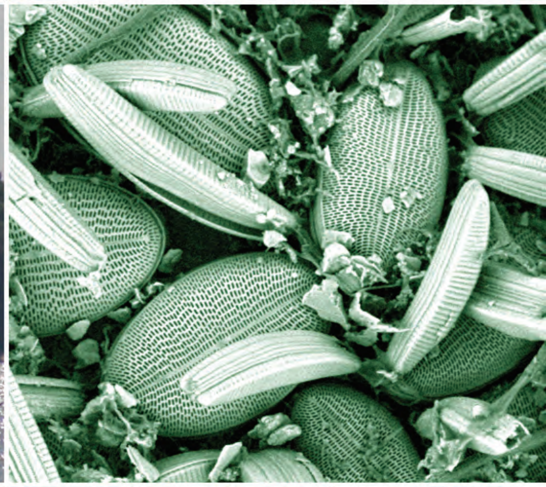
A Primer on Using Biological Assessments to Support Water Quality Management

October 2011



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Foreword

This guide serves as a primer on the role of biological assessments in a variety of water quality management program applications, including reporting on the condition of the aquatic biota, establishing biological criteria, and assessing the effectiveness of Total Maximum Daily Load determinations and pollutant source controls. This guide provides a brief discussion of technical tools and approaches for developing strong biological assessment programs and presents examples of successful application of those tools.

The objective of the Clean Water Act (CWA), and water quality management programs generally, is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Although we have achieved major water quality improvements over the past four decades and have reduced the discharge of many toxic chemicals into our nation's waters, many environmental challenges remain, such as loss and fragmentation of habitat, altered hydrology, invasive species, climate change, discharge of new chemicals, stormwater, and nitrogen or phosphorus (nutrient) pollution. In the face of such challenges, how can we best deploy our water quality programs to meet the vision of the CWA for protection of aquatic life?

Biological integrity has been defined to mean the capability of supporting and maintaining a balanced, integrated, and adaptive community of organisms having a composition and diversity comparable to that of natural habitats of the region (Frey 1975; modified by Karr and Dudley 1981). **Biological assessments** can be used to directly measure the condition of the biota residing in a waterbody and provide information on biological integrity. Resident biota include species that spend all or a part of their life cycle in the aquatic environment.

Measuring the condition of the resident biota in surface waters using biological assessments and incorporating that information into management decisions can be an important tool to help federal, state, and tribal water quality management programs meet many of the challenges. Biological assessments are an evaluation of the condition of a waterbody using surveys of the structure and function of a community of resident biota (e.g., fish, benthic macroinvertebrates, periphyton, amphibians) (for more information, see *Biological Assessment Key Concepts and Terms*)[1]. Assessments of habitat condition, both instream and riparian, are typically conducted simultaneously. Such information can reflect the overall ecological integrity of a waterbody and provides a direct measure of both present and past effects of stressors on the biological integrity of an aquatic ecosystem. The benefit of a biological assessment program is based in its capability to:

- Characterize the biological condition of a waterbody relative to water quality standards (WQS).
- Integrate the cumulative effects of different stressors from multiple sources, thus providing a holistic measure of their aggregate effect.
- Detect aquatic life impairment from unmeasured stressors and unknown sources of impairment.
- Provide field data on biotic response variables to support development of empirical stressor response models.
- Inform water quality and natural resource managers, stakeholders, and the public on the environmental outcomes of actions taken.

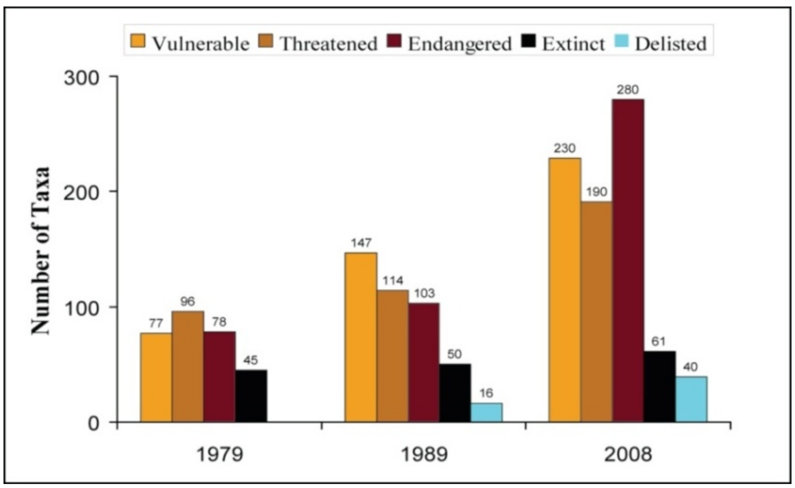
[1] http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/biocriteria/upload/primer_factsheet.pdf

It is EPA's long-standing policy that biological assessments should be fully integrated in state and tribal water quality programs and used together with whole effluent and ambient toxicity testing, and with chemical-specific analyses, to assess attainment of designated aquatic life uses in WQS (USEPA 1991b). Each of these methods can be used to provide a valid assessment of aquatic life use impairment. Biological assessments complement chemical-specific, physical, and whole effluent toxicity measures of stress and exposure by directly assessing the response of the community in the field (USEPA 1991a). Measurable changes in the biotic community—for example, the return of native species, decrease in anomalies and lesions in fish and amphibians, and decrease in pollution-tolerant species paired with an increase in pollution-sensitive species—can be readily communicated to the public and the regulated community. This can result in greater stakeholder understanding of effects from stressors and support for management actions. Additionally, as response-stressor relationships are documented, biological assessments in concert with stressor data can be used to help predict and track environmental outcomes of management actions.

Chapter 1. Incorporating Biological Assessments into Water Quality Management

1.1 Why Is Measuring Biological Condition Important?

With the passage of the Clean Water Act (CWA) in 1972 and subsequent national investment in water infrastructure and regulation, much work has been done to restore rivers, lakes, streams, wetlands, and estuaries. However, despite our best efforts and many documented successes, we continue to lose aquatic resources (Figure 1-1) (H. John Heinz III Center for Science, Economics, and the Environment 2008; Jelks et al. 2008; USEPA 2006). Pollutants (e.g., pathogens, metals, nitrogen, phosphorus pollution) continue to be major causes of water quality degradation. Additionally, the impact of other significant stressors, including habitat loss and fragmentation, hydrologic alteration, invasive species, and climate change, can be better understood using analytical tools and information that can operate at the ecosystem scale, such as biological assessments.



Source: Jelks et al. 2008

Figure 1-1. Numbers of imperiled North American freshwater and diadromous fish taxa.

Note: The increase in total number of taxa identified as vulnerable, threatened, or endangered might be due in part to improvements in our understanding, naming, and assessing aquatic resources, resulting in more complete and accurate assessments.

Biological assessments can be used to directly measure the overall biological integrity of an aquatic community and the synergistic effects of stressors on the aquatic biota residing in a waterbody where there are well-developed biological assessment programs (Figure 1-2) (USEPA 2003). Resident biota function as continual monitors of environmental quality, increasing the sensitivity of our assessments by providing a continuous measure of exposure to stressors and access to responses from species that cannot be reared in the laboratory. This increases the likelihood of detecting the effects of episodic events (e.g., spills, dumping, treatment plant malfunctions), toxic nonpoint source (NPS) pollution (e.g., agricultural pesticides), cumulative pollution (i.e., multiple impacts over time or continuous low-level stress), nontoxic mechanisms of impact (e.g., trophic structure changes due to nutrient enrichment), or other impacts that periodic chemical sampling might not detect. Biotic response to impacts on the physical habitat such as sedimentation from stormwater runoff and physical habitat alterations from dredging, filling, and channelization can also be detected using biological assessments.

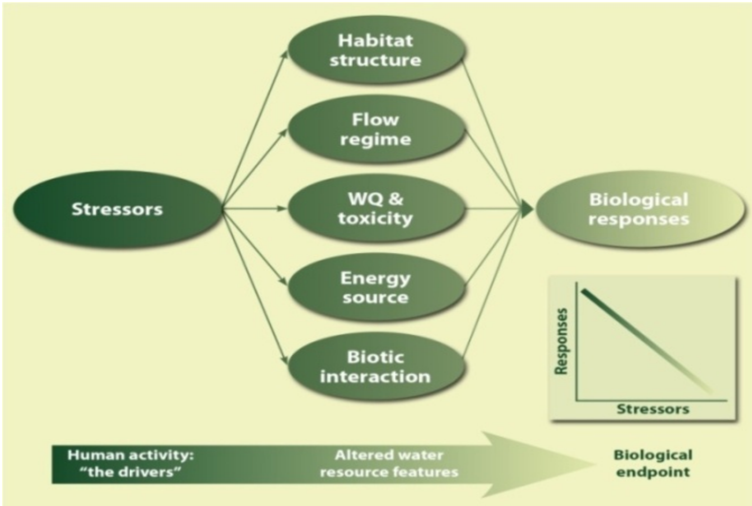
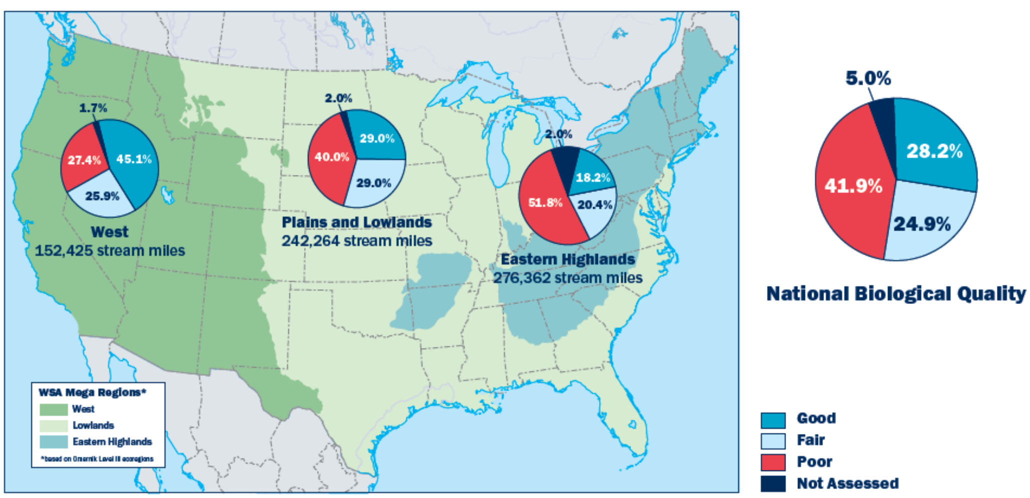


Figure 1-2. Biological assessments provide information on the cumulative effects on aquatic communities from multiple stressors. Figure courtesy of David Allen, University of Michigan.

States and tribes have used biological assessments to set environmental goals, detect degradation, prioritize management actions, and track improvements (USEPA 2002). Multiple examples of applications are presented in Chapter 3. Additionally, the U.S. Environmental Protection Agency (EPA) [2] and U.S. Geological Survey (USGS) [3] are conducting national and regional assessments of the condition of aquatic communities and the presence and distribution of stressors that affect the aquatic biota. The EPA National Aquatic Resource Surveys (NARS) program employs a probability-based sampling design while the USGS National Water-Quality Assessment (NAWQA) Program utilizes a targeted design. The data provide a baseline for assessing biological conditions and key stressors over time and tracking environmental improvements at the national or regional level (Figure 1-3).



Source: USEPA 2006.

Figure 1-3. Biological condition of our nation's streams. In its first survey of stream condition, EPA found that 28 percent of the nation's stream miles are in good condition compared to the best existing reference sites in their regions, 25 percent are in fair condition, and 42 percent are in poor condition.

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[2] http://water.epa.gov/type/watersheds/monitoring/nationalsurveys.cfm.

[3] http://water.usgs.gov/nawqa.

1.2 Using Biological Assessment Information in State and Tribal Water Quality Management Programs

Biological assessment information has been used by states and tribes to:

- ***Define goals for a waterbody***—Information on the composition of a naturally occurring aquatic community can provide a description of the expected biological condition for other similar waterbodies and a benchmark against which to measure the biological integrity of surface waters. Many states and tribes have used such information to more precisely define their designated aquatic life uses, develop *biological criteria*, and measure the effectiveness of controls and management actions to achieve those uses.
- ***Report status and trends***—Depending on level of effort and detail, biological assessments can provide information on the status of the condition of the expected aquatic biota in a waterbody and, over time with continued monitoring, provide information on long-term trends.
- ***Identify high-quality waters and watersheds***—Biological assessments can be used to identify high-quality waters and watersheds and support implementation of state and tribal antidegradation policies.
- ***Document biological response to stressors***—Biological assessments can provide information to help develop biological response signatures (e.g., a measurable, repeatable response of specific species to a stressor or category of stressors). Examples include sensitivity of mayfly species (pollution-sensitive aquatic insects) to metal toxicity or temperature-specific preferences of fish species. Such information can provide an additional line of evidence to support stressor identification and causal analysis (USEPA 2000a), as well as to inform numeric criteria development (USEPA 2010a).
- ***Complement pollutant-specific ambient water quality criteria***—Biological assessment information can complement water quality standards (WQS) by providing field information on the cumulative effects on aquatic life from multiple pollutants, as well as detecting impacts from pollutants that do not have EPA recommended numeric criteria.
- ***Complement direct measures of whole effluent toxicity (WET) tests***—Biological assessments can provide information to help document improvements in aquatic life following actions taken to address the aggregate toxic effects of wastewater discharge effluents detected through laboratory WET tests. Additionally, biological assessments complement WET tests by directly measuring the cumulative or post-impact effects that both point source and NPS contaminants have on aquatic biota in the field.
- ***Address water quality impacts of climate change***—EPA, states, and tribes are exploring how biological assessments can be used in concert with physical, chemical, and land use data to help identify baseline biological conditions against which the effects of global climate change on aquatic life can be studied and compared. Such information could enable a water quality management program to calibrate biological assessment endpoints and criteria to adjust for long-term climate change conditions. Additionally, long-term data sets will enable trends analysis and support predictive modeling and forecast analysis.

1.3 Water Quality Program Applications and Case Studies

The CWA employs a variety of regulatory and nonregulatory approaches to reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. Those approaches are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. The role of biological assessment information to support such approaches is described below, and case studies of successful implementation are provided in Chapter 3.

Water Quality Standards

State and tribal WQS programs can use biological assessment information in developing descriptions of CWA-designated aquatic life uses in terms of the expected biological community. For example, in states and tribes that identify high-quality waters for antidegradation purposes on a waterbody-by-waterbody basis, biological assessments can provide information to help define and protect existing aquatic life uses and identify Tier 2 waters (e.g., where the quality of the waters exceed levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water) and Outstanding National Resource Waters (ONRWs). Maryland is using biological assessments to help identify high-quality streams for antidegradation purposes on a waterbody-by-waterbody basis (case study 3.3). Pennsylvania is exploring the use of biological assessment information to help assess attainment of aquatic life uses and to describe biological characteristics of waters along a gradient of condition (case study 3.4). This information may potentially be used to support protection of waters of the highest quality that require special protection. Arizona used biological assessments to develop numeric biological criteria using the reference condition approach (Stoddard et al. 2006) that takes into account the quality of the reference sites (case example 3.2).

Some states have calibrated biological response to gradients of anthropogenic stress impacting surface waters (see Chapter 2, Tool #2, *The Biological Condition Gradient*). This approach, when applied to WQS by defining the designated aquatic life uses along a gradient of condition, has provided these states with the capability to improve waters incrementally, protect high-quality waters, and help identify factors that affect attainability. For example, Maine assigns a waterbody to a specific condition class on the basis of its current condition and potential for improvement. Numeric biological criteria have been developed for each class and adopted into their WQS (case study 3.1). Over the past 30 years, the use designations for many streams and rivers in Maine have been upgraded according to documented biological improvements and attainment of the biological criteria that define higher quality use classes. This approach is sometimes referred to as tiered aquatic life uses and has also been implemented by the State of Ohio (case study 3.5).

Additionally, biological assessments can provide information on the species composition at a site under consideration for site-specific criteria. Using the species recalculation procedure, a state or tribe can adjust chemical water quality to reflect the chemical sensitivity of species that occur at a site (USEPA 1994). Biological assessment information may support modification of the default species sensitivity distribution to better reflect the expected community composition at the site. For example, if the site is a naturally occurring warm body of water, coldwater fish species could be replaced by resident warmwater fish species in the species sensitivity distribution from which a site-specific criterion is calculated.

Monitoring and Assessment

Biological monitoring and assessments provide data to aquatic resources managers at the local, state, tribal, regional, and national levels to help assess status and trends of aquatic resources as well as to measure the effectiveness of management actions to protect or restore waters. For example, the biological monitoring program in Montgomery County, Maryland, produces biological assessment information on the condition of the County's streams and the effectiveness of innovative best management practices (BMPs) for stormwater control.[4] At the state level, the Maryland Department of the Environment (MDE) conducts biological monitoring to evaluate permit effectiveness, conduct impact assessments, and identify high-quality waters (case studies 3.3 and 3.12). Also, Maryland Department of Natural Resources (MDNR)[5] provides MDE and the public with a statewide biological assessment of status and trends for streams and rivers that may serve as a yardstick for measuring the overall effectiveness of local and state management actions.

Biological assessment information has been used by counties and state/tribal agencies to facilitate collaboration and effective use of limited resources. For example, two state agencies in Oregon jointly conducted biological assessments to address their information needs (case study 3.17). For the Oregon Department of Fish and Wildlife (ODFW), monitoring of aquatic benthic macroinvertebrate communities in streams and rivers, in conjunction with chemical and physical monitoring, provided important information on water quality and habitat conditions identified as critical to coho salmon viability. Oregon's Department of Environmental Quality (ODEQ) used the same biological assessment information to assess attainment of the designated uses to protect and maintain salmonid populations.

At the national level, biological data from the *National Aquatic Resource Surveys*[6] are being used in EPA's strategic plan to track improvements in water quality for streams, rivers, wetlands, and coastal waters. The results of the first national surveys for streams and coastal waters are included in EPA's *Report on the Environment.*[7] These surveys, which incorporate a statistical probabilistic design, are key tools for communicating to the public what the Agency knows about the condition of the nation's waters at national and regional scales. The biological components of the national surveys will continue to provide nationally consistent indicators of water quality that can be used to gauge the overall effect of the national investment in protecting and restoring the nation's watersheds.

EPA also uses biological assessments to assess status and trends at a regional or large ecosystem scale (e.g., in the Upper Mississippi River Basin or the Great Lakes) and measure biological response to restoration efforts related to disasters (e.g., Hurricane Katrina and the Gulf of Mexico oil spill). National and regional biological assessments provide information that helps facilitate interagency collaboration for large-scale restoration and protection efforts. For example, a recent USGS multiregional assessment found that alteration of streamflow is a major predictor of biological integrity of both fish and macroinvertebrate communities (Carlisle et al. 2010). Alterations in stream flow are associated with riparian disturbance and can influence the release of nitrogen, phosphorus, and sediments into streams (Poff and Zimmerman 2010). The combined results of national, regional, and state/tribal ecological assessments will provide the data needed to predict and better manage future impacts of stressors from

[4] For an additional example, see http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/aqlife/biocriteria/npdesmaryland.cfm.

[5] http://www.dnr.state.md.us.

[6] http://water.epa.gov/type/watersheds/monitoring/nationalsurveys.cfm.

[7] http://www.epa.gov/roe.

human activities such as urban development, water allocation, and agriculture. The results of different program actions to address different stressors and their sources can be related to a common measure of environmental improvement—the condition of the aquatic biota.

Identification of Impaired and Threatened Waters in States' Integrated Water Quality Reports

Under section 303(d) of the CWA and supporting regulations (40 CFR 130.7), states, territories, and authorized tribes (hereafter referred to as states) are required to develop lists of impaired and threatened waters that require Total Maximum Daily Loads (TMDLs). Impaired waters are those that do not meet any applicable WQS, including designated uses, narrative criteria and numeric criteria such as biological criteria adopted as a standard. EPA recommends that states consider as threatened those waters that are currently attaining WQS, but which are expected to not meet WQS by the next listing cycle (every 2 years). Consistent with EPA recommendation, many states consolidate their section 303(d) and section 305(b) reporting requirement into one "integrated" report.

If biological assessments indicate that a waterbody is impaired or threatened, the waterbody is included on the state's section 303(d) list and scheduled for TMDL development. Some 30 states have used biological assessment information as the basis for concluding that designated aquatic life use(s) were not supported and included these waters on their section 303(d) lists. In some cases, these listings were based on comparison of the biological assessments to state-adopted numeric biological water quality criteria. However, in most cases, biological assessments were treated as translations of one or more of a state's narrative water quality criteria or as direct evidence that designated aquatic life uses were not supported.

How to reconcile conflicting results among different datasets (e.g., chemical, physical, biological) is discussed in EPA's Integrated Reporting Guidance (IRG) for the 2006 sections 303(d) and 305(b) reporting cycle. Also discussed in the IRG, if a designated use, such as aquatic life, is not supported and the water is impaired or threatened, the fact that the specific pollutant may not be known does not provide a basis for excluding the water from the section 303(d) list.[8] These waters are often identified on a state's list as cause or pollutant unknown. These waters must be included on the list until the pollutant is identified and a TMDL completed or the state can demonstrate that no pollutant(s) cause or contribute to the impairment. For example, in 1998, Iowa listed a 20-mile segment of the North Fork Maquoketa River as aquatic life use impaired—cause unknown, based on biological assessments. Using EPA's CADDIS stressor identification (SI) methodology, Iowa determined that the aquatic life use was impaired due to sediments, nutrients, and ammonia (see Tool #3, Stressor Identification and Causal Analysis/Diagnosis Decision Information System). A TMDL was developed for each of these pollutants and these were approved by EPA in 2007 (case study 3.7).

Development of Total Maximum Daily Loads

Under the CWA, states are required to develop TMDLs for impaired and threatened waters on their 303(d) lists. States and tribes may use biological assessments to support developing one or more water quality targets for the pollutant of concern on the basis of well-documented stressor-response relationships, from reference conditions or through use of mechanistic modeling. This is done in conjunction with other water quality monitoring data, such as data on concentrations of specific

[8] EPA Integrated Reporting Guidance for the 2006 Section 303(d) and 305(b) Reporting Cycle website: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/2006IRG_index.cfm

stressors and toxicity effects. For example, Connecticut has developed a relationship between pollutant loads, stormwater flows, and impervious land cover (IC) for streams in small watersheds with no other known point source discharge (case study 3.8). Connecticut used these relationships to develop a TMDL for a small stream identified as impaired based on biological assessments. Because the cause of impairment was unknown, an SI was completed. The SI determined that the most probable cause of impairment was the complex array of pollutants transported by stormwater into the stream. The TMDL is expressed as a reduction target for specific segments of the stream and is to be implemented through reduction of IC where practical and improved stormwater management throughout the watershed. Connecticut will evaluate progress toward the TMDL's implementation using biological assessments in conjunction with surface water chemistry assessments.

Additionally, EPA is encouraging states and tribes to develop TMDLs on a watershed basis (e.g., to bundle TMDLs together) to enhance program efficiencies and foster more holistic analysis. Ideally, TMDLs would be incorporated into comprehensive watershed strategies, while biological assessments would provide information on how the aquatic community responds to the full array of restoration activities. EPA is launching the Recovery Potential Screening Tools and Resources website (USEPA 2012),[9] designed to help state, tribal, and other restoration programs evaluate the relative restorability of impaired waters and help prioritize TMDL development. The website provides an approach to identify the use impaired waters and watersheds most likely to respond well to restoration, as well as information on methods, tools, technical information, and instructional examples that managers can customize for restoration programs in any geographic locality. Application of a gradient of biological response to levels of stress, like the Biological Condition Gradient (BCG) (see Chapter 2, Tool # 2, *The Biological Condition Gradient*), can provide a framework to help assess incremental progress in restoring a waterbody's aquatic life use and report environmental outcomes.

National Pollutant Discharge Elimination System Permits

Under section 402 of the CWA, point source discharges of pollutants to waters of the United States are covered by National Pollutant Discharge Elimination System (NPDES) permits. Under EPA regulations at 40 CFR 122.44(d), an NPDES permit must contain water quality-based effluents if it is found that a discharge will cause, have the reasonable potential to cause, or contribute to an excursion above a WQS. States must assess permitted effluent discharges in a manner that is consistent with EPA NPDES regulations (40 CFR 122.44).[10] States and tribes can use biological assessment information in addition to chemical-specific and WET data to support development of permit conditions that will protect water quality, including attainment of state WQS. Data from biological assessments can be used independently from, or in combination with, WET or chemical data to assess WQS attainment (USEPA 1991b). If any one or a combination of these three assessment methods demonstrates that the applicable WQS are not attained, appropriate and corrective action would be taken to address the findings as necessary, including compliance with applicable NPDES permit development provisions at 40 CFR PART 122.44(d)(1).

While narrative biological criteria might exist for many states and some authorized tribes in their WQS, in order for biological assessment information to effectively support the NPDES permit process there should be an EPA-approved numeric interpretation of the narrative biological criteria. States and tribes that have adopted biological criteria in their WQS may benefit from the use of biological assessment

[9] EPA Recovery Potential Screening website: http://www.epa.gov/recoverypotential.

[10] For more information on NDPES regulations, go to http://cfpub.epa.gov/npdes/regs.cfm?program_id=45.

data as an additional biological check of permit controls, including limits, to see if they result in abating pollutant impacts, restoring water quality, or preventing further degradation. In addition, biological assessments as a "special studies/additional monitoring" permit condition can be used to assess overall permit effectiveness to control source pollutant(s) and used as an NPDES permit trigger to reopen and potentially modify the permit[11] if the biological assessment studies indicate that the permitted discharge continues to impact the receiving waterbody.

Also, while biological assessments can establish that aquatic life use impairment exists in the area of the discharge, the cause of the impairment might be wholly or partially due to point sources or NPS pollution. In such cases, an NPDES permit could establish controls based on the portion of impairment that is related to the effluent. Thus, additional chemical analysis and WET tests and/or source identification are typically conducted. For example, Vermont has used biological assessment information to support changes to effluent limits for metals on the basis of impact analysis, WET tests, and documented stressor-response relationships between metals and the aquatic biota (case study 3.9). That information helped support requiring additional treatment technologies that resulted in improved water quality. Upstream and downstream biological assessments were part of the follow-up monitoring plan and, with chemical and WET data, documented the resulting improvements in ambient biological and chemical conditions. Thus, in conjunction with required NPDES effluent monitoring such as WET and chemical-specific information, Vermont used biological assessments and its EPA-approved biological criteria to support narrative NPDES permit requirements to protect aquatic life. Currently Vermont has refined aquatic life uses (e.g., tiered aquatic life uses) and narrative biological criteria in its WQS supported by published peer-reviewed technical procedures for translating the narrative biological criteria into a numeric threshold.

NPS Pollution

Biological assessments can be a sensitive indicator of cumulative effects from multiple and unpredictable stressors from NPS pollution. Tracking water quality conditions using biological assessments is one way to assess whether the biological community is affected by NPS pollution and that efforts to improve degraded waters using voluntary BMPs are effective. In managing NPS pollution, a natural resource agency could initiate cooperative land use programs in an area or install BMPs to improve the water resource and establish biological goals as a benchmark for restoration. Before-and-after biological assessments compared to the biological benchmark make it possible to evaluate the success of management actions. For example, Michigan has used biological assessments to help determine biological impairments, target restoration efforts, and monitor results in Carrier Creek (case study 3.11).

Compliance Evaluation and Enforcement Support

Regulatory authorities can use biological assessment information to support enforcement actions by helping to document biological impacts and measure recovery of the aquatic community due to mitigation and cleanup actions. For example, a fish kill in a tributary to the Potomac River in Maryland and the District of Columbia was caused by illegal dumping of pesticide wastes in Maryland. Biological and chemical sampling data were used to locate the source of the pesticide wastes, identify the responsible party, and show subsequent improvements in water quality as a result of enforcement activities (case study 3.12). Biological assessment information, in conjunction with biological assays and chemical and physical assessments, can assist enforcement agencies in assessing damage and levying

[11] As prescribed under NPDES regulatory requirements for permit reopeners/modifications (CFR 122.44). For more information on NDPES regulations, go to http://cfpub.epa.gov/npdes/regs.cfm?program_id=45.

fair and reasonable damage assessments on those proven responsible for toxic spills, and determining the rate and level of stream recovery.

Watershed Protection

Increasingly, EPA, states, territories, and tribes are implementing CWA programs on an integrated watershed basis—including air, land, and ecosystem relationships and related regulatory tools such as those used in the Chesapeake Bay[12] and the National Estuary programs (NEPs)[13] (USEPA 2007). Biological assessments are used in watershed-level programs to help define ecological goals and assess progress in achieving those goals. Recently, EPA has embarked on the Healthy Watershed Initiative, which focuses on protecting high-quality waters and watersheds (USEPA In draft). It is a strategic approach that identifies healthy waters and watersheds at the state level and then targets resources at both the state and local levels for their protection. Biological assessments provide critical information and measurable benchmarks to identify high-quality waters in healthy watersheds and then, over time, evaluate how effectively such systems are being protected. The State of Virginia is using biological assessments in its own Healthy Watersheds initiative to define protection and restoration goals that resonate with the public (case study 3.14). EPA's Office of Research and Development (ORD) is working with several states, territories, and NEPs to develop biological assessment tools and approaches that can be applied at multiple scales to protect estuarine and coastal ecosystems and their watersheds (case study 3.16). Additionally, the BCG (see Chapter 2, Tool # 2) can be applied as a field-based assessment framework to describe the health of waterbodies and their watersheds and communicate the biological condition to the public (USEPA In draft). And, in conjunction with refined aquatic life uses and biological criteria adopted into WQS, a BCG-like framework can be used to support management actions to protect existing high-quality waters in a healthy watershed, as demonstrated by the State of Maine (case study 3.1).

[12] Chesapeake Bay Program website: http://www.chesapeakebay.net.

[13] National Estuary Program website: http://water.epa.gov/type/oceb/nep/estuaries_index.cfm.

Chapter 2. Tools for Improving the Use of Biological Assessments in Water Quality Management

EPA has published several documents that provide guidance on incorporating biological assessment information into water quality programs, many of which have been in use for several years. They include technical guidance on developing biological criteria and general program guidance on application of biological assessment information in different water quality programs. A summary of these documents is provided in Appendix A. Additionally, other technical support documents, or technical tools, have been recently developed to further assist states and tribes in developing robust biological assessment programs and applying biological assessment information. Three of these recent tools are listed below and briefly summarized in the following pages.

- ***Tool #1: The Biological Assessment Program Review.*** The level of program rigor determines how well the monitoring and assessment program produces the information needed to support management decision making. A review process and checklist have been developed and piloted by regions, states, and tribes to help assess the technical capability of a state or tribal biological assessment program and strategically determine where to invest resources to develop a technically robust biological assessment program.
- ***Tool #2: The Biological Condition Gradient (BCG).*** The BCG is a conceptual model that describes how biological attributes of aquatic ecosystems might change along a gradient of increasing anthropogenic stress. The model can serve as a template for organizing field data (biological, chemical, physical, landscape) at an ecoregional, basin, watershed, or stream segment level. A BCG calibrated with field data can help states and tribes more precisely define biological expectations for their designated aquatic life uses, interpret current condition relative to CWA objective and goals, track biological community response to management actions, and communicate environmental outcomes to the public. The BCG was designed to help map different biological indicators on a common scale of biological condition to facilitate communication among programs and across jurisdictional boundaries. The BCG is currently being field tested in several regions and states.
- ***Tool #3: Stressor Identification (SI) and Causal Analysis/Diagnosis Decision Information System (CADDIS).*** In 2010 EPA updated its technical support document on causal analysis and literature database to help states and tribes identify the most probable cause of impairment to a waterbody. Specific databases on biological response to stress have been compiled and will undergo continuous updating so that the best available and peer-reviewed literature will be accessible as part of CADDIS. This document and database will assist states that have listed waters as impaired on the basis of biological assessments when the cause of impairment is not known.

2.1 Tool #1: Biological Assessment Program Review

Purpose: To provide a stepwise process to assist states in evaluating the technical capability of their biological assessment programs and to strategically determine where to invest resources to enhance the technical capability of their programs.

This tool can be used to answer questions, including the following:

- Does the quality of data being generated support the management decisions I need to make?
- What are the strengths and needs of my existing program?
- How do I build on my current program and further strengthen it?

Source: EPA's website on key concepts for using biological indicators: http://www.epa.gov/bioiweb1/html/keyconcepts.html

The information provided below describes technical elements of a biological assessment program, summarizes the process and benefits of conducting a program review, and discusses regional/state pilot programs.

The Program Review Process

The critical technical elements review is a systematic ***process*** to evaluate biological assessment program rigor and to identify logical next steps for overall program improvement. The document provides a ***template*** for evaluating critical technical components of a biological assessment program that are scored to arrive at a level of program rigor, from level 1 (the least rigorous) to level 4 (the most rigorous) (Table 2-1). The review provides a framework for identifying programmatic strengths and weaknesses and helps program managers and technical staff members determine key tasks to upgrade the technical abilities of their program (Figure 2-1). The evaluation process also identifies opportunities to improve integration of WQS and monitoring and assessment programs. This review process was initially piloted in EPA Region 5 and more recently applied and further refined in Region 1. Initial programs reviews have focused on biological assessments of streams and rivers, but with some refinements in methodology this evaluation process can be applied to other types of waterbodies. The states have used the results of the review to target resources and prioritize actions to strengthen the technical basis of their biological assessment programs.

The first part of the review involves discussion on the design of the existing monitoring and assessment program, the degree to which there is systematic collection of data from the environment, and how well the data analysis produces information suitable for making the various decisions asked of it—such as determining attainment of aquatic life uses, identifying high-quality waters for antidegradation purposes on a waterbody-by-waterbody basis, evaluating the severity and extent of impairments, and supporting causal analysis and pollutant source identification (i.e., toxicity identification evaluation [TIE] and toxicity reduction evaluation [TRE]). It is essential that experts in the different program areas be engaged in the discussions to help ensure that data quality and information requirements are accurately represented and properly implemented, especially with regard to EPA-published methodologies. The information helps document how monitoring and assessment information is used to support the reporting requirements mandated by the CWA and other state or tribal efforts to characterize the status of waterbodies and plan for implementing restoration efforts. This part of the program review might also examine how the state or tribe uses biological assessment information to more precisely define aquatic life uses and develop biological criteria.

Table 2-1. Key features of the technical attributes for levels of rigor in state/tribal biological assessment programs (streams and rivers).
(Terms in the table are included in the glossary, this template can be modified and applied to other waterbody types.)

	Attributes of levels of biological assessment program rigor			
Key features	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Temporal and spatial coverage	Variable data collection times; upstream/downstream and fixed stations	Index period for convenience; non-random design at a coarse scale (e.g., 4- to 8-digit hydrologic unit code [HUC])	Calibrated seasonal index periods; statewide spatial design using rotating basins at a coarse scale (e.g., 4- to 8-digit HUC)	Scientifically-derived temporal sampling for management decisions; multiple spatial designs for multiple issues; 11- to 14-digit HUC
Natural classification of aquatic ecosystems	No partitioning of natural variability; no incorporation of differences in stream characteristics such as size, gradient	Classification usually a geo-graphical or other similar organization (e.g., fishery-based cold or warmwater; lacks intra-regional strata [size, gradient])	Classification based on a combination of landscape features and physical habitat structure; considers all intra-regional strata and specific ecosystems	Fully partitioned and stratified classification scheme that transcends jurisdictions and recognizes zoogeographical aspects of assemblages
Reference conditions	No reference conditions; presence and absence of key taxa are based on best professional judgment	A site-specific control or paired watershed approach can be used for assessment; regional reference sites are lacking	Reference conditions used in watershed assessments; regional reference sites are too few in number or spatial density	Regional reference conditions are established in the applicable waterbody ecotypes and aquatic resource classes
Sampling and sample processing	Approach is cursory and relies on operator skill and best professional judgment, producing highly variable and less comparable results	Textbook methods are used rather than in-house development of standard operating procedures to specify methods	Methods are calibrated for state purposes and are detailed and well documented; supported by in-house testing and development	Same as Level 3, but methods cover multiple assemblages; high taxonomic resolution
Data management	Sampling event data are organized in a series of spreadsheets	Separate databases are used for physical, chemical, and biological data with separate GIS shapefiles of sites	A true relational database is specifically designed to include data validation checks (e.g., Oracle, SQL Server, Access)	Relational database of biological assessment data with automated data review validation tools and geospatial analysis
Biological endpoints and thresholds	Assessment based on presence or absence of targeted or key species; attainment thresholds are not specified and no BCG	A biological index or endpoint is by specific waterbodies; single dimension measures used	A biological index, or model, developed and calibrated for use throughout the state for the various waterbody types	Biological indexes, or models, for multiple assemblages are developed and calibrated for a state and uses the BCG
Causal analysis	Support for causal analysis is lacking	Coarse indications of response via assemblage attributes at gross level (i.e., general indicator groups)	Developed indicator guilds and other aggregations to support causal associations; diagnostic capability is supported by studies	Response patterns are most fully developed and supported by extensive research and case studies across spatial and temporal scales

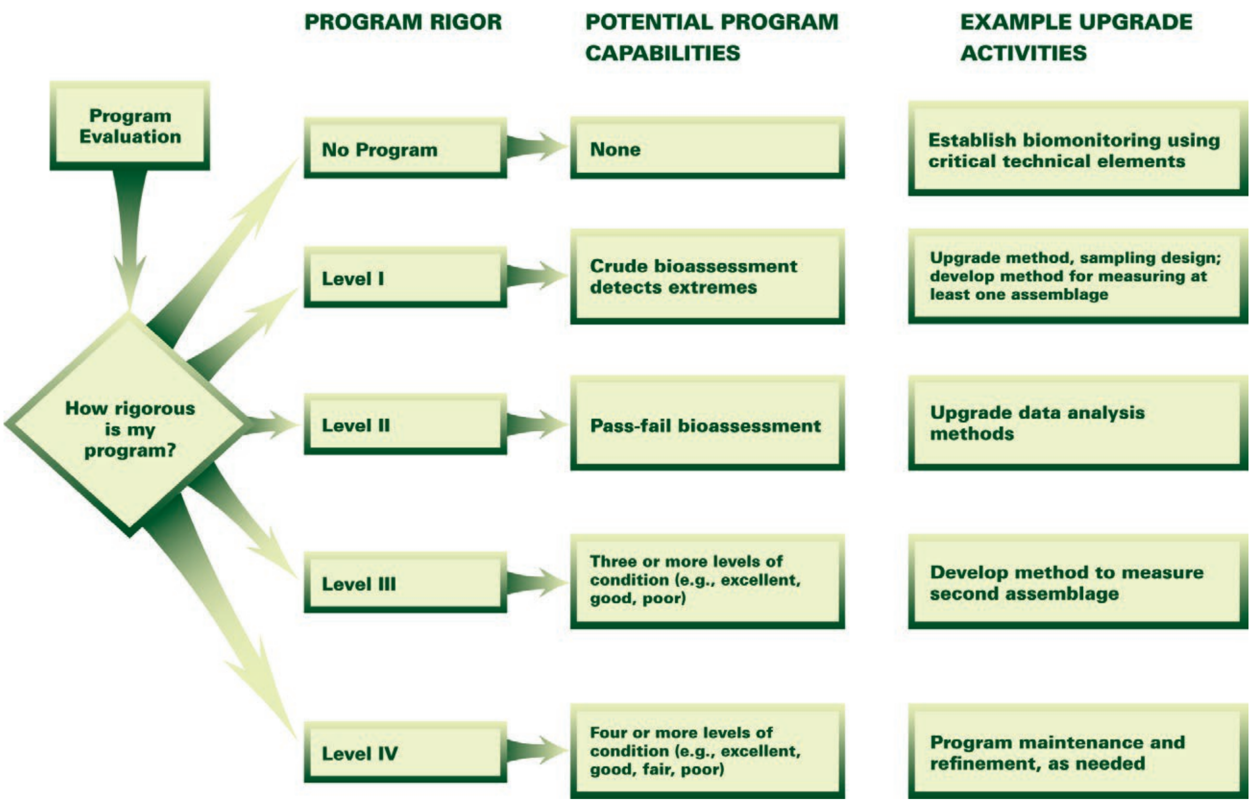


Figure 2-1. Key features of the program review process and examples of commensurate upgrades.

Evaluation of Critical Technical Elements of a State's or Tribe's Biological Assessment Program

The program review evaluates 13 critical technical elements of a biological assessment program associated with design, methods, and data interpretation (e.g., survey design, method of classification, procedures to establish reference conditions, protocols for sampling collection and processing, data management and analysis, formal peer review). On the basis of the discussions in the first phase of the review, where program information needs are identified, a list of recommendations is developed according to the strengths and gaps identified in the technical program evaluation. The recommendations are presented in a logical, stepwise progression so that a state or tribe can build on its technical program strengths and target resources effectively to address the program gaps. Participation of program managers and technical staff representing different water quality programs is important in the review to build a shared understanding and broad perspective on existing use of biological assessment information and begin to identify the technical program gaps and areas for improved use.

Case Example: Technical Evaluations in Minnesota and Connecticut

The Minnesota Pollution Control Agency (MPCA) decided in 2005 to use biological assessment information to develop refined aquatic life uses and numeric biological criteria in its WQS to meet its objectives of setting management goals for waterbodies on the basis of their best potential condition. MPCA also found biological assessment information as useful to educate and engage stakeholders and the public. MPCA used the Critical Technical Elements Program Evaluation process to determine *where* its program was in 2005 and what tasks were yet to be accomplished to reach its stated goals. Using the findings, MPCA developed a detailed plan for developing a technical program sufficiently rigorous to support adoption in the state's WQS in 2011–2014 of the most appropriate aquatic life uses and numeric biological criteria. MPCA continues to follow the plan, addressing the priority recommendations identified in the program evaluation, and is proceeding with biological criteria development. As part of this effort, MPCA is exploring application of the BCG, the second tool discussed in this document, to develop biological goals for their waters that are tailored to specific waterbody types and uses.

The Connecticut Department of Environmental Protection (CT DEP) has been monitoring aquatic biological conditions using benthic macroinvertebrates since the late 1980s and has steadily upgraded its technical program over the years. The state operates a statewide monitoring and assessment program that includes multiple spatial designs to produce both statewide assessments using probabilistic design and listings of impaired waters using targeted sampling design. CT DEP underwent a Critical Elements Program Evaluation in 2006 to help identify and prioritize additional technical program improvements needed to develop numeric biological criteria for different levels of quality along a gradient of condition (e.g., excellent and good quality waters). The program was evaluated at a level 2 with specific tasks identified to build its technical capability (e.g., improved spatial resolution in watershed assessment design from 8-digit HUC to 10- to 12-digit HUC; a regionally-calibrated multimetric index for benthic macroinvertebrates and one for fish that distinguishes between coldwater and warmwater assemblages; instituting an independent peer review process). Since the review, CT DEP has improved the technical capability of the biological assessment program to a level 3 and now has two numeric indices and enhanced spatial monitoring design.

These examples show how states and tribes can use the results of the Critical Elements Program Evaluation to develop a *blueprint* for making orderly improvements and attaining the technical proficiency to respond to management questions and improve decision making—including support for condition assessments, attainment of WQS, diagnosis of biological impairment, and effectiveness monitoring. The program review process identifies specific and successive improvements that are needed to improve the rigor of the biological assessment program and a checklist so that progress can be identified and tracked.

2.2 Tool #2: The Biological Condition Gradient

Purpose: To provide a common scale of biological condition to support comparisons between programs and across jurisdictional boundaries.

This tool can be used to help answer questions, including the following:

- What biological community should be at a site, e.g., natural conditions?
- Are we protecting our high-quality waters?
- Are we making progress to restore our degraded systems?
- Are our actions making real and lasting environmental improvements?

Source: *The biological condition gradient: A descriptive model for interpreting change in aquatic ecosystems* (Davies and Jackson 2006)

This section provides an overview of the BCG and how it can be calibrated for specific use by a state or tribe. The BCG is being applied and tested in several regions and states.

What Is the BCG?

Over the past 40 years, states have independently developed technical approaches to assess biological condition and set designated aquatic life uses for their waters. The BCG was designed to provide a means to map different indicators on a common scale of biological condition to facilitate comparisons between programs and across jurisdictional boundaries in context of the CWA. The BCG is a conceptual, narrative model that describes how biological attributes of aquatic ecosystems change along a gradient of increasing anthropogenic stress. It provides a framework for understanding current conditions relative to natural, undisturbed conditions (Figure 2-2). Some states, such as Maine and Ohio, have used a framework similar to the BCG to more precisely define their designated aquatic life uses (case studies 3.1 and 3.5).

Agreeing that, even in different geographic and climatological areas, a similar sequence of biological alterations occurs in streams and rivers in response to increasing stress, biologists from across the United States developed the model (Davies and Jackson 2006). The model shows an ecologically based relationship between the stressors affecting a waterbody (e.g., physical, chemical, biological impacts) and the response of the aquatic community (i.e., biological condition). The model is consistent with ecological theory and can be adapted or calibrated to reflect specific geographic regions and waterbody type (e.g., streams, rivers, wetlands, estuaries, lakes). Approaches to calibrate the BCG to region-, state-, or tribe-specific conditions are being piloted in several ecological regions by multiple states and tribes.

In practice, the BCG is used to first identify the critical attributes of an aquatic community (see Table 2-2) and then describe how each attribute changes in response 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. For example, Pennsylvania is exploring the use of a BCG calibrated to its streams to complement its existing biological indices for macroinvertebrates and to describe the biological characteristics of waters along a gradient of condition. The state is evaluating using this information to help assess aquatic life use impairments and to describe waters of the highest quality (case study 3.4).

The Biological Condition Gradient: Biological Response to Increasing Levels of Stress

Levels of Biological Condition

Level 1. Natural structural, functional, and taxonomic integrity is preserved.

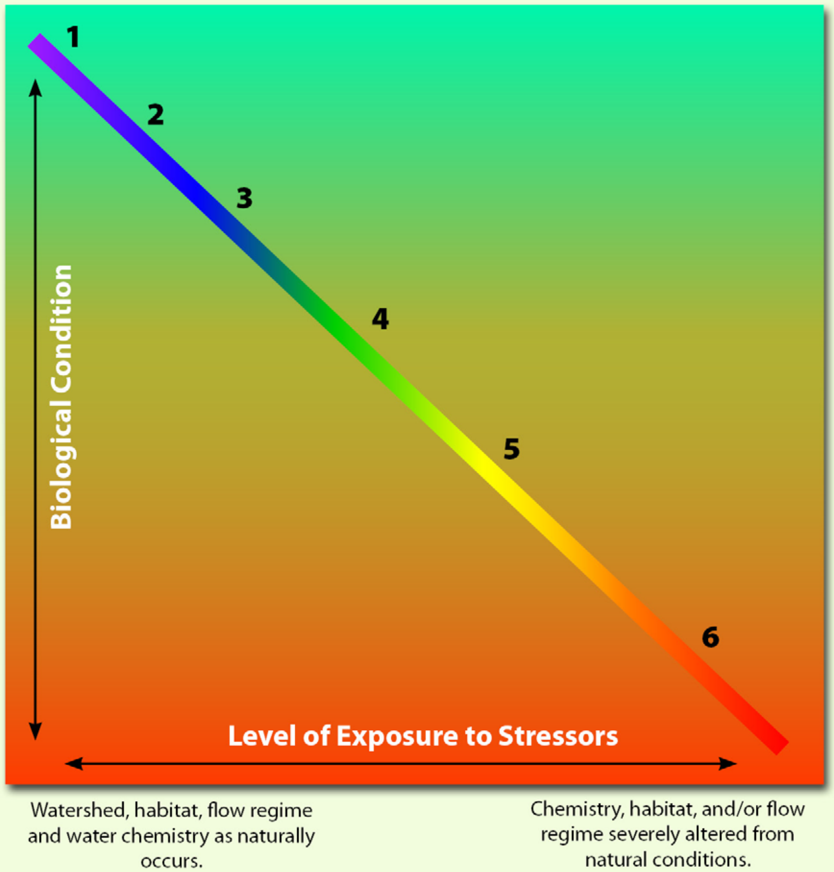
Level 2. Structure & function similar to natural community with some additional taxa & biomass; ecosystem level functions are fully maintained.

Level 3. Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance; ecosystem level functions fully maintained.

Level 4. Moderate changes in structure due to replacement of some sensitive ubiquitous taxa by more tolerant taxa; ecosystem functions largely maintained.

Level 5. Sensitive taxa markedly diminished; conspicuously unbalanced distribution of major taxonomic groups; ecosystem function shows reduced complexity & redundancy.

Level 6. Extreme changes in structure and ecosystem function; wholesale changes in taxonomic composition; extreme alterations from normal densities.



Source: Modified from Davies and Jackson 2006.

Figure 2-2. The BCG.

Note: The BCG was developed to serve as a scientific framework to synthesize expert knowledge with empirical observations and develop testable hypotheses on the response of aquatic biota to increasing levels of stress. It is intended to help support more consistent interpretations of the response of aquatic biota to stressors and to clearly communicate this information to the public, and it is being evaluated and piloted in several regions and states.

The BCG model provides a framework to help water quality managers do the following:

- Decide what environmental conditions are desired (goal-setting)—The BCG can provide a framework for organizing data and information and for setting achievable goals for waterbodies relative to “natural” conditions (e.g., condition comparable or close to undisturbed or minimally disturbed condition).
- Interpret the environmental conditions that exist (monitoring and assessment)—Practitioners can get a more accurate picture of current waterbody conditions.

- Plan for how to achieve the desired conditions and measure effectiveness of restoration—The BCG framework offers water program managers a way to help evaluate the effects of stressors on a waterbody, select management measures by which to alleviate those stresses, and measure the effectiveness of management actions.
- Communicate with stakeholders—When biological and stress information is presented in this framework, it is easier for the public to understand the status of the aquatic resources relative to what high-quality places exist and what might have been lost.

How Is the BCG Constructed?

The BCG is divided into six levels of biological conditions along the stressor-response curve, ranging from observable biological conditions found at no or low levels of stress (level 1) to those found at high levels of stress (level 6) (Figure 2-2). The technical document provides a detailed description of how 10 attributes of aquatic ecosystems change in response to increasing levels of stressors along the gradient, from level 1 to 6 (see Table 2-2). The attributes include several aspects of community structure, organism condition, ecosystem function, spatial and temporal attributes of stream size, and connectivity.

Each attribute provides some information about the biological condition of a waterbody. Combined into a model like the BCG, the attributes can offer a more complete picture about current waterbody conditions and also provide a basis for comparison with naturally expected waterbody conditions. All states and tribes that have applied a BCG used the first seven attributes that describe the composition and structure of biotic community on the basis of the tolerance of species to stressors and, where available, included information on the presence or absence of native and nonnative species and, for fish and amphibians, observations on overall condition (e.g., size, weight, abnormalities, tumors).

The last three BCG attributes of ecosystem function and connectance and spatial and temporal extent of detrimental effects can provide valuable information when evaluating the potential for a waterbody to be protected or restored. For example, a manager can choose to target resources and restoration activities to a stream where there is limited spatial extent of stressors or there are adjacent intact wetlands and stream buffers or intact hydrology versus a stream with comparable biological condition but where adjacent wetlands have been recently eliminated, hydrology is being altered, and stressor input is predicted to increase. Pennsylvania is evaluating indicators comparable to the BCG spatial and connectance attributes IX and X to characterize the biological conditions of streams in healthy watersheds where resources may be well spent to successfully protect such waters (see case study 3.4). Additionally, several of EPA's NEPs, in conjunction with EPA ORD, are exploring application of those attributes at a whole-estuary scale (e.g., distribution and connectance of critical aquatic habitats and associated biota) (see case study 3.16).

Additionally, individual attributes might uniquely respond to a specific stressor or group of associated stressors (biological response signatures) (Yoder and Rankin 1995; Yoder and Deshon 2003). That information could contribute to the causal analysis of biological impairment discussed in Tool #3*, Stressor Identification (SI) and Causal Analysis/Diagnosis Decision Information System (CADDIS)*.

Table 2-2. Biological and other ecological attributes used to characterize the BCG.

Attribute	Description
I. Historically documented, sensitive, long-lived, or regionally endemic taxa	Taxa known to have been supported according to historical, museum, or archeological records, or taxa with restricted distribution (occurring only in a locale as opposed to a region), often due to unique life history requirements (e.g., sturgeon, American eel, pupfish, unionid mussel species).
II. Highly sensitive (typically uncommon) taxa	Taxa that are highly sensitive to pollution or anthropogenic disturbance. Tend to occur in low numbers, and many taxa are specialists for habitats and food type. These are the first to disappear with disturbance or pollution (e.g., most stoneflies, brook trout [in the east], brook lamprey).
III. Intermediate sensitive and common taxa	Common taxa that are ubiquitous and abundant in relatively undisturbed conditions but are sensitive to anthropogenic disturbance/pollution. They have a broader range of tolerance than attribute II taxa and can be found at reduced density and richness in moderately disturbed sites (e.g., many mayflies, many darter fish species).
IV. Taxa of intermediate tolerance	Ubiquitous and common taxa that can be found under almost any conditions, from undisturbed to highly stressed sites. They are broadly tolerant but often decline under extreme conditions (e.g., filter-feeding caddisflies, many midges, many minnow species).
V. Highly tolerant taxa	Taxa that typically are uncommon and of low abundance in undisturbed conditions but that increase in abundance in disturbed sites. Opportunistic species able to exploit resources in disturbed sites. These are the last survivors (e.g., tubificid worms, black bullhead).
VI. Nonnative or intentionally introduced species	Any species not native to the ecosystem (e.g., Asiatic clam, zebra mussel, carp, European brown trout). Additionally, there are many fish native to one part of North America that have been introduced elsewhere.
VII. Organism condition	Anomalies of the organisms; indicators of individual health (e.g., deformities, lesions, tumors).
VIII. Ecosystem function	Processes performed by ecosystems, including primary and secondary production; respiration; nutrient cycling; decomposition; their proportion/dominance; and what components of the system carry the dominant functions. For example, shift of lakes and estuaries to phytoplankton production and microbial decomposition under disturbance and eutrophication.
IX. Spatial and temporal extent of detrimental effects	The spatial and temporal extent of cumulative adverse effects of stressors; for example, groundwater pumping in Kansas resulting in change in fish composition from fluvial dependent to sunfish.
X. 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. For example, levees restrict connections between flowing water and floodplain nutrient sinks (disrupt function); dams impede fish migration, spawning.

Source: Modified from Davies and Jackson 2006.

Calibrating the Conceptual Model to Local Conditions

The BCG can serve as a starting point for defining the response of aquatic biota to increasing levels of stress in a specific region. Although the BCG was developed primarily using forested stream ecosystems, the model can be applied to any region or waterbody by calibrating it to local conditions using specific expertise and local data. To date, most states and tribes are calibrating the BCG using the first seven attributes that characterize the biotic community primarily on the basis of tolerance to stressors, presence/absence of native and nonnative species, and organism condition. Although the model has been developed for six levels of condition, six levels might not be necessary or feasible depending on limitations in data or level of technical rigor (see Chapter 2, Tool #1, *Biological Assessment Program Evaluation*) or naturally occurring conditions. For example, ephemeral streams in the arid Southwest naturally support a community of aquatic organisms that tolerate extreme conditions that range from intense, monsoon-like precipitation to extensive periods of drought. Those organisms might also be able to tolerate the presence of stressors. Thus, the range of response to anthropogenic stress in such streams (e.g., moderately tolerant to very tolerant species) might be abbreviated compared to that of a forested stream community in a temperate climate (e.g., very sensitive to very tolerant species). Three or four tiers might be suitable for those waters.

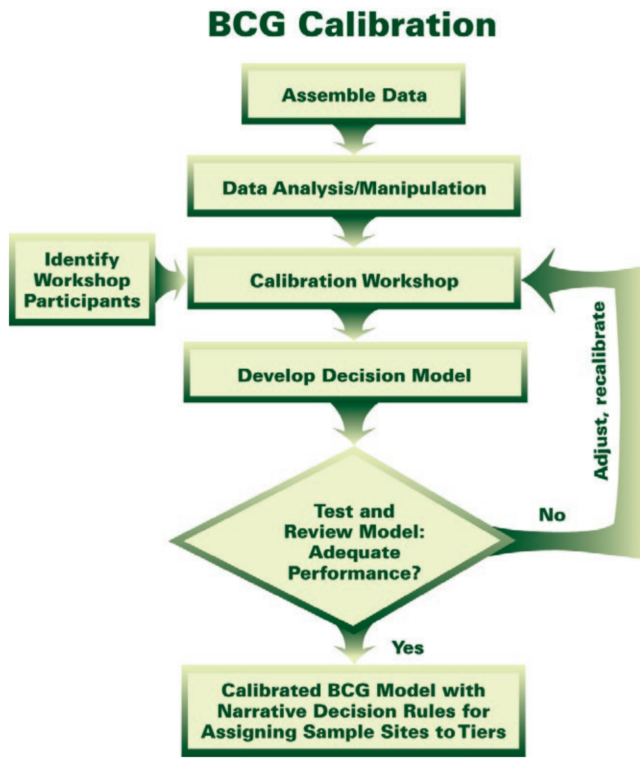


Figure 2-3. Steps in a BCG calibration.

It is a multistep process to calibrate a BCG to local conditions (Figure 2-3). That process is followed to describe the native aquatic assemblages under natural conditions; identify the predominant regional stressors; and describe the BCG, including the theoretical foundation and observed assemblage response to stressors. Calibration begins with the assembly and analysis of biological monitoring data. Next, a calibration workshop is held in which experts familiar with local 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. New Jersey is one of several states that are field testing this approach. Documentation of expert opinion in assigning sites to tiers is a critical part of the process. A decision model can then be developed that encompasses those rules and is tested with independent data sets. A decision model based on the tested decision rules is a transparent, formal, and testable method for documenting and validating expert knowledge (see Table 2-3 for examples). A quantitative data analysis program can then be developed using those rules. EPA recommends peer review of model.

Table 2-3. Example of narrative decision rules for distinguishing BCG Level 2 from Level 3 for streams, modified from New Jersey BCG expert workshop

Attributes	**Rules for BCG Level 2** Structure and function of community similar to natural community with some additional taxa and biomass	**Rules for BCG Level 3** Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance
Total taxa	More than 12 taxa	More than 12 taxa
Highly Sensitive Taxa (Attribute II only)	More than two taxa	May be absent
Richness of Sensitive Taxa (combination of Attributes II and III,see table 2-2)	Attribute II + Attribute III are more than 50% of total taxa richness	Attribute II + Attribute III are more than 35% of total taxa richness
Abundance of Tolerant Taxa (Attribute V)	Abundance of Attribute V is less than 20% of community	Abundance of Attribute V is less than 50% of community

In the example above, both BCG levels 2 and 3 support comparable levels of overall taxa (e.g., total taxa). However, there is a shift from BCG level 2 to BCG level 3 in proportion and abundance of sensitive and tolerant taxa (e.g., a decrease in proportion of sensitive taxa and an increase in abundance of pollution-tolerant taxa). The BCG describes incremental shifts in community composition and other biological parameters along a gradient of increasing anthropogenic stress. The BCG can be used to detect measurable changes in the aquatic biota before there is a complete loss of a certain type or category of taxa such as loss of pollution sensitive or native species. This tool will enable earlier detection and support action to prevent loss of species or other biological changes. This tool can be used to raise the discriminatory power of biological assessment programs in a nationally consistent, transparent manner. Narrative decision rules are the first step in formalizing expert opinion and expressing empirical findings that can then be tested and validated.

Glossary

aquatic assemblage	An association of interacting populations of organisms in a given waterbody; for example, fish assemblage or a benthic macroinvertebrate assemblage.
aquatic community	An association of interacting assemblages in a waterbody, the biotic component of an ecosystem.
aquatic life use	A beneficial use designation in which the waterbody provides, for example, suitable habitat for survival and reproduction of desirable fish, shellfish, and other aquatic organisms.
attribute	The measurable part or process of a biological system.
benthic macroinvertebrates or benthos	Animals without backbones, living in or on the sediments, of a size large enough to be seen by the unaided eye and which can be retained by a U.S. Standard no. 30 sieve (28 meshes per inch, 0.595-mm openings); also referred to as benthos, infauna, or macrobenthos.
best management practice	An engineered structure or management activity, or combination of those, that eliminates or reduces an adverse environmental effect of a pollutant.
biological assessment or bioassessment	An evaluation of the biological condition of a waterbody using surveys of the structure and function of a community of resident biota.
biological criteria or biocriteria	Narrative expressions or numeric values of the biological characteristics of aquatic communities based on appropriate reference conditions; as such, biological criteria serve as an index of aquatic community health.
biological indicator or bioindicator	An organism, species, assemblage, or community characteristic of a particular habitat, or indicative of a particular set of environmental conditions.
biological integrity	The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats in a region.
biological monitoring or biomonitoring	Use of a biological entity as a detector and its response as a measure to determine environmental conditions; ambient biological surveys and toxicity tests are common biological monitoring methods.
biological survey or biosurvey	Collecting, processing, and analyzing a representative portion of the resident aquatic community to determine its structural and/or functional characteristics.

biotope	An area that is relatively uniform in physical structure and that is identified by a dominant biota.
Clean Water Act	The act passed by the U.S. Congress to control water pollution (formally referred to as the Federal Water Pollution Control Act of 1972). Public Law 92-500, as amended. 33 U.S.C. 1251 *et seq*.
Clean Water Act 303(d)	This section of the act requires states, territories, and authorized tribes to develop lists of impaired waters for which applicable WQS are not being met, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that the jurisdictions establish priority rankings for waters on the lists and develop TMDLs for the waters. States, territories, and authorized tribes are to submit their lists of waters on April 1 in every even-numbered year.
Clean Water Act 305(b)	Biennial reporting requires description of the quality of the nation's surface waters, evaluation of progress made in maintaining and restoring water quality, and description of the extent of remaining problems.
criteria	Elements of state water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use.
designated uses	Those uses specified in WQS for each waterbody or segment whether or not they are being attained.
disturbance	Human activity that alters the natural state and can occur at or across many spatial and temporal scales.
ecological integrity	The condition of an unimpaired ecosystem as measured by combined chemical, physical (including physical habitat), and biological attributes. Ecosystems have integrity when they have their native components (plants, animals and other organisms) and processes (such as growth and reproduction) intact.
ecoregion	A relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.
function	Processes required for normal performance of a biological system (may be applied to any level of biological organization).
guild	A group of organisms that exhibit similar habitat requirements and that respond in a similar way to changes in their environment.

historical data	Data sets from previous studies, which can range from handwritten field notes to published journal articles.
index of biological/biotic integrity	An integrative expression of site condition across multiple metrics; an IBI is often composed of at least seven metrics.
invasive species	A species whose presence in the environment causes economic or environmental harm or harm to human health. Native species or nonnative species can show invasive traits, although that is rare for native species and relatively common for nonnative species. (Note that this term is not included in the biological condition gradient [BCG].)
least disturbed condition	The best available existing conditions with regard to physical, chemical, and biological characteristics or attributes of a waterbody within a class or region. Such waters have the least amount of human disturbance in comparison to others in the waterbody class, region, or basin. Least disturbed conditions can be readily found but can depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition can change significantly over time as human disturbances change.
maintenance of populations	Sustained population persistence; associated with locally successful reproduction and growth.
metric	A calculated term or enumeration that represents some aspect of biological assemblage, function, or other measurable aspect and is a characteristic of the biota that changes in some predictable way with increased human influence.
minimally disturbed condition	The physical, chemical, and biological conditions of a waterbody with very limited, or minimal, human disturbance.
multimetric index	An index that combines indicators, or metrics, into a single index value. Each metric is tested and calibrated to a scale and transformed into a unitless score before being aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition. See **index of biological/biotic integrity (IBI).**
narrative biological criteria	Written statements describing the structure and function of aquatic communities in a waterbody that support a designated aquatic life use.
native	An original or indigenous inhabitant of a region; naturally present.

nonnative or intentionally introduced species	With respect to an ecosystem, any species that is not found in that ecosystem; species introduced or spread from one region of the United States to another outside their normal range are nonnative or non-indigenous, as are species introduced from other continents.
numeric biological criteria	Specific quantitative measures of the structure and function of aquatic communities in a waterbody necessary to protect a designated aquatic life use.
periphyton	A broad organismal assemblage composed of attached algae, bacteria, their secretions, associated detritus, and various species of microinvertebrates.
rapid bioassessment protocols	Cost-effective techniques used to survey and evaluate the aquatic community to detect aquatic life impairments and their relative severity.
reference condition (biological integrity)	The condition that approximates natural, unaffected conditions (biological, chemical, physical, and such) for a waterbody. Reference condition (biological integrity) is best determined by collecting measurements at a number of sites in a similar waterbody class or region undisturbed by human activity, if they exist. Because undisturbed conditions can be difficult or impossible to find, minimally or least disturbed conditions, combined with historical information, models, or other methods can be used to approximate reference condition as long as the departure from natural or ideal is understood. Reference condition is used as a benchmark to determine how much other waterbodies depart from this condition because of human disturbance. See definitions for minimally and least disturbed condition
reference site	A site selected for comparison with sites being assessed. The type of site selected and the types of comparative measures used will vary with the purpose of the comparisons. For the purposes of assessing the ecological condition of sites, a reference site is a specific locality on a waterbody that is undisturbed or minimally disturbed and is representative of the expected ecological integrity of other localities on the same waterbody or nearby waterbodies.
refugia	Accessible microhabitats or regions in a stream reach or watershed where adequate conditions for organism survival are maintained during circumstances that threaten survival; for example, drought, flood, temperature extremes, increased chemical stressors, habitat disturbance.

sensitive taxa	Taxa intolerant to a given anthropogenic stress; first species affected by the specific stressor to which they are *sensitive* and the last to recover following restoration.
sensitive or regionally endemic taxa	Taxa with restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often because of unique life history requirements. Can be long-lived, late-maturing, low-fecundity, limited-mobility, or require mutualist relation with other species. Can be among listed endangered/threatened or special concern species. Predictability of occurrence often low; therefore, requires documented observation. Recorded occurrence can be highly dependent on sample methods, site selection, and level of effort.
sensitive - rare taxa	Taxa that naturally occur in low numbers relative to total population density but can make up large relative proportion of richness. Can be ubiquitous in occurrence or can be restricted to certain micro-habitats, but because of low density, recorded occurrence is dependent on sample effort. Often stenothermic (having a narrow range of thermal tolerance) or coldwater obligates; commonly k-strategists (populations maintained at a fairly constant level; slower development; longer life span). Can have specialized food resource needs or feeding strategies. Generally intolerant to significant alteration of the physical or chemical environment; are often the first taxa observed to be lost from a community.
sensitive - ubiquitous taxa	Taxa ordinarily common and abundant in natural communities when conventional sample methods are used. Often having a broader range of thermal tolerance than sensitive or rare taxa. These are taxa that constitute a substantial portion of natural communities and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.
stressors	Physical, chemical, and biological factors that adversely affect aquatic organisms.
structure	Taxonomic and quantitative attributes of an assemblage or community, including species richness and relative abundance structurally and functionally redundant attributes of the system and characteristics, qualities, or processes that are represented or performed by more than one entity in a biological system.
taxa	A grouping of organisms given a formal taxonomic name such as species, genus, family, and the like.

taxa of intermediate tolerance	Taxa that compose a substantial portion of natural communities; can be r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics). Can be eurythermal (having a broad thermal tolerance range). Can have generalist or facultative feeding strategies enabling utilization of relatively more diversified food types. Readily collected with conventional sample methods. Can increase in number in waters with moderately increased organic resources and reduced competition but are intolerant of excessive pollution loads or habitat alteration.
tolerant taxa	Taxa that compose a small proportion of natural communities. They are often tolerant of a broader range of environmental conditions and are thus resistant to a variety of pollution- or habitat-induced stresses. They can increase in number (sometimes greatly) in the absence of competition. Commonly r-strategists (early colonizers with rapid turnover times; boom/bust population characteristics), able to capitalize when stress conditions occur; last survivors.
total maximum daily load	The sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources; the calculated maximum amount of a pollutant a waterbody can receive and still meet WQS and an allocation of that amount to the pollutant's source.
toxicity identification evaluation	A set of procedures to identify the specific chemicals responsible for effluent toxicity.
toxicity reduction evaluation	A site-specific study conducted in a stepwise process designed to identify the causative agents of effluent toxicity, isolate the sources of toxicity, evaluate the effectiveness of toxicity control options, and then confirm the reduction in effluent toxicity.
water quality management (nonregulatory)	Decisions on management activities relevant to a water resource, such as problem identification, need for and placement of best management practices, pollution abatement actions, and effectiveness of program activity.
water quality standard	A law or regulation that consists of the designated use or uses of a waterbody, the narrative or numerical water quality criteria (including biological criteria) that are necessary to protect the use or uses of that waterbody, and an antidegradation policy.

whole effluent toxicity	The aggregate toxic effect of an aqueous sample (e.g., whole effluent wastewater discharge) as measured by an organism's response after exposure to the sample (e.g., lethality, impaired growth or reproduction); WET tests replicate the total effect and actual environmental exposure of aquatic life to toxic pollutants in an effluent without requiring the identification of the specific pollutants.

Abbreviations and Acronyms

ADEQ	Arizona Department of Environmental Quality
BCG	biological condition gradient
BMIBI	benthic macroinvertebrate index of biotic integrity
BMP	best management practice
CADDIS	Causal Analysis/Diagnosis Decision Information System
CT DEP	Connecticut Department of Environmental Protection
CWA	Clean Water Act
CWH	coldwater habitat
EPA	U.S. Environmental Protection Agency
EPT	ephemeroptera, plecoptera, trichoptera taxa
ESU	evolutionarily significant unit
EV	exceptional value (Pennsylvania)
EWH	exceptional warmwater habitat
FIBI	fish index of biotic integrity
FQI	Floristic Quality Index
FSS	fine sediment stress
GIS	geographic information system
GPS	global positioning system
HQ	high-quality (Pennsylvania)
HUC	hydrologic unit code
IBI	index of biological/biotic integrity
IC	impervious cover
ICI	invertebrate community index
IDNR	Iowa Department of Natural Resources
INSTAR	Interactive Stream Assessment Resource
IRG	Integrated Reporting Guidance
LRW	limited resource water
LWH	limited warmwater habitat
MDE	Maryland Department of the Environment
MDEQ	Michigan Department of Environmental Quality
MDNR	Maryland Department of Natural Resources
ME DEP	Maine Department of Environmental Protection
mIBI	modified index of biological integrity
MIwb	modified index of well-being
MPCA	Minnesota Pollution Control Agency
MWH	modified warmwater habitat
NARS	National Aquatic Resource Surveys
NAWQA	National Water-Quality Assessment
NBEP	Narragansett Bay Estuary Program

NEP	National Estuary Program
NFMR	North Fork Maquoketa River
NJ DEP	New Jersey Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NTU	nephelometric turbidity unit
NWQC	numeric water quality criteria
O/E	observed over expected
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ONRW	Outstanding National Resource Water
ORD	Office of Research and Development (U.S. Environmental Protection Agency)
PA DEP	Pennsylvania Department of Environmental Protection
PREDATOR	PREDictive Assessment Tool for Oregon
QHEI	qualitative habitat evaluation index
RIVPACS	River Invertebrate Prediction and Classification System
SI	stressor identification
SSH	seasonal salmonid habitat
TBEP	Tampa Bay Estuary Program
TIE	toxicity identification evaluation
TMDL	Total Maximum Daily Load
TRE	toxicity reduction evaluation
TS	temperature stress
UAA	use attainability analysis
UCONN	University of Connecticut
USGS	U.S. Geological Survey
UT DEQ	Utah Department of Environmental Quality
VA DCR	Virginia Department of Conservation and Recreation
VSA	Virtual Stream Assessment
VT DEC	Vermont Department of Environmental Conservation
WET	whole effluent toxicity
WQL	water quality limited
WQS	water quality standards
WWH	warmwater habitat
WWTF	wastewater treatment facility
WWTP	wastewater treatment plant

Appendix A. Additional Resources

Biological Assessment and Biological Criteria: Technical Guidance

Biological assessment and biological criteria	Description/summary
Biological Criteria: National Program for Surface Waters (EPA 440-5-90-004) Source: U.S. Environmental Protection Agency Date of Publication: 1990	This document provides EPA regions, states and others with the conceptual framework and assistance necessary to develop and implement narrative and numeric biological criteria and to promote national consistency in application.
http://www.epa.gov/bioindicators/pdf/EPA-440-5-90-004Biologicalcriterianationalprogramguidanceforsurfacewaters.pdf	
Policy on the Use of Bioassessments and Criteria in the Water Quality Program Source: U.S. Environmental Protection Agency Date of Publication: 1991	This document provides policy guidance on integration of biological surveys, assessments, and criteria with chemical-specific analysis and whole effluent and ambient toxicity testing methods in the water quality program.
http://www.epa.gov/bioiweb1/pdf/PolicyonBiologicalAssessmentsandCriteria.pdf	
Coral reefs	**Description/summary**
Stony Coral Rapid Bioassessment Protocol (EPA 600-R-06-167) Source: U.S. Environmental Protection Agency Date of Publication: 2007	The principal purpose of the *Stony Coral Rapid Bioassessment Protocol* is to introduce a simple and rapid coral survey method that provides multiple biological indicators to characterize coral condition. The document offers insight on indicator relevance to ecosystem services (societal values), reef condition, and sustainability. It provides information regarding regulatory programs, and it presents a few examples describing how biological assessment indicators can be incorporated into a regulatory biological criteria program to conserve coral resources.
http://www.epa.gov/bioindicators/pdf/EPA-600-R-06-167StonyCoralRBP.pdf	
Coral Reef Biological Criteria: Using the Clean Water Act to Protect a National Treasure (EPA-600-R-10-054) Source: U.S. Environmental Protection Agency Date of Publication: 2010	Coral reef resource managers can use this document as a guide for developing and implementing biological criteria as part of water quality standards. Biological criteria are complementary to chemical and physical criteria and, once established, carry the same regulatory authority. The document introduces the role of biological criteria under the Clean Water Act and describes the process for identifying metrics, establishing reference values, designing a long-term monitoring program, and integrating biological criteria with existing management programs. It includes sections that link biological criteria to high-visibility issues such as ecosystem services, climate change, and ocean acidification.
http://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=223392	
Estuaries and coastal waters	**Description/summary**
Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical Guidance (EPA 822-B-00-024) Source: U.S. Environmental Protection Agency Date of Publication: 2000	This technical guidance provides an extensive collection of methods and protocols for conducting biological assessments in estuarine and coastal marine waters and the procedures for deriving biological criteria from the results. See also *National Coastal Condition Reports* (2001, 2004 and 2008) under *National Aquatic Resource Surveys* listed below.
http://www.epa.gov/waterscience/biocriteria/States/estuaries/estuaries.pdf	

Lakes and reservoirs	**Description/summary**
Lakes and Reservoir Bioassessment and Biocriteria Technical Guidance Document (EPA 841-B-98-007) Source: U.S. Environmental Protection Agency Date of Publication: 1998	This guidance is intended to provide managers and field biologists with functional methods and approaches that will facilitate the implementation of viable lake biological assessment and biological criteria programs that meet their needs and resources. Procedures for program design, reference condition determination, field biological surveys, biological criteria development, and data analysis are detailed. In addition, the document provides information on the application and effectiveness of lake biological assessment to existing EPA and state/tribal programs such as the Clean Lakes Program, 305(b) assessments, NPDES permitting, risk assessment, and watershed management. See also *National Lakes Assessment Report* (2010) under *National Aquatic Resource Surveys* listed below.
http://www.epa.gov/owow/monitoring/tech/lakes.html	
Non-wadeable streams and rivers	**Description/summary**
Concepts and Approaches for the Bioassessment of Non-wadeable Streams and Rivers (EPA 600-R-06-127) Source: U.S. Environmental Protection Agency Date of Publication: 2006	This document provides a framework for the development of biological assessment programs and biological criteria for large rivers. It helps states establish or refine their large river protocols for field sampling, laboratory sample processing, data management and analysis, and assessment and reporting.
http://www.epa.gov/eerd/rivers/non-wadeable_full_doc.pdf	
Streams and wadeable rivers	**Description/summary**
Biological Criteria: Technical Guidance for Streams and Small Rivers (EPA 822-B-96-001) Source: U.S. Environmental Protection Agency Date of Publication: 2001	The goal of this document is to help states develop and use biological criteria for streams and small rivers. It includes a general strategy for biological criteria development, identifies steps in the process, and provides technical guidance on how to complete each step, using the experience and knowledge of existing state, regional, and national surface water programs. See also *Wadeable Streams Assessment Report* (2006) under *National Aquatic Resource Surveys* listed below.
http://www.epa.gov/bioindicators/pdf/EPA-822-B-96-001BiologicalCriteria-TechnicalGuidanceforStreamsandSmallRivers-revisededition1996.pdf	
Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, 2nd ed. (EPA 841-B-99-002) Source: U.S. Environmental Protection Agency Date of Publication: 1999	This document is a practical technical reference for conducting cost-effective biological assessments of lotic systems. The Rapid Bioassessment Protocols (RBPs) are a blend of existing methods used by various states to sample biological assemblages and assess physical habitat.
http://www.epa.gov/owow/monitoring/rbp/download.html	

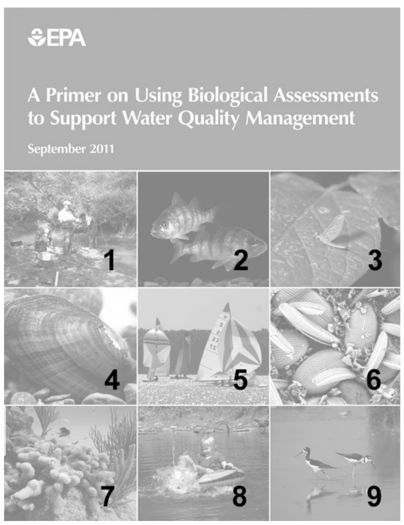
Other Relevant Water Program Guidance

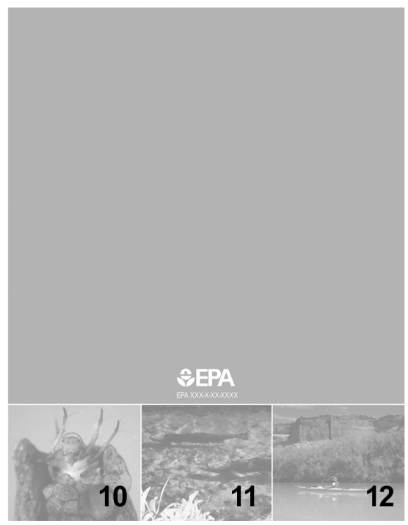
Listing and TMDLs	Description/summary
Memorandum: Clarification of the Use of Biological Data and Information in the 2002 Integrated Water Quality Monitoring and Assessment Report Guidance Source: U.S. Environmental Protection Agency Date of Publication: 2002	This memorandum modified the 2002 *Integrated Water Quality Monitoring and Assessment Report Guidance* to provide clarity and promote consistency in the manner in which states use biological data and information in developing their submissions.
http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/biochange20302.cfm	
Guidance for 1994 Section 303(d) Lists Source: U.S. Environmental Protection Agency Date of Publication: 1994	This memorandum clarified how biological data can be used to support listing of a waterbody on the section 303(d) list.
http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/1994guid.cfm	
Recovery Potential Screening Source: U.S. Environmental Protection Agency Date of Publication: 2012	The Recovery Potential Screening website is a user-driven, flexible approach for comparing relative differences in restorability among impaired waters. The screening process uses ecological, stressor, and social indicators to evaluate and compare waters and reveal factors that may explain the relative restorability of waters. This technical method and website are intended to assist in complex planning and prioritizing decisions, provide a systematic and transparent comparison approach, reveal underlying environmental and social factors that affect restorability, and better inform restoration strategies to help achieve results. The website provides step-by-step directions in the screening process, downloadable tools for calculating indices and displaying results, summaries of indicators and their measurement from common data sources, a recovery literature database, and several case studies and related links.
http://www.epa.gov/recoverypotential/	

Monitoring and assessment	Description/summary
Guidance for 2006 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act Source: U.S. Environmental Protection Agency Date of Publication: 2005	This guidance is for states, territories, authorized tribes, and interstate commissions that help prepare and submit section 305(b) reports (referred to as *jurisdictions*). It outlines the development of biennial Integrated Reports, which that would support EPA's strategy for achieving a broad-scale, national inventory of water quality conditions. The objective of this guidance is to provide jurisdictions (1) a recommended reporting format and (2) suggested content to be used in developing a single document that integrates the reporting requirements of CWA sections 303(d), 305(b), and 314. (Pursuant to the CWA, jurisdictions report to EPA biannually on the condition of waters within their boundaries.)
http://www.epa.gov/owow/tmdl/2006IRG/report/2006irg-report.pdf	
Elements of a State Water Monitoring and Assessment Program (EPA 841-B-03-003) Source: U.S. Environmental Protection Agency Date of Publication: 2003	This document recommends 10 basic elements of a state water monitoring program and serves as a tool to help EPA and states determine whether a monitoring program meets the prerequisites of CWA section 106(e)(1).
http://www.epa.gov/owow/monitoring/elements/	
Consolidated Assessment and Listing Methodology (CALM): Toward a Compendium of Best Practices Source: U.S. Environmental Protection Agency Date of Publication: 2002	CALM provides a framework for states and other jurisdictions to document how they collect and use water quality data and information for environmental decision making. The primary purposes of the data analyses are to determine the extent to which all waters are attaining water quality standards, to identify waters that are impaired and need to be added to the 303(d) list, and to identify waters that can be removed from the list because they are attaining standards.
http://www.epa.gov/owow/monitoring/calm.html	
Biological Criteria: Technical Guidance for Survey Design and Statistical Evaluation of Biosurvey Data (EPA 822-B97-002) Source: U.S. Environmental Protection Agency Date of Publication: 1997	The emphasis of this guidance is on the practical application of basic statistical concepts to the development of biological criteria for surface water resource protection, restoration, and management.
http://www.epa.gov/bioindicators/pdf/EPA-822-B-97-002BiologicalCriteria-TechnicalGuidanceforSurveyDesignandStatisticalEvaluationofBiosurveyData.pdf	
Generic Quality Assurance Project Plan Guidance for Programs Using Community Level Biological Assessment in Wadeable Streams and Rivers (EPA 841-B-95-004) Source: U.S. Environmental Protection Agency Date of Publication: 1995	This document represents generic guidance for development of QAPPs for specific biological assessment projects or programs. It has been specifically designed for use by states using biological assessment protocols that focus on community-level responses as indicated by a multimetric approach and taxonomy to the genus/species level.
http://www.epa.gov/bioindicators/pdf/EPA-841-B-95-004GenericQualityAssuranceProjectPlanBioassessment.pdf	

National Aquatic Resource Surveys: *National Coastal Condition Report*. (2001) EPA-620/R-01/005 *National Coastal Condition Report II*. (2004) EPA-620/R-03/002 *Wadeable Streams Assessment.* (2006) EPA-841-B-06-002 *National Coastal Condition Report III*. (2008) EPA/842-R-08-002 *National Lakes Assessment*. (2010) EPA-841-R-09-001 Source: U.S. Environmental Protection Agency Dates of Publication: see above	The surveys are conducted using a statistical survey design to yield unbiased, statistically representative estimates of the biological condition of the whole water resource (e.g., wadeable streams, lakes, rivers). Data are collected, processed, and analyzed through EPA-state collaboration to assess and report on the condition of the nation's waters with documented confidence. Surveys collect a suite of indicators relating to the biological/physical habitat and water quality of the resource to assess the resource condition and determine the percentage meeting the goals of the CWA. Surveys collect information on biological and abiotic factors at 30–50 sites on an ecoregion level II scale for each resource.
http://www.epa.gov/owow/monitoring/nationalsurveys.html http://www.epa.gov/owow/oceans/nccr/ http://www.epa.gov/owow/streamsurvey/ http://www.epa.gov/owow/lakes/lakessurvey/	
Predictive Tools	**Description/summary**
Landscape and Predictive Tools: A Guide to Spatial Analysis for Environmental Assessment (draft) (EPA-100-R-11-002) Source: U.S. Environmental Protection Agency Date of Publication: In process of finalization. Release expected 2012.	This methods manual describes the purpose, rationale, and basic steps for using landscape and predictive tools for Clean Water Act monitoring, assessment, and management purposes such as filling monitoring gaps and prioritizing protection and rehabilitation actions. This guidance stresses simultaneous use of matched (or paired) landscape and in situ data for empirical modeling to enhance predictive capabilities and encourage science-based targeting and priority setting. Example and potential applications include criteria and standards development, problem identification and prevention, prioritization and targeting of rehabilitation, and advancing science, education, and society's ability to effectively manage aquatic and terrestrial resources. This methods guidance is organized into four sections: (I) Introduction to Landscape and Predictive Tools; (II) Geographic Frameworks, Spatial Data, and Analysis Tools; (III) Examples and Case Studies; and (IV) Gaps and Needs for Research and Applications; plus an extensive Toolbox providing links to and short descriptions of a wide range of easily accessed data sets and analytical tools. Wider application of these tools and approaches should yield better protection for high-quality waters and quicker, more cost-effective restoration of impaired waters.
http://www.epa.gov/raf/pubecological.htm	
Stressor Response	
Causal Analysis/Diagnosis Decision Information System (CADDIS) Source: U.S. Environmental Protection Agency Date: Last updated September 23, 2010	The Causal Analysis/Diagnosis Decision Information System, or CADDIS, is a website developed to help scientists and engineers in the Regions, States, and Tribes conduct causal assessments in aquatic systems. It is organized into five volumes: • Volume 1: Stressor Identification • Volume 2: Sources, Stressors & Responses • Volume 3: Examples & Applications • Volume 4: Data Analysis • Volume 5: Causal Databases
http://www.epa.gov/caddis	

Using Stressor-response Relationships to Derive Numeric Nutrient Criteria (EPA-820-2-10-001) Source: U.S. Environmental Protection Agency Date of Publication: 2010	This document provides guidance on statistical methods for estimating stressor-response relationships between changes in nutrient concentrations and changes in biological response variables. The document also provides guidance on methods for interpreting these relationships to derive numeric nutrient criteria. Other specific topics discussed include selecting appropriate covariates to improve the accuracy of estimated relationships, and methods for accounting for uncertainty in estimated relationships when deriving criteria.
http://water.epa.gov/scitech/swguidance/standards/criteria/nutrients/upload/finalstressor2010.pdf	
Water quality-based toxics control	**Description/summary**
Technical Support Document for Water Quality-based Toxics Control (EPA-5052-90-001) Source: U.S. Environmental Protection Agency Date of Publication: 1991	This document provides technical guidance for assessing and regulating discharge of toxic substances to waters of the United States. It was issued in support of EPA regulations and policy initiatives involving the application of biological assessment and chemical techniques to control toxic pollution to surface waters.
http://www.epa.gov/npdes/pubs/owm0264.pdf	
Watershed Protection	**Description/summary**
Identifying and Protecting Healthy Watersheds: A Technical Guide (draft) Source: U.S. Environmental Protection Agency Date of Publication: In process of finalization. Release expected 2012.	This draft technical document provides an overview of the key concepts behind an approach to identify and protect healthy watersheds, examples of assessments of healthy watershed components, an integrated assessment framework for identifying healthy watersheds, examples of management approaches, sources of national data, and key assessment tools. It contains numerous examples and case studies from across the country. The intended audience for this document is aquatic resource scientists and managers at the state, tribal, regional, and local levels; non-governmental organizations; and federal agencies. It will also benefit local government land use managers and planners as they develop protection priorities.
http://water.epa.gov/polwaste/nps/watershed/index.cfm	





Front cover:

1. Sampling in Rich Fork Creek, Davidson County, NC; Credit: Tetra Tech, Inc.
2. Yellow Perch, *P. flavescens*; Credit: U.S. Department of Agriculture
3. Adult Mayfly, Order: Ephemeroptera; Credit: Extension Entomology, Texas A&M University
4. Appalachian elktoe; Credit: Dick Biggins**,** U.S. Fish and Wildlife Service
5. Sailing in Carlyle Lake, IL; Credit: U.S. Army Corps of Engineers
6. Micrograph of freshwater diatoms; Credit: Algal Ecology Laboratory, Bowling Green State University
7. Coral Reef, St. Croix, USVI; Credit: Wayne Davis, U.S. Environmental Protection Agency
8. North River, Mount Crawford, VA; Credit: Tetra Tech, Inc.
9. Black-necked Stilt (*Himantopus mexicanus*), Maui, HI; Credit: John J. Mosesso, National Biological Information Infrastructure

Back cover:

10. Caddisfly; Credit: Rick Levey, Vermont Department of Environmental Conservation
11. California, salmon resting in a pool before resuming migration; Credit: U.S. Department of Agriculture, National Resources Conservation Service
12. Green River, UT; Credit: Scott T. Eblen, Medical University of South Carolina