}$	$0.17_{(0.17)}$	$0.17_{(0.17)}$	$0_{(0.00)}$
St. Martin	$0.45_{(0.16)}$	$0_{(0.00)}$	$0_{(0.00)}$	$0_{(0.00)}$
Isle of Wight	$1.00_{(0.00)}$	$0.44_{(0.16)}$	$0_{(0.00)}$	$0.33_{(0.15)}$
Sinepuxent	$1.00_{(0.00)}$	$1.00_{(0.00)}$	$0.20_{(0.20)}$	$0.6_{(0.24)}$
Newport	$0.58_{(0.15)}$	$0.17_{(0.11)}$	$0.08_{(0.08)}$	$0.25_{(013)}$
North Chincoteague	$1.00_{(0.00)}$	$0.67_{(0.21)}$	$0.17_{(0.17)}$	$0.67_{(0.21)}$
South Chincoteague	$1.00_{(0.00)}$	$1.00_{(0.00)}$	$0_{(0.00)}$	$0.09_{(0.00)}$

Note: (0: all sites failed to meet threshold, 1: all sites met threshold)

Summary
Overall, the Coastal Bays show generally poor or degraded water quality in or close to tributaries and good or excellent water quality in well-flushed open bay regions. Sinepuxent and north Chincoteague had good water quality, Isle of Wight poor conditions, while Assawoman Bay, St Martin River, Newport Bay and southern Chincoteague exhibited degraded water quality (Table 4.4.3, Figure 4.4.2). Variations in water quality between regions reflects variation in nutrient concentrations, however many sites throughout the system display effects of eutrophication (especially high nutrients and reduced dissolved oxygen). This has implications for aquatic communities, suggesting that many regions within the Coastal Bays do not provide suitable habitat for submerged grasses and/or fish.

Table 4.4.3 Summary of Water Quality Index , WQI,by Region. Comparison of 2001-2003 WQI results to 2011 -2013.

Region	n (sites)	WQI (se) 01-03	Health	WQI 11-13	
Assawoman	6	**0.33** (0.05)	Degraded	**0.33** (0.05)	**Degraded**
St Martin	11	**0.33** (0.05)	Degraded	**0.11** (0.04)	**Very degraded**
Isle of Wight	9	**0.53** (0.07)	Poor	**0.44** (0.08)	**Poor**
Sinepuxent	5	**0.85** (0.06)	Excellent	**0.70** (0.05)	**Good**
Newport	12	**0.39** (0.08)	Degraded	**0.27**(0.08)	**Degraded**
North Chincoteague	6	**0.63** (0.09)	Good	**0.63** (0.03)	**Good**
South Chincoteague	11	**0.82** (0.04)	Excellent	**0.52** (0.02)	**Degraded**

References

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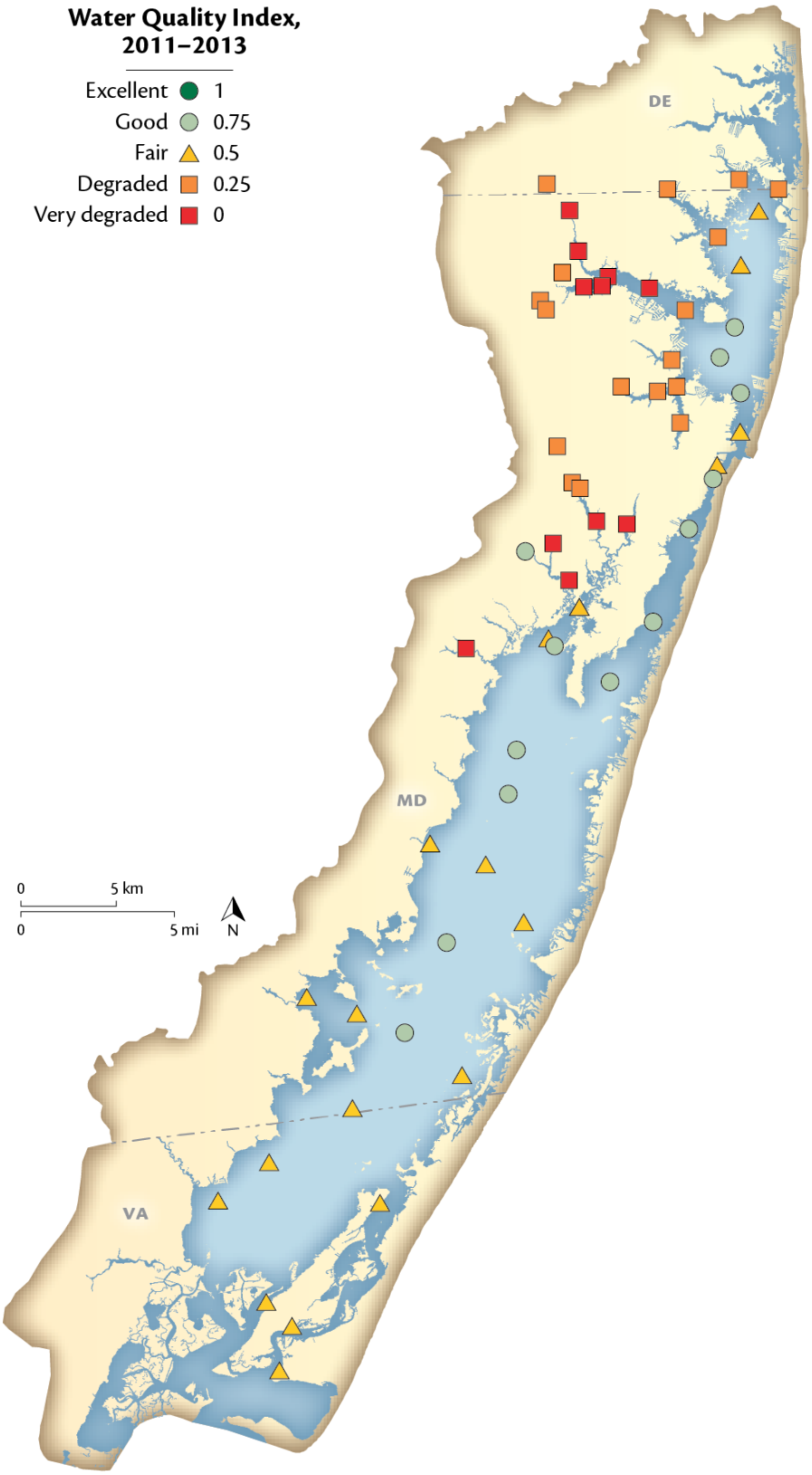

Figure 4.4.1 Water Quality Index values, 2011-2013, for all fixed sampling stations based on amalgamated median indicator values.

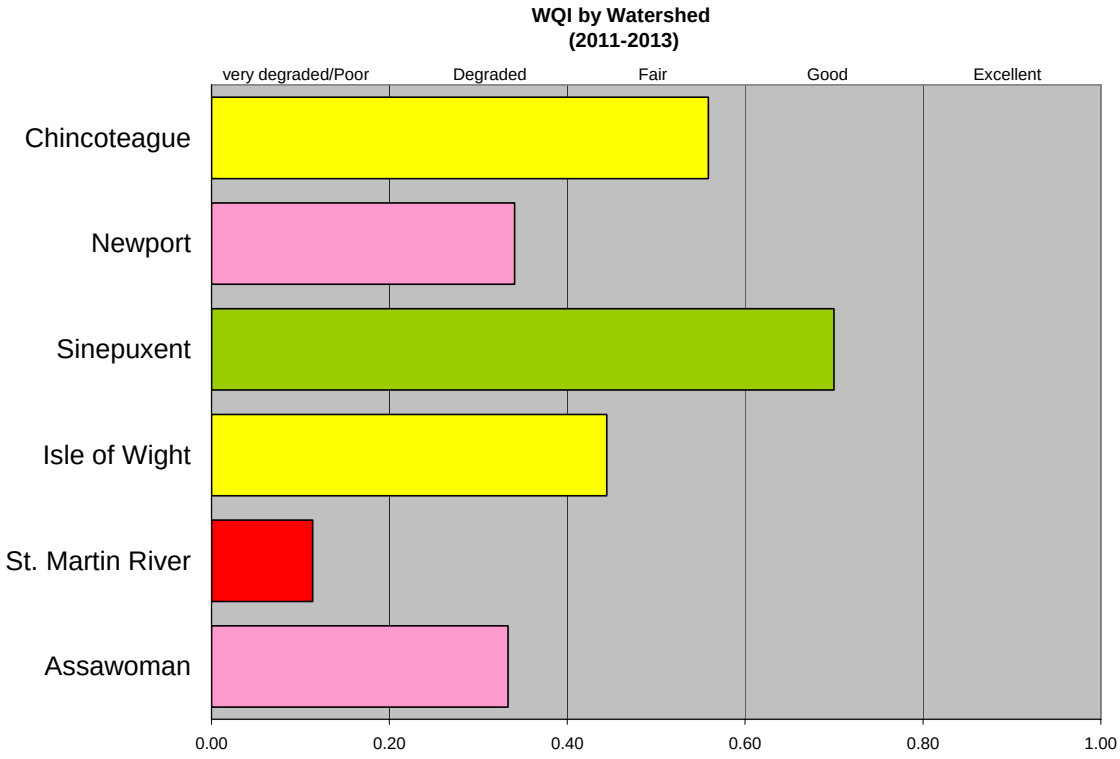

Figure 4.4.2 Overall Water Quality Index values for each of the Coastal Bays.