Technical Components of State and Tribal Bioassessment Programs

United States
Environmental Protection
Agency

National Program Summary

Since 1989 the U.S. EPA has periodically prepared inventories of state bioassessment programs for streams and wadeable rivers. This inventory was recently updated based on 2001 program status and expanded to include tribes, territories, and basin commissions (Figure 1).

Six technical components are summarized below from the 2001 inventory:

- Uses of Bioassessment
- Field and Lab Methods
- Monitoring Program Design
- Data Analysis and Interpretation
- Aquatic Life Use Designations and Decision Making
- Reference Site/Condition Development

This brochure presents highlights of information which is illustrated in greater detail in the full survey report entitled *Summary of Biological Assessment Programs and Biocriteria Development for States, Tribes, Territories, and Interstate Commissions: Streams and Wadeable Rivers, EPA-822-R-02-048* and can be ordered from EPA Office of Water's, Water Resource Center at *http://www.epa.gov/OGWDW/resource*, or viewed online at: *http://www.epa.gov/bioindicators*.

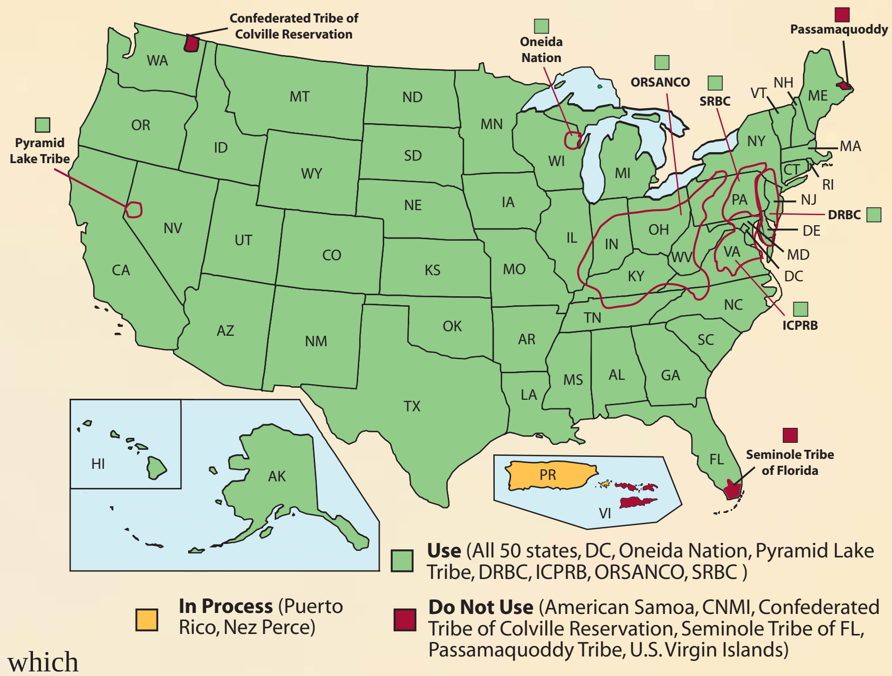


Figure 1. States, tribes, territories and interstate commissions that have bioassessment programs for streams and small rivers (2001).

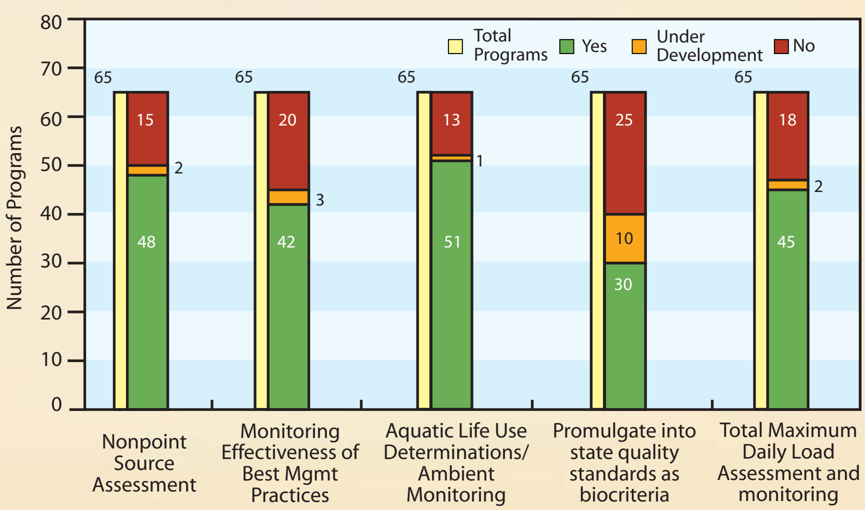


Figure 2. Uses of bioassessment for management of streams and small rivers (2001).

Uses of Bioassessment

Water quality monitoring, assessment, and standards programs rely heavily upon bioassessments (Figure 2). In 1989, only 37 inventoried programs used bioassessment. Today, all 50 States, DC, four basin commissions, and two tribes use bioassessment in their water quality programs. At least two-thirds of these programs rely upon bioassessments for nonpoint source assessments, monitoring the effectiveness of Best Management Practices (BMP), aquatic life designated use assessments, and Total Maximum Daily Load (TMDL) assessments. Slightly more than half of these programs also use bioassessment for promulgating biocriteria into their water quality standards (narrative or numeric - see discussion later), but an additional 10 programs are developing such standards.

Field and Lab Methods

Assessment of only one assemblage of organism (or type of animal or plant) leads to only 80-85% effectiveness in identifying Aquatic Life Use (ALU) attainment or non-attainment (water quality standard effectiveness)[1]. EPA encourages the use of two or more organism groups in biological assessments.

Benthic macroinvertebrates are the most common type of organism used in bioassessment, but fish and algae (periphyton) are also used. All three organism groups increased in usage in bioassessments between 1995 and 2001; algae use increased the most (Figure 3). The number of programs using more than one assemblage increased by about 29% within the original 52 programs with 45 of the 65 total programs using more than one assemblage (see Figure 3). Twenty-two of the 45 programs use three or more assemblages for assessment.

In addition to macroinvertebrates and fish, there are 11 programs that collect periphyton, nine macrophyte programs, three that collect amphibians and reptiles (herpatofauna), three that use zooplankton and one that counts waterfowl.

Habitat Assessment

Assessment Type	# of Programs
Total	57
Visual	48
Quantitative	24
Hydrogeomorphology	12
Combination	22

1 Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio. In *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making*, W.S. Davis and T.P. Simon (editors), pp. 109-144. Lewis Publishers, Boca Raton, FL.

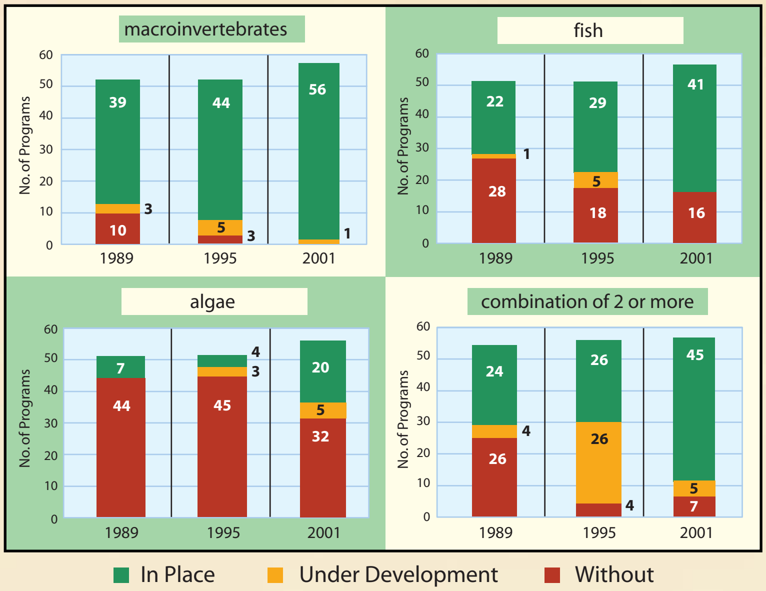


Figure 3. Types of assemblages used for bioassessments.

The number of sites sampled each year is dependent upon the monitoring design and resources available. Many more sample sites were devoted to benthic macroinvertebrate sampling than either fish or periphyton. Four invertebrate programs sample more than 500 sites per year (California, Michigan, Wisconsin, and West Virginia) while most collect invertebrates from 100-500 sites. Only one fish program (Wisconsin) collects from more than 500 sites while the majority collect less than 100 sites per year. Periphyton was collected at less than 100 sites in 14 of 19 programs.

Number of Sites Sampled for Each Assemblage

# sites sampled/yr	Invertebrates	Fish	Periphyton*
< 100	20	30	14
100-500	32	10	5
> 500	4	1	0

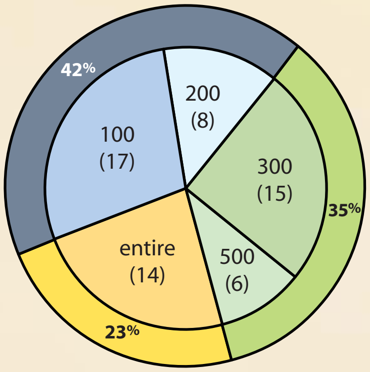
** not all programs reported information*

Physical characteristics and water quality are basic elements for assessing habitat quality. Physical characteristics can include land use, land cover, riparian vegetation, condition of stream banks and substrate, as well as flow, depth and width. Habitat quality assessments can be based on visual observations or detailed measurements of the physical characteristics. All bioassessment programs (57) depend upon either a visual habitat assessment comparable to EPA's Rapid Bioassessment Program (48), a more quantitative physical habitat assessment similar to EPA's Environmental Monitoring Assessment Program or EMAP (24), or a hydrogeomorphology habitat assessment based on Rosgen (12).

Twenty-two programs use a combination of these habitat assessments.

Benthic Macroinvertebrates

Sampling Gear Used	# of Programs Using Gear
D-Frame	31
Kicknet	24
Multiplate	14
By Hand	14
Dipnet	14
Surber	12
Rock Baskets	7



( ) = Number of programs
Total of 60 programs

Figure 5. Number of benthic macroinvertebrates subsampled.

Assessments are conducted in various ways depending on the program that a state uses and the tools accessible to the program. Different techniques are used for different types of assemblages. Macroinvertebrates are mainly measured using netting techniques because these animals are benthic and live within the material at the bottom of a stream or pond. The most common technique used to sample macroinvertebrates is the D-frame net (Figure 4), followed by the kick net. Most macroinvertebrates are found in and sampled from riffles or runs because they are considered the richest and most productive habitat. On average, about 250 specimens are collected for each sample. This number ranges for different programs from 100 to 1200 (Figure 5). When organizing macroinvertebrates, most organisms are classified down to genus and/or species, the lowest classification is typically used. Only five states have the lowest classification as family level.

Photo courtesy of B. Bateman

Figure 4. Sampling benthic invertebrates with D-nets.

Fish

Sampling Gear Used	# of Programs Using Gear
Electro-fisher	backpack - 38 boat - 18 pram - 16
Seine	25
Rotenone	1
Gill nets	3

When fish are sampled most states use electro-fishers (backpack - see Figure 6, boat, or pram/tote barges). Seines and other types of nets are used as well to capture fish. Fish are captured in a variety of habitats and all fish are identified to species.

Figure 6. Sampling fish with backpack electro-fisher.

Periphyton is an assemblage that is becoming more popular in waterbody assessment. The most frequent way to obtain periphyton samples is through brushing or scraping rocks or artificial surfaces to which the periphyton are attached. Periphyton are found in a variety of habitats and are typically classified as diatoms or down to the species level.

Periphyton/Algae

Sampling Gear Used	# of Programs Using Gear
Brushing/Scraping	16
By Hand	8
Periphytometer	5
Suction	5
Microslides	4

Monitoring Program Design

Site selection for assessment and monitoring can be "targeted", i.e., relevant to special studies that focus on potential or existing problems and/or "probabilistic", which provides information on the overall status or condition of the watershed, basin, or region (Figure 7).

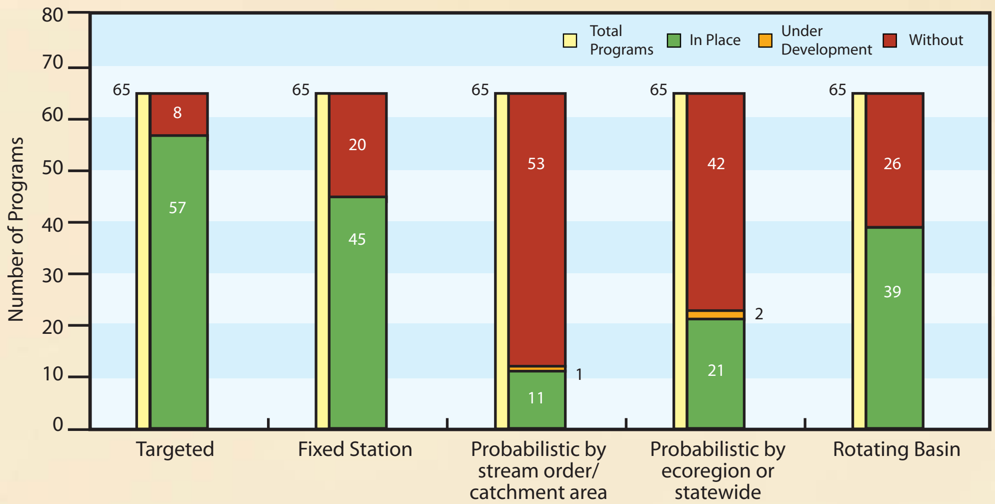


Figure 7. Monitoring designs used by state and tribal bioassessment programs (2001).

Most studies conducted by state water quality agencies for identification of problems and sensitive waters are done with a **targeted design**. In this case, sampling site selection is based on the knowledge of an existing problem, events that will adversely affect the waterbody (development or deforestation), or actions intended to improve the quality of the waterbody (installation of BMPs or habitat restoration). This method provides assessments of individual sites or stream reaches.

To meaningfully evaluate biological condition in a **targeted design**, sampling locations must be similar enough to have similar biological expectations, which, in turn, provide a basis for comparison of impairment. If the goal of an assessment is to evaluate the effects of water chemistry degradation, comparable physical habitat should be sampled at all stations, otherwise, the differences in the biology attributable to a degraded habitat will be difficult to separate from those resulting from chemical pollution. Availability of appropriate habitat at each sampling location can be established during preliminary reconnaissance. In evaluations where several stations on a waterbody will be compared, the station with the least number of productive habitats available will often determine the type of habitat to be sampled at all sample stations.

Fixed station monitoring is a type of targeted monitoring that samples the same site on a periodic basis to detect trends or changes over time.

In a **probabilistic** or random sampling regime, stream characteristics may be highly dissimilar among the sites, but will provide a more accurate assessment of biological condition throughout the area than a targeted design. Selecting sites randomly provides an unbiased assessment of the condition of the waterbody at a scale above the individual site or stream. Thus, an agency can address questions at multiple scales. Studies conducted for 305(b) status reports on the conditions of a state's waters and trend assessments are best done with a probabilistic design. Probabilistic sample designs were reported to be used by 23 programs in 2001, and 15 of those programs have either adopted or are developing a probabilistic sample design in addition to their targeted design (Figure 8).

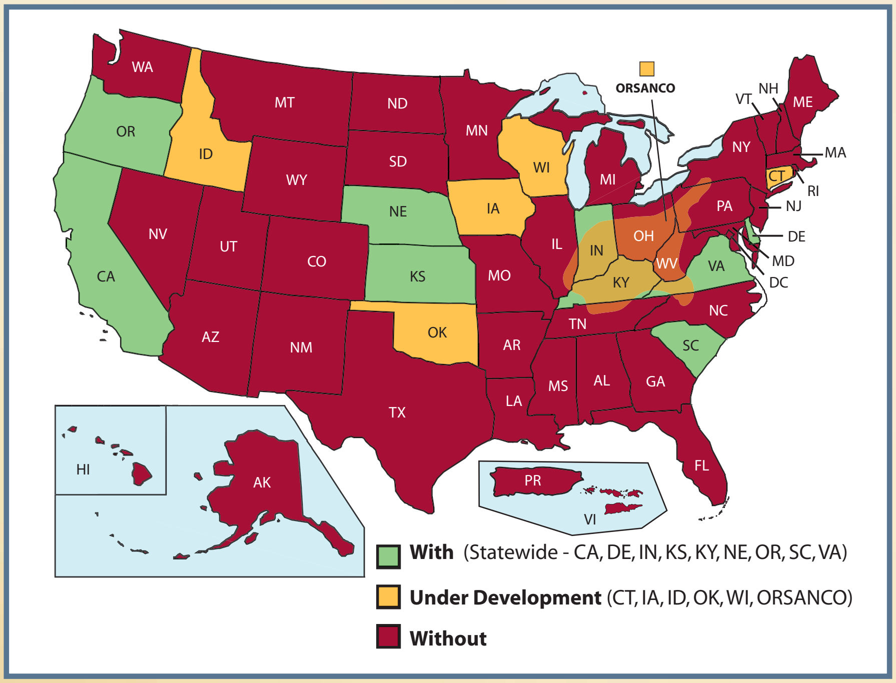


Figure 8. Implementation status of probabilistic designs for bioassessment of streams and rivers (2001).

Rotating basin designs ensure that all basins will be monitored over a period of years determined by the respective programs. These designs are compatible with targeted, fixed station, and probabilistic designs and are used by 39 programs inventoried.

Recently (March 2003), the EPA issued a monitoring design guideline for all states[2]. The State monitoring programs integrate their monitoring designs (e.g., fixed station, intensive and screening-level monitoring, rotating basin, judgmental and probability design) to meet the full range of decision needs. EPA recommends that state monitoring design should include probability-based networks (at the watershed or state-level) that support statistically valid inferences about the condition of all State waterbody types, over time. Studies for ALU determination and those related to TMDLs can be done with random (watershed or higher level) or targeted (site-specific) designs.

[2] USEPA. 2003. Elements of a State Water Monitoring and Assessment Program. EPA-841-B-03-003. U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watershed, Assessment and Watershed Protection Division, Washington, DC.

Data Analysis and Interpretation

Several methods have been used to analyze biological community data (Figure 9). The most common method is the use of biotic metrics, which are individual measurements (metrics) of the structure, function, and/or pollution sensitivity of the aquatic community, usually combined to create a multi-metric index. Graphical presentations which create meaningful visual displays of the data over time, or stream distance, can provide additional evidence to support the analysis. Sometimes the graphical displays of data will yield important findings that may not be statistically evident. Multivariate analysis is important during different phases of the analysis and has been used to validate multi-metric indices as well as determining associations of the biotic response to various stressors. These methods have been expanding in use, especially the use of multivariate analysis.

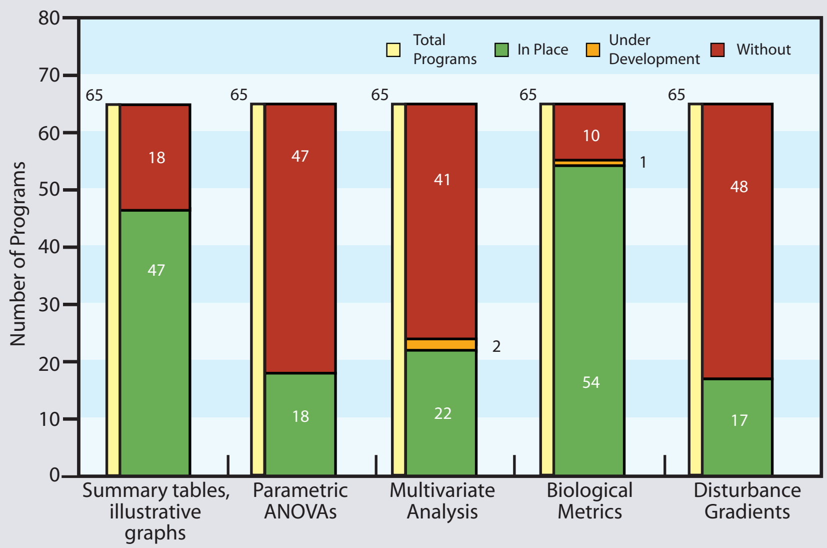


Figure 9. Biological data analysis tools and methods.

The multi-metric index for biological assessment has become widely used since it first appeared in Karr's Index[3] of Biotic Integrity (IBI). By using a combination of metrics that have been calibrated and validated using natural classifications of waterbodies, IBIs characterize and assess the overall biological condition of streams. IBIs also provide an index that changes in a predictable manner across a gradient of human influence. The multi-metric approach is the basis for the EPA's Rapid Bioassessment Protocols (*http://www.epa.gov/owow/monitoring/rbp*). Biometrics and multivariate analysis are data analysis tools used to reduce raw data into workable indicators. This approach is more objective and systematic, reducing the chance for conflicting findings among different investigators. Some states use multivariate analysis to provide additional insight and to calibrate their multimetric reference conditions. All programs with bioassessment programs also assess the physical habitat quality at their sample sites, usually employing visual based methods in combination with other measurements.

Multimetric Index:

An index that combines indicators, or metrics, into a single index value. Each metric is tested and calibrated to a scale aggregated into a multimetric index. Both the index and metrics are useful in assessing and diagnosing ecological condition.

Multivariate Analysis:

Statistical methods (e.g. ordination or discriminant analysis) for analyzing physical and biological community data using multiple variables.

[3] Karr, J.R. 1981. "Assessments of biotic integrity using fish communities." *Fisheries*, 66:21-27.

Aquatic Life Use Designations and Decision Making

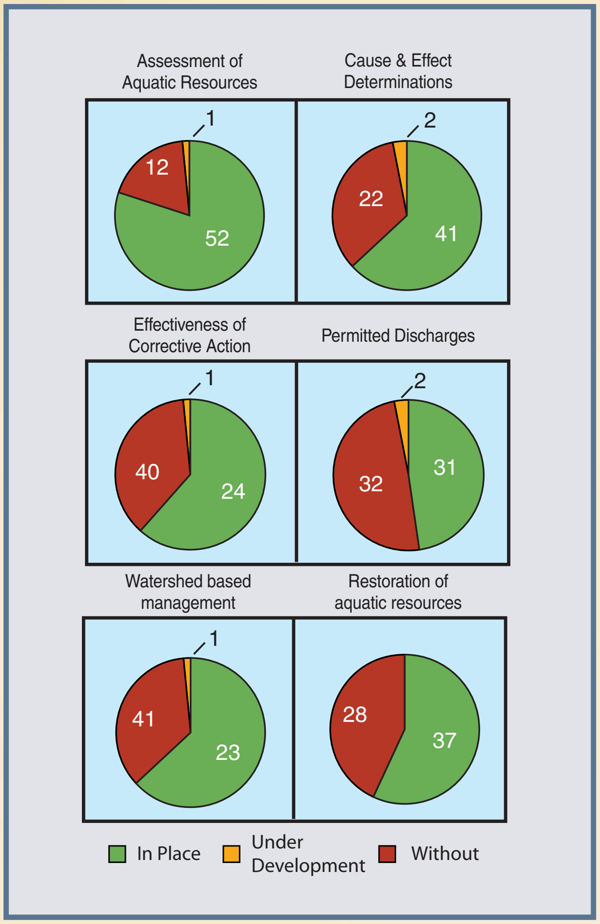


Figure 10. Uses of bioassessment data in integrated assessments for decision-making.

Narrative biocriteria are written expressions of desired biointegrity in an aquatic community. Numeric biocriteria on the other hand, achieve the same objective, but through a numeric expression of the biological condition. Many states utilize a variety of bioassessment information to develop biological criteria for streams and rivers. Biocriteria, when developed and adopted in water quality standards (WQS), are very effective tools to protect aquatic life. The goals for the preservation and restoration of aquatic life are referred to as designated aquatic life uses (ALUs). Designated uses to support aquatic life can cover a broad range of biological conditions to support both intact communities as well as establishing restoration goals for compromised ecosystems. Bioassessments can aid in the development of ALUs.

Biocriteria are an effective tool for addressing water quality problems by providing mechanisms to assess and help protect the biological resources at risk from chemical, physical or biological impacts (Figure 10).

ALUs help to describe the overall quality of water based on levels of support provided for the aquatic life by the water quality (rated as fully supporting verses partially/non supporting). Waterbodies not fully supporting aquatic life must be listed by the states and tribes on the 303(d) list, a summary of all the impaired waters in a state. States and tribes must develop and adopt criteria or water quality standards necessary to protect designated ALUs. Because chemical water quality standards alone may not ensure a healthy biological condition, most states are working to integrate a greater amount of biological information, including biocriteria (Figure 11), into their water quality standards.

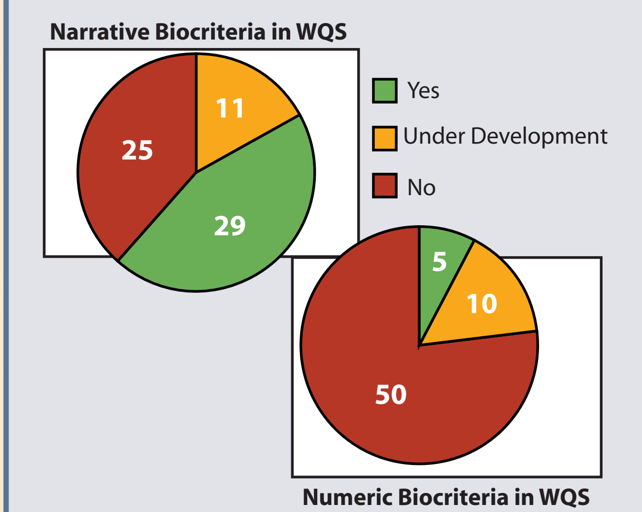


Figure 11. Number of bioassessment programs using narrative biocriteria vs. those using numeric.

Reference Site/Reference Condition Development

One of the key elements in bioassessment programs is the establishment of reference conditions to help discern human impacts from natural variation. A reference condition is essentially the benchmark against which changes in water quality are measured.

EPA recommends using a regional reference condition (USEPA 2002) and the most common method for basin-wide use is based on ecoregions, whereas paired watersheds are used at a local scale.

The ecoregion approach recognizes geographic patterns of similarity among ecosystems and the subsequent distribution of biological communities grouped on the basis of environmental variables such as climate, soil type, physiography, and vegetation. Describing a reference condition from a combination of data collected from several minimally disturbed sites is preferable to using data from only a single reference site to compare biosurvey results. Regional reference conditions are developed from data collected from a combination of specific sites with similar physical characteristics. Reference conditions typically represent the healthiest conditions that can be identified for sites with the same or similar characteristics.

One of the more impressive improvements to bioassessment programs found within the past six years was the increase in regional reference conditions as a basis for making comparisons and detecting use impairment (see Figures 12 and 13). In 1989, only four states (Arkansas, Nebraska, North Carolina, and Ohio) were actively using reference conditions to establish numeric values for biological community expectations. Between 1995 and 2001, the number of programs using regional reference conditions increased by 21, from 15 to 36 programs. Meanwhile, programs using site-specific reference conditions decreased by 12.

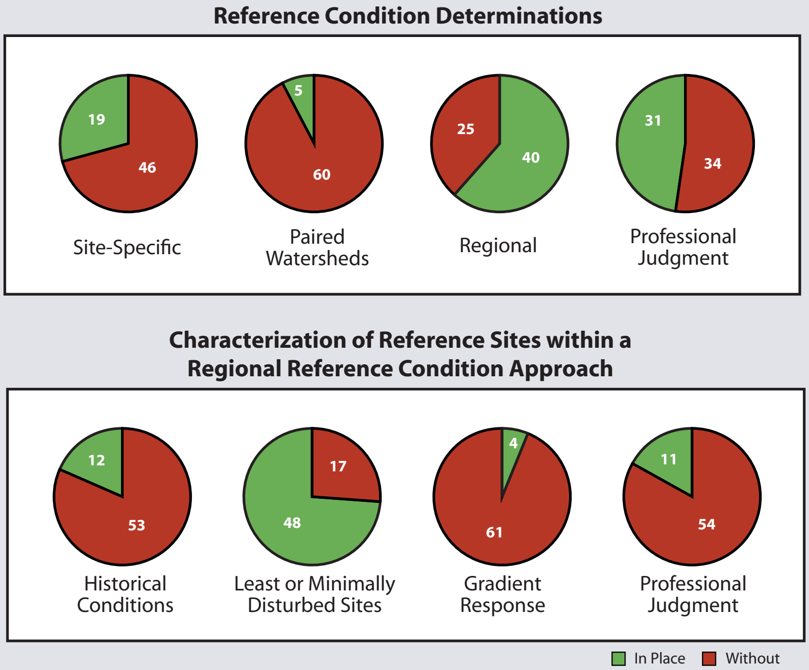


Figure 12. Number of bioassessment programs by method to determine reference condition and reference sites for regionalization method.

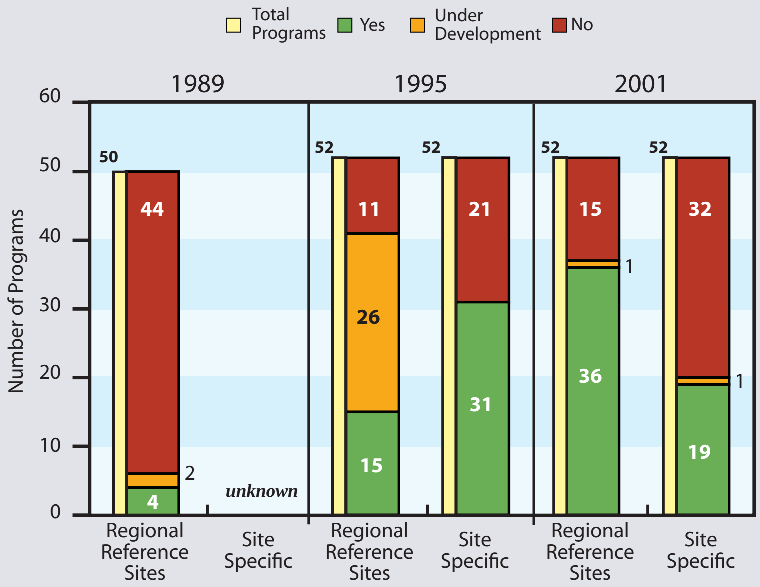


Figure 13. Growth in bioassessment programs using regional reference sites vs. programs using site-specific reference conditions.

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Washington DC 20460
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EPA recommends the following bioassessment program elements[4] for the most effective assessment and management of aquatic life resources:

- **Index period:**
  A well-documented seasonal index period(s) calibrated with data for reference conditions;
- **Natural Classification of Waterbodies:**
  True regional approach that transcends jurisdictional boundaries to strengthen inter-regional classification and recognizes zoogeographical aspects of assemblages;
- **Reference conditions:**
  Regional reference conditions are established within the applicable waterbody ecotype;
- **Indicator Assemblages:**
  Two or more assemblages with high taxonomic resolution;
- **Field and Laboratory Protocols:**
  Standard operating procedures are well documented supported by a formal QA/QC program;
- **Precision of Biological Methods:**
  High repeatability in assessments and a high level of confidence in analytical results that can distinguish between human and natural influences based on a gradient of stressors/human influence;
- **Analysis of the Data:**
  Biological index(es) or model(s) for multiple assemblages is developed and calibrated throughout the State or region. Attainment thresholds are based on discriminant model or distribution of candidate reference sites

[4] USEPA. 2002. Consolidated Assessment and Listing Methodology: Toward a Compendium of Best Practices. First Edition. Prepared by U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC July 2002. (*http://www.epa.gov/owow/monitoring/calm.html*)

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