Biological Assessment of Water Quality for Non-Tidal Streams

Executive Summary

As mandated by the Clean Water Act (CWA), the Maryland Department of the Environment (MDE) is required to describe the methodology used to assess use support and define impaired waters (CWA sections 305b/303d). The assessment methodology should be consistent with the state's WQSs, describe how data and information were used to make attainment determinations, and report changes in the assessment methodology since the last reporting cycle (US EPA 2006).

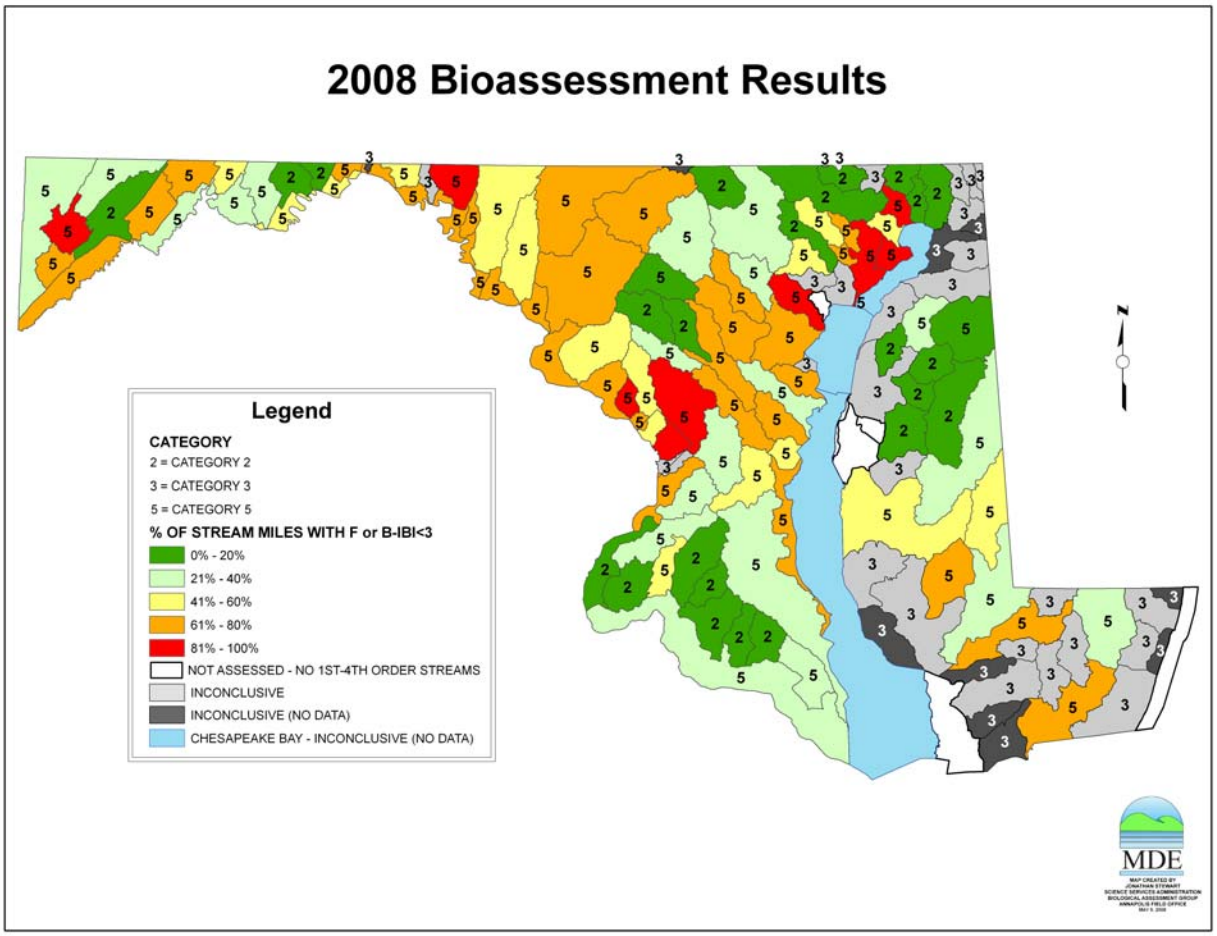
The MDE is proposing a refinement to the current biological listing assessment methodology. The revised approach maintains consistent application at a single water quality management spatial scale (i.e., MD 8-digit watersheds), maximizes the advantages of a probabilistic monitoring design, includes a report on the level of impact within the stream system (i.e., stream miles), and considers the uncertainty in various components of the assessment approach. This contrasts with the current methodology that reports at multiple watershed scales (i.e., 8 and 12-digit watersheds), but does not have consistency at these multiple spatial scales and does not fully maximize the probabilistic monitoring design, which is the foundation for the Maryland index of biological integrity (IBI) assessments.

The revised biological listing method is consistent with the watershed approach of the original method, but does not assess the condition of watersheds based on single sites. Southerland et al. (2007) demonstrated that IBI results from single sites are not representative of 12-digit or larger watersheds. Therefore, the revised listing method focuses on assessing the condition of 8-digit watersheds with multiple sites by measuring the percentage of stream miles that are degraded. Use of the percentage of degraded stream miles allows quantification of the extent of degradation in a watershed and comparison with a reference watershed. The power of these comparisons increases with the number of sites sampled in the watershed.

The revised methodology follows this process: First is a review of the biological monitoring data quality that removes sites for listing decisions where either the Fish or Benthic IBI is not applicable (e.g., tidal waters, blackwater streams). Once this step has been completed, the next step is the watershed assessment, where a watershed is evaluated based on comparison to a reference condition that accounts for variability in sampling design (i.e. spatial variability and temporal variability) and establishes a target value for degradation. During this step of the assessment, a watershed that is significantly different than reference condition is listed as impaired (Category 5) on the Integrated List (formerly known as the 303d List). If a watershed is not determined to be different than reference condition, the assessment must have an acceptable precision before the watershed is listed as attaining (Category 1 or 2) the biological water quality criterion. If the precision is not acceptable then the watershed is listed as inconclusive (Category 3) and designated for further monitoring. Finally, if a watershed is classified as impaired (Category 5) then a stressor identification procedure is completed to determine if a Total Maximum Daily Load (TMDL) is necessary.

This document describes how biological data is assessed for the purposes of the Integrated [combined 303(d) and 305(b)] Report. The methodology considers all existing and readily available data and information, and explains the analytical approaches used to infer watershed conditions at the 8-digit scale. A summary table and map of the 2008 biological assessment using MBSS Rounds 1 and 2 data for non-tidal streams (1st through 4th order) are presented below:

Integrated Report Final Status	Number of 8-digit Watersheds	Stream Miles (a)	% of Total Stream Miles (a/9,199)	Stream Miles with F or B-IBI<3 (b)	% of Stream Miles with F or B-IBI<3 (b/a)	% of Total Stream Miles with F or B-IBI<3 (b/9,199)	Integrated Report of Watershed Stream Miles Impaired (c)	Integrated Report of % of Total Watershed Stream Miles Impaired (c/9,199)
Category 2	24	1,750	19%	234	13%	3%	0	0
Category 3 (Inconclusive)	19	488	5%	183	37%	2%	NA	NA
Category 3 (No data)	25	148	2%	0			NA	NA
Category 4 or 5	70	6,813	74%	3,494	51%	38%	3,494	38%
Total	**138**	**9,199**	**100%**	**3,911**	**43%**	**43%**	**3,494**	**38%**



I. Background

All of the State's waters must be of sufficient quality to provide for the protection and propagation of a balanced population of shellfish, fish, and wildlife and allow for recreational activities in and on the water (40 CFR §130.11). Biological criteria (biocriteria) provide a tool with which water quality managers may directly evaluate whether such balanced populations are present. Maryland's biocriteria uses two multi-metric indices of biological integrity (IBI), one based on fish communities (F-IBI) and the other on benthic (bottom) communities of macroinvertebrates (B-IBI). These indices are developed from reference sites that consider regional differences in biological communities. These indices, as described below, are based on characteristics of fish and benthic communities commonly used to assess the ability of streams to support aquatic life, and can be calculated in a consistent and objective manner. Both indices will be used in Maryland to evaluate biological data for the Clean Water Act requirements.

The condition of all streams could in principle be measured through a census (i.e., without the need to resort to inferring condition), but would require visiting every length of stream in the state. The reality is that monitoring cannot be conducted on every foot or even mile of streams in a state due to resource constraints. Also, the sampling of a targeted non-random stream segment does not provide an unbiased estimate on the conditions of streams within a larger assessment unit. As a result the Department of Natural Resources (DNR) Maryland Biological Stream Survey (MBSS) program, on which the biocriteria methods are based, uses a statewide probability-based design to assess the biological condition of first, second, third, and fourth order, non-tidal streams (determined based on the solid blue line shown on U.S. Geological Survey 1:100,000-scale maps) within Maryland's 8-digit watersheds (Klauda et al. 1998, Roth et al. 2005). MBSS sites are sampled within a 75-meter segment of stream length. Individual sampling results are considered representative at the 75-meter segment, but because of design, the data can be used to estimate unbiased conditions of streams within an assessment unit. The MBSS conducted two rounds of sampling between 1995 and 2004: the first round of MBSS sampling was designed to assess major drainage basins (i.e., Maryland 6-digit) on 1:250,000-scale maps; and the second round was designed to assess smaller (i.e., Maryland 8-digit) watersheds on 1:100,000-scale maps. The use of random assignment of sampling locations within the population of first, second, third and fourth-order streams support the assessment of all of the State's waters.

The results of biological sampling will be applied for management and regulatory purposes (i.e., CWA §303(d)) at the same spatial resolution (i.e., 8-digit watersheds) used in the assessment effort (CWA 305(b)). If a watershed is determined to be impaired, corrective action must be taken. That action may begin with additional monitoring and evaluation to determine the cause of the impairment (i.e., stressor identification). Once the stressor has been identified, it may be appropriate to develop an estimate of the TMDL of the stressor that can be assimilated by the body of water and still allow it to achieve the water quality standards.

II. Rationale for Changing Approach

The current listing methodology uses the average watershed IBI score, for both fish and benthic communities, to determine watershed impairment. While the average IBI score does provide information on the magnitude of the degradation it does not give an indication of the extent of degradation (e.g., length of stream) found within a watershed, a current EPA requirement for integrated reporting. In addition, the current method utilizes a smaller scale assessment (i.e., 12-digit watershed) that classifies a 12-digit watershed (approximately 10 square miles) as impaired if one low IBI value from one site (i.e., 75 meter sample) is present. This site-level listing scale negates the advantage of the random monitoring design and the ability to report on the total stream system. Moreover, Southerland et al. (2007) assessed the average variability of the F-IBI and B-IBI scores at different spatial scales, and demonstrated that single site IBI scores are not representative at the 12-digit watershed scale.

Therefore, MDE requires an integrated biocriteria assessment approach that meets the following criteria:

1. Maintains consistent application at the current water quality management spatial scale (i.e., MD 8-digit watersheds);
2. Maximizes the advantages of a probabilistic monitoring design;
3. Includes a report on the extent of impact within the stream system (i.e., number of stream miles not supporting the aquatic life designated use);
4. Considers the uncertainty in various components of the assessment approach.

Addressing these four key items ensures accurate regulatory decisions regarding water quality in Maryland. Justification for these criteria is first that the Maryland Integrated [combined 303(d) and 305(b)] Report process typically uses a watershed-based water quality management scale for listing purposes. The advantages of this listing scale are (1) an appropriate water quality management scale specific to the pollutant or designated use; (2) promotes consistency with subsequent TMDL development; (3) allows for further spatial refinements during the TMDL development process, where more data may be available; and (4) promotes the use of probabilistic monitoring designs. Next, for biological assessment, Maryland uses a robust statewide random monitoring design that allows the State to estimate, with a specified confidence, the condition of 1st through 4th order streams within a watershed assessment unit.

Third, the biological reporting metric should be changed so that the extent of degradation in stream miles (or proportion of stream miles) can be applied in listing, a metric that is unavailable in the current biocriteria listing methodology. Identifying the extent of degraded stream miles within an assessment unit is consistent with EPA Integrated reporting requirements and meets EPA EMAP reporting recommendations. Using a watershed-based approach and reporting the extent of degraded conditions also allows the converse estimate, i.e., the extent of non-degraded or healthy streams. This allows the inclusion and identification of high quality (Tier II) waters that may be present in assessment units (8-digit watersheds) that are listed as impaired.

Finally, addressing uncertainty is critical to making accurate water quality management decisions that has significant implications on water quality improvement funding. Therefore, it is recommended that the biological listing method incorporate the uncertainty that results from the temporal and spatial variability in the sampling design. Addressing these four key items involves revising MDE's current biological listing methodology.

III. Revised Biological Listing Method

This section describes the revised biocriteria listing approach. Figure 6 illustrates the critical steps in the listing process. The first step is vetting the biological monitoring data and removing sites from consideration for listing decisions where either the F-IBI or B- IBI is not applicable (e.g., tidal waters, blackwater streams). This process is described in detail in section 3.1. Once this step has been completed, the next step is the watershed assessment, where a watershed is evaluated based on comparison to a reference condition that accounts for variability in sampling design (i.e. spatial variability and temporal variability) and establishes a target value for degradation. During this step of the assessment, a watershed that is significantly different than reference condition is listed as impaired (Category 5) on the Integrated List. If a watershed is not determined to be significantly different from reference conditions, the assessment must have an acceptable precision (margin of error) before the watershed is listed as attaining (Category 1 or 2) the water quality criterion. If the precision is not acceptable, the watershed is listed as inconclusive (Category 3). Details of this process are explained in section 3.2. Finally, if a watershed is identified as inconclusive (Category 3) then an evaluation of additional monitoring options are considered. Suggestions for this process are listed in section 3.3. If a watershed is classified as impaired (Category 5), then a stressor identification procedure is completed to determine if a TMDL is necessary. This process is described in section 3.4.

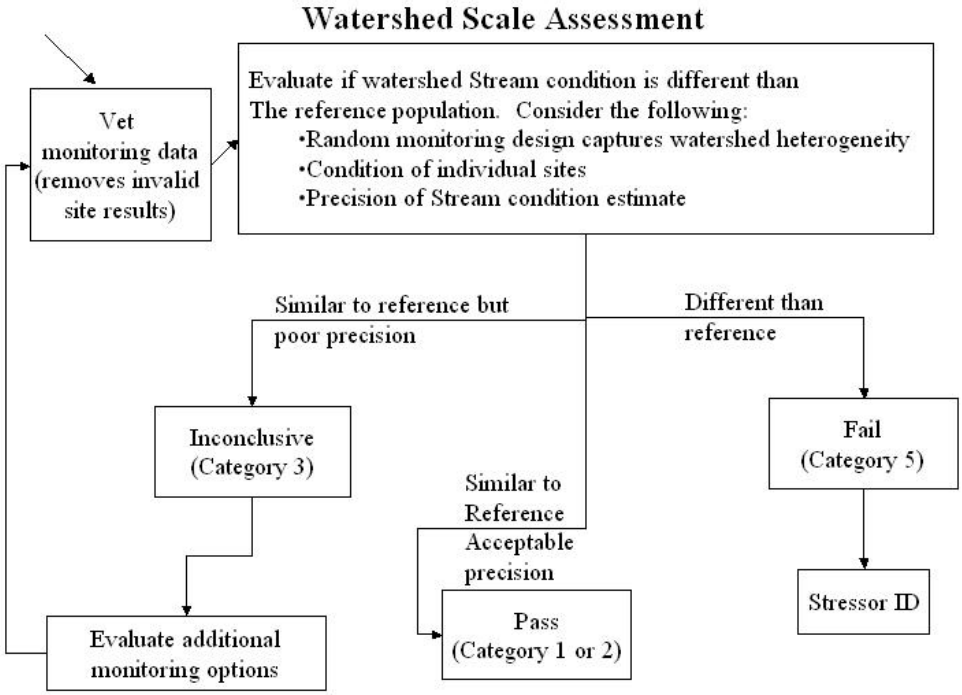


Figure 1: Watershed scale assessment procedure for determining biological impairment.

The revised biological listing method is consistent with the watershed approach of the original method, but does not assess the condition of watersheds based on single sites. Southerland et al. (2007) demonstrated that IBI results from single sites are not representative of 12-digit or larger watersheds. Therefore, the revised listing method focuses on assessing the condition of 8-digit watersheds with multiple sites by measuring the percentage of stream miles that are degraded. Use of the percentage of degraded stream miles allows quantification of the extent of degradation in a watershed and comparison with a reference watershed.

III.a. Vetting Monitoring Data

In all cases, state biologists may use professional judgment in evaluating biological results. However, to aid in the data review, a set of rules is used guide the data vetting process. These rules evaluate specific data parameters such as flow, catchment size, and buffer width to determine if the IBIs are reliable indicators of current watershed conditions. As a specific example, if there was a temporary or significant natural stressor such as drought or flood, sample results were evaluated to determine whether IBI scores resulted from anthropogenic influences or natural conditions. The final master database contains all biological sites considered valid for use in the listing process. The following rules for eliminating site results were developed by MDE with help from DNR to address situations when the IBIs are not representative of stream condition.

(a) Watersheds with less than a 300 acres often have limited fish habitat and naturally low fish diversity. As a result, the F-IBI will not be used for listing decisions at these sites unless the score is significantly greater than 3.
(b) Due to the unique chemistry of blackwater streams and the lack of defined blackwater reference conditions, the IBIs tend to underrate this stream type. For this reason, all blackwater sites (dissolved organic carbon > 8 mg/l and either pH <5 or acid neutralizing capacity (ANC) <200 μeq/L) with either the B-IBI or F-IBI indeterminate or significantly less than 3 will not be used. If the B-IBI and the F-IBI are significantly greater than 3, the stream will be rated as meeting the aquatic life designated use.
(c) If the number of organisms in a benthic sample is less than 60, that sample will not be used unless the B-IBI is significantly greater than 3 or supporting data (e.g., habitat rating, water quality data) indicate impairment and there is no evidence of sampling error or unusual natural phenomena.
(d) Heavy rain and runoff events (e.g., heavy rains, sudden heavy snowmelt) can scour the streambed and transport fish and/or benthics out of a stream segment. As such, samples taken within two weeks of such events may be considered invalid in the best professional judgment of State biologists and not used for evaluation of stream condition.
(e) The IBI scores of stream sampling sites that are tidally influenced will not be used to determine designated use attainment.
(f) The IBI scores of streams affected by excessive drought or intermittent conditions will not be used in listing decisions. Other sampling sites influenced by low flow conditions may also not be used.
(g) The IBI scores of sampling sites that are dominated by wetland-like conditions (e.g., no flowing water, shallow, abundant organic matter) may be considered invalid in the best professional judgment of State biologists.

(h) The IBI scores of streams impounded by beaver dams may be considered invalid. For example, a site within a natural impoundment that was created by beaver activity between the spring benthic macroinvertebrate sampling and the summer fish sampling. Man-made alterations to selected stream segments (e.g., channelization, dredging) should be noted, but they do not invalidate the IBIs.
(i) Sampling sites where the results may be skewed due to sampling error will not be used for assessment purposes.

In addition to these cases, State biologists may use best professional judgment to evaluate any streams sampled under conditions that are not characterized by reference stations.

III.b. Watershed Assessment Procedure

Desirable properties for any assessment or listing methodology are clarity and transparency. While water quality evaluations often deal with complex issues, the priorities for this listing methodology are that it be objective, transparent, and quantitative. Specifically, the revised biological assessment methodology should: 1) use a scientifically defensible numeric indicator (IBI) based on reference sites, 2) produce unbiased results for the assessment units, 3) follow a clear and logical framework and 4) be robust enough to yield the same results when applied by multiple analysts.

The revised listing methodology uses the scientifically robust F- and B- IBI developed by the MBSS program and documented in Southerland et al. (2005). To obtain unbiased results, we invoked a quantitative component to address temporal variability and sampling uncertainty from the MBSS monitoring design. In this report, variability is the year-to-year change in stream conditions that results from non-anthropogenic variation (e.g., climate, hydrology) and uncertainty is the result of inferring condition from the limited number at sites that can be sampled; given available resources. Finally, the listing method employs an assessment approach that is transparent and can be understood by a wide audience.

III.b.1. Reference Sites and Conditions

Reference sites are the foundation for biological assessment. Using reference sites that are minimally disturbed is critical to IBI development because reference conditions define the scoring criteria applied to the individual metrics (Figure 7). Selection of metrics for inclusion in the IBIs is based on how well they distinguish between reference and degraded sites. In Maryland, reference and degraded sites are identified using lists of abiotic criteria. A complete list of criteria for reference and degraded conditions can be found in Southerland et al. (2005).

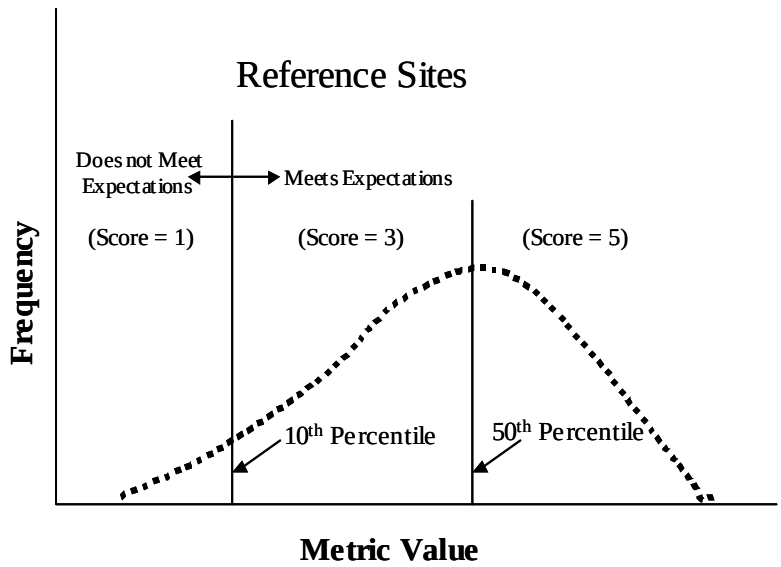


Figure 2: Scoring Criteria based on reference site distribution.

Once reference sites have been identified, they are sequestered into groups at minimal natural ecological variability by geography and stream type. The MBSS dataset provided enough reference sites (approximately 40) for F-IBI development in each of four naturally different stream types: Coastal Plain, Eastern Piedmont, warmwater Highlands, and coldwater Highlands. For the B-IBI, the coldwater stratum was not used because, unlike fish, benthic macroinvertebrates assemblages are not typically depauperate in minimally disturbed coldwater streams.

The MBSS computes the IBI as the average of individual metric scores for a site (see Southerland et al. 2005). Individual metric scores are based on comparison with the distribution of metric values at reference sites within each geographic stratum (Figure 7). Metrics are scored 1 (if < 10th percentile of reference value), 3 (10th to 50th percentile), or 5 (> 50th percentile). The final IBI scores are calculated as the average of the scores and therefore range from 1 to 5.

III.b.2. Year-to-Year Variability

All streams, regardless of anthropogenic changes, experience natural variability. These changes are a result of variability in precipitation and corresponding flows that result in fluctuation in the physical characteristics of the stream systems (Grossman et al. 1990). MBSS sentinel sites used to evaluate the natural year-to-year variability represent the best (based on physical, chemical and biological data) streams in Maryland. Sentinel sites are present in all regions (highland, eastern piedmont and coastal plain) and stream orders (1st through 3rd). Most importantly, they are located in catchments that are not likely to experience a change in anthropogenic disturbances over time.

The year-to-year variability of the sentinel sites was examined by comparing the annual IBI values for individual sites over a five-year monitoring period. The coefficient of variation was used to compare site results since this normalizes the site variability to the mean site score. There were a total of 17 sites that had five years of B-IBI scores and 15 sites with five years of F-IBI

scores. The average coefficient of variation was approximately 9% for the B-IBI and 13% for the F-IBI. Therefore, it can be expected that over a five-year period the standard deviation of year-to-year IBI scores will vary by 9 – 13% of the mean score.

III.b.3. Spatial Uncertainty of Stream Condition

The condition of all streams could in principle be measured through a census (i.e., without the need to resort to inferring condition), but would require visiting every length of stream in the state. The reality is that monitoring cannot be conducted on every foot or even mile of streams in a state due to resource constraints. Also, the sampling of a targeted non-random stream segment does not provide an unbiased estimate on the conditions of streams within a larger assessment unit. Therefore, MDE uses the MBSS dataset which is a statewide probability-based sample survey for assessing biological condition of wadeable, non-tidal streams in Maryland (Klauda et al. 1998, Roth et al. 2005) within Maryland's 8-digit watersheds. MBSS sites are randomly selected from the 1:100,000-scale stream network and sampled within a 75-m segment of stream length. Individual sampling results are considered representative at the 75-m segment, but because of design the data can be used to estimate unbiased conditions of streams within an assessment unit.

Realizing that randomly selected sampling sites may not always proportionately represent the assessment unit in which they are selected, MDE investigated the relationship between the number of sampling sites and the representation of watershed heterogeneity (See Appendix A). Generally, it was found that when approximately 10 sites were sampled within a watershed, that the average percent similarity between the number of sites within each land use were 85% similar to the stream mileage found within those same land uses (within the same watershed). Using this information as a guide, and a precision level of 25%, a minimum sample size of 8 samples was developed so as to capture both spatial heterogeneity and sample uncertainty for the watershed assessments.

III.b.4. Developing a Target Value for Degradation

Using the scoring criteria at reference sites, an IBI > 3 indicates the presence of a biological community with attributes (metric values) comparable to those of reference sites, while an IBI < 3 means that, on average, metric values fall short of reference expectations. Because a metric score of 3 represents the 10th percentile threshold of reference conditions, IBI values less than 3 represent sites that are suspected to be degraded. In contrast, values greater than or equal to 3 (i.e., fair or good) indicate that most attributes of the community are within the range of those at reference sites. However, Southerland et al. (2005) reported that "good" water quality was found at reference sites with low IBIs and that the distribution of reference and degraded site IBI values overlap, thus sites with a metric below the 10th percentile of reference sites (used for scoring) may have good quality waters. It is therefore recommended that an average site IBI score, based on a minimum of three consecutive years of data, be compared to the threshold of 3.

The State recognizes that in most cases three years of data will not be available. If less than three years of data are available, the year-to-year variability will be based on the information from sentinel sites. Given the natural variation of IBI scores in time, it is expected that a site with an average score of 3 will likely have a distribution of annual values above and below 3 (Figure 8). For these cases the coefficient of variation in combination with an assumed normal distribution is used to determine the minimum detectable difference and the subsequent minimum allowable limit (MAL). The MAL decreases the likelihood of a type I error, classifying a site is degraded when it is actually in good condition, given there is only one sample in time. The following formula is applied to estimate the MAL:

$$MAL = IBI_{avg} - z * IBI_{avg} * CV$$

where

MAL = Minimum Allowable IBI Limit to determine if a site is degraded
IBI_{avg} = Average annual allowable IBI value (3 for B-IBI and F-IBI)
z = Standard normal score (1.28 for 90% one-sided confidence interval)
CV = Coefficient of variation

The minimum allowable limit for the F-IBI is 2.5, assuming a coefficient of variation of 13%, while the minimum allowable limit for the B-IBI is 2.65, assuming a coefficient of variation of 9%.

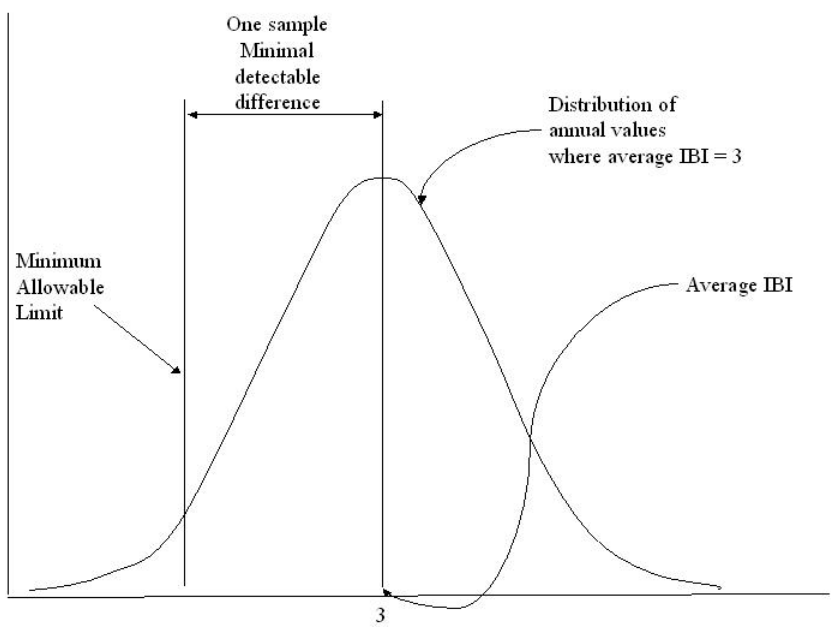


Figure 3: Distribution of annual values at site with average IBI of 3.

III.b.5. Watershed Assessment: The Null Hypothesis

The watershed assessment method tests the null hypothesis that the candidate assessment unit does not violate narrative criteria for the support of aquatic life. In the watershed assessment method there is a general sample size provision to ensure that the random monitoring sites generally represent the spatial heterogeneity in the Maryland 8-digit assessment units. This sample size helps control the type II error (false negative - classifying a water body as meeting criteria when it does not) and an alpha level is set to control the type I error (false positive - listing a water body as impaired when it is not).

To test the null hypothesis (i.e., assess a watershed), the exact binomial confidence intervals are calculated using the monitoring data in an assessment unit. Calculation of the binomial confidence intervals requires the total number of monitoring sites, the number of sites that are degraded, and the confidence level. The null hypothesis is that the populations of streams in the assessment unit are similar to the population of reference sites, which equates to less than 10% of the streams classified as degraded. A degraded site is defined as a site with either the benthic or F-IBI score below the specified threshold of 3 or MAL. With small sample sizes the type II error rate is typically large and can result in accepting the null hypothesis when it is not true (classifying a watershed as meeting criteria when it does not). To reduce the type II error rate, a required precision is specified in the method. The three possible outcomes are as follows:

- Null hypothesis accepted but precision is low: If the lower confidence limit is less than or equal to 10% but half the width of the confidence interval is greater than 25% (low precision), the watershed will be classified as inconclusive and assigned to Category 3 of the Integrated list and considered for future monitoring.
- Null hypothesis accepted and precision is acceptable: If the lower confidence limit is less or equal to 10% and half the width of the confidence interval is less than 25% (acceptable precision), the watershed will be classified as pass and assigned to Category 2 on the Integrated list.
- Null hypothesis rejected: If the lower confidence limit is greater than 10% the watershed will be classified as failing and assigned to Category 5 on the Integrated list.

To further reduce possible listing errors, the development of the methodology took into account the spatial distribution of the random monitoring sites as compared to the spatial heterogeneity of landscape features in the watershed. To do so, the Maryland 8-digit watershed landscape heterogeneity was determined using landscape clusters (groups of similar landscape conditions) that incorporate land use, land use change, soil erodibility, slope, precipitation, and population density (US EPA 2007). For all assessment units, the distribution of streams within landscape clusters were compared to the distribution of MBSS round 1 and round 2 monitoring sites. Results indicate that, on average, approximately 85% of the heterogeneity in 8-digit watersheds is captured with ten monitoring stations (see appendix A).

To ensure clarity and transparency, the assessment method was summarized in a simple lookup table (Table 4). The table incorporates (1) testing the null hypothesis that the candidate assessment unit does not violate narrative criteria for the support of aquatic life; (2) applying 90% exact binomial confidence intervals; (3) requiring a precision of 25%; and (4) ensuring that

the monitoring sites capture the watershed landscape heterogeneity. Considering the watershed/monitoring site similarity analysis results and the required statistical precision for a definitive classification, a watershed can be reasonably assessed if there are at least eight random monitoring sites. However, if less then eight sites are within an 8-digit watershed and three of them are classified as degraded the watershed will be classified as not supporting aquatic life and placed on Category 5 of the Integrated List. The rationale is that if five more samples were collected (to total eight) then the watershed would be listed on Category 5 regardless of the results at the new sites. Likewise, if there are less than eight monitoring sites but at least six sites are not degraded then the watershed will be classified as supporting aquatic life and placed in Category 2. Similarly, the rationale is that if two more sites were added to the monitoring design the watershed would be listed on Category 2 regardless of the new site results. However, it is recommended that at least eight sites be used for future monitoring designs.

Table 1: Biocriteria Assessment Table.

Total Number of Random Sites in Assessment Unit	Maximum Number of Degraded Samples in Assessment Unit to be Classified as Pass (Category 2)	Minimum Number of Degraded Samples in Assessment Unit to be Classified as Fail (Category 5)
≤7	(c)	3 (d)
8-11	2	3
12-18	3	4
19-25	4	5
26-32	5	6
33-40	6	7
41-47	7	8
48-55	8	9
56-63	9	10
64-71	10	11
72-79	11	12

Notes:

a. Using 90% one-sided exact binomial confidence intervals.
b. Classification of pass must have a precision <25%.
c. If n<=7 and at least 6 samples are not degraded then watershed classified as Pass (Category 2).
d. If n<=7 and 3 or more samples are degraded then watershed classified as Fail (Category 5).

Reporting for the Integrated Report will be as follows: If a watershed is determined to not meet criteria based on biological data, the watershed will be identified in the Integrated List database as “Not supporting aquatic life uses”, Category 5. A watershed determined to meet criteria, or for

which the data are inconclusive, will be identified in the Integrated List in categories 2 ("Fully supporting aquatic life uses") or 3 ("Inconclusive"), respectively.

III.c. Data Use Limitations

For Integrated Reporting assessments, only biological data from the most recent 10-year moving window will be used so as to ensure the use of accurate and up-to-date information. For instance, for the 2010 IR cycle, only biological data collected between the years 2000 and 2009 (Round II and Round III) will be used for assessment. Round 1 data (1995-1997) would no longer be used to update the 8-digit watershed assessments.

As the MBSS Program continues to collect more data around the state, they may continue to refine and enhance the respective benthic and fish IBIs in order to better discriminate between healthy and degraded stream conditions. In doing so, the IBI scores from an older site may change depending on what metrics are used and how the IBI is calculated. To keep assessments transparent and repeatable for regulatory purposes, MDE will not reassess sites sampled prior to 2008 using IBIs (fish or benthic) created after 2005. In essence, all IBIs from sites sampled prior to 2008, will be frozen at their current values. New sites sampled in 2008 or 2009 may be reanalyzed with a new IBI should one be developed.

III.d. Future Monitoring Priorities

Future monitoring will focus on the watersheds determined to be inconclusive in the final assessment. The watersheds will be categorized based on the number of samples (i.e., 7 having highest priority and 0 having lowest). To allow for the most efficient use of resources, consideration will also be given to the number of stations monitored by the DNR during the Round 3 MBSS sampling being conducted from 2007 to 2009.

Following this categorization of watersheds, monitoring prioritization will be based on the following factors. Firstly, the watersheds with the largest percentage of perennial non-tidal 1st through 4th order stream miles/drainage area will receive preference over basins with a large percentage of tidal stream miles/drainage area. Secondly, the available data for each watershed will be evaluated and best professional judgment applied to determine whether obvious causes of low IBI scores exist due to natural conditions (i.e., a high percentage of intermittent or blackwater streams in the watershed) and/or anthropogenic influences. In these cases, the watershed will be addressed by a Water Quality Analysis or referred for further stressor identification.

III.e. Stressor Identification

Cause/source identification - If a watershed is determined to be impaired based on biological data, the cause of the impairment(s) will then be determined by a review of all relevant chemical, physical, and physical habitat data. If the source of the impairment(s) cannot be determined from the data, an on-site evaluation of the watershed may be undertaken including more detailed diagnostic testing such as sediment and water column chemistry, and toxicity and geomorphic analyses. Habitat evaluation during sampling, along with chemical and physical data, will be used to evaluate the potential causes of impairments. It may be determined in some cases that the appropriate remedy is stream restoration rather than reduction of a specific chemical pollutant.

This methodology went largely unchanged between the 2008 and 2010 IR cycles with the exception of the incorporation of the biological stressor identification analysis (BSID) and the changing of the impairment 'cause' from "Combination Benthic/Fishes Bioassessments" to "Cause Unknown". The impairment cause was changed to better reflect the actual cause/pollutant impairing the watershed. Those watersheds that do not have the stressor identification process completed will remain as "Cause Unknown" until stressors are identified. As a result, a watershed may be listed in category 5 (impaired) with an unknown cause of impairment. However, it will be shown for such a listing, that the indicator of impairment was benthic and fish IBIs.

The 2008 Maryland Integrated Report contained seventy category 5 and thirty-nine category 3 listings for biological/cause unknown impairments. The current category 5 listings for biological/cause unknown impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, which will enable the Department to update current Integrated Report listings. The BSID analysis and process can be reviewed in more detail in the report entitled *Maryland Biological Stressor Identification Process* (*http://www.mde.state.md.us/assets/document/BSID_Methodology_Final_03-12-09.pdf*).

In effect, the BSID process links potential causes/stressors identified by the analysis with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID process is completed, one or several stressors (pollutants) may be identified as probable causes of the poor biological conditions within the Maryland 8-digit watershed.[1] MDE will use identified stressor(s) (e.g., sediment, chlorides, and nutrients) to support current pollutant listings, add new pollutant listings, and/or change the category listing for a pollutant on the Integrated Report. As a result, when stressor(s)/pollutant(s) are identified for a biologically-impaired watershed, the biological listing will be removed from category 5 and will be replaced by the appropriate pollutant listing(s) (in category 5). An example of this is illustrated below.

Table 5: Example of a 2008 Biological Listing

AU-ID	Basin Name	Category	Cause	Indicator
MD-02130906	Patapsco Lower North Branch	5	Combination Benthic/Fishes Bioassessments	N/A

[1] These probable causes each have an associated 'percent attributable risk' value which is essentially an estimate of what proportion of the watershed impairment can be attributed to the specified pollutant/cause.

Table 6: 2010 Listings Resulting from the BSID Analysis. These three listings essentially take the place of the previous biological listing (combination benthic/fishes bioassessments) for MD-02130906.

Cycle First Listed	AU-ID	Basin Name	Category	Cause	Indicator	Notes
1996	MD-02130906	Patapsco Lower North Branch	5	Total Suspended Solids (TSS)	Fish and Benthic IBIs	This pollutant listing existed previous to the BSID analysis. The BSID confirmed that this pollutant was impairing the watershed.
2010	MD-02130906	Patapsco Lower North Branch	5	Chlorides	Fish and Benthic IBIs	Newly identified stressor/cause
2010	MD-02130906	Patapsco Lower North Branch	5	Sulfates	Fish and Benthic IBIs	Newly identified stressor/cause

IV. Use of Non-MBSS data

Given that a key use of these procedures is for the Integrated list of impaired waters, and that the State is required to consider all readily available data. MDE recognizes the need to incorporate local biological data into the assessment process. Counties or other water monitoring programs that intend to submit their data to support decisions made using the biological framework should carefully follow the general guidelines below.

- Data collected using MBSS (field, laboratory and IBI protocols) or comparable methodology must be:
  - Documented to be of good quality;
  - Can be fully integrated with MBSS data;
  - Provided in a format readily available for merging into the MBSS database;
  - Contain the additional habitat, physical, and chemical information that the MBSS provides that allow for vetting.

- If MBSS methodology is not used but data are documented to be of good quality, in accordance with guidance and technical direction from the State, data will be used to supplement fully integrated MBSS and local data.

Data not meeting the requirements stated above may be helpful for non-regulatory purposes (e.g., targeting, education). Such data will be stored and documented for these uses. State biologists may refer submitters to information sources that will help them to improve the quality of their monitoring data.

V. Using Biological Data for Tier II Designation

As specified in COMAR [26.08.02.04-1] biological assessment data will be used for the purpose of identifying Tier II waters to be protected under the Department's Anti-degradation Policy Implementation Procedures. According to these regulations, when biological assessment data indicates that water quality is within 20% of the maximum attainable value of the index of biological integrity, those waters will be assigned a Tier II designation. For data sampled and scored according to MBSS protocols, this equates to having both a fish and benthic IBI score of 4 or greater at a single site. Using these two pieces of biological information sampled during different seasons of the year helps to independently validate the high quality status of a segment.

Tier II segments can exist in watersheds that are listed as impaired (Category 5) by the methodology spelled out in this document, despite Section 26.08.02.04-1D(2) of the Anti-degradation Procedures. This section states "Water bodies included in the List of Impaired Waters (303(d) List) are not Tier II waters for the impairing substance." The biological listing methodology only assesses the biological condition of streams at the 8-digit watershed scale (approximately 90 square miles) and calculates the percentage of stream miles impaired within this larger scale. As a result, it is possible for smaller stream segments located within 'impaired' (Category 5) 8-digit watersheds to be of Tier II quality due to local variation in stressors and land use. Since local water quality conditions are better characterized through site-specific monitoring, individual stations are used to identify and designate Tier II segments regardless of the watershed assessment result. For maps of current Tier II waters please refer to http://www.mde.state.md.us/ResearchCenter/Data/waterQualityStandards/Antidegradation/index.asp.

VI. Watershed Assessment Summary

MBSS Round 2 data were collected in 2000-2004 at sites allocated randomly among all nontidal streams present on 1:100,000-scale maps. The number of sites sampled in individual MD 8-digit watersheds varied generally with the length of nontidal streams in each watershed. To increase the number of sites in each watershed, MBSS Round 2 data were supplemented with Round 1 data collected in 1995-1997. MBSS Round 1 data were collected on nontidal streams present on 1:250,000-scale maps and therefore sampled larger streams slightly more often than random. Supplementing Round 2 data with Round 1 data does not significantly bias the assessment of nontidal streams at the scale of 8-digit watersheds.

Using the MBSS round 1 and round 2 (2000-2004) data as input into the listing method, a total of 113 out of 135 Maryland 8-digit watersheds were assessed for biological impairments. Table 5 and Figure 9 present a summary of the 2008 watershed assessment. Details of the biological assessment analysis are presented in Table 6. A comparison between the previous the biocriteria method (average IBI) and the revised biocriteria method (% stream mile) is presented in Table 7.

In summary, 25 watersheds do not have any monitoring data. Using the 1:100,000 stream coverage, eight of the watersheds were reported to have zero 1st through 4th order non-tidal wadeable streams. Also many of these watersheds are in areas with a predominance of tidal streams. The remaining 17 watersheds without any data only accounted for 2% (148 miles) of the total 1st –4th order stream miles in Maryland. The 25 watersheds without monitoring data will be placed in Category 3 on the 2008 Integrated list and prioritized for additional monitoring.

A total of 70 watersheds were classified as impaired and will be placed on Category 5 of the 2008 Integrated list. These watersheds represent 74% (6,813 miles) of the 1st through 4th order streams in Maryland. Within these watersheds, a total of 51% (3,494/6,813 miles) of the streams are degraded.

A total of 24 watersheds were classified as similar to reference conditions and fully supporting the aquatic life use. These watersheds account for 19% (1,750 miles) of the 1st through 4th order streams in Maryland. These 24 watersheds will be placed in Category 2 of the 2008 Integrated List.

The remaining 19 watersheds were classified as inconclusive and account for 5% (488 miles) of Maryland's 1st through 4th order streams. These watersheds were classified as inconclusive because either the monitoring data does not capture the heterogeneity of the watershed or the uncertainty is too high for the watershed to be classified as passing. These watersheds will be placed in Category 3 of the 2008 Integrated List and will be targeted for additional monitoring.

Table 7: Summary of 2008 Watershed Assessments Using MBSS Rounds 1 and 2 Data.

Integrated Report Final Status	Number of 8-digit Watersheds	Stream Miles (a)	% of Total Stream Miles (a/9,199)	Stream Miles with F or B-IBI<3 (b)	% of Stream Miles with F or B-IBI<3 (b/a)	% of Total Stream Miles with F or B-IBI<3 (b/9,199)	Integrated Report of Watershed Stream Miles Impaired (c)	Integrated Report of % of Total Watershed Stream Miles Impaired (c/9,199)
Category 2	24	1,750	19%	234	13%	3%	0	0
Category 3 (Inconclusive)	19	488	5%	183	37%	2%	NA	NA
Category 3 (No data)	25	148	2%	0			NA	NA
Category 4 or 5	70	6,813	74%	3,494	51%	38%	3,494	38%
Total	**138**	**9,199**	**100%**	**3,911**	**43%**	**43%**	**3,494**	**38%**

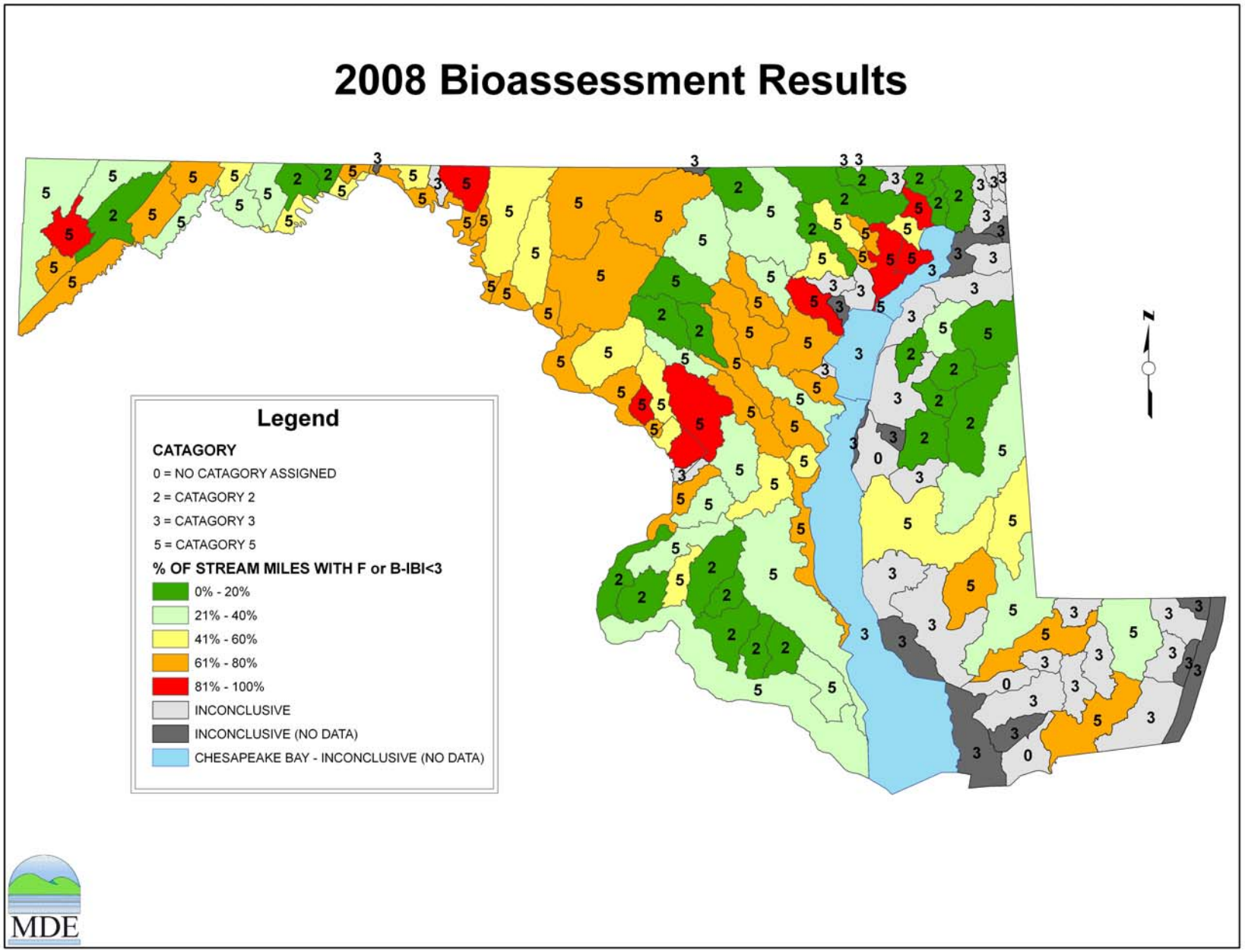


Figure 4: Summary of 2008 Watershed Assessment Using MBSS Rounds 1 and 2 Data.

Table 8: 2008 Biological Assessment for Maryland 8-digit Watersheds.

MDE8DIGT	MDE8NAME	% Stream Mile Assessment						
		Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
2050301	Conewago Creek	n=0						
2120201	L Susquehanna River	Fail	83%	49%	98%	73%	6	5
2120202	Deer Creek	Pass	11%	5%	19%	1%	46	5
2120203	Octoraro Creek	Pass	8%	1%	29%	-2%	12	1
2120204	Conowingo Dam Susq R	Inc	20%	2%	58%	10%	5	1
2120205	Broad Creek	Pass	12%	3%	28%	2%	17	2
2130101	Atlantic Ocean	n=0						
2130102	Assawoman Bay	n=0						
2130103	Isle of Wight Bay	Inc	50%	14%	86%	40%	4	2
2130104	Sinepuxent Bay	n=0						
2130105	Newport Bay	n=0						
2130106	Chincoteague Bay	n=0						
2130201	Pocomoke Sound	n=0						
2130202	Lower Pocomoke River	Fail	63%	34%	85%	53%	8	5
2130203	Upper Pocomoke River	Fail	35%	21%	50%	25%	23	8
2130204	Dividing Creek	Inc	0%	0%	44%	-10%	4	0
2130205	Nassawango Creek	Inc	40%	11%	75%	30%	5	2
2130206	Tangier Sound	n=0						
2130207	Big Annemessex River	n=0						
2130208	Manokin River	Inc	50%	5%	95%	40%	2	1
2130301	Lower Wicomico River	Fail	71%	40%	92%	61%	7	5
2130302	Monie Bay	n=0						
2130303	Wicomico Creek	n=0						
2130304	Wicomico River Head	Inc	20%	2%	58%	10%	5	1
2130305	Nanticoke River	Fail	35%	21%	50%	25%	23	8
2130306	Marshyhope Creek	Fail	55%	32%	76%	45%	11	6

MDE8DIGT	MDE8NAME	% Stream Mile Assessment						
		Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
2130307	Fishing Bay	n=0						
2130308	Transquaking River	Fail	67%	33%	91%	57%	6	4
2130401	Honga River	n=0						
2130402	Little Choptank	n=0						
2130403	Lower Choptank	Fail	45%	24%	68%	35%	11	5
2130404	Upper Choptank	Fail	38%	26%	50%	28%	32	12
2130405	Tuckahoe Creek	Pass	19%	10%	33%	9%	26	5
2130501	Eastern Bay	n=0						
2130502	Miles River	Inc	50%	5%	95%	40%	2	1
2130503	Wye River	Pass	15%	4%	36%	5%	13	2
2130504	Kent Narrows	n=0						
2130505	Lower Chester River	Inc	33%	3%	80%	23%	3	1
2130506	Langford Creek	Pass	14%	1%	45%	4%	7	1
2130507	Corsica River	Pass	8%	1%	27%	-2%	13	1
2130508	Southeast Creek	Pass	0%	0%	19%	-10%	11	0
2130509	Middle Chester River	Fail	36%	22%	52%	26%	22	8
2130510	Upper Chester River	Fail	20%	11%	32%	10%	30	6
2130511	Kent Island Bay	n=0						
2130601	Lower Elk River	n=0						
2130602	Bohemia River	Inc	67%	20%	97%	57%	3	2
2130603	Upper Elk River	Inc	33%	3%	80%	23%	3	1
2130604	Back Creek	n=0						
2130605	Little Elk Creek	Inc	17%	2%	51%	7%	6	1
2130606	Big Elk Creek	Inc	17%	2%	51%	7%	6	1
2130607	Christina River	Inc	100%	32%	100%	90%	2	2
2130608	Northeast River	Pass	14%	4%	34%	4%	14	2
2130609	Furnace Bay	Pass	11%	1%	37%	1%	9	1
2130610	Sassafras River	Inc	25%	3%	68%	15%	4	1
2130611	Stillpond-Fairlee	Inc	20%	2%	58%	10%	5	1

MDE8DIGT	MDE8NAME	% Stream Mile Assessment						
		Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
2130701	Bush River	Fail	100%	56%	100%	90%	4	4
2130702	Lower Winters Run	Fail	70%	45%	88%	60%	10	7
2130703	Atkisson Reservoir	Fail	56%	30%	79%	46%	9	5
2130704	Bynum Run	Fail	80%	55%	95%	70%	10	8
2130705	Aberdeen Proving Ground	Fail	83%	49%	98%	73%	6	5
2130706	Swan Creek	Fail	57%	28%	83%	47%	7	4
2130801	Gunpowder River	n=0						
2130802	Lower Gunpowder Falls	Fail	54%	33%	74%	44%	13	7
2130803	Bird River	Inc	100%	32%	100%	90%	2	2
2130804	Little Gunpowder Falls	Pass	15%	7%	27%	5%	27	4
2130805	Loch Raven Reservoir	Fail	27%	18%	37%	17%	45	12
2130806	Prettyboy Reservoir	Pass	16%	6%	32%	6%	19	3
2130807	Middle River - Browns	n=0						
2130901	Back River	Fail	100%	90%	100%	90%	21	21
2130902	Bodkin Creek	Inc	100%	32%	100%	90%	2	2
2130903	Baltimore Harbor	Fail	69%	55%	81%	59%	26	18
2130904	Jones Falls	Fail	36%	22%	52%	26%	22	8
2130905	Gwynns Falls	Fail	79%	65%	88%	69%	28	22
2130906	Patapsco River L N Br	Fail	61%	48%	72%	51%	33	20
2130907	Liberty Reservoir	Fail	22%	16%	29%	12%	77	17
2130908	S Branch Patapsco	Fail	20%	12%	30%	10%	40	8
2131001	Magothy River	Fail	67%	33%	91%	57%	6	4
2131002	Severn River	Fail	35%	21%	52%	25%	20	7
2131003	South River	Fail	80%	55%	95%	70%	10	8
2131004	West River	Fail	57%	28%	83%	47%	7	4
2131005	West Chesapeake Bay	Fail	71%	55%	84%	61%	21	15
2131101	Patuxent River lower	Fail	38%	27%	50%	28%	37	14
2131102	Patuxent River middle	Fail	41%	25%	59%	31%	17	7
2131103	Western Branch	Fail	38%	24%	53%	28%	24	9

MDE8DIGT	MDE8NAME	% Stream Mile Assessment						
		Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
2131104	Patuxent River upper	Fail	73%	54%	88%	63%	15	11
2131105	Little Patuxent River	Fail	70%	56%	82%	60%	27	19
2131106	Middle Patuxent River	Pass	20%	8%	39%	10%	15	3
2131107	Rocky Gorge Dam	Fail	24%	11%	42%	14%	17	4
2131108	Brighton Dam	Pass	11%	4%	23%	1%	27	3
2139996	Upper Chesapeake Bay	n=0						
2139997	Middle Chesapeake Bay	n=0						
2139998	Lower Chesapeake Bay	n=0						
2140101	Potomac River L tidal	Fail	38%	15%	66%	28%	8	3
2140102	Potomac River M tidal	Pass	15%	4%	36%	5%	13	2
2140103	St. Mary's River	Fail	23%	13%	37%	13%	26	6
2140104	Breton Bay	Pass	14%	1%	45%	4%	7	1
2140105	St. Clements Bay	Pass	15%	4%	36%	5%	13	2
2140106	Wicomico River	Pass	17%	5%	39%	7%	12	2
2140107	Gilbert Swamp	Pass	14%	4%	34%	4%	14	2
2140108	Zekiah Swamp	Pass	15%	8%	26%	5%	33	5
2140109	Port Tobacco River	Fail	50%	29%	71%	40%	12	6
2140110	Nanjemoy Creek	Pass	20%	8%	39%	10%	15	3
2140111	Mattawoman Creek	Fail	26%	13%	43%	16%	19	5
2140201	Potomac River U tidal	Fail	62%	40%	80%	52%	13	8
2140202	Potomac River MO Cnty	Fail	67%	56%	76%	57%	42	28
2140203	Piscataway Creek	Fail	33%	17%	53%	23%	15	5
2140204	Oxon Creek	Inc	100%	32%	100%	90%	2	2
2140205	Anacostia River	Fail	84%	73%	91%	74%	37	31
2140206	Rock Creek	Fail	56%	38%	72%	46%	18	10
2140207	Cabin John Creek	Fail	100%	75%	100%	90%	8	8
2140208	Seneca Creek	Fail	59%	47%	71%	49%	32	19
2140301	Potomac River FR Cnty	Fail	79%	62%	90%	69%	19	15
2140302	Lower Monocacy River	Fail	61%	54%	69%	51%	83	51

MDE8DIGT	MDE8NAME	% Stream Mile Assessment						
		Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
2140303	Upper Monocacy River	Fail	62%	53%	71%	52%	58	36
2140304	Double Pipe Creek	Fail	65%	54%	75%	55%	43	28
2140305	Catoctin Creek	Fail	47%	30%	65%	37%	17	8
2140501	Potomac River WA Cnty	Fail	73%	60%	84%	63%	30	22
2140502	Antietam Creek	Fail	59%	47%	71%	49%	32	19
2140503	Marsh Run	Fail	67%	33%	91%	57%	6	4
2140504	Conococheague Creek	Fail	85%	64%	96%	75%	13	11
2140505	Little Conococheague	Inc	29%	8%	60%	19%	7	2
2140506	Licking Creek	Fail	43%	17%	72%	33%	7	3
2140507	Tonoloway Creek	n=0						
2140508	Potomac River AL Cnty	Fail	56%	30%	79%	46%	9	5
2140509	Little Tonoloway Creek	Fail	67%	40%	87%	57%	9	6
2140510	Sideling Hill Creek	Pass	20%	5%	45%	10%	10	2
2140511	Fifteen Mile Creek	Pass	4%	0%	13%	-6%	28	1
2140512	Town Creek	Fail	23%	11%	38%	13%	22	5
2141001	Potomac River L N Branch	Fail	21%	12%	31%	11%	39	8
2141002	Evitts Creek	Fail	50%	30%	70%	40%	14	7
2141003	Wills Creek	Fail	63%	43%	79%	53%	16	10
2141004	Georges Creek	Fail	76%	58%	89%	66%	17	13
2141005	Potomac River U N Branch	Fail	62%	46%	76%	52%	21	13
2141006	Savage River	Pass	7%	3%	16%	-3%	41	3
5020201	Youghiogheny River	Fail	29%	22%	38%	19%	65	19
5020202	Little Youghiogheny R	Fail	63%	46%	78%	53%	19	12
5020203	Deep Creek Lake	Fail	100%	75%	100%	90%	8	8
5020204	Casselman River	Fail	29%	19%	42%	19%	34	10

Table 9: Comparison Between Previous Biocriteria Method (average IBI) and New Biocriteria Method (% stream mile).

			Average IBI Listing Methodology →									% Stream Mile Listing Methodology						
MDE8DIGT	MDE8NAME	Total MBSS Sites	Final Status using Average IBI	Average BIBI	BIBI (LCL)	BIBI (UCL)	BIBI n	Average FIBI	FIBI LCL	FIBI UCL	FIBI n	Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
2050301	Conewago Creek	0	n=0									Inc						
2120201	L Susquehanna River	6	n<10	3.39	2.59	4.19	6	2.20	1.33	3.07	5	Fail	83%	49%	98%	73%	6	5
2120202	Deer Creek	46	Pass	4.00	3.85	4.15	46	3.94	3.77	4.10	38	Pass	11%	5%	19%	1%	46	5
2120203	Octoraro Creek	12	Pass	3.60	3.26	3.93	12	3.68	3.32	4.05	10	Pass	8%	1%	29%	-2%	12	1
2120204	Conowingo Dam Susq R	5	n<10	3.00	2.57	3.43	5	3.93	3.51	4.36	5	Inc	20%	2%	58%	10%	5	1
2120205	Broad Creek	17	Pass	3.45	3.24	3.66	17	3.67	3.41	3.92	12	Pass	12%	3%	28%	2%	17	2
2130101	Atlantic Ocean	0	n=0									Inc						
2130102	Assawoman Bay	0	n=0									Inc						
2130103	Isle of Wight Bay	4	n<10	2.71	2.24	3.19	4	3.50	2.83	4.17	2	Inc	50%	14%	86%	40%	4	2
2130104	Sinepuxent Bay	0	n=0									Inc						
2130105	Newport Bay	0	n=1									Inc						
2130106	Chincoteague Bay	0	n=1									Inc						
2130201	Pocomoke Sound	0	n=0									Inc						
2130202	Lower Pocomoke River	8	n<10	2.50	2.19	2.81	8	2.93	2.54	3.33	5	Fail	63%	34%	85%	53%	8	5
2130203	Upper Pocomoke River	23	Inc	3.16	2.94	3.37	22	3.73	3.52	3.94	22	Fail	35%	21%	50%	25%	23	8
2130204	Dividing Creek	4	n<10	4.71	4.56	4.86	4	4.00	3.85	4.15	4	Inc	0%	0%	44%	-10%	4	0
2130205	Nassawango Creek	5	n<10	3.47	2.66	4.28	5	3.92	3.01	4.82	4	Inc	40%	11%	75%	30%	5	2
2130206	Tangier Sound	0	n=0									Inc						
2130207	Big Annemessex River	0	n=0									Inc						
2130208	Manokin River	2	n<10	3.57	2.84	4.30	2	3.00	2.27	3.73	2	Inc	50%	5%	95%	40%	2	1
2130301	Lower Wicomico River	7	n<10	2.76	2.38	3.13	7	3.17	2.76	3.57	6	Fail	71%	40%	92%	61%	7	5

			Average IBI Listing Methodology →									% Stream Mile Listing Methodology						
MDE8DIGT	MDE8NAME	Total MBSS Sites	Final Status using Average IBI	Average BIBI	BIBI (LCL)	BIBI (UCL)	BIBI n	Average FIBI	FIBI LCL	FIBI UCL	FIBI n	Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
2130302	Monie Bay	0	n=0									Inc						
2130303	Wicomico Creek	0	n=1									Inc						
2130304	Wicomico River Head	5	n<10	3.91	3.32	4.51	5	3.59	2.99	4.18	5	Inc	20%	2%	58%	10%	5	1
2130305	Nanticoke River	23	Inc	3.32	3.06	3.58	23	3.11	2.82	3.40	18	Fail	35%	21%	50%	25%	23	8
2130306	Marshyhope Creek	11	Inc	3.26	2.81	3.71	11	3.48	2.99	3.98	9	Fail	55%	32%	76%	45%	11	6
2130307	Fishing Bay	0	n=1									Inc						
2130308	Transquaking River	6	n<10	2.48	2.24	2.72	6	3.25	2.96	3.54	4	Fail	67%	33%	91%	57%	6	4
2130401	Honga River	0	n=0									Inc						
2130402	Little Choptank	0	n=1									Inc						
2130403	Lower Choptank	11	Inc	3.05	2.66	3.44	11	3.56	3.03	4.08	6	Fail	45%	24%	68%	35%	11	5
2130404	Upper Choptank	32	Inc	3.20	2.94	3.45	32	3.74	3.44	4.03	24	Fail	38%	26%	50%	28%	32	12
2130405	Tuckahoe Creek	26	Pass	3.59	3.35	3.84	26	4.05	3.81	4.30	25	Pass	19%	10%	33%	9%	26	5
2130501	Eastern Bay	0	n=0									Inc						
2130502	Miles River	2	n<10	3.29	2.19	4.38	2	1.83	0.74	2.93	2	Inc	50%	5%	95%	40%	2	1
2130503	Wye River	13	Pass	3.90	3.54	4.26	13	3.67	3.27	4.06	11	Pass	15%	4%	36%	5%	13	2
2130504	Kent Narrows	0	n=0									Inc						
2130505	Lower Chester River	3	n<10	2.81	2.28	3.34	3	2.17	1.52	2.82	2	Inc	33%	3%	80%	23%	3	1
2130506	Langford Creek	7	n<10	3.33	2.89	3.77	7	3.93	3.41	4.45	5	Pass	14%	1%	45%	4%	7	1
2130507	Corsica River	13	Pass	4.04	3.77	4.32	13	4.30	3.97	4.63	9	Pass	8%	1%	27%	-2%	13	1
2130508	Southeast Creek	11	Pass	3.65	3.30	3.99	11	4.19	3.80	4.57	9	Pass	0%	0%	19%	-10%	11	0
2130509	Middle Chester River	22	Inc	3.09	2.91	3.27	22	3.32	3.13	3.50	21	Fail	36%	22%	52%	26%	22	8
2130510	Upper Chester River	30	Pass	3.75	3.51	3.99	30	3.93	3.68	4.18	28	Fail	20%	11%	32%	10%	30	6
2130511	Kent Island Bay	0	n=0									Inc						
2130601	Lower Elk River	0	n=0									Inc						
2130602	Bohemia River	3	n<10	2.33	1.53	3.13	3	3.50	2.52	4.48	2	Inc	67%	20%	97%	57%	3	2
2130603	Upper Elk River	3	n<10	3.71	2.61	4.82	3	3.67	2.56	4.77	3	Inc	33%	3%	80%	23%	3	1
2130604	Back Creek	0	n=0									Inc						
2130605	Little Elk Creek	6	n<10	3.44	3.14	3.75	6	3.67	3.36	3.97	6	Inc	17%	2%	51%	7%	6	1
2130606	Big Elk Creek	6	n<10	3.85	3.18	4.52	6	4.27	3.53	5.00	5	Inc	17%	2%	51%	7%	6	1

			Average IBI Listing Methodology →									% Stream Mile Listing Methodology						
MDE8DIGT	MDE8NAME	Total MBSS Sites	Final Status using Average IBI	Average BIBI	BIBI (LCL)	BIBI (UCL)	BIBI n	Average FIBI	FIBI LCL	FIBI UCL	FIBI n	Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
2130607	Christina River	2	n<10	2.17	1.95	2.38	2	2.67	2.67	2.67	1	Inc	100%	32%	100%	90%	2	2
2130608	Northeast River	14	Pass	3.29	3.06	3.53	14	4.13	3.89	4.37	13	Pass	14%	4%	34%	4%	14	2
2130609	Furnace Bay	9	n<10	3.92	3.48	4.36	9	4.14	3.64	4.64	7	Pass	11%	1%	37%	1%	9	1
2130610	Sassafras River	4	n<10	2.86	2.48	3.24	4	4.33	3.89	4.77	3	Inc	25%	3%	68%	15%	4	1
2130611	Stillpond-Fairlee	5	n<10	3.23	2.96	3.50	5	3.33	3.03	3.63	4	Inc	20%	2%	58%	10%	5	1
2130701	Bush River	4	n<10	1.58	1.26	1.90	4	3.83	3.38	4.29	2	Fail	100%	56%	100%	90%	4	4
2130702	Lower Winters Run	10	Inc	2.17	1.86	2.47	10	3.78	3.45	4.10	9	Fail	70%	45%	88%	60%	10	7
2130703	Atkisson Reservoir	9	n<10	2.67	2.18	3.15	8	4.26	3.80	4.72	9	Fail	56%	30%	79%	46%	9	5
2130704	Bynum Run	10	Inc	1.83	1.48	2.18	10	3.85	3.48	4.22	9	Fail	80%	55%	95%	70%	10	8
2130705	Aberdeen Proving Ground	6	n<10	2.05	1.65	2.44	6	1.33	0.77	1.89	3	Fail	83%	49%	98%	73%	6	5
2130706	Swan Creek	7	n<10	2.70	2.19	3.22	7	3.93	3.32	4.54	5	Fail	57%	28%	83%	47%	7	4
2130801	Gunpowder River	0	n=1									Inc						
2130802	Lower Gunpowder Falls	13	Fail	2.33	1.93	2.74	13	3.20	2.74	3.66	10	Fail	54%	33%	74%	44%	13	7
2130803	Bird River	2	n<10	2.00	1.15	2.85	2	3.00	2.15	3.85	2	Inc	100%	32%	100%	90%	2	2
2130804	Little Gunpowder Falls	27	Pass	3.69	3.51	3.87	27	3.63	3.43	3.84	21	Pass	15%	7%	27%	5%	27	4
2130805	Loch Raven Reservoir	45	Pass	3.88	3.68	4.07	45	3.32	3.09	3.54	34	Fail	27%	18%	37%	17%	45	12
2130806	Prettyboy Reservoir	19	Pass	3.75	3.52	3.98	19	3.96	3.73	4.20	18	Pass	16%	6%	32%	6%	19	3
2130807	Middle River - Browns	0	n=0									Inc						
2130901	Back River	21	Fail	1.66	1.53	1.78	21	1.95	1.82	2.08	20	Fail	100%	90%	100%	90%	21	21
2130902	Bodkin Creek	2	n<10	2.14	1.78	2.51	2	1.33	0.97	1.70	2	Inc	100%	32%	100%	90%	2	2
2130903	Baltimore Harbor	26	Fail	2.40	2.12	2.68	26	2.65	2.30	2.99	17	Fail	69%	55%	81%	59%	26	18
2130904	Jones Falls	22	Inc	3.22	2.87	3.58	22	2.68	2.29	3.06	19	Fail	36%	22%	52%	26%	22	8
2130905	Gwynns Falls	28	Fail	2.26	2.03	2.49	28	2.94	2.70	3.19	24	Fail	79%	65%	88%	69%	28	22
2130906	Patapsco River L N Br	33	Fail	2.30	2.05	2.56	33	2.88	2.59	3.16	27	Fail	61%	48%	72%	51%	33	20
2130907	Liberty Reservoir	77	Pass	3.35	3.21	3.50	77	4.22	4.07	4.37	70	Fail	22%	16%	29%	12%	77	17
2130908	S Branch Patapsco	40	Pass	3.21	3.02	3.40	38	4.36	4.16	4.56	37	Fail	20%	12%	30%	10%	40	8
2131001	Magothy River	6	n<10	2.43	1.99	2.87	6	2.44	1.82	3.07	3	Fail	67%	33%	91%	57%	6	4
2131002	Severn River	20	Inc	3.43	3.15	3.70	20	3.09	2.80	3.38	18	Fail	35%	21%	52%	25%	20	7
2131003	South River	10	Inc	2.54	2.32	2.77	10	3.67	3.25	4.08	3	Fail	80%	55%	95%	70%	10	8

			Average IBI Listing Methodology →									% Stream Mile Listing Methodology						
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2131004	West River	7	n<10	2.06	1.68	2.44	7	NA	NA	NA	0	Fail	57%	28%	83%	47%	7	4
2131005	West Chesapeake Bay	21	Fail	3.18	2.88	3.47	20	2.12	1.79	2.46	15	Fail	71%	55%	84%	61%	21	15
2131101	Patuxent River lower	37	Pass	3.69	3.49	3.89	37	3.30	3.06	3.54	25	Fail	38%	27%	50%	28%	37	14
2131102	Patuxent River middle	17	Inc	3.42	3.07	3.77	17	3.04	2.67	3.42	15	Fail	41%	25%	59%	31%	17	7
2131103	Western Branch	24	Inc	3.05	2.85	3.24	24	3.70	3.49	3.91	20	Fail	38%	24%	53%	28%	24	9
2131104	Patuxent River upper	15	Fail	2.41	2.16	2.66	15	2.33	2.06	2.61	12	Fail	73%	54%	88%	63%	15	11
2131105	Little Patuxent River	27	Fail	2.11	1.89	2.33	27	3.27	3.04	3.50	25	Fail	70%	56%	82%	60%	27	19
2131106	Middle Patuxent River	15	Pass	3.49	3.23	3.75	15	3.49	3.20	3.77	13	Pass	20%	8%	39%	10%	15	3
2131107	Rocky Gorge Dam	17	Pass	3.56	3.26	3.85	17	3.52	3.21	3.83	15	Fail	24%	11%	42%	14%	17	4
2131108	Brighton Dam	27	Pass	3.77	3.56	3.97	27	3.61	3.40	3.82	25	Pass	11%	4%	23%	1%	27	3
2139996	Upper Chesapeake Bay	0	n=0									Inc						
2139997	Middle Chesapeake Bay	0	n=0									Inc						
2139998	Lower Chesapeake Bay	0	n=0									Inc						
2140101	Potomac River L tidal	8	n<10	4.00	3.76	4.24	8	2.42	2.08	2.76	4	Fail	38%	15%	66%	28%	8	3
2140102	Potomac River M tidal	13	Pass	3.86	3.51	4.21	12	4.21	3.85	4.58	11	Pass	15%	4%	36%	5%	13	2
2140103	St. Mary's River	26	Pass	3.53	3.26	3.79	20	3.54	3.29	3.78	23	Fail	23%	13%	37%	13%	26	6
2140104	Breton Bay	7	n<10	3.98	3.48	4.48	7	3.78	3.01	4.55	3	Pass	14%	1%	45%	4%	7	1
2140105	St. Clements Bay	13	Pass	4.16	3.85	4.47	13	3.59	3.22	3.96	9	Pass	15%	4%	36%	5%	13	2
2140106	Wicomico River	12	Pass	4.02	3.68	4.37	12	3.63	3.20	4.05	8	Pass	17%	5%	39%	7%	12	2
2140107	Gilbert Swamp	14	Inc	3.69	3.38	4.00	14	3.10	2.73	3.47	10	Pass	14%	4%	34%	4%	14	2
2140108	Zekiah Swamp	33	Pass	4.05	3.82	4.28	33	4.01	3.75	4.27	26	Pass	15%	8%	26%	5%	33	5
2140109	Port Tobacco River	12	Inc	3.38	2.97	3.79	11	2.93	2.47	3.38	9	Fail	50%	29%	71%	40%	12	6
2140110	Nanjemoy Creek	15	Pass	3.98	3.67	4.29	15	3.90	3.54	4.26	11	Pass	20%	8%	39%	10%	15	3
2140111	Mattawoman Creek	19	Pass	3.77	3.50	4.04	19	3.48	3.17	3.78	15	Fail	26%	13%	43%	16%	19	5
2140201	Potomac River U tidal	13	Fail	2.58	2.31	2.85	13	3.21	2.92	3.51	11	Fail	62%	40%	80%	52%	13	8
2140202	Potomac River MO Cnty	42	Fail	2.27	2.10	2.45	42	3.40	3.22	3.57	41	Fail	67%	56%	76%	57%	42	28
2140203	Piscataway Creek	15	Inc	2.87	2.58	3.16	15	3.49	3.18	3.80	13	Fail	33%	17%	53%	23%	15	5
2140204	Oxon Creek	2	n<10	1.29	0.92	1.65	2	1.00	0.63	1.37	2	Inc	100%	32%	100%	90%	2	2
2140205	Anacostia River	37	Fail	2.02	1.84	2.21	37	3.28	3.09	3.48	33	Fail	84%	73%	91%	74%	37	31

			Average IBI Listing Methodology →									% Stream Mile Listing Methodology						
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2140206	Rock Creek	18	Fail	2.39	2.14	2.63	18	3.40	3.14	3.66	16	Fail	56%	38%	72%	46%	18	10
2140207	Cabin John Creek	8	n<10	1.54	1.29	1.80	8	2.50	2.21	2.79	6	Fail	100%	75%	100%	90%	8	8
2140208	Seneca Creek	32	Fail	2.44	2.24	2.64	32	4.07	3.84	4.29	24	Fail	59%	47%	71%	49%	32	19
2140301	Potomac River FR Cnty	19	Fail	2.01	1.82	2.21	19	2.98	2.75	3.21	14	Fail	79%	62%	90%	69%	19	15
2140302	Lower Monocacy River	83	Fail	2.37	2.26	2.48	82	3.91	3.80	4.03	69	Fail	61%	54%	69%	51%	83	51
2140303	Upper Monocacy River	58	Fail	2.50	2.36	2.65	57	3.63	3.48	3.78	54	Fail	62%	53%	71%	52%	58	36
2140304	Double Pipe Creek	43	Fail	2.33	2.18	2.48	42	3.76	3.60	3.93	35	Fail	65%	54%	75%	55%	43	28
2140305	Catoctin Creek	17	Fail	2.71	2.49	2.92	17	3.03	2.75	3.32	10	Fail	47%	30%	65%	37%	17	8
2140501	Potomac River WA Cnty	30	Fail	2.63	2.43	2.84	30	1.92	1.66	2.17	20	Fail	73%	60%	84%	63%	30	22
2140502	Antietam Creek	32	Fail	2.47	2.27	2.67	31	3.47	3.26	3.67	29	Fail	59%	47%	71%	49%	32	19
2140503	Marsh Run	6	n<10	2.04	1.74	2.34	6	3.27	2.94	3.60	5	Fail	67%	33%	91%	57%	6	4
2140504	Conococheague Creek	13	Fail	2.25	1.99	2.51	13	2.69	2.43	2.96	13	Fail	85%	64%	96%	75%	13	11
2140505	Little Conococheague	7	n<10	3.07	2.60	3.54	7	4.13	3.57	4.69	5	Inc	29%	8%	60%	19%	7	2
2140506	Licking Creek	7	n<10	3.57	3.01	4.13	7	2.20	1.54	2.86	5	Fail	43%	17%	72%	33%	7	3
2140507	Tonoloway Creek	0	n=0									Inc						
2140508	Potomac River AL Cnty	9	n<10	3.39	3.02	3.76	9	2.17	1.61	2.72	4	Fail	56%	30%	79%	46%	9	5
2140509	Little Tonoloway Creek	9	n<10	2.56	2.18	2.93	9	3.24	2.81	3.66	7	Fail	67%	40%	87%	57%	9	6
2140510	Sideling Hill Creek	10	Pass	3.28	3.02	3.53	10	3.67	3.38	3.95	8	Pass	20%	5%	45%	10%	10	2
2140511	Fifteen Mile Creek	28	Pass	4.04	3.91	4.16	28	4.16	4.00	4.32	16	Pass	4%	0%	13%	-6%	28	1
2140512	Town Creek	22	Pass	3.47	3.27	3.66	22	3.64	3.41	3.88	15	Fail	23%	11%	38%	13%	22	5
2141001	Potomac River L N Branch	39	Inc	3.59	3.42	3.77	39	3.17	2.95	3.38	26	Fail	21%	12%	31%	11%	39	8
2141002	Evitts Creek	14	Fail	2.70	2.42	2.98	14	3.29	2.97	3.60	11	Fail	50%	30%	70%	40%	14	7
2141003	Wills Creek	16	Fail	2.88	2.49	3.27	16	2.36	1.94	2.78	14	Fail	63%	43%	79%	53%	16	10
2141004	Georges Creek	17	Fail	2.79	2.43	3.16	17	2.33	1.94	2.72	15	Fail	76%	58%	89%	66%	17	13
2141005	Potomac River U N Branch	21	Fail	2.93	2.66	3.20	21	2.40	2.12	2.68	20	Fail	62%	46%	76%	52%	21	13
2141006	Savage River	41	Pass	4.09	3.98	4.21	41	4.09	3.97	4.20	39	Pass	7%	3%	16%	-3%	41	3
5020201	Youghiogheny River	65	Pass	3.48	3.34	3.62	64	3.47	3.32	3.62	55	Fail	29%	22%	38%	19%	65	19
5020202	Little Youghiogheny R	19	Fail	3.12	2.89	3.34	19	2.23	1.97	2.49	14	Fail	63%	46%	78%	53%	19	12
5020203	Deep Creek Lake	8	n<10	2.41	1.96	2.85	8	1.55	1.07	2.02	7	Fail	100%	75%	100%	90%	8	8

			Average IBI Listing Methodology									% Stream Mile Listing Methodology						
MDE8DIGT	MDE8NAME	Total MBSS Sites	Final Status using Average IBI	Average BIBI	BIBI (LCL)	BIBI (UCL)	BIBI n	Average FIBI	FIBI LCL	FIBI UCL	FIBI n	Final Status Using % Stream Miles	% Stream Miles with possible Degradation	% (LCL)	% (UCL)	% Difference from Reference	Total Sites	Sites Degraded
5020204	Casselman River	34	Pass	3.21	3.02	3.41	34	3.26	3.06	3.46	34	Fail	29%	19%	42%	19%	34	10

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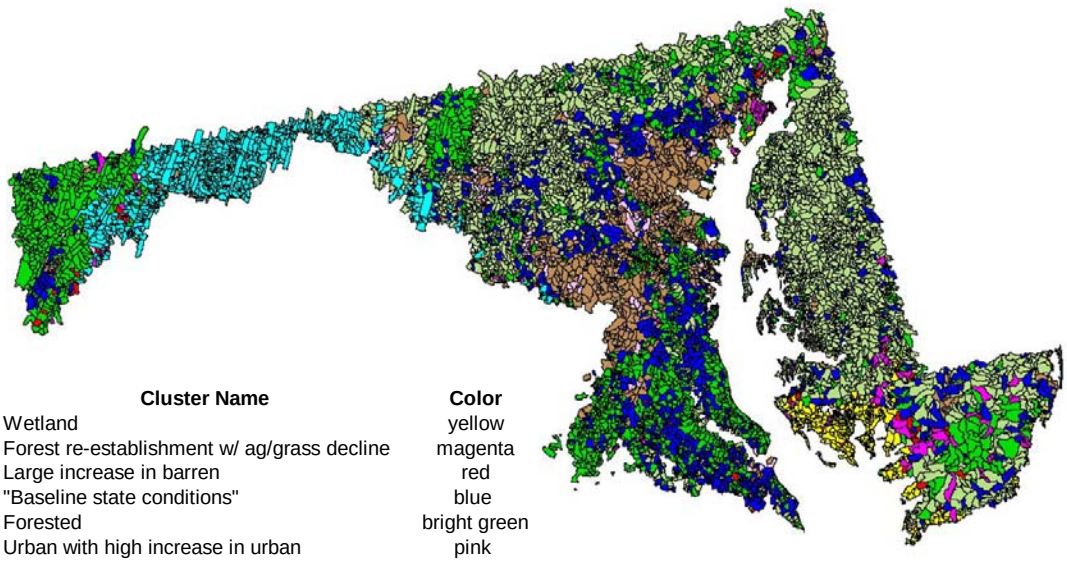
Appendix A. Evaluating the Spatial Representation of the Monitoring Data

An analysis of MBSS data representation of each 8-digit watershed determines if stream monitoring stations adequately capture watershed landscape heterogeneity and can thus be used to support a biological assessment. Watershed landscape heterogeneity is assessed using the distribution of landscape clusters (groups of similar landscape conditions) that incorporate land use, land use change, soil erodibility, slope, precipitation, and population density (US EPA 2007). Nine distinct cluster types were identified and are presented in Figure A-1.



Cluster	Cluster Name	Color
1	Wetland	yellow
2	Forest re-establishment w/ ag/grass decline	magenta
3	Large increase in barren	red
4	"Baseline state conditions"	blue
5	Forested	bright green
6	Urban with high increase in urban	pink
7	Forest with wide range in slopes	cyan
8	Agriculture	soft green
9	Urban with more modest increase in urban	brown

Figure A-1. Landscape similarity in Maryland.

The Nine cluster groups can be described as follows: Cluster 1 watersheds are dominated by wetlands and concentrated in the southwest corner of the Delmarva Peninsula. Cluster 2 watersheds are characterized by forest re-growth mainly at the expense of agriculture. Cluster 3 watersheds are characterized by large increases in barren. They are mainly scattered around the margins of the Chesapeake Bay with another concentration in the westernmost portion of the panhandle. Cluster 4 is perhaps best labeled as “baseline state condition,” since all cluster means are close to the average. Cluster 4 watersheds are scattered throughout the state. Cluster 5 and 7 watersheds are dominated by forest with the main difference being that cluster 7 watersheds have a broader range of slopes. Clusters 6 and 9 are dominated by urban land use, with cluster 6 having a much higher rate of urban increase. Cluster 8 watersheds are dominated by agriculture.

Representation of watershed heterogeneity is assessed by determining if the distribution of sample stations within cluster groups is proportional to the distribution of stream

length within cluster groups. A Percent Similarity Index (PSI), also called the Renkonen Index (Krebs 1989), is calculated using proportions of 1st through 4th order streams within clusters and proportions of monitoring stations within clusters. Despite the simplicity of this measure, it is a robust quantitative similarity coefficient and is commonly used in ecological research when comparing communities using species proportions. The PSI ranges from 0% (no similarity) to 100% (complete similarity). The index is calculated as

$$\text{PSI} = \sum_{i=S} \text{minimum}\left(p_i^{\text{Streams}}, p_i^{\text{Stations}}\right)$$

where p_i^A is the percentage of 1st – 4th order streams in cluster i
p_i^B is the percentage of monitoring stations in cluster i
i is a cluster type
S is the number of cluster types occurring in a watershed (sum of proportions must equal 100% within a watershed)

A plot of the similarity between the watershed landscape clusters and the number of MBSS round 1 and round 2 monitoring sites in an 8-digit watershed is presented in Figure A-2. It is clearly evident that more sites results in a higher watershed percent similarity index. Also, Figure A-2 illustrates that percent similarity index has a large range for watersheds with less then ten sites but begins to reach an average of about 85% around when the number of sites are greater than eight.

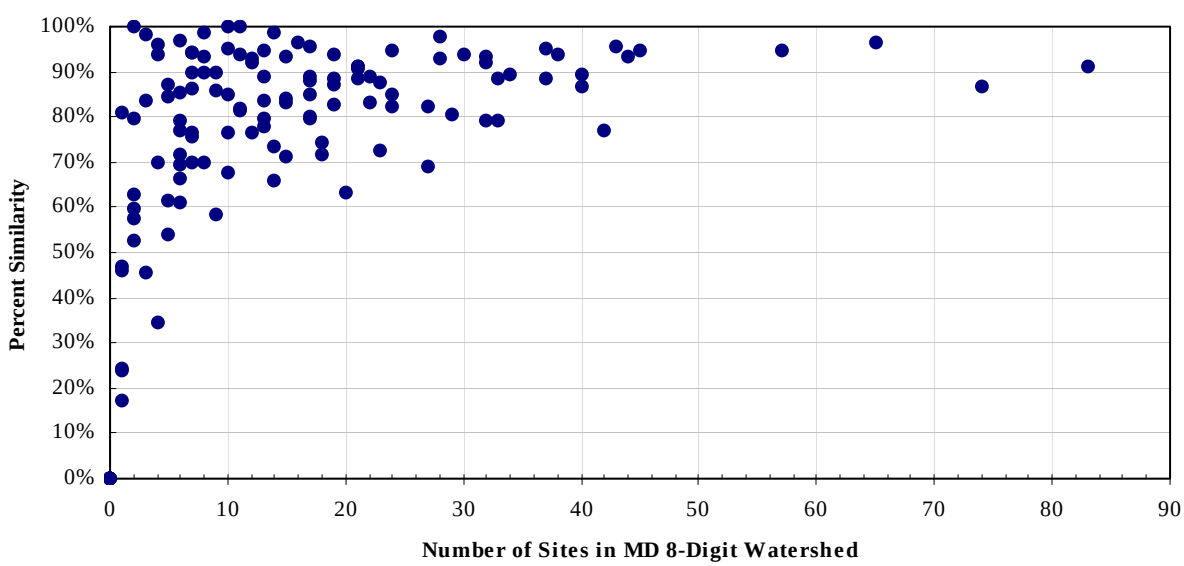


Figure A-2. Watershed Percent similarity index vs. number of sites in a Maryland 8-digit watershed.