

Methods and Procedures for Calculating the Chesapeake Basin-wide Index of Biotic Integrity (Chessie BIBI)

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Purpose, Scope, and Audience

Purpose

This document describes the methodology used to calculate and report the Chesapeake Basin-wide Index of Biotic Integrity (Chessie BIBI) for stream macroinvertebrates. It provides a transparent record of data handling, analytical approaches, and publication of results and data. This methodology underlies the preparation of the “Stream Health in the Chesapeake Bay Watershed, 2018 – 2023 Update” report (Buchanan et al. 2025).

Scope

This methodology document covers data acquisition, standardization, quality assurance, index calculation, results reporting, and data publication. It also details recent updates made to the Chessie BIBI analysis and their effect on the index scores and ratings. The document does not cover details of field sample collection.

Audience

This document is intended for readers of the “Stream Health in the Chesapeake Bay Watershed, 2018 – 2023 Update” report (Buchanan et al. 2025), including Chesapeake Bay Program (CBP) Stream Health Workgroup members, Chesapeake Bay Program staff monitoring progress toward the Stream Health Outcome, individuals who utilize or interpret Chessie BIBI results, external researchers seeking to document related independent analyses, and Interstate Commission on the Potomac River Basin (ICRPB) staff responsible for data management, analysis, and reporting.

1. Overview

1.1 Background

Excess nutrients, sediments, and other pollutants are impairing the Chesapeake Bay, necessitating a Total Maximum Daily Load (TMDL) or watershed “pollution diet” (U.S. Environmental Protection Agency, 2010). The Chesapeake Bay Program (CBP) partnership recognized that healthier stream ecosystems can boost TMDL pollutant reduction efforts

in the watershed while also supporting fish and wildlife and benefiting public uses such as drinking water and recreation. The partnership pledged to improve stream health and function in multiple agreements (e.g., Executive Order No.13508, 2009; Chesapeake Bay Program 2014; Chesapeake Bay Program 2025).

Benthic macroinvertebrates are commonly used as indicators of stream biological health. They represent a broad range of trophic levels and pollution tolerances, respond quickly to stressors, and have limited migration ranges and relatively short life spans. Their communities reflect integrated responses to multiple environmental stressors, some of which may be unknown or not monitored. As of 2025, over 40,000 stream macroinvertebrate samples have been collected in the Chesapeake watershed by multiple federal, state, local, and citizen monitoring programs. Approximately 70% of samples were collected by the six states within the Chesapeake Bay watershed: Virginia, West Virginia, Maryland, Delaware, Pennsylvania, and New York. Assessments of each state's data are reported to U.S. Environmental Protection Agency (EPA) in accordance with the Clean Water Act (CWA) Section 303(d) which requires states to list waters they deem impaired. The assessments are unfortunately not comparable because the states use different methods to determine impairment (metrics, indexes, impairment thresholds, assessment units). Sharp differences can be seen across jurisdictional boundaries (e.g., Wolf 2008).

Most macroinvertebrate monitoring programs in the region use similar field and laboratory methods, and careful comparisons (e.g., Astin 2006) and paired site studies (e.g., Vølstad et al. 2003) demonstrate the raw taxonomic counts can be merged and integrated. Stream macroinvertebrate indexes have been created for parts of the watershed from the raw data, albeit after carefully merging and harmonizing data from various monitoring programs (e.g., Maxted 2000; Astin 2007). Rotational sampling strategies of the watershed's monitoring programs prevent annual estimates, but full coverage of the watershed can be achieved in 6-year intervals.

The Chessie BIBI, or Chesapeake basin-wide index of biotic integrity, is a family-level macroinvertebrate index developed specifically for the Chesapeake watershed (Foreman 2008; Buchanan et al. 2011; Smith et al. 2017a, b). It is a reference-based, multi-metric index that follows a general index development strategy supported in the literature (e.g., Barbour et al. 1996; Gerritsen et al. 2000; Pond et al. 2011). The raw data are obtained from federal, state, local, and citizen monitoring programs in periodic Data Calls issued by the Interstate Commission on the Potomac River Basin (ICPRB), with support from the CBP Data Center. The index derived from the processed data meets the CBP partnership's need for an indicator that can measure progress in achieving watershed goals for stream health. It has proven useful in investigating macroinvertebrate responses to anthropogenic

stressors and climate change in the Chesapeake watershed (e.g., Buchanan et al. 2013; Maloney et al. 2018, 2020, 2021). Appendix A provides a timeline of index development and early uses.

1.2 Overview of Workflow

ICPRB follows a structured workflow to assess stream health across the Chesapeake watershed using the Chessie BIBI index. The process begins with data management, including data acquisition through a data call, standardization of received data, quality assurance and control, determination of relevant geospatial parameters, taxonomic standardization, and formatting of macroinvertebrate, water quality, and habitat data.

Prepared datasets are then used to calculate the Chessie BIBI index scores, which involves filtering the data, calculating and scoring biological metrics, repeating the analysis 100 times, and assigning a comparable narrative rating (excellent, good, fair, poor, very poor) to each sampling event. The final Chessie BIBI index scores and ratings are then used to estimate the percentage of healthy streams in the Chesapeake watershed, and maps of the results are produced.

Finally, technical results are communicated in a final report, and plain-language summaries are published on the ICPRB website (<https://www.potomacriver.org/focus-areas/aquatic-life/macroinvertebrates/chessie-bibi-index-for-streams/>). The processed data and Chessie BIBI results are published via the CBP's Data Hub (<https://datahub.chesapeakebay.net/>) and a Chessie BIBI Analysis Toolkit are also made available to the public (https://archive.chesapeakebay.net/?prefix=LR/Chessie_BIBI_Analysis_Toolkit_December_2025/).

In 2025, updates to the Chessie BIBI methodology were implemented. These changes are documented in section 4 of this document, along with an assessment of the effects of these updates on the index results.

1.3 Personnel Roles and Responsibilities

ICPRB Data Manager - The Habitat and Living Resources Data Manager for the Chesapeake Bay Program (hereafter “Data Manager”) is responsible for data acquiring, standardizing, verifying, and preparing all data for analysis and publication.

ICPRB Data Analysts - ICPRB's Aquatic Ecologist II and Director Emerita, Program Operations are currently responsible for performing the Chessie BIBI analyses, writing the report, and evaluating updates to the Chessie BIBI methodology.

ICPRB Communications Team - ICPRB's Director of Communication and Education and Outreach Program Manager are responsible for providing editorial review of the final report, preparing a press-release of the findings, and updating the ICPRB Chessie BIBI webpage.

Stream Health Workgroup Chairs - The co-chairs of the Chesapeake Bay Program's Stream Health Workgroup are responsible for providing technical oversight and reviewing the interpretation of assessment results.

1.4 Reporting Schedule

Progress in attaining the stream health outcome(s) is reported by ICPRB to the CBP Stream Health Workgroup and the data providers in 6-year intervals after data acquired in each Data Call have been processed. This occurs typically two years after the end of each 6-year interval. For example, the Data Call for the 2024 – 2029 interval will be issued in 2030 and a finalized dataset and report produced in 2031. This methodology document will be updated at the same time and will discuss any changes to the data acquisition, processing, and analysis procedures.

2. Data Management

The Chessie BIBI operates on a recurring 6-year analysis and data call cycle. During each cycle, monitoring agencies are asked to submit stream monitoring data collected over the most recent six-year interval, as well as any updated or additional data from earlier intervals that were not included in previous submissions.

Three primary types of data are requested from monitoring agencies:

1. Stream macroinvertebrate data (taxonomic count data)
2. Water quality data
3. Habitat assessment scores

2.1 Data Call and Acquisition

The Chessie BIBI index is derived from macroinvertebrate samples routinely collected with kick nets by federal, state, county, and volunteer monitoring programs in non-tidal streams in the Chesapeake watershed.

Before initiating a new data call, the Data Manager reviews the Data Provider Contact List (Appendix B) used during the previous data call. This review is conducted collaboratively with ICPRB Data Analysts and the Stream Health Workgroup Chairs to confirm that all agency contacts, partner organizations, and responsible staff are correct. Any additions,

removals, or updates to contact information are incorporated into the working copy of the list prior to distributing the data call.

To initiate a new data collection cycle, the Data Manager prepares and sends a formal data call email to the data providers, which is reviewed and co-signed by the Stream Health Workgroup Chairs. The email includes a summary of the purpose and scope of the data call, submission deadlines, and instructions for submitting files (Appendix C). An Excel Workbook is attached to the email (“ChessieBIBI_2024DataCallGuidance.xlsx”, available in the [Chessie BIBI Analysis Toolkit](#)) which contains (1) a table identifying the required and desired fields for submission (Table 1), (2) a table summarizing the number of sampling events currently stored in the database, organized by data provider and by year, and (3) lookup tables for each data field to indicate CBP code names and descriptions. (e.g., method codes, gear codes, parameter names, units).

The Data Manager tracks receipt of the submitted data files, downloads data from online portals where necessary, and collects field manuals, Standard Operating Procedures (SOPs), Quality Assurance Project Plans (QAPPs), and other supporting documentation.

Table 1. Required data fields requested from monitoring agencies.

Data type	Required Data Field
Event	Station name
	Sample date
	Sample start time (if available)
	Organization/agency providing data
	Name of monitoring program
	Latitude (preferably in decimal degrees)
	Longitude (preferably in decimal degrees)
	Datum (e.g., NAD83)
	Site type code
Taxonomic	Station name
	Sample date
	Sample type
	Biological sample number (e.g., 1, 2, 3, etc.)
	Field gear method
	Taxonomic serial number (TSN)
	Latin name
	Species code (internal agency code)
	Life stage (if available)
	Biological collection & analysis method
Count	
Water Quality	Station name
	Sample date
	Sample type

Data type	Required Data Field
Habitat	Water quality sample number
	Sample depth
	Parameter name
	Parameter value
	Parameter units
	Qualifier (indicator of a possible problem)
	Water Quality Method
Habitat	Station name
	Sample date
	Habitat Parameter
	Habitat Value (usually a score of 0 - 20)
	Habitat Method

2.2 Data Standardization

The Data Manager is responsible for putting all datasets into a consistent and analysis-ready format. This includes:

- Standardizing data structures and field names.
- Converting categorical values to standardized codes (e.g., gear types, method codes, water quality and habitat parameters, defined in Appendix D).
- Standardizing time and date formats.
- Ensuring units are consistent across datasets.
- Constructing a UNIQUE_ID for each sampling event by concatenating **DataProviderCode, Latitude, Longitude, SampleDate,** and **SampleReplicateNumber**, where Latitude and Longitude are always formatted to four decimal places (e.g., SHEN_38.7450-78.2818_2016-05-04_S1).

To identify each sample location consistently across years, we use LATLON4, defined as latitude and longitude rounded to four decimal places and concatenated. Station names may change over time while the physical location remains the same, and LATLON4 provides a stable identifier in most cases. However, if a station’s reported coordinates shift, LATLON4 may no longer reliably represent a single intended site. Section 4.2 details the effects of employing LATLON4 in the analysis.

2.3 Quality Assurance and Quality Control (QA/QC)

The dataset undergoes a comprehensive quality verification process to ensure accuracy. This includes:

- Checking for missing and impossible values (e.g., negative counts).

- Checking for duplicate records (including those duplicated across different agencies).
- Validating taxonomic names against the accepted nomenclature according to the Integrated Taxonomic Information System (ITIS; www.itis.gov).
- Verifying that station coordinates fall within expected hydrologic boundaries and match provided stream names.
- Checking that station coordinates submitted for the same site are consistent year-to-year.
- Reviewing coordinates ending in repeated zeros to identify potential rounding or truncation errors.

Data standardization and QA/QC procedures are performed using R (version 4.4.1; R Core Team, 2024) and documented throughout the R scripts.

2.4 Geospatial Parameter Determination

Each sampling event is assigned key geospatial attributes required for Chessie BIBI scoring and regional analyses. ArcGIS Pro (version 3.4.3) is used to spatially join each sampling location to the appropriate hydrologic and regional layers.

2.4.1 Strahler Stream Orders

Strahler Stream Order data are obtained from NHDPlusFlowLineVAA (value-added attribute) tables of the NHDPlus High Resolution dataset (NHDPlus HR; U.S. Geological Survey 2022). Flowline attributes are first joined to corresponding NHDPlus catchment polygons, and sampling stations are then joined to these catchments.

2.4.2 ICPRB Bioregions

Sampling events are assigned bioregions by spatially joining sample locations to the ICPRB Bioregion shapefile (available in the [Chessie BIBI Analysis Toolkit](#)). The twelve bioregions of the Chesapeake watershed were delineated by Smith et al. (2017a) using hydrologic subregions, physiographic provinces, and level III ecoregions (Omernik 1987; Woods et al. 1999) (Figure 1).

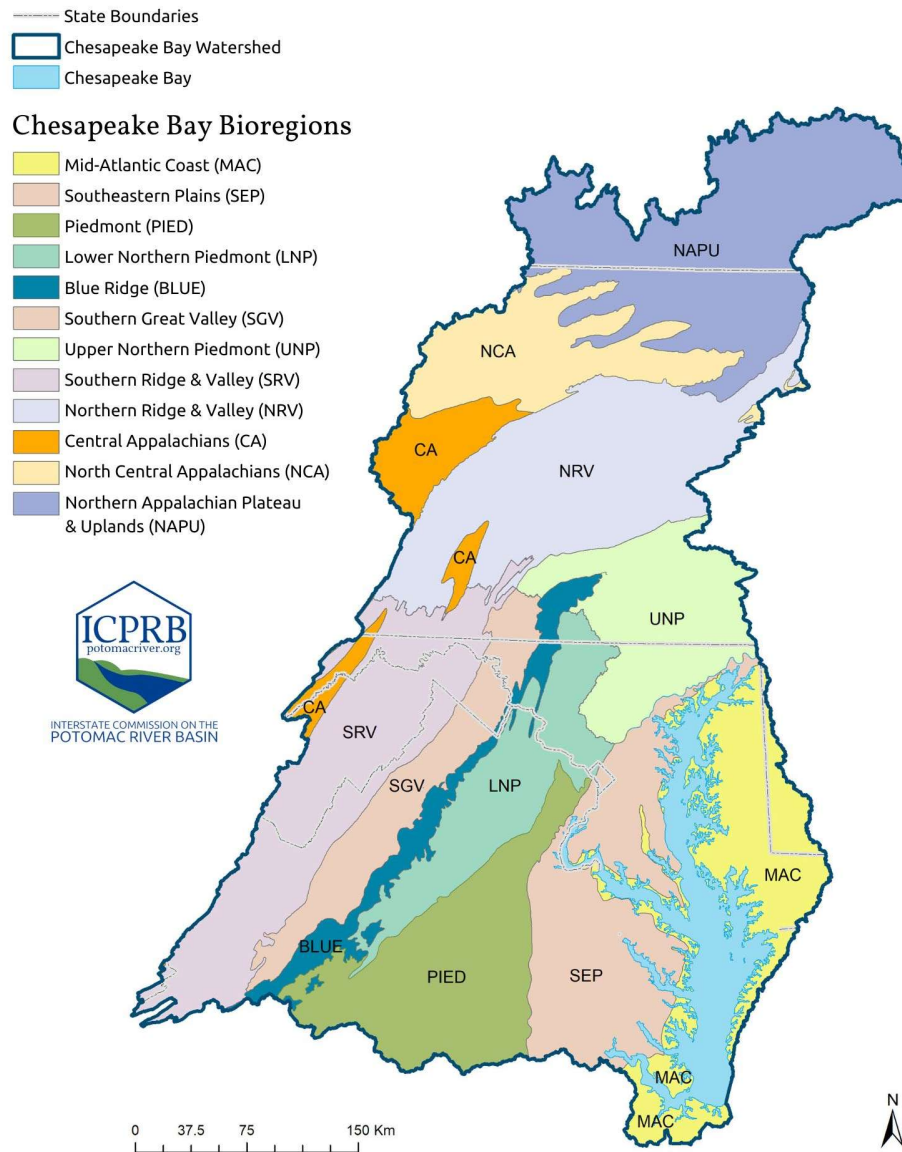


Figure 1. Chesapeake watershed bioregions for stream macroinvertebrates. Blue Ridge, BLUE; Central Appalachians, CA; Lower Northern Piedmont, LNP; Mid-Atlantic Coast Plain, MAC; Northern Appalachian Plateau and Uplands, NAPU; North Central Appalachians, NCA; Northern Ridge and Valley, NRV; Piedmont, PIED; Southeastern Plain, SEP; Southern Great Valley, SGV; Southern Ridge and Valley SRV; Upper Northern Piedmont, UNP.

2.4.3 HUC12 and NHDPlus Catchments

Sampling events are spatially joined to HUC12 watersheds and NHDPlusCatchment polygons. HUC12 boundaries are acquired from the Watershed Boundary Dataset (WBD) feature class and NHDPlus catchment polygons (NHDPlusID) are obtained from the NHDPlusCatchment polygon feature class, both accessed from the NHDPlus High Resolution dataset.

2.4.4 Tidal Stations

Station coordinates are spatially joined to the Chesapeake Bay 92-segment tidal segmentation feature layer (U.S. Environmental Protection Agency 2010) to determine which sampling events fall within tidal waters. Stations intersecting with any tidal polygon are coded as tidal; all others are classified as non-tidal. This designation is required to exclude tidal stations from subsequent BIBI analyses, because the index is applicable only to non-tidal streams.

2.5 Taxonomic Information Standardization

Calculation of the Chessie BIBI requires (1) consistent and standardized taxonomy across datasets and (2) taxonomic attributes, or traits, defined for each taxon. The Master Taxonomic File (hereafter, Master Taxa File) is a reference table used to ensure taxonomic consistency across all macroinvertebrate data ingested into the Chessie BIBI analysis script. This file contains authoritative data for each taxon observed in the datasets, including:

- Taxonomic name and corresponding Taxonomic Serial Number (TSN).
- Full hierarchical taxonomy (Phylum, Subphylum, Class, Subclass, Order, Suborder, Family, Subfamily, Tribe, Genus, Species).
- Functional attributes at the Family level:
 - Average Score Per Taxon (ASPT)
 - Tolerance Value (BIBI_TV)
 - Habit Category (BIBI_HABIT)
 - Functional Feeding Group Category (BIBI_FFG)

An initial Master Taxa File was established during index development (Smith et al. 2017a). Taxonomic names, TSNs, and hierarchies were verified against the ITIS database, and average score per taxon, tolerance values, habit, and functional feeding group assignments were compiled from available literature sources.

Some entries in the Master Taxa File are intentionally “rolled up” to a higher taxonomic level to accommodate inconsistent taxonomic resolution provided by data submitters.

Bivalvia, Gastropoda, Clitellata, and Trepaxonemata taxa are rolled-up to the class-level, and Collembola, Lepidoptera, and Neophora taxa are rolled-up to the order-level. Rolled-up taxonomic groups were established during index development (Smith et al. 2017a).

When new taxa appear in submitted datasets, the Data Manager adds them to the Master Taxa File by verifying the taxonomic name, TSN, and hierarchy with the ITIS database, and assigning family-level attributes from Merritt et al. (2019). If a TSN is not available for a given taxonomic name, a seven-digit “BAY number” (e.g., BAY0001) is instead assigned. BAY numbers are unique identifiers maintained and stored within the Chesapeake Environmental Data Repository (CEDR) to ensure consistent reference across datasets.

The Master Taxa File is joined to the analysis dataset before ingestion into the Chessie BIBI program and is available in the [Chessie BIBI Analysis Toolkit](#).

2.6 Data Formatting for the Chessie BIBI Analysis Script

The Data Manager compiles and formats all datasets to meet the input requirements of the Chessie BIBI analysis script. The Comma Separated File (.CSV) must follow the standardized column structure shown in Table 2. Detailed instructions for generating this file, along with a template, are included in the “Directions and Scripts for Calculating the Chessie BIBI_Dec2025.Rmd” R-Markdown file in the [Chessie BIBI Analysis Toolkit](#).

Table 2. Standardized table schema of the Chessie BIBI input .CSV file.

Column Name	Description	Format
UNIQUE_ID	The unique monitoring event identifier	integer or alphanumeric
STATION_ID	The station name from which the sample was collected	alphanumeric
SAMPLE_DATE	Date that the sample was collected	date (MM/DD/YYYY)
MONTH	Month that the sample was collected	integer
SAMPLE_TIME	Time that the sample was collected	time (HH:MM)
STRAHLER_STREAM_ORDER	Strahler stream order	integer
ICPRB_BIOREGION_ID	Bioregion used in Chessie BIBI calculations	text
G_METHOD	Gear Code	integer
BIO_METHOD	The method used to collect the biological sample.	alphanumeric
TSN_FINAL	Taxonomic Serial Number (TSN) of the taxon	alphanumeric
REPORTING_VALUE	Number of individuals of a given taxa counted in the sample	integer
FINAL_ID	Taxon name, identified to the lowest taxonomic resolution	text
PHYLUM	Taxonomic classification	text
SUBPHYLUM	Taxonomic classification	text
CLASS	Taxonomic classification	text
SUBCLASS	Taxonomic classification	text

Column Name	Description	Format
ORDER	Taxonomic classification	text
SUBORDER	Taxonomic classification	text
FAMILY	Taxonomic classification	text
SUBFAMILY	Taxonomic classification	text
TRIBE	Taxonomic classification	text
GENUS	Taxonomic classification	text
SPECIES	Taxonomic classification	text
ASPT	Modified Average Score Per Taxon (ASPT) assigned from the literature	integer
BIBI_TV	Tolerance Value (TV) assigned from the literature	integer
BIBI_HABIT	Habit assigned from the literature	text
BIBI_FFG	Functional Feeding Group (FFG) assigned from the literature	text

2.7 Water Quality and Habitat Data

Water quality and habitat data are collected alongside macroinvertebrate data but are not used directly in the calculation of the Chessie BIBI. Instead, these data inform index development and refinement and are published alongside taxonomic data and Chessie BIBI results to provide additional ecological context. All water quality and habitat data are quality-assured and processed by the Data Manager.

3. Chessie BIBI Index Calculation

The Chessie BIBI index is calculated by ICPRB Data Analysts from the standardized input file containing raw macroinvertebrate count data prepared by the Data Manager (described in Section 2). The workflow includes dataset preparation, index computation, estimation of % healthy streams, and mapping results. Dataset preparation and index calculation are executed through the Chessie BIBI R-script (available in the [Chessie BIBI Analysis Toolkit](#)). The R-script is extensively documented, including step-by-step comments within the code and an accompanying README file. Additional methodological detail is provided in Smith et al. (2017a) which describes index development, and Buchanan et al. (2023, 2025), which offers additional clarification and supporting analyses building on that work.

3.1 Dataset Preparation

Data preparation ensures that the macroinvertebrate samples used in the Chessie BIBI analysis meet the minimum biological, seasonal, geographical, and methodological criteria required for valid index computation.

3.1.1 Taxonomic Criteria

Taxa counted by only a few monitoring programs are excluded to harmonize the data and remove a potential source of bias in the index (Smith et al. 2017a). For the analysis data set, any taxon not classified within the phyla Annelida, Arthropoda, Mollusca, or Platyhelminthes are excluded. At the subphylum-level, taxa are excluded if they are not classified as Clitellata, Crustacea, Hexapoda, or Rhabditophora; if no subphylum-level exists within the ITIS database but the taxon could be classified within the four specified phyla, the taxon is not excluded from the analysis. At the class-level, taxa that are classified as Branchiopoda, Maxillopoda, and Ostracoda are excluded. Additionally, taxa within the families Gerridae, Hebridae, Velliidae, Hydrometridae, and Salidae are excluded from the analysis because they are classified as skimmer taxa. Skimmer taxa are considered semi-aquatic because they live on the surface of the water and are not directly associated with the benthic macroinvertebrate communities. Finally, taxa of the order Hymenoptera are excluded because aquatic Hymenoptera are often small, parasitic organisms that may easily go unnoticed during processing. Carter and Resh's (2013) review of state agency benthic macroinvertebrate indices indicated that a similar list of taxa are excluded by one or more agencies in the United States.

3.1.2 Minimum Count Threshold

Macroinvertebrate samples with counts of fewer than 70 individuals are removed to prevent skewing metric calculations in the analysis dataset. This threshold was determined as the minimum acceptable deviation from standard sample counts used by participating agencies and programs ($n = 100$) (Smith et al. 2017a).

3.1.3 Seasonal Criteria

Samples collected in winter (December – February) are excluded, because the index was developed using data collected in spring, summer, and autumn (Smith et al. 2017a).

3.1.4 Strahler Stream Order Criteria

Samples from streams with a Strahler Stream Order (SSO) of 6 or higher, as mapped at high resolution (1:24,000 scale), are excluded from the analysis dataset. This represents a change from previous Strahler order criteria due to improvements in mapping resolution, which have altered stream order designations. Further analysis and discussion of this adjustment is provided in section 4.3

3.1.5 Sampling Method and Gear Criteria

Sampling protocols and gear types are evaluated and filtered before the analysis. The method protocols are reviewed (Appendix D) and methods designated for sampling in

pools are excluded. Only samples collected with a kick-net or a similar procedure were included in the analysis dataset (e.g., D-Frame Net, Rectangular Dip Net, Kick Net, Kick Seine, Post-Hole Digger, and Slack Sampler). Hester Dendy Multi-Plate samplers, Surber Sampler, Petite Ponar Grab, Box Core Grab, Portable Invertebrate Box Sampler, Hand-Picked samples, and unspecified collection methods were excluded from the analyses.

3.2 Chessie BIBI Score Calculation

The following section describes how Chessie BIBI scores are generated for benthic macroinvertebrate samples. Briefly, a suite of biological metrics is calculated for each sample, and the metrics are then scored per bioregion. Metrics are selected that reliably discriminate between reference and degraded conditions (Smith et al. 2017). The metric calculation and scoring is repeated 100 times to account for slight variations in taxa that may occur during the rarefaction step, and the mean of those 100 scores is the Chessie BIBI score. A narrative rating is then assigned to each sample (i.e., Excellent, Good, Fair, Poor, Very Poor) to make scores comparable across bioregions. Then, the percentage of healthy streams are calculated, and results are mapped.

3.2.1 Metric Calculation, Metric Scoring

Biological metrics are calculated for each unique sampling event using rarefied data for richness-based metrics and non-rarefied data for percentage-based metrics. A list of the bioregion-specific metrics can be found in Appendix E. Rarefaction standardizes counts to 100 organisms to account for differences in sample size. For each bioregion, five or more family-level macroinvertebrate metrics capable of strongly distinguishing least-disturbed reference (REF) from severely degraded (SEV) conditions are used to create the index. The REF and SEV conditions for each bioregion were determined during index development using three water quality parameters (specific conductivity, dissolved oxygen, pH) and five to eight stream habitat metrics (Appendix E)

Each metric is scored using a limited gradient or “broken stick” approach. Ceiling and floor values were established during index development using the metric’s median value in REF and the best separation point (BSP) (Appendix E, Table 15, Smith et al. 2017a). Values greater than the REF median (50th %ile) are assigned a score of 100 in metrics that increase with improving conditions (or 0 in metrics that increase with degrading condition). Intermediate values are scored proportionally on a linear slope determined by the median and the best separation point (BSP), with BSP scoring 50 (Figure 2). The BSP is the metric value where REF and SEV are equally likely to be identified (balanced discrimination efficiency).

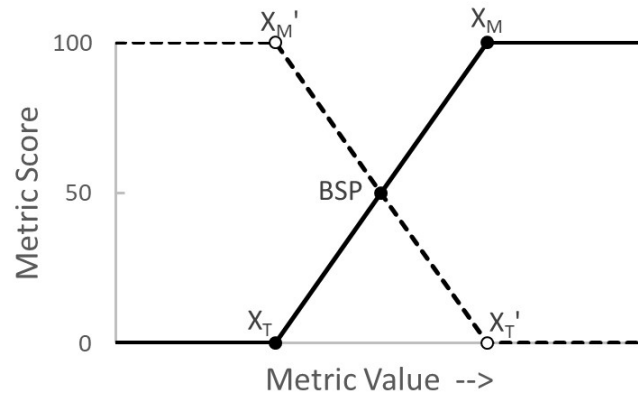


Figure 2. Broken Stick scoring thresholds for metrics. Generalized approach for scoring macroinvertebrate metrics. BSP is the “best separation point” between metric values in reference and degraded stream conditions, representing a balanced discrimination efficiency; X_M and X_T are the scoring ceiling and floor for metrics that decrease with stream degradation (e.g., %EPT); X_M' and X_T' are the scoring ceiling and floor for metrics that increase with increasing stream degradation (e.g. %Tolerants). X_M and X_M' are the 50th percentiles of the metric’s reference distribution.

3.2.2 Chessie BIBI Score Calculation

The Chessie BIBI index score for each sample is calculated as the mean of the metric scores within each bioregion.

3.2.3 Repeated BIBI Analysis Runs

To account for variability introduced during rarefaction, the Chessie BIBI analysis is repeated 100 times for each sample. Each run generates a slightly different assemblage of taxa due to the random selection of rare taxa and thus generates slightly different scores.

Summary statistics of the 100 runs are calculated, including the median, mean, and standard deviation for each sampling event. Subsequent analyses are based on the mean of the 100 runs; however, section 4.4 evaluates the impact of using median scores.

3.2.4 Narrative ratings

To enable comparisons across bioregions, the final (average of 100 runs) index scores for each sampling event are assigned a narrative rating of excellent, good, fair, poor, or very poor based on percentiles of the distribution of index scores at reference sites in each bioregion. An index score above the 50th percentile of the scores for a bioregion’s reference sites is rated excellent (E); an index score between the 25th and 50th percentile is good (G); between the 10th and 25th percentile, fair (F); below the 10th percentile, poor (P); and below half the value of the 10th percentile, very poor (VP). For purposes of CBP reporting, scores rated as E, G, and F indicate healthy stream macroinvertebrate populations. Table 4 lists the bioregion-specific index scores that are currently used as thresholds to determine narrative ratings (from Table 5 in Smith et al. 2017a).

All sampling events included in the analysis receive a bioregion-specific Chessie BIBI score and a narrative rating. Geospatial information associated with each site, such as bioregion, NHDPlusID, and SSO, can then be used to investigate or filter the results. If BIBI scores are subsequently averaged (e.g., replicates, multiple visits to the site), the bioregion-specific thresholds are applied to the average score to determine the narrative rating of the average (Table 4).

Table 4. Bioregion-specific Chessie BIBI index scores used to assign the five narrative ratings (from Table 5 in Smith et al. 2017a). Very poor, VP; poor, P; fair, F; good, G; excellent, E. See Figure 1 for bioregion names.

Bioregion	VP	P	F	G	E
BLUE	<30.9	30.9 - <61.7	61.7 - <82.2	82.2 - <92.1	≥92.1
CA	<27.9	27.9 - <55.8	55.8 - <69.5	69.5 - <78.6	≥78.6
LNP	<35.2	35.2 - <70.3	70.3 - <80.2	80.2 - <91.3	≥91.3
MAC	<22.7	22.7 - <45.4	45.4 - <63.2	63.2 - <76.8	≥76.8
NAPU	<17.9	17.9 - <35.9	35.9 - <47.4	47.4 - <61.9	≥61.9
NCA	<15.7	15.7 - <31.5	31.5 - <56.3	56.3 - <78.7	≥78.7
NRV	<19.1	19.1 - <38.2	38.2 - <50.8	50.8 - <75.0	≥75.0
PIED	<30.3	30.3 - <60.6	60.6 - <73.2	73.2 - <81.8	≥81.8
SEP	<16.3	16.3 - <32.6	32.6 - <56.7	56.7 - <83.9	≥83.9
SGV	<29.9	29.9 - <59.9	59.9 - <66.0	66.0 - <76.5	≥76.5
SRV	<21.6	21.6 - <43.2	43.2 - <58.0	58.0 - <71.9	≥71.9
UNP	<31.3	31.3 - <62.6	62.6 - <69.9	69.9 - <80.5	≥80.5

3.3 Estimation of Healthy Stream Percentages

Chessie BIBI scores are analyzed in 6-year intervals to accommodate the rotational sampling schedules of the major monitoring programs and obtain full coverage of the watershed in each interval. The 6-year intervals analyzed to-date are 2000–2005, 2006–2011, 2012–2017, and 2018–2023. In each interval, there is typically only one sampling event at a location (LATLON4). At locations sampled multiple times on the same date (replicates), the Chessie BIBI index scores are calculated for each sample and the scores averaged. Then, if locations are sampled multiple times within the same period (repeat, annual), their scores are also averaged. Averaged scores are assigned to the bioregion-appropriate rating according to the thresholds in Table 4. At this stage, tidal stations are also removed from the results.

In each 6-year interval, sampled locations are grouped by HUC12, and their Chessie BIBI ratings are weighted by equal portions of the HUC12's total non-tidal stream length. For example, in a HUC12 with four sampled locations in the 2000–2005 interval, each location's rating is weighted by ¼ of the HUC12's total stream kilometers. By proportionally weighting the ratings, the spatial diversity evident in the ratings is preserved. The rating of a mean score would not do this. The approach assumes each site is representative of a roughly equal portion of its HUC12's stream length. Analysis shows multiple sampling locations *within* individual HUC12s are for the most part randomly distributed. This is

because state monitoring programs typically use probabilistic or systematic sampling designs to select many of their sites for CWA 303d reporting purposes. Thus, the assumption has merit. Sample density is higher in HUC12s around large metropolitan areas due to overlapping monitoring programs and higher in the HUC12s of some states due to more intensive monitoring programs. Proportionally weighting the results in each HUC12 also prevents heavily sampled areas from overwhelming sparsely sampled areas.

HUC12s are used here as a framework for grouping the results because they are very evenly dispersed across the Chesapeake watershed. Despite the irregular shapes of many HUC12 polygons, the distribution of their centroids receives an extremely high z-score of 11.64 ($p < 0.001$) from the Average Nearest Neighbor Analysis tool in ArcGIS Pro (version 3.5.4). There are 1971 HUC12s with freshwater streams in the watershed and they are roughly the same size, averaging 117.7 km² with an interquartile range 72.9 – 153.3 km². The HUC12 boundaries provide a systematic arrangement of cells with which to group the rating results while the proportional weighting within each HUC12 (above) preserves the diversity evident in the ratings in each cell and prevents bias caused by unequal sample densities in the cells.

Estimating the percentage of healthy Chesapeake streams with this HUC12-based framework is predicated on the *sampled* HUC12s also being randomly or evenly distributed in the Chesapeake Bay watershed. The assumption was tested in November 2025 with the ArcGIS Pro (version 3.4.3) Average Nearest Neighbor tool using centroids of the sampled HUC12s from the 2024 Data Call. Sampled HUC12s were not randomly or evenly distributed in the data earlier than 2000, but were very evenly dispersed in the three subsequent intervals, and randomly distributed and tending towards evenly dispersed in the last one (Table 5).

Table 5. Spatial distribution of sampled HUC12s, by interval as determined with ArcGIS Pro (version 3.4.3) Average Nearest Neighbor tool. NNR, nearest neighbor ratio. Tidally influenced locations and large rivers (HR_SSO = 6 – 8) are removed from the analysis.

Interval	NNR	z-Score	p-Value	Distribution
Before 2000	0.965	-1.951	0.051	Clumped
2000–2005	1.035	2.308	0.021	Evenly Dispersed
2006–2011	1.058	4.115	<0.001	Evenly Dispersed
2012–2017	1.036	2.334	0.020	Evenly Dispersed
2018–2023	0.978	-1.309	0.190	Random -> Dispersed

To generate an estimate of the percentage of stream lengths supporting each rating in the Chesapeake watershed (%E, %G, %F, %P, %VP), the proportionally weighted ratings of all the sampled HUC12s in the Chesapeake watershed (Figure 3A) are summed by rating and interval (Figure 3B) and the summed weighted ratings divided by the sum of the stream lengths of all sampled HUC12s in that interval (Figure 3C). The sum of the percentages of the E, G, and F ratings is used to estimate the number of kilometers supporting healthy stream populations across the entire watershed (%_nEGF). Non-tidal stream lengths are obtained from the 1:24,000 scale NHDPlus High Resolution dataset (NHDPlus HR; U.S. Geological Survey 2022). Non-tidal stream lengths totaled 232,017 kilometers (144,168 miles) for the Chesapeake watershed.

A					Count of each rating					HUC12-based weighted rating				
For HR_SSO 1 - 5					E	G	F	P	VP	E	G	F	P	VP
PERIOD	HUC12	Total Stream Length (km)	Count	Weight										
2_PreBaseline	020501010202	91.59316	1	91.59316			1				91.593			
2_PreBaseline	020501010302	103.8576	1	103.8576				1					103.86	
2_PreBaseline	020501010604	164.8064	1	164.8064		1					164.81			
2_PreBaseline	020501010801	110.2688	1	110.2688		1					110.27			
2_PreBaseline	020501010802	141.3801	3	47.1267		2	1				94.253	47.127		
2_PreBaseline	020501010803	142.901	4	35.72525		2	2				71.451	71.451		
2_PreBaseline	020501010901	42.55824	1	42.55824				1						42.558
2_PreBaseline	020501010908	167.5214	1	167.5214		1					167.52			
2_PreBaseline	020501010909	59.287	1	59.287	1						59.287			
2_PreBaseline	020501060601	44.35914	1	44.35914	1						44.359			
2_PreBaseline	020501060602	179.2	9	19.91111	5	2		2			99.556	39.822		39.822
2_PreBaseline	020501060701	89.82092	3	29.94031					3		89.821			
2_PreBaseline	020501060702	67.51175	1	67.51175	1						67.512			

B		Sum of all weights	E	G	F	P	VP
Pre-Baseline	2000-2005	146011.633	24485	29853	28214	36483	26977
Baseline	2006-2011	166760.761	39926	34332	26992	40502	25010
First	2012-2017	145544.059	39113	30444	25625	30868	19494
Second	2018-2023	117989.842	33562	26477	18836	23064	16051

C		%EGF	E	G	F	P	VP
Pre-Baseline	2000-2005	56.5%	16.8%	20.4%	19.3%	25.0%	18.5%
Baseline	2006-2011	60.7%	23.9%	20.6%	16.2%	24.3%	15.0%
First	2012-2017	65.4%	26.9%	20.9%	17.6%	21.2%	13.4%
Second	2018-2023	66.8%	28.4%	22.4%	16.0%	19.5%	13.6%

Figure 3. Illustration of calculation steps. E, G, F, P, and VP are the index ratings (excellent, good, fair, poor, very poor). A, the final period-specific rating of each location (LATLON4) in a HUC12 is weighted by an equal portion of the total stream length in the HUC12; B, the stream length-weighted ratings in each period are summed for the entire watershed; C, sums are divided by the sum of all weighted ratings in the period. %EGF is the percent of stream lengths estimated to be “healthy” (i.e., E, G, and F) in the Chesapeake Bay watershed, by period.

3.4 Mapping the Chessie BIBI Ratings

The proportional weighting approach used to estimate the percentage of healthy streams in the Chesapeake Bay watershed (section 3.3) does not lend itself to mapping. To create a map of the watershed's stream conditions for illustration purposes, the scores of all locations in a HUC12-bioregion polygon are averaged by interval and the average score is given an appropriate bioregion-specific rating. Locations are grouped by HUC12 and bioregion because, although the same percentiles of each bioregion's REF populations are used as thresholds to assign a rating, the Chessie BIBI scores that are those bioregion-specific rating thresholds are different (Table 4). Thus, index scores from different bioregions cannot be averaged and the average assigned a rating.

A color gradient is used to indicate stream condition (E, G, F, P, VP) in each HUC12-bioregion polygon. A colored point is placed in a polygon if it has only one sampling location; the entire polygon is shaded if it has two or more locations. HUC12-bioregion polygons are colored using a red to green color ramp, as well as an accessible color scheme (Table 6). Points (size 7 pt., outline 0.5 pt. and colored Grey 70%) follow the same color schemes. See Figure 4 for an illustration.

Table 6. Mapping color assignments for each narrative rating type under the standard and accesible color schemes.

Narrative Rating	Polygon Fill / Outline	
	Standard Colors	Accessible Colors
Excellent	Fir Green / Medium Olivenite	R105 G109 B72 / Grey 60%
Good	Macaw Green / Tarragon Green	R161 G169 B28 / Dark Olivenite
Fair	Solar Yellow / Light Sienna	R252 G227 B151 / Grey 60%
Poor	Electron Gold / Raw Umber	Blue Grey Dust / Medium Azul
Very Poor	Poinsettia Red / Tuscan Red	Dark Navy / Grey 60%

Other layers that are displayed in the maps are the Chesapeake Bay watershed outline, the Chesapeake Bay waterbody, unfilled HUC12-bioregion polygons, and seventeen cities spread across the watershed.

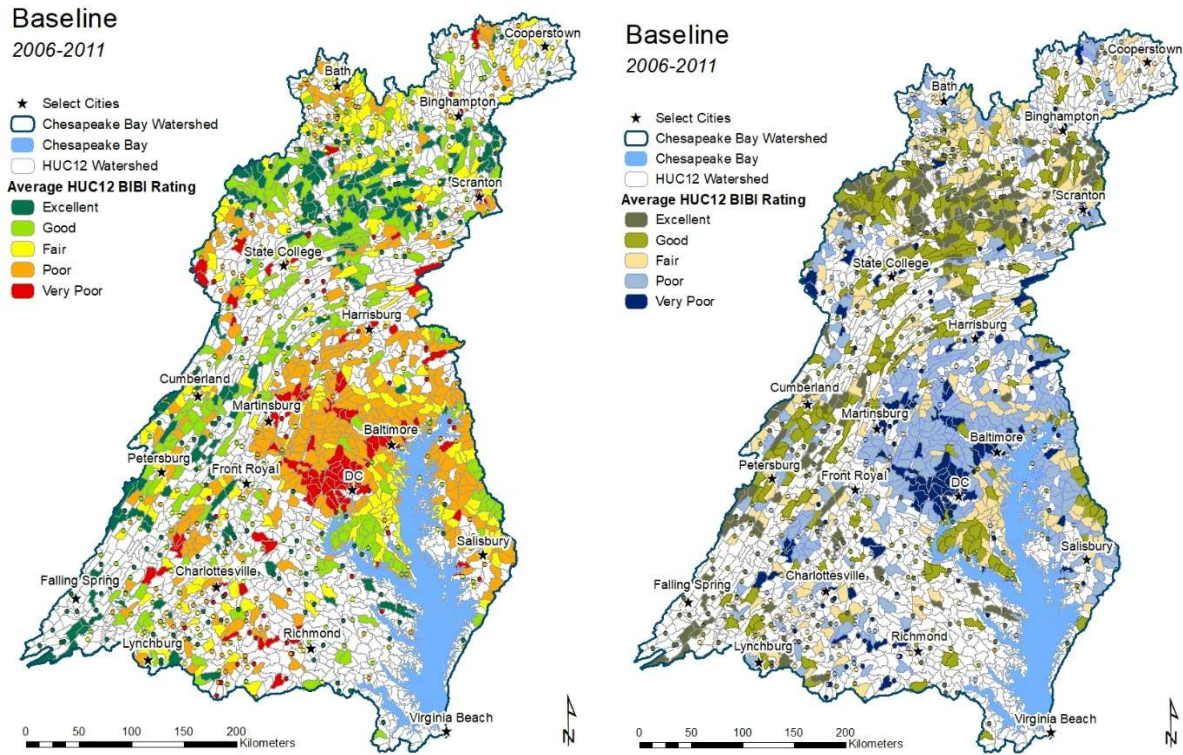


Figure 4. Illustrative example of Chessie BIBI maps, with standard (left) and accessible (right) colors.

4. 2025 Analysis Updates

4.1 Additional Sampling Events

The number of sampling events in each analysis interval has changed since the last Chessie BIBI analysis (Buchanan et al. 2023). The total number of sampling events increased from 10,101 to 10,986 (+8.8%) in the 2006-2011 interval, and from 7,698 to 10,649 (+38.3%) in the 2012-2017 interval (Table 7). The number of sampling events changed for several reasons: new providers contributed data, existing providers submitted updated datasets with additional events, and one data provider updated presence/absence data to count data which enabled inclusion. Minor changes reflect QA/QC adjustments and the shift to identifying stations at 0.0001° latitude/longitude precision, as described in the following section.

Table 7. Count of sampling events in the previous analysis dataset (Buchanan et al. 2023) and the 2025 updated dataset (Buchanan et al. 2025). See Appendix F for Data Provider names.

Data Provider Code	< 2000		2000–2005		2006–2011		2012–2017		2018–2023
	Previous Analysis	2025 Update	Previous Analysis	2025 Update	Previous Analysis	2025 Update	Previous Analysis	2025 Update	2025 Update
AACO			99	99	286	285	120	171	363
BAL			127	127	121	121	144	144	47
BCO			311	312	786	793	623	644	739
CMC								972	243
DCDOEE			17	17	15	14		68	
DEDNREC			34	34	81	81	23	23	
FCO			122	122	326	228	196	197	240
FXCO			120	122	304	301	443	445	
HCO			161	161	128	132			213
LCO					177	178			
MCO			635	637	557	556	688	651	617
MDDNR	1	776	4011	4022	2905	2927	858	905	755
NPS						12		7	4
NYSDEC			151	176	184	201	108	179	121
PADEP	7	8	219	362	1465	1962	1120	2288	1235
PGCO	149	149	362	363	154	156	373	373	399
SHEN	57	57						133	
SRBC	57	80	572	641	730	860	867	1043	429
USEPA	406	437	61	63	36	112		80	86
USFS			3	3					
USGS	174	201	41	40	18	18	17	18	
VADEQ	713	870	1073	1194	1316	1499	1859	2022	1529
VCU	19	19	497	499	167	171			
WVDEP	229	232	337	355	345	379	259	286	417
Grand Total	1813	2829	8953	9349	10101	10986	7698	10649	7437

4.2 Station Identification by Coordinates Instead of Name

Unique sampling events were identified by station name, date, and sample number in 2017 refinement of the index (Smith et al. 2017a). However, we found that the station name of a location could change over time, or the location could have different station names if several agencies collected samples at the site. For the 2025 analysis, we used a concatenation of each sampling location’s latitude and longitude rounded to four decimal places to identify discrete locations (LATLON4). For example, a station with the provided coordinates of 38.85 latitude and -76.56356 longitude was assigned 38.8500-76.5636 as

its location identifier. Sampling events associated with the same location identifier, including duplicates, annual samples, and samples collected by different agencies, were more easily grouped.

We compared the LATLON4-based approach of identifying stations with one that uses NHDPlusID catchments. Catchment attributes, including land use/land cover and local precipitation, are used in predictive models of the Chessie BIBI to complement the monitoring results and to explore stream macroinvertebrate responses to different stressors (e.g., Maloney et al. 2018, 2020, 2021). Catchment-based %EGFs were -0.1% to -0.5% lower than the LATLON4-based %EGF estimates indicating a slight negative bias, but otherwise they produced the same results. Analysis done with either approach should be comparable.

4.3 Updated Strahler Stream Order Criteria

The Chessie BIBI index was originally developed for streams and small wadeable rivers identified as 1st - 4th SSO in the medium resolution NHDPlusID layer (1:100,000 scale). Exclusions of 5th order and higher streams removed approximately 6.7% of sampling events from the database. A higher resolution geospatial dataset (NHDPlus HR; U.S. Geological Survey 2022) has led to the delineation of more headwater streams, which has significantly changed Strahler Stream Order designations. The 4th order streamlines at the 1:100,000 scale are now classified as high as 7th or 8th order streamlines. Correspondence between the medium and high resolution SSO results is not straightforward, and for this reason, we did not preemptively exclude sites based on SSO before calculating the index in the 2024 analysis and instead conducted further investigation into the impact of using high versus medium resolution streamline data.

We found that the correspondence between medium and high resolution SSO results is not straightforward (Figure 5). At the higher resolution, SSO remained the same at 30.46% of the sites (blue) and increased one, two, or three levels at 64.19% of the sites (light green). SSO *decreased* at 5.22% of the sites (purple). Some of these sites were located on streams near their confluences with large river mainstems and were incorrectly assigned to the mainstem's SSO in the medium resolution ArcGIS layer. At other times, sites were actually located in a high order SSO mainstem but were incorrectly identified as a 1st order in the higher resolution ArcGIS Pro layer.

		High Resolution SSO								
		1	2	3	4	5	6	7	8	N
Medium Resolution SSO	-9	10	5							15
	1	8423	9006	2756	357	22	19	8	2	20593
	2	960	2743	6713	1524	181	1	15	5	12142
	3	426	290	1960	4261	814	8		7	7766
	4	224	165	31	879	2552	216			4067
	5	115	56	12	2	332	1142	256		1915
	6	34	17	33	5		25	400	215	729
	7	80	26	25	1				217	349
N		10272	12308	11530	7029	3901	1411	679	446	47576

Figure 5. Comparison of medium- and high-resolution Strahler Stream Order identifications. Comparison of Strahler Stream Order (SSO) at 47576 macroinvertebrate sites sampled between 1983 and 2024, as determined with medium and high-resolution layers. Blue, SSO unchanged at medium and high resolutions (30.19%); light green, SSO increases one to three SSO levels in high resolution (64.37%); dark green, SSO increases more than three SSO levels in high resolution (0.18%); purple, SSO decreases in high resolution (5.26%).

Roughly 0.18% of sites (n=87, dark green) had SSOs that increased more than three SSO levels, which was concerning. Closer examination shows that either the medium- or high-resolution layer was incorrectly identifying a site’s SSO. We were also curious about the 2,587 sites identified as SSO ≥ 5 at both the medium and high resolutions. The reported location coordinates invariably place these sampling sites in the mainstems of medium to large rivers. Since all sites in the analysis dataset are sampled with hand-held nets and kicks or jabs are used to dislodge benthic macroinvertebrates into the nets, these large mainstem locations would have had to be wadeable.

We cannot know the extent to which SSO is misidentified in ArcGIS Pro without individually examining each site’s location, a prohibitively time-consuming exercise. We do know that standard operating procedures and field manuals for stream monitoring programs instruct field crews to sample wadeable, flowing waters where kicking or jabbing the bottom to dislodge benthic macroinvertebrates can be effectively and safely done while standing in the water. The field sampling gear method code (G_Method) indicates if this type of sampling approach was used (Appendix D). Large rivers in the Mid-Atlantic can be wadeable across entire transects where the exposed bedrock geology keeps the river broad and shallow, and they can be sampled with a kick net (Selckmann et al. 2018, Shull et al. 2019). Examples include the Susquehanna at Harrisburg, PA, the Potomac upstream of Washington, D.C., and the James upstream of Richmond, VA.

4.4 Use of Mean Index Score for Repeated Runs

Previously, the median index score of the 100 runs and its associated rating were used to represent individual sampling events. We wanted to avoid the potential of a few extreme

results in the 100 runs biasing the mean. Use of the median scores, however, appears to introduce greater variability than use of the mean (Figure 6). Comparisons of separate 100-runs produced by the same analysis on the same samples show slightly less variability in most results when the mean score is used. Going forward, we are using the mean score and its associated rating to represent a sampling event.

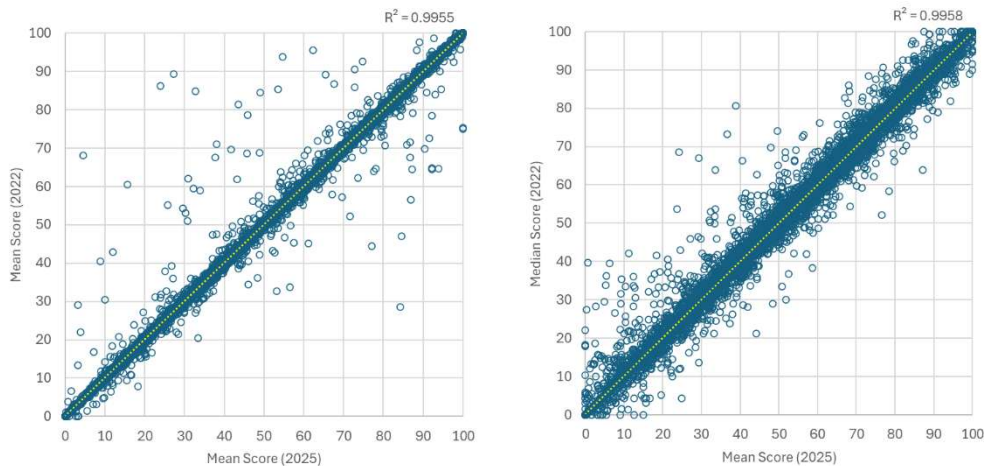


Figure 6. Comparison of mean (left) and median (right) Chessie BIBI scores from separate 100 runs of the analysis in 2022 and 2025 on the same raw data for 29,154 sampling events using the same analysis.

4.5 Taxonomic Attribute Updates

No changes were made to existing entries in the Master Taxa File for this analysis, except for the addition of new taxa from newly submitted datasets. Any changes in 2025 Chessie BIBI results since the previous analysis are not due to significant changes in biological attributes. Future updates will revise existing family-level functional feeding groups, pollution tolerance and dominant habit attributes based on updated literature reviews and other sources.

4.6 Comparison of the 2025 Analysis with Previous Index Versions

To determine if, and by how much, the recent method changes described above affected estimates of healthy streams, we compared the 2000-2005, 2006-2011, and 2012-2017 interval estimates from this 2024 Data Call to those published in Buchanan et al. (2023) (Table 8). With the changes made in 2025, stream health estimates dropped 2.0% in the 2000–2005 interval, 1.0% in the 2006–2011 interval and 2.5% in 2012–2017 interval. However, improvement in stream health from 2006–2017 is still found using either method.

The differences appear to be partly due to the change in criteria for Strahler Stream Order (Table 8). Estimates published in Buchanan et al. (2023) were for streams identified as SSO

≤ 4 at the medium resolution (1:100,000) scale. Estimates in the 2025 analysis were for streams identified as SSO ≤ 5 at the high resolution (1:24,000) scale. However, we also calculated %EGF at the medium resolution scale. The change to the high-resolution scale resulted in a less than 0.5% difference in %EGF.

The largest source of the differences is the additional sampling events that were included in the revised estimates of %EGF (Table 8).

Table 8. Comparison of %EGF values derived from three analyses: 2024 Data Call data with 1st-5th order streams determined using high resolution data (HR_SSO 1-5), 2024 Data Call data with 1st-4th order streams determined using medium resolution data (Med SSO 1-4), and results published in Buchanan et al. (2023) using data mapped at medium resolution for 1st-4th order streams.

Interval	2024 Data Call HR_SSO 1-5			Med SSO 1-4			Buchanan et al. 2023 Med SSO 1-4		
	%EGF	+%EGF	N sites	%EGF	+%EGF	N sites	%EGF	+%EGF	N sites
2000–2005	56.43%		7029	56.21%		7108	58.40%		7035
2006–2011	60.72%	4.29%	8273	60.55%	4.35%	8381	61.70%	3.30%	8016
2012–2017	65.31%	4.59%	6170	65.56%	5.01%	6269	67.80%	6.10%	4713

5. Publication and Dissemination

Output of the Chessie BIBI analysis includes a summary report prepared for the Stream Health Workgroup, publication of the raw and processed data, publication of the [Chessie BIBI Analysis Toolkit](#), and updates to the Chessie BIBI webpage. Together, these activities ensure transparent communication of results and broad accessibility of data and documentation.

5.1 Report Preparation

ICPRB Analysts prepare the Chessie BIBI assessment report, with technical support from the Data Manager, Stream Health Workgroup Chairs, and editorial review by the ICPRB Communications Team. The report summarizes the principal findings of the Chessie BIBI analysis and documents trends and progress towards the Chesapeake Bay Program’s Stream Health Outcome goals. The report includes summary tables of results and accompanying maps. Once finalized, the report is shared with the Stream Health Workgroup, distributed to data providers, and posted to the Stream Health Workgroup’s webpage.

5.2 Data Publication

All finalized and processed datasets, including macroinvertebrate data, Chessie BIBI scores and ratings, and associated water quality and habitat data, are published in the

Chesapeake Environmental Data Repository (CEDR) by the Data Manager and are made publicly accessible through the Chesapeake Bay Program's DataHub website (<https://datahub.chesapeakebay.net/>). Taxonomic data processed according to the steps in section 2 are uploaded to CEDR (not reflecting any preparation steps performed during the Chessie BIBI analysis, section 3). Final taxonomic identifications reflect the lowest taxonomic resolution submitted by the Data Provider, not rolled up to any order or class levels. Links to supporting documentation (e.g., sampling protocols, field manuals, Quality Assurance Project Plans) for submitted data are included in Appendix F.

The [Chessie BIBI Analysis Toolkit](#), which includes the Master Taxa File, input file set up guide and template, analysis R script, bioregion shapefile and accompanying README file, is also hosted by the Chesapeake Bay Program and made available through the ICPRB website.

5.3 Website Updates

The ICPRB Chessie BIBI webpage is updated to reflect the most recent analysis results and documentation. Webpage updates include plain-language summaries, links to current, past, and related reports, links to the [Chessie BIBI Analysis Toolkit](#), an interactive map of results, and downloadable high-resolution maps and summary graphics.

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APPENDIX A

Timeline of the Chessie BIBI Index Development, 2005 – 2025.

[Next page].

The Chessie BIBI: An Index Twenty Years in the Making Now Supports CBP Stream Health Outcome Assessments

FAQs:

What is the Chessie BIBI?
It is the **Chesapeake Basin-wide Index of Biotic Integrity**, a multi-metric index of stream biological health applicable anywhere in the Chesapeake watershed.

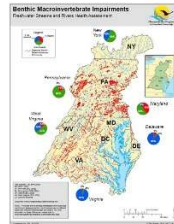
What Data are Used?
Macroinvertebrate samples routinely collected in streams and small rivers by federal, state, local and citizen monitoring programs and **voluntarily shared** with the Chesapeake Bay Program.

Are the Data Available?
Yes, the raw data, calculated metrics, and R-programs used to calculate the index can be obtained from the Chesapeake Environmental Data Repository at www.chesapeakecbay.net

How Often Will the Index Be Updated?
About every six (6) years, to account for state rotational sampling schedules.

Any Progress?
The Chesapeake watershed is on track to meet the stream health outcomes in both the **Executive Order** (70% healthy streams) and **2014 Agreement** (10% improvement above Baseline).

Chesapeake Bay Program



Gaps

Need for a Watershed-Wide Stream Health Indicator is Recognized

"State Assessments Are Not Comparable"
CBP Non-Tidal Workgroup

Outcomes

Chesapeake Bay Executive Order 13508

Improve the health of streams so that **70 percent of sampled streams** throughout the Chesapeake watershed are in **fair, good or excellent** condition as measured by the Index of Biotic Integrity **by 2025**

2014 Chesapeake Agreement Signed

Improve health and function of **ten percent of stream miles above the 2008 baseline** for the Chesapeake Bay watershed

Models

Baseline

2006 – 2011 Selected as "2008 Baseline"
[8, 9]

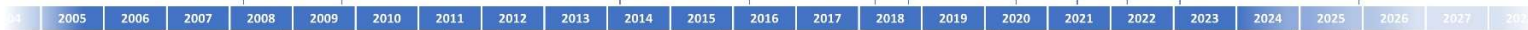
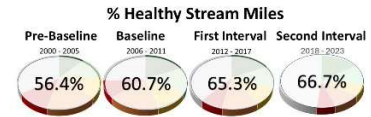
Cacapon WV 2018 Workshop

Landscape Features Are Used to Predict Chessie BIBI & Model its Responses to Climate Change, Development, and Flow Alteration
[10, 11, 12, 13]

Progress Report Submitted to CBP
[14]

Revised Outcome

"Beyond 2025"
Improve the health and the ecological integrity of at least an additional **4,340 nontidal stream miles every six years**.



Potomac Benthic Index of Biotic Integrity is Created
[1, 2]

Proof of Concept for Chesapeake Completed
ICPRB Pilot Project

Data Call & ICPRB Database Built

Chessie BIBI 1.0
[3]

Index Sensitivity to Nutrients, Land Use & Flow Alteration Demonstrated
[4, 5, 6]

Data Call & ICPRB Database Updated

Chessie BIBI 2.0 "Refinement"
[7]

Data Call Data Updated, Analysis Tools Developed, Conversion to Chesapeake Environmental Data Repository

Chessie BIBI 3.0
[chesapeakebay.net/what/data]

Chessie BIBI Selected as an Indicator for Potomac Water Resources Comprehensive Plan
[15]
ICPRB Advisory Committee

Data Call & Update CEDR Database

Progress Report to CBP

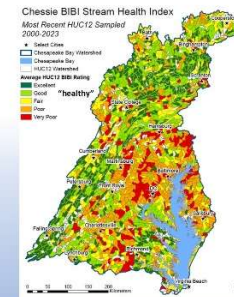


Interstate Commission on the Potomac River Basin

Development

Updates

Assessments



Credits:

Chessie BIBI Development Team, Past & Present

- Claire Buchanan (ICPRB)
- Emily Young (ICPRB/CBPO)
- Rikke Jepsen (ICPRB)
- Michael Maloney (ICPRB/CBPO)
- Andree Nagel (ICPRB)
- Zaslavsky Smith (formerly ICPRB)
- Adam Griggs (formerly ICPRB)
- Jacqueline Johnson (formerly ICPRB/CBPO)
- Kathleen Foreman (formerly ICPRB/CBPO)

Stream Monitoring Programs that Answered the Data Call

- Anne Arunakel Co
- Baltimore City
- Baltimore Co
- DC, DOTT
- Delaware NREC
- Fairfax Co
- Frederick Co
- Howard Co
- Loudoun Co
- Mayland DNR
- Montgomery Co
- National Park Service
- New York DEC
- Pennsylvania DEP
- Prince Georges Co
- SRBC
- USEPA
- USFS
- USGS NAWQA
- Virginia DEQ
- West Virginia DEP
- Maryland SOS

Federal, State, County and Academic Representatives

- who guided development of the Chessie BIBI index through their participation in our **Technical Advisory Groups** and "2008 Baseline" Workshop
- Consultation and Collaboration** of key individuals who gave freely of their time and insights, including Kelly O. Maloney & John Young & Kevin Krause & Rich Walker (USGS, I, eelown); Greg Poad (EPA3); Neely Law (formerly CWP and now Fairfax Co)

Chesapeake Bay Program support was crucial in helping ICPRB expand the scope of the index from the Potomac to the Chesapeake. We thank Peter Tango (USGS/CBPO) Scott Phillips (USGS) Jennifer Greiner (EWS) and the members of the Non-Tidal Workgroup, Stream Health Mgmt. Strategy Team, Stream Health Workgroup, and CBPO Data Center Team

Citations

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More information:
http://bit.ly/Chessie_BIBI

Poster prepared April 2023 by Claire Buchanan with Renee Bourassa and Rikke Jepsen

APPENDIX B

2024 Data Provider Contact List

Data Provider Name (Code)	Email contacts and/or data portal
Anne Arundel County Department of Public Works (AACO)	Bryan Perry pwper85@aacounty.org
Baltimore City Department of Public Works (BAL)	Robert McAulay Robert.Mcaulay@baltimorecity.gov
Baltimore County Department of Environmental Protection and Sustainability (BCO)	Morgan Kaumeyer mkaumeyer@baltimorecountymd.gov
Chesapeake Monitoring Cooperative (CMC)	Matthew Kierce Mkierce@iwla.org
District of Columbia Department of Energy and Environment (DCDOEE)	Lucretia Brown Lucretia.Brown@dc.gov Gerald Haywood gerald.haywood@dc.gov
Delaware Department of Natural Resources and Environmental Control (DEDNREC)	Christopher Main Christopher.main@delaware.gov Brittany Sturgis Brittany.Sturgis@delaware.gov
Frederick County Department of Stormwater (FCO)	Ben Green bgreen@frederickcountymd.gov Donald Dorsey DDorsey1@frederickcountymd.gov
Fairfax County Department of Public Works and Environmental Services (FXCO)	Chris Ruck Christopher.Ruck@fairfaxcounty.gov
Howard County (HCO) Department of Public Works	Mark Richmond msrichmond@howardcountymd.gov Andy Becker andy.becker@kci.com
Loudon County Department of Building and Development (LCO)	David Ward david.ward@loudoun.gov
Montgomery County Department of Environmental Protection (MCO)	Mark Rockman mark.rockman@montgomerycountymd.gov askdep@montgomerycountymd.gov Kenny Mack Kenny.Mack@montgomerycountymd.gov
Maryland Department of Natural Resources (MDDNR)	Katherine Hanna katherine.hanna@maryland.gov Mark Trice mark.trice@maryland.gov Tom Parham tom.parham@maryland.gov https://dnr.maryland.gov/streams/pages/datarequest.aspx
New York State Department of Environmental Conservation (NYSDEC)	Zachary Smith Zachary.Smith2@dec.ny.gov Brian Duffy brian.duffy@dec.ny.gov

Chesapeake Basin-wide Index of Biotic Integrity (Chessie BIBI) - Methods and Procedures

Data Provider Name (Code)	Email contacts and/or data portal
Pennsylvania Department of Environmental Protection (PADEP)	Dustin Shull dushull@pa.gov Erika Arnold erikarnold@pa.gov Matthew Shank mattheshan@pa.gov https://gis.dep.pa.gov/macroviewer/index.html https://www.waterqualitydata.us/
Prince George's County Department of the Environment (PGCO)	Jerry Madonado jgmaldonado@co.pg.md.us Sam Stribling james.stribling@tetrattech.com Erik Leppo Erik.Leppo@tetrattech.com
Prince William County Department of Public Works	Tom Dombrowski tdombrowski@pwcgov.org
National Park Service, Natural Resource Stewardship and Science Office (SHEN)	https://irma.nps.gov/DataStore/Reference/Profile/2310531 https://www.nps.gov/im/midn/benthic-macroinvertebrates-shenandoah.htm
Susquehanna River Basin Commission (SRBC)	Elyn Campbell ecampbell@srbc.net Dawn Hintz DHintz@srbc.net
US Environmental Protection Agency National Aquatic Resource Surveys (USEPA)	https://www.epa.gov/national-aquatic-resource-surveys/nrsa
US Geological Society National Water-Quality Assessment (USGS)	Chad Wagner cwagner@usgs.gov Mindi Dalton msdalton@usgs.gov James Webber jwebber@usgs.gov
Virginia Department of Environmental Quality (VADEQ)	Andrew Kirk Andrew.Kirk@deq.virginia.gov Richard Browder richard.browder@deq.virginia.gov Cindy Johnson Cindy.Johnson@deq.virginia.gov
West Virginia Department of Environmental Protection (WVDEP)	Michael Whitman michael.j.whitman@wv.gov

APPENDIX C

2024 Data Call email sent to monitoring agencies

Subject: Data request: Chesapeake non-tidal stream and river monitoring data - [Data Provider Agency Code]

Body:

Dear [Data Providers],

The Chesapeake Bay Program (CBP) and Interstate Commission on the Potomac River Basin (ICPRB) are once again calling for recently collected non-tidal stream macroinvertebrate data and the related water quality data and habitat scores. Our objective is to update the stream health indicator, or “[Chessie BIBI](#)” (Chesapeake Basin-wide Index of Biotic Integrity), with data from 2018 to 2023. Specific details of the data request are described in the attached guidance.

For those of you unfamiliar with it, the Chessie BIBI indicator is calculated from macroinvertebrate data contributed by agencies and organizations such as yours. It is used to measure progress towards the CBP partnership’s 2014 Stream Health [goal](#). The indicator can also help resource managers and watershed groups 1) identify and protect healthier streams and 2) focus restoration efforts on degraded streams. Your support in updating this indicator will ensure its continued usefulness. Information about the indicator can be found [here](#). A package of R-scripts, shape files, and lookup tables is used to normalize the raw data and calculate the Chessie BIBI as well as more than 80 individual macroinvertebrate metrics. The package and an Excel spreadsheet with Chessie BIBI scores from the 2019 data call (version 3.01) are available for download [here](#). Chessie BIBI scores and raw macroinvertebrate, habitat, and water quality data are also available to the public via the CBP DataHub (<https://datahub.chesapeakebay.net/LivingResources>).

The database housing the raw macroinvertebrate counts, habitat scores, and water quality measurements from earlier data calls is being incorporated into CBP’s CEDR (Chesapeake Environmental Data Repository) database. Dr. Emily Young (CBP Habitat and Living Resources Data Manager) is resolving data entry errors, duplicates, and other issues. The attached Excel (xlsx) file includes a table showing the number of sampling events in the current CEDR database by year and agency. For today’s data call, we are soliciting all data not yet in the CEDR database but most particularly data from 2018 – 2023.

Data contributed in response to this data call will be processed through CBP’s DUET (Data Upload and Evaluation Tool) application that transforms and imports the data streams (sampling events, benthic macroinvertebrate counts, habitat assessments, and water quality) into the CEDR database. The CEDR database is compatible with the national Water Quality Portal (WQP) database. A crosswalk between your field names and CEDR’s field names will be created as part of this data processing. The list of necessary fields (“data elements”) and information we need from you to do this is also in the attached Excel file.

Contributed datasets should be sent to Emily Young (eyoung@chesapeakebay.net). We would like to begin processing data by **February 28, 2025**. Emily will contact you if questions arise. We will keep you and the CBP Stream Health Workgroup updated on our progress. You are also invited to participate in any Stream

Chesapeake Basin-wide Index of Biotic Integrity (Chessie BIBI) - Methods and Procedures

Health Workgroup meetings. Claire Buchanan (cbuchan@icprb.org) can provide further detail about the near-term objectives and proposed outputs and outcomes of the data analysis.

We greatly appreciate your cooperation in providing us the requested data sets and hope the Chesapeake basin-wide databases and analysis results will be useful to you as well in addressing your agency's information needs. Please forward this email to the correct individual if you are not responsible for responding to data requests. Thank you.

Sincerely,

Emily Young

(Habitat and Living Resources Data Manager, ICPRB at CBPO, 808-312-9206, eyoung@chesapeakebay.net)

Claire Buchanan

(Emerita Director, ICPRB, cbuchan@icprb.org)

Alison Santoro

(Co-Chair Stream Health Workgroup, Section Chief – Restoration Science, Maryland Department of Natural Resources, alisona.santoro@maryland.gov)

Sara Weglein

(Co-Chair Stream Health Workgroup, Restoration Science Specialist, Maryland Department of Natural Resources, sara.weglein@maryland.gov)

Attachment: 2024_CBP_DataCall_Streams.xlsx

APPENDIX D

Gear, Method, Habitat, and Water Quality Parameter codes and descriptions used in the Chessie BIBI analysis and in the Chesapeake Environmental Data Repository (CEDR).

Gear codes:

G_METHOD	Equipment Name	Equipment Description
57	D-frame Net	500 Micron Mesh, 12 Inch Diameter
86	Kick Net	23 x 46 Centimeter, Open Size 0.8 X 0.9 Millimeter
87	Kick Net	Unspecified
89	D-frame Net	Unspecified
90	Hester Dendy Multiplate Sampler	NULL
91	Surber Sampler	NULL
92	Kick Seine	NULL
93	D-frame Net	600 Micron Mesh, 12 Inch Diameter
94	Kick Net	600 Micron Mesh, 1 Square Meter Kick Screen
98	Petite Ponar Grab	25 Square Centimeters
101	Post-Hole Digger	0.125 Square Meters
102	Box Core Grab	0.0225 Square Meters
103	Slack Sampler	Rectangular net frame (50 by 33 cm) fitted with a tapered 500 Micron Nitex collection net
104	Rectangular Aquatic Net	Used in 2010 and 2011 by SRBC
105	Portable Invertebrate Box Sampler (PIBS)	31 x 31 Centimeter; 363 Micron Mesh
106	Modified Kick Net	D-frame net with 500 µm mesh and 52" handle; non-wadeable stream use
107	D-frame Net	540 Micron Mesh, 12 Inch Diameter
108	D-frame Net	250 Micron Mesh
110	D-frame Net	700 Micron Mesh, 30 cm Diameter

Method codes:

BIO_METHOD	Method Name
BE101A	PADEP Nontidal Stream Rapid Benthic Bio-assessment Protocol
BE101B	PADEP Nontidal Stream Rapid Benthic Bio-assessment Protocol With Replication
BE101C	PADEP Nontidal Stream Rapid Benthic Bio-assessment Protocol Limestone: 2-Dframe Composite, 300 subsample (with replicate)
BE101D	PADEP Nontidal Stream Rapid Benthic Bio-assessment Protocol Limestone: 2-Dframe Composite, 300 subsample
BE101E	PADEP Nontidal Stream Rapid Benthic Bio-assessment Protocol Multihabitat: 10 Jabs, 200 subsample
BE101F	PADEP Nontidal Stream Rapid Benthic Bio-assessment Protocol Multihabitat: 10 Jabs, 200 subsample (with replicate)
BE101G	PADEP Nontidal Stream Rapid Benthic Bio-assessment Protocol Multihabitat: 10 Jabs, 200 subsample (proportional habitat)
BE102	The NYSDEC Nontidal Stream Biomonitoring- Kick Sample Protocol

Chesapeake Basin-wide Index of Biotic Integrity (Chessie BIBI) - Methods and Procedures

BIO_METHOD	Method Name
BE103	Maryland Biological Stream Survey Bioassessment Protocol
BE104	Maryland Core Trend Stream Bioassessment Protocol
BE105	VADEQ Nontidal Stream Rapid Bio-assessment Protocol: Single-habitat Method
BE105G	VADEQ Nontidal Stream Rapid Bio-assessment Protocol: Single-habitat Method
BE106	VADEQ Nontidal Stream Rapid Benthic Bio-assessment Protocol: Multi- Habitat Method
BE106G	VADEQ Nontidal Stream Rapid Benthic Bio-assessment Protocol: Multi- Habitat Method
BE107	WVDEP Nontidal Stream Modified EPA Rapid Benthic Bio-assessment Protocol II, Single Habitat-100 CT
BE107B	WVDEP Nontidal Stream Modified EPA Rapid Benthic Bio-assessment Protocol II, Single Habitat-200 CT
BE107C	Benthic Sampling Methodology: RBP III Single-Habitat; Benthic Subsampling Methodology: 300-Count Subsample
BE108	Mid-Atlantic Coastal Streams Method
BE110	SRBC Nontidal Stream Rapid Benthic Bio-assessment Protocol (RBP) III
BE111	Montgomery County- Nontidal Stream Assessment Protocol
BE112	Fairfax County- Nontidal Stream Rapid Benthic Bio-assessment Protocol For Piedmont/Triassic
BE113	Fairfax County- Nontidal Stream Rapid Benthic Bio-assessment Protocol For Coastal Plain
BE116	EPA Wadeable Streams Benthic Assessment Protocol
BE117	District Of Columbia Nontidal Stream Benthic Assessment-contractor Protocol
BE118	Prince Georges County Nontidal Stream Benthic Assessment Protocol
BE119	USFS Protocol
BE120	The NYSDEC Stream Biomonitoring- Jab Sample Protocol
BE121	Louden County Single-Riffle Habitat Protocol
BE122	District Of Columbia-inhouse Protocol
BE123	VCU Nontidal Stream Assessment Protocol
BE1240	EPA EMAP-Other Habitat Protocol
BE124P	EPA EMAP-Pool Habitat Protocol
BE124R	EPA EMAP-Riffle Habitat Protocol
BE125A	USGS-RTH-No Snag Habitat Protocol
BE125B	USGS-RTH-Snag Habitat Protocol
BE126	Shenandoah National Park Benthic Macroinvertebrate Monitoring Protocol
BE127	USEPA Non-Wadeable National Rivers and Streams Assessment; 2018 - 2019
BE128	Shenandoah National Park Benthic Macroinvertebrate Monitoring Protocol - Qualitative
BE129	NPS Eastern Rivers and Mountains Network Benthic Macroinvertebrate Procedure
BE130	CBP Benthic Macroinvertebrate Sample Collection Protocol
BE131	Nature Forward Data Collection Protocol for Piedmont Streams
BE132	Rivanna Conservation Alliance
BE133	MBSS Stream Waders Protocol
BE134	The NYSDEC Nontidal Stream Biomonitoring- Low Gradient Protocol
BE135	Macroinvertebrate Sampling for ALPO/JOFL Level I Inventory 11NPSWRD_WQX_ALPO_MI
BE137	Capelli's Macrobenthos Sampling for Yorktown Battlefield Area 11NPSWRD_WQX COLO_BIO3

Habitat Codes:

Habitat Code	Habitat Description
AESTH	Aesthetics
BANKS	Bank Stability
BANKV	Bank Vegetation
CH_ALT	Channel Alteration
COVER	Bottom Substrate And Available Cover
EMBED_SC	Embeddedness Score
EPI_SUB	Epifaunal Substrate
FLOW	Flow / Channel Flow Status
GRAZE	Grazing
INSTR	Instream Habitat
POOL_SUB	Pool Substrate Characterization
POOL_VAR	Pool/Glide Quality / Variability
REMOT_SC	Remoteness Score
RIFF	Riffle/Run/Pool Ratio / Frequency of Riffles
RIP_SC	Riparian Vegetation Score
RIP_W	Riparian Vegetation Zone Width
ROOT	Number Of Rootwads
SED	Sedimentation
SHAD_SC	Shading Score
SINU	Channel Sinuosity
THAL	Thalweg Depth
VEL_D	Velocity/Depth Ratio
WOOD	Number Of Wood Debris
WWID	Wetted Width

Water Quality Parameter Codes:

Water Quality Parameter Name	Description	Units
DO	Dissolved Oxygen	MG/L
DO_SAT_P	DO Saturation Using Probe Units	Percent
PH	Ph Corrected For Temperature (25 Deg C)	Parts Per Thousand (PPT), Equal To Practical Salinity Units (PSU)
SPCOND	In-situ Specific Conductance At 25 C	µS/cm
TURB_NTU	Turbidity; Nephelometric Method	Nephelometric Turbidity Units (NTU)
WTEMP	Water Temperature	DEG C
FLOW_INS	Stream Flow; Instantaneous	M/S

APPENDIX E

Metrics included in the family-level bioregion indices. Reference median is the 50th percentile of metric values at least-disturbed, highest quality “reference” sites. It is X_M or X_M' in Figure 2. Metric values greater than X_M (or less than X_M') are scored 100. Bound is the metric value when the metric score is zero. It is X_T or X_T' in Figure 2. Metric values less than X_T (or greater than X_T') are scored 0. Metric BDE is the metric value when the discrimination efficiency is balanced. From table 15 from Smith et al. (2017a).

Bio-region	Metric	Metric Class	Influence of Disturbance	Reference Median	Bound	Metric BDE
BLUE	PCT_SYSTELLOGNATHA	Composition	Decrease	6.06	0.00	86.47
BLUE	PCT_EPT_RICH_NO_TOL	Richness/Diversity	Decrease	52.78	34.74	82.71
BLUE	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	4.00	0.33	85.71
BLUE	PCT_SCRAPE	FFG	Decrease	15.23	0.00	90.23
BLUE	PCT_BURROW	Habit	Increase	12.65	40.71	87.97
CA	PCT_EUHOLOGNATHA	Composition	Decrease	17.98	0.23	71.43
CA	PCT_HEPTAGENIIDAE	Composition	Decrease	6.69	0.00	77.14
CA	PCT_NON_HYDROP_TRICHOPTERA	Composition	Decrease	40.40	25.02	71.43
CA	PCT_PISCIFORMA	Composition	Decrease	12.33	5.49	74.29
CA	PCT_SYSTELLOGNATHA	Composition	Decrease	5.44	0.08	71.43
CA	PCT_HYDRO_EPT	Composition	Increase	12.50	21.73	68.57
CA	PCT_EPT_RICH	Richness/Diversity	Decrease	66.82	56.82	65.71
CA	RICH_PLECOPTERA	Richness/Diversity	Decrease	4.00	0.47	74.29
CA	RICH_COLLECT	FFG	Decrease	7.00	5.13	62.86
CA	RICH_FILTER	FFG	Decrease	2.91	1.38	51.43
CA	RICH_PREDATOR	FFG	Decrease	3.00	1.44	80.00
CA	RICH_BURROW	Habit	Decrease	3.00	1.40	82.86
CA	PCT_MOD_TOL_4_6	Tolerance	Increase	43.04	57.26	71.43
LNP	PCT_PTERYGOTA	Composition	Decrease	98.36	92.09	74.64
LNP	PCT_EPT_RICH	Richness/Diversity	Decrease	52.32	38.07	70.89
LNP	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	3.00	1.70	81.56
LNP	PCT_COLLECT	FFG	Increase	72.82	92.49	88.47
LNP	PCT_PREDATOR	FFG	Decrease	7.78	1.43	87.90
LNP	PCT_CLING	Habit	Decrease	62.77	4.54	91.35
LNP	RICH_CLING	Habit	Decrease	7.00	3.69	88.18
LNP	ASPT_MOD	Tolerance	Decrease	6.62	2.70	93.66
LNP	PCT_MOD_TOL_4_6	Tolerance	Increase	46.54	77.78	88.47
MAC	GOLD	Composition	Decrease	58.96	33.91	64.71
MAC	PCT_ARTHROPODA	Composition	Increase	74.01	95.38	70.59
MAC	PCT_CHIRONOMIDAE	Composition	Increase	23.01	42.68	64.71
MAC	PCT_ODONATA	Composition	Decrease	1.82	0.43	76.47
MAC	PCT_COLLECT	FFG	Increase	73.25	96.19	70.59
MAC	PCT_PREDATOR	FFG	Decrease	5.16	4.01	76.47

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Bio-region	Metric	Metric Class	Influence of Disturbance	Reference Median	Bound	Metric BDE
MAC	PCT_SCRAPE	FFG	Decrease	12.07	0.00	76.47
MAC	RICH_CLIMB	Habit	Decrease	2.45	0.00	64.71
MAC	ASPT_MOD	Tolerance	Decrease	3.27	2.90	70.59
MAC	PCT_MOD_TOL_4_6	Tolerance	Increase	52.49	75.48	64.71
MAC	PCT_URBAN_INTOL	Tolerance	Increase	65.28	71.78	76.47
MAC	RICH_TOL	Tolerance	Decrease	4.00	2.16	52.94
NAPU	PCT_EPT_NO_HYDRO	Composition	Decrease	87.96	70.51	67.42
NAPU	PCT_NON_HYDROP_TRICHOPTERA	Composition	Decrease	45.08	20.60	68.54
NAPU	PCT_EPHEMEROPTERA	Composition	Decrease	31.47	19.62	57.30
NAPU	PCT_EPT	Composition	Decrease	62.26	54.08	56.18
NAPU	MARGALEFS	Richness/Diversity	Decrease	2.83	2.74	53.93
NAPU	PCT_EPT_RICH_NO_TOL	Richness/Diversity	Decrease	45.32	32.85	68.54
NAPU	PIELOU	Richness/Diversity	Increase	0.79	0.80	51.69
NAPU	RICH_PLECOPTERA	Richness/Diversity	Decrease	2.13	0.70	67.42
NAPU	PCT_COLLECT	FFG	Increase	71.84	82.80	59.55
NAPU	PCT_FILTER	FFG	Increase	15.51	22.62	61.80
NAPU	PCT_PREDATOR	FFG	Increase	5.36	6.24	56.18
NAPU	PCT_SCRAPE	FFG	Decrease	9.36	6.89	58.43
NAPU	RICH_GATHER	FFG	Increase	5.00	6.01	53.93
NAPU	RICH_SHRED	FFG	Decrease	2.00	0.84	61.80
NAPU	PCT_CLING	Habit	Decrease	59.19	50.98	55.06
NAPU	RICH_BURROW	Habit	Decrease	2.95	1.93	53.93
NAPU	RICH_CLING	Habit	Decrease	8.00	6.77	64.04
NAPU	RICH_SPRAWL	Habit	Increase	1.00	2.30	56.18
NAPU	PCT_INTOL_0_3	Tolerance	Decrease	44.70	24.22	61.80
NAPU	RICH_MODTOL	Tolerance	Increase	6.00	7.03	55.06
NCA	PCT_HEPTAGENIIDAE	Composition	Decrease	13.72	0.00	76.73
NCA	PCT_COTE	Composition	Decrease	63.95	47.71	68.55
NCA	PCT_EPHEMEROPTERA	Composition	Decrease	40.73	9.02	77.36
NCA	PCT_LIMESTONE	Composition	Decrease	8.93	0.00	79.25
NCA	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	4.00	3.83	70.13
NCA	RICH_EPT	Richness/Diversity	Decrease	12.00	8.02	68.55
NCA	RICH_PLECOPTERA	Richness/Diversity	Decrease	4.04	3.45	68.24
NCA	RICH_CLING	Habit	Decrease	10.00	7.75	78.62
NCA	ASPT_MOD	Tolerance	Decrease	7.54	6.67	65.41
NRV	PCT_EPHEMEROPTERA_NO_BAETID	Composition	Decrease	23.69	6.01	68.46
NRV	PCT_EPT_RICH	Richness/Diversity	Decrease	64.70	47.53	73.15
NRV	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	4.00	1.80	85.23
NRV	RICH_TRICHOPTERA	Richness/Diversity	Decrease	3.00	2.53	65.10
NRV	RICH_COLLECT	FFG	Decrease	8.00	7.14	62.42

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Bio-region	Metric	Metric Class	Influence of Disturbance	Reference Median	Bound	Metric BDE
NRV	RICH_PREDATOR	FFG	Decrease	3.00	0.32	79.19
NRV	RICH_SHRED	FFG	Decrease	2.00	1.27	69.80
NRV	ASPT_MOD	Tolerance	Decrease	6.27	4.59	72.48
PIED	PCT_EPT_RICH	Richness/Diversity	Decrease	53.58	38.51	68.42
PIED	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	3.60	0.86	84.21
PIED	RICH_TRICHOPTERA	Richness/Diversity	Decrease	2.03	0.45	78.95
PIED	PCT_CLING	Habit	Decrease	62.62	32.33	81.95
PIED	RICH_CLING	Habit	Decrease	8.00	2.96	91.73
PIED	PCT_INTOL_0_4	Tolerance	Decrease	58.15	27.97	81.20
PIED	PCT_TOLERANT_7_10	Tolerance	Increase	1.60	4.84	75.94
PIED	PCT_URBAN_INTOL	Tolerance	Decrease	95.41	86.93	66.17
SEP	GOLD	Composition	Decrease	50.30	32.16	69.57
SEP	PCT_COTE	Composition	Decrease	26.37	1.62	80.43
SEP	PCT_EPT_RICH_NO_TOL	Richness/Diversity	Decrease	24.73	16.49	63.04
SEP	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	2.00	0.00	86.96
SEP	RICH_TRICHOPTERA	Richness/Diversity	Decrease	2.00	0.41	63.04
SEP	RICH_COLLECT	FFG	Decrease	8.00	4.62	78.26
SEP	RICH_FILTER	FFG	Decrease	2.31	0.04	84.78
SEP	PCT_CLING	Habit	Decrease	43.05	0.00	78.26
SEP	RICH_CLING	Habit	Decrease	4.93	1.03	82.61
SEP	ASPT_MOD	Tolerance	Decrease	4.65	3.18	63.04
SEP	HBI	Tolerance	Increase	5.12	5.86	76.09
SGV	PCT_EPT_NO_HYDRO	Composition	Decrease	83.21	73.53	65.35
SGV	PCT_HEPTAGENIIDAE	Composition	Decrease	7.89	0.00	81.89
SGV	PCT_NON_HYDROP_TRICHOPTERA	Composition	Decrease	30.54	10.57	66.93
SGV	PCT_PISCIFORMA	Composition	Decrease	17.07	0.10	79.53
SGV	PCT_PTERYGOTA	Composition	Decrease	96.88	90.20	64.57
SGV	GOLD	Composition	Decrease	80.89	64.95	61.42
SGV	PCT_EPHEMEROPTERA_NO_BAETID	Composition	Decrease	23.94	5.23	75.59
SGV	PCT_EPT_RICH_NO_TOL	Richness/Diversity	Decrease	32.97	19.39	91.34
SGV	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	3.94	0.61	84.25
SGV	RICH_TRICHOPTERA	Richness/Diversity	Decrease	2.54	0.08	89.76
SGV	PCT_COLLECT	FFG	Increase	71.17	94.57	81.10
SGV	PCT_FILTER	FFG	Decrease	22.79	8.60	62.20
SGV	PCT_PREDATOR	FFG	Decrease	5.28	0.02	74.02
SGV	PCT_SCRAPE	FFG	Decrease	15.43	0.32	77.17
SGV	RICH_COLLECT	FFG	Decrease	8.00	6.32	66.93
SGV	RICH_FILTER	FFG	Decrease	3.00	1.36	66.14
SGV	PCT_CLING	Habit	Decrease	62.23	39.70	71.65
SGV	PCT_SPRAWL	Habit	Increase	1.79	4.54	59.84

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Bio-region	Metric	Metric Class	Influence of Disturbance	Reference Median	Bound	Metric BDE
SGV	ASPT_MOD	Tolerance	Decrease	6.44	3.94	81.89
SGV	PCT_MOD_TOL_4_6	Tolerance	Increase	52.49	76.71	71.65
SGV	PCT_TOLERANT_7_10	Tolerance	Increase	1.73	4.30	75.59
SRV	PCT_COTE	Composition	Decrease	57.55	43.78	68.69
SRV	PCT_EPHEMEROPTERA_NO_BAETID	Composition	Decrease	21.00	2.80	75.25
SRV	PCT_EPT_RICH_NO_TOL	Richness/Diversity	Decrease	47.16	34.94	66.16
SRV	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	4.00	3.66	66.16
SRV	RICH_PLECOPTERA	Richness/Diversity	Decrease	3.00	0.65	73.23
SRV	RICH_TRICHOPTERA	Richness/Diversity	Decrease	3.00	2.79	61.62
SRV	PCT_PREDATOR	FFG	Decrease	7.12	2.24	67.17
SRV	PCT_SCRAPE	FFG	Decrease	10.88	0.47	78.03
SRV	RICH_COLLECT	FFG	Decrease	7.97	6.02	79.29
SRV	RICH_PREDATOR	FFG	Decrease	3.00	2.72	60.10
SRV	PCT_BURROW	Habit	Increase	17.13	31.28	70.96
SRV	PCT_CLING	Habit	Decrease	58.45	40.16	71.46
SRV	RICH_CLING	Habit	Decrease	8.43	6.16	74.49
SRV	ASPT_MOD	Tolerance	Decrease	6.44	4.95	67.42
SRV	RICH_INTOL	Tolerance	Decrease	8.00	4.15	73.23
UNP	PCT_PISCIFORMA	Composition	Decrease	9.43	0.00	80.26
UNP	PCT_RETREAT_CADDISFLY	Composition	Decrease	10.97	2.89	72.37
UNP	PCT_HEXAPODA	Composition	Decrease	99.50	96.59	81.58
UNP	PCT_EPT_RICH_NO_TOL	Richness/Diversity	Decrease	37.09	22.10	93.42
UNP	RICH_EPHEMEROPTERA	Richness/Diversity	Decrease	3.00	1.44	73.68
UNP	RICH_PLECOPTERA	Richness/Diversity	Decrease	2.23	0.00	89.47
UNP	RICH_TRICHOPTERA	Richness/Diversity	Decrease	3.00	1.01	56.58
UNP	PCT_COLLECT	FFG	Increase	80.32	90.97	77.63
UNP	PCT_FILTER	FFG	Decrease	18.14	1.91	73.68
UNP	PCT_SCRAPE	FFG	Decrease	5.72	0.22	77.63
UNP	HBI	Tolerance	Increase	4.01	5.74	84.21
UNP	PCT_URBAN_INTOL	Tolerance	Decrease	98.46	91.71	72.37

APPENDIX F

Links to supporting documentation (field manuals, QAPPs, and other resources) for each organization.

Data Provider (Code)	Link(s) to Documentation
Anne Arundel County Department of Public Works (AACO)	https://www.aacounty.org/public-works/bwpr/ecological-assessment-evaluation/biological-monitoring
Baltimore City Department of Public Works (BAL)	https://publicworks.baltimorecity.gov/watching-waters
Baltimore County Department of Environmental Protection and Sustainability (BCO)	https://www.baltimorecountymd.gov/departments/environment/watersheds/stream-monitoring
Chesapeake Monitoring Cooperative (CMC)	https://www.chesapeakemonitoringcoop.org/services/ https://www.chesapeakemonitoringcoop.org/wp-content/uploads/2022/04/BenthicMethodsManual2022_lowres.pdf https://natureforward.org/wp-content/uploads/2022/11/Data_Collection_Protocol_rev_103122.pdf https://www.rivannariver.org/wp-content/uploads/2021/09/RCA-benthic-sampling-instructions-20210914.pdf
District of Columbia Department of Energy and Environment (DCDOEE) Delaware Department of Natural Resources and Environmental Control (DEDNREC)	Email eyoung@chesapeakebay.net for the latest metadata file. https://dnrec.delaware.gov/watershed-stewardship/assessment/water-quality-monitoring/

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Data Provider (Code)	Link(s) to Documentation
Frederick County Department of Stormwater (FCO)	https://frederickcountymd.gov/8126/Frederick-County-Stream-Survey
Fairfax County Department of Public Works and Environmental Services (FXCO)	https://www.fairfaxcounty.gov/publicworks/sites/publicworks/files/Assets/documents/stream-assessment-sop.pdf
Howard County (HCO) Department of Public Works	https://www.howardcountymd.gov/bureau-environmental-services/watershed-management
Loudon County Department of Building and Development (LCO)	https://www.loudoun.gov/DocumentCenter/View/5094/Stream-Assessment-Strategic-Plan?bidId=
Montgomery County Department of Environmental Protection (MCO)	https://www.montgomerycountymd.gov/DEP/water/clean-water-montgomery/stream-health/what-we-monitor-SH.html
Maryland Department of Natural Resources (MDDNR)	https://dnr.maryland.gov/streams/Publications/MBSSFieldManual.pdf
National Parks Service (NPS) New York State Department of Environmental Conservation (NYSDEC)	https://irma.nps.gov/DataStore/Reference/Profile/2231854 https://dec.ny.gov/environmental-protection/water/water-quality/assurance https://dec.ny.gov/environmental-protection/water/water-quality/monitoring
Pennsylvania Department of	https://www.pa.gov/agencies/dep/programs-and-services/water/clean-water/water-quality/data-collection-protocols

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Data Provider (Code)	Link(s) to Documentation
Environmental Quality (PADEP)	
Prince George's County (PGCO) National Park Service, Natural Resource Stewardship and Science Office (SHEN)	Email eyoung@chesapeakebay.net for the latest QAPP. https://www.nps.gov/im/midn/benthic-macroinvertebrates-shenandoah.htm
Susquehanna River Basin Commission (SRBC)	https://www.srbc.gov/portals/water-quality-projects/
U.S. Environmental Protection Agency (USEPA)	Rapid Bioassessment Protocols 1999 https://www3.epa.gov/region1/npdes/merrimackstation/pdfs/ar/AR-1164.pdf National Rivers and Streams Assessment https://www.epa.gov/national-aquatic-resource-surveys/nrsa
U.S. Fish and Wildlife Service (USFS) US Geological Society National Water-Quality Assessment (USGS)	https://stream-mechanics.com/wp-content/uploads/2012/01/Rapid-Assessment-Methodology.pdf https://pubs.usgs.gov/of/2013/1129/pdf/ofr20131129.pdf
Virginia Commonwealth University (VCU) Virginia Department of Environmental Quality (VADEQ)	Email eyoung@chesapeakebay.net for the latest metadata file. https://www.deq.virginia.gov/home/showpublisheddocument/6996
West Virginia Department of Environmental Protection (WVDEP)	West Virginia Department of Environmental Protection (WVDEP) https://dep.wv.gov/WWE/watershed/Pages/WBSOPs.aspx