Methods for Calculating The Chesapeake Bay Benthic Index of Biotic Integrity

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INTRODUCTION

The Chesapeake Bay benthic index of biotic integrity (B-IBI) was developed to assess benthic community health and environmental quality in Chesapeake Bay. The B-IBI evaluates the ecological condition of a sample by comparing values of key benthic community attributes ("metrics") to reference values expected under non-degraded conditions in similar habitat types. It is therefore a measure of deviation from reference conditions.

The B-IBI is used by the Chesapeake Bay Benthic Monitoring Program, which is conducted by the Maryland Department of Natural Resources (MD DNR) and by the Virginia Department of Environmental Quality (VA DEQ). The program contains two primary elements: a fixed site monitoring effort directed at identifying trends in benthic community condition, and a probability-based sampling effort intended to estimate the area of the Chesapeake Bay and its major tributaries with benthic communities meeting the Chesapeake Bay Program Benthic Community Restoration Goals (Ranasinghe et al. 1994). Further information about the benthic monitoring program can be found in the World Wide Web at www.baybenthos.versar.com.

The development of the Chesapeake Bay B-IBI has been described in Weisberg et al. (1997). In addition, a series of statistical and simulation studies were conducted to evaluate and optimize the B-IBI (Alden et al. 2002). The results of Alden et al. (2002) indicated that the B-IBI is sensitive, stable, robust, and statistically sound. New sets of metric and threshold combinations for the tidal freshwater and oligohaline habitats were also developed in Alden et al. (2002) with a larger dataset than was available to Weisberg et al. (1997) for these two habitats. The present document includes the latest updates and the necessary information to calculate the Chesapeake Bay B-IBI.

OVERVIEW

The Chesapeake Bay B-IBI is calculated by scoring each of several attributes of benthic community structure and function (abundance, biomass, Shannon diversity, etc.) according to thresholds established from reference data distributions. The scores (on a 1 to 5 scale) are then averaged across attributes to form the index. Samples with index values of 3.0 or more are considered to have good benthic condition indicative of good habitat quality.

The B-IBI is both habitat and season dependent. Therefore data must be selected for time of year and pre-classified according to the habitat type from which the samples were collected. Habitats are defined by salinity and sediment type. The application of the B-IBI is limited to samples collected in summer, defined as July 15 through September 30.

DATA COLLECTION AND PREPARATION

Samples to which the B-IBI is to be applied should be collected from unvegetated soft substrates (sand or mud) using a Young grab with a sampling area of 0.0440 m^2 to a depth of 10 cm, and within the July 15 through September 30 time period. The B-IBI has not been developed for vegetated or hard substrates (e.g., pebbly or rocky bottoms, oyster reefs), so these types of substrates should be avoided. The use of uniform sample collection and processing methods ensures within-program data comparability and avoids the need for data correction or standardization procedures.

Samples are gently sieved through a 0.5-mm mesh screen using ambient seawater. The material retained on the screen is transferred to 1-liter labeled plastic jars and preserved in seawater with 10% buffered formalin and Rose Bengal stain. The stain aids in the sorting of organisms in the laboratory.

In the laboratory, samples are washed in fresh water, and the organisms separated from the detritus and sorted into major taxa using a binocular dissecting microscope. After sorting, the organisms are stored in 70% ethanol and subsequently identified to the lowest possible taxonomic level (usually, species) and counted. Fragments without heads are eliminated from the counts but included in biomass determinations.

Ash-free dry weight biomass is measured for each species by drying the organisms to a constant weight at 60^{o}C followed by ashing in a muffle furnace at 500^{o}C for four hours. Because most species of oligochaetes need to be slide mounted for identification, species-specific biomass of oligochaetes cannot be provided except for *Tubificoides* spp., which do not require slide mounting for identification.

DATA REDUCTION

The B-IBI is based on observations about macrofauna that indicate benthic community condition. Taxa that are not usually retained on a 0.5-mm mesh screen (e.g., nematods, copepods, and ostracods) are eliminated from the data. Data sets must be standardized by applying uniform naming conventions. Taxa that are not sampled quantitatively or that are not truly indicative of sediment conditions are retained in the data sets but excluded from the B-IBI calculations. These taxa include benthic algae, fish, pelagic invertebrates, and epifauna. See <u>Table 1</u> for currently omitted Chesapeake Bay organisms.

HABITATS

Benthic communities differ significantly according to habitat. The B-IBI was designed to account for this variability. Metrics and thresholds were derived for each of seven habitat types in Chesapeake Bay. The major factors affecting the structure of benthic communities in Chesapeake Bay are salinity and sediment type. Before metrics can be calculated, a sample must be assigned to one of five salinity classes: tidal freshwater, oligohaline, low mesohaline, high mesohaline, and polyhaline. These classes were defined according to a modified Venice System for the classification of marine waters (Symposium on the Classification of Brackish Waters 1958). See Table 2.

Salinity is determined by the long-term average of the data collected concurrently with the biological sample (Chesapeake Bay Benthic Monitoring Program fixed stations) or by the point-in-time measurement in the absence of long-term data (Chesapeake Bay Benthic Monitoring Program random stations).

Within the high mesohaline and polyhaline classes, a sample must be further assigned to one of two sediment classes according to the percent silt-clay content of the sample. Table 2 shows the resulting habitats into which samples are classified.

METRICS

Eleven metrics are used to calculate the B-IBI:

- Shannon-Wiener species diversity index
- Total species abundance
- Total species biomass
- Percent abundance of pollution-indicative taxa
- Percent abundance of pollution-sensitive taxa
- Percent biomass of pollution-indicative taxa
- Percent biomass of pollution-sensitive taxa
- Percent abundance of carnivore and omnivores
- Percent abundance of deep-deposit feeders
- Tolerance Score
- Tanypodini to Chironomidae percent abundance ratio

Two additional metrics are used only at fixed stations by the Virginia Benthic Monitoring Program:

- Percent biomass of organisms found >5cm below the sediment-water interface
- Percent number of taxa found >5cm below the sediment-water interface

Data for the calculation of these two last metrics are obtained from box corers. Box core samples are partitioned into 2 sediment layers: 0-5 cm and 5-25 cm below the sediment-water interface. Data from the 5-25 cm layer are used to calculate the metrics.

Metrics used in the calculation of the B-IBI are those of Weisberg et al. (1997), except for the tidal freshwater and oligohaline habitats. Metrics for these two last habitats were developed in Alden et al. (2002). The metric selection process was based on Mann-Whitney U tests for differences in means between the reference and the degraded sites of the index development data sets, and on consistency with ecological principles (Weisberg et al. 1997). Not all the metrics are used in all habitats. Table 3 shows metric usage by habitat.

Metrics are calculated as follows:

- Shannon-Wiener species diversity index

The Shannon index of diversity (Shannon 1948) is computed for each sample as follows:

$$H' = -\sum_{i=1}^{S} p_i \cdot \log_2 \cdot p_i$$

where S is the number of species per sample and p_i is the proportion of total individuals in the i^{th} species.

In counting the number of taxa present in a sample, general taxonomic designations at the generic, familial, and higher taxonomic levels are dropped if there is one valid lower-level designation for that group. For example, if both *Leitoscoloplos* sp. and *Leitoscoloplos fragilis* have been identified in one sample, *Leitoscoloplos* sp. is skipped when counting the number of taxa. Skip codes are used to track these general taxonomic designations.

- Total species abundance

  The total number of organisms present in a sample (after dropping the epifauna and incidental species, as it is done for all metrics, see Table 1) is normalized to number of organisms per meter squared of surface area. The conversion factor for the Young grab is 1 count = 22.73 individuals/ m^2.

- Total species biomass

  Total species biomass is the ash-free dry weight of each species, summed over all the species present in the sample, and normalized to grams per meter squared of surface area.

- Percent abundance of pollution-indicative taxa

  Percent abundance of pollution-indicative taxa is the percent abundance contribution of taxa classified as pollution-indicative to the total abundance of organisms in a sample.

Pollution-indicative taxa are species or higher taxonomic level designations that are tolerant of pollution. Many pollution-tolerant species display opportunistic life-history characteristics, such as small size, rapid growth, high reproductive potential, and short-life spans; however, not all opportunist species are classified as pollution-indicative. In addition to life-history characteristics, statistical testing comparing the abundance of each species at reference sites with the abundance at polluted sites, was used to develop pollution-indicative and sensitive species lists (Weisberg et al. 1997). Table 4 lists taxa that are currently defined as pollution indicative for Chesapeake Bay. The list is modified from that of Weisberg et al. (1997).

- Percent abundance of pollution-sensitive taxa

  Percent abundance of pollution-sensitive taxa is the percent abundance contribution of taxa classified as pollution-sensitive to the total abundance of organisms in a sample. Pollution-sensitive species are often called "equilibrium" species because they grow slowly and are relatively long-lived, and thus they tend to characterize undisturbed, mature communities. Table 5 lists taxa that are currently defined as pollution sensitive for Chesapeake Bay. The list is modified from that of Weisberg et al. (1997).

- Percent biomass of pollution-indicative taxa

Percent biomass of pollution-indicative taxa is the percent biomass contribution of taxa classified as pollution-indicative to the total biomass of organisms in a sample.

- Percent biomass of pollution-sensitive taxa

Percent biomass of pollution sensitive taxa is the percent biomass contribution of taxa classified as pollution-sensitive to the total biomass of organisms in a sample.

- Percent abundance of carnivore and omnivores

Percent abundance of carnivore and omnivores is the percent abundance contribution of taxa currently classified as carnivores or omnivores to the total abundance of organisms in a sample. See Table 6 for carnivore/omnivore assignments of species collected by the Chesapeake Bay Benthic Monitoring Program.

- Percent abundance of deep-deposit feeders

Percent abundance of deep-deposit feeders is the percent abundance contribution of taxa that feed below the sediment-water interface to the total abundance of organisms in a sample. See Table 7 for deep-deposit feeding assignments of species collected by the Chesapeake Bay Benthic Monitoring Program.

- Tolerance Score

The Tolerance Score is a weighted abundance average for taxa classified according to their sensitiveness to pollution. The Tolerance Score is based on the North Carolina biotic index of Lenat (1993):

$$\text{Tolerance Score} = \frac{\sum TV_i \cdot N_i}{\sum N_i}$$

where TV_i is the tolerance value of the i^{th} taxa, and N_i is the abundance of the i^{th} taxa. The tolerance values are those of Lenat (1993), expanded to include piedmont and coastal taxa from Chesapeake Bay streams and tributaries. The higher the tolerance value (on a 1-10 scale), the more resistant is the species to stress, whether from pollution or from other sources. Not all taxa occurring in tidal freshwater or oligohaline habitats of the Chesapeake Bay have tolerance values assigned. Table 8 shows the list of taxa and their tolerance values.

- Tanypodini to Chironomidae percent abundance ratio

The Tanypodini to Chironomidae percent abundance ratio is a measure of the relative contribution of midges in the tribe Tanypodini to all the midges (Class Insecta, family Chironomidae) found in a sample. The Tanypodini are considered tolerant of pollution (Lenat 1993), and the ratio is expected to increase in perturbed areas. Similar ratios have been used in other studies (Barbour et al. 1996). The following Chesapeake Bay genera are classified in the tribe Tanypodini:

  - *Ablabesmyia* spp.
  - *Coelotanypus* spp.
  - *Procladius* spp.
  - *Tanypus* spp.

- Percent biomass of organisms found >5cm below the sediment-water interface

Percent biomass of organisms found >5cm below the sediment-water interface is the percent biomass contribution of organisms in the 5-25 cm layer of sediment to the total biomass of organisms (0-5 plus 5-25 cm layers) in a sample.

- Percent number of taxa found >5cm below the sediment-water interface

Percent number of taxa found >5cm below the sediment-water interface is the percent contribution of taxa found in the 5-25 cm layer of sediment to the total number of taxa in a sample. The total number of taxa in a sample is the number of species (or higher taxonomic level designations) found in the 0-5 cm sediment fraction plus those species found in the 5-25 cm sediment fraction that are not present in the 0-5 cm fraction. Species for which only parts of an individual are found in the 5-25 cm fraction (e.g., nemerteans), are counted as occurring in this fraction.

SCORING OF METRICS

The scoring of metrics to calculate the B-IBI is done by comparing the value of a metric from the sample of unknown sediment quality to thresholds established from reference data distributions. These thresholds, called "Restoration Goals" (Ranasinghe et al. 1994), were established as the 5th (or 95th, see below) and 50th (median) percentile values of reference sites for each metric-habitat combination. Reference sites were those that showed no chemical contaminant impact or significant low dissolved oxygen events (see Weisberg et al. 1997).

1. For the following metrics,

- Shannon-Wiener species diversity index
- Percent abundance of pollution-sensitive taxa
- Percent biomass of pollution-sensitive taxa
- Percent abundance of carnivore and omnivores
- Percent abundance of deep-deposit feeders (polyhaline sand habitat)
- Percent biomass of organisms found >5cm below the sediment-water interface
- Percent number of taxa found >5cm below the sediment-water interface

a score of 1 is assigned to a metric if the value of the metric for the sample being evaluated is below the 5th percentile of corresponding reference values, a score of 3 is assigned for values between the 5th percentile and the median, and a score of 5 is assigned for values above the median. For any metric, a score of 1 indicates impaired conditions.

A maximum score of 3 is assigned for the pollution-sensitive taxa metric if the overall abundance in a sample is low (i.e., below the lower abundance threshold). This is done to avoid high scores due to the presence of a few organisms of pollution sensitive species found among a small number of organisms within a sample.

2. An upper threshold corresponding to the 95th percentile of reference sites is used for the following metrics:

- Percent abundance of pollution-indicative taxa
- Percent biomass of pollution-indicative taxa
- Percent abundance of deep-deposit feeders (tidal freshwater habitat)
- Tolerance Score
- Tanypodini to Chironomidae percent abundance ratio

This is done because the direction of the response for these metrics is such that higher percentages are expected in degraded sites than in reference sites. For these metrics, the scoring is reversed so that a score of 1 is assigned for values above the 95th percentile of corresponding reference values, a score of 3 is assigned for values between the 95^{th} percentile and the median, and a score of 5 is assigned for values below the median.

No score is assigned to the Tanypodini to Chironomidae percent abundance ratio metric if there are no chironomids in the sample (the ratio cannot be calculated). Likewise, no score is assigned to the Tolerance Score metric if none of the species for which there are tolerance values (see Table 8) are present in the sample.

3. Abundance and biomass respond bimodally to pollution (Pearson and Rosenberg 1978). An increase in abundance and/or biomass of organisms is expected at polluted sites when stress from pollution is moderate, such as at sites where there is organic enrichment of the sediment. A decrease in the abundance and biomass of organisms is expected at sites with high degrees of stress from pollution. Therefore, for these two metrics, an upper threshold corresponding to the 95^{th} percentile of reference sites was established in addition to the lower threshold corresponding to the 5^{th} percentile.

For total species abundance and total biomass, a score of 1 is assigned if the value of these metrics for the sample being evaluated is below the 5^{th} percentile or above the 95^{th} percentile of corresponding reference values, a score of 3 is assigned for values between the 5^{th} and 25^{th} or between the 75^{th} and 95^{th} percentiles, and a score of 5 is assigned for values between the 25^{th} and 75^{th} percentiles.

Table 9 shows the thresholds used to score each metric of the Chesapeake Bay B-IBI. For the percent biomass of pollution-indicative and pollution-sensitive taxa metrics, abundance-based thresholds may be substituted for biomass-based thresholds whenever species-specific biomass is unavailable (Weisberg et al. 1997). Table 10 shows these abundance-based thresholds.

B-IBI VALUE

The index value for a sample is computed by averaging the scores of the individual metrics (range 1-5). If the Tanypodini to Chironomidae percent abundance ratio or the Tolerance Score cannot be calculated (see above), the denominator to calculate the average of scores should be reduced accordingly. For sites with replicate samples (Chesapeake Bay Benthic Monitoring Program fixed stations), an index value is first calculated for each sample and then averaged over the samples.

The Chesapeake Bay Benthic Monitoring Program classifies benthic community condition into four levels: “meets goals”, “marginally degraded”, “degraded”, and “severely degraded”. B-IBI values of 3.0 are the breakpoint between degraded and non-degraded conditions. Table 11 shows the four condition levels and the B-IBI ranges.

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Table 1. Currently omitted Chesapeake Bay organisms*. List based on taxa identified in Maryland and Virginia Benthic Monitoring Program data files, 1984-2000.

Taxon	Taxon
Benthic algae	Mollusca: Bivalvia:
Hydrozoa	*Anomia simplex*
Scyphozoa	*Crassostrea virginica*
Anthozoa:	Mytilidae
Diadumene leucolena	*Mytilopsis leucophaeata*
Turbellaria	Arthropoda: Merostomata:
Nematoda	*Limulus polyphemus*
Polychaeta:	Arthropoda: Pycnogonida
Harmathoe spp.	Arthropoda: Branchiura
Lepidonotus spp.	Arthropoda: Cirripedia
Polydora websteri	Arthropoda: Mysidacea
Polynoidae[1]	Arthropoda: Isopoda:
Proceraea spp.	*Caecidotea communis*
Sabellariidae	*Cassidinidea* spp.
Serpulidae	Cymothoidae
Spirorbidae	*Edotea* spp.
Hirudinea	*Erichsonella* spp.
Mollusca: Gastropoda[1]:	Idoteidae[2]
Calyptraeidae	*Paracerceis caudata*
Cerithiidae	*Sphaeroma quadridentatum*
Columbellidae	Arthropoda: Amphipoda:
Cylichnidae	Ampithoidae
Epitoniidae	*Batea catharinensis*
Ferrissia spp.	Caprellidae
Goniobasis virginica	Corophiidae
Gyraulus spp.	Gammaridae
Helisoma spp.	*Incisocalliope aestuarius*
Hydrobiidae	Isaeidae
Littorina spp.	Ischyroceridae
Menetus spp.	Melitidae
Muricidae	*Parathemisto compressa*
Nudibranchia	Pleustidae
Physa spp.	Stenothoidae
Physella spp.	Arthropoda: Decapoda[1]:
Pleuroceridae	*Callinectes sapidus*
Pyramidellidae	*Crangon septemspinosa*
Skeneopsis planorbis	Majidae
Turridae	Paguridae
Vitrinellidae	Palaemonidae

*All species of taxa listed at the generic, familial, and higher taxonomic levels are omitted.
[1]Omitted when identified only to this higher taxonomic level. [2]Omitted except species of *Chiridotea* spp.

Table 1. (continued).

Taxon	Taxon
Arthropoda: Decapoda[1]:	Arthropoda: Plecoptera:
Pinnotheres ostreum	*Allocapnia* spp.
Xanthidae	Arthropoda: Coleoptera
Arthropoda: Ephemeroptera:	Arthropoda: Trichoptera
Caenis spp.	Bryozoa
Eurylophella spp.	Chordata: Ascidiacea
Paraleptophlebia spp.	Chordata: Vertebrata
Stenacron spp.	
Tricorythodes spp.	
Arthropoda: Odonata[1]:	
Aeshna spp.	
Ischnura spp.	

*All species of taxa listed at the generic, familial, and higher taxonomic levels are omitted.
[1]Omitted when identified only to this higher taxonomic level.

Table 2. Habitat classification.

Habitat Class	Bottom Salinity (ppt)	Silt-clay (<62 μ) content by Weight (%)
Tidal freshwater (TF)	0 - 0.5	N/A
Oligohaline (OH)	≥0.5 - 5.0	N/A
Low mesohaline (LM)	≥5.0 - 12.0	N/A
High mesohaline (HM) sand	≥12.0 - 18.0	0 - 40
High mesohaline (HM) mud	≥12.0 - 18.0	>40
Polyhaline (PO) sand	≥18.0	0 - 40
Polyhaline (PO) mud	≥18.0	>40

Table 3. Metric usage by habitat.

Metric	Habitat Class						
	TF	OL	LM	HM sand	HM mud	PO sand	PO mud
Shannon-Wiener species diversity index			X	X	X	X	X
Total species abundance	X	X	X	X	X	X	X
Total species biomass			X	X	X	X	X
Percent abundance of pollution-indicative taxa	X	X	X	X			
Percent abundance of pollution-sensitive taxa		X		X		X	
Percent biomass of pollution-indicative taxa*					X	X	X
Percent biomass of pollution-sensitive taxa*			X		X		X
Percent abundance of carnivore & omnivores		X		X	X		X
Percent abundance of deep-deposit feeders	X					X	
Tolerance Score	X	X					
Tanypodini to Chironomidae percent abundance ratio		X					
Percent biomass >5 cm below the sediment-water interface			X		X		
Percent number of taxa >5 cm below the sed-iment-water interface							X

*Whenever species-specific biomass is unavailable, the abundance-based metric is used in the B-IBI calculations.

Table 4. Pollution-indicative taxa for Chesapeake Bay.

A. Tidal freshwater pollution-indicative taxa. After Alden et al. (2002).

Oligochaeta:
Limnodrilus hoffmeisteri
Tubificidae without capilliform chaetae

B. Oligohaline pollution-indicative taxa*. After Alden et al. (2002).

Polychaeta:	Oligochaeta:
Heteromastus filiformis	*Limnodrilus udekemianus*
Leitoscoloplos spp.	*Quistadrilus multisetosus*
Mediomastus ambiseta	*Telmatodrilus vejdoskyi*
Neanthes succinea	Tubificidae without capiliform chaetae
Polydora cornuta	Tubificidae with capiliform chaetae
Streblospio benedicti	*Tubificoides* spp.
Oligochaeta[1]:	Bivalvia:
Aulodrilus limnobius	*Corbicula fluminea*
Aulodrilus paucichaeta	Arthropoda: Amphipoda:
Aulodrilus pigueti	*Leptocheirus plumulosus*
Aulodrilus pluriseta	Arthropoda: Chironomidae:
Branchiura sowerbyi	*Chironomus* spp.
Haber cf. *speciosus*	*Cladotanytarsus* spp.
Ilyodrilus templetoni	*Coelotanypus* spp.
Isochaetides freyi	*Glyptotendipes* spp.
Limnodrilus cervix	*Polypedilum spp.*
Limnodrilus claparedianus	*Procladius* spp.
Limnodrilus hoffmeisteri	*Tanypus* spp.

*All species of taxa listed at the generic level are classified as pollution-indicative.
[1] Oligochaetes are identified to the lowest possible taxonomic level, but unidentifiable specimens are classified as pollution-indicative.

C. Low mesohaline through polyhaline pollution-indicative taxa*.
Modified from Weisberg et al. (1997).

Polychaeta:	Arthropoda: Chironomidae:
Eteone heteropoda	*Chironomus* spp.
Leitoscoloplos fragilis	*Cladotanytarsus* spp.
Paraprionospio pinnata	*Coelotanypus* spp.
Streblospio benedicti	*Glyptotendipes* spp.
Oligochaeta:	*Polypedilum spp.*
Tubificidae without capiliform chaetae	*Procladius* spp.
Limnodrilus hoffmeisteri	*Tanypus* spp.
Bivalvia:	
Mulinia lateralis	

*All species of taxa listed at the generic level are classified as pollution-indicative.

Table 5. Pollution-sensitive taxa for Chesapeake Bay.

A. Oligohaline pollution-sensitive taxa. After Alden et al. (2002).

Polychaeta:
Marenzelleria viridis
Arthropoda: Isopoda:
Chiridotea almyra

B. Low mesohaline through polyhaline pollution-sensitive taxa. Modified from Weisberg et al. (1997).

Anthozoa:	Bivalvia:
Ceriantheopsis americanus	*Anadara ovalis*
Polychaeta:	*Anadara transversa*
Bhawania heteroseta	*Ensis directus*
Chaetopterus variopedatus	*Macoma balthica*
Clymenella torquata	*Mercenaria mercenaria*
Diopatra cuprea	*Mya arenaria*
Glycera americana	*Rangia cuneata*
Glycinde solitaria	*Spisula solidissima*
Loimia medusa	*Tagelus divisus*
Macroclymene zonalis	*Tagelus plebeius*
Marenzelleria viridis	*Tellina agilis*
Mediomastus ambiseta	Arthropoda: Isopoda:
Nephtys picta	*Cyathura polita*
Sabaco elongatus	Arthropoda: Amphipoda:
Spiochaetopterus costarum	*Listriella clymenellae*
Spiophanes bombyx	Phoronida:
Gastropoda:	*Phoronis* spp.
Acteocina canaliculata	Echinodermata:
	Microphiopholis atra

Table 6. Species classified as carnivores-omnivores*. List based on taxa identified in Maryland and Virginia Benthic Monitoring Program data files, 1984-2000.

Anthozoa[1]	Gastropoda:
Nemertina	*Natica pusilla*
Polychaeta:	*Polinices duplicata*
Amphinomidae	*Rictaxis punctostriatus*
Arabellidae	Arthropoda: Stomatopoda:
Chrysopetallidae	*Squilla empusa*
Dorvilleidae	Arthropoda: Isopoda:
Eunicidae	Anthuridae
Glyceridae	*Chiridotea* spp.
Goniadidae	Arthropoda: Decapoda:
Hesionidae	Alpheidae
Lepidametria commensalis	Callianassidae
Lumbrineridae	*Ogyrides alphaerostris*
Malmgreniella spp.	*Pinnixa* spp.
Nephtyidae	Porcellanidae
Nereididae	Thalassinidea
Onuphidae	*Upogebia affinis*
Phyllodocidae	Arthropoda: Ephemeroptera:
Pilargidae	*Ephoron* spp.
Sigalionidae[2]	*Hexagenia* spp.
Syllidae[3]	*Potamanthus* spp.
Gastropoda:	Arthropoda: Odonata:
Aceteocina canaliculata	*Dromogomphus* spp.
Busycon canaliculatum	*Gomphus* spp.
Busycum spp.	Arthropoda: Diptera
Caecidae	Arthropoda: Chironomidae
Haminoea solitaria	Equinodermata:
Ilyanassa obsoleta	Echinoidea[4]
Nassarius trivittatus	*Mellita quinquiesperforata*
Nassarius vibex	

*All species of taxa listed at the generic, familial, and higher taxonomic levels are classified as carnivore-omnivore.

[1]All species except the epifaunal *Diadumene leucolena*.

[2]All species except the epifaunal *Pholoe minuta*.

[3]All species except the epifaunal *Odontosyllis* spp. and *Proceraea* spp.

[4]Unidentifiable specimens are classified as carnivore-ommnivores.

Table 7. Species classified as deep-deposit feeders*. List based on taxa identified in Maryland and Virginia Benthic Monitoring Program data files, 1984-2000.

Polychaeta:	Bivalvia:
Capitellidae	*Nucula proxima*
Maldanidae	*Nuculana messanensis*
Opheliidae	*Solemya velum*
Orbiniidae	*Yoldia limatula*
Pectinariidae	Hemichordata[1]:
Oligochaeta	*Balanoglossus aurantiacus*

*All species of taxa listed at the familial (polychaetes) or higher taxonomic level (oligochaetes) are classified as deep-deposit feeders.
[1]Unidentifiable specimens are classified as deep-deposit feeders.

Table 8. List of taxa and tolerance values. List based on taxa identified in Maryland and Virginia Benthic Monitoring Program data files, 1984-2000.

Taxon	Value	Taxon	Value
Oligochaeta:		Arthropoda: Chironomidae:	
Aulodrilus limnobius	5.2	*Chironomus* spp.	9.8
Aulodrilus pigueti	4.7	*Cladopelma* spp.	2.5
Aulodrilus spp.	4.7	*Cladotanytarsus* spp.	3.7
Branchiura sowerbyi	8.4	*Clinotanypus* spp.	9.1
Dero digitata	10.0	*Coelotanypus* spp.	6.2
Enchytraeidae	10.0	*Cricotopus sylvestris*	10.0
Haber cf. speciosus	2.8	*Cryptochironomus* spp.	7.3
Ilyodrilus templetoni	9.4	*Cryptotendipes* spp.	6.1
Isochaetides freyi	7.6	*Dicrotendipes neomodestus*	8.3
Limnodrilus cervix	10.0	*Dicrotendipes* spp.	7.9
Limnodrilus hoffmeisteri	9.8	*Endochironomus* spp.	7.5
Limnodrilus udekemianus	9.7	*Glyptotendipes* spp.	8.5
Lumbriculidae	7.3	*Harnischia* spp.	7.5
Slavina appendiculata	7.1	*Nanocladius* spp.	7.2
Stylaria lacustris	8.5	*Palpomyia* spp.	6.9
Tubificidae with capiliform chaetae	9.4	*Parachironomus* spp.	9.2
Tubificidae without capiliform chaetae	9.8	*Paracladopelma* spp.	6.4
Bivalvia:		*Paralauterborniella* spp.	4.8
Corbicula fluminea	6.3	*Phaenopsectra* spp.	6.8
Elliptio complanata	5.4	*Polypedilum* spp.	6.7
Sphaeridae	7.7	*Procladius* spp.	9.3
Unionidae	3.6	*Pseudochironomus* spp.	4.2
Arthropoda: Ephemeroptera:		*Rheotanytarsus* spp.	6.4
Hexagenia limbata	4.7	*Stictochironomus caffarius*	6.7
Hexagenia spp.	4.7	*Stictochironomus* spp. group	6.7
Arthropoda: Diptera:		*Tanypus neopunctipennis*	9.6
Chaoborus punctipennis	8.5	*Tanypus* spp.	9.6
Arthropoda: Chironomidae:		*Tanypus stellatus*	9.6
Ablabesmyia parajanta	7.1	*Tanytarsus* spp.	6.7

Table 9. Thresholds used to score each metric of the Chesapeake Bay B-IBI. Updated for the tidal freshwater and oligohaline habitats, and corrected from Weisberg et al. (1997) for the high mesohaline mud and polyhaline sand habitats.

	Scoring Criteria		
	5	**3**	**1**
Tidal Freshwater			
Abundance (#/m^2)	≥1050-4000	800-1050 or ≥4000-5500	<800 or ≥5500
Abundance of pollution-indicative taxa (%)	≤39	39-87	>87
Abundance of deep-deposit feeders (%)	≤70	70-95	>95
Tolerance Score	≤8	8-9.35	>9.35
Oligohaline			
Abundance (#/m^2)	≥450-3350	180-450 or ≥3350-4050	<180 or ≥4050
Abundance of pollution-indicative taxa (%)	≤27	27-95	>95
Abundance of pollution-sensitive taxa (%)	≥26	0.2-26	<0.2
Abundance of carnivores and omnivores (%)	≥35	15-35	<15
Tolerance Score	≤6	6-9.05	>9.05
Tanypodini to Chironomidae abundance ratio (%)	≤17	17-64	>64
Low Mesohaline			
Shannon-Wiener	≥2.5	1.7-2.5	<1.7
Abundance (#/m^2)	≥1500-2500	500-1500 or ≥2500-6000	<500 or ≥6000
Biomass (g/m^2)	≥5-10	1-5 or ≥10-30	<1 or ≥30
Abundance of pollution-indicative taxa (%)	≤10	10-20	>20
Biomass of pollution-sensitive taxa (%)	≥80	40-80	<40
Biomass deeper than 5 cm (%)	≥80	10-80	<10

Table 9. Continued.

	Scoring Criteria		
	5	**3**	**1**
High Mesohaline Sand			
Shannon-Wiener	≥3.2	2.5-3.2	<2.5
Abundance (#/m²)	≥1500-3000	1000-1500 or ≥3000-5000	<1000 or ≥5000
Biomass (g/m²)	≥3-15	1-3 or ≥15-50	<1 or ≥50
Abundance of pollution-indicative taxa (%)	≤10	10-25	>25
Abundance of pollution-sensitive taxa (%)	≥40	10-40	<10
Abundance of carnivores and omnivores (%)	≥35	20-35	<20
High Mesohaline Mud			
Shannon-Wiener	≥3.0	2.0-3.0	<2.0
Abundance (#/m²)	≥1500-2500	1000-1500 or ≥2500-5000	<1000 or ≥5000
Biomass (g/m²)	≥2-10	0.5-2 or ≥10-50	<0.5 or ≥50
Biomass of pollution-indicative taxa (%)	≤5	5-30	>30
Biomass of pollution-sensitive taxa (%)	≥60	30-60	<30
Abundance of carnivores and omnivores (%)	≥25	10-25	<10
Biomass deeper than 5 cm (%)	≥60	10-60	<10
Polyhaline Sand			
Shannon-Wiener	≥3.5	2.7-3.5	<2.7
Abundance (#/m²)	≥3000-5000	1500-3000 or ≥5000-8000	<1500 or ≥8000
Biomass (g/m²)	≥5-20	1-5 or ≥20-50	<1 or ≥50
Biomass of pollution-indicative taxa (%)	≤5	5-15	>15
Abundance of pollution-sensitive taxa (%)	≥50	25-50	<25
Abundance of deep-deposit feeders (%)	≥25	10-25	<10

Table 9. Continued.

	Scoring Criteria		
	5	**3**	**1**
Polyhaline Mud			
Shannon-Wiener	≥3.3	2.4-3.3	<2.4
Abundance (#/m^2)	≥1500-3000	1000-1500 or ≥3000-8000	<1000 or ≥8000
Biomass (g/m^2)	≥3-10	0.5-3 or ≥10-30	<0.5 or ≥30
Biomass of pollution-indicative taxa (%)	≤5	5-20	>20
Biomass of pollution-sensitive taxa (%)	≥60	30-60	<30
Abundance of carnivores and omnivores	≥40	25-40	<25
Number of taxa >5 cm below the sediment-water interface (%)	≥40	10-40	<10

Table 10. Abundance-based thresholds that may be substituted for biomass-based thresholds. Corrected from Weisberg et al. (1997).

	Scoring Criteria		
	5	**3**	**1**
Low Mesohaline			
Abundance of pollution-sensitive taxa (%)	≥25	5-25	<5
High Mesohaline Mud			
Abundance of pollution-indicative taxa (%)	≤20	20-50	>50
Abundance of pollution-sensitive taxa (%)	≥30	10-30	<10
Polyhaline Sand			
Abundance of pollution-indicative taxa (%)	≤10	10-40	>40
Polyhaline Mud			
Abundance of pollution-indicative taxa (%)	≤15	15-50	>50
Abundance of pollution-sensitive taxa (%)	≥40	25-40	<25

Table 11. B-IBI ranges and benthic community condition used by the Chesapeake Bay Benthic Monitoring Program.

B-IBI	Benthic Community Condition
≥3.0	Meets restoration goals
2.7-2.9	Marginal
2.1-2.6	Degraded
≤2.0	Severely degraded