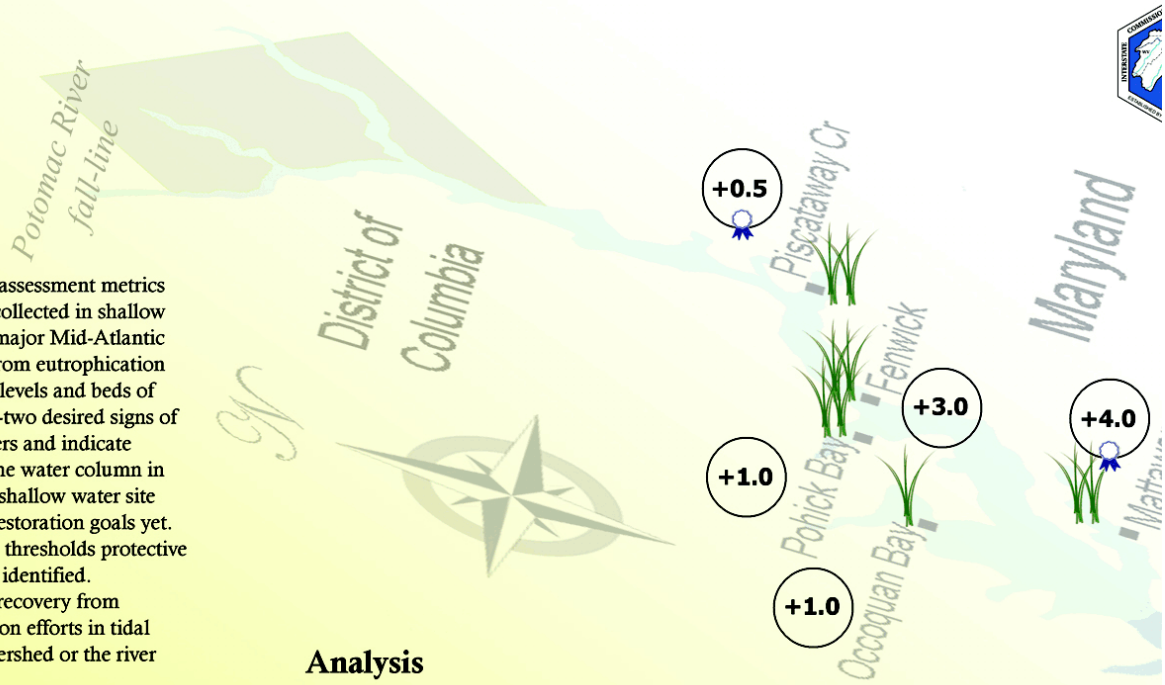
Quantifying Recovery

Benthic algae inferred

SAV sparse or distant from sonde

SAV abundant and near sonde



Abstract

State water quality criteria and other assessment metrics were applied to high frequency data collected in shallow waters of the tidal Potomac River, a major Mid-Atlantic tributary. The estuary is recovering from eutrophication impacts. Low summer chlorophyll *a* levels and beds of SAV (submerged aquatic vegetation)--two desired signs of recovery--occur in some shallow waters and indicate primary production is shifting from the water column in spring to the bottom in summer. No shallow water site achieves all water quality criteria or restoration goals yet. Chlorophyll *a*, DO, pH, and turbidity thresholds protective of criteria and ecosystem 'health' are identified. Successional stages in shallow water recovery from eutrophication are evident. Restoration efforts in tidal shallow waters rather than in the watershed or the river mainstem might expedite recovery.

Field Methods

Virginia and Maryland placed "continuous monitoring" (CMON) sondes at 20 embayment and river flank sites in the tidal Potomac River from March or April through October or November, 2004-2008. Measurements were made every 15 minutes with a YSI 6600 sonde (sensors and data logger) equipped with the Clean Sweep Extended Deployment System. Parameters included water temperature, salinity, dissolved oxygen (DO), % DO saturation, pH, turbidity, and chlorophyll *a* readings. Sondes were housed in perforated 4" PVC pipes for protection, and attached to a pier, dock, or free-standing post. Most sondes were anchored 0.3 m - 0.5 m above bottom and experience tidal changes in depth. Sondes were deployed for 1-2 weeks, and then switched out for cleaning and recalibration.

High Frequency Data

Data flagged as problematic by the data collectors were excluded from the analysis. The data can be downloaded from:

Maryland Department of Natural Resources (MDDNR) "Eyes on the Bay" website:
http://mddnr.chesapeakebay.net/eyesonthebay/index.cfm

Virginia Institute of Marine Sciences (VIMS) "VECOS" website:
http://www2.vims.edu/vecos/

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Analysis

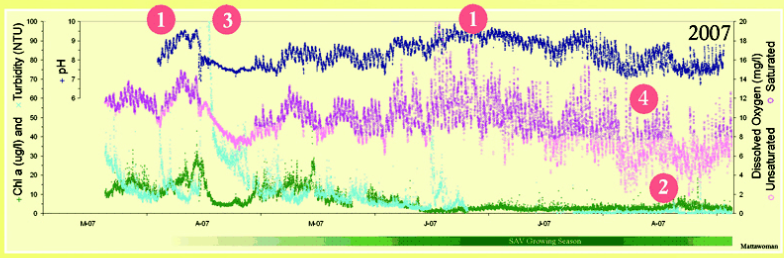
The failure rates of 5 short-interval numeric criteria encoded in Virginia and/or Maryland water quality standards and the exceedance rates of 6 screening thresholds were calculated from 2004 - 2008 CMON data. A suite of these metrics was used to create a scoring approach after apparent conflicts were resolved and protective levels identified.

River in Recovery

Massive summer algal blooms in the 1960s to 1980s regularly drove pH values above 10. Dissolved oxygen levels "sagged" to stressful concentrations as blooms peaked and died. In the 2004 - 2008 CMON data, high frequencies of pH>9.0 and saturated DO observations (%SatDO) and large diel (24-hr) changes in DO percent saturation (DM%Sat) demonstrate that photosynthesis is still strong in shallow waters, but production may be shifting from the water column to the bottom.

- **Phytoplankton** (expressed as chlorophyll *a*) can still be excessive in spring but are approaching low "reference" levels in summer and autumn.
- **SAV**, or underwater grasses, are returning to most tidal fresh and some higher salinity shallow waters (see map above).
- **Benthic algae** are not monitored but their presence is suspected.
  Presence inferred at sites having little or no SAV .and. low summer median Chla (<8 µg/l) .and. indications of strong primary production, such as high %SatDO or large DM%Sat.

Mattawoman Cr. now achieves its SAV goal, has low water column chlorophyll *a* (median ~2.5 µg/l) in summer and is noted for its fishing. Despite these restoration successes, the embayment still occasionally fails pH (1), DO (2), and turbidity (3) criteria. Large diel changes in DO (4) and dropping saturation levels lead to DO failures.



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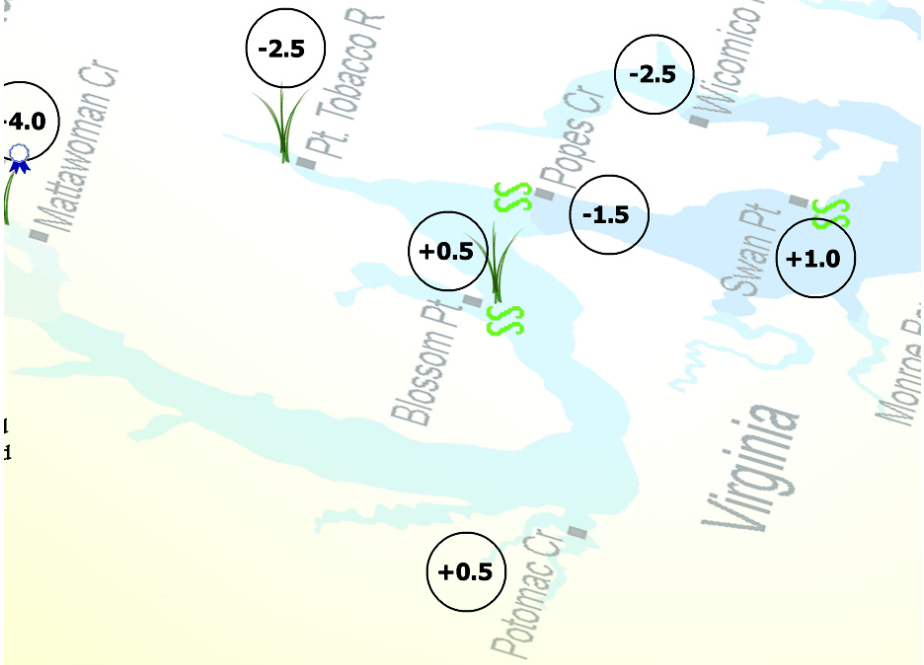
2008 Status of Tidal Potomac River Shallow Waters

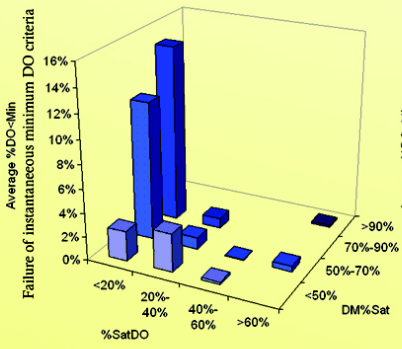
Possible Range: -8 (worst) to +8 (best).



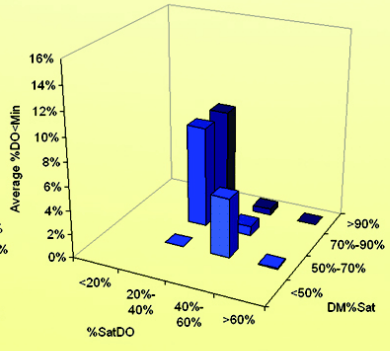
Instantaneous Minimum DO Criteria Failures

Large magnitude diel changes in DO percent saturation (DM%Sat) indicate strong daytime oxygen production countered by strong oxygen consumption from biota and/or geochemical processes. When the frequency of saturated DO observations (%SatDO) is low, large DM%Sat will result in more frequent failure of the instantaneous minimum DO criteria (%DO<Min). The bar graphs below show that embayments and river flanks presently supporting abundant SAV tend to have larger DM%Sat than those with sparse or no SAV. This increases their likelihood of DO criteria failure at relatively moderate %SatDO levels (20% - 60%) in summer. The desired return of SAV seems to be initially accompanied by an uptick in DO minimum criteria failures.

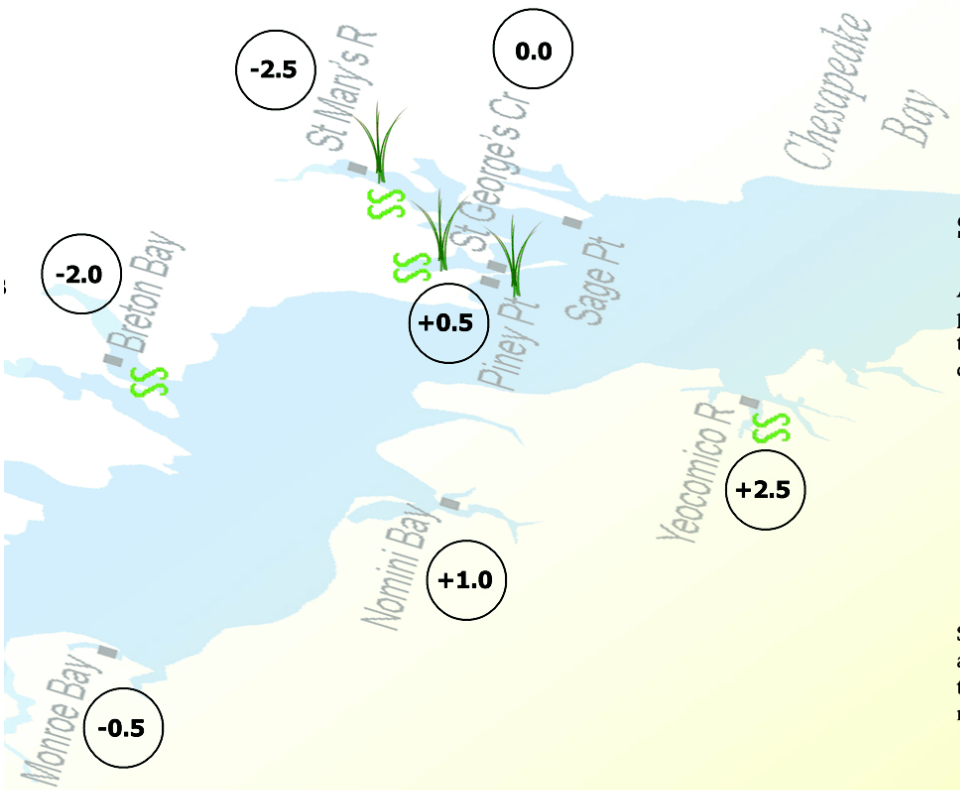
SAV Sparse or Absent



SAV Abundant



sing High Frequency Data



Sonde site

SAV goal achieved

Final site score for year 2008

Scoring Protocol

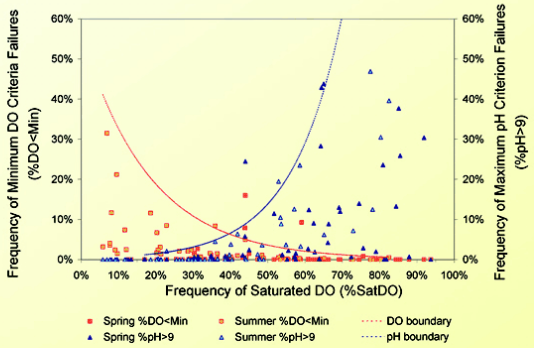
A simple index integrating metric scores for four eutrophication parameters-Chla, pH, DO, and turbidity-was created by finessing the conflicting pH and DO criteria and using protective metrics in combination with screening thresholds and water quality criteria.

Parameter	Metric Score 1	0.5	0	-0.5	-1
Chla	%Chla>Ref is ≤5% .and. %Chla≥50 is 0%	%Chla>Ref is >5%-23% .and. %Chla≥50 is 0%	%Chla>Ref is >23% -37% .and. %Chla≥50 is 0%	%Chla≥50 is >0%-10%	%Chla≥50 is >10%
DO	%DO<Min is 0% .and. %SatDO is 30%-50%	%DO<Min is 0%	%DO<Min is >0%-1%	%DO<Min is >1%-2.5%	%DO<Min is >2.5%
pH	%pH>9 is 0% .and. %SatDO is 30%-50%	%pH>9 is 0%	%pH>9 is >0%-10%	%pH>9 is >10%-20%	%pH>9 is >20%
Turbidity	%Turb>50 is 0%	%Turb>50 is >0%-2.5% .and. %Turb≥150 is 0%	%Turb>50 is >2.5% .and. %Turb≥150 is 0%	%Turb≥150 is >0%-1%	%Turb≥150 is >1%

SAV effects on DO were not given special consideration. Spring and summer/autumn scores for each parameter are summed. A total score of +8 indicates all four water quality parameters meet the most stringent criteria and thresholds in both spring and summer.

Conflicting pH and DO Criteria

The frequent occurrence of saturated DO is a safeguard against DO criteria failure, but high %SatDO is also associated with failure of the pH 9.0 criterion in the tidal Potomac's poorly buffered waters. %SatDO levels between 30% and 50% seem best for attaining *both* the pH and DO criteria.



Protective Metrics

A metric is protective of another when its exceedance or failure is more likely to occur than that of the other metric. Several metric thresholds apparent in the tidal Potomac CMON data can clearly indicate the failure probability of water quality guidelines and criteria.

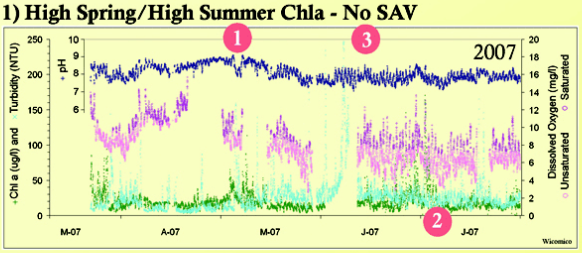
When this metric:	is:	frequency of this metric is low or 0%:
Median Chla	<16 µg/l	%Chla>=50 µg/l (WHO 2003 guideline)
%Chla>Ref *	<37%	%Chla>=50 µg/l (WHO 2003 guideline)
%SatDO	>30%	%DO<Min (MD/VA/DC criteria)
%SatDO	<50%	%pH>9 (VA criterion)
%Turbidity>50 NTU	<2.5%	%Turbidity>=150 NTU (MD criterion)

* Percent of chlorophyll *a* observations exceeding season- and salinity-specific maximal (95th percentile) levels of Chesapeake Bay phytoplankton reference communities (from Buchanan, C., R. V. Lacouture, H. G. Marshall, M. Olson, and J. M. Johnson. 2005. Phytoplankton Reference Communities for Chesapeake Bay and its Tidal Tributaries. Estuaries 28(1):138-159.)

WHO. 2003. Guidelines for safe recreational water environments. Volume 1. Coastal andfresh waters. World Health Organization, Geneva, Switzerland.

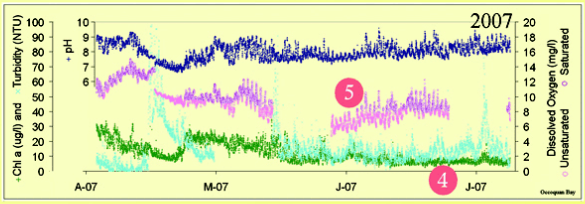
Apparent Successional Stages

1) High Spring/High Summer Chla - No SAV



Spring and summer chlorophyll *a* levels frequently exceed 50 µg/l. Failure of the pH 9.0 criterion 1 can occur when Chla is very high (especially in tidal fresh). The minimum DO criteria fails often in summer 2. Turbidity exceeds the 150 NTU criterion multiple times 3. Legacy sediments are a major nutrient source.

2) High Spring/Low Summer Chla - No/Sparse SAV



Spring Chla can exceed 50 µg/l; summer median Chla is <8 µg/l 4. Summer turbidity, pH, and DO criteria failures are infrequent. Magnitude of diel change in DO is small 5. Inferred presence of benthic algae at some sites suggests water clarity is adequate to support SAV. Nutrients in water column, and possibly sediments, are lower. Watershed nutrient reductions are not very effective. Restoration efforts inside embayments encourage return of SAV.

3) High Spring/Low Summer Chla - Abundant SAV

see Mattawoman Cr. graphic


Benthic algae inferred
SAV sparse or distant from sonde
SAV abundant and near sonde
Sonde site
SAV goal achieved
Final site score for year 2008
Potomac River fall-line
District of Columbia
Maryland
Virginia
Chesapeake Bay
Piscataway Cr
Fenwick
Pohick Bay
Occoquan Bay
Mattawoman Cr
Pt. Tobacco R
Popes Cr
Blossom Pt
Potomac Cr
Wicomico R
Swan Pt
Monroe Bay
Breton Bay
St Mary's R
St George's Cr
Piney Pt
Sage Pt
Nomini Bay
Yeocomico R
+0.5
+1.0
+3.0
+1.0
+4.0
-2.5
-2.5
+0.5
-1.5
+1.0
-0.5
+0.5
-2.0
-2.5
0.0
+0.5
+1.0
+2.5