APPENDIX 11 ADDENDUM TO CHAPTER 4.8

Since Chapter 4.8 of Virginia's 2012 305(b)/303(d) Integrated Water Quality Report (IR) was prepared and the entire IR was submitted to EPA and the public for comments, the Institute of Marine and Coastal Sciences of Rutgers University published and posted on the Internet a final report (Ramey et al. 2011) on the development of a benthic index for assessment of the ecological status of benthic communities in the marine coastal waters of New Jersey. The report and associated appendices are available on the Internet at http://marine.rutgers.edu/main/Front-Page-News/Rutgers-Study-Assesses-the-Condition-of-New-Jersey-Coastal-Ocean-Waters.html. The provisional benthic index described in the report is derived from the European AZTI Marine Biotic Index (AMBI - Borja et al., 2000), which has been adapted for the oceanic waters of New Jersey's Atlantic coast. The authors recognize that the index, in its present form, has various limitations and is not yet adequate for the regulatory classification and formal assessment of oceanic waters. It requires additional refinement, with the inclusion of additional samples and taxa from unimpaired, moderately impaired, and heavily impacted sites in its further development and calibration. It should not be considered adequate for formal assessment purposes until a proper validation test has been performed and approved using an independent dataset. Nonetheless, it is at present the only index of benthic biotic integrity intended specifically for coastal oceanic waters of the mid-Atlantic region.

This addendum summarizes the application of the provisional New Jersey benthic index (NJ-AMBI or AMBI) to the probabilistic benthic samples collected during Virginia's 2010 near-shore oceanic survey. Although the NJ-AMBI has not yet been validated for the formal assessment of benthic communities in oceanic waters, we feel that the inclusion of this addendum is appropriate and desirable for three primary reasons: (1) the coastal Atlantic waters of New Jersey and Virginia are relatively close to one another and reside in the same Marine Biogeographical Province – the Virginia Province – of the mid-Atlantic region, (2) the NJ-AMBI provides a fifth, and probably more appropriate line of evidence for evaluating Virginia's marine benthic communities – three of the other four indices applied were developed for estuarine communities, and the fourth is only a preliminary effort – and, (3) the NJ-AMBI is the only one of the five indices that was developed specifically for the evaluation of, and provides provisional threshold values for classifying the ecological habitat quality and health of oceanic benthic communities.

Development of the Method: The development and validation of the method in New Jersey coastal oceanic waters is described in detail in the original report (Ramsey, et al. 2011). In brief, a selected list of benthic taxa commonly encountered in near-shore, soft-bottomed oceanic waters of New Jersey and nearby areas was first evaluated by a committee of benthic experts from the Institute of Marine and Coastal Sciences (Rutgers), and was then distributed to 13 anonymous experts at other US research institutions. The original committee, acting as a single expert, and each of the additional experts that agreed to participate in the study, assigned as many taxa as possible to one of five ecological (tolerance) groups (EG):

Group I - Species very sensitive to organic enrichment and present under unpolluted conditions (initial state). Includes specialist carnivores, and some deposit-feeding tubicolous polychaetes.

Group II - Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight imbalance). These include suspension feeders, less sensitive carnivores and scavengers.

Group III - Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slightly unbalanced situations). They are surface deposit-feeding species (e.g., tubicolous spionids).

Group IV - Second-order opportunistic species (pronounced unbalanced situations). Mainly small polychaetes: subsurface deposit-feeders (e.g., cirratulids).

Group V - First-order opportunistic species (pronounced unbalanced situations). These are deposit feeders, which proliferate in reduced sediments.

The resultant EG classifications were compared, evaluated, and integrated across the various experts and final EG scores from I to V were finally assigned to each of 218 individually classified (assigned) taxa.

Calculation of the Index: In evaluating individual benthic samples, all non-classified taxa are removed from further consideration and the total number of unassigned individuals and their total percentage of community abundance are noted. Among the classified taxa, the percentage of individuals in each taxon is calculated. An overall biotic coefficient (BC) for the sample is calculated by multiplying the percentage representation of each EG by a coefficient specific to its ecological tolerance group (G_I through G_V), and summing across all EGs, as described in equation (1) below.

$$(1)\quad \text{Biotic coefficient (BC)} = \frac{(0.0 \times \%G_I) + (1.5 \times \%G_{II}) + (3.0 \times \%G_{III}) + (4.5 \times \%G_{IV}) + (6.0 \times \%G_V)}{100}$$

Biotic coefficients constitute a continuous variable with values between 0 and 6. Higher values indicate a greater degree of pollution. They are subsequently converted into a discrete biotic index value (NJ-AMBI score) ranging from 0 (i.e., unpolluted/normal conditions) to 7 (i.e., extremely polluted/azoic conditions) based on the relative abundances of each of the ecological groups (EG). Threshold values for assigning AMBI scores and their interpretations are summarized in Table 1, provided in Ramey et al. (2011), as modified from Borja et al. (2000). It should be noted that these threshold values are subject to modification following additional refinement and calibration of the index.

Table 1 - Summary of biotic coefficients with corresponding biotic index values, dominant ecological group, ecological quality, and community health designations as modified from Borja et al. (2000).

Biotic Coefficient (BC)	Biotic Index (BI)	Dominant Ecological Group (EG)	Ecological Quality	Community Health
$0.0 < BC \leq 0.2$	0	I	unpolluted	normal
$0.2 < BC \leq 1.2$	1		unpolluted	impoverished
$1.2 < BC \leq 3.3$	2	III	slightly polluted	unbalanced
$3.3 < BC \leq 4.3$	3		moderately polluted	transitional to pollution
$4.3 < BC \leq 5.0$	4	IV - V	moderately polluted	polluted
$5.0 < BC \leq 5.5$	5		heavily polluted	transitional to heavily polluted
$5.5 < BC \leq 6.0$	6	V	heavily polluted	heavily polluted
Azoic	7	Azoic	extremely polluted	azoic

Application to Virginia's Near-shore Oceanic Study: Each of the benthic samples from Virginia's 2010 near-shore oceanic survey was evaluated following the procedure described above. In all, 55 samples from 50 random sites (five samples were quality assurance duplicates) were individually evaluated. The depths (8.5 – 25.8 m) and bottom salinities (27.5 – 32.0 ‰) of all sites were within the ranges described for the NJ-AMBI. Five sites had muddy substrates (≤ 60% sand), with sand fractions below those characteristic of the datasets used to develop the NJ-AMBI, but they were included in this analysis for comparative purposes.

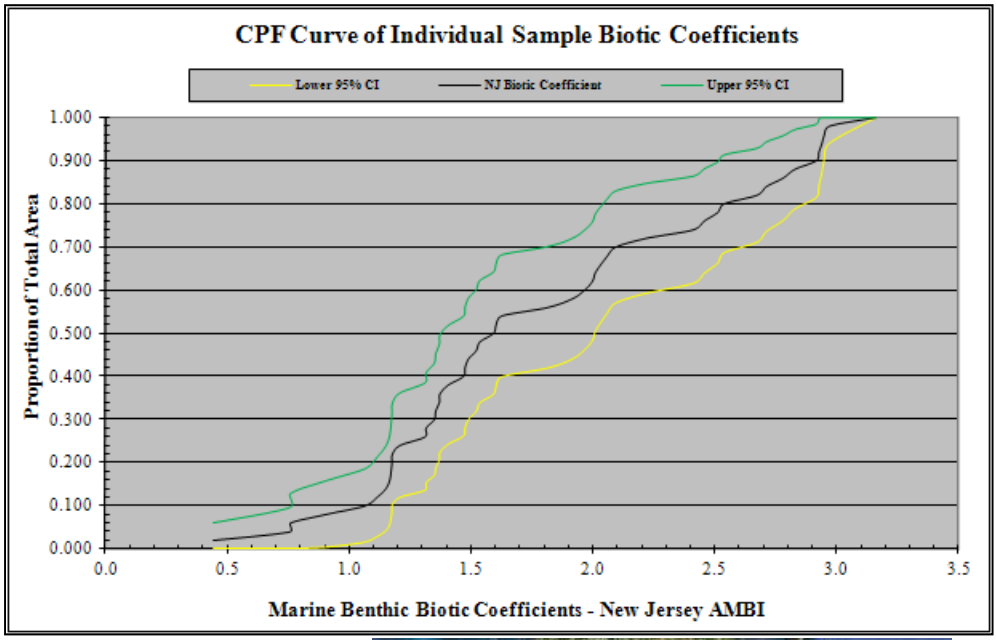
Among the 55 benthic samples evaluated in this study, the percent of total taxonomic abundance not classified into EGs (% unassigned) varied from 0.0% to 38.7% (average = 7.3 ± 8.3% SD). Forty-five of the 55 samples (81.8%) had fewer than 10% unassigned individuals. Five samples exceeded 20% unassigned, the recommended threshold above which Borja et al. (2005), recommend caution in the interpretation of the AMBI. No samples exceeded the upper limit of 50% unassigned, above which the authors considered a sample inappropriate for application and interpretation of the AMBI.

Biotic Coefficients: The sample biotic coefficients (BC's) calculated using equation (1) above varied from a minimum of 0.446 (BI = 1) to a maximum of 3.163 (BI = 2), with an average of 1.818 (Std. dev. = 0.706). The statistical and geographic distributions of the BI's are illustrated in Figure 1, below. The geographic distribution of higher biotic coefficients, indicating "slightly polluted" sites with "unbalanced" community health (BI = 2), closely paralleled that revealed by the other indices of benthic degradation, sediment quality and water quality. Sites with higher biotic coefficients (slightly more polluted) clustered in two separate areas; (1) along the oceanic shore of Assateague Island and into the notch below Chincoteague Inlet, and (2) in the tidal plume from Chesapeake Bay.

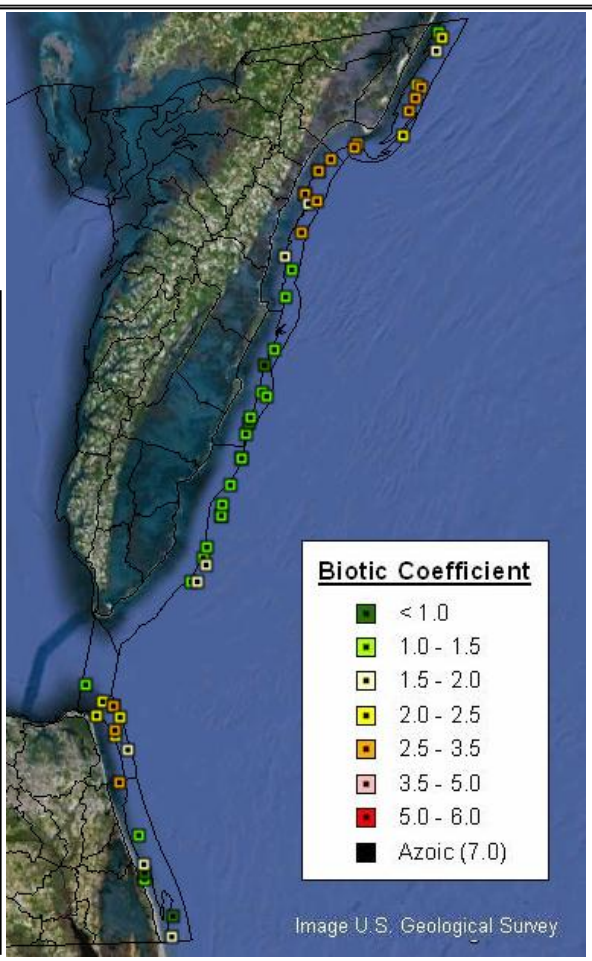
Both Pearson (r = parametric) and Spearman (*r* = rank) correlations were calculated between the BC's and each of the other biotic indices utilized in the original IR. Both parametric and nonparametric correlations were highly significant between BC values and the mid-Atlantic B-IBI (values r = -0.5609, $\alpha < 0.0001$; ranks $r = -0.6167$, $\alpha < 0.0001$) and with the Site Benthic Score (values r = -0.4774, $\alpha < 0.0003$; ranks $r = -0.5715$; $\alpha < 0.0001$). Both significant correlations were inverse (negative) due to the fact that higher values of the BC's indicate more pollution/degradation, whereas higher values of the other indices indicate healthier benthic communities (less degradation). Correlation with the EMAP Virginia Province IEC was of marginal significance (values r = -0.2334, $\alpha = 0.0864$; ranks $r = -0.2439$; $\alpha = 0.0727$). Correlation between the BC's and the Chesapeake Bay B-IBI was very weak and insignificant, possibly because of the narrow range of values and extremely high frequency of tied values presented by this index. Correlations were also calculated between the BC's and various habitat parameters. Bottom DO (r = -0.4659, $\alpha < 0.0004$) and percent sand in the sediment (r = -0.7076, $\alpha < 0.0001$) were both highly and inversely correlated with BC's, while percent TOC in sediment was positively correlated ($r = 0.7033$, $\alpha < 0.0001$). Two community metrics, Shannon's diversity index (H', $r = -0.6065$, $\alpha < 0.0001$) and Pielou's evenness (J'; $r = -0.6206$, $\alpha < 0.0001$), were both highly and negatively correlated with BC's.

In most but not all cases, correlations between the BC's and other variables had higher values and greater significance when using nonparametric rank statistics. This tendency was most notable when the other variables had discrete values (*e.g.*, B-IBI's, Fig. 2A) or when the relationship between variables was non-linear (sediment TOC, Fig. 2B). Among the five pairs of QA duplicate samples, the relative percent differences between BC's within pairs varied from 1.2% to 12.2% with an average of 6.1% (Std. dev. = 4.4%). In all cases, both members of each duplicate pair received the same Biotic Index score.

Figure 1 - Geographic and statistical distributions of "Biotic Coefficients" calculated using the provisional New Jersey AZTI Marine Biotic Index or NJ-AMBI (Ramey et al. 2011).



Attributes	Biotic Coefficients
N	55
Max	3.163
90th%	2.925
75th%	2.527
UL 95%	1.862
50th%	1.606
LL 95%	1.349
25th%	1.316
10th%	1.087
Min	0.446
Mean	1.854
StdDev	0.724
StdErr	0.098



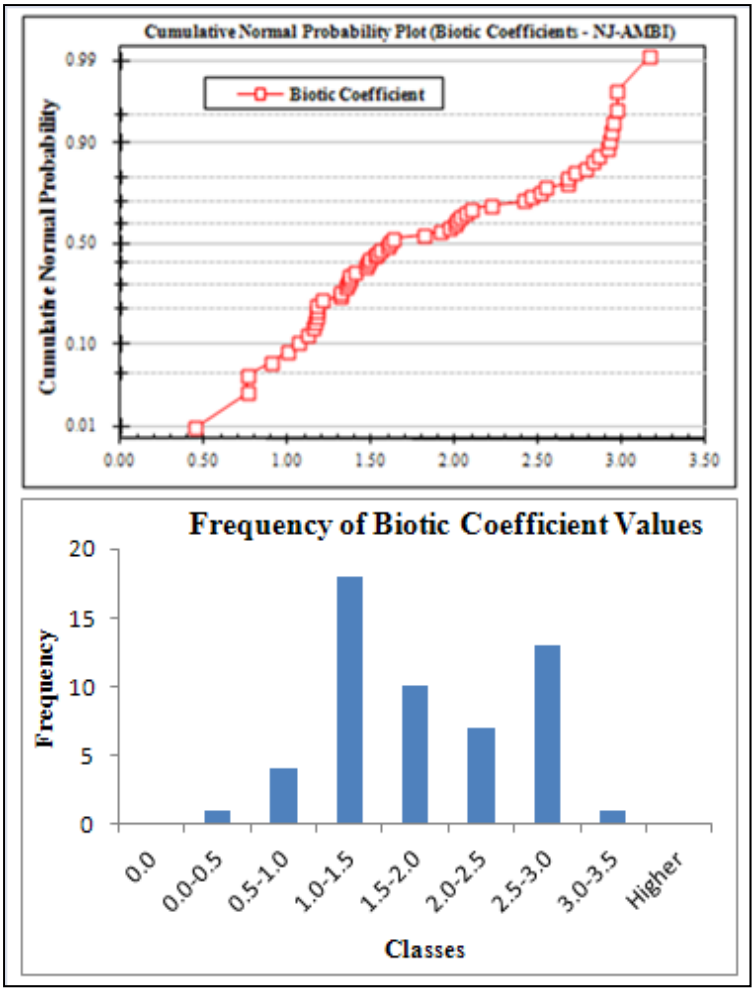
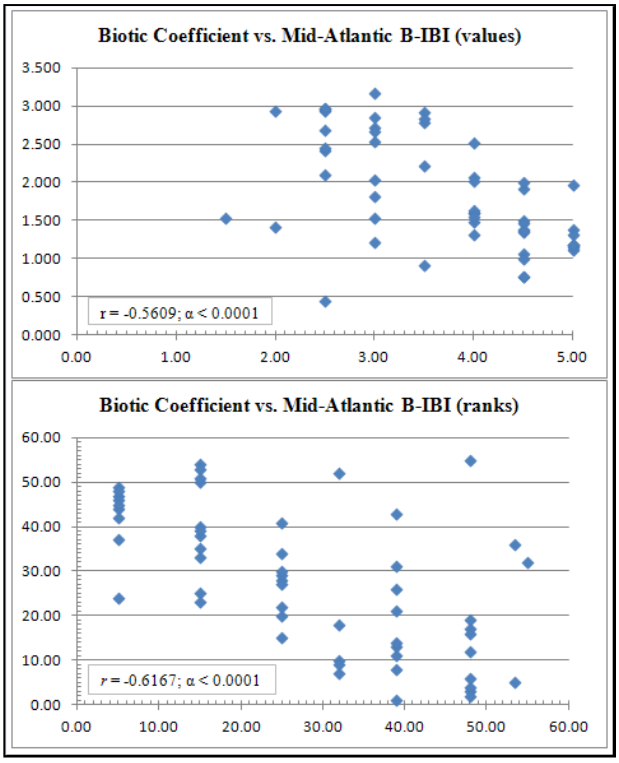
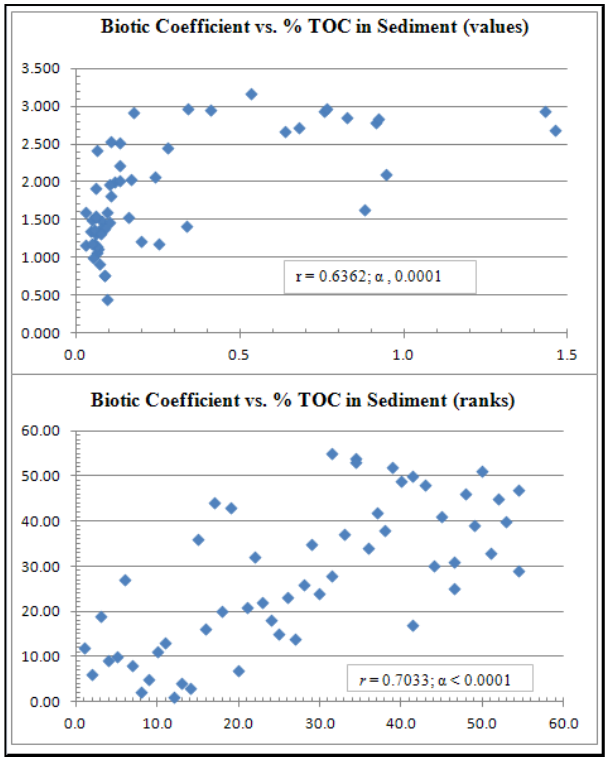


Figure 2 – Comparisons between parametric correlations (of values) and nonparametric correlations (of ranks) of (A) a discrete variable (mid-Atlantic B-IBI), and (B) a continuous variable with a non-linear relationship (sediment TOC) with site Biotic Coefficient (BC) scores.



A



B

Biotic Indices: The geographic distribution of the provisional Biotic Index (AMBI) scores of Virginia's near-shore oceanic sites, determined from Table 1 (above), is illustrated in Figure 3. As observed among the Biotic Coefficients from which they are derived, the distribution of sites with Biotic Indices denoting

“slightly polluted” ecological quality and “unbalanced” community health closely parallels those demonstrated by other water quality, sediment quality, and benthic quality indicators.

Discussion: As Ramsey et al. (2011) pointed out, the fact that the index correlates well with habitat parameters and benthic community measures (as well as with several other existing benthic indices) is encouraging. This is especially true considering that the sites evaluated in the current study are very limited in range, with biotic coefficients varying from 0.446 to 3.163 and Biotic Indices falling in only two ecological classes, unpolluted and slightly polluted with scores of 1 and 2, respectively. A broader range, including moderately and highly polluted sites, would help better define the relationships between the provisional benthic index and other physical, chemical, and biological variables in the environment. Ramsey et al. (2011) observed that the relatively narrow geographic and ecological range of sites that predominated in the dataset used to define the preliminary index limited the number of pollution tolerant taxa available for assignment to the higher-numbered ecological groupings characteristic of polluted to highly polluted habitats; to date, only six taxa have been assigned to Group IV and none to Group V. As those authors indicated, inclusion of a broader range of samples in further calibration and validation of the index would “1) provide information generally lacking on species composition, distribution and abundance patterns of benthic macrofauna inhabiting potentially impacted coastal areas in New Jersey, which could be used to assign and evaluate species tolerance designations; 2) determine the sensitivity/ability of the index in detecting a wider range/continuum of ecological conditions; 3) statistically analyze relationships among a wider range of biotic indices (currently BI = 0−2,) and over a wider range of environmental parameters/ community measures; 4) provide a test dataset to determine if the index is able to differentiate impacted/ degraded stations from reference/non-degraded stations to validate it; and 5) assess the thresholds currently being used to determine benthic community health and ecological status.”

Conclusions: The performance of the provisional New Jersey AMBI was effective and reassuring in this brief evaluation. In spite of using a completely independent dataset from a geographic area outside that used for development of the index, its biotic coefficient scores correlated well and in the expected direction with several other (estuarine) biotic indices, as well as with other physical, chemical and biological variables of the study sites. Site characterizations derived from the AMBI scores agreed well with those resulting from the integrated water quality indices and sediment quality indices used in the National (Estuarine) Coastal Condition Assessment, with various estuarine benthic indices, and with the results of weight-of-evidence characterizations performed by the Virginia DEQ for its 2012 305(b)/303(d) Integrated Water Quality Report (IR).

Although the New Jersey AMBI has not yet been calibrated and validated for formal regulatory assessment, it successfully identified, in agreement with other methods utilized in Virginia’s 2012 IR, two geographic areas of concern along the Virginia coastline. Slightly polluted sites with low-level benthic degradation are evident (1) within the southerly long-shore current which sweeps along the Atlantic shore of Assateague Island and into the coastal notch immediately south of Chincoteague Inlet (Fig. 3, Fig. 4 A), and (2) the tidal plume from Chesapeake Bay (Fig 3), which periodically fans northward (Fig. 4 B) or more commonly deflects southward (Fig. 4 C) from the mouth of the Bay.

Hopefully, continued refinement and validation of the New Jersey AMBI, using additional datasets from a broader geographic area and including sites of more varied ecological conditions, will result in its successful calibration, validation, and acceptance as an approved marine biotic index for the mid-Atlantic Bight and possibly the south Atlantic Bight regions. Virginia would welcome the opportunity to participate in this process.

Figure 3 – Geographic distribution of sites with their provisional Biotic Index (NJ-AMBI) scores. All sites were scored as "unpolluted" (Biotic Index of 0 or 1) or as "slightly polluted" (Biotic Index of 2), following the guidelines in Table 1, above.

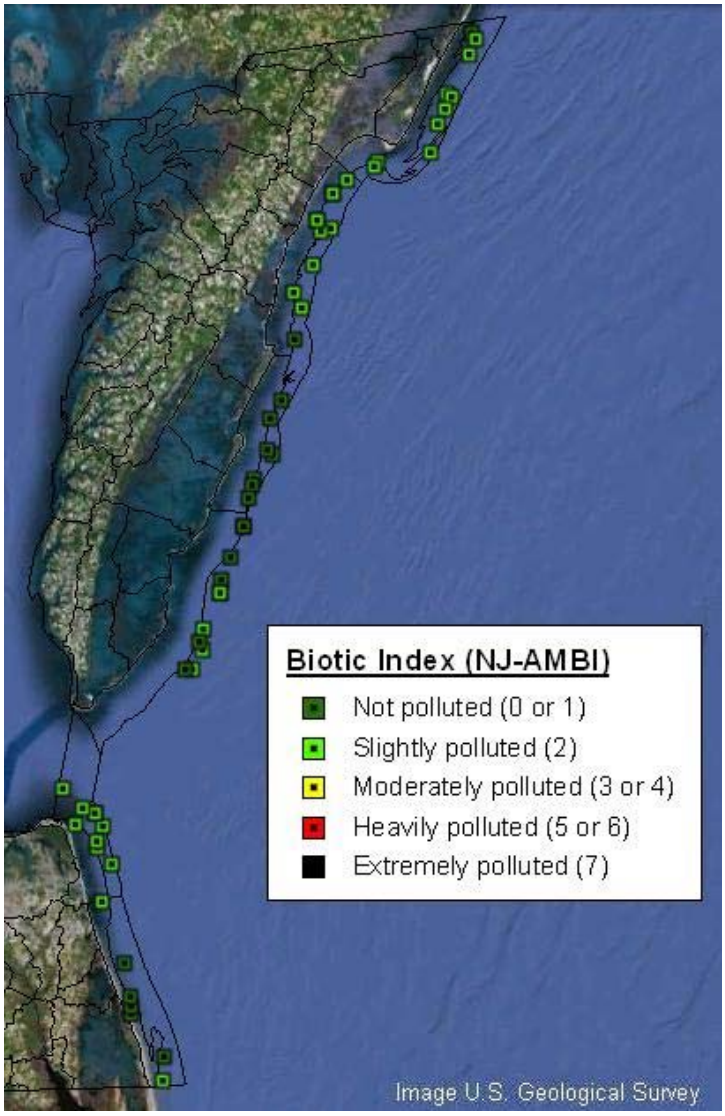
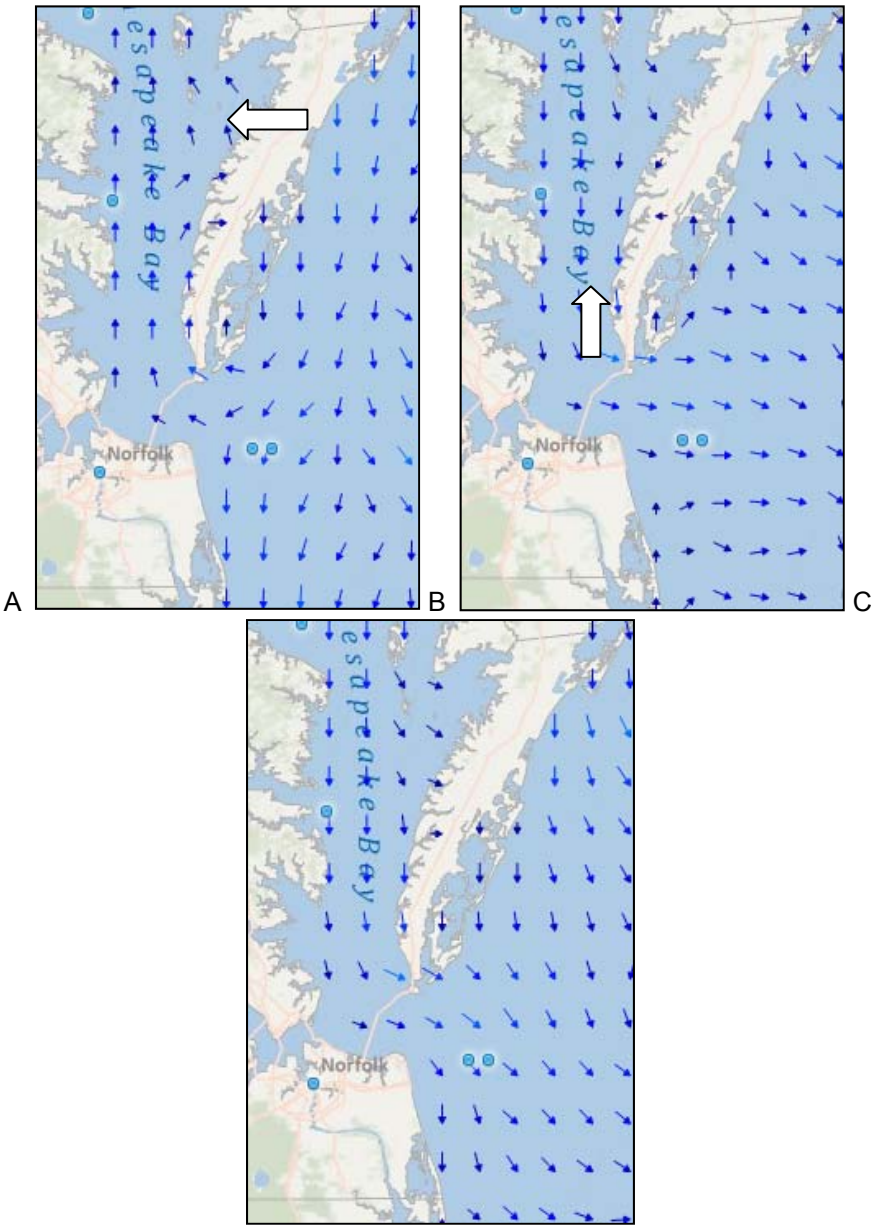


Figure 4 – Temporally progressive current maps from the Mid Atlantic Bight Ocean Surface Currents Network web pages (http://assets.maracoos.org/), illustrating the southerly long-shore current descending the Delmarva coast (A), and tidal plumes from Chesapeake Bay periodically fanning to the north (B) and more commonly deflecting to the south (C).



References:

Borja, A., Franco, and J., Pérez, V. 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Marine Pollution Bulletin 40, 1100-1114.

Borja, A., and Muxika, I., 2005. Guidelines for the use of AMBI (AZTI's Marine Biotic Index) in the assessment of the benthic ecological quality. Marine Pollution Bulletin 50, 787-789.

Ramey, P.A., M.J. Kennish, and R.M. Petrecca. 2011. Benthic Index Development: Assessment of Ecological Status of Benthic Communities in New Jersey Marine Coastal Waters - December 2011. Prepared for: US Environmental Protection Agency and New Jersey Department of Environmental Protection, by the Institute of Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ 08901.
(http://marine.rutgers.edu/main/Front-Page-News/Rutgers-Study-Assesses-the-Condition-of-New-Jersey-Coastal-Ocean-Waters.html)