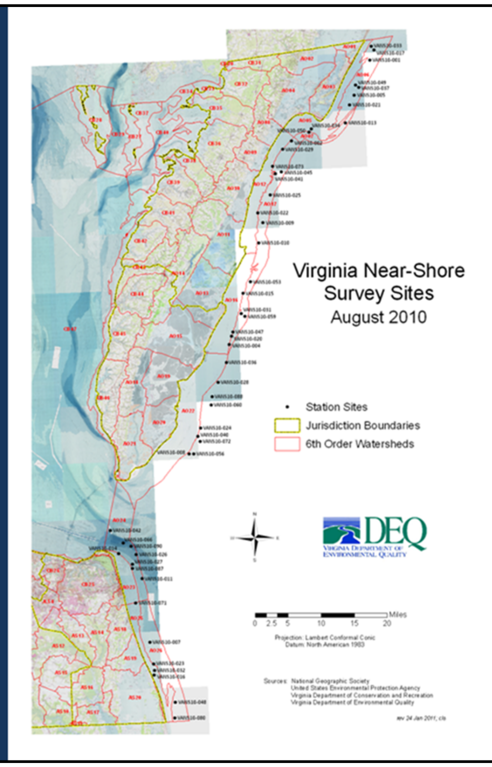
This survey was only possible because several sources of human, logistical, and financial resources coincided during the summer of 2010.

1. The National Aquatic Resources Survey/National Coastal Assessment (NARS/NCCA) provided resources for field supplies and analytical services, as well as for the study design and nominal site designations for the study (Tony Olsen - USEPA NHEER, Corvallis, OR),
2. The EPA Ocean Survey Vessel, the OSV Bold, and its crew were available and provided as a gratuitous logistical platform for off-shore sampling,
3. Field crews from EPA National HQ (Washington, DC) and Region 3 HQ (Philadelphia, PA) joined the Virginia DEQ field crew to provide 24 hour, around the clock sampling, and
4. Virginia DEQ suspended its normal Estuarine Probabilistic Monitoring Program (50 sites) for the summer of 2010 to provide additional resources for the Near-Shore Oceanic Survey.



Final Site Distribution

Thanks to Tony Olsen
USEPA NHEERL - Corvallis
(Original Design)

Nominal Sites rejected for…

- Non-target – land, tidal flats
- Insufficient depth – surf, accessibility…
- Unsafe – shipping lanes, etc.

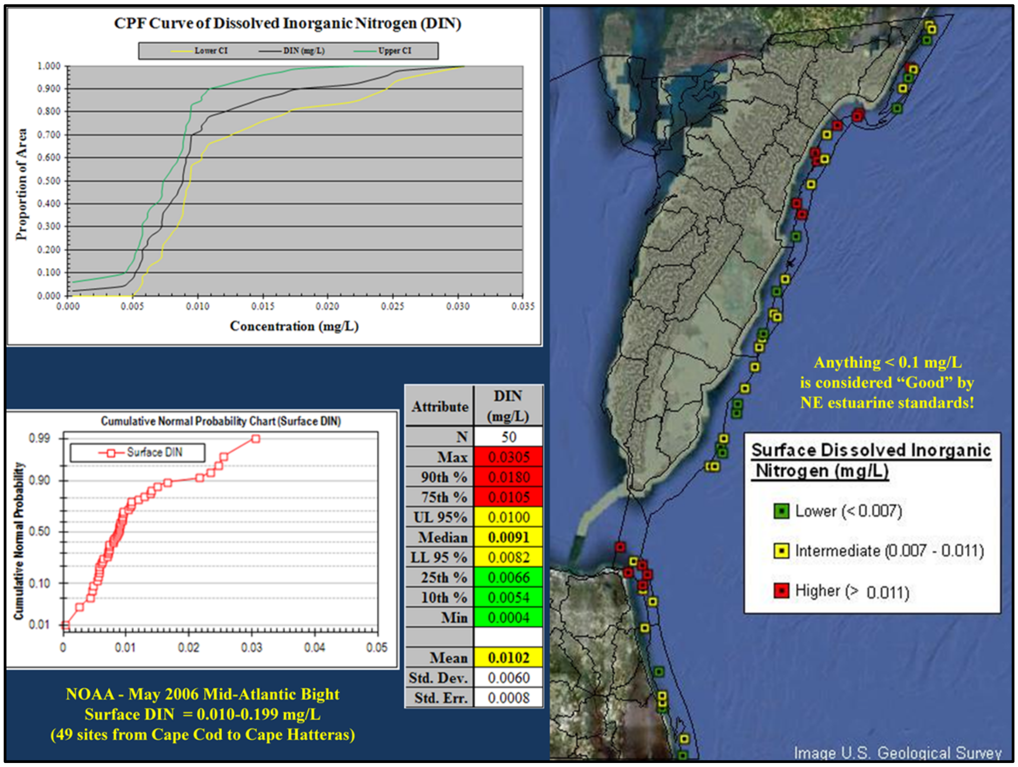
Depths further restricted by

- draft of OSV Bold…
- wave amplitude (wind)…
- discretion of pilot…

Final depth distribution

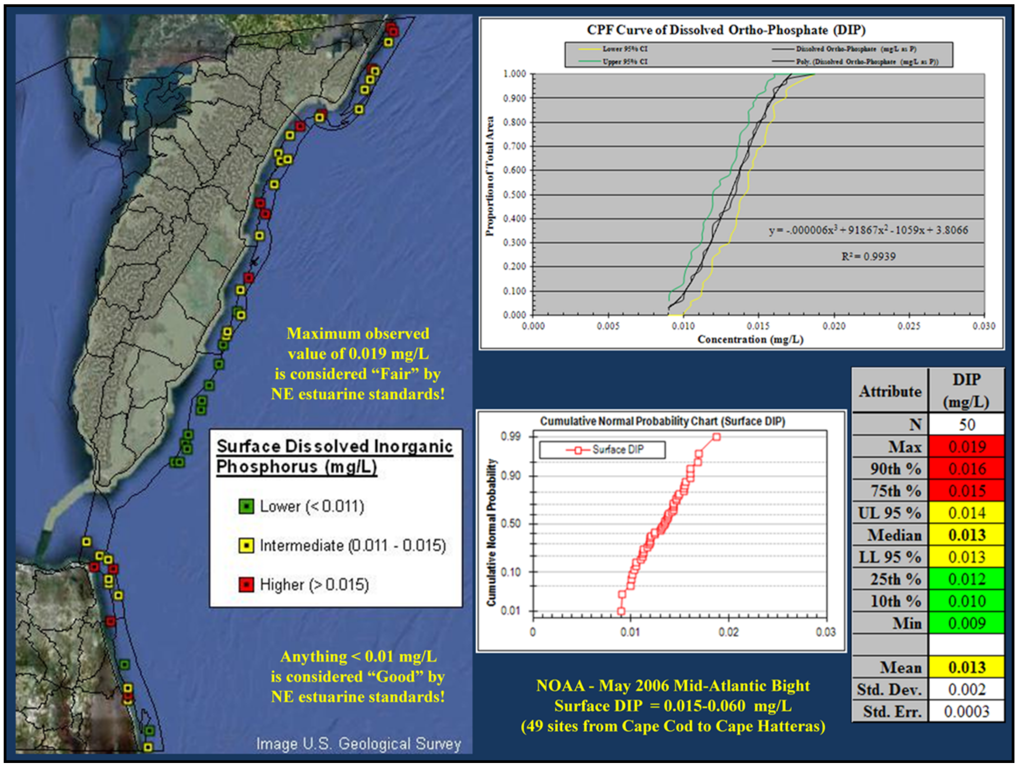
- Min = 8.5 m (27.9 ft)
- Max = 25.9 m (84.6 ft)
- Mean = 11.9 m (39.1 ft)

The nominal coordinates for each site were approached from due east. If depth became a consideration before the site was reached, DEQ accepted the nearest approach coordinates as an alternate site.



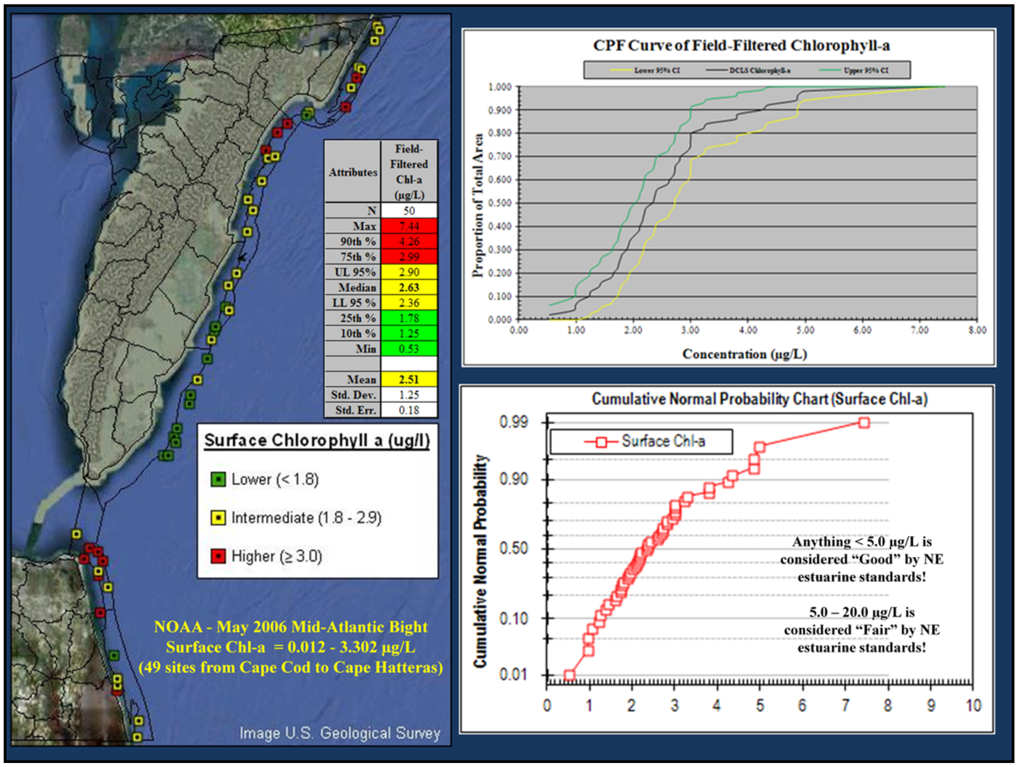
Because no oceanic standards or thresholds have been established for most of the water quality parameters being evaluated, thresholds for "stop light" values of "Red" and "Green" were based on the upper and lower quartiles, respectively (Red = less desirable, Green = more desirable, Yellow = intermediate)

Near-surface DIN concentrations were highest in the tidal plume from Chesapeake Bay and in the "Notch" between Chincoteague Inlet and Wachapreague Inlet, although maximum values were low in comparison with northeastern estuarine criteria and with NOAA's May 2006 results from the Mid-Atlantic Bight. NOAA considered concentrations at or above their observed 90th percentile to be "potentially elevated"!

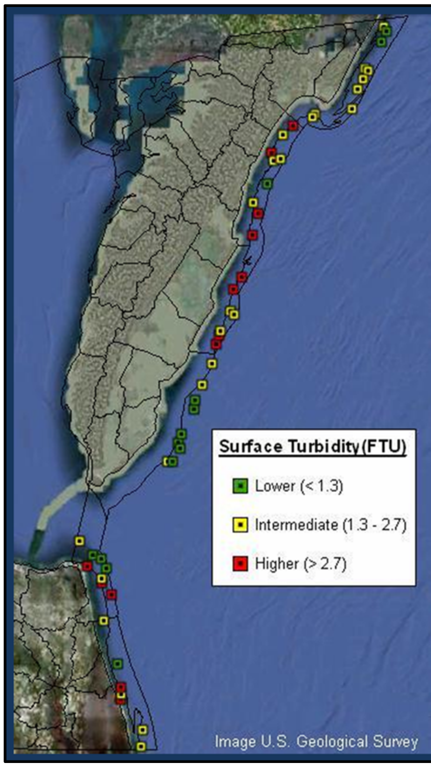


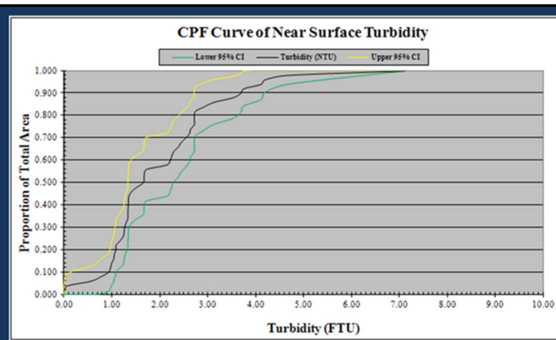
Attribute	DIP (mg/L)
N	50
Max	0.019
90th %	0.016
75th %	0.015
UL 95 %	0.014
Median	0.013
LL 95 %	0.013
25th %	0.012
10th %	0.010
Min	0.009
Mean	0.013
Std. Dev.	0.002
Std. Err.	0.0003

Maximum near-surface DIP concentrations would be considered "Fair" by NE estuarine criteria, and were generally below values NOAA reported (May 2006) for further off-shore. NOAA considered concentrations at or above their observed 90th percentile to be "potentially elevated"! Upper quartile values of DIP observed in this study were scattered all along the northern Delmarva and southeastern shores, indicating potential sources were probably oceanic and non-point in nature. Lower quartile values were clustered in southern Delmarva and scattered along the coast south of Chesapeake Bay mouth..

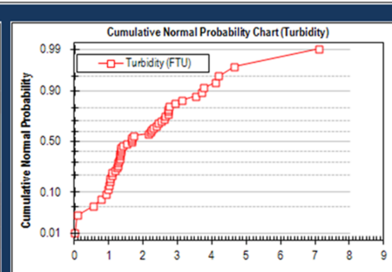


The highest near-surface chlorophyll concentrations were clustered in the tidal plume from Chesapeake Bay and off Assateague Island and into the northern portion of the Notch. Maximum concentrations would be classified as "Fair" by NE estuarine criteria; the 5.0 µg/L upper threshold for the "Good" classification in NE estuaries represents the approximate 98th percentile of the observed distribution! In general, concentrations were higher than those reported from further offshore by NOAA in May of 2006.





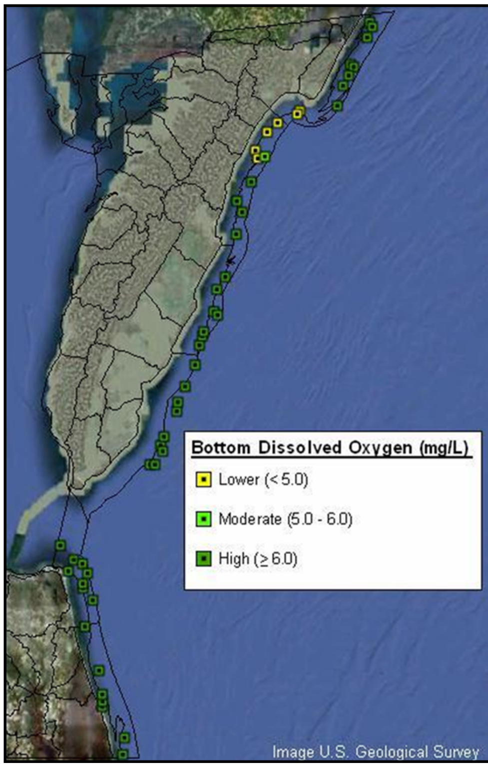
Attributes	Surface Turbidity (FTU)
N	50
Max	7.12
90th %	3.70
75th %	2.71
UL 95%	1.98
Median	1.67
LL 95%	1.35
25th %	1.28
10th %	0.97
Min	0.01
Average	2.05
Std. Dev.	1.28
Std. Err.	0.18

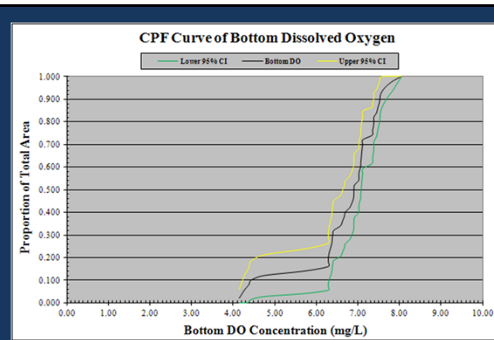


Water Clarity – Seapoint Turbidity Meter

(Neither Secchi depth or PAR are convenient for a 24-hr, 'round-the-clock sampling regimen!)

(FTU = Formazin Turbidity Units)
Turbidity as a surrogate for water clarity was only loosely correlated with chlorophyll concentrations (r-squared = 0.166), and even less so with depth (r-square = 0.077, inverse). Higher and lower turbidity values were scattered along the coast without a well defined pattern, and without submerged aquatic vegetation water clarity is not a high priority parameter!

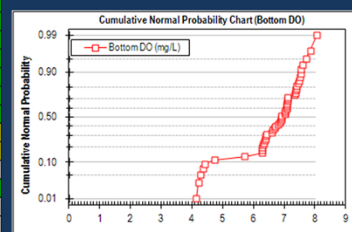




Virginia *Oceanic*
Dissolved Oxygen Standard
Instantaneous minimum - 5.0 mg/L

< 5.0 mg/L at six of the 50 sites
(12.0 ± 9.2%)

Attributes	Near Bottom DO (mg/L)
N	50
Max	8.08
90th %	7.56
75th %	7.32
UL 95%	7.29
Median	7.07
LL 95 %	6.85
25th %	6.33
10th %	4.71
Min	4.17
Mean	6.68
Std. Dev.	0.98
Std. Err.	0.14



Dissolved oxygen and pH are the only standard field parameters for which Virginia has saltwater standards: DO - 5.0 mg/L instantaneous minimum, and pH – 6.0 – 9.0
Six near-bottom DO values violated the 5.0 mg/L instantaneous minimum standard for DO; none were below 4.17 mg/L. All six violation occurred in the northern portion of the Notch, between Chincoteague Inlet and Metompkin Inlet.

Integrated "Water Quality Index" (WQI)

Since no oceanic threshold values were available for scoring "Good" *vs.* "Fair" *vs.* "Poor", the normal NCCA guidelines for calculating the WQI were not applicable. An alternative method was needed to integrate the scores of the five water quality parameters!

"Ranging" of parameter values to standardize their scores:
Most desirable observed value = 1.000
Least desirable observed value = 0.000

1. For those parameters for which higher values are more desirable (*i.e.*, DO),

   $$X_i'{}_{\text{(ranged)}} = (X_i - X_{min}) / (X_{max} - X_{min}).$$

   And for those for which lower values are more desirable (*i.e.*, DIN, DIP, Chl-α, and Turb),

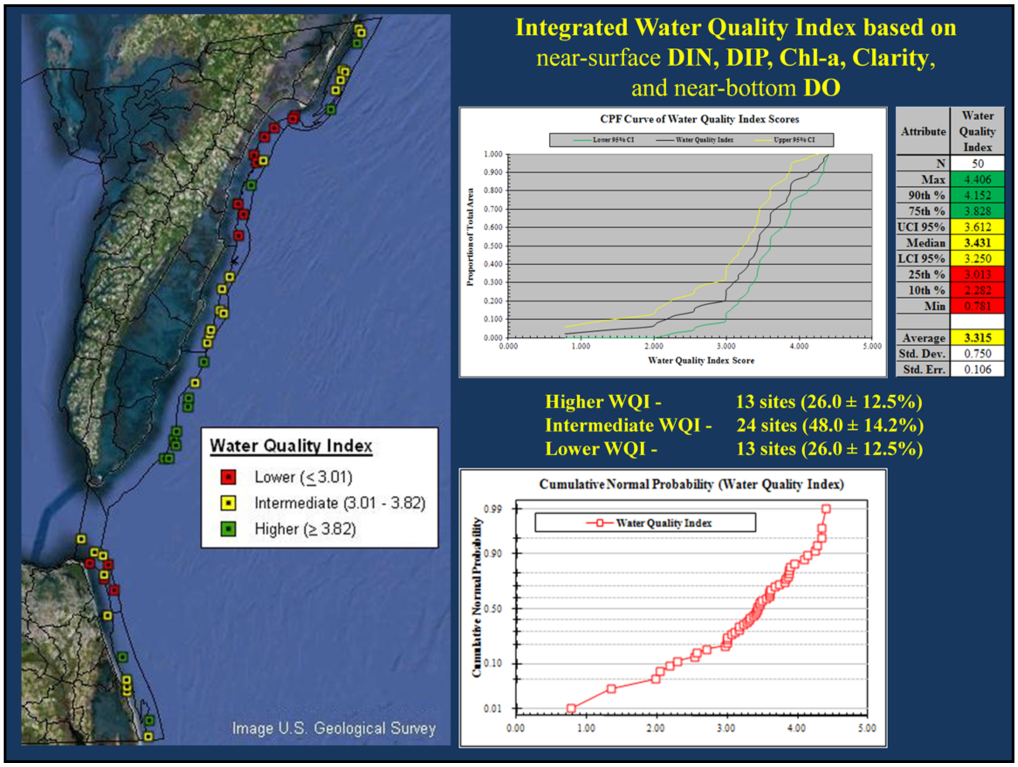
   $$X_i'{}_{\text{(ranged)}} = 1.000 - [(X_i - X_{min}) / (X_{max} - X_{min})].$$

2. Sum the ranged scores across all five parameters = Integrated Water Quality Index (WQI)

   Potential WQI scores theoretically could vary from 0.000 to 5.000

   Observed maximum WQI score = 4.406
   Observed minimum WQI score = 0.781

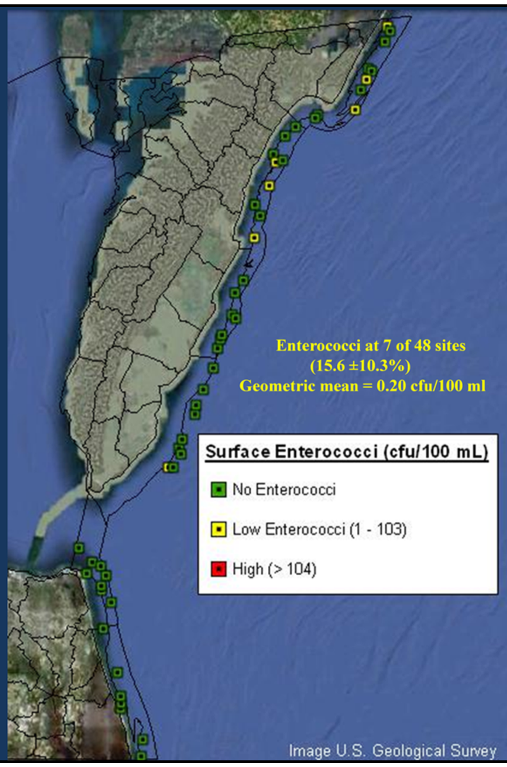
3. Use upper and lower quartile values to identify "Higher" *vs.* "Intermediate" *vs.* "Lower" WQI scores…



Two areas are of primary concern, although the observed nutrient and chlorophyll concentrations were not problematic…

1. The tidal plume from Chesapeake Bay (CB) – the concern relative to elevated nutrient concentrations within CB is well known; a multi-state TMDL has been developed and Virginia's watershed implementation plans have been submitted to EPA.

2. The "Notch", extending southward from Chincoteague Inlet to Wachapreague Inlet, has considerably less estuarine buffer between the peninsula and oceanic waters than do the areas to the north (coastal bays and barrier islands from Delaware, through Maryland, to Virginia) and to the south (broad expanses of tidal wetlands, Nature Conservancy holdings, wildlife refuges, etc.). Inputs here come from three potential sources: (a) the lower extremity of the Labrador Current bringing materials from further north, (b) outflow from Chincoteague Bay (where MD is working on nutrient and bacterial TMDLs, and (c) the adjacent Virginia headlands, where poultry production and other agriculture are intense (some local streams are already listed for low DO). Evaluation of the relative contributions of the three sources will be a priority.



Attribute	Near-surface Enterococci (cfu/100ml)
N	48
Max	16
90th %	1
75th %	0.0
UL 95%	0.0
Median	0.0
LL 95 %	0.0
25th %	0.0
10th %	0.0
Min	0.0
Mean	0.6
Std. Dev.	2.5
Std. Err.	0.4

"Enterococci bacteria shall not exceed a monthly geometric mean of 35 cfu/100 ml in transition and saltwater… If there are insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 104 cfu/100 ml."

Enterococcus presence sporadic… No observed values anywhere near the instantaneous maximum standard of 104 cfu/100ml. Universal geometric mean = 0.20 cfu/100 ml.

Summary of Saltwater Aquatic Life Use Standards and Observed Values for Dissolved Metals Virginia Near-shore Oceanic Survey - August 2010											
Analyte [1]	**Form**	**Matrix**	**Units**	**MDL**	**Acute Standard**	**Chronic Standard**	**Minimum Value Observed**	**Average Value Observed**	**Maximum Value Observed**	**Number Exceeding Chronic Standard**	**Percent Non-detects**
Aluminum (Al)	Dissolved	Saltwater	µg/L	2.0	N/A	N/A	2.0	5.13	15.4	N/A	52.7
Antimony (Sb)	Dissolved	Saltwater	µg/L	0.2	N/A	N/A	0.2	0.20	0.2	N/A	98.2
Arsenic (As)	Dissolved	Saltwater	µg/L	0.2	69	36	0.5	0.79	1.1	0	0.0
Cadmium (Cd)	Dissolved	Saltwater	µg/L	1.0	40	8.8	1.0	1.00	1.0	0	100.0
Calcium (Ca)	Dissolved	Saltwater	mg/L	0.5	N/A	N/A	42.9	323.00	366.0	N/A	0.0
Chromium III (Cr)	Dissolved	Saltwater	µg/L	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chromium VI (Cr)	Dissolved	Saltwater	µg/L	N/A	1,100	50	N/A	N/A	N/A	N/A	N/A
Copper (Cu)	Dissolved	Saltwater	µg/L	1.0	9.3	6	1.0	1.44	5.80	0	64.5
Iron (Fe)	Dissolved	Saltwater	µg/L	N/A	N/A	N/A	200.0	200.00	200.0	N/A	100.0
Lead (Pb)	Dissolved	Saltwater	µg/L	1.0	240	9.3	1.0	1.00	1.0	0	100.0
Magnesium (Mg)	Dissolved	Saltwater	mg/L	0.5	N/A	N/A	87.6	1011.32	1150.0	N/A	0.0
Manganese (Mn)	Dissolved	Saltwater	µg/L	1.0	N/A	N/A	1.0	1.96	12.2	N/A	70.9
Mercury (Hg)	Dissolved	Saltwater	ng/L	1.5	1,800 ng/L	940 ng/L	1.5	1.50	1.5	0	100.0
Nickel (Ni)	Dissolved	Saltwater	µg/L	1.0	74	8.2	1.0	1.49	3.2	0	65.5
Potassium	Dissolved	Saltwater	mg/L	1.0	N/A	N/A	30.2	306.77	341.0	N/A	0.0
Selenium (Se)	Dissolved	Saltwater	µg/L	0.2	290	71	0.2	0.20	0.2	0	100.0
Sodium (Na)	Dissolved	Saltwater	mg/L	1.0	N/A	N/A	742.0	8448.40	9430.0	N/A	0.0
Silver (Ag)	Dissolved	Saltwater	µg/L	N/A	1.9	N/A	N/A	N/A	N/A	N/A	N/A
(Tributyltin) [2] TBT	Dissolved	Saltwater	µg/L	N/A	0.42	0.0074	N/A	N/A	N/A	N/A	N/A
Vanadium (V)	Dissolved	Saltwater	µg/L	2.0	N/A	N/A	2.0	2.02	2.2	N/A	80.0
Zinc (Zn)	Dissolved	Saltwater	µg/L	2.0	90	81	2.0	2.70	13.9	0	78.2

[1] **Analytes in bold font are included in the saltwater dissolved clean metals Parameter Group Code DMETS1.**

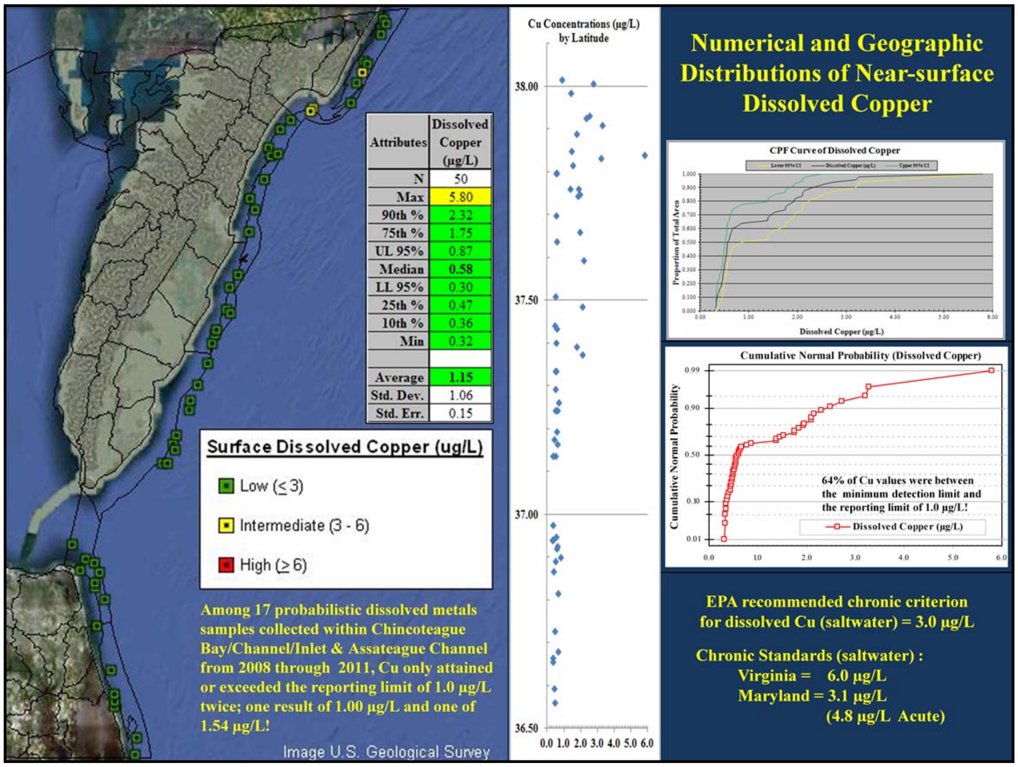
[2] **Tributyltin is the only organo-metalic compound for which the Commonealth has saltwater criteria.**

17 dissolved metals
8 with chronic WQS

Acute aquatic life standard (red) — **Chronic aquatic life standard** (yellow) — **All observed values < chronic standard** (green)

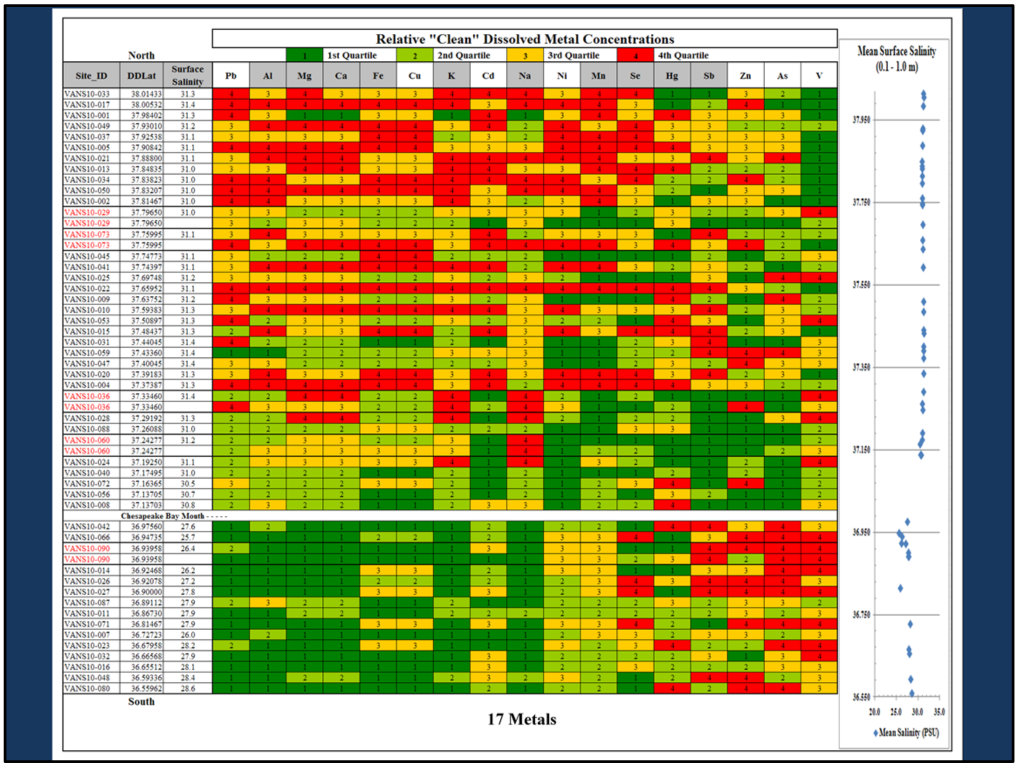
Seventeen dissolved metals – eight with chronic saltwater standards evaluated (vanadium was added because of concern related to Deep Horizon spill and potential contamination of the Gulf Stream).

Observed values in the table were censored at the reporting limit for each metal. “Percent Non-detects” represents those results below the reporting limit for the specific dissolved metal. At DEQ’s request, the Virginia Department of General Services, Division of Consolidated Laboratory Services (DCLS) provides the agency with uncensored low-level results as well as the censored results for our database. The uncensored values between the detection limit and the reporting limit were included in the construction of the following figures…



Dissolved Cu: MDL = 0.3 µg/L, reporting limit = 1.0 µg/L
Among dissolved metals samples collected at **17 probabilistic sites within Chincoteague Bay/Channel/Inlet and Assateague Channel** from 2008 through 2011, only two copper values attained or exceeded the reporting limit for the analytical method utilized - one of 1.0 µg/L and another of 1.54 µg/L. Results from **another 20 probabilistic sites along the Delmarva coast south of Chincoteague Bay** were similar. Only two samples attained or exceeded 1.0 µg/L - one of 1.0 µg/L and one of 1.19 µg/L.

CH2MHILL. 2000. Site Specific Saltwater Criteria for Copper Determined by the Recalculation Procedure for the Hampton Roads/Elizabeth River Estuary, Final Report. Submitted to Department of the Navy, October 2000. 14+ii pp. (Virginia chronic standard set at 6.0 µg/L, approved by EPA)



Stations arrayed from north to south by latitude; five sites with QA duplicates are identified by red font.

Salinity relatively constant (31.0 – 31.4 psu) from 38.0143º N to 37.1750º N, drops to 25.7 psu at Bay mouth (36.9473º N) and progressively recovers to 28.6 psu at 36.5596º N .

Although concentrations were well below chronic standards for other dissolved toxic metals, the declining north to south gradient observed for copper was also apparent in others…

In addition to copper… Pb, Cd, and Ni

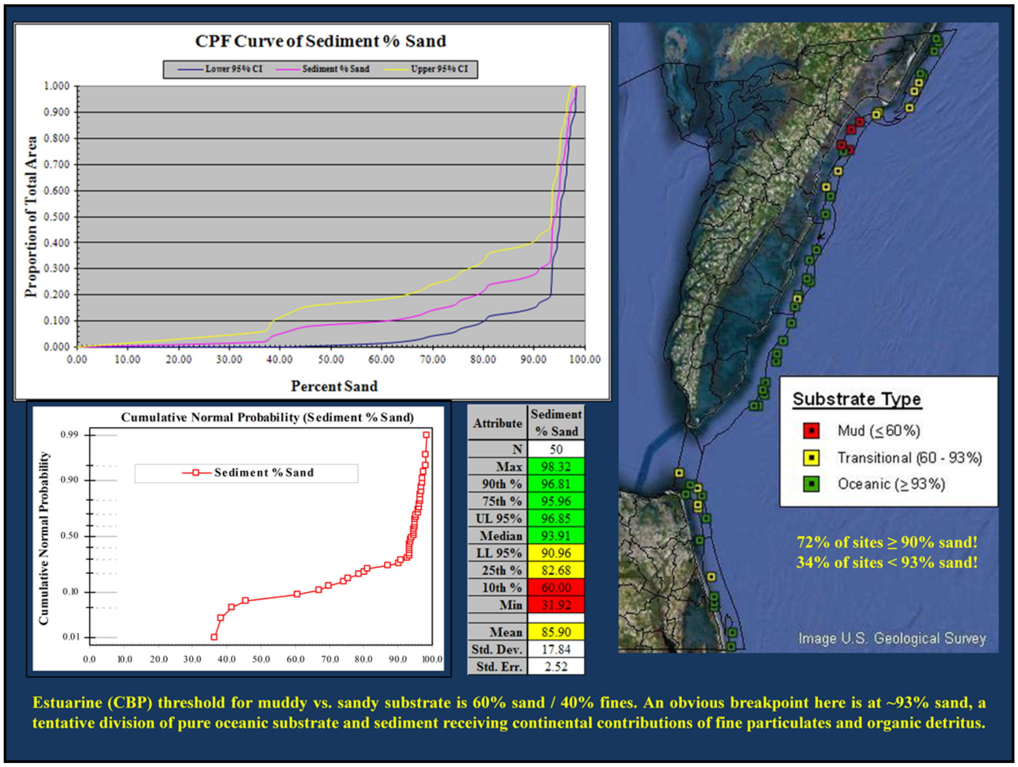
Less evident in Se and Hg (aerial deposition?)

Sb, Zn, As and V concentrations rebounded in the tidal plume from Chesapeake Bay! (Se to a lesser extent)

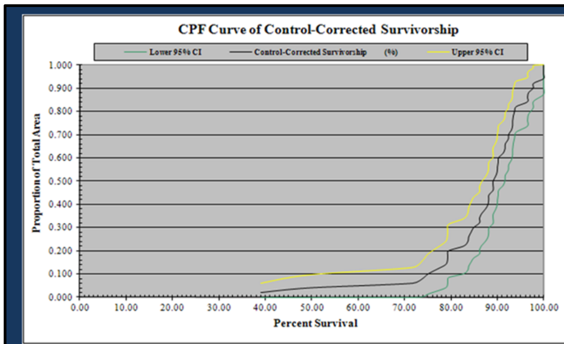
19 PAHs		Aquatic Life Use		Human Health		EPA Water Quality PAH Benchmarks for Aquatic Life [1]			
		Saltwater		Public Water Supply	All Other Surface Waters	Acute Potency Divider[1]	Chronic Potency Divider[1]	Alkylation Multiplier [1]	Maximum Observed Concentration
Analyte	Units	Acute	Chronic						
1-Methylnaphthalene	µg/L	-	-	-	-	340	81.7	1	< 0.1 µg/L
2-Methylnaphthalene	µg/L	-	-	-	-	340	81.7	1	< 0.1 µg/L
Acenaphthene	µg/L	-	-	670	990	232	55.8	1	< 0.1 µg/L
Acenaphthylene	µg/L	-	-	-	-	1280	307	1	< 0.1 µg/L
Anthracene	µg/L	-	-	8,300	40,000	86.1	20.7	1	< 0.1 µg/L
Benzo(a)anthracene	µg/L	-	-	0.038	0.18	9.28	2.23	1	< 0.1 µg/L
Benzo(b)fluoranthene	µg/L	-	-	0.038	0.18	2.82	0.677	1	< 0.1 µg/L
Benzo(k)fluoranthene	µg/L	-	-	0.038	0.18	2.67	0.642	1	< 0.1 µg/L
Benzo(a)pyrene	µg/L	-	-	0.038	0.18	3.98	0.957	1	< 0.1 µg/L
Benzo(e)pyrene	µg/L	-	-	-	-	3.75	0.901	1	< 0.1 µg/L
Benzo(ghi)perylene	µg/L	-	-	-	-	1.83	0.439	1	< 0.1 µg/L
Chrysene	µg/L	-	-	0.0038	0.018	8.49	2.04	5	< 0.1 µg/L
Dibenz(a,h)anthracene	µg/L	-	-	0.038	0.18	1.17	0.282	1	< 0.1 µg/L
Fluoranthene	µg/L	-	-	130	140	29.6	7.11	1	< 0.1 µg/L
Fluorene	µg/L	-	-	1,100	5,300	164	39.3	14	< 0.1 µg/L
Indeno(1,2,3-cd)pyrene	µg/L	-	-	0.038	0.18	1.14	0.275	1	< 0.1 µg/L
Naphthalene	µg/L	-	-	-	-	803	193	120	< 0.1 µg/L
Phenanthrene	µg/L	-	-	-	-	79.7	19.1	6.8	< 0.1 µg/L
Pyrene	µg/L	-	-	830	4,000	42.0	10.1	2.1	< 0.1 µg/L

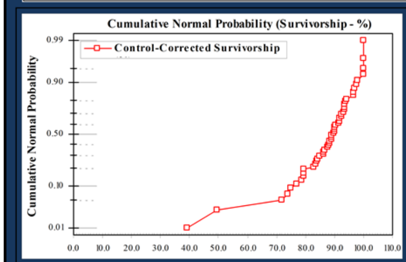
[1] Oil-related organic compounds are assessed jointly through a mixture approach because they all have the same type of effect on aquatic organisms. Potency divisors are not chemical-specific benchmarks, but are intermediates used in calculating the aggregate toxicity of the mixture. To assess the potential hazard to aquatic organisms, the sum of the calculated values is compared to a hazard index of 1. A value greater than 1 (>1) indicates that the sample has the potential to cause an acute or chronic effect on aquatic life like fish, crabs, and clams.
http://www.epa.gov/bpspill/water/explanation-of-pah-benchmark-calculations-20100622.pdf

Nineteen petroleum-related PAHs were evaluated in near-surface waters (1.0 m depth). None of the evaluated PAHs attained its method detection limit of 0.1 µg/L at any of the sites! If the concentrations of all 19 of the evaluated PAHs were equal to their MDLs, and no other PAHs were present, the calculated Water Quality Benchmark for combined PAHs would still exceed 1.0, indicating the potential for chronic effects on aquatic life! Much more could be said…



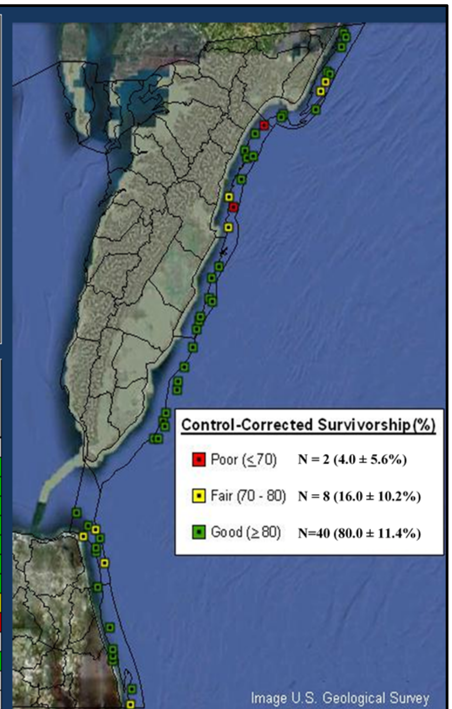
Seventy-two percent of the sites in this near-shore oceanic survey exceeded 90% sand in their sediments.
Thirty-four percent of sites < 93% sand





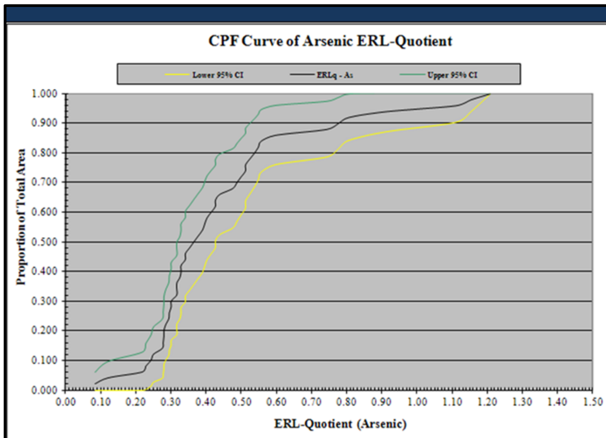
Attribute	Control-Corrected Survivorship (%)
N	50
Max	100.00%
90th %	97.78%
75th %	93.33%
UL 95%	91.47%
Median	89.39%
LL 95%	87.32%
25th %	84.00%
10th %	76.82%
Min	39.08%
Mean	87.29%
Std. Dev.	11.49%
Std. Err.	1.62%

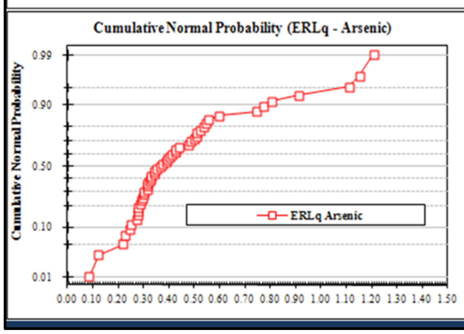
(Emery et al. , 1997)
28-day survivorship of *Leptocheirus* in their study was less than 70% when tested in a 100% sand substrate. Seventy-two % of the sites in the present study had ≥ 90% sand in their sediment!



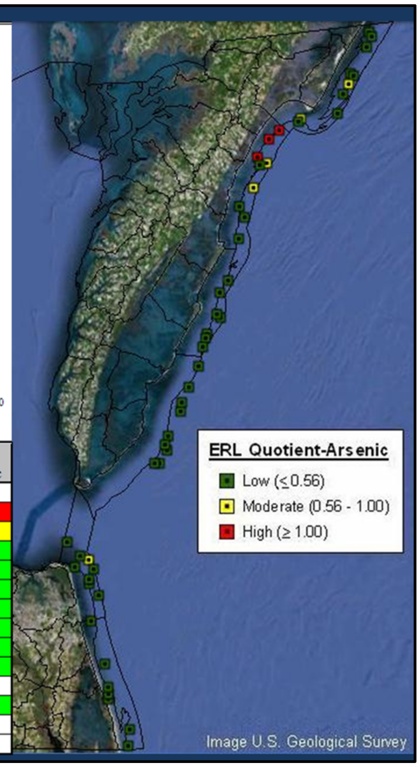
Emery, V.L., Jr., D.W. Moore, B.R. Gray, B.M. Duke, A.B. Gibson, R.B. Wright, and J.D. Farrar. 1997. Development of a chronic sublethal sediment bioassay using the estuarine amphipod Leptocheirus plumulosus (Shoemaker). Environ. Toxicol. Chem. 16(9):1912-1920.

Emery et al. (1997), in the development of chronic sublethal sediment bioassay protocols using *L. plumulosus*, reported reduced amphipod survivorship in sediments greater than 75% sand. With all other parameters being controlled, the 28-day survivorship of *Leptocheirus* in their study was less than 70% when tested in a 100% sand substrate.

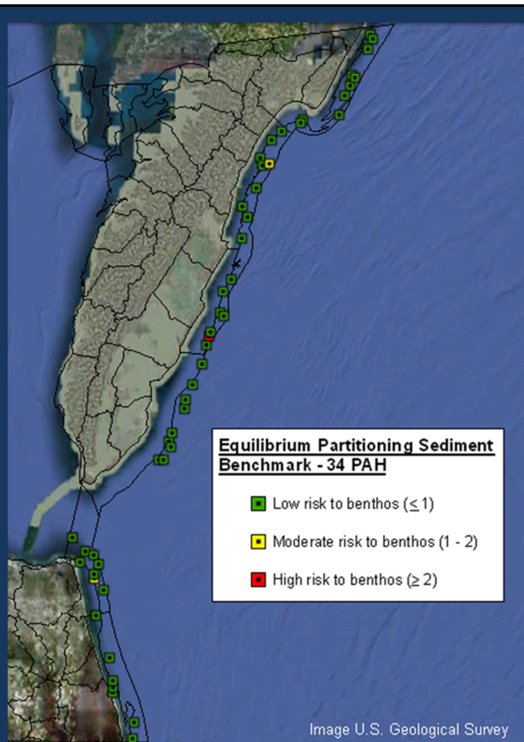




Attribute	ERLq Arsenic
N	50
Max	1.207
90th %	0.779
75th %	0.512
UL 95%	0.420
Median	0.372
LL 95%	0.324
25th %	0.297
10th %	0.250
Min	0.085
Mean	0.446
Std. Dev.	0.244
Std. Err.	0.035



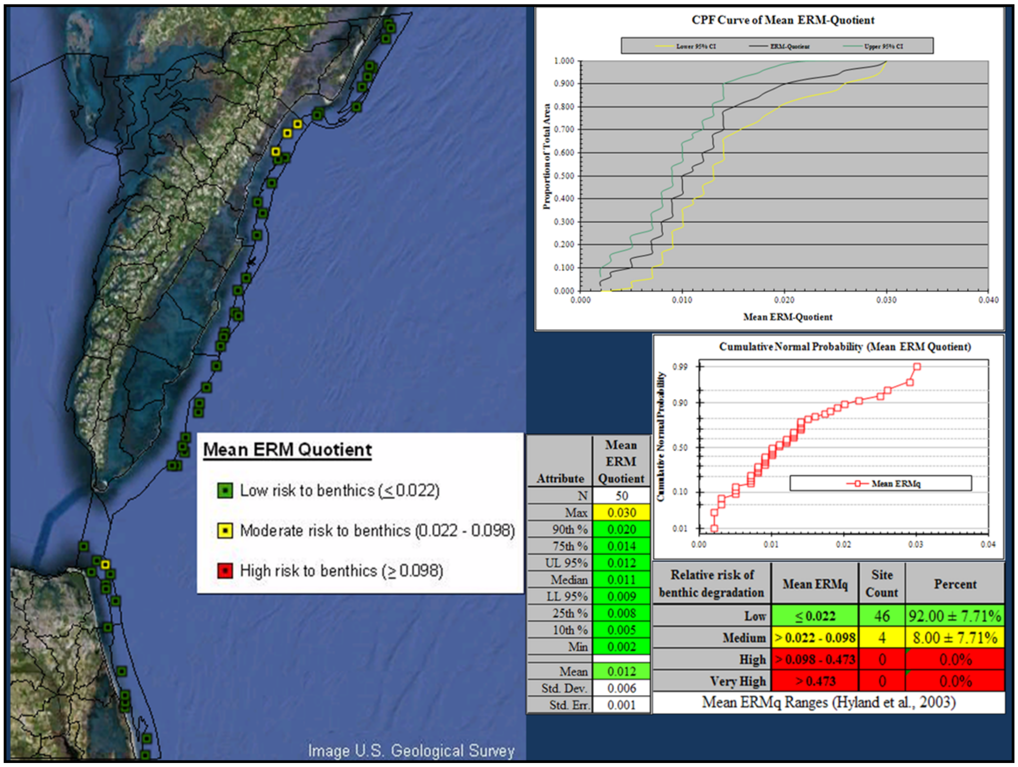
Among nine metals with ERM/ERL screening values, no ERM exceedances were observed. Arsenic was the only metal that exceeded its ERL screening value: three sites (6.0 ± 6.7%) with ERL quotients between 1.110 and 1.207.
All three sites were in the "Notch" where permitted poultry production facilities are numerous on the headlands and the tidal marsh buffer between shore and oceanic waters is much narrower. May well be a "legacy" problem – poultry industry has greatly reduced the use of arsenic in recent years…



Attribute	ESB.50s 34 PAH Mixture
N	50
Max	17.810
90th %	0.759
75th %	0.188
UL 95%	0.060
Median	0.018
LL 95%	-0.024
25th %	0.000
10th %	0.000
Min	0.000
Mean	0.517
Std. Dev.	2.514
Std. Err.	0.356

ESBs for PAH mixtures were calculated based on the suite of 23 PAHs included in the NCCA sediment analyses. A correction factor (x 1.64) was then applied to the calculated ESBs to estimate the expected median score for mixtures of 34 PAHs. Only three sites (6.0 ± 6.7%) exceeded adjusted scores of 1.0, and only one site exceeded a score of 2.0. The extreme score (17.81) was NE of Great Machipongo Inlet and field sheets from the site reported a dark 2-3 cm anoxic layer on the surface of the sediment and an aluminum can in the large sediment grab. Possible sunken vessel (?) – no other apparent source of PAHs!

U.S. EPA. 2003. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures. EPA-600-R-02-013. Office of Research and Development. Washington, DC 20460



Attribute	Mean ERM Quotient
N	50
Max	0.030
90th %	0.020
75th %	0.014
UL 95%	0.012
Median	0.011
LL 95%	0.009
25th %	0.008
10th %	0.005
Min	0.002
Mean	0.012
Std. Dev.	0.006
Std. Err.	0.001

Relative risk of benthic degradation	Mean ERMq	Site Count	Percent
Low	≤ 0.022	46	92.00 ± 7.71%
Medium	> 0.022 - 0.098	4	8.00 ± 7.71%
High	> 0.098 - 0.473	0	0.0%
Very High	> 0.473	0	0.0%

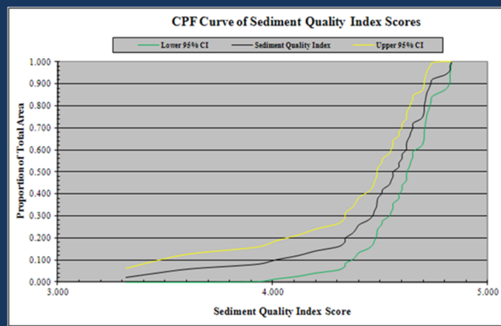
Mean ERMq Ranges (Hyland et al., 2003)

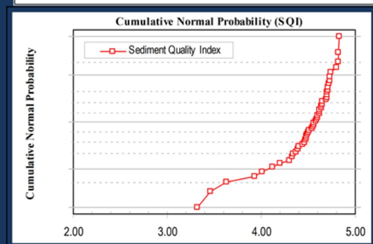
Means based on As, Cr, Cd, Cu, Pb, Hg, Ag, Zn, Total PCBs, Total DDT, 4,4'-DDE, and 13 individual PAHs

The mean ERM-quotient ranges (Hyland, et.al, 3003) were derived from estuarine results along the Atlantic and Gulf coasts, where sediments were higher in silt/clay components as well as in TOC content. They may be a bit conservative for use in oceanic waters, where TOC was almost always < 1.0 %

Correlation between % fines and mean ERMq = 0.833 (r-squared = 0.695)

Correlation between % TOC and mean ERMq = 0.736 (r-squared = 0.542)

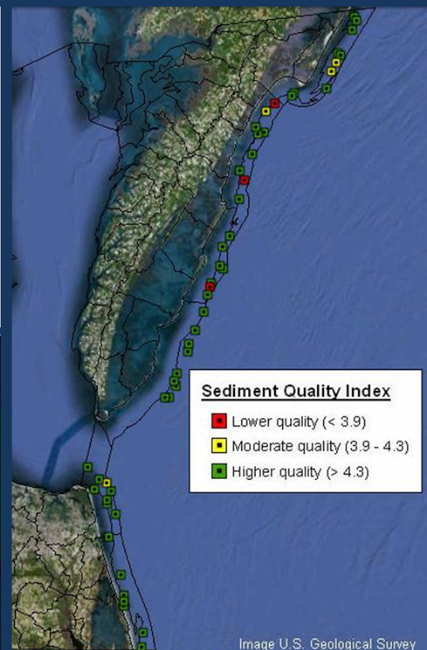




Attribute	Sediment Quality Index
N	50
Max	4.831
90th %	4.735
75th %	4.697
UCI 95%	4.635
Median	4.572
LCI 95%	4.508
25th %	4.411
10th %	4.109
Min	3.316
Average	4.481
Std. Dev.	0.326
Std. Err.	0.046

Based on sediment TOC, ERM and ERL exceedances, ESB for PAHs, mean ERM quotient, and toxicity

(Each parameter was ranged from 0.00 to its threshold for "High Risk" to the benthic community.)



Sediment TOC (Max = 1.43%; only one site > 1.0%)
ERM exceedances = 0
ERL exceedances = 3 (As – Max = 1.207)
ESB exceedances for PAH mixtures = 3 (1.185, 1.252, 17.810) Note: ESB calculations take TOC concentration into account!
Mean ERMq (Max = 0.030) Note: ERM screening values do not consider TOC concentrations in the sediment!

Regional estuarine benthic indices:

Chesapeake Bay B-IBI	**50.0 ± 14.2% in "Good" condition**
mid-Atlantic B-IBI	**75.0 ± 12.3% in "Good" condition**
EMAP Virginia Province Index of Estuarine Condition	**47.0 ± 14.2% in "Good" condition**

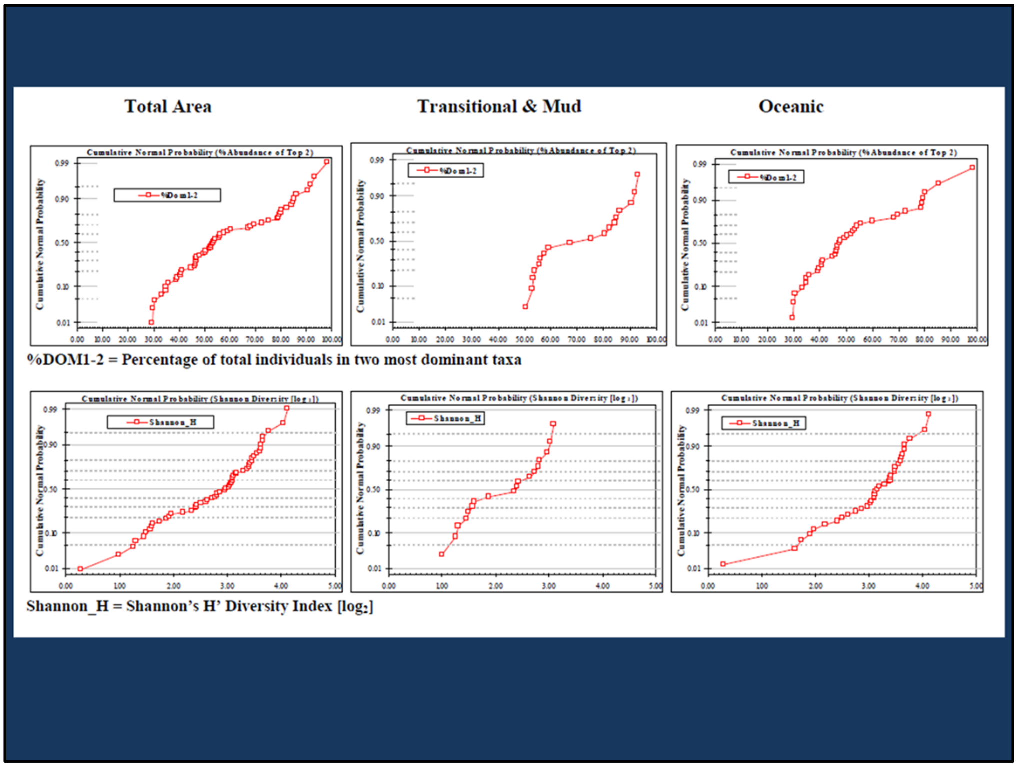
Threshold Values for Scoring Individual Benthic Metrics and Classifying Standardized Marine Benthic Samples (0.04 m^2)

Class > Score >	Less Desirable (1)	Intermediate (3)	More Desirable (5)
Total Abundance (Number of Individuals)	< 113 or > 1315	113 to 186 or 578 to 1315	186 - 578
Number of Taxa	< 20	20 - 26	≥ 27
% Dominance of Two Most Abundant Taxa	> 77%	46% - 77%	< 46%
Shannon-Weiner H' (Log_2)	< 2.271	2.271 - 3.403	> 3.403
Gleason D	< 3.345	3.345 - 4.572	> 4.572
Pielou J' - Evenness (Log_2)	< 0.476	0.467 - 0.770	> 0.770
Number of Tubificidae	> 11	5 - 11	< 5
Number of Spionidae	< 10 or > 74	37 to 74 or 10 to 21	21 - 37
% Abundance - Pollution Indicative Taxa	> 3.53%	1.18% - 3.53%	≤ 1.18%
% Abundance - Pollution Sensitive Taxa	< 21.98	22.00% - 46.99%	> 47.00%
% Abundance - Bivalve Taxa	< 3.76%	3.76% - 14.56%	> 14.56%
% Abundance - Deep-Feeding Taxa	< 5.96%	5.96% - 47.23%	> 47.23%
Skewness of Log_e Taxon Abundance Distribution	> 1.309	0.727 - 1.309	< 0.727
Kurtosis of Log_e Taxon Abundance Distribution	< -0.180 or > +2.985	-0.180 to -0.457 or +0.265 to +2.985	-0.457 to +0.265
Final Site Benthic Score Threshold Values	< 2.43 (14.8%)	2.44 - 2.99 (16.6%)	≥ 3.00 (68.6%)

Note: The Site Benthic Score serves only to rank sites from more perturbed to less perturbed on a benthic community gradient. The threshold values defined here are not intended to distinguish impaired (significantly degraded sites) from non-impaired (non-degraded) sites!

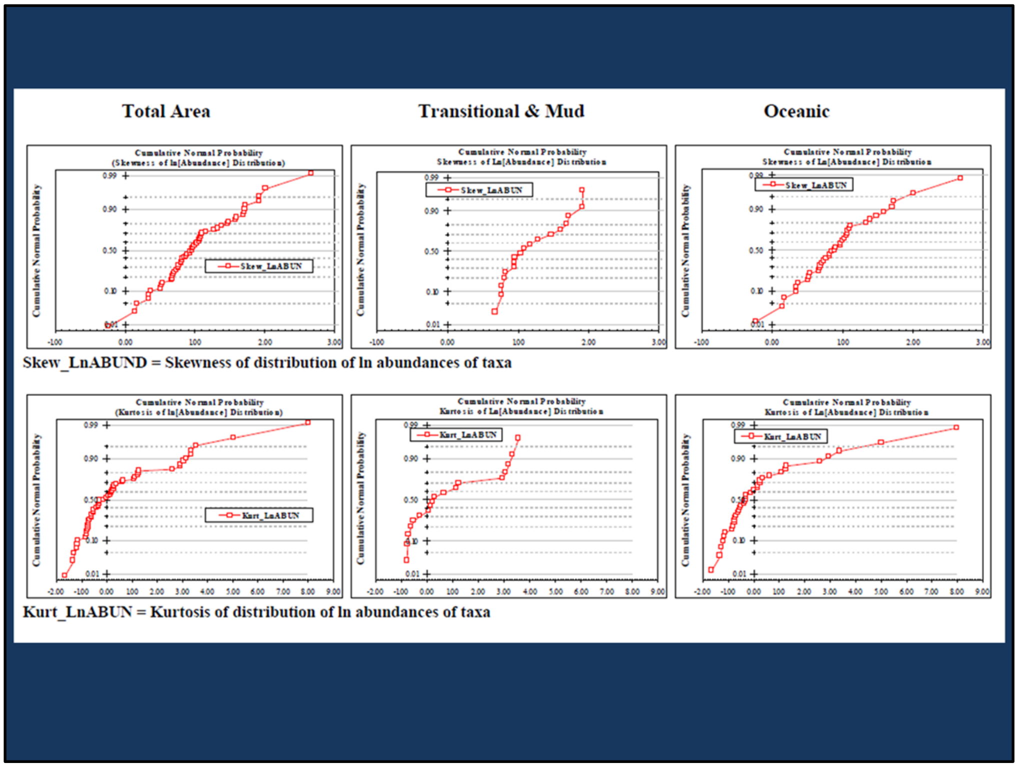
Selected 12 metrics for which polarity was considered non-controversial from other benthic indices; added two metrics based on theoretical considerations.

1. Weisberg, S.B., J.A. Ranasinghe, D.M. Dauer, L.C. Schaffner, R.J. Diaz, and J.B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries* 20:149-158.
2. Alden, R.W. III, D.M. Dauer, J.A. Ranasinghe, L.C. Scott, R.J. Llansó. 2002. Statistical Verification of the Chesapeake Bay Benthic Index of Biotic Integrity. Environmetrics 2002; 13: 1–22
3. Llanso, R.J., L.C. Scott, J.L. Hyland, D.M. Dauer, D.E. Russell, and F.W. Kutz. 2002. An Estuarine Benthic Index of Biotic Integrity for the Mid-Atlantic Region of the United States. II. Index Development. Estuaries Vol. 25, No. 6A, p. 1231–1242 December 2002.
4. Paul, J.F., K.J. Scott, D.E. Campbell, J.H. Gentile, C.S. Strobel, R.M. Valente, S.B. Weisberg, A.F. Holland, J.A. Ranasinghe. 2001. Developing and applying a benthic index of estuarine condition for the Virginian Biogeographic Province. Ecological Indicators 1 (2001) 83–99.



Two conventional metrics…

Examined cumulative distributions of each metric for near-shore area as a whole, for transitional and muddy substrates, and for sandy oceanic substrates. In many cases transitional & mud substrates revealed notably different distributions from sandy substrates, suggesting that the habitat type should be considered when developing future oceanic indices for the mid-Atlantic coast.



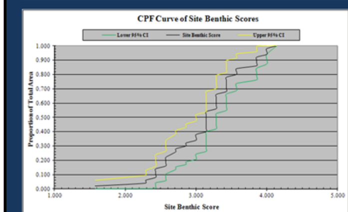
Two non-conventional metrics based on the log-normal distribution of species (taxon) abundances…

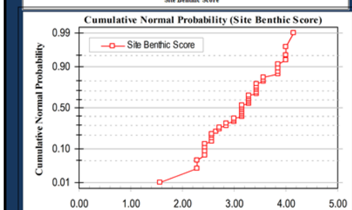
Is the log-normal distribution of species abundances really characteristic of large samples from stable, climax communities?

Preston, F.W. 1948. The Commonness, and Rarity of Species. Ecology 29 (3): 254–283. (… and Preston's veil line!)

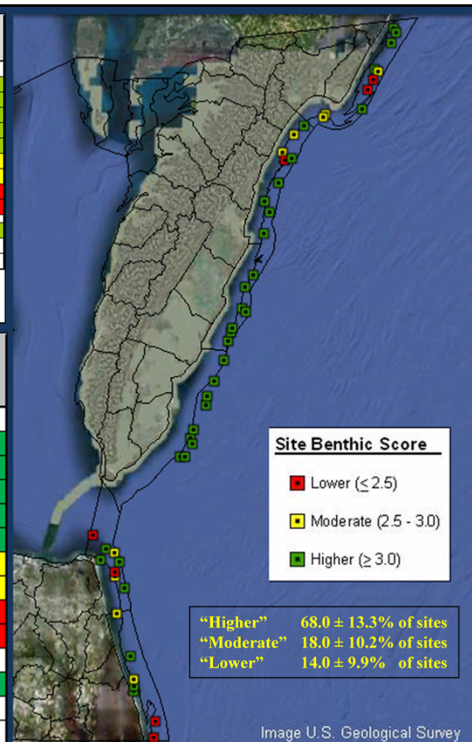
Distributional Attributes of Near-shore Benthic Communities	Chesapeake Bay Program B-IBI	mid-Atlantic B-IBI	EMAP Index of Estuarine Condition	Near-shore Oceanic Site Benthic Score
N	55	55	55	55
Maximum Value	4.00	5.00	1.814	4.14
90th Percentile	3.33	5.00	0.518	3.86
75th Percentile	3.33	4.50	0.289	3.43
UL 95% CI Median	3.15	4.33	0.122	3.32
50th Percentile (Median)	3.00	4.00	-0.019	3.14
LL 95% CI Median	2.85	3.67	-0.160	2.97
25th Percentile	2.67	3.00	-0.346	2.64
10th Percentile	2.33	2.50	-0.666	2.43
Minimum Value	2.00	1.50	-1.362	1.57
Mean	2.94	3.69	-0.047	3.12
Std.Dev.	0.43	0.97	0.540	0.54
Std. Err.	0.06	0.13	0.073	0.07

Meets Goals / Non-Degraded / More Desirable
Marginal / Intermediate
Degraded / Less Desirable



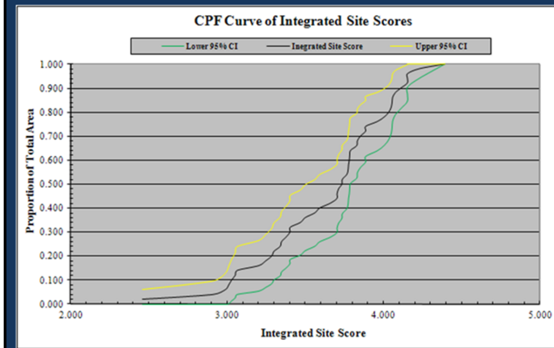


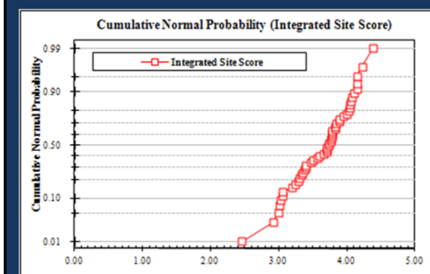
Attribute	Site Benthic Scores
N	50
Max	4.143
90th %	3.857
75th %	3.429
UCI 95%	3.301
Median	3.143
LCI 95%	2.984
25th %	2.714
10th %	2.429
Min	1.571
Average	3.133
Std. Dev.	0.545
Std. Err.	0.077



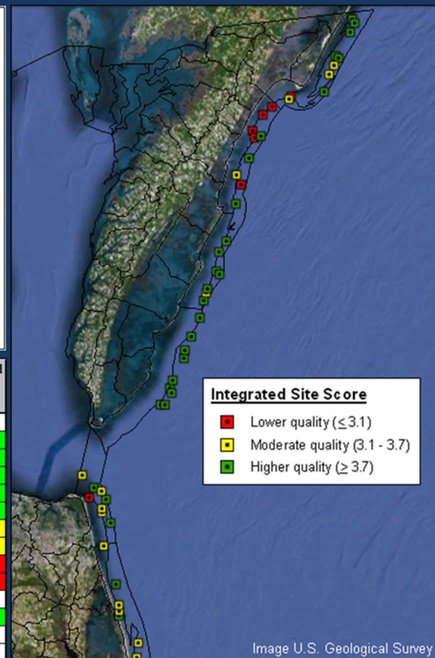
Individual site benthic scores were calculated as the arithmetic mean of the 14 previously described metrics at each site. The resultant distribution of site scores was positively correlated with each of the three estuarine benthic indices, having a maximum r^2 value of 0.699 with the mid-Atlantic B-IBI, with which it shared the most metrics. The final choice of thresholds for the "More Desirable", "Intermediate", and "Less Desirable" classes of the SBS was based on three considerations: (1) agreement with the classification by the three estuarine indices, (2) degree of chemical contamination observed in the sediment at the site, and (3) results of toxicity tests of the sediment at the site.

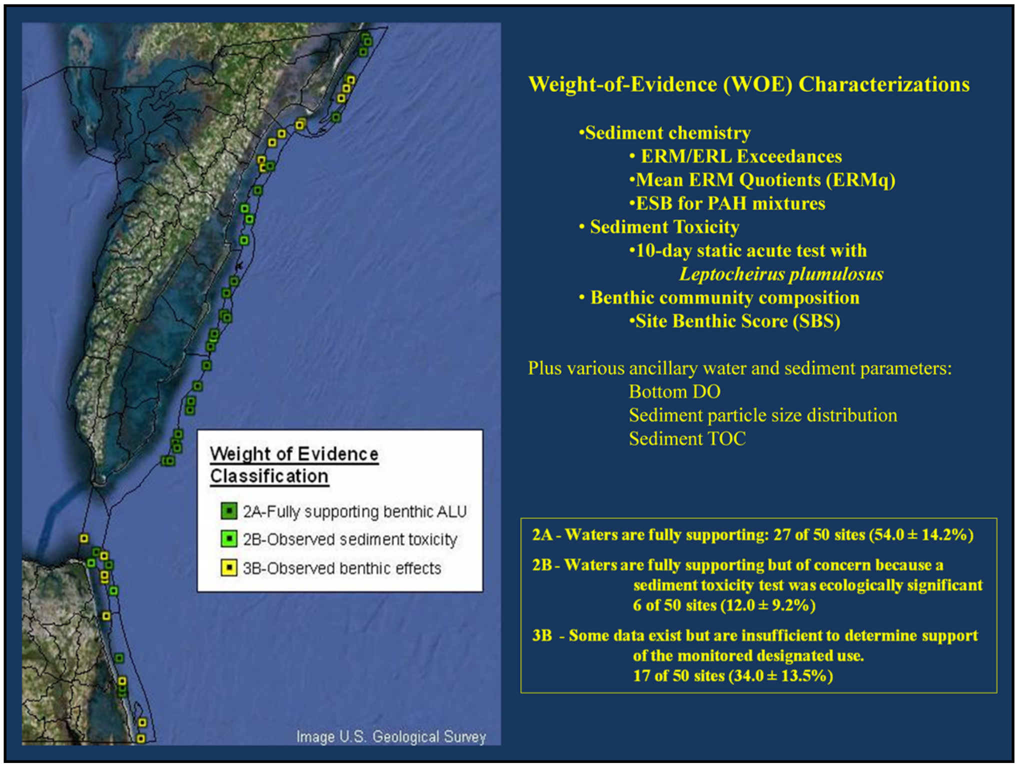
Integrated Site Score (ISS) calculated as the arithmetic mean of Water Quality Index (WQI), Sediment Quality Index (SQI), and Site Benthic Score (SBS)





Attribute	Integrated Site Score
N	50
Max	4.392
90th %	4.114
75th %	3.940
UCI 95%	3.864
Median	3.735
LCI 95%	3.605
25th %	3.356
10th %	3.051
Min	2.461
Average	3.643
Std. Dev.	0.408
Std. Err.	0.058





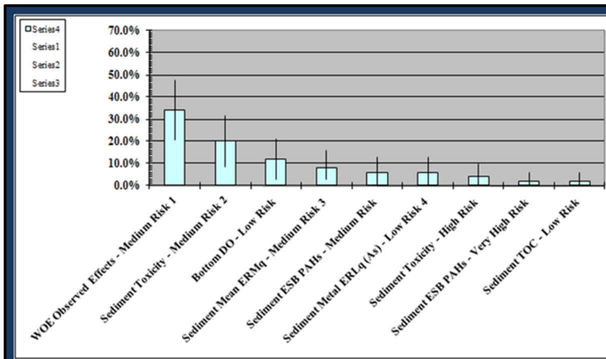
All classifications are only tentative until a validated marine benthic index is established for mid-Atlantic oceanic waters!

2A - Waters are fully supporting of the use (aquatic life – benthic) for which they were monitored. Benthic community, sediment contaminants, and observed survival during toxicity tests were all good! 27 of 50 sites (54.0 ± 14.2%)

2B - Waters are fully supporting but of concern because a sediment toxicity test resulted in ecologically significant control-corrected mortality.

6 of 50 sites (12.0 ± 9.2%) Note: A significant portion of observed mortality may have resulted from particle size (% sand) considerations rather than from chemical contamination; 72% of the sites had substrate with greater than 90% sand! (Emery et al. (1997), in the development of chronic sublethal sediment bioassay protocols using L. plumulosus, reported reduced amphipod survivorship in sediments greater than 75% sand. With all other parameters being controlled, the 28-day survivorship of Leptocheirus in their study was less than 70% when tested in a 100% sand substrate.

3B - Some data exist but are insufficient to determine support of the monitored designated use. Classification in this subcategory results from a benthic classification of "Marginal" or "Poor" by the majority of the benthic indices and/or an elevated risk of benthic impact as indicated by mean ERM quotients and/or Equilibrium Partitioning Sediment Benchmarks (ESBs) for PAHs. 17 of 50 sites (34.0 ± 13.5%)



[1] The Weight-of-Evidence toxics characterization, based on the sediment quality triad, is not a stressor; it evaluates the combined influence of several other stressors (contamination, toxicity) in the figure and is included for the purpose of comparison.

[2] Control-corrected survivorship may be a function of particle size (% sand) as well as being contaminant related!

[3] The maximum mean Effects Range Median Quotient (ERMq) fell in the lower half of the medium risk range.

[4] Arsenic (As) slightly exceeded its Effects Range Low (ERL) screening value at three sites.

Stressor - Designated Use	Criterion	Relative Risk	Extent
Weight-of-Evidence Observed Effects - ALU [1]	Varied	Medium Risk	34.0 ± 13.5%
Sediment Toxicity (Control-corrected Survivorship) - ALU [2]	< 80%	Ecological Risk	20.0 ± 11.4%
Dissolved Oxygen - WQS 5.0 mg/L - ALU (near bottom)	4.0 - 5.0 mg/L	Low Risk	12.0 ± 9.2%
Sediment Mean ERM-Quotient - ALU [3]	≥ 0.022	Medium Risk	8.0 ± 7.7%
Sediment Equilibrium Partitioning Benchmark (ESB_{34}) for PAHs - ALU	> 1.0	Low to High Risk	6.0 ± 6.7%
Sediment Individual Metals - ERL exceedance - ALU [4]	≥ 1.0	Low Risk	6.0 ± 6.7%
Sediment Toxicity (Control-corrected Survivorship) - ALU	< 70%	High Risk	4.0 ± 5.6%
Sediment Equilibrium Partitioning Benchmark (ESB_{34}) for PAHs - ALU	> 15.0	Very High Risk	2.0 ± 3.9%
Sediment Total Organic Carbon	> 1.0%	Medium Risk	2.0 ± 3.9%
Dissolved Metals (near-surface) Chronic WQS exceedance - ALU	Varied	Low Risk	0.0 ± 0.0%
Sediment Individual Metals ERM-Quotient - ALU	≥ 1.0	Low Risk	0.0 ± 0.0%
Sediment Individual Organics ERM-Quotient - ALU	≥ 1.0	Low Risk	0.0 ± 0.0%
Sediment Individual Organics ERL-Quotient - ALU	≥ 1.0	Low Risk	0.0 ± 0.0%
Bacteria - Human health primary contact (Enterococcus - near surface)	≥ 104	Low Risk	0.0 ± 0.0%
Dissolved PAHs (near-surface) ALU, Human health	Varied	Low Risk	0.0 ± 0.0%


OSV Bold, berthed at the NOAA Pier, Norfolk, VA.
14 August 2010
U.S. ENVIRONMENTAL PROTECTION AGENCY
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EPA Region 3 Field Team
VA DEQ Field Team
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