Biological Condition Gradient (BCG) Attribute Assignments for Macroinvertebrates and Fish in the Mid-Atlantic Region (Virginia, West Virginia, and Maryland)

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Final Report
August 5, 2019

Executive Summary

Macroinvertebrates and fish have varying levels of sensitivity to pollution based on their taxa specific adaptations and the magnitude, frequency, and type of stressors. Environmental conditions influence the structure of lotic communities in the Mid-Atlantic. The Biological Condition Gradient is a conceptual model that describes the condition of waterbodies relative to well-defined levels of condition that are known to vary with levels of disturbance based on the pollution tolerances of aquatic organisms. In biological assessment programs, the tolerance characteristics of the aquatic organisms are part of the determination of overall stream health. This study represents the first phase of statewide BCG development in Virginia by assigning tolerance attributes to many common macroinvertebrates and fish in the Mid-Atlantic.

BCG tolerance attributes reflect taxa sensitivity to stream conditions. The attributes (I – X) represent commonness, rarity, regional specialization, tolerance to disturbance, organism condition, ecosystem function and connectivity (Table 1, Appendix A). Attributes I – VI are related to tolerance to disturbance. These are used in BCG models to describe aspects of the community relative to disturbance (Table 2). Attributes I, VI, and X can be assigned to taxa to describe the natural biological condition of a waterbody.

The biological monitoring and assessment agencies of several Mid-Atlantic States provided biological and water quality data and engaged in a cooperative effort to investigate fish and macroinvertebrate responses to a range of stressors. The Virginia Department of Environmental Quality, West Virginia Department of Environmental Protection, Maryland Department of Natural Resources, Fairfax County Virginia, Montgomery County Maryland, and the United States Environmental Protection Agency provided macroinvertebrate and fish data, including taxa occurrence and abundance enumerations. The participating groups provided expertise as well as water quality and habitat data that was collocated with macroinvertebrate and fish collections in the stressor-response analyses. Pollution tolerance values were assigned to regional macroinvertebrate and fish taxa based on analytical data and expert consensus. In order to enhance understanding and improve capabilities, the group also analyzed stressor-response relationships for taxa based on seven individual stressors. The potential stressors included dissolved oxygen concentration, pH (acidity and alkalinity), specific conductance (chloride and sulfate), nutrients (TN and TP), total habitat score, the Relative Bed Stability index, and percent impervious surface in the watershed.

The stressor-response analyses utilized a variety of different statistical techniques and models. General Additive Models (GAM) were used to compare taxa occurrence and abundance to the individual stressors throughout the region by showing the trend in occurrence with increasing stress. Other statistical techniques included cumulative frequency distributions of taxa by environmental stress, taxa spatial distributions, and Threshold Indicator Taxa ANalysis (TITAN). These analytics were available as reference for all taxa that occurred often enough in the dataset to provide robust statistical results (Appendices B and C). Results from previous taxa attribution studies were compiled and also considered. Expert consensus is the basis for BCG attributions; the consensus involved review of taxa and stressor-response data while drawing upon personal experience to rationalize and add logical value to the empirical and historical

evidence. This exercise resulted in matrices of fish and macroinvertebrate taxa compared to nine stressors with attributes for each and remarks from the experts regarding evidence or experience that lead to the attribute assignments.

Five hundred and sixty macroinvertebrate taxa were considered for attributes. Of those 560 taxa, 322 macroinvertebrates were assigned a general attribute, and 209 were assigned at least one stressor-specific attribute (Appendix B). Most of the taxa with attribute assignments were attribute IV (moderately tolerant; 53%, Table E-1). Another 40% of taxa were assigned to the sensitive attributes II and III. Tolerant taxa (attribute V) made up 8% of the assigned taxa.

Two hundred forty-three Mid-Atlantic fish were assigned a general attribute, 106 of which were assigned at least one stressor-specific attribute (Appendix C). The most common attribute assignment was IV, which was 37% of the assignments (Table E-1). Sensitive taxa (attributes I, II, and III) made up a total of 29% of the assignments and tolerant taxa (attribute V) made up 11%. Other assignments in attributes VI (non-native) and X (connectance indicators) made up 14% of the assignments.

Table E-1. Counts of taxa attributes for the general attribute assignment and for specific stressors.

	BCG General	BCG DisOxy	BCG acidity	BCG alkal.	BCG spCond	BCG Chloride	BCG Sulfate	BCG TN.TP	BCG totHab	BCG RBS	BCG %IMP
Fish											
I	17	0	0	0	0	0	0	0	0	0	0
II	25	1	0	4	3	1	0	0	1	0	3
III	52	36	68	5	9	10	9	5	13	19	16
IV	89	42	27	15	52	59	57	62	65	57	44
V	26	24	1	0	36	23	28	28	22	6	27
Macroinvertebrates											
I	0	0	0	0	0	0	0	0	0	0	1
II	26	21	19	19	10	31	10	7	16	6	40
III	99	89	68	106	93	90	60	44	79	26	65
IV	172	81	105	81	83	84	124	125	94	97	67
V	24	18	16	1	23	3	13	12	19	11	23

The level of detail in this attribution effort exceeds the detail in comparable BCG calibration exercises, especially regarding the relationships to specific stressors. The volume of collocated biological and water quality data that was collected, compiled, and analyzed allowed the experts to rely on data as well as expert knowledge. In most BCG exercises, attribute assignments reflect general tolerance to a range of stressors. In this exercise, both a general attribute assignment and stressor-specific assignments were made. The general attribute assignment might be applicable for general assessments, such as application in a complete regional BCG calibration for the Mid-Atlantic region or in general tolerance metrics that could be used in multimetric indices. The stressor-specific attribute assignments allow for innovative applications in assessment of specific stressor conditions. The applications are still being developed and are expected to include stressor specific metrics that might provide evidence for stressor identification analyses.

Acknowledgements

This project was conducted in cooperation with the United States Environmental Protection Agency Office of Science and Technology as part of contract EP-C-14-016 with Tetra Tech, addressing the Use of Bioassessment Information and Tools to Support Water Quality Management Programs. The assignment of BCG attributes was accomplished through the efforts of biological expert representatives from the Virginia Department of Environmental Quality, West Virginia Department of Environmental Protection, Maryland Department of Natural Resources, Fairfax County Virginia, Montgomery County Maryland, Virginia Tech, Virginia Commonwealth University, and the United States Environmental Protection Agency.

The following VDEQ statement shows appreciation for the entire process and workgroup:
This has been a great process. We keep seeing more ways to improve the process and to classify the data. Unfortunately, we ran out of time. VDEQ wishes to thank everyone for taking time to help with this project. Some of you have spent a ton of time on this and we want you to know how much we appreciate it.

ACRONYMS

AFS	American Fisheries Society
ALU	Aquatic Life Use
BPJ	Best Professional Judgment
BCG	Biological Condition Gradient
BMP	Best management practices
CDF	Cumulative Distribution Frequencies
CWA	Clean Water Act
Dis Oxy	Dissolved Oxygen
EMAP	Environmental Monitoring and Assessment Program
EPT	Ephemeroptera, Plecoptera and Trichoptera
FFX	Fairfax County Virginia
GAM	Generalized Additive Model
IBI	Index of Biological Integrity
MDNR	Maryland Department of Natural Resources
NA	Not Assigned
NIH	National Institutes of Health
NRSA	National Rivers and Streams Assessment
R	R statistical coding language and software
RBS	Relative Bed Stability
RTE	Rare, Threatened, or Endangered
TALU	Tiered Aquatic Life Uses
TN	Total Nitrogen
Tot Hab	Total Habitat
TP	Total Phosphorus
USEPA	U. S. Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
WQS	Water Quality Standards
WVDEP	West Virginia Department of Environmental Protection

Contents

Supplement I	Macroinvertebrate Fall GAM plots	MidAtlanticBCG_MacroSpringGAMs.pdf
Supplement II	Macroinvertebrate Spring GAM plots	MidAtlanticBCG_MacroFallGAMs.pdf
Supplement III	Fish GAM plots	MidAtlanticBCG_FishGAMs.pdf
Supplement IV	Macroinvertebrate Workbook (MASTER_ATTRIBUTES_BUGS_06062019.xlsx)	
Supplement V	Fish Workbook (MasterAttributeFish_2019_May9.xlsx)	

List of Tables

List of Figures

1.0 Introduction

The Clean Water Act (CWA) directs the United States Environmental Protection Agency (USEPA) to restore and maintain the biological integrity of the Nation's waters. Under the CWA, the EPA has established a Water Quality Standards (WQS) Program to help achieve this objective. The EPA is developing and testing methods to support incorporation of bioassessment information, methods and approaches, such as the Biological Condition Gradient (BCG), into EPA, State and Tribal Water Quality Management Programs.

The Virginia Department of Environmental Quality (VDEQ) conducted a calibration exercise in 2015-2016 to develop a BCG in the Central Appalachian ecoregion (69) of Virginia, West Virginia, and Kentucky (Jessup and Stamp 2016). Additional model evaluations were conducted in the Northern Piedmont ecoregion (64). The 2015-2016 BCG calibration resulted in models for fish and macroinvertebrates using ecoregion-specific attributes for generalized stressors. The results reported here build on the earlier work for application of statewide biological indicators. The ecoregion-specific attributes were re-examined in relation to statewide conditions for multiple stressors, and responses.

Goals of the project were as follow:

- To expand the development and application of the BCG and other indicators in Virginia and the region
- To develop taxa specific tolerance attributes in relation to natural and stressor conditions in ecoregions in Virginia, including shared ecoregions/basins with West Virginia and Maryland.

"The Biological Condition Gradient (BCG) is a conceptual, scientific framework for interpreting biological response to increasing effects of stressors on aquatic ecosystems" (USEPA 2016). The framework was developed based on common patterns of biological response to anthropogenic stressors observed empirically by aquatic biologists and ecologists from different geographic areas of the United States (Davies and Jackson 2006). The BCG is a conceptual model to describe the condition of waterbodies relative to well-defined levels of condition that are known to vary with levels of disturbance (Figure 1). It describes how measurable characteristics of aquatic ecosystems change in response to increasing levels of stress, from a natural condition (undisturbed or minimally disturbed by modern human activities) to severely altered conditions (highly disturbed). In the BCG framework, these measurable characteristics are defined as "attributes" of the biological communities and the physical habitat that reflect the condition of an aquatic ecosystem (USEPA 2016). The attributes (Table 1) include properties of the system and communities (e.g., richness, structure, abundance, system functions) and organisms (e.g., tolerance, rarity, native-ness, organism condition).

In practice, the BCG is used to first identify the critical attributes of individual taxa and then describe how each taxa responds to stress. Practitioners can use the BCG to interpret biological condition along a standardized gradient regardless of assessment method and apply that information to different state or tribal programs. An increasing number of programs are using the BCG to address watershed-specific management needs such as detailed biological descriptions of designated aquatic life uses (ALUs), identification of high-quality waters and impaired waters, and documentation of incremental improvements due to controls and best management practices (BMPs). For example, Minnesota and Pennsylvania are using BCGs calibrated to identify exceptional and high-quality waters based on biological condition (exceptional waters may also be identified with other criteria- i.e., scenic or recreational value) (Bouchard et al. 2016, USEPA 2011, Gerritsen 2017). The Pennsylvania example is described in greater detail in the BCG Practitioner's Guide (USEPA 2016), which also contains case studies on water quality programs in Minnesota, Alabama, Maryland, Maine and Ohio that have used the BCG for assessment and in some cases, for setting tiered aquatic life uses (TALUs) in water quality standards (WQS).

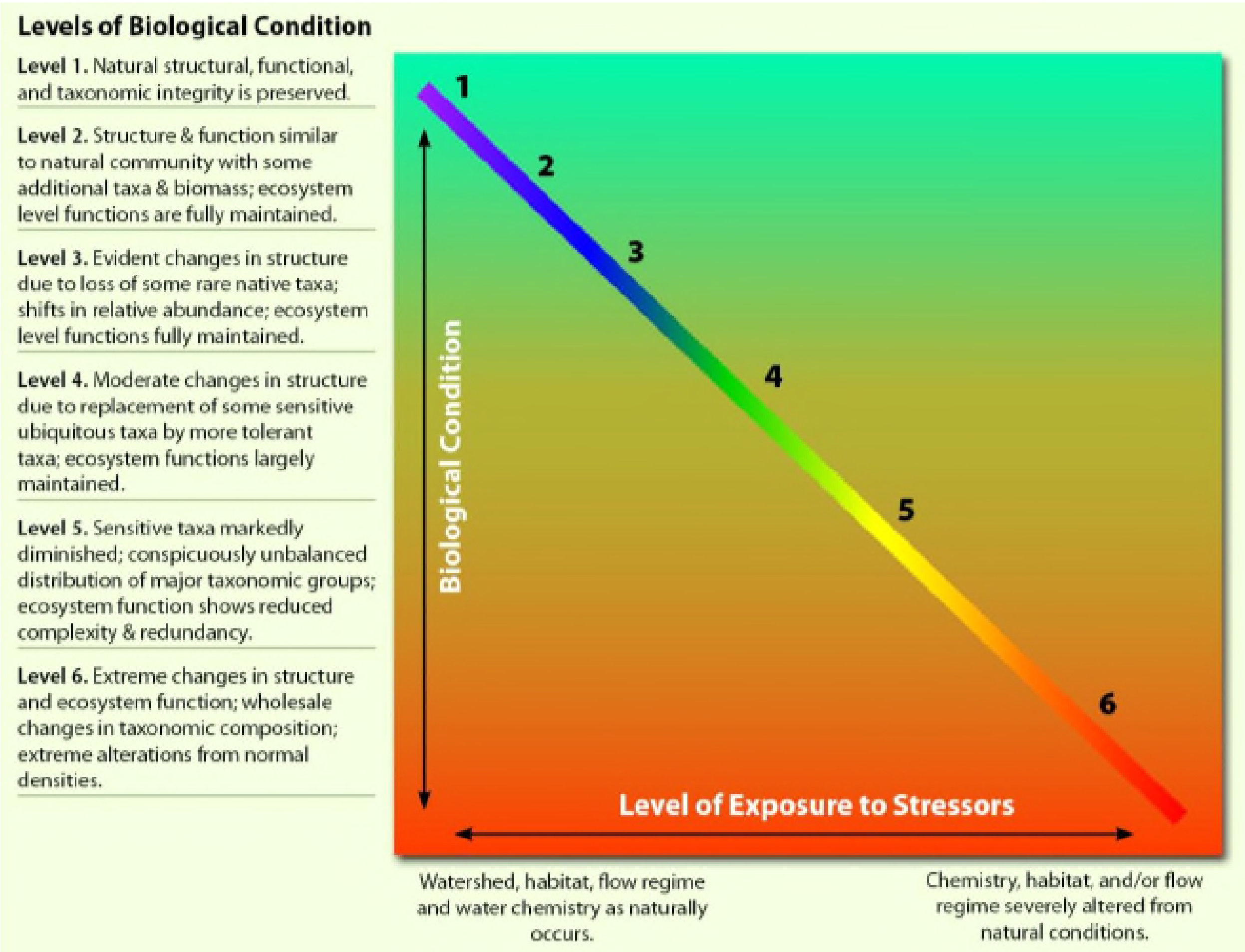


Figure 1. Schematic diagram of the Biological Condition Gradient (BCG, Davies and Jackson 2006).

Traits of the taxa within biological samples that affect description of the condition level are standardized as BCG attributes. The attributes (I – X) represent commonness, rarity, regional specialization, tolerance to disturbance, organism condition, ecosystem function and connectivity (Table 1, Appendix A). Attributes I – VI are related to regional origin and tolerance to disturbance. These are often used in BCG assessment models to describe aspects of the community relative to disturbance (Table 2). Attributes I, VI, and X can be assigned to taxa, though they do not automatically imply pollution tolerance. To identify tolerance with these attributes, a suffix can be added to the categorical assignment to denote tolerance. For example, non-native taxa (attribute VI) can be assigned a 6i, 6m, or 6t to denote intolerant, moderately tolerant, and tolerant characteristics in addition to the non-native status. Also note, as in the example, the roman numerals are the correct attribute terms, but the Arabic numerals are often used as shorthand and to facilitate sorting in worksheets.

Assignment of attributes is accomplished through expert discussion and consensus, supported by analytical evidence within appropriate data sets of organism presence and abundance relative to natural and disturbance site characteristics. A general outline of the attribute assignment process shows a parallel sequence of analysis and expert engagement that begins with goal-setting and ends with consensus agreement of attributes for fish and macroinvertebrate taxa (Figure 2).

BCG calibration requires professional judgment and development of consensus (USEPA 2016). Assessing biological community attributes and conditions, including all common biotic indexes, involves professional judgment, even though such judgment may be hidden in apparently objective, quantitative approaches. Professional judgment is applied in the development of all assessment frameworks (e.g., Steedman 1994, Borja et al. 2004, Weisberg et al. 2008). Use of professional consensus has a long pedigree in the medical field, including the National Institutes of Health (NIH) Consensus Development Conferences to recommend best practices for diagnosis and treatment of diseases (NIH http://consensus.nih.gov/).

The first step in BCG calibration is the assembly and analysis of biological monitoring data. Next, a calibration workshop is held in which experts familiar with regional taxa and conditions use the data to define the ecological attributes and set narrative statements (for example, narrative decision rules for assigning sites to a BCG level on the basis of the biological information collected at sites). In the current project, attribute assignment was the goal and calibration of a BCG model was not addressed, though it was used as a framework for the attribute importance and possible application.

This report describes the data sets that were used in analyzing stressor-response relationships of fish and macroinvertebrates in the mid-Atlantic region, methods used in interpretation of stressor-response patterns, the process for BCG attribute assignments, and the resulting attributes relative to specific stressors.

Figure 2. Process diagram of tasks and objectives for assigning BCG attributes to taxa.

Table 1. Abbreviated BCG attribute definitions and examples (see detailed definitions in Appendix A).

BCG Taxa Attribute Definitions
I - Historically documented, sensitive, long-lived, regionally endemic taxa
• documented presence prior to CWA
• unique life history requirements
• may be a listed RTE or Special Concern species
• ex: New River shiner; Kanawha minnow
II - Sensitive - uncommon or specialist taxa
• may require special habitats;
• intolerant of disturbance in environmental conditions
• naturally low densities;
• commonly k-strategists (slow development, longer lifespan, stable population density over time)
• ex: Pteronarcys; brook trout;
III - Sensitive - ubiquitous taxa
• ordinarily common and abundant
• broader range of thermal and habitat tolerance;
• mild pollution loads have a negative effect on populations;
• ex: Ephemerella; Wormaldia; slimy sculpin; glassy darter;
IV - Taxa of intermediate tolerance
• may have generalist feeding strategies
• densities commonly increase in response to nutrient enrichment
• may be r-strategists (early colonizers with rapid turnover times and boom/bust populations)
• ex: Baetis; Oecetis; johnny darter; yellow perch;
V - Tolerant Taxa
• often tolerant of a broad range of environmental conditions
• often r-strategists or opportunist taxa;
• densities may increase greatly in absence of competition and predation;
• ex: Cheumatopsyche; Oligochaeta; creek chub; green sunfish
VI - Non-native taxa
• species that do not naturally occur in a given locale or ecosystem
• ex: Corbicula; common carp (6t); brown trout (6m)

Table 2. BCG Levels 1-6 and generally expected responses of taxa within I-V attributes.

Attributes	BCG Levels					
	1 Natural or native condition Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability	2 Minimal changes in the structure of the biotic community and minimal changes in ecosystem function Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability	3 Evident changes in structure of the biotic community and minimal changes in ecosystem function Some changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but sensitive-ubiquitous taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system	4 Moderate changes in structure of the biotic community and minimal changes in ecosystem function Moderate changes in structure due to replacement of some sensitive-ubiquitous taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes	5 Major changes in structure of the biotic community and moderate changes in ecosystem function Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from that expected; organism condition shows signs of physiological stress; system function shows reduced complexity and redundancy; increased build- up or export of unused materials	6 Severe changes in structure of the biotic community and major loss of ecosystem function Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor; ecosystem functions are severely altered
I Historically documented, sensitive, long-lived or regionally endemic taxa	As predicted for natural occurrence except for global extinctions	As predicted for natural occurrence except for global extinctions	Some may be marginally present or absent due to global extinction or local extirpation	Some may be marginally present or absent due to global, regional, or local extirpation	Usually absent	Absent
II Highly sensitive taxa	As predicted for natural occurrence; at most minor changes from natural densities	Most are maintained with some changes in densities	Some loss, with replacement by functionally equivalent sensitive-ubiquitous taxa	May be markedly diminished	Usually absent or only scarce individuals	Absent
III Intermediate sensitive taxa	As predicted for natural occurrence; at most minor changes from natural densities	Present and may be increasingly abundant	Common and abundant; relative abundance greater than sensitive-rare, taxa	Present with reproducing populations maintained; some replacement by functionally equivalent taxa of intermediate tolerance.	Frequently absent or markedly diminished	Absent
IV Intermediate tolerant taxa	As predicted for natural occurrence, with at most minor changes from natural densities	As naturally present with slight increases in abundance	Often evident increases in abundance	Common and often abundant; relative abundance may be greater than sensitive-ubiquitous taxa	Often exhibit excessive dominance	May occur in extremely high or extremely low densities; richness of all taxa is low
V Tolerant taxa	As naturally occur, with at most minor changes from natural densities	As naturally present with slight increases in abundance	May be increases in abundance of functionally diverse tolerant taxa	May be common but do not exhibit significant dominance	Often occur in high densities and may be dominant	Usually comprise the majority of the assemblage; often extreme departures from normal densities (high or low)

2.0 Data Sources

Biological data for two assemblages (fish and macroinvertebrates) were obtained, from VDEQ, West Virginia Department of Environmental Protection (WVDEP), USEPA National Rivers and Stream Assessment (NRSA), Environmental Monitoring and Assessment Program (EMAP), Fairfax County (FFX), Virginia, and Maryland Department of Natural Resources (MDNR). Sampling methods used by the VDEQ, WVDEP, USEPA, FFX, and MDNR were reviewed by the expert panel (as appropriate per assemblage) and determined to be comparable sample data for taxa stressor response evaluation.

The data sets used in associating regional taxa with specific stressors contained several thousand sites with fish and/or macroinvertebrate samples (Tables 3 and 4). Only sites with stressor information were useful in the tolerance assignment process. Stressors were not available for all taxa at all sites.

Analyzed stressors were selected from a large suite of possible stressors. The final list of stressors was reduced from 14 to 7 through principal components analysis (PCA) to find commonalities and through discussion with the workgroup to identify critical regional stressors (Figure 3). The stressor information was typically collected through the biological monitoring programs of the agencies contributing the data. Each agency was responsible for data integrity. Discussions among agency representatives during the workshop and during data preparation established that the data were comparable among agencies, especially in light of the types of analyses used in this project, which primarily addressed the presence/absence of biological data in relation to the stressors. Stressors associated with the biological samples included the following:

- Dissolved oxygen concentration (Dis Oxy)
- pH (responses to acidity and alkalinity were considered independently)
- Specific conductance (chloride and sulfate were also considered as independent ions)
- Nutrients (TN and TP were analyzed separately, but assessed as a common response)
- Total habitat score (Tot Hab)
- Relative Bed Stability (RBS)
- Percent impervious surface in the watershed

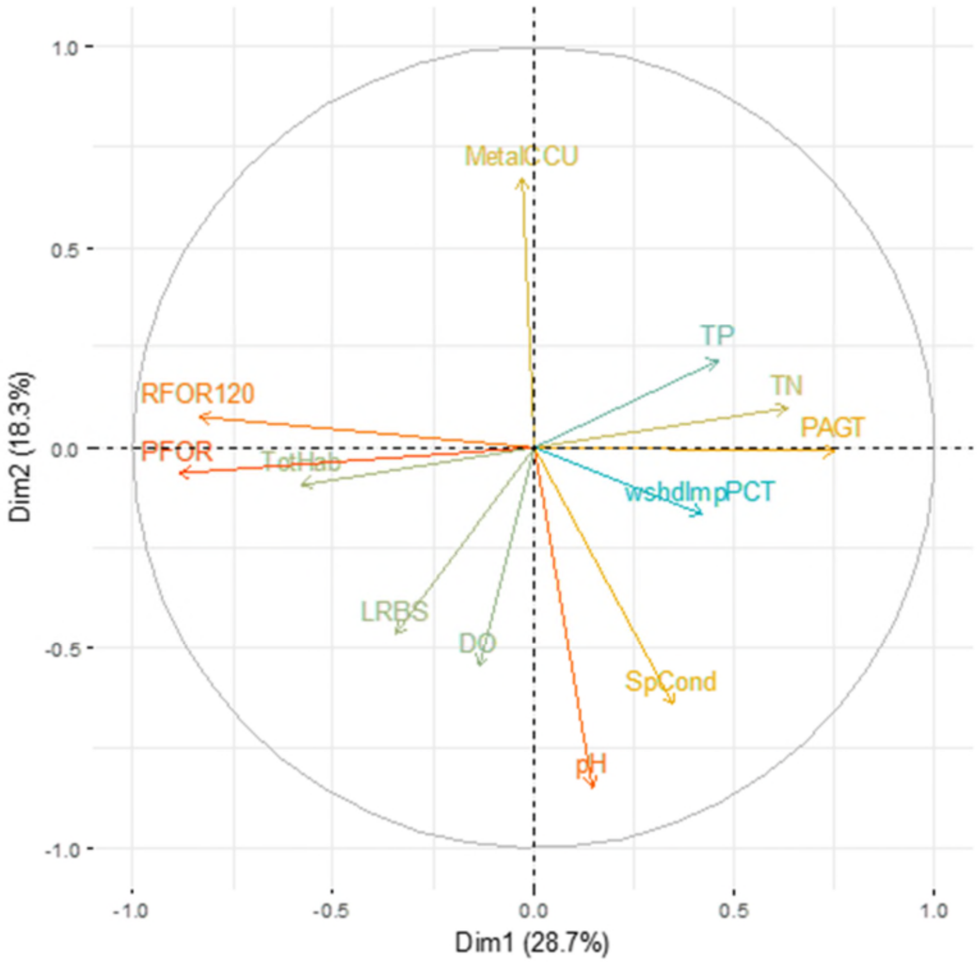


Figure 3. List of candidate stressors reduced by Principal Components Analysis (PCA).

The data sets were compiled, maintained and stored by VDEQ. During the workshops and webinars, access to the information was through an internet application using R coding software (R Core Team 2018, Chang et al. 2019). The stressor-response GAM plots are available as supplemental materials (Supplement I, Supplement II, and Supplement III).

Table 3. Sample sizes for mid-Atlantic macroinvertebrate data sets used in stressor-response analyses.

MACROINVERTEBRATES	
Total sample records: 11,112	Total records with Environmental Data: 5,492
Taxa: 559 taxa observed in samples, 252 of these were assigned attributes	
Spring is defined as 2/1 - 6/30	
Total spring sites: 6,718	Total spring records with Environmental Data: 4,609
Fall is defined as 7/1 - 11/30	
Total fall sites: 3,561	Total fall records with Environmental Data: 657
Virginia	
Total sample records: 4,483	Total records with associated environmental data: 677
	Spring records- 337 records
	Fall records- 335 records
Fairfax	
Total sample records: 915	Total records with associated environmental data: 680
	Spring records- 680 records
	Fall records- 0 records
West Virginia	
Total sample records: 3,756	Total records with associated environmental data: 2,178
	Spring records- 1635 records
	Fall records- 322 records
Maryland	
Total sample records: 1,958	Total records with associated environmental data: 1,957
	Spring records- 1957 records
	Fall records- 0 records

Table 4. Sample sizes for mid-Atlantic fish data sets used in stressor-response analyses.

FISH	
Total sample records: 3,323	Total records with Environmental Data: 2,774
Taxa: 243 taxa observed in samples and evaluated	
Virginia	
Total sample records: 883	Total records with associated environmental data: 411
Fairfax	
Total sample records: 363	Total records with associated environmental data: 289
West Virginia	
Total sample records: 272	Total records with associated environmental data: 272
Maryland	
Total sample records: 1805	Total records with associated environmental data: 1,802

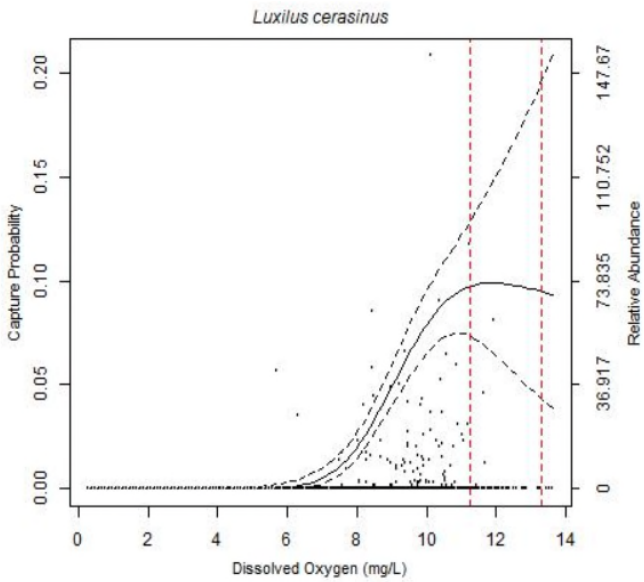
3.0 Methods

3.1 Stressor-response Analysis

A number of statistical techniques have been applied to develop response curves and tolerance values for taxa in relation to stressors. Those commonly used approaches tended to examine the central location of a species' preferred environmental conditions and its spread in the niche along the environmental gradient. Developing indicator values of biological organisms to environmental stressors focuses on three different statistical approaches i.e., (1) central tendencies, (2) environmental limits, and (3) optima (Yuan 2006). Tolerance values expressed in terms of central tendencies attempt to describe the average environmental conditions under which a species is likely to occur; indicator values expressed in terms of environmental limits attempt to capture the maximum or the minimum level of an environmental variable under which a species can persist; and indicator values expressed in terms of optima define the environmental conditions that are most preferred by a given species. These three types of indicator values are expressed in terms of locations on a continuous numerical scale that represents the environmental gradient of interest. In the meantime, both abundance based and presence/absence based models can be built using these three statistical approaches.

A variety of approaches were considered in characterizing the taxa stressor response, including GAMs, Cumulative Distribution Frequencies (CDFs), weighted averaging, environmental tolerance, environmental limits with cumulative percentiles, weighted CDFs, TITAN, and variations on regression estimates (linear and quadratic regression models). To simplify interpretation, the GAMs and CDFs were emphasized, along with meaningful distribution statistics from each. The results were presented as graphics and tabulated statistics specific to the stressor and to the geomorphological region (mountains, Piedmont, and coastal plain).

The graphical illustration of the GAMs included points representing taxa relative abundance, curves representing the GAM model on taxa presence, and thresholds relative to areas under the GAM curve (Figure 4). The slope of the GAM curve is commonly interpreted as an indicator of attribute characteristics, with steep slopes indicating high sensitivity or high tolerance. The CDFs are interpreted in relation to the stressor gradient, showing the percentage of the occurrences with increasing (or decreasing) stressor conditions (Figure 5). Taxa distribution maps were the third graphic tool available for interpreting taxa attributes (Figure 6). The maps can be interpreted in relation to natural conditions that vary over the regional landscape. Tabulated distribution and GAM statistics were available so that experts could sort taxa by statistics or by taxon, facilitating comparisons among taxa (Figure 7).



Taxa	n	GAM 50th	GAM 95th
Luxilus cerasinus	99	11.24	13.31

GAM plots show general regional patterns of frequency and abundance in relation to an environmental gradient

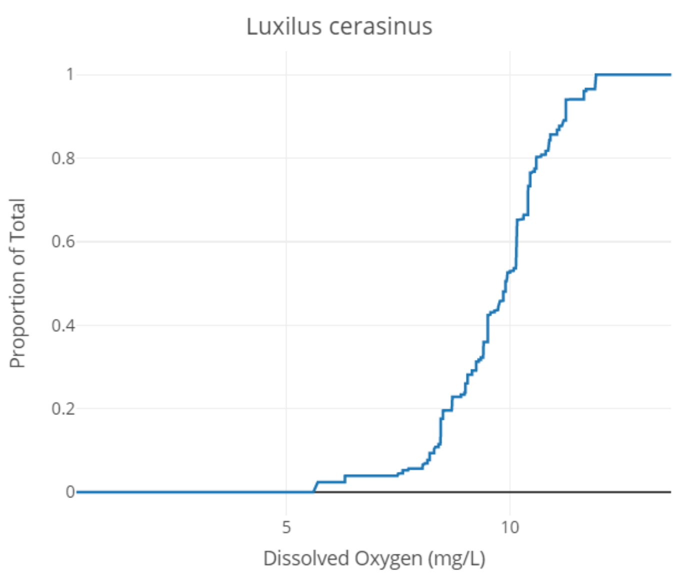
Multiple stressors can be placed on the X-axis – (with dissolved oxygen, taxa that occur with low values are tolerant)

Points: site values for relative abundance

Curve: capture probability (GAM fit and confidence interval based on presence)

50% capture probability and 95% probability (dashed vertical lines) represent optimum and tolerance (though with dissolved oxygen, the 5th would be more appropriate tolerance)

Figure 4 Example GAM plot and statistics illustrating the relationships between Luxilus cerasinus (Crescent Shiner) and dissolved oxygen in the Mid-Atlantic region.



Taxa	5th	25th	50th	75th	95th
Luxilus cerasinus	7.6	9	9.9	10.45	11.65

Figure 5. Example CDF plot and statistics illustrating the relationships between Luxilus cerasinus (Crescent Shiner) and dissolved oxygen in the Mid-Atlantic region.

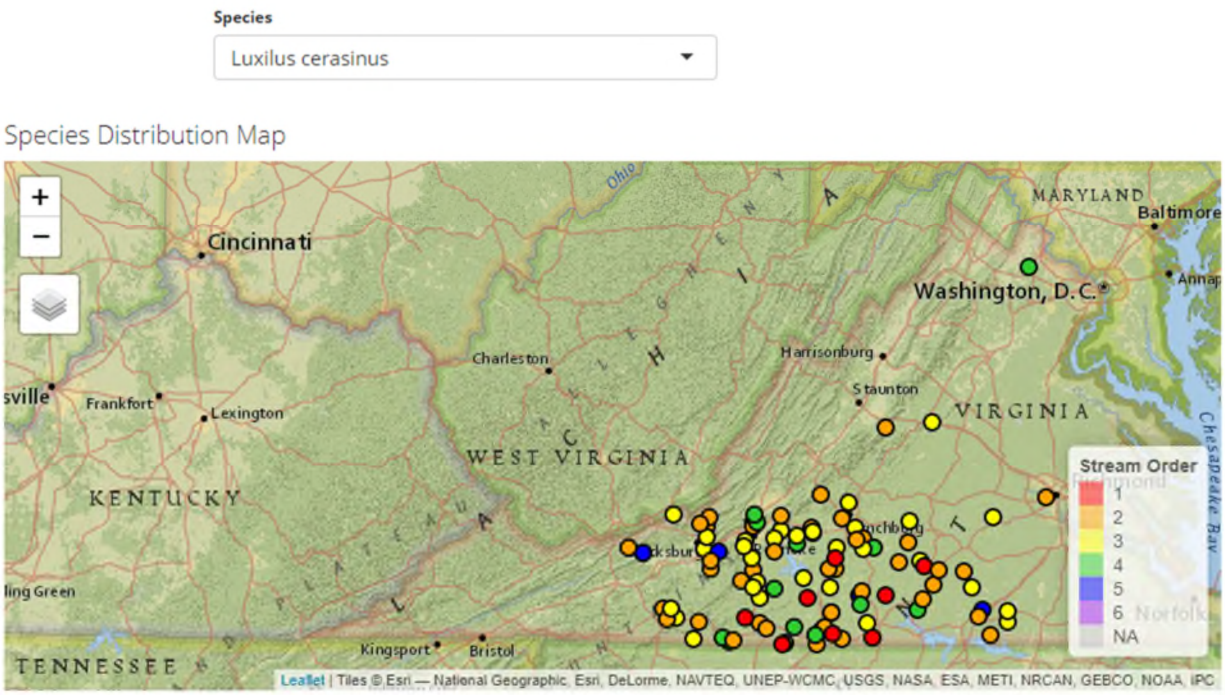


Figure 6. Example taxa distribution map showing locations in which Luxilus cerasinus (Crescent Shiner) was observed and the stream order of the sampled sites.

CDF					
Taxa	**x5**	**x25**	**x50**	**x75**	**x95**
Acantharchus pomotis	7.6	8.8	10.29	10.29	11.25
Alosa aestivalis	6.68	8.3	8.3	8.3	8.3
Alosa pseudoharengus	7.4	7.4	7.4	7.4	8.3
Alosa sapidissima	6.68	8.7	8.7	8.7	8.7
Ambloplites cavifrons	6.9	7.7	8.02	8.02	10.96
Ambloplites rupestris	6.6	8	8.815	10	11.11
Ameiurus brunneus	7.48	7.48	7.48	7.48	7.48
Ameiurus catus	6.68	6.68	11.02	11.02	11.02
Ameiurus melas	9.615	9.615	9.615	9.615	9.615
Ameiurus natalis	NA	NA	NA	NA	NA
Ameiurus nebulosus	NA	NA	NA	NA	NA
Ameiurus platycephalus	6.94	8.5	9.5	10.14	10.4
Amia calva	4	6.35	6.68	8.02	8.02
Anguilla rostrata	NA	NA	NA	NA	NA

GAM			
tnames	**N**	**GAM_50_th**	**GAM_95_th**
Ambloplites rupestris	290	10.57	13.25
Ameiurus natalis	461	7.96	13.11
Ameiurus nebulosus	277	3.01	9.97
Ameiurus platycephalus	13	10.91	13.25
Anguilla rostrata	1053	5.22	11.71
Aphredoderus sayanus	313	3.41	8.63
Campostoma anomalum	471	10.84	13.31
Campostoma oligolepis	35	10.44	12.24
Campostoma spp	545	10.37	13.18
Carassius auratus	24	2.94	10.24
Catostomus commersonii	1254	9.7	13.18
Chrosomus oreas	171	10.57	12.91
Clinostomus funduloides	856	9.9	13.18
Cottus bairdii	63	9.37	12.51

Fish Occurrence | **DO** | pH | SpCond | TP | TN | TotHab | TotHab_wMD | LRBS | wshdImpPCT | Cl | Sf

Figure 7. Example partial table of distribution and GAM statistics for fish in relation to dissolved oxygen.

3.2 Workshop and Webinar Discussions

During the March 2018 workshop, the fish and macroinvertebrate groups reviewed and assigned attributes to about 30 taxa each. The workshop goals were presented to all participants and then the two assemblage groups were separated for specific taxa discussions. The review process included review of the analytical information (GAMs, CDFs, distribution maps, etc.), independent assignment of attributes, group discussion of taxa ecological requirements and interpretation of analytical results, and assignment of attributes for each taxon and specific stressor through consensus. In most cases, attributes were assigned for the entire region, though in few cases attributes were assigned for specific physiographic regions (mountain, Piedmont, coastal plain).

Evaluation of taxa began with display and interpretation of the analytical results. A general attribute (not specific to a stressor) was volunteered by any participant. Other participants would offer rationale in support of the candidate attribute or in support of something different. As discussion continued, specific stressors were considered, and attributes were suggested and debated in turn. A return to discussion of the original general attribute assignment would usually conclude the evaluation for a single taxon. BCG attribute assignments were often given to the general or overall attribute category and to all, some, or none of the stressor specific categories.

For some taxa, the familiar knowledge of the experts could override the analytical results. This was uncommon but could be justified due to a truncated stressor gradient in the observations or to a scarcity of observations, making the analysis uncertain. The GAM analysis could only be performed with a minimum of 10 observations and was not considered reliable until there were 20-30 observations. The expert knowledge was highly valued especially with respect to taxa with few observations as statistical modeling and analytics were not available. Expert participants were encouraged to present all perspectives for incorporation into the consensus of the attribution process. Experts compared previously assigned attributes among taxa so that commonalities and relative sensitivities could be considered.

After the face-to-face workshop, a series of small group meetings and webinars were conducted, during which attributes were assigned to taxa that had not been addressed previously or that needed re-evaluation. In the final stages of the attribute assignment process, panelists were asked to review decisions and notes, and to approve or refute the preliminary group consensus. Taxa with wide ranges of attributes among stressors were reviewed, as were taxa with attribute assignments by individual experts that were not in alignment with other group members. The attribute assignment process concluded with a final reconciliation and consensus for all taxa in all-inclusive webinars.

4.0 Results

Each assemblage group addressed seven stressors, three regions, and 30 taxa during the initial attribute assignment workshop. In subsequent webinars and working groups, the experts addressed a total of 359 fish and 560 macroinvertebrate taxa. Stressors included nutrients (TN and TP), dissolved oxygen, pH (acidity and alkalinity), specific conductance (sulfate and chloride), percent watershed imperviousness, total habitat score, and relative bed stability (RBS). Geomorphological regions included mountains, Piedmont, and coastal plain, delineated by level 3 ecoregions (Woods et al. 1996). Final results are described in Section 4.3 after the workshop results.

4.1 Benthic Macroinvertebrate Workshop Results

Benthic macroinvertebrate experts convened in Richmond VA and by webinar on March 22nd and 23rd to review taxa in the context of BCG attributes. The 21 experts (Table 5) reviewed 19 taxa on the first day and an additional 11 species on the second day. Experts assigned general attributes ranging from II – V and not applicable (NA) (Table 6). The full range of possible attribute assignments was I to VI, and X, though no I, VI, or X attributes were assigned during the workshop.

The "general" attributes were meant to characterize tolerance and other ecological attributes in relation to broad physical and chemical conditions. Attributes for seven specific stressors were also assigned. Stressor-specific attributes ranged from II to V, concentrating only on the tolerance and abundance aspects of the attributes.

The group tended to assign an overall "general" rating first before looking at analytical data and the more specific BCG ratings. Before moving on to the next taxon the group re-examined the general rating in context with the other assigned attributes. Some taxa were altered from their initial ratings (both up and down). Discussion notes were captured by designated note-takers during the workshop and subsequent meetings and webinars. These notes are archived with VDEQ.

Table 5. Mid-Atlantic BCG expert panel, benthic macroinvertebrates.

Association	Participant	Email
Virginia DEQ	Larry Willis	larry.willis@deq.virginia.gov
	Chip Sparks	Lanny.Sparks@deq.virginia.gov
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	Ted Turner	Robert.Turner@deq.virginia.gov
	George Devlin	George.Devlin@deq.virginia.gov
	Lilly Edmond	Lilly.Edmond@deq.virginia.gov
	Warren Smigo	Warren.Smigo@deq.virginia.gov
	Tony Silvia	Antone.Silvia@deq.virginia.gov
	Drew Garey	Andrew.Garey@deq.virginia.gov
	Kelly Hazlegrove	Kelly.Hazlegrove@deq.virginia.gov
	Mike Shaver	Michael.Shaver@deq.virginia.gov
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USEPA, HQ	Richard Mitchell	Mitchell.Richard@epa.gov
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	Jonathan Witt	Jonathan.Witt@fairfaxcounty.gov
	LeAnne Astin	Leanne.Astin@fairfaxcounty.gov
WV DEP	Jeff Bailey	Jeffrey.E.Bailey@wv.gov
	Michael Whitman	Michael.J.Whitman@wv.gov
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	Jay Kilian	jay.kilian@maryland.gov
Tetra Tech	Michael Paul (Facilitator)	Michael.Paul@tetratech.com
	Erik Leppo (Facilitator)	Erik.Leppo@tetratech.com

Table 6. Example taxa assigned to BCG Attributes II – V and not assigned (NA), showing the general attribute assignment established during the March 2018 workshop.

II	IV	V
Cinygmula	Optioservus	Physidae
Pteronarcys	Stenelmis	Cheumatopsyche
	Chironomidae (A)	Oligochaeta
III	Hemerodromia	
Acentrella	Simulium	**NA**
Ephemerella	Baetis	Shipsa
Isoperla	Caenis	Hydropsyche_Ceratopsyche
Dolophilodes	Isonychia	Tubificidae
Wormaldia	Maccaffertium	
Rhyacophila	Perlesta	
	Taeniopteryx	
	Chimarra	
	Oecetis	
	Naididae	
	Enallagma	

4.2 Fish Workshop Results

The 17 fish experts (Table 7) reviewed 17 fish species on the first day of the March 2018 workshop and an additional 18 species on the second day. Experts assigned general attributes ranging from I to VI, and X (Table 8). Expert remarks were recorded to describe rationale for assignments, to highlight special exceptions, and to check consistency across assignments. When recorded by note-takers, these remarks were archived with VDEQ.

There was considerable discussion on interpreting evidence for Attribute V species. Attribute V taxa are the most tolerant of stressors and attribute conventions describe an increase in dominance in the assemblage as stressor intensity increases. Attribute V species were not expected to increase with increasing stress for fish in this data set. The expert panel had a perspective based on taxa abundance, not on taxa relative abundance, making the degree of dominance in the samples difficult to assess. For samples with targeted effort (similar numbers of individuals among samples), an increase in tolerant individuals would be mirrored by a decrease in more sensitive taxa. This is a typical response signal that was probably the framework used in original BCG model descriptions of the response for tolerant taxa. However, when no limits are placed on the number of fish captured and abundance is counted as individual counts per sample (not relative to the whole sample size), then tolerant Attribute V taxa can occur in high numbers in undisturbed sites or in disturbed sites. In undisturbed sites, they might occur with several sensitive taxa and individuals. In disturbed sites, tolerant taxa might be the only taxon and in high counts. Therefore, Attribute V was assigned to taxa that persisted in highly stressful conditions, regardless of abundance in less stressful conditions. In other words, the number and occurrence of Attribute V taxa did not necessarily increase with increasing disturbance. Attribute IV taxa did not have change in occurrence or abundance over the stressor gradient, though they might not occur in the most stressful conditions (where Attribute V taxa might persist).

Table 7. Mid-Atlantic BCG expert panel for fish.

Association	Participant	Email
Virginia DEQ	Jason Hill	jason.hill@deq.virginia.gov
	Royce Steiner	Royce.Steiner@deq.virginia.gov
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	Brett Stern	Brett.Stern@deq.virginia.gov
	Mike Hutchison	Michael.Hutchison@deq.virginia.gov
	Scott Hasinger	Scott.Hasinger@deq.virginia.gov
	Emma Jones (Facilitator)	Emma.Jones@deq.virginia.gov
Fairfax County, VA	Curtis, Shannon	Shannon.Curtis@fairfaxcounty.gov
	Chad Grupe	Chad.Grupe@fairfaxcounty.gov
WV DEP	Jason Morgan	Jason.A.Morgan@wv.gov
	Ryan Pack	Philip.R.Pack@wv.gov
Maryland DNR	Scott Stranko	scott.stranko@maryland.gov
	Jay Kilian	jay.kilian@maryland.gov
Montgomery County, MD	Kenny Mack	Kenny.Mack@montgomerycountymd.gov
Virginia Tech	Paul Angermeier	biota@vt.edu
Virginia Commonwealth Univ.	Steve McIninch	spmcinin@vcu.edu
U.S. EPA	Lou Reynolds	Reynolds.Louis@epa.gov
	Frank Borsuk	borsuk.frank@epa.gov
Tetra Tech	Ben Jessup (Facilitator)	benjamin.jessup@tetratech.com

Table 8. Fish taxa assigned to BCG Attributes I – VI and X, showing the general attribute assignment established during the March 2018 workshop.

I	II	III	IV	V	VI	X
Notropis scabriceps	Chologaster cornuta	Cottus caeruleomentum	Hypentelium nigricans	Catostomus commersonii	Oncorhynchus mykiss	Anguilla rostrata
Percina rex	Acantharchus pomotis	Clinostomus funduloides	Campostoma spp	Lepomis cyanellus	Micropterus salmoides	
	Enneacanthus chaetodon	Exoglossum maxillingua	Chrosomus oreas	Notemigonus crysoleucas		
	Enneacanthus obesus	Noturus insignis	Notropis procne	Rhinichthys atratulus		
	Phenacobius uranops	Percina notogramma	Rhinichthys cataractae	Semotilus atromaculatus		
	Etheostoma chlorobranchium	Ichthyomyzon bdellium	Semotilus corporalis	Umbra pygmaea		
	Percina peltata		Ameiurus natalis			
	Ichthyomyzon greeleyi		Etheostoma flabellare			
	Salvelinus fontinalis					
	Notropis bifrenatus					

4.3 Final Attribute Assignments

The experts addressed a total of 359 fish and 655 macroinvertebrate taxa. Not all the taxa were assigned BCG attributes, either because there was insufficient knowledge and evidence for the taxon, because of a course taxonomic identification that might encompass a variety of taxa, or because the taxa were on the list but determined to be absent from the region and regional samples. These taxa were assigned an “x” or 0, signifying no attribute.

The attribution process for macroinvertebrates and fish followed a similar stepwise progression of initial attribution, review and adjustment (See Table 9 for example from the macroinvertebrate workgroup). The stepwise process allowed multiple opportunities for collaboration between several groups and progressed from data-driven interpretations towards refinements based on BPJ and experience influenced consensus.

Table 9. Steps in the macroinvertebrate attribution process. Note that the fish attribution workgroup followed a parallel process.

Step 1. Initial attribution	• 506 potential macroinvertebrate taxa evaluated for attribution for seven stressors through workshop, phone calls, and homework with participation from all participants • Range and taxonomic issues were identified in an ongoing process • Emphasis on interpreting statistical analyses.
Step 2. Review	• Results of Step 1 reviewed by small workgroups to identify errors in assignment • Incorporated both statistical analyses and Best Professional Judgement (BPJ)
Step 3. Re-evaluation	• Discrepancies were compiled and re-evaluated for each stressor • VDEQ biologists carefully considered proposed changes by re-evaluating data and considering experience with taxa and stressors. (For example, preference was given to the opinions of WVDEP biologists for specific conductance and sulfate stress and to Fairfax biologists for impervious surface and chloride).
Step 4. Further Review	• Step 3 Results review by all participants • Emphasis placed on BPJ and experience • Directed effort to identify more potential Attribute II, III and V taxa
Step 5. Final Evaluation	• Final meeting of VDEQ biologists to reach a consensus on all proposals. • Taxonomic and range issues finalized (e.g. appropriate level of ID for various groups, and significance of taxa occurrence in Virginia). • 252 macroinvertebrate taxa were attributed for most stressors and 322 were assigned a generalized tolerance score • The Final Attribution was a consensus agreement of Virginia DEQ Biologists taking into account all available information, statistics, experience and opinions.

The macroinvertebrate taxa list included 95 taxa that were omitted because they did not occur in the region or were not identified at an applicable taxonomic level, leaving 560 taxa that were considered for attributes. Of those 560 taxa, 322 macroinvertebrates were assigned a general attribute, 209 of which were assigned at least one stressor-specific attribute (Appendix B). Most of the taxa with general attribute assignments were attribute IV (53%, Figure 8, Table 10). Another 40% of taxa were assigned to the sensitive attributes II and III. Tolerant taxa (attribute V) made up 8% of the assigned taxa. For specific stressors, attribute IV was not always the most common.

Two hundred forty-three Mid-Atlantic fish were assigned a general attribute, 106 of which were assigned at least one stressor-specific attribute (Appendix C). The most common attribute assignment was IV (moderately tolerant), which was 37% of the assignments (Figure 9 and Table 10). Sensitive taxa (attributes I, II, and III) made up a total of 29% of the assignments and tolerant taxa (attribute V) made up 11%. Other assignments in attributes VI (non-native) and X (connectance indicators) made up 14% of the assignments.

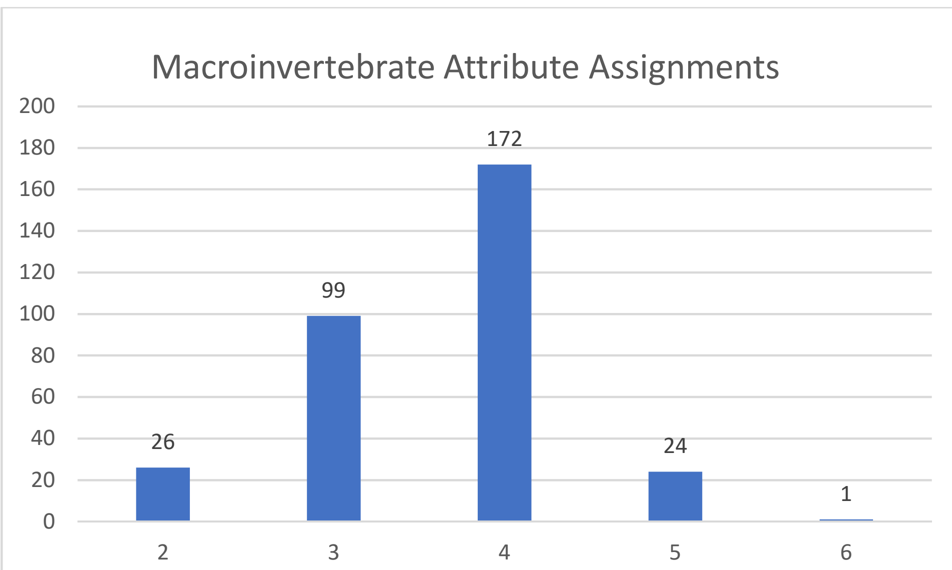

Figure 8. Count of macroinvertebrate taxa in each final attribute category (total N = 322).

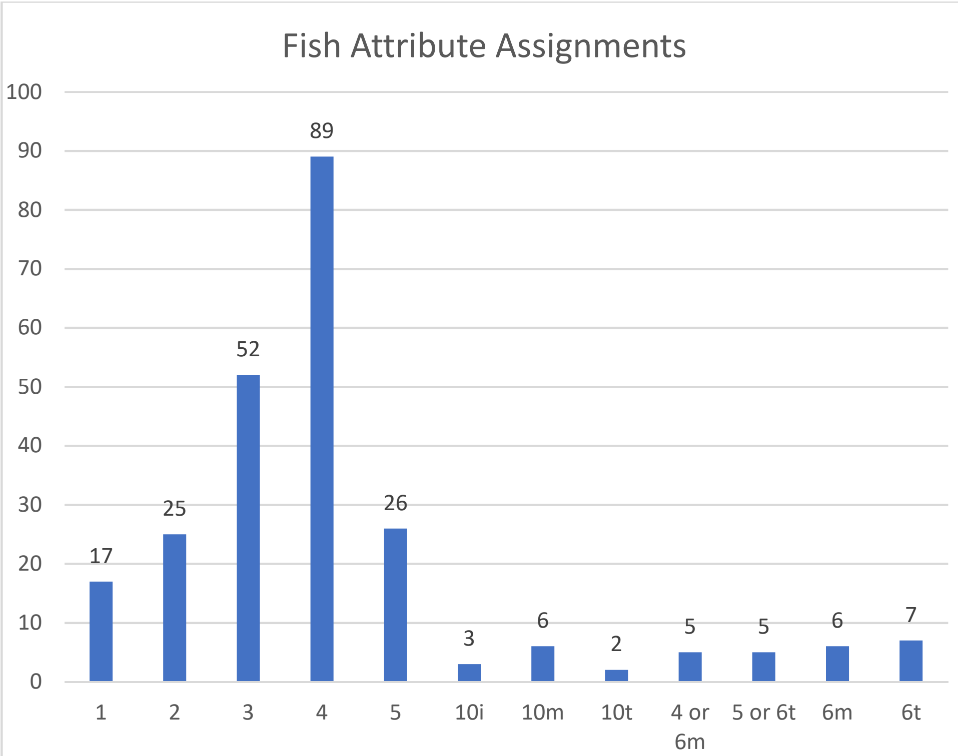

Figure 9. Count of fish taxa in each final attribute category (total N = 243).

Table 10. Counts of taxa attributes for the general attribute assignment and for specific stressors.

	BCG General	BCG DisOxy	BCG acidity	BCG alkal.	BCG spCond	BCG Chloride	BCG Sulfate	BCG TN.TP	BCG totHab	BCG RBS	BCG %IMP
Fish											
I	17	0	0	0	0	0	0	0	0	0	0
II	25	1	0	4	3	1	0	0	1	0	3
III	52	36	68	5	9	10	9	5	13	19	16
IV	89	42	27	15	52	59	57	62	65	57	44
V	26	24	1	0	36	23	28	28	22	6	27
Macroinvertebrates											
I	0	0	0	0	0	0	0	0	0	0	1
II	26	21	19	19	10	31	10	7	16	6	40
III	99	89	68	106	93	90	60	44	79	26	65
IV	172	81	105	81	83	84	124	125	94	97	67
V	24	18	16	1	23	3	13	12	19	11	23

5.0 Discussion

5.1 Summary of process and process issues

Though the process is not necessarily a result, the lessons learned from the process could be instructive to future BCG attribute assignment efforts. The effort for this project was impressive. VDEQ conducted data assembly for two assemblages, 10 stressors, and multiple monitoring programs and then organized the data in tables, figures, and an R application. The expert panel was large and diverse. With a large panel, not only are logistics complex, but collection and compilation of multiple attribute assignments and remarks required patient discussions and reconciliation over multiple iterations. The number of assemblages, taxa, stressors, physiological regions, and analytical results was daunting, but the workgroups were committed to completing attribute assignments for a large percentage of the taxa lists.

A few issues appeared and were rectified after the attribute assignment workshop. These included 1) the separation of stressor responses to pH into different responses for acidity and alkalinity, 2) nutrient GAM plots were skewed and difficult to interpret due to a few high (but valid) outliers, 3) possible differences in ionic components of specific conductance, and 4) recognition of different expectations for coastal plains fish and setting.

1. Acidity and alkalinity were separated as two stressors. Some taxa were found to be sensitive to only one end of the pH stressor scale.
2. The experts suggested that patterns would be better discerned if the nutrient scales were log-transformed.
3. The group hypothesized that ions in the mountains were dominated by sulfates and in the Piedmont by chloride. These ions might act differently (e.g., *Hypentelium nigricans* seems more sensitive to chlorides in the east of the state than to sulfates in the west).
4. Fish that are adapted to coastal plains conditions might require different designations to recognize that acidity or sedimentation might be natural conditions in some places and that sensitivity to these “stressors” might have different meaning depending on where the fish are sampled. A list of obligate and facultative coastal plains fishes will be prepared to help with future attribute assignments.

In the fish workgroup, representatives from the more populated areas (Fairfax and Montgomery counties) noted that the urban gradient was biased towards rural conditions in the VDEQ and WVDEP data sets. Therefore, VDEQ incorporated additional state data sets and recompiledthe data.

With the revised analysis, the TITAN analysis was not repeated. It is not specific to each taxon, but is instead a relative ranking of taxa in response to stressors. The graphics were not generated nor incorporated into theanalysis. The experts were not especially reliant on the TITAN results when they were available in the first round of analysis.

In the macroinvertebrate group, the biologists expressed an interest in an attribute category between IV and V. There were many taxa were marginal IV and were assigned to that category, though they also had some tolerant characteristics. Typically, these are taxa that are not necessarily "bad" but are indicators when they are highly dominant in the sample. The scale of attributes seems to be more refined in the sensitive attributes (I, II, and III) while it only includes one tolerant category (V) other than the moderately tolerant and generally unresponsive attribute IV taxa.

In a similar issue with the attribute V designation, the fish group noted that some fish occurred in a range of disturbance conditions from relatively undisturbed to moderately disturbed. This would typically be designated as an attribute IV because it could appear in various conditions and would not necessarily indicate site stress levels. Other fish showed similar patterns except that they persisted in severely disturbed conditions as well as in relatively undisturbed and moderately disturbed conditions. These fish were considered highly tolerant, but poor indicators because they also occurred with less stress. There was discussion about calling these tolerant fish attribute V, and that was the decision for some species. However, the uncertainty suggests that a different designation might be needed; something between attributes IV and V.

In future analyses, the relative richness and abundance of fish (as percentages of total taxa and individuals) could be illustrated to show the degree to which tolerant taxa become dominant with increasing stress. This response is expected, though it was not illustrated for the attribute assignment exercise because total abundance was analyzed, not relative abundance.

5.2 Summary of results of interest

General BCG attributes were assigned for a 60 – 70% of the mid-Atlantic macroinvertebrate and fish taxa that were considered. Specific attributes were assigned for 65% and 44% of the macroinvertebrate and fish taxa that were given general attributes. The taxa that were not addressed at all nor specifically were those that are less common and less familiar.

5.3 Application potential

The attribute assignments to specific stressors is a new application of the BCG concepts, because most BCG efforts assign attributes only for a general stressor gradient. The stressor-specific attribute values could be used to make stressor-specific inferences from biological community data. This might lead to diagnostic analyses for stressor identification in the TMDL process. VDEQ has expressed that they intend to use the expert-assigned attribute values in calibration of multimetric indices as assessment tools. Sample metrics based on taxa enumeration and attributes could be used for calibration of either general or stressor-specific indices that show responses along a predefined stressor gradient, as described by comparing least disturbed reference sites and most disturbed stressed sites. An index development process will probably require site classification and stressor-specific reference and stressed site designations. Developing metrics from the stressor-specific attributes could include counts and relative abundance of taxa by attribute. Other metric formulations might include simple averaging of stressor-specific attributes or weighted averaging of attributes by percentage of individuals; similar to calculation of a Hilsenhoff Biotic Index.

Another approach for developing assessment tools is to use the stressor-specific attribute values in calibration of a BCG model. The BCG levels that are natural or show minor changes in community structure and function (Levels 1 -3) could be described by experts in terms of expectations for the sensitive and intermediate tolerant taxa for a region. As disturbance becomes apparent in a sample, sensitive taxa typically decline as tolerant taxa become more dominant. With stressor-specific attributes, the types of stressors acting on the community might become apparent based on the taxa-specific sensitivities. For example, a sample taxa list would include all of the stressor-specific attributes (Table 11), which might lead not only to a BCG Level assignment, but also to an estimate of the stressors that contribute to the condition. While IBI are generally developed based on reference and stressed site gradients, calibration of the IBI to the BCG model could proceed with expert consensus on sample designations along the biological condition gradient.

5.4 Next steps

The following bullets represent developing ideas on how the BCG attribute assignment might be used in continuing analyses and studies.

1. Calculation of BCG attribute-based assemblage metrics for incorporation in IBI development
2. Recommendations on metric combinations that approximate expert decision process more so than simple summation of multiple metrics
3. Formatting of sample worksheets for BCG sample review and ratings.
    a. These could be region and stressor-specific, or at least highlight stressor signals from the taxa lists.
4. Development of Attribute Assignment Tools
    a. Detailed narrative attribute descriptions
    b. Expert knowledge of taxa characteristics and habitats
    c. Example attributes and traits from other systems/programs
    d. Taxa distributions
    e. Stressor-response analysis
    f. Taxon spreadsheet with tabular results and traits
    g. Shiny app with maps, graphic results, and stats

Table 11. Example BCG sample worksheet with multiple stressor-specific BCG attributes displayed per taxon.

TAXA SUMMARY

BCG Attribute	TN.TP	pctIMP	acidity	alkalinity	spCond	DisOxy	RBS	totHab	Number of Taxa	Count	Pct Taxa	Pct Individuals
1									0	0	0%	0%
2									0	0	0%	0%
3	0	3	1	0	2	2	0	3	5	42	33%	43%
4	5	1	7	7	1	6	6	1	2	28	13%	29%
5	2	3	0	0	4	0	1	3	5	17	33%	18%
6t									2	7	13%	7%
10									1	3	7%	3%
Total									*15*	*97*	*100%*	*100%*

TAXA LIST

Attribute	TN.TP	pctIMP	acidity	alkalinity	spCond	DisOxy	RBS	totHab	Common Name	Scientific Name	Count	Family
10	x	x	x	x	x	x	x	x	American eel	Anguilla rostrata	3	Anguillidae
5	5	5	4	4	5	4	5	5	white sucker	Catostomus commersonii	4	Catostomidae
3									torrent sucker	Moxostoma rhothoeca	11	Catostomidae
3	4	4	3	x	5	4	4	3	northern hog sucker	Hypentelium nigricans	1	Catostomidae
5									redbreast sunfish	Lepomis auritus	4	Centrarchidae
6t	5	5	4	4	5	4	4	5	green sunfish	Lepomis cyanellus	3	Centrarchidae
6t									bluegill	Lepomis macrochirus	4	Centrarchidae
3	4	3	4	4	3	3	4	3	rosyside dace	Clinostomus funduloides	2	Cyprinidae
4									common shiner	Luxilus cornutus	16	Cyprinidae
4									bluehead chub	Nocomis leptocephalus	12	Cyprinidae
5	4	5	4	4	5	4	4	5	blacknose dace	Rhinichthys atratulus	1	Cyprinidae
5	5	5	4	4	5	4	5	5	creek chub	Semotilus atromaculatus	1	Cyprinidae
3	4	3	4	4	4	3	4	4	fallfish	Semotilus corporalis	23	Cyprinidae
3	4	3	4	4	3	4	4	3	margined madtom	Noturus insignis	5	Ictaluridae
5									johnny darter	Etheostoma nigrum	7	Percidae

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Appendix A: Taxa Attribute Descriptions:

The BCG model depicts ecological condition in terms of measurable changes in response to stress in ten system attributes expressed at different spatial scales. In biological assessments, most information is collected at the spatial scale of a site or reach and the temporal scale of a single sampling event. Many of the attributes that make up the BCG are based on these scales. Site scale attributes include aspects of taxonomic composition and community structure (attributes I–V), organism condition (attribute VI), and organism and system performance (attributes VII and VIII). At larger temporal and spatial scales, physical-biotic interactions (attributes IX and X) were also included because of their importance in evaluating the longer-term impacts, restoration potential, and recoveries. Attributes I–X are described below (from Davies and Jackson 2006).

Attribute I: Historically documented, sensitive, long-lived or regionally endemic taxa

Taxa that are *historically documented* refer those known to have been supported in a water body or region according to historical records. This attribute was derived to cover taxa that are s*ensitive or regionally endemic taxa* that have restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often due to unique life history requirements. They may be long-lived, late maturing, have low fecundity, have limited mobility, or require a mutualist relation with other species. They may be among listed Endangered or Threatened (E/T) or special concern species. Predictability of occurrence is often low, and therefore requires documented observation. The presence or absence of a population might provide significant information in an assessment, but there is typically insufficient data to develop the stress response relationships needed to assign these taxa to attributes II through V (as discussed below). Recorded occurrence may be highly dependent on sample methods, site selection, and level of effort. The taxa that are assigned to this category require expert knowledge of life history and regional occurrence of the taxa to appropriately interpret the significance of their presence or absence. For example, many species of freshwater mussels in the Southeast U.S. are highly endemic and have been extirpated in many areas. The presence of freshwater mussels in a stream might signify high quality conditions, but their absence does not necessarily indicate poor conditions if overharvesting of the mussels is the cause.

Attribute II: Highly sensitive taxa

Highly sensitive taxa naturally occur in low numbers relative to total population density, but they might make up a large relative proportion of richness. In high quality sites, they might be ubiquitous in occurrence or might be restricted to certain micro-habitats. Many of these species commonly occur at low densities, thus their occurrence is dependent on sample effort. They are often stenothermic (i.e., having a narrow range of thermal tolerance) or cold-water obligates, and they are commonly K-strategists (i.e., populations maintained at a fairly constant level; slower development; longer life-span). They might have specialized food resource needs or feeding strategies, and they are generally intolerant to significant alteration of the physical or chemical environment. They are often the first taxa observed to be lost from a community following moderate disturbance or pollution.

In earlier descriptions of the BCG, highly sensitive taxa were called *sensitive-rare* taxa (Davies and Jackson 2006), but experience with calibrating the BCG showed that some highly sensitive species are found at many exceptional sites, and some were occasionally highly abundant (e.g., Snook et al. 2007). The distinguishing characteristic was found to be sensitivity and not relative rarity, although some of these taxa might be uncommon in the data set (e.g., 1 or 2 occurrences in 100 samples)

Attribute III: Intermediate sensitive taxa (or sensitive ubiquitous taxa)

Taxa that are *intermediate sensitive* are ordinarily common and abundant in natural communities when conventional sampling methods are used. They often have a broader range of tolerances than highly sensitive taxa, and they usually occur in reduced abundance and reduced frequencies at disturbed or polluted sites. These are taxa that comprise a substantial portion of natural communities and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.

Attribute IV: Taxa of intermediate tolerance

Attribute IV taxa commonly comprise a substantial portion of natural communities. They might be r-strategists (i.e., early colonizers with rapid turn-over times; boom/bust population characteristics) or they might be eurythermal (i.e., having a broad thermal tolerance range). Many have generalist or facultative feeding strategies enabling utilization of diverse food types. They are readily collected with conventional sample methods. These species have little or no detectable response to a stress gradient, and they are often equally abundant in both reference and stressed sites. Some intermediate taxa may show an "intermediate disturbance" response, where densities and frequency of occurrence are highest at intermediate levels of stress, but they are intolerant of excessive pollution loads or habitat alteration. These taxa are readily collected with conventional sample methods.

Attribute V: Tolerant taxa

Tolerant taxa are those that comprise a low proportion of natural communities. Taxa often are tolerant of a greater degree of disturbance and stress than other organisms and are, thus, resistant to a variety of pollution or habitat induced stress. They may increase in number (sometimes greatly) under severely altered or stressed conditions, and they may possess adaptations in response to organic pollution, hypoxia, or toxic substances. Commonly r-strategists, these are the last survivors in severely disturbed systems.

Attribute VI: Non-native or intentionally introduced taxa

With respect to a particular ecosystem, species fitting attribute VI are any species not native to that ecosystem. Species introduced or spread from one region of the U.S. to another outside their normal ranges are non-native or non-indigenous, as are species introduced from other continents. This attribute represents both an effect of human activities and a stressor in the form of biological pollution. Although some intentionally introduced species are valued by large segments of society (e.g., gamefish), these species might be just as disruptive to native species as undesirable opportunistic invaders (e.g., zebra mussels). Many rivers in the U.S. are now dominated by non-native fish and invertebrates (Moyle 1986), and the introduction of alien species is the second most important factor contributing to fish extinctions in North America (Miller et al. 1989). The BCG identifies maintenance of native taxa as an essential characteristic of BCG level 1 and 2 conditions. The model only allows for the occurrence of non-native taxa in these levels if those taxa do not displace native taxa and do not have a detrimental effect on native structure and function. Condition levels 3 and 4 depict increasing occurrence of non-native taxa. Extensive replacement of native taxa by tolerant or invasive, non-native taxa can occur in levels 5 and 6. Note: Attribute VI taxa can be VIi (intolerant), VIm (moderately tolerant), or VIt (tolerant).

Attribute VII: Organism Condition

Organism condition is an element of ecosystem function, expressed at the level of anatomical or physiological characteristics of individual organisms. Organism condition includes direct and indirect indicators such as fecundity, morbidity, mortality, growth rates, and anomalies (e.g., lesions, tumors, and deformities). Some of these indicators are readily observed in the field and laboratory, whereas the assessment of others requires specialized expertise and much greater effort. Organism condition can also change with season or life stage, or occur as short-term events making assessment difficult. The most common approach for state programs is to forego complex and demanding direct measures of organism condition (e.g., fecundity, morbidity, mortality, disease, growth rates) in favor of indirect or surrogate measures (e.g., percent of organisms with anomalies, age or size class distributions). Organism anomalies in the BCG vary from naturally occurring incidence in levels 1 and 2 to higher than expected incidence in levels 3 and 4. In levels 5 and 6, biomass is reduced, the age structure of populations indicates premature mortality or unsuccessful reproduction, and the incidence of serious anomalies is high. This attribute has been successfully used in stream indices based on the fish assemblage.

Attribute VIII: Ecosystem Function

Ecosystem function refers to any processes required for the performance of a biological system expected under naturally occurring conditions. Naturally occurring conditions have been typically interpreted as those conditions found in undisturbed to minimally disturbed conditions but some processes can be sustained under moderate levels of disturbance. Examples of ecosystem functional processes are primary and secondary production, respiration, nutrient cycling, and decomposition. Assessing ecosystem function includes consideration of the aggregate performance of dynamic interactions within an ecosystem, such as the interactions among taxa (e.g., food web dynamics) and energy and nutrient processing rates (e.g., energy and nutrient dynamics).

Additionally, ecosystem function includes aspects of all levels of biological organization (e.g., individual, population, and community condition). Altered interactions between individual organisms and their abiotic and biotic environments might generate changes in growth rates, reproductive success, movement, or mortality. These altered interactions are ultimately expressed at ecosystem-levels of organization (e.g., shifts from heterotrophy to autotrophy, onset of eutrophic conditions) and as changes in ecosystem process rates (e.g., photosynthesis, respiration, production, decomposition). At this time, the level of effort required to directly assess ecosystem function is beyond the means of most state monitoring programs. Instead, in streams and wadeable rivers, most programs rely on taxonomic and structural indicators to make inferences about functional status (Karr et al. 1986). For example, shifts in the primary source of food might cause changes in trophic guild indices or indicator species.

Attribute IX: Spatial and Temporal Extent of Detrimental Effects

The spatial and temporal extent of stressor effects includes the near-field to far-field range of observable effects of the stressors on a water body. Such information can be conveyed by biological assessments provided the spatial density of sampling sites is sufficient to convey changes along a pollution continuum. Use of a continuum provides a method for determining the severity (i.e., departure from the desired state) and extent (i.e., distance over which adverse effects are observed) of an impairment from one or more sources. As with attribute VIII above, attribute IX has not yet been developed and applied in BCG models for specific streams and wadeable rivers.

Attribute X: Ecosystem Connectance

Attribute X refers to the access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life. It is the opposite of fragmentation and is necessary for persistence of metapopulations and natural flows of energy and nutrients across ecosystem boundaries. Ecosystem connectance can be indirectly expressed by certain species that depend on the connectance, or lack of connectance, within an aquatic ecosystem to fully complete their life cycles and thus maintain their populations. Diadromous fish species are one such example—their absence or presence can provide information on the presence or absence of critical habitats to support different life stages. However, the inverse of connectance, isolation, is important for some species (e.g., amphibians, which are negatively impacted by fish that gain access to amphibian habitat via artificial or natural connections). Note: Attribute X taxa can be Xi (intolerant), Xm (moderately tolerant), or Xt (tolerant).

General Terms:

attribute: measurable part or process of a biological system and a value assigned to an organism or ecosystem component as described in the BCG attribute definitions

ecosystem-level functions: processes performed by ecosystems, including, among other things, primary and secondary production; respiration; nutrient cycling; decomposition.

function: processes required for normal performance of a biological system (may be applied to any level of biological organization)

life-history requirements: environmental conditions necessary for completing life cycles (including, among other things, reproduction, growth, maturation, migration, dispersal)

maintenance of populations: sustained population persistence; associated with locally successful reproduction and growth

native: an original or indigenous inhabitant of a region; naturally present

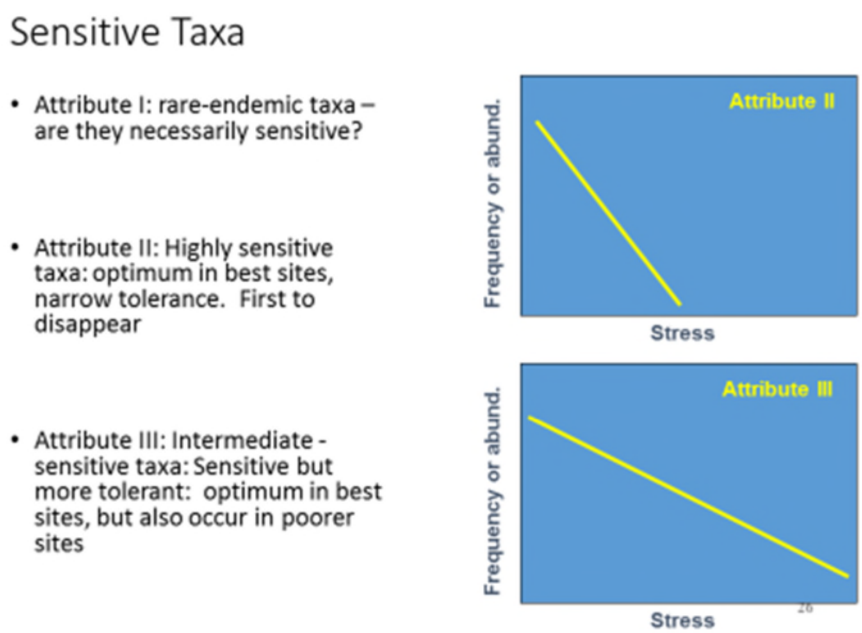
non-detrimental effect: do not displace native taxa

refugia: accessible microhabitats or regions within a stream reach or watershed where adequate conditions for organism survival are maintained during circumstances that threaten survival, eg drought, flood, temperature extremes, increased chemical stressors, habitat disturbance, etc

spatial and temporal ecosystem connectance: access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life; the opposite of fragmentation; necessary for metapopulation maintenance and natural flows of energy and nutrients across ecosystem boundaries

structure: taxonomic and quantitative attributes of an assemblage or community, including species richness and relative abundance

structurally & functionally redundant attributes of the system: characteristics, qualities, or processes that are represented or performed by more than one entity in a biological system.



Attribute 6: Non-native: 6i (intolerant), 6m (moderately tolerant), 6t (tolerant)

Attribute 7: Condition: DELT anomalies

Attribute 8: Ecosystem Function

Attribute 10: Connectivity: e.g., Anadromous/catadromous fish

Appendix B:

BCG Attribute Assignments for Macroinvertebrates in the Mid-Atlantic Region

The following tables describe 1) the attributes assigned by the expert panel for selected macroinvertebrate taxa and 2) the taxa that were considered, but were not assigned attributes due to lack of supporting data, limited distribution in the region, or characteristics that were unknown by the expert panel. These tables were derived from the Excel workbook used during workshops and webinars; available from VDEQ and including ancillary data not shown here (Supplement IV; MASTER_ATTRIBUTES_BUGS_06062019.xlsx).

Table B-1. Final attribute assignments for macroinvertebrates in the Mid-Atlantic region.

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Non-Insect														
Annelida/ Platyhelminthes														
Hirudinea	5	3	2	2	4	4	4	4	4	x	5			
Oligochaeta	5	4	4	3	5	4	4	5	5	5	5			
Tricladida	4	4	3	3	4	4	4	4	4	4	4			
Mollusca														
Ancylidae	4	4	4	4	4	4	4	4	4	4	4			
Hydrobiidae	4	4	3	3	4	3	3	4	4	4	4			
Lymnaeidae	5	5	4	4	5	5	4	5	5	x	5			
Physidae	5	5	4	5	5	4	3	5	5	5	5			
Planorbidae	5	5	4	3	4	4	3	5	5	4	5			
Pleuroceridae	3	3	2	4	3	3	3	4	3	3	4			
Viviparidae	4	5	4	3	3	4	3	x	4	4	4			
Corbicula	6	4	3	4	5	4	4	5	5	4	5			
Sphaeriidae	4	4	4	3	3	3	3	4	4	5	4			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Unionidae	4	x	x	x	x	x	x	x	x	x	x			
Amphipoda														
Amphipoda	4	5	5	3	4	4	3	x	5	x	4			
Crangonyx	4	5	5	3	4	5	4	5	5	x	5			
Gammaridae	4	4	4	4	4	4	4	4	4	4	4			
Gammarus	4	5	4	4	5	4	4	4	5	x	4			
Hyalella	4	5	4	3	4	4	3	4	4	x	5			
Talitridae	4	x	x	x	x	x	x	x	x	x	x			
Decapod/Isopod/Shrimp														
Cambaridae	4	4	4	4	4	4	4	4	4	4	4			
Asellidae	5	5	5	2	4	4	4	4	5	4	4			
Palaemonetes	4	x	x	x	x	x	x	x	x	x	x			
Arachnida														
Hydracarina	4	x	x	x	x	x	x	x	x	x	x			
Insecta														
Ephemeroptera														
Ameletus	3	3	4	3	3	3	3	3	3	4	3			
Acentrella	3	3	3	3	4	3	4	4	3	3	2			
Acerpenna	3	4	3	3	3	3	2	3	4	4	3	3	2	
Baetidae	4	3	3	4	4	4	4	4	4	4	3			
Baetis	4	3	4	4	4	4	5	4	4	4	4	4	3	3
Callibaetis	4	x	x	x	x	x	x	x	x	x	x			
Centroptilum	4	4	2	2	3	3	3	4	4	4	4			
Cloeon	4	x	x	x	x	x	x	x	x	x	x			
Diphetor hageni	3	3	3	3	3	2	3	4	3	4	2			
Heterocloeon	3	2	3	3	2	2	2	3	3	3	3	3	2	
Plauditus	4	3	3	3	4	3	4	4	3	4	3			
Procloeon	3	3	3	3	3	3	4	3	3	4	3			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Pseudocloeon	4	x	x	x	x	x	x	x	x	x	x			
Baetisca	3	3	3	3	4	3	4	3	4	4	3			
Caenidae	4	x	x	x	x	x	x	x	x	x	x			
Caenis	4	4	3	4	4	4	4	4	4	5	5			
Attenella	3	4	3	4	3	3	3	4	3	4	3			
Dannella	3	3	3	3	3	2	3	4	3	4	3			
Drunella	3	2	3	4	3	2	4	3	2	3	2	3	2	
Ephemerella	3	3	3	3	3	3	3	3	3	4	3			
Ephemerellidae	3	3	3	4	3	3	3	3	3	4	3			
Eurylophella	3	4	4	4	3	3	3	4	4	4	3			
Serratella	3	4	3	4	3	3	3	4	3	3	2			
Teloganopsis deficiens	3	2	2	4	3	2	2	3	3	4	3			
Timpanoga hecuba	3	3	4	3	3	2	4	4	4	x	x			
Ephemera	3	3	3	4	3	2	3	3	3	x	2			
Ephemeridae	3	x	x	x	x	x	x	x	x	x	x			
Hexagenia	4	x	x	x	x	x	x	x	x	x	x			
Cinygmula	2	3	4	3	2	2	3	3	2	2	2	2	NA	NA
Epeorus	3	3	4	4	3	2	3	3	3	3	2	3	2	
Heptagenia	3	x	x	x	x	x	x	x	x	x	x			
Heptageniidae	3	3	3	4	3	3	3	3	3	4	4			
Leucrocuta	2	3	3	4	2	2	2	4	2	3	2			
Maccaffertium	4	4	4	4	3	3	3	4	4	4	4			
Nixe	3	3	3	4	3	2	4	4	4	x	x			
Rhithrogena	2	2	2	2	2	2	2	2	2	2	2			
Stenacron	4	4	4	4	3	2	3	4	3	4	4			
Stenonema	4	x	x	x	x	x	x	x	x	x	x			
Isonychia	4	3	3	4	4	3	4	4	3	4	3	4	3	3
Leptohyphidae	4	x	x	x	x	x	x	x	x	x	x			
Tricorythodes	4	4	3	4	5	4	5	4	3	4	3			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Habrophlebia vibrans	2	x	x	x	x	x	x	x	x	x	x			
Habrophlebiodes	2	3	2	2	3	2	2	3	3	3	2			
Leptophlebia	3	4	4	3	2	3	3	3	4	4	2			
Leptophlebiidae	3	3	4	3	3	2	3	4	3	4	3			
Paraleptophlebia	3	3	3	3	3	2	3	4	3	4	2			
Neoephemera	3	x	x	x	x	x	x	x	x	x	x			
Ephoron	3	x	x	x	x	x	x	x	x	x	x			
Polymitarcyidae	3	x	x	x	x	x	x	x	x	x	x			
Tortopus	3	x	x	x	x	x	x	x	x	x	x			
Anthopotamus	3	x	x	x	x	x	x	x	x	x	x			
Siphlonurus	4	x	x	x	x	x	x	x	x	x	x			
Plecoptera														
Allocapnia	4	3	4	3	4	4	4	4	4	4	3			
Capniidae	3	3	3	3	4	3	4	4	4	4	3			
Paracapnia	3	4	4	3	3	4	4	4	3	x	2			
Alloperla	3	3	4	3	3	3	4	4	3	x	3			
Chloroperlidae	3	4	4	3	2	3	4	2	3	x	2			
Haploperla	3	3	4	3	3	3	4	3	3	3	4	3	2	
Suwallia	2	x	x	x	x	x	x	x	x	x	x			
Sweltsa	3	3	4	3	3	3	4	4	2	3	2	3	2	
Utaperla	2	x	x	x	x	x	x	x	x	x	x			
Leuctra	3	3	5	4	4	2	5	4	3	4	3			
Leuctridae	3	3	5	4	4	4	4	4	3	4	4			
Paraleuctra	2	x	x	x	x	x	x	x	x	x	x			
Amphinemura	4	3	4	3	3	3	4	4	3	4	3	4	3	
Nemouridae	4	5	5	3	3	4	4	4	4	4	3			
Ostrocerca	3	4	5	2	3	4	3	x	4	x	2			
Paranemoura	2	x	x	x	x	x	x	x	x	x	x			
Prostoia	4	4	4	3	3	4	3	x	4	3	3			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Shipsa	2	x	x	x	x	x	x	x	x	x	x			
Soyedina	4	3	4	4	5	4	5	x	4	x	x			
Peltoperla	2	2	4	3	4	3	4	4	3	x	2			
Peltoperlidae	2	2	4	3	3	2	4	3	2	2	2			
Tallaperla	2	2	4	3	3	3	3	2	2	3	2	2	2	NA
Acroneuria	3	3	4	4	3	3	4	3	2	3	2			
Agnetina	3	2	3	4	3	2	3	4	2	3	2			
Eccoptura xanthenes	3	3	4	3	3	3	4	4	3	4	2			
Neoperla	3	3	3	4	3	3	3	3	3	3	2			
Paragnetina	2	2	2	3	3	2	4	3	2	3	2			
Perlesta	4	4	3	4	4	2	4	4	4	4	3	4	3	3
Perlidae	3	3	3	3	3	3	4	4	3	4	3			
Clioperla clio	3	4	3	3	3	3	3	x	4	x	2			
Cultus	2	2	2	3	3	3	4	x	4	x	3			
Diploperla	3	3	4	3	3	3	3	4	4	4	2			
Isoperla	3	3	3	3	3	3	4	3	3	4	3			
Malirekus hastatus	3	2	3	3	4	3	4	3	3	x	x			
Perlodidae	3	4	4	3	3	3	4	4	3	4	3			
Remenus	2	3	4	3	2	2	3	3	3	2	2			
Yugus	2	3	4	2	3	2	4	4	3	x	2			
Pteronarcys	2	2	3	3	3	3	4	3	2	4	2	3	2	NA
Oemopteryx contorta	3	4	3	3	3	3	3	x	3	x	3			
Strophopteryx	3	4	4	3	3	3	2	3	3	x	3			
Taenionema atlanticum	2	2	x	x	3	4	2	x	2	x	2			
Taeniopterygidae	4	4	4	4	4	4	4	4	4	4	4			
Taeniopteryx	4	3	3	4	3	3	4	4	4	4	3	4	3	3
Trichoptera														
Apatania	2	2	2	2	2	3	2	2	2	x	3			
Apataniidae	2	x	x	x	x	x	x	x	x	x	x			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Brachycentridae	3	x	x	x	x	x	x	x	x	x	x			
Brachycentrus	3	4	3	3	3	3	3	3	3	4	3			
Micrasema	3	3	2	3	3	3	3	3	3	x	2			
Calamoceratidae	3	x	x	x	x	x	x	x	x	x	x			
Heteroplectron americanum	3	4	4	2	2	3	3	x	4	x	3			
Phylocentropus	4	x	x	x	x	x	x	x	x	x	x			
Agapetus	3	3	3	4	3	2	3	3	3	x	2			
Glossosoma	3	3	3	3	4	3	4	4	3	3	3			
Glossosomatidae	3	x	x	x	x	x	x	x	x	x	x			
Goera	2	2	3	3	3	3	4	4	3	x	2			
Goeridae	2	x	x	x	x	x	x	x	x	x	x			
Helicopsyche borealis	4	2	3	4	4	4	4	3	4	3	2			
Cheumatopsyche	5	4	3	4	5	4	4	5	4	4	5			
Diplectrona	3	3	5	3	4	3	4	4	4	4	4			
Hydropsyche	4	3	3	x	5	4	5	5	4	4	5			
Hydropsychidae	4	3	3	4	4	3	4	4	4	4	4			
Macrostemum	3	3	2	3	3	2	3	3	3	x	x			
Hydroptila	4	3	2	3	5	4	5	5	4	3	5			
Hydroptilidae	4	x	x	x	x	x	x	x	x	x	x			
Leucotrichia	4	3	2	3	4	4	4	4	3	x	4			
Ochrotrichia	3	2	3	3	4	3	4	3	3	x	x			
Orthotrichia	4	x	x	x	x	x	x	x	x	x	x			
Oxyethira	3	4	4	3	3	3	3	x	4	x	3			
Lepidostoma	3	3	4	3	3	3	4	4	3	4	3			
Lepidostomatidae	3	x	x	x	x	x	x	x	x	x	x			
Ceraclea	3	4	3	3	3	3	3	3	3	4	3			
Leptoceridae	3	4	3	3	3	3	3	4	4	4	4			
Mystacides	4	x	x	x	x	x	x	x	x	x	x			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Nectopsyche	3	3	3	3	4	3	4	4	4	3	3			
Oecetis	4	4	3	3	4	4	4	4	4	4	4			
Setodes	3	x	x	x	x	x	x	x	x	x	x			
Triaenodes	4	5	4	3	3	3	3	4	4	5	3			
Hydatophylax argus	3	3	4	3	3	3		x	4	x	3			
Ironoquia	4	5	5	3	3	4	3	4	5	5	4			
Limnephilidae	4	4	5	2	3	4	4	4	4	x	4			
Platycentropus	4	4	4	2	3	4	4	x	4	x	3			
Pycnopsyche	3	4	4	3	3	3	4	4	4	5	3			
Pycnopsyche/ Hydatophylax	3	x	x	x	x	x	x	x	x	x	x			
Molanna	3	4	5	2	3	4	3	x	5	x	2			
Odontoceridae	3	x	x	x	x	x	x	x	x	x	x			
Psilotreta	2	4	4	3	3	4	3	4	4	x	3			
Chimarra	4	4	4	4	4	4	4	4	4	4	5			
Dolophilodes	3	3	3	4	3	3	4	3	3	3	2	3	2	
Philopotamidae	3	3	4	4	3	2	3	3	3	4	4			
Wormaldia	2	3	4	4	3	2	4	2	3	4	3	3	2	
Phryganeidae	3	x	x	x	x	x	x	x	x	x	x			
Ptilostomis	3	4	4	2	3	3	3	x	4	x	3			
Cyrnellus fraternus	3	3	3	3	4	3	4	4	2	x	x			
Neureclipsis	3	3	3	4	4	3	4	3	3	3	4			
Nyctiophylax	4	4	4	4	4	3	4	4	4	x	4			
Polycentropodidae	4	x	x	x	x	x	x	x	x	x	x			
Polycentropus	3	3	4	3	4	3	4	4	3	3	3			
Polycentropus/Cernotina	3	x	x	x	x	x	x	x	x	x	x			
Lype diversa	4	4	4	4	3	3	3	4	4	4	4			
Psychomyia	4	3	4	4	4	3	4	4	3	x	3			
Psychomyiidae	4	x	x	x	x	x	x	x	x	x	x			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Rhyacophila	3	2	4	4	3	3	4	2	3	4	3			
Neophylax	3	3	4	3	3	4	3	4	3	4	4			
Coleoptera														
Helichus	4	4	4	3	4	3	4	4	4	4	4			
Dytiscidae	4	4	4	3	4	4	4	4	4	4	4			
Ancyronyx variegatus	4	4	3	2	3	4	3	4	4	5	5			
Dubiraphia	4	4	3	3	4	4	4	4	4	4	4			
Elmidae	4	3	3	4	3	3	4	3	3	4	4			
Macronychus glabratus	4	4	3	3	3	4	4	4	4	4	4			
Microcylloepus	4	3	3	4	4	3	4	4	3	4	4			
Optioservus	4	3	3	4	4	4	5	4	4	4	3			
Oulimnius	3	3	4	4	4	4	4	4	3	4	3			
Promoresia	3	3	4	4	2	3	4	3	2	4	2			
Stenelmis	4	4	4	4	5	4	4	4	5	4	5			
Dineutus	4	4	4	4	4	4	4	4	4	4	3			
Gyrinidae	4	x	x	x	x	x	x	x	x	x	x			
Gyrinus	4	4	4	3	3	3	3	x	4	x	3			
Peltodytes	4	5	3	3	4	4	x	x	x	x	x			
Berosus	4	4	4	4	4	4	4	4	3	4	4			
Hydrophilidae	4	4	4	3	4	4	4	4	4	x	4			
Ectopria	3	3	4	4	4	3	4	4	3	4	4			
Psephenidae	4	x	x	x	x	x	x	x	x	x	x			
Psephenus	4	3	3	4	4	3	4	3	3	3	3			
Anchytarsus	3	4	4	3	3	3	3	4	4	5	3			
Scirtidae	4	5	5	3	4	4	4	x	4	x	3			
Odonata														
Aeshna	4	x	x	x	x	x	x	x	x	x	x			
Aeshnidae	4	4	4	4	4	3	4	4	4	x	4			
Anax	4	x	x	x	x	x	x	x	x	x	x			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Boyeria	4	4	4	3	4	4	4	4	4	4	4			
Cordulegaster	4	4	4	3	4	3	4	4	4	x	4			
Corduliidae	4	x	x	x	x	x	x	x	x	x	x			
Epitheca	4	x	x	x	x	x	x	x	x	x	x			
Helocordulia	4	x	x	x	x	x	x	x	x	x	x			
Neurocordulia	4	x	x	x	x	x	x	x	x	x	x			
Somatochlora	4	x	x	x	x	x	x	x	x	x	x			
Arigomphus	4	x	x	x	x	x	x	x	x	x	x			
Dromogomphus	4	x	x	x	x	x	x	x	x	x	x			
Erpetogomphus	4	x	x	x	x	x	x	x	x	x	x			
Gomphidae	4	3	4	4	4	3	4	4	4	4	4			
Gomphus	4	4	3	3	3	4	4	4	4	4	4			
Hagenius brevistylus	4	x	x	x	x	x	x	x	x	x	x			
Lanthus	4	3	4	3	4	3	4	4	3	x	x			
Octogomphus	4	x	x	x	x	x	x	x	x	x	x			
Ophiogomphus	3	x	x	x	x	x	x	x	x	x	x			
Progomphus	3	3	3	2	3	3	2	4	4	3	x			
Stylogomphus	4	4	3	4	4	4	4	4	4	x	4			
Stylurus	4	x	x	x	x	x	x	x	x	x	x			
Celithemis	4	x	x	x	x	x	x	x	x	x	x			
Erythemis	4	x	x	x	x	x	x	x	x	x	x			
Erythrodiplax	4	x	x	x	x	x	x	x	x	x	x			
Ladona	4	x	x	x	x	x	x	x	x	x	x			
Libellula	4	x	x	x	x	x	x	x	x	x	x			
Libellulidae	4	4	4	3	4	4	3	x	4	x	4			
Nannothemis bella	4	x	x	x	x	x	x	x	x	x	x			
Pachydiplax longipennis	4	x	x	x	x	x	x	x	x	x	x			
Pantala	4	x	x	x	x	x	x	x	x	x	x			
Perithemis	4	x	x	x	x	x	x	x	x	x	x			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Sympetrum	4	x	x	x	x	x	x	x	x	x	x			
Tramea carolina	4	x	x	x	x	x	x	x	x	x	x			
Plathemis lydia	4	x	x	x	x	x	x	x	x	x	x			
Libellulidae/Cordullidae	4	x	x	x	x	x	x	x	x	x	x			
Didymops transversa	4	x	x	x	x	x	x	x	x	x	x			
Macromia	4	x	x	x	x	x	x	x	x	x	x			
Macromiidae	4	x	x	x	x	x	x	x	x	x	x			
Calopterygidae	4	x	x	x	x	x	x	x	x	x	x			
Calopteryx	4	4	4	3	4	5	4	5	5	x	5			
Hetaerina	4	x	x	x	x	x	x	x	x	x	x			
Argia	4	4	3	4	4	4	4	4	4	4	5			
Coenagrion	4	x	x	x	x	x	x	x	x	x	x			
Coenagrion/Enallgma	4	x	x	x	x	x	x	x	x	x	x			
Coenagrionidae	4	5	4	3	4	4	3	4	4	4	5			
Enallagma	4	4	3	3	5	4	4	4	5	4	5			
Ischnura	4	4	2	2	4	4	3	4	5	x	5			
Diptera														
Atherix	3	3	2	4	4	4	4	4	3	2	3			
Blepharicera	2	2	2	3	3	2	3	2	2	2	1			
Alluaudomyia	4	x	x	x	x	x	x	x	x	x	x			
Atrichopogon	4	3	4	4	5	4	4	4	4	x	2			
Bezzia	4	4	4	3	4	4	4	4	4	4	4			
Bezzia/Palpomyia	4	3	4	4	4	2	4	4	4	4	x			
Ceratopogon	4	x	x	x	x	x	x	x	x	x	x			
Ceratopogonidae	4	5	5	3	4	4	4	4	4	x	4			
Culicoides	4	x	x	x	x	x	x	x	x	x	x			
Dasyhelea	4	2	3	3	4	3	4	3	4	x	4			
Forcipomyia	4	x	x	x	x	x	x	x	x	x	x			
Mallochohelea	4	x	x	x	x	x	x	x	x	x	x			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Monohelea	4	x	x	x	x	x	x	x	x	x	x			
Probezzia	4	4	4	4	4	4	4	4	5	4	3			
Chironomidae (A)	4	4	4	4	4	4	4	4	4	4	4			
Anopheles	5	4	4	3	4	x	4	3	4	x	x			
Culicidae	5	x	x	x	x	x	x	x	x	x	x			
Dixa	3	3	4	3	4	3	5	4	4	x	4			
Dixella	4	x	x	x	x	x	x	x	x	x	x			
Dixidae	3	x	x	x	x	x	x	x	x	x	x			
Dolichopodidae	4	x	x	x	x	x	x	x	x	x	x			
Chelifera	4	3	4	4	5	4	5	5	3	x	4			
Clinocera	4	3	2	4	5	4	4	4	3	4	4			
Empididae	4	3	3	4	5	4	4	3	4	x	4			
Hemerodromia	5	4	4	4	5	4	5	4	4	4	5			
Neoplasta	4	2	4	4	5	3	4	3	3	4	4			
Oreogeton	4	x	x	x	x	x	x	x	x	x	x			
Trichoclinocera	4	x	x	x	x	x	x	x	x	x	x			
Ephydridae	5	x	x	x	x	x	x	x	x	x	x			
Muscidae	5	x	x	x	x	x	x	x	x	x	x			
Pericoma	5	x	x	x	x	x	x	x	x	x	x			
Psychodidae	5	x	x	x	x	x	x	x	x	x	x			
Ptychopteridae	5	x	x	x	x	x	x	x	x	x	x			
Sciomyzidae	5	x	x	x	x	x	x	x	x	x	x			
Prosimulium	3	4	4	4	3	4	4	3	3	4	2			
Simuliidae	4	3	4	4	3	3	3	4	4	4	4			
Simulium	4	4	4	4	4	3	5	5	4	4	4			
Stegopterna	4	5	5	2	3	4	4	x	5	x	3			
Chrysops	5	4	4	4	3	4	3	4	5	x	3			
Hybomitra	4	x	x	x	x	x	x	x	x	x	x			
Tabanidae	4	x	x	x	x	x	x	x	x	x	x			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Tabanus	5	4	4	3	3	4	4	4	4	x	4			
Antocha	4	3	2	4	5	4	4	4	3	4	4			
Brachypremna dispellens	4	x	x	x	x	x	x	x	x	x	x			
Cryptolabis	3	3	4	3	3	3	4	3	3	x	x			
Dicranota	3	3	4	3	4	3	4	4	3	4	4			
Epiphragma	4	x	x	x	x	x	x	x	x	x	x			
Erioptera	4	x	x	x	x	x	x	x	x	x	x			
Gonomyia	4	x	x	x	x	x	x	x	x	x	x			
Helius	4	x	x	x	x	x	x	x	x	x	x			
Hexatoma	3	3	4	3	3	3	4	4	3	4	2			
Limnophila	3	3	4	3	4	2	4	4	3	x	4			
Limonia	4	4	4	4	5	4	5	4	4	x	4			
Molophilus	4	3	4	3	4	4	4	4	3	x	3			
Ormosia	4	4	4	2	4	4	4	4	4	x	4			
Pedicia	4	x	x	x	x	x	x	x	x	x	x			
Pilaria	4	4	4	3	4	2	4	4	4	5	3			
Prionocera	4	x	x	x	x	x	x	x	x	x	x			
Pseudolimnophila	4	4	5	3	4	4	4	4	4	4	3			
Tipula	4	3	4	4	4	4	4	4	4	4	5			
Tipulidae	4	4	5	3	4	4	4	4	4	5	4			
Hemiptera														
Belostomatidae	5	x	x	x	x	x	x	x	x	x	x			
Corixidae	4	5	4	2	3	3	4	x	5	x	4			
Lepidoptera														
Crambidae	4	x	x	x	x	x	x	x	x	x	x			
Petrophila	4	3	2	4	5	3	4	4	3	x	5			
Pyralidae	4	x	x	x	x	x	x	x	x	x	x			
Megaloptera														
Chauliodes	4	x	x	x	x	x	x	x	x	x	x			

FinalID	BCG General	Dis Oxy	acidity	alka-linity	Spec Cond	Chlor-ide	Sul-fate	TN TP	Total Hab	RBS	pct IMP	BCG Mtns	BCG Pied	BCG Coastal
Corydalidae	4	x	x	x	x	x	x	x	x	x	x			
Corydalus	4	4	3	4	5	4	5	4	3	3	4			
Nigronia	4	3	4	3	4	4	4	4	3	4	3			
Sialis	5	4	4	4	5	4	4	4	4	x	3			

Table B-2. Macroinvertebrate taxa that were not evaluated due to insufficient data and unfamiliar characteristics. These would be assigned an "x" BCG attribute.

Macroinvertebrate taxa that were not evaluated	Comments
Non-Insect	
Mollusca	
Valvatidae	
Amphipoda	
Pontoporeia	
Insecta	
Ephemeroptera	
Barbaetis benfieldi	Second choice: 4; VA Final ID should be the Genus
Fallceon	Second choice: 4
Iswaeon	Second choice: 4
Paracloeodes	Second choice: 4
Dolania americana	VA Final ID should be the Genus
Americaenis	
Brachycercus	
Cercobrachys	
Penelomax septentrionalis	VA Final ID should be the Genus
Tsalia berneri	VA Final ID should be the Genus
Litobrancha recurvata	Second choice: 3; VA Final ID should be the Genus
Macdunnoa	
Raptoheptagenia cruentata	VA Final ID should be the Genus
Astioplax dolani	VA Final ID should be the Genus
Choroterpes basalis	VA Final ID should be the Genus
Siphloplecton	
Homoeoneuria	
Pseudiron centralis	
Plecoptera	
Capnia	
Nemocapnia carolina	VA Final ID should be the Genus
Rasvena terna	
Megaleuctra	
Zealeuctra	
Nemoura	
Podmosta	
Zapada	
Viehoperla ada	VA Final ID should be the Genus
Attaneuria ruralis	
Beloneuria	

Macroinvertebrate taxa that were not evaluated	Comments
Hansonoperla	
Perlinella	
Helopicus	
Hydroperla	
Isogenoides	
Oconoperla innubila	VA Final ID should be the Genus
Bolotoperla rossi	VA Final ID should be the Genus
Trichoptera	
Manophylax	
Beraea	
Adicrophleps hitchcocki	VA Final ID should be the Genus
Anisocentropus pyraloides	VA Final ID should be the Genus
Culoptila	
Matroptila jeanae	VA Final ID should be the Genus
Protoptila	
Goerita	
Arctopsyche	
Homoplectra	
Parapsyche	
Potmayia flava	
Agraylea	
Dibusa angata	VA Final ID should be the Genus
Ithytrichia	
Mayatrichia	
Neotrichia	
Palaeagapetus	
Paucicalcaria	
Stactobiella	
Theliopsyche	
Leptocerus americanus	VA Final ID should be the Genus
Anabolia	
Chyranda	
Frenesia	
Hesperophylax	
Lenarchus	
Leptophylax gracilis	VA Final ID should be the Genus
Limnephilus	
Nemotaulius hostilis	VA Final ID should be the Genus
Pseudostenophylax	
Psychoglypha	
Pseudogoera singularis	VA Final ID should be the Genus

Macroinvertebrate taxa that were not evaluated	Comments
Fumonta	
Agrypnia	
Banksiola	
Oligostomis	
Phyrganea	
Cernotina	likely mis id
Agarodes	
Fattigia pele	VA Final ID should be the Genus
Sericostomatidae	
Coleoptera	
Agasicles	
Bagous	
Curculionidae	
Phytobius	
Tanysphyrus	
Tyloderma capitale	VA Final ID should be the Genus
Gonielmis	
Gyretes	
Haliplus	
Helodidae	
Hydraena	
Hydraenidae	
Limnebius	
Ochthebius	
Anacaena	
Chaetarthria	
Crenitis	
Cymbiodyta	
Derallus altus	VA Final ID should be the Genus
Enochrus	
Helobata	
Helochares	
Helocombus	
Helocombus bifidus	VA Final ID should be the Genus
Helophorus	
Hydrobius	
Hydrochara	
Hydrochus	
Hydrophilus	
Laccobius	
Paracymus	

Macroinvertebrate taxa that were not evaluated	Comments
Sperchopsis tessellata	VA Final ID should be the Genus
Tropisternus	
Lutrochus	
Hydrocanthus	
Noteridae	
Suphis inflatus	
Suphisellus	
Dicranopselaphus	
Eubrianax	
Cyphon	
Elodes	
Prionocyphon	
Sacodes	
Scirtes	
Odonata	
Basiaeschna janata	Second choice: 4; VA Final ID should be the Genus
Coryphaeschna ingens	Second choice: 4; VA Final ID should be the Genus
Epiaeschna heros	Second choice: 4; VA Final ID should be the Genus
Gomphaeschna	Second choice: 4
Nasiaeschna pentacantha	Second choice: 4; VA Final ID should be the Genus
Remartina luteipennis	Second choice: 4; VA Final ID should be the Genus
Rhionaeschna	Second choice: 4
Aphylla williamsoni	Second choice: 4; VA Final ID should be the Genus
Tachopteryx thoreyi	VA Final ID should be the Genus
Amphiagrion	
Chromagrion conditum	VA Final ID should be the Genus
Lestes	
Diptera	
Canace	
Clinohelea	Second choice: 4
Jenkinshelea	Second choice: 4
Leptoconops	Second choice: 4
Nilobezzia	Second choice: 4
Palpomyia	Second choice: 4
Serromyia	Second choice: 4
Sphaeromias	Second choice: 4
Stilobezzia	Second choice: 4
Chaoboridae	Second choice: 5
Chaoborus	Second choice: 5
Aedes	Second choice: 5
Culex	Second choice: 5

Macroinvertebrate taxa that were not evaluated	Comments
Achradocera	
Amblypsilopus	
Chrysptimus	
Diostracus	
Dolichopus	
Enlinia	
Harmstonis	
Hercostomus	
Liancalus	
Nematoproctus	
Nepalomyia	
Paraclius	
Peloropeodes	
Plagionerus univittatus	VA Final ID should be the Genus
Rhaphium	
Sympycnus	
Telmaturgus parvus	VA Final ID should be the Genus
Chelipoda	
Dolichocephala	
Heleodromia pullata	VA Final ID should be the Genus
Proclinopyga	
Rhamphomyia	
Wiedemannia	
Callinapaea	
Ephydra	
Lytogaster	
Parydra	
Setacera	
Caricea	
Limnophora	
Lispe	
Lispoides aequifrons	VA Final ID should be the Genus
Spilogona	
Nymphomyia	
Glutops	
Phoridae	
Philosepedon	
Psychoda	
Telmatoscopus	
Bittacomorpha	
Bittacomorphella	

Macroinvertebrate taxa that were not evaluated	Comments
Ptychoptera	
Cnephia	
Allognosta	
Caloparyphus	Second choice: 5
Euparyphus	Second choice: 5
Hedriodiscus	
Labostigmina	
Myxosargus	Second choice: 5
Nemotelus	Second choice: 5
Odontomyia	Second choice: 5
Oxycera	
Stratiomyidae	Second choice: 5
Stratiomys	Second choice: 5
Syrphidae	Second choice: 5
Diachlorus	
Merycomyia	
Protoplasa fitchii	VA Final ID should be the Genus
Androprosopa	
Thaumaleidae	
Trichothaumalea	
Arctoconopa	Second choice: 4
Dactylolabis	Second choice: 4
Dicranoptycha	Second choice: 4
Hesperoconopa	Second choice: 4
Lipsothrix	Second choice: 4
Polymera	Second choice: 4
Rhabdomastix	Second choice: 4
Ulomorpha	Second choice: 4
Hemiptera	
Abedus	
Belostoma	
Lethocerus	
Cenocorixa	
Graptocorixa	
Hesperocorixa	
Palmacorixa	
Ramphocorixa	
Sigara	
Trichocorixa	
Naucoridae	
Pelocoris	

Macroinvertebrate taxa that were not evaluated	Comments
Nepa apiculata	VA Final ID should be the Genus
Nepidae	
Ranatra	
Buenoa	
Notonecta	
Notonectidae	
Lepidoptera	
Megaloptera	
Neohermes	
Neuroptera	
Climacia	
Sisyra	
Sisyridae	

Appendix C:

BCG Attribute Assignments for Fish in the Mid-Atlantic Region

The following tables describe 1) the attributes assigned by the expert panel for selected fish taxa, 2) the taxa associated with blackwater streams, and 3) the taxa that were considered, but were not assigned attributes due to lack of supporting data, limited distribution in the region, or characteristics that were unknown by the expert panel. These tables were derived from the Excel workbook used during workshops and webinars; available from VDEQ and including ancillary data not shown here (Supplement V; MasterAttributeFish_2019_May9.xlsx).

Table C-1. Final attribute assignments for fish in the Mid-Atlantic region.

AFS Common Name	Scientific Name	BCG General	TN TP	pct IMP	Acid-ity	alka-linity	Spec Cond	Sulf-ate	Chlor -ide	Dis Oxy	RBS	Total Hab
Achiridae												
hogchoker	Trinectes maculatus	4	x	x	x	x	x	x	x	x	x	x
Acipenseridae												
shortnose sturgeon	Acipenser brevirostrum	10i	x	x	x	x	x	x	x	x	x	x
Atlantic sturgeon	Acipenser oxyrinchus	10i	x	x	x	x	x	x	x	x	x	x
Amblyopsidae												
swampfish	Chologaster cornuta	2	x	x	x	x	x	x	x	x	x	x
Amiidae												
bowfin	Amia calva	5	x	x	x	x	x	x	x	x	x	x
Anguillidae												

AFS Common Name	Scientific Name	BCG General	TN TP	pct IMP	Acid-ity	alka-linity	Spec Cond	Sulf-ate	Chlor-ide	Dis Oxy	RBS	Total Hab
American eel	Anguilla rostrata	10t	x	x	x	x	x	x	x	x	x	x
Aphredoderidae												
pirate perch	Aphredoderus sayanus	4	4	3	4	x	4	4	3	5	4	4
Atherinopsidae												
brook silverside	Labidesthes sicculus	4	x	x	x	x	x	x	x	x	x	x
Catostomidae												
river carpsucker	Carpiodes carpio	4	x	x	x	x	x	x	x	x	x	x
quillback carpsucker	Carpiodes cyprinus	5	x	x	x	x	x	x	x	x	x	x
highfin carpsucker	Carpiodes velifer	4	x	x	x	x	x	x	x	x	x	x
white sucker	Catostomus commersonii	5	5	5	4	4	5	4	5	4	4	5
creek chubsucker	Erimyzon oblongus	4	5	4	4	x	4	4	4	5	4	4
lake chubsucker	Erimyzon sucetta	4	x	x	x	x	x	x	x	x	x	x
northern hog sucker	Hypentelium nigricans	4	4	4	3	x	5	5	4	4	4	4
Roanoke hog sucker	Hypentelium roanokense	4	4	4	3	x	4	x	x	3	4	4
silver redhorse	Moxostoma anisurum	4	x	x	x	x	x	x	x	x	x	x
bigeye jumprock	Moxostoma ariommum	1	x	x	x	x	x	x	x	x	x	x
smallmouth redhorse	Moxostoma breviceps	4	x	x	x	x	x	x	x	x	x	x
river redhorse	Moxostoma carinatum	3	x	x	x	x	x	x	x	x	x	x
blacktip jumprock	Moxostoma cervinum	3	4	4	3	x	4	4	3	3	3	4
notchlip redhorse	Moxostoma collapsum	4	x	x	x	x	x	x	x	x	x	x
black redhorse	Moxostoma duquesnei	4	x	x	x	x	x	x	x	x	x	x
golden redhorse	Moxostoma erythrurum	4	4	4	3	x	5	5	4	3	4	4
rustyside sucker	Moxostoma hamiltoni	1	x	x	x	x	x	x	x	x	x	x
harelip sucker	Moxostoma lacerum	1	x	x	x	x	x	x	x	x	x	x
shorthead redhorse	Moxostoma macrolepidotum	4	x	x	x	x	x	x	x	x	x	x
v-lip redhorse	Moxostoma pappillosum	4	x	x	x	x	x	x	x	x	x	x
torrent sucker	Moxostoma rhothoeca	3	4	4	3	x	4	4	3	3	4	3
mud sunfish	Acantharchus pomotis	2	x	x	x	2	x	x	x	x	x	x

AFS Common Name	Scientific Name	BCG General	TN TP	pct IMP	Acid-ity	alka-linity	Spec Cond	Sulf-ate	Chlor -ide	Dis Oxy	RBS	Total Hab
Roanoke bass	Ambloplites cavifrons	4	4	3	3	x	4	4	4	4	3	3
rock bass	Ambloplites rupestris	4	4	3	3	x	4	4	4	4	3	3
flier	Centrarchus macropterus	4	x	x	x	x	x	x	x	x	x	x
blackbanded sunfish	Enneacanthus chaetodon	2	x	x	x	2	x	x	x	x	x	x
bluespotted sunfish	Enneacanthus gloriosus	3	x	x	x	x	x	x	x	x	x	x
banded sunfish	Enneacanthus obesus	2	x	x	x	2	x	x	x	x	x	x
redbreast sunfish	Lepomis auritus	4	4	4	4	x	5	4	4	4	4	4
green sunfish	Lepomis cyanellus	5	5	5	4	4	5	5	5	4	4	5
pumpkinseed	Lepomis gibbosus	4	4	4	4	x	4	4	4	5	4	4
warmouth	Lepomis gulosus	4	4	4	4	x	4	4	4	4	4	4
bluegill	Lepomis macrochirus	5 or 6t	5	5	4	x	5	4	5	4	5	5
longear sunfish	Lepomis megalotis	4	4	4	3	x	4	4	4	4	x	4
redear sunfish	Lepomis microlophus	4 or 6m	4	5	x	x	4	x	x	4	x	x
smallmouth bass	Micropterus dolomieu	4 or 6m	4	4	3	x	5	5	4	4	3	4
spotted bass	Micropterus punctulatus	6m	4	x	3	x	5	5	4	4	x	5
largemouth bass	Micropterus salmoides	6t	5	5	4	4	4	4	4	4	4	5
white crappie	Pomoxis annularis	5 or 6t	x	x	x	x	x	x	x	x	x	x
black crappie	Pomoxis nigromaculatus	5	x	5	4	x	4	4	4	5	x	5
Channidae												
northern snakehead	Channa argus	6t	x	x	x	x	x	x	x	x	x	x
Clupeidae												
blueback herring	Alosa aestivalis	10m	x	x	x	x	x	x	x	x	x	x
skipjack herring	Alosa chrysochloris	10i	x	x	x	x	x	x	x	x	x	x
Hickory shad	Alosa mediocris	10m	x	x	x	x	x	x	x	x	x	x
alewife	Alosa pseudoharengus	10m	x	x	x	x	x	x	x	x	x	x
American shad	Alosa sapidissima	10m	x	x	x	x	x	x	x	x	x	x
Atlantic menhaden	Brevoortia tyrannus	4	x	x	x	x	x	x	x	x	x	x
gizzard shad	Dorosoma cepedianum	4	x	4	3	x	4	4	4	4	x	5
threadfin shad	Dorosoma petenense	5 or 6t	x	x	x	x	x	x	x	x	x	x

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Cottidae												
Black Sculpin	Cottus baileyi	3	x	x	x	x	x	x	x	x	x	x
mottled sculpin	Cottus bairdii	3	4	3	3	x	3	3	4	3	4	3
Bluestone sculpin	Cottus bluestone	3	x	x	x	x	x	x	x	x	x	x
Blue Ridge sculpin	Cottus caeruleomentum	3	4	3	3	4	4	4	4	3	3	3
banded sculpin	Cottus carolinae	3	4	3	3	x	3	3	4	3	4	3
Clinch sculpin	Cottus clinch	3	x	x	x	x	x	x	x	x	x	x
slimy sculpin	Cottus cognatus	3	x	x	x	x	x	x	x	x	x	x
Potomac sculpin	Cottus girardi	3	4	3	3	x	4	3	4	3	4	3
Holston sculpin	Cottus holston	3	x	x	x	x	x	x	x	x	x	x
Kanawha sculpin	Cottus kanawhae	3	x	x	x	x	x	x	x	x	x	x
checkered sculpin	Cottus robinsi	3	x	x	x	x	x	x	x	x	x	x
Cottus_Broadband	Cottus_Broadband	3	x	x	x	x	x	x	x	x	x	x
Cyprinidae												
central stoneroller	Campostoma anomalum	4	5	4	3	4	5	5	4	3	3	4
largescale stoneroller	Campostoma oligolepis	4	5	4	3	4	5	5	4	3	3	4
stoneroller	Campostoma spp	4	5	4	3	4	5	5	4	4	3	4
goldfish	Carassius auratus	6t	5	5	4	x	5	5	5	5	x	5
blackside dace	Chrosomus cumberlandensis	1	x	x	x	x	x	x	x	x	x	x
mountain redbelly dace	Chrosomus oreas	4	5	3	3	x	3	3	3	3	4	4
laurel dace	Chrosomus saylori	1	x	x	x	x	x	x	x	x	x	x
Clinch dace	Chrosomus sp cf. saylori	1	x	x	x	x	x	x	x	x	x	x
Tennessee dace	Chrosomus tennesseensis	3	x	x	x	x	x	x	x	x	x	x
rosyside dace	Clinostomus funduloides	4	4	4	4	4	3	4	4	4	4	4
grass carp	Ctenopharyngodon idella	6t	x	x	x	x	x	x	x	x	x	x
satinfin shiner	Cyprinella analostana	4	4	5	3	x	4	4	5	4	4	4
whitetail shiner	Cyprinella galactura	4	4	4	3	x	4	4	4	4	3	4

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thicklip chub	Cyprinella labrosa	3	x	x	x	x	x	x	x	x	x	x
turquoise shiner	Cyprinella monacha	2	x	x	x	x	x	x	x	x	x	x
spotfin shiner	Cyprinella spiloptera	4	4	5	3	x	4	4	5	4	4	4
Cyprinella spp	Cyprinella spp	4	4	5	3	x	4	4	5	4	4	4
steelcolor shiner	Cyprinella whipplei	3	x	x	x	x	x	x	x	x	x	x
sheepshead minnow	Cyprinodon variegatus	5	x	x	x	x	x	x	x	x	x	x
common carp	Cyprinus carpio	6t	5	5	4	x	5	5	5	5	x	5
slender chub	Erimystax cahni	2	x	x	x	x	x	x	x	x	x	x
streamline chub	Erimystax dissimilis	4	x	x	x	x	x	x	x	x	x	x
blotched chub	Erimystax insignis	2	x	x	x	x	x	x	x	x	x	x
tonguetied minnow	Exoglossum laurae	2	x	x	x	x	x	x	x	x	x	x
cutlip minnow	Exoglossum maxillingua	3	4	4	4	x	3	3	4	3	3	4
eastern silvery minnow	Hybognathus regius	5	5	5	4	x	4	4	4	5	5	5
bigeye chub	Hybopsis amblops	4	4	x	3	x	4	4	4	3	4	4
white shiner	Luxilus albeolus	4	4	4	3	x	4	4	4	3	4	4
crescent shiner	Luxilus cerasinus	4	4	4	3	x	4	4	4	3	4	4
striped shiner	Luxilus chrysocephalus	4	4	x	3	x	5	5	4	4	4	4
warpaint shiner	Luxilus coccogenis	4	4	x	3	x	4	4	4	3	4	4
common shiner	Luxilus cornutus	4	5	4	3	x	4	4	4	4	4	4
rosefin shiner	Lythrurus ardens	3	4	4	3	x	4	4	4	3	4	3
mountain shiner	Lythrurus lirus	3	x	x	x	x	x	x	x	x	x	x
pearl dace	Margariscus margarita	3	x	x	x	x	x	x	x	x	x	x
bluehead chub	Nocomis leptocephalus	4	5	4	3	x	4	4	3	3	4	4
river chub	Nocomis micropogon	4	5	4	3	x	4	4	4	4	4	4
bigmouth chub	Nocomis platyrhynchus	4	4	x	3	x	4	4	3	3	x	4
bull chub	Nocomis raneyi	4	4	x	3	x	4	4	3	3	x	4
golden shiner	Notemigonus crysoleucas	5 or 6t	5	5	x	3	5	4	4	5	4	4
whitemouth shiner	Notropis alborus	4	x	x	x	x	x	x	x	x	x	x

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highfin shiner	Notropis altipinnis	4	x	x	x	x	x	x	x	x	x	x
comely shiner	Notropis amoenus	4	4	4	3	x	4	3	3	4	4	4
popeye shiner	Notropis ariommus	3	x	x	x	x	x	x	x	x	x	x
emerald shiner	Notropis atherinoides	4	x	x	x	x	x	x	x	x	x	x
bridle shiner	Notropis bifrenatus	3	x	x	x	x	x	x	x	x	x	x
silverjaw minnow	Notropis buccatus	4	4	4	3	x	5	4	4	4	4	4
ironcolor shiner	Notropis chalybaeus	3	x	x	x	x	x	x	x	x	x	x
redlip shiner	Notropis chiliticus	3	x	x	x	x	x	x	x	x	x	x
spottail shiner	Notropis hudsonius	4	5	4	3	x	5	4	5	4	4	4
Tennessee shiner	Notropis leuciodus	4	4	x	3	x	4	4	4	3	4	4
highland shiner	Notropis micropteryx	4	x	x	x	x	x	x	x	x	x	x
silver shiner	Notropis photogenis	4	4	x	3	x	5	5	4	4	x	4
swallowtail shiner	Notropis procne	4	4	5	3	4	4	4	5	4	4	4
rosyface shiner	Notropis rubellus	4	4	3	3	x	5	5	4	4	4	4
saffron shiner	Notropis rubricroceus	3	x	x	3	x	3	3	x	3	4	4
New River shiner	Notropis scabriceps	1	x	x	x	x	x	x	x	x	x	x
roughhead shiner	Notropis semperasper	1	x	x	x	x	x	x	x	x	x	x
Sawfin Shiner	Notropis sp., Sawfin shiner	4	x	x	x	x	x	x	x	x	x	x
mirror shiner	Notropis spectrunculus	3	x	x	x	x	x	x	x	x	x	x
sand shiner	Notropis stramineus	4	x	x	x	x	x	x	x	x	x	x
telescope shiner	Notropis telescopus	4 or 6m	4	4	3	x	4	4	4	3	3	4
mimic shiner	Notropis volucellus	4	4	4	3	x	4	4	4	4	4	4
fatlips minnow	Phenacobius crassilabrum	3	x	x	x	x	x	x	x	x	x	x
suckermouth minnow	Phenacobius mirabilis	4	x	x	x	x	x	x	x	x	x	x
Kanawha minnow	Phenacobius teretulus	1	x	x	x	x	x	x	x	x	x	x
stargazing minnow	Phenacobius uranops	2	x	x	x	x	x	x	x	x	x	x
bluntnose minnow	Pimephales notatus	5	5	5	3	x	5	5	5	5	4	5
fathead minnow	Pimephales promelas	6t	5	5	3	x	5	5	5	5	5	5

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bullhead minnow	Pimephales vigilax	5	x	x	x	x	x	x	x	x	x	x
blacknose dace	Rhinichthys atratulus	5	5	5	4	x	5	5	5	4	4	5
longnose dace	Rhinichthys cataractae	4	4	4	3	4	4	4	5	3	3	4
western blacknose dace	Rhinichthys obtusus	5	5	5	4	x	5	5	5	4	5	5
creek chub	Semotilus atromaculatus	5	5	5	4	4	5	5	5	4	5	5
fallfish	Semotilus corporalis	4	4	3	3	4	4	4	4	4	4	4
Esocidae												
redfin pickeral	Esox americanus	4	4	3	x	3	4	4	4	5	4	4
grass pickerel	Esox americanus vermiculatus	4	x	x	x	x	x	x	x	x	x	x
northern pike	Esox lucius	6m	x	x	x	x	x	x	x	x	x	x
muskellunge	Esox masquinongy	6m	x	x	x	x	x	x	x	x	x	x
chain pickerel	Esox niger	4	4	4	4	x	3	3	3	5	4	4
Fundulidae												
northern studfish	Fundulus catenatus	3	x	x	x	x	x	x	x	x	x	x
banded killifish	Fundulus diaphanus	5	5	5	3	x	5	5	5	5	x	5
Eastern banded killifish	Fundulus diaphanus	5	x	x	x	x	x	x	x	x	x	x
Western banded killifish	Fundulus diaphanus	5	x	x	x	x	x	x	x	x	x	x
mummichog	Fundulus heteroclitus	5	x	5	4	x	5	5	5	4	x	5
lined topminnow	Fundulus lineolatus	4	x	x	x	x	x	x	x	x	x	x
speckled killifish	Fundulus rathbuni	4	x	x	x	x	x	x	x	x	x	x
Gasterosteidae												
fourspine stickleback	Apeltes quadracus	3	x	x	x	x	x	x	x	x	x	x
Threespine stickleback	Gasterosteus aculeatus	4	x	x	x	x	x	x	x	x	x	x
Ictaluridae												
snail bullhead	Ameiurus brunneus	6m	x	x	x	x	x	x	x	x	x	x
white catfish	Ameiurus catus	4	x	x	x	x	x	x	x	x	x	x

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black bullhead	Ameiurus melas	5	x	x	x	x	x	x	x	x	x	x
yellow bullhead	Ameiurus natalis	5	5	5	4	4	5	4	5	5	4	5
brown bullhead	Ameiurus nebulosus	5	4	5	4	4	4	4	4	5	4	4
flat bullhead	Ameiurus platycephalus	4	x	x	x	x	x	x	x	x	x	x
blue catfish	Ictalurus furcatus	6t	x	x	x	x	x	x	x	x	x	x
channel catfish	Ictalurus punctatus	5	5	5	3	x	5	4	5	5	x	4
mountain madtom	Noturus eleutherus	3	x	x	x	x	x	x	x	x	x	x
yellowfin madtom	Noturus flavipinnis	2	x	x	x	x	x	x	x	x	x	x
stonecat	Noturus flavus	4	x	x	x	x	x	x	x	x	x	x
orangefin madtom	Noturus gilberti	1	x	x	x	x	x	x	x	x	x	x
tadpole madtom	Noturus gyrinus	4	x	4	4	x	4	4	4	5	x	4
margined madtom	Noturus insignis	3	4	4	4	4	3	3	4	4	4	3
flathead catfish	Pylodictis olivaris	5 or 6t	x	x	x	x	x	x	x	x	x	x
Lepisosteidae												
longnose gar	Lepisosteus osseus	5	x	x	x	x	x	x	x	5	x	x
Moronidae												
white perch	Morone americana	10m	x	x	x	x	x	x	x	x	x	x
white bass	Morone chrysops	4 or 6m	x	x	x	x	x	x	x	x	x	x
striped bass	Morone saxatilis	10m	x	x	x	x	x	x	x	x	x	x
Percidae												
western sand darter	Ammocrypta clara	3	x	x	x	x	x	x	x	x	x	x
eastern sand darter	Ammocrypta pellucida	4	x	x	x	x	x	x	x	x	x	x
diamond darter	Crystallaria cincotta	1	x	x	x	x	x	x	x	x	x	x
sharphead darter	Etheostoma acuticeps	2	x	x	x	x	x	x	x	x	x	x
greenside darter	Etheostoma blennioides	4	4	4	3	x	5	5	4	4	3	3
Carolina fantail darter	Etheostoma brevispinum	4	x	x	x	x	x	x	x	x	x	x
rainbow darter	Etheostoma caeruleum	4	4	4	3	x	5	5	4	4	x	4
bluebreast darter	Etheostoma camurum	3	x	x	x	x	x	x	x	x	x	x

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greenfin darter	Etheostoma chlorobranchium	2	x	x	x	x	x	x	x	x	x	x
ashy darter	Etheostoma cinereum	2	x	x	x	x	x	x	x	x	x	x
Carolina darter	Etheostoma collis	2	x	x	x	x	x	x	x	x	x	x
golden darter	Etheostoma denoncourti	2	x	x	x	x	x	x	x	x	x	x
fantail darter	Etheostoma flabellare	4	4	4	3	x	4	4	4	4	3	4
swamp darter	Etheostoma fusiforme	3	x	x	x	x	x	x	x	x	x	x
blueside darter	Etheostoma jessiae	3	x	x	x	x	x	x	x	x	x	x
Kanawha darter	Etheostoma kanawhae	1	x	x	x	x	x	x	x	x	x	x
longfin darter	Etheostoma longimanum	3	3	2	x	x	x	x	x	3	3	3
bluespar darter	Etheostoma meadiae	3	x	x	x	x	x	x	x	x	x	x
johnny darter	Etheostoma nigrum	4	4	4	3	x	4	4	4	3	4	4
tessellated darter	Etheostoma olmstedi	5	5	5	4	x	4	4	5	5	4	5
candy darter	Etheostoma osburni	1	x	x	x	x	x	x	x	x	x	x
duskytail darter	Etheostoma percnurum	1	x	x	x	x	x	x	x	x	x	x
riverweed darter	Etheostoma podostemone	3	4	3	3	x	4	x	x	3	4	4
redline darter	Etheostoma rufilineatum	3	3	3	3	x	4	4	4	3	3	4
sawcheek darter	Etheostoma serrifer	3	x	x	x	x	x	x	x	x	x	x
Tennessee snubnose darter	Etheostoma simoterum	4	4	4	3	x	5	5	4	3	4	4
Swannanoa darter	Etheostoma swannanoa	3	x	x	x	x	x	x	x	x	x	x
Tennessee darter	Etheostoma tenneseense	4	4	4	3	x	5	5	4	3	4	4
variegate darter	Etheostoma variatum	4	4	x	3	x	5	5	4	3	x	4
glassy darter	Etheostoma vitreum	3	4	4	3	x	3	4	3	3	4	4
wounded darter	Etheostoma vulneratum	2	x	x	x	x	x	x	x	x	x	x
banded darter	Etheostoma zonale	4	4	x	3	x	5	5	x	4	4	4
yellow perch	Perca flavescens	4	x	4	4	x	4	4	4	5	x	4
tangerine darter	Percina aurantiaca	3	x	x	x	x	x	x	x	x	x	x

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Chesapeake logperch	Percina bimaculata	1	x	x	x	x	x	x	x	x	x	x
blotchside darter	Percina burtoni	2	x	x	x	x	x	x	x	x	x	x
logperch	Percina caprodes	4	x	x	x	x	x	x	x	x	x	x
channel darter	Percina copelandi	2	x	x	x	x	x	x	x	x	x	x
gilt darter	Percina evides	3	x	x	x	x	x	x	x	x	x	x
Appalachia darter	Percina gymnocephala	1	x	x	x	x	x	x	x	x	x	x
longhead darter	Percina macrocephala	3	x	x	x	x	x	x	x	x	x	x
blackside darter	Percina maculata	3	x	x	x	x	x	x	x	x	x	x
chainback darter	Percina nevisense	2	x	x	x	x	x	x	x	x	x	x
stripeback darter	Percina notogramma	3	3	3	3	3	2	x	x	4	3	3
sharpnose darter	Percina oxyrhynchus	2	x	x	x	x	x	x	x	x	x	x
shield darter	Percina peltata	2	3	2	3	3	2	x	x	3	3	3
Roanoke logperch	Percina rex	1	x	x	x	x	x	x	x	x	x	x
Roanoke darter	Percina roanoka	4	4	4	3	x	4	4	4	3	4	4
sickle darter	Percina williamsi	2	x	x	x	x	x	x	x	x	x	x
sauger	Sander canadensis	4	x	x	x	x	x	x	x	x	x	x
Saugeye Hybrid	Sander canadensis x S.vitreus	4	x	x	x	x	x	x	x	x	x	x
walleye	Sander vitreus	4 or 6m	x	x	x	x	x	x	x	x	x	x
Percopsidae												
trout-perch	Percopsis omiscomaycus	3	x	x	x	x	x	x	x	x	x	x
Petromyzontidae												
Ohio lamprey	Ichthyomyzon bdellium	3	x	x	x	x	x	x	x	x	x	x
mountain brook lamprey	Ichthyomyzon greeleyi	2	x	x	x	x	x	x	x	x	x	x
least brook lamprey	Lampetra aepyptera	4	4	4	x	x	4	5	4	5	x	4
American brook lamprey	Lethenteron appendix	4	4	x	3	x	x	x	x	4	4	4
sea lamprey	Petromyzon marinus	10t	x	5	5	x	5	x	5	5	x	5

AFS Common Name	Scientific Name	BCG General	TN TP	pct IMP	Acid-ity	alka-linity	Spec Cond	Sulf-ate	Chlor -ide	Dis Oxy	RBS	Total Hab
Poeciliidae												
mosquitofish	Gambusia affinis	5	x	x	x	x	x	x	x	x	x	x
eastern mosquitofish	Gambusia holbrooki	5	5	5	4	x	5	5	5	5	5	5
Polyodontidae												
paddlefish	Polyodon spathula	2	x	x	x	x	x	x	x	x	x	x
Salmonidae												
rainbow trout	Oncorhynchus mykiss	6m	4	3	3	x	4	4	4	3	4	4
brown trout	Salmo trutta	6m	4	3	3	x	4	4	4	3	x	4
brook trout	Salvelinus fontinalis	2	3	2	3	3	2	4	2	2	3	2
Sciaenidae												
freshwater drum	Aplodinotus grunniens	5	x	x	x	x	x	x	x	x	x	x
Umbridae												
eastern mudminnow	Umbra pygmaea	5	5	4	x	2	4	4	4	5	4	5

Table C-2. Blackwater Guild.

AFSCommonName	Scientific Name	Blackwater Guild (Specialist)	Opportunistic can be found in blackwaters, brownwaters
bowfin	*Amia calva*	YES-VCU 2013	
tadpole madtom	*Noturus gyrinus*	YES-VCU 2013	
banded sunfish	*Enneacanthus obesus*	YES-VCU 2013	
blackbanded sunfish	*Enneacanthus chaetodon*	YES-VCU 2013	
bridle shiner	*Notropis bifrenatus*	YES-VCU 2013	
flier	*Centrarchus macropterus*	YES-VCU 2013	
ironcolor shiner	*Notropis chalybaeus*	YES-VCU 2013	
lined topminnow	*Fundulus lineolatus*	YES-VCU 2013	
sawcheek darter	*Etheostoma serrifer*	YES-VCU 2013	
swamp darter	*Etheostoma fusiforme*	YES-VCU 2013	
swampfish	*Chologaster cornuta*	YES-VCU 2013	
redfin pickeral	*Esox americanus*	YES-VCU 2013	
mud sunfish	*Acantharchus pomotis*		Yes-VCU 2013
pirate perch	*Aphredoderus sayanus*		Yes-VCU 2013
warmouth	*Lepomis gulosus*		Yes-VCU 2013
bluegill	*Lepomis macrochirus*		Yes-VCU 2013
bluespotted sunfish	*Enneacanthus gloriosus*		Yes-VCU 2013
brown bullhead	*Ameiurus nebulosus*		Yes-VCU 2013
creek chubsucker	*Erimyzon oblongus*		Yes-VCU 2013
eastern mosquitofish	*Gambusia holbrooki*		Yes-VCU 2013
eastern mudminnow	*Umbra pygmaea*		Yes-VCU 2013
golden shiner	*Notemigonus crysoleucas*		Yes-VCU 2013
largemouth bass	*Micropterus salmoides*		Yes-VCU 2013
redear sunfish	*Lepomis microlophus*		Yes-VCU 2013
American eel	*Anguilla rostrata*		Yes-VCU 2019
lake chubsucker	*Erimyzon sucetta*		Yes-VCU 2019
longnose gar	*Lepisosteus osseus*		Yes-VCU 2019
white catfish	*Ameiurus catus*		Yes-VCU 2019
yellow bullhead	*Ameiurus natalis*		Yes-VCU 2019
yellow perch	*Perca flavescens*		Yes-VCU 2019

Table C-3. Fish taxa that were not evaluated due to insufficient data and/or unfamiliar characteristics. These would be assigned an "x" BCG attribute.

Family	AFS Common Name	Scientific Name	Comment
Acipenseridae	lake sturgeon	Acipenser fulvescens	not in VA
Acipenseridae	shovelnose sturgeon	Scaphirhynchus platorynchus	not in VA
Belonidae	Atlantic needlefish	Strongylura marina	not in VA
Catostomidae	bigmouth buffalo	Ictiobus cyprinellus	not in VA
Catostomidae	black buffalo	Ictiobus niger	
Catostomidae	blue sucker	Cycleptus elongatus	not in VA
Catostomidae	brassy jumprock	Moxostoma sp., brassy	not in VA
Catostomidae	greater redhorse	Moxostoma valenciennesi	not in VA
Catostomidae	longnose sucker	Catostomus catostomus	not in VA
Catostomidae	Redhorse Sucker sp.	Moxostoma	not in VA
Catostomidae	robust redhorse	Moxostoma robustum	not in VA
Catostomidae	smallmouth buffalo	Ictiobus bubalus	not in VA
Catostomidae	spotted sucker	Minytrema melanops	not in VA
Centrarchidae	Sunfish	Centrarchidae	not in VA
Centrarchidae	Sunfish Hybrid	Centrarchidae Hybrid	not in VA
Centrarchidae	Lepomis Hybrid	Lepomis Hybrid	not in VA
Centrarchidae	orangespotted sunfish	Lepomis humilis	not in VA
Cichlidae	blue tilapia	Tilapia aurea	not in VA
Clupeidae	Atlantic herring	Clupea harengus	not in VA
Cobitidae	pond loach	Misgurnus anguillicaudatus	not in VA
Cottidae	Freshwater Sculpin	Cottus	not in VA
Cottidae	deepwater sculpin	Myoxocephalus thompsoni	not in VA
Cottidae	Spoonhead sculpin	Cottus ricei	not in VA
Cyprinidae	hybrid minnow	Cyprinidae	not in VA
Cyprinidae	bigeye shiner	Notropis boops	not in VA
Cyprinidae	bighead carp	Hypophthalmichthys nobilis	not in VA
Cyprinidae	bigmouth shiner	Notropis dorsalis	
Cyprinidae	Blackchin shiner	Notropis heterodon	not in VA
Cyprinidae	Blackchin shiner	Notropis heterodon	not in VA
Cyprinidae	Blacknose shiner	Notropis heterolepis	not in VA
Cyprinidae	Blacknose shiner	Notropis heterolepis	not in VA
Cyprinidae	brassy minnow	Hybognathus hankinsoni	not in VA
Cyprinidae	central stoneroller pullum	Campostoma anomalum pullum	not in VA
Cyprinidae	channel shiner	Notropis wickliffi	not in VA
Cyprinidae	Cheat minnow	Pararhinichthys bowersi	not in VA
Cyprinidae	Eastern Shiners	Notropis	not in VA

Family	AFS Common Name	Scientific Name	Comment
Cyprinidae	finescale dace	Chrosomus neogaeus	not in VA
Cyprinidae	ghost shiner	Notropis buchanani	not in VA
Cyprinidae	gravel chub	Erimystax x-punctatus	not in VA
Cyprinidae	highback chub	Hybopsis hypsinotus	not in VA
Cyprinidae	hornyhead chub	Nocomis biguttatus	not in VA
Cyprinidae	Hybrid Minnow	Hybrid Minnow	not in VA
Cyprinidae	Lake chub	Couesius plumbeus	not in VA
Cyprinidae	Mississippi silvery minnow	Hybognathus nuchalis	not in VA
Cyprinidae	Northern redbelly dace	Chrosomus eos	not in VA
Cyprinidae	Notropis Hybrid	Notropis Hybrid	not in VA
Cyprinidae	ozark minnow	Notropis nubilus	not in VA
Cyprinidae	palezone shiner	Notropis albizonatus	not in VA
Cyprinidae	pugnose minnow	Opsopoeodus emiliae	not in VA
Cyprinidae	pugnose shiner	Notropis anogenus	not in VA
Cyprinidae	redfin shiner	Lythrurus umbratilis	not in VA
Cyprinidae	redside dace	Clinostomus elongatus	not in VA
Cyprinidae	redtail chub	Nocomis effusus	not in VA
Cyprinidae	river shiner	Notropis blennius	not in VA
Cyprinidae	rudd	Scardinius erythrophthalmus	not in VA
Cyprinidae	scarlet shiner	Lythrurus fasciolaris	not in VA
Cyprinidae	shoal chub	Macrhybopsis hyostoma	not in VA
Cyprinidae	silver carp	Hypophthalmichthys molitrix	not in VA
Cyprinidae	silver chub	Macrhybopsis storeriana	not in VA
Cyprinidae	silverband shiner	Notropis shumardi	not in VA
Cyprinidae	southern redbelly dace	Chrosomus erythrogaster	not in VA
Cyprinidae	speckled chub	Macrhybopsis aestivalis	not in VA
Engraulidae	bay anchovy	Anchoa mitchilli	not in VA
Esocidae	Amur pike	Esox reichterii	not in VA
Fundulidae	blackstripe topminnow	Fundulus notatus	not in VA
Fundulidae	rainwater killifish	Lucania parva	not in VA
Fundulidae	spotfin killifish	Fundulus luciae	not in VA
Fundulidae	striped killifish	Fundulus majalis	not in VA
Gadidae	Burbot	Lota lota	not in VA
Gasterosteidae	Blackspotted stickleback	Gasterosteus wheatlandi	not in VA
Gasterosteidae	brook stickleback	Culaea inconstans	not in VA
Gasterosteidae	Ninespine stickleback	Pungitius pungitius	not in VA

Family	AFS Common Name	Scientific Name	Comment
Gobiidae	round goby	Neogobius melanostomus	not in VA
HIODONTIDAE	goldeye	Hiodon alosoides	not in VA
HIODONTIDAE	mooneye	Hiodon tergisus	not in VA
ICTALURIDAE	brindled madtom	Noturus miurus	not in VA
ICTALURIDAE	freckled madtom	Noturus nocturnus	not in VA
ICTALURIDAE	northern madtom	Noturus stigmosus	not in VA
ICTALURIDAE	slender madtom	Noturus exilis	not in VA
Lepisosteidae	shortnose gar	Lepisosteus platostomus	not in VA
Lepisosteidae	Spotted gar	Lepisosteus oculatus	not in VA
Menidia	inland silverside	Menidia beryllina	not in VA
Mugilidae	flathead grey mullet	Mugil cephalus	not in VA
Osmeridae	rainbow smelt	Osmerus mordax	not in VA
Percidae	arrow darter	Etheostoma sagitta	not in VA
Percidae	crystal darter	Crystallaria asprella	not in VA
Percidae	dusky darter	Percina sciera	not in VA
Percidae	emerald darter	Etheostoma baileyi	not in VA
Percidae	frecklebelly darter	Percina stictogaster	not in VA
Percidae	Iowa darter	Etheostoma exile	not in VA
Percidae	least darter	Etheostoma microperca	not in VA
Percidae	least darter	Etheostoma microperca	not in VA
Percidae	orangethroat darter	Etheostoma spectabile	not in VA
Percidae	piedmont darter	Percina crassa	not in VA
Percidae	river darter	Percina shumardi	not in VA
Percidae	ruffe	Gymnocephalus cernuus	not in VA
Percidae	slenderhead darter	Percina phoxocephala	not in VA
Percidae	speckled darter	Etheostoma stigmaeum	not in VA, blueside and bluespar now
Percidae	spotted darter	Etheostoma maculatum	not in VA
Percidae	striped darter	Etheostoma virgatum	not in VA
Percidae	tippecanoe darter	Etheostoma tippecanoe	now golden darter in VA
Petromyzontidae	chestnut lamprey	Ichthyomyzon castaneus	not in VA
Petromyzontidae	lamprey	Lampetra	not in VA
Petromyzontidae	northern brook lamprey	Ichthyomyzon fossor	not in VA
Petromyzontidae	silver lamprey	Ichthyomyzon unicuspis	not in VA
SALMONIDAE	Atlantic salmon	Salmo salar	not in VA
SALMONIDAE	Chinook salmon	Oncorhynchus tshawytscha	not in VA
SALMONIDAE	coho salmon	Oncorhynchus kisutch	not in VA
SALMONIDAE	cutthroat trout	Oncorhynchus clarkii	not in VA
SALMONIDAE	lake trout	Salvelinus namaycush	not in VA
SALMONIDAE	pink salmon	Oncorhynchus gorbuscha	not in VA

Family	AFS Common Name	Scientific Name	Comment
Salmonidae	cisco	Coregonus artedi	not in VA
Salmonidae	lake whitefish	Coregonus clupeaformis	not in VA
Sciaenidae	spot	Leiostomus xanthurus	not in VA
Umbridae	central mudminnow	Umbra limi	not in VA
	Hybrid Z	Hybrid Z	not in VA