Sediment and Stream Water Quality in a Changing Environment: Trends and Explanation
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STREAM SURVEYS — THE IMPORTANCE OF THE RELATION BETWEEN HABITAT QUALITY AND BIOLOGICAL CONDITION

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ABSTRACT An evaluation of habitat quality is critical to any assessment of ecological integrity (Plafkin *et al.*, 1989). For streams, a holistic approach to assessing habitat quality includes an evaluation of variety and quality of substrate, channel morphology, and bank structure and riparian vegetation. Biological potential is limited by the quality of the habitat. Three general relations between habitat quality and biological condition can be expected: (1) a direct response of the biological community to variation in the habitat quality in the absence of water quality problems; (2) a degradation of the biological community greater than habitat quality would predict, when combined with toxicant or organic pollution loadings to the stream; and (3) an artificial elevation of the biological condition beyond that predicted by habitat quality, when organic enrichment is present. Studies from different areas of the United States have shown that a knowledge of the habitat quality has enhanced an assessment of biological impairment due to water quality problems. The ability to establish confidence limits for a relation between biological integrity and habitat quality improves the interpretation biological integrity. This relation between habitat quality and biological integrity may vary among physiographic regions or ecoregions, but is determined for reference databases. Once confidence limits are established, the reference database can be monitored to adjust for changes in habitat quality or the condition of the biological communities.

RELATION BETWEEN HABITAT QUALITY AND BIOLOGICAL CONDITION

Habitat assessment plays a supporting role within these protocols. It is used to identify obvious constraints on the attainable potential of the site, assists in the selection of appropriate sampling stations, and provides basic information for interpreting biosurvey results. Variability of environmental conditions directly affects patterns of life history, population, and micro- and macro-geographic distribution of all organisms (Price, 1975; Smith, 1974; Cooper, 1984). Physical habitat quality is a major factor influencing the biological condition of aquatic communities. Bioassessment procedures such as the Rapid Bioassessment Protocols, called RBPs (Plafkin *et al.*, 1989), recognize and stress the importance of this variability because it is a major determinant of the biological potential of a particular habitat when assessing ecological conditions. This potential relates to the structure and composition of the biota and must be recognized before habitat evaluations can be made. In fact, the recommended use of the biological potential is in tandem with the community analysis.

To acquire an estimate of the biological potential, reference conditions are used to normalize the assessment. An understanding of the characteristics of reference or expected conditions is inherent in the judgment of impairment or degradation. For most surface waters, baseline data were not collected prior to an impact, thus impairment must be inferred from differences between the impact site and established references (U.S.Environmental Protection Agency, 1990). This approach is also critical to the assessment because stream characteristics will vary dramatically across different regions (Plafkin *et al.*, 1989). Furthermore, wide variability among streams and rivers across the country resulting from climatic, landform, and other geographic differences prevents the development of nationwide reference conditions (U.S.Environmental Protection Agency, 1990). Reference conditions, representing "best attainable" condition in terms of habitat quality and aquatic communities, will exist for a set of ecosystems with similar physical and chemical dimensions, individual watersheds, or individual streams. A decision as which of these situations will prevail is crucial to the bioassessment process.

Assuming that water quality remains constant, the predictable relation between habitat quality and biological condition can be a sigmoid curve, as illustrated in Fig. 1. On the x-axis, habitat is shown to vary from poor to optimal, relative to the reference conditions. Therefore, the quality of the habitat can range from 0 to 100% of the reference, and can be categorized as nonsupporting, partially supporting, supporting, or comparable referring to the support of well-balanced biological communities.

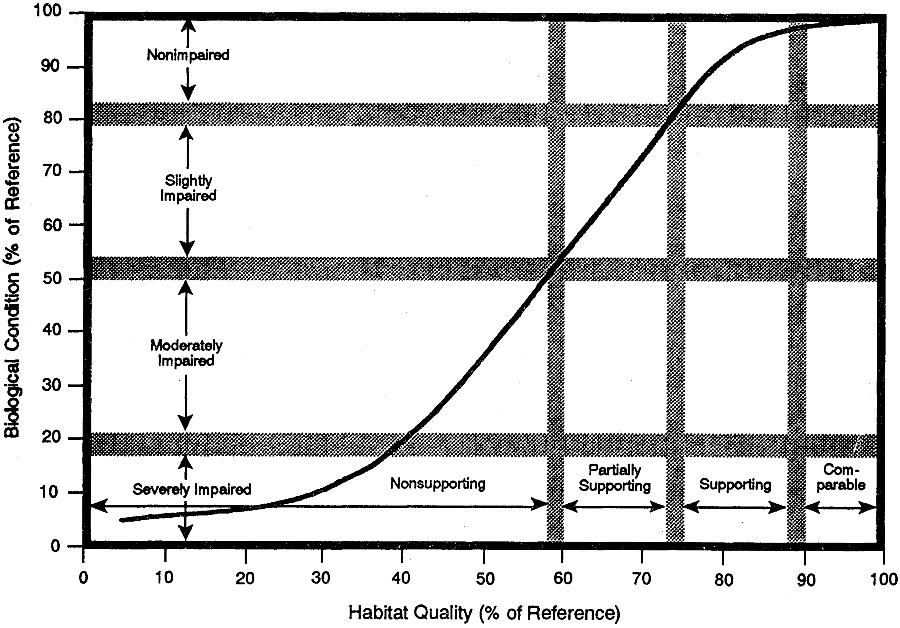

FIG. 1 The relation between habitat and biological condition.

There are essentially three parts to the curve. The first, or upper right hand corner of the curve, reflects a situation with good habitat quality and good biological condition. Some variability in habitat quality is possible without affecting the condition of the biological communities. As the habitat quality decreases within some range of "good to excellent", the biological condition will remain high, and subtle differences will be difficult to detect. However, there is a point where a decrease in biological condition is proportional to a decrease in habitat quality. This is the second, or midsection of the curve. This situation occurs when habitat quality decreases, and the biological community responds with a concomitant decrease. In the lower left hand section of the curve, habitat quality is poor, and further degradation may result in relatively little difference in biological condition. Communities in this region of the curve are pollution tolerant, opportunistic, thrive in areas of reduced competition, and are able to withstand highly variable conditions.

A holistic habitat assessment which accounts for habitat parameters influencing the structure and function of communities needs to be conducted. Other habitat assessment approaches may be used, but the importance of a holistic habitat assessment to enhance the interpretation of biological data cannot be overemphasized (Plafkin *et al.*, 1989).

The actual orientation of the relation line between habitat quality and biological condition is not fixed and may differ in the degree of linearity, slope, and y-intercept depending on the physiographic region of the country. The development of a substantial reference database would allow for the development of this empirical line along with statistical confidence intervals. From this information, the expected biological relation can be determined from a known range of habitat quality conditions (Fig. 2). In this manner, estimates of water quality effects beyond those expected from habitat constraints are possible. As depicted in Fig. 2, three general outcomes are possible when comparing ambient stream stations to a reference: (1) no biological effects, or effects due to habitat degradation; (2) effects due to water quality; or (3) an artificial elevation of the perceived condition of the community beyond the expected relation because of mild enrichment effects. A fourth outcome not illustrated by this generic graph (Fig. 2), is the area of the graph where it's not possible to separate the individual effects of habitat and water quality degradation.

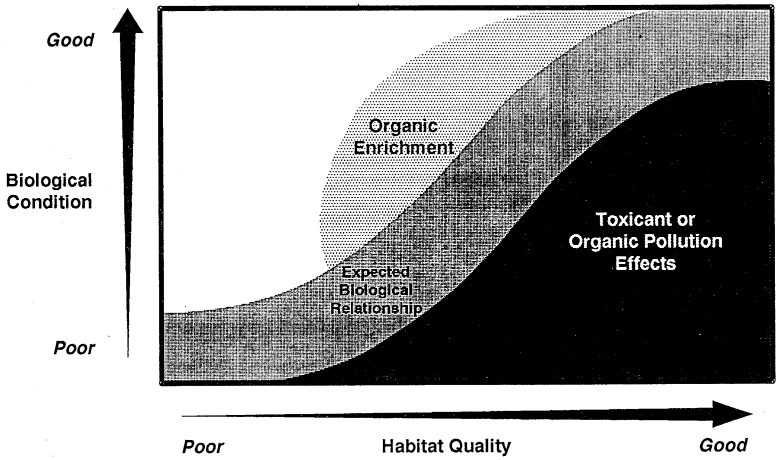

FIG. 2 Combined influence of habitat and water quality on biological condition.

The determination of all of these possible outcomes is strengthened by an adequate reference database to define the expected relation between habitat quality and biological integrity. The theoretical regression between habitat quality and biological condition should be substantiated with a larger database than is currently available. To date, habitat assessment results are not available in the historical database, with the possible exception of the U.S. Forest Service and the Ohio Environmental Protection Agency. Data analysis should be conducted to produce guidance on data variability expectations and the slope of the regression to be used for predictions.

The limitation of acceptable habitat quality may be all that is needed to judge impairment. The quantification of habitat quality to control non-point source impact may be as important as measuring the in-stream communities. Guidance for this type of definitive assessment needs to be provided.

HABITAT PARAMETERS

The habitat parameters designed to assess habitat quality are separated into three main categories: primary, secondary, and tertiary parameters. Primary parameters are those that characterize the stream "microscale" or specific niche habitat and have the greatest direct influence on the structure of the indigenous communities (Plafkin *et al.*, 1989). The secondary parameters measure the "macroscale" habitat such as channel morphology characteristics. Tertiary parameters evaluate riparian and bank structure, features which are most often ignored in biosurveys. These three categories are weighted according to their influence on the biota, with primary parameters having more weight than secondary or tertiary parameters.

Although the streams in the US exhibit a wide range in variability, generalizations can be made about the types and similarities. The gradient of the streams is perhaps the most influential factor in "type casting" a stream, because it is related to topography and landform, geological formations, and elevation, which in turn influence vegetation types. Four generic stream categories can be identified that relate to gradient: mountain, piedmont, valley/plains, and coastal. From these four categories, two sets of habitat parameters to conduct a holistic habitat assessment can be developed, roughly equivalent to evaluation of high gradient (riffle/run prevalence) and low gradient streams (glide/pool prevalence). These two categorical approaches are intended to provide guidance in assessing habitat quality of two very different stream/river types based on gradient. Further subsets are possible depending on regional specifications. However, the evaluation of habitat quality is still put in the context of reference conditions which will automatically adjust for some regional differences. A mountain trout stream should not be used as a benchmark for a lowland plains stream. Habitat parameters, which have been selected to fulfill the assessment approach for the two general stream type categories, include twelve items separated into primary, secondary, and tertiary parameter groupings (Table 1).

The main differences between these two habitat assessment matrices are in the primary parameter grouping. These parameters relate directly to the specific niche characteristics and will need to be altered depending on the stream type being evaluated. The secondary parameters have only minor differences in the descriptions of the specific parameter characteristics between the two matrices, and the tertiary parameters are identical. Some alteration of the decision criteria might be useful to refine the application of the assessment for regional purposes. The difficulty in making comprehensive biological generalizations is understood, and these two categorical approaches are intended to provide a refined framework for increased accuracy in, and applicability of, this field process.

The original habitat assessment matrix presented by Plafkin *et al.* (1989) is based on Ball (1982) and Platts *et al.* (1983). Although these still make up the primary foundation for the RBP habitat assessment matrix, additional sources were reviewed that provide information for refinement of the habitat assessment approach. A description of each of the parameters for the two categorical approaches is presented in more detail in Plafkin *et al.*

(1989) and Barbour and Stribling (in press). An explanation of the scoring procedures for performing a habitat assessment is provided in Plafkin *et al.* (1989).

TABLE 1 Parameters used in the assessment of habitat quality.

Riffle/Run Prevalence	Glide/Pool Prevalence
Primary - Substrate, In-stream cover, and Canopy	
• Substrate variety/in-stream cover	• Substrate variety/in-stream cover
• Embeddedness	• Bottom substrate characterization
• Flow or velocity and depth	• Pool variability
• Canopy cover (shading)	• Canopy cover (shading)
Secondary - Channel morphology	
• Channel alteration	• Channel alteration
• Bottom scouring and deposition	• Deposition
• Pool/riffle, run/bend ratio	• Channel sinuosity
• Lower bank channel capacity•	• Lower bank channel capacity
Tertiary - Riparian and bank structure	
• Upper bank stability	• Upper bank stability
• Bank vegetative stability (grazing/disruptive pressure)	• Bank vegetative stability (grazing/disruptive pressure)
• Streamside cover	• Streamside cover
• Riparian vegetative zone width	• Riparian vegetative zone width

CASE STUDIES

Case studies provide examples of the effectiveness of an integrated bioassessment and the application of this approach to detect impairment and possible sources in different regions of the country. Four case studies that resulted from national workshops on the rapid bioassessment protocols which use an integrated assessment of the benthic community and habitat quality evaluations are presented here. The first two case studies focus on the evaluation of non-point source pollutant effects. Results of a bioassessment conducted on the Trinity River, Texas, in May 1989, indicated that no substantial habitat limitations were present at any of the sampling stations. All stations were either classified as supporting of a well-balanced indigenous community or considered comparable to the reference condition (Fig. 3). The condition of the biological community was judged to be slightly impaired at all Trinity River stations. However, these results may be within the variability of the data. A more complete reference database might allow for this kind of discrimination. A similar non-point source evaluation was conducted on Rock Creek, Idaho, in September 1988, using the RBPs. As in Texas, no habitat limitations were detected (Fig. 4). However, the biological community at one station (S-3) was classified as moderately impaired, when compared to the reference (S-6). This level of biological condition is attributed to water quality effects.

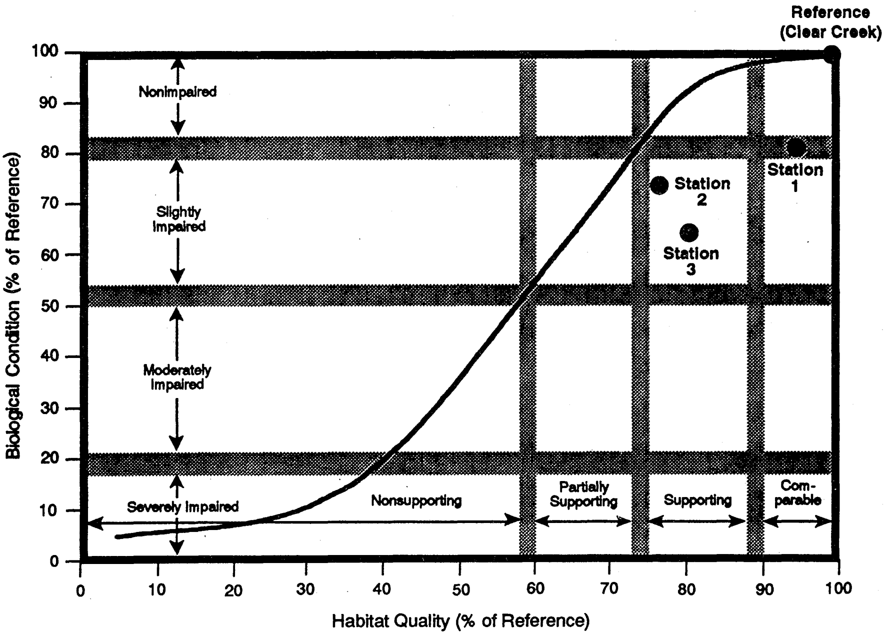

FIG. 3 Benthic bioassessment of the Trinity River, Texas.

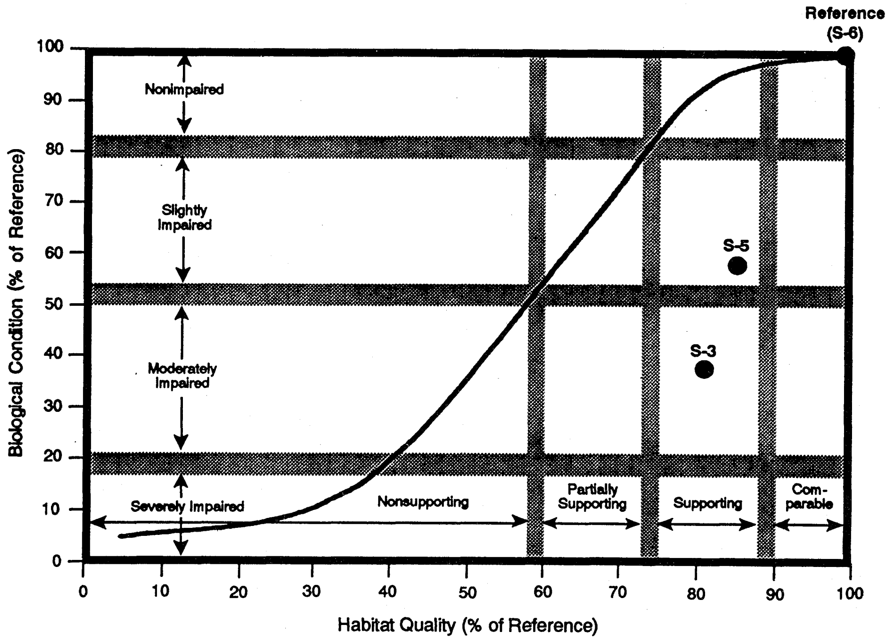

FIG. 4 Benthic bioassessment of Rock Creek, Idaho.

The assessment of a point source influence (WWTP) to Little Mill Creek, Kansas, indicated a highly degraded benthic community immediately downstream of the WWTP; but a recovery of the condition of the community was noted at station 3 located approximately

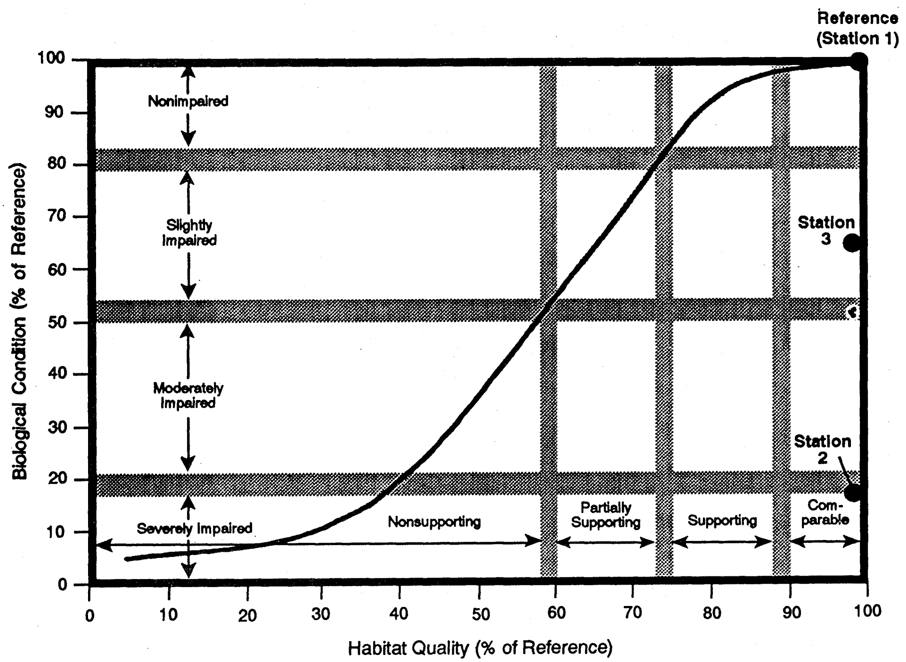

FIG. 5 Benthic bioassessment of Little Mill Creek, Kansas.

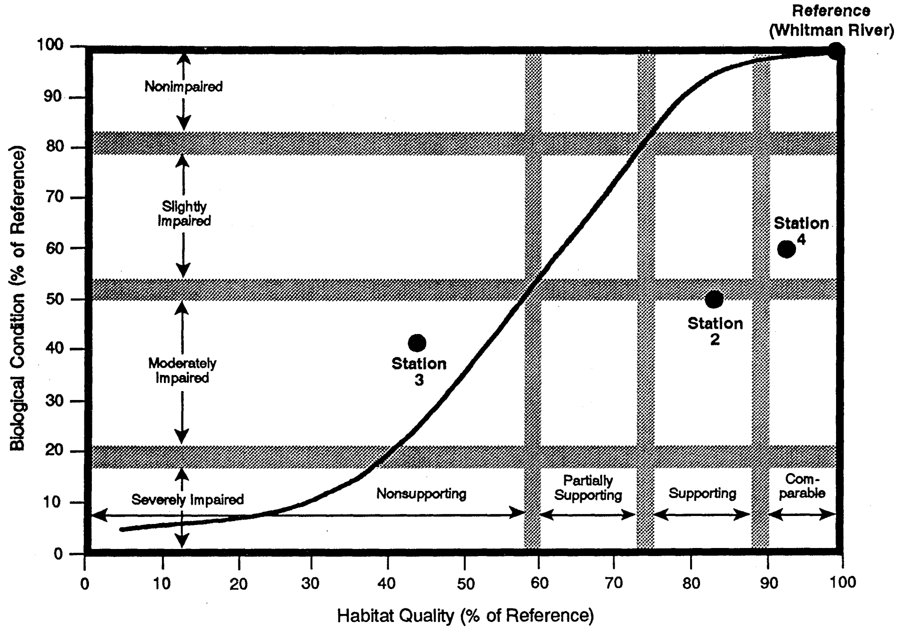

FIG. 6 Benthic bioassessment of North Nashua River, Massachusetts.

one mile downstream of the WWTP (Fig. 5). In this case study, the habitat quality was highly comparable among all stations because of a riparian protection program implemented in Johnson County, Kansas. The point source discharge being assessed on the North

Nashua River, Massachusetts, was a small paper mill and a WWTP. An additional complication at this site was the presence of urban runoff. A combination of habitat and water quality effects was noted from the bioassessment conducted in June 1989. Station 3 was influenced dramatically by a severe habitat degradation due to construction activities (Fig. 6). Station 2, located less than a half mile downstream of the paper mill and WWTP, was judged to be moderately impaired and having a supporting habitat quality. A recovery, both in terms of habitat quality and biological condition, was observed at station 4, located approximately six miles downstream of the point source discharges.

In all of these case studies, a knowledge of the variability to be expected in the relation between habitat quality and biological integrity (the condition or structure and function of the community) would enhance the interpretation of the results. The limitation in biological attainment that is imposed by habitat degradation is critical to the understanding of the potential of the biological system. In situations where habitat degradation occurs, the ability to mitigate or improve the habitat through stream restoration activities needs to be evaluated. The implementation of water quality improvements can be independent of the habitat quality, but judgment of the improvement in biological integrity cannot.

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REFERENCES

Ball, J. (1982) Stream Classification Guidelines for Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin. Wisconsin Department of Natural Resources, Madison, Wisconsin In: U.S.Environmental Protection Agency. 1983. *Water Quality Standards Handbook.* Office of Water Regulations and Standards, Washington, D.C.

Barbour, M.T., and Stribling, J.B. (In press) A habitat assessment approach for evaluating the biological integrity of stream communities, In: *Proc. of the National Biocriteria Symp.*, 12-13 December 1990, Crystal City, Virginia.

Cooper, J.E. (1984) Vanishing species: The dilemma of resources without price tags, In: *Threatened and Endangered Plants and Animals of Maryland*, (Norden, A.W., D.C. Forester, and G.H. Fenwick, eds.). Maryland Natural Heritage Program Special Publication **84-I**:7-32.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., & Hughes, R.M. (1989) *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish.* U.S. EPA, Office of Water. **EPA/444/4-89-001**, Washington, D.C.

Platts, W.S., Megahan,W.F. & Minshall, G.W. (1983) *Methods for Evaluating Stream, Riparian, and Biotic Conditions.* General Technical Report **INT-138**. U.S. Department of Agriculture, U.S. Forest Service, Ogden, Utah.

Price, P.W. (1975) *Insect Ecology.* John Wiley and Sons. New York, NY.

Smith, R.L. (1974) *Ecology and Field Biology.* Second edition. Harper and Row Publishers. New York, NY.

U.S. Environmental Protection Agency (1990) *Biological Criteria: National Program Guidance for Surface Waters.* Office of Water Regulations and Standards. **EPA-440/5-90-004**. Washington, D.C.