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Tiered Aquatic Life Uses and Comparison of Biological-based Attainment/Impairment Measures: Single vs. Multiple Tiers

Aquatic Life Use Attainment
Fact Sheet 1-CABB-03

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Tiered Aquatic Life Uses

Differences in Aquatic Life Use Attainment at Stream Stations in Ohio Between a Tiered vs. a Single Aquatic Life Use

Use Attainment Under A Tiered Use System with Biocriteria

Background

The Clean Water Act (CWA) has both the ultimate goal of achieving biological integrity and the interim goal promoting the propagation of fish and shellfish. Even under minimally impacted "reference" conditions the distribution of aquatic species varies with natural gradients of habitat and chemical conditions. As a result, it is clear that the potential of streams to support aquatic life varies with natural background conditions and along a gradient of human disturbance that is associated with the best use of the land by man.

> Biological Integrity: "The ability of an aquatic community to support and maintain a structural and functional performance comparable to the natural habits of a region." As modified from Karr and Dudley (1981)

To define what is attainable under a range of least impacted conditions in a state such as Ohio the concept of reference sites and biological integrity (see inset) have been instrumental in moving from a conceptual to a practical framework for setting aquatic life goals for streams To this end Ohio has adopted a series of aquatic life uses that represent a gradient of potential from that achieving the biological integrity goal of the CWA down to streams (Limited Resource Waters , LRW) that are ephemeral or otherwise physically limited to the extent that they do not harbor much more than a temporary assemblage of "pioneering" aquatic life adapted to rapidly colonizing essentially temporary habitats. The purpose of this fact sheet is to examine the consequences of using a tiered vs. a single aquatic life use on determining impairment for purposes such as 305(b) reporting. Other fact sheets will deal with comparisons between organism groups (Rankin 2003a draft) and between chemical criteria-based vs. biocriteria-based methods Rankin 2003b draft) for determining aquatic life use attainment and impairment.

Ohio's Biocriteria

Ohio has pioneered the use of numerical biocriteria to judge the attainment or impairment of CWA goals. Numerical biological criteria in Ohio (Appendix Figure 1) are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (ICI), which measures the response of the macroinvertebrate community.

Plate 1. Illustration of a typical Modified Warmwater Habitat (MWH) aquatic life use stream (top, Blues Creek in NW Ohio, by Brian Alsdorf) and an Exceptional Warmwater Habitat (EWH) stream in Ohio (Kokosing River central Ohio, by Marc Smith).

The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch et al. (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon et al. 1981). Performance expectations for the principal aquatic life uses in the Ohio WQS (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes et al. 1986; Omernik 1987). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981). Numerical endpoints are stratified by ecoregion, use designation, and stream or river size. These biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-14).

Three attainment status results are possible at each sampling location - Full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the Ohio WQS biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or, for WWH and EWH streams, one of the organism groups reflects poor or very poor performance.

Methods

The data used in this study is derived from Ohio's intensive survey studies, sampling of reference sites, and other miscellaneous studies. Absolute fish and macroinvertebrate station locations do not always match exactly, partly because fish data is collected along a transect of 150-500 depending on streams size while macroinvertebrate data, with the exception of a qualitative sampling of all available habitats, is a point sample where the sampling device was set (generally in flowing water of sufficient depth to ensure the device is underwater during the six week colonization period). A station identifier was created for each common study site in the Ohio database. Fish and/or macroinvertebrate sampling sites at the same or nearby sites were linked along with habitat (QHEI) data and water chemistry data sampled during the same summer period in the same year. Linking was done on a case-by-case basis to ensure that the effects of dischargers and other pollution sources, habitat, and confluences were similar among data types. Data for this study ranged from 1979 to 2001.

This document examines the effects of a tiered aquatic life use system by examining aquatic life use attainment status under the Ohio EPA current tiered used system (EWH, WWH, MWH) and then re-examining the same data under the scenario of a single WWH use for all streams using the existing WWH biocriteria appropriate for each ecoregion and stream size.

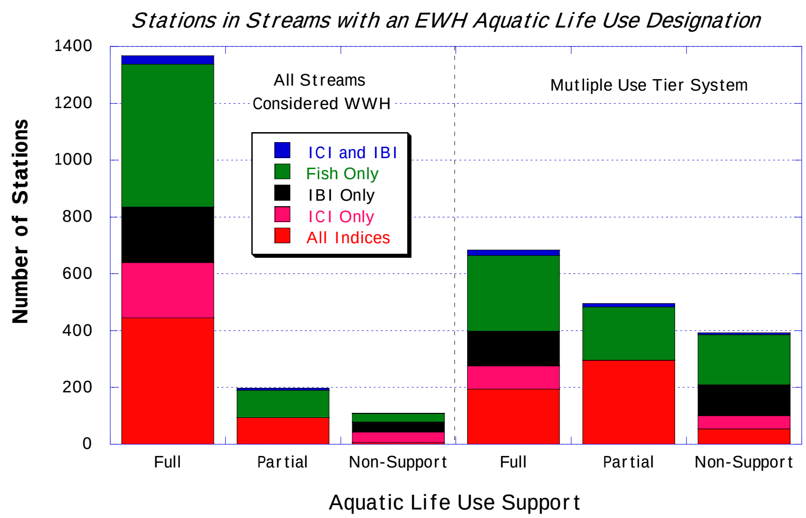
Results and Discussion

As expected the absence of a tiered aquatic life use system resulted in fewer impairments in EWH streams (Figure 1, top left) and a greater frequency of impairments for MWH streams (Figure 1, bottom left). For high quality EWH streams a single aquatic life use in Ohio would results in a change from 43.5% of stations attaining the aquatic life use to 81.2% of stations attaining these uses. This means for 305(b) and subsequent TMDL listing only 17.8% of stations would be considered impaired, compared to 56.5% of EWH sites under a tiered framework. MWH sites are "over-protected" under a single aquatic life use with nearly 46%

considered impaired in this scenario vs. only about 9% of stations considered impaired under a tiered use system. A visual inspection of the indices responsible for the attainment decisions shows no strong pattern with any particular index in this change (Figure 1). This indicates that tier uses based on a single organism group would likely show a similar pattern between single vs. multi-tiered uses.

It is clear that a tiered use system has had a substantial impact on Ohio's listing of waters for 305(b) and 303(d) lists. Reliance on a single aquatic life use would have resulted in many EWH streams not be listed as impaired under a single WWH use. This is a serious issue because the ultimate goal of the CWA is the restoration of the biological integrity of waters, and in Ohio the EWH aquatic life use is the closest to their goal. Most of the impacts to these waters are NPS in origin (Figure 3) and are restorable. In addition, the EWH waters are arguably those that provide the greatest "use" to the citizens of Ohio.

EWH streams are much more likely to be State Scenic Rivers than WWH streams and as such likely receive many more "visits" for recreation than WWH streams. Streams in Ohio proposed for protection under the State Resource Water (SRW) and Superior High Quality Water (SHQW) Antidegradation tiers are also more frequently EWH waters and support the largest populations of Ohio and Federal endangered, threatened and declining aquatic species in the state. Data from Ohio also indicate a strong association between populations of important sport fish (e.g., smallmouth bass) and important non game species and IBI and ICI scores in the EWH ranges. Figure 2 illustrates some of this data for fish species and IBI. For declining fish species (Figure 2a), smallmouth bass (Figure 2b) and total darter species (Figure 2f) the highest values of these are clearly attained at EWH IBI scores of 50 or higher. For two intolerant species, black redhorse and river chubs (Figure 2c,d), most sizable populations *only* occur in EWH sites. Creek chub, a tolerant species is illustrated for contrast (Figure 2e). This species actually reaches its high abundance at IBI scores generally associated with MWH or impaired waters (20-28, Figure 2e) and declines at better sites. This is just a small sampling of such relationships that exist in Ohio streams. Clearly, failure to list as impaired EWH streams and rivers with such high potential will lead to a loss of many valued ecological attributes and put Ohio further away from the biological integrity goal of the CWA. In Ohio, and we expect elsewhere as well, a failure to protect high tiers of streams may will result in a lack of focus on those high quality waters most used and beloved by the public.



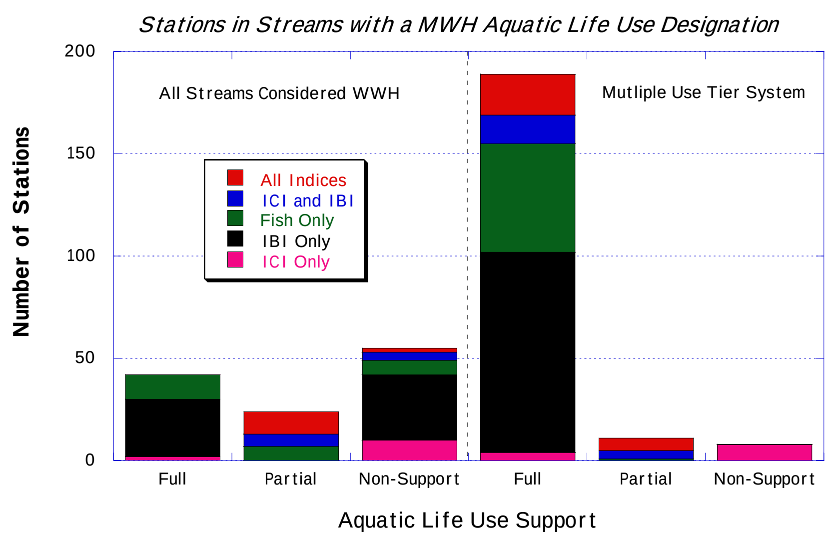


Figure 1 Aquatic life use attainment for streams currently designated by Ohio EPA as Exceptional Warmwater Habitat (EWH, Top) or Modified Warmwater Habitat (MWH, Bottom) under the existing scenario of tiered uses (right side) or assuming a single Warmwater Aquatic Life Use (WWH, left side). Attainment decisions based on average index values collected from Jun 15-Oct 15 and tiered biological criteria or WWH biological criteria for the appropriate stream size and ecoregion.

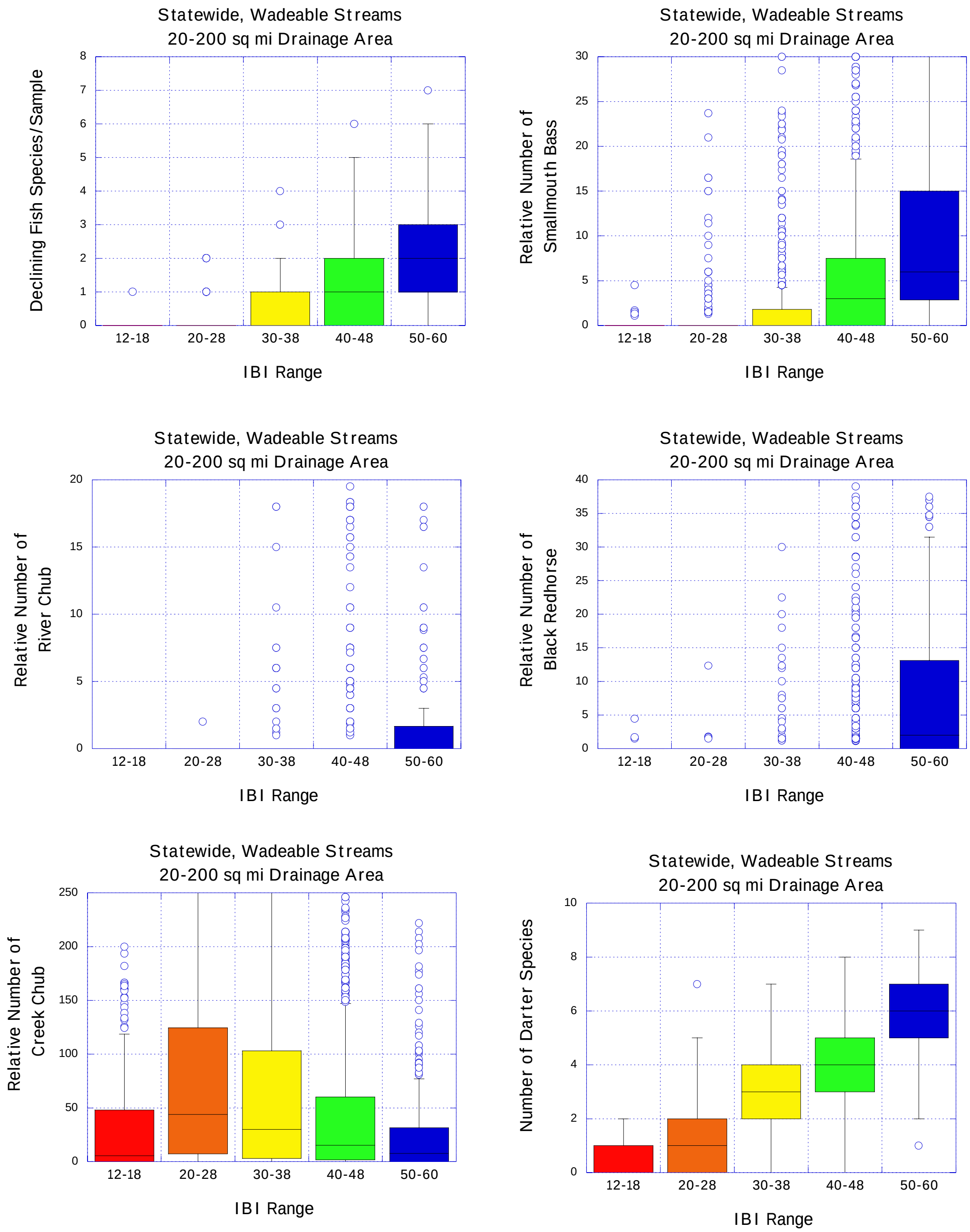


Figure 2. Box and whisker plots of selected "valued ecological attributes" for wadeable streams in Ohio by IBI range. IBI scores of 50-60 represent a general EWH range in Ohio and IBI scores in the 20 are associated with impaired WWH and EWH streams or approximate MWH ranges. Data from 4,059 sites collected from 1991-2002.

Antidegradation provisions of the CWA are not likely to be strong enough to ensure that all high quality waters will eventually achieve the biological goal of the Act. First, application of antidegradation policies across the U.S. are variable. Second, many activities that do not fall under regulatory provisions of the CWA (e.g., many aspects of agriculture for example) may not be protective of higher existing uses where these uses are not defined as a specific aquatic life use category. Third, “assimilative capacity” of streams can be “given away” with an antidegration view whereas an upper tier aquatic life use provides an inviolable floor. The antidegradatgion process is itself rooted in the point source lexicon of the CWA and may not apply to many impacts (e.g., habitat) unless directly linked to aquatic life uses via biocriteria or specific parts of the CWA (e.g., 401/404).

In contrast to EWH streams, MWH and LRW streams represent the other end of the spectrum of biological quality. Although it could be argued that since the ultimate goal of the CWA is biological integrity there is no “need” for a less stringent use, there are serious practical consequences to an increased listing of MWH waters as impaired under a single WWH use. The process and basis for determining that some waters cannot attain fishable goals is specified in the CWA although application of “Use Attainability Analyses (UAAs),” which have not been widely or consistently applied among States.

With limited resources for stream restoration activities, it may not make fiscal sense to expend resources on trying to restore streams to a level not attainable under current management practices that are 1) maintained by other government programs (e.g., drainage, flood control, public water supply), or 2) not likely or not feasible to be improved or changed over the next 20 or so years given present technology. A non-CWA aquatic life use should not result in lack of protection, but rather should represent a level of protection commensurate with physical limitations that define many of these waters. Ohio, for example, does list certain MWH and LRW waters as impaired. For MWH streams most toxicant water quality criteria still apply and ammonia and dissolved oxygen criteria (which are less stringent in these waters) reflect the tolerant organisms that are naturally adapted to physically harsh conditions. Even so, excessive organic enrichment and low dissolved oxygen, often worsened by extreme modifications of habitat, lowered flow regimes and excessive siltation are the major causes associated with impaired MWH waters in Ohio EPA’s 305(b) report (Figure 3). Thus MWH streams do not lack protection, rather this use permits application of criteria (biological and chemical) that appropriately protect the more tolerant assemblages in these waters and downstream uses.

Tiered Uses and Priority Setting

As discussed above tiered uses allow much more tailored management of waters related to their inherent and/or realistic potential. There are various ways of setting priorities for management and restoration of streams and these can vary depending on the goal of a management program. Often specific sections of a regulation may limit how waters can be prioritized. It is important that a water quality management agency or entity not become totally imprisoned by constraints of certain programs. The goals of the Clean Water Act provide broad objectives that should guide such agencies charged with carrying out the spirit and word of these programs.

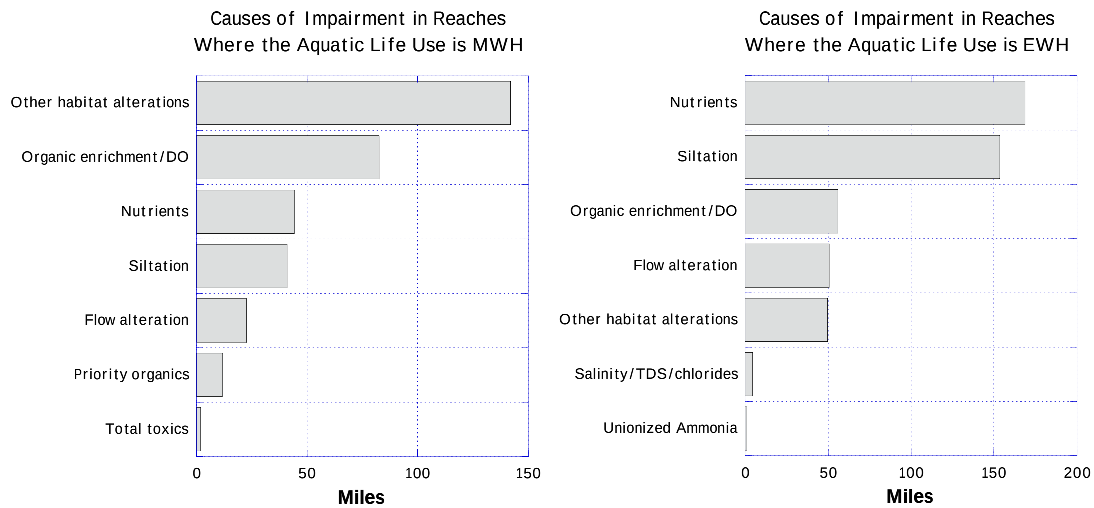


Figure 3. Causes of aquatic life impairment in MWH (left) and EWH (right) streams in Ohio based on data collected up to the year 2000 and in reaches where the data was still considered current (generally 1990s or later).

We argue that water quality management agencies should start with broad, technically sound priority setting process that focuses on the goals of the Clean Water Act. Various programs can share the sound scientific data that would form the foundation of this process and program constraints, resource issues, and political issues can be added later and should not influence the basic data used in the process.

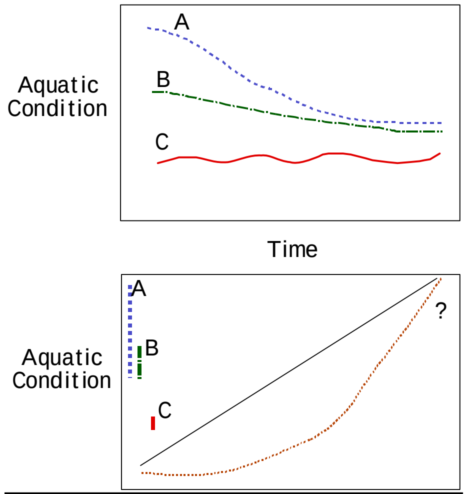


Figure 4. Hypothetical curves show examples of likely degradation over time of waters with no active protection programs (top) and hypothetic curves representing cost of restoration to various tiers of aquatic condition. A – EWH, B – WWH, C – MWH.

For aquatic life the goals of the CWA provide the broad focus on the protection and restoration of the biological, chemical, and physical integrity of surface waters. It is important that such goals be measureable and biological data and biocriteria provide and excellent way to quantify and accomplish this. To this end, we suggest that State look outward 10 to 20 years to create a vision for what the aquatic conditions of their surface waters should look like.

There are several categories of factors that need to be considered in setting priorities aside from the obvious and sometimes unpredictable political factors that are obviously important. We know from several large examples that restoration is much more expensive than protection (e.g., Kissamee River restoration project in Florida).

One way to consider this and other factors is to try to estimate what is called the "cost of inaction." Given several stream reaches or watersheds what would be lost in doing nothing for a period of say 10 years? Figure 4 illustrates three examples: a EWH stream near a growing city (A), a WWH stream in a similar situation (B), and a habitat degraded WWH stream in a heavily agricultural area (C). EWH streams are more sensitive than WWH streams and the same amount of stress will degrade a EWH stream (A) more than a WWH stream (B) because of the loss of sensitive and intolerant species. Example C is already degraded and aside from increased variation in stress from natural sources (drought, floods) the degradation remains similar along as the physical stress (i.e., channel maintenance) is maintained. At the end of a hypothetical 10 year time period we have accrued the large "cost of inaction" related to ignoring the EWH stream. We have lost little or nothing by ignoring the habitat degradation in situation C and relative more for scenario B. In scenario C simple reduction of channel maintenance would start the stream moving towards stream B without much cost at all. Scenario A is the most troubling because of (1) the high cost of restoration and (2) scientific questions about whether restoration is possible of very high quality streams under an urbanizing land use.

Inaction on high quality waters can have some important consequences for States related to TMDL listing issues and the setting of water quality goals through State WQS programs. Use attainability analyses can be performed to change use designation that can be shown to be unattainable because of very specific conditions (e.g., natural, hydromodifications, etc.). For human induced conditions, these are assumed to have occurred before 1975. The CWA protects all existing uses that can be documented to have existed after this date. Scenario A in Figure 4 can create a serious legal problem for states in that even a UAA will not allow the used to be changed to a lower tier since it was documented as being able to attain this higher use after 1975. This is as it should be, however, the failure to protect that use when costs were relatively low will leave the State with a costly or near impossible restoration scenario or an entrenched set of degraded waters.

Biocriteria and tiered uses allows States to quantify the biological parts of the scenarios discussed above. More detailed work on restoration costs along a biological disturbance gradient is needed to help make prioritization decisions. These costs or "costs of inaction" will vary by stressor types, land use, tiers, etc. It seems however, that such costs should be generated if we are to make sensible decisions about paths to follow in a quest to restoring biological integrity to our Nation's waters.

Practicality of Conducting Use Attainability Analyses

As illustrated in Figure 5, Ohio EPA has implemented an active program of conducting UAAs as part of their ongoing, routine intensive monitoring program. UAAs are conducted in waters where aquatic life uses were never validated with monitoring data or where data was collected prior to the creation of the MWH aquatic life use or where improving water quality conditions justify an upgrade to a higher or more stringent aquatic life use. This is compatible with the ultimate goal of moving waters to the biological integrity goal of the CWA and demonstrates that UAAs do not equate with a race to a general decline of biological condition in streams. In fact the *existing* uses of waters are protected as of 1975 as mandated in the CWA. This creates a powerful floor for protection of designated uses. This provision is only practical where monitoring data is collected to verify an existing use. States which lack such data may be vulnerable to loss of uses because a higher use has not been verified prior to an impact such as stream channelization, urbanization etc.

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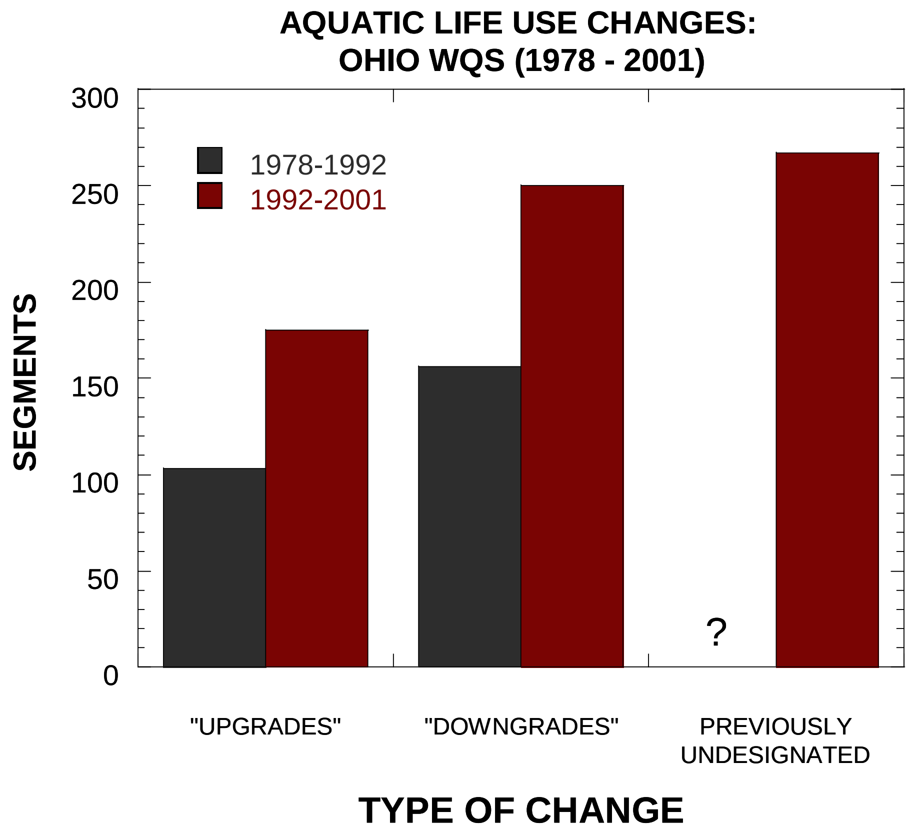

Figure 5 Summary of Aquatic life use changes based on Use Attainability Analyses (UAAs) in Ohio streams and river from 1978-1992 and from 1992-2001. Assignment of aquatic life uses to previously undesignated waters was not tracked during earlier period. Upgrades indicate changes from WWH to EWH or LRW to WWH; downgrades indicate WWH to MWH or LRW or EWH to WWH, MWH or LRW.

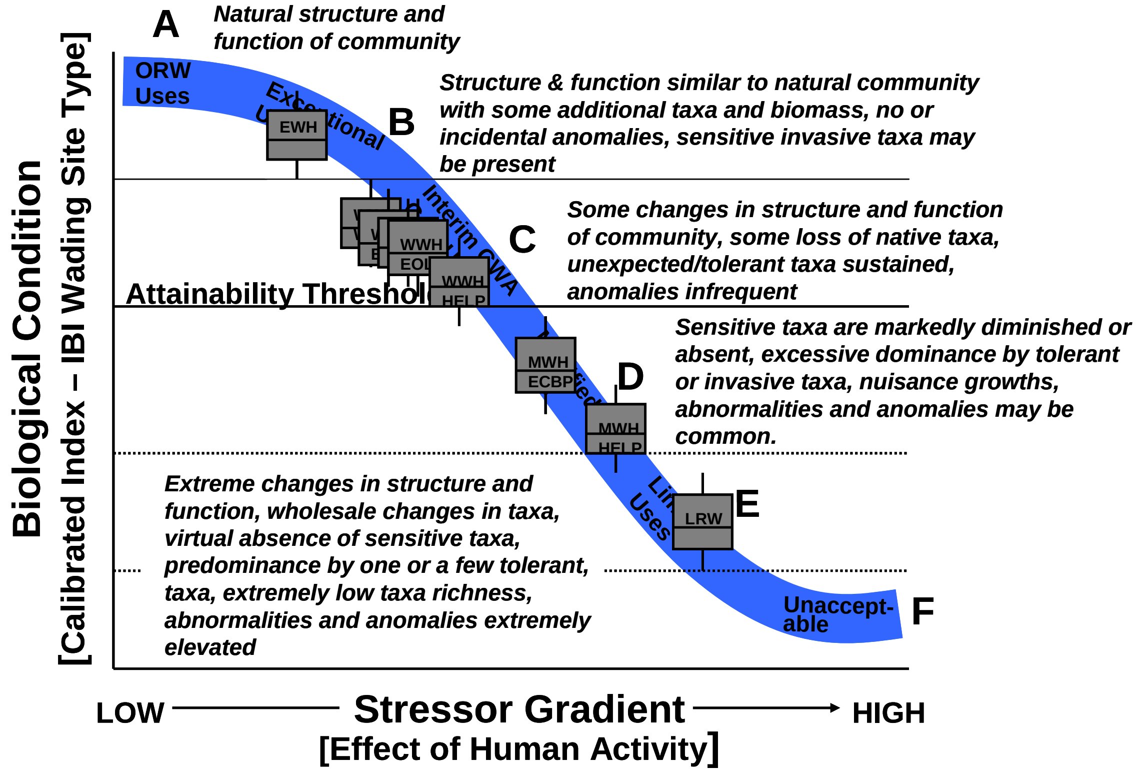

Figure 2 Summary of the theoretical Biological Condition Gradient (BCG) response to a human stressor gradient and how some of Ohio's tiered uses may fit along the gradient.

Conclusions
It is clear from these analyses, that for Ohio the implementation of a tiered use systems has provided both higher protection for high quality waters and more flexibility in addressing water quality management of MWH and LRW uses that are not considered to be attaining the basic fishable goal of the CWA. The tiered use system that Ohio EPA uses fits fairly well into the proposed Biological Condition Gradient (BCG) that has been proposed by a US EPA workgroup. One goal of the group is to consider consequences related to the implementation of tiered aquatic life uses by States and Tribes and of finding ways to promote consistency across the country in definitions of the BCG. Specifics will be expected to change between various ecosystems, however, general attributes of tiers and how the related to various definitions of natural, reference, and the fishable goal of the CWA should strive for common ground. An example of how some of Ohio's tiered aquatic life uses might fit into a draft of that gradient is illustrated in Figure 6.

It is clear that for most States where there is variation in natural landscape patterns and variation in long term anthropogenic changes, tiered uses directly linked to an adequate monitoring can provide both more protective and flexible pathways to the ultimate goal of sustainable biological integrity of the Nation's waters.

Summary
Tiered aquatic life uses have given Ohio the potential to develop an efficient template for restoring and protecting its aquatic life uses. With a single aquatic life use, Ohio would be under-protecting its high quality streams and over-protecting modified and limited resource streams. EWH streams comprise about 12.6% of named streams in Ohio and MWH streams comprise about 3.7% of named streams (Ohio EPA 2000). This is a substantial proportion of streams to be misclassifying in terms of listing for 305(b) and 303(d) and for expenditure of funds for restoration and protection.

The EWH aquatic life use would be considered to be above the floor that defines acceptable swimmable and fishable conditions related to 304(a) pollutants and water quality criteria. While a useful program, antidegradation does not provide as inviolable protection for high quality waters as does the EWH designation. EWH streams generally provide the "highest" use to the citizens of Ohio and contain fauna that could be greatly diminished if degraded to WWH levels.

MWH and lower aquatic life uses do not meeting the CWA swimmable-fishable goal and as such are considered temporary designations. In Ohio, this use has less stringent biocriteria as well as certain chemical criteria (e.g., dissolved oxygen and ammonia). Such streams may typically have less stringent nutrient criteria when they are derived. The long term goal for all waters of the U.S. is biological integrity. The hope is, at least for certain streams that technological advances may make it possible to achieve a higher use (e.g., use of natural stream restoration methods and development of a two-stage channel in modified streams).

References

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DeShon, J.D. 1995. Development and application of the invertebrate community index (ICI), pp. 217-243. in W.S. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Fausch, D.O., Karr, J.R. and P.R. Yant. 1984. Regional application of an index of biotic integrity based on stream fish communities. Trans. Amer. Fish. Soc. 113:39 55.

Gallant, A.L., T.R. Whittier, D.P. Larsen, J.M. Omernik, and R.M. Hughes. 1989. Regionalization as a tool for managing environmental resources. EPA/600/3 89/060. 152 pp.

Gammon, J.R. 1976. The fish populations of the middle 340 km of the Wabash River. Tech. Report No. 86. Purdue University. Water Resources Research Center, West Lafayette, Indiana. 73 pp.

Gammon, J.R., A. Spacie, J.L. Hamelink, and R.L. Kaesler. 1981. Role of electrofishing in assessing environmental quality of the Wabash River. pp. 307 324. In: Ecological assessments of effluent impacts on communities of indigenous aquatic organisms. ASTM STP 703, J.M. Bates and C.I. Weber (eds.). Philadelphia, PA.

Hughes, R. M., D. P. Larsen, and J. M. Omernik. 1986. Regional reference sites: a method for assessing stream pollution. Env. Mgmt. 10(5): 629 635.

Hughes, R.M. and D.P. Larsen. 1988. Ecoregions: an approach to surface water protection. J. Water Poll. Contr. Fed. 60(4):486 493.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 (6): 21 27.

Karr, J.R. and D.R. Dudley. 1981. Ecological perspective on water quality goals. Env. Mgmt. 5(1): 55 68.

Karr, J.R., K.D. Fausch, P.L. Angermier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Ill. Nat. Hist. Surv. Spec. Publ. 5. 28 pp.

Larsen, D.P., D.R. Dudley, and R.M. Hughes. 1988. A regional approach for assessing attainable surface water quality: an Ohio case study. J. Soil Water Cons. Soc. 43(2): 171 176.Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecological Assessment Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1989c. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1990. The use of biological criteria in the Ohio EPA surface water monitoring and assessment program. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

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

Yoder, C.O. and E.T. Rankin. 1995. Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. 1995. Policy issues and management applications for biological criteria, pp. 327-344. in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

Yoder, C.O. and E.T. Rankin. 1995. The role of biological criteria in water quality monitoring, assessment, and regulation. Environmental Regulation in Ohio: How to Cope With the Regulatory Jungle. Inst. of Business Law, Santa Monica, CA. 54 pp.

Yoder, C.O. and E.T. Rankin. 1996. Assessing the condition and status of aquatic life designated Uses in urban and suburban watersheds, pp. 201-226. in L.A. Roesner (ed.). Effects of Watershed Development and Management on Aquatic Ecosystems, American Society of Civil Engineers, New York, NY.

Rankin, E. T. 1995. The use of habitat assessments in water resource management programs, pp. 181-208 (Chapter 13). in W. Davis and T. Simon (eds.). Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Publishers, Boca Raton, FL.

U. S. EPA. 1997a. Guidelines for preparation of the comprehensive state water quality assessments (305(B) reports) and electronic updates: Report Contents. USEPA, Office of Water, EPA-841-B-97-002A, Washington DC.

U. S. EPA. 1997b. Guidelines for preparation of the comprehensive state water quality assessments (305(B) reports) and electronic updates: Supplement. USEPA, Office of Water, EPA-841-B-97-002A, Washington DC.

B. A. Bohn and J. L. Kershner
2002. Establishing aquatic restoration priorities using a watershed approach. Journal of Environmental Management 64: 000–000 (to be published in May)
Abstract: Since the passage of the Clean Water Act in 1972, the United States has made great strides to reduce the threats to its rivers, lakes, and wetlands from pollution. However, despite our obvious successes, nearly half of the nation's surface water resources remain incapable of supporting basic aquatic values or maintaining water quality adequate for recreational swimming. The Clean Water Act established a significant federal presence in water quality regulation by controlling point and non-point sources of pollution. Point-sources of pollution were the major emphasis of the Act, but Section 208 specifically addressed non-point sources of pollution and designated silviculture and livestock grazing as sources of non-point pollution. Non-point source pollutants include runoff from agriculture, municipalities, timber harvesting, mining, and livestock grazing. Non-point source pollution now accounts for more than half of the United States water quality impairments. To successfully improve water quality, restoration practitioners must start with an understanding of what ecosystem processes are operating in the watershed and how they have been affected by outside variables. A watershed-based analysis template developed in the Pacific Northwest can be a valuable aid in developing that level of understanding. The watershed analysis technique identifies four ecosystem scales useful to identify stream restoration priorities: region, basin, watershed, and site. The watershed analysis technique is based on a set of technically rigorous and defensible procedures designed to provide information on what processes are active at the watershed scale, how those processes are distributed in time and space. They help describe what the current upland and riparian conditions of the watershed are and how these conditions in turn influence aquatic habitat and other beneficial uses. The analysis is organized as a set of six steps that direct an interdisciplinary team of specialists to examine the biotic and abiotic processes influencing aquatic habitat and species abundance. This process helps develop an understanding of the watershed within the context of the larger ecosystem. The understanding gained can then be used to identify and prioritize aquatic restoration activities at the appropriate temporal and spatial scale. The watershed approach prevents relying solely on site-level information, a common problem with historic restoration efforts. When the watershed analysis process was used in the Whitefish Mountains of northwest Montana, natural resource professionals were able to determine the dominant habitat forming processes important for native fishes and use that information to prioritize, plan, and implement the appropriate restoration activities at the watershed scale. Despite considerable investments of time and resources needed to complete an analysis at the watershed scale, the results can prevent the misdiagnosis of aquatic problems and help ensure that the objectives of aquatic restoration will be met.
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Horan, D.L., J.L. Kershner, C.P. Hawkins, and T.A. Crowl.
2000. Effects of habitat area and complexity on Colorado River cutthroat trout density in Uinta mountain streams. Transactions of the American Fisheries Society. 129: 1250-12

Hilderbrand, R.H. and J.L. Kershner. 2000. Movement patterns of stream-resident cutthroat trout in Beaver Creek, Idaho-Utah. Transactions of the American Fisheries Society: 129:1160-1170.

Henderson, R.C., J.L. Kershner, and C.A. Toline. 2001. Timing and location of spawning of non-native wild rainbow trout and native cutthroat trout in the South Fork Snake River, Idaho, with implications for hybridization. North American Journal of Fisheries Management 20: 584-596.

Bragg, D.C.; Kershner, J.L.; Roberts, D.W. 2000. Modeling large woody debris recruitment for small streams of the central Rocky Mountains. General Technical Report RMRS-GTR-55. Ft. Collins, CO. USDA Forest Service, Rocky Mountain Research Station. 36p.

Hilderbrand, R.H. and J.L. Kershner. 2000. Conserving inland cutthroat trout in small streams: how much stream is enough? North American Journal of Fisheries Management 30:513-520.

Streams change predictably from the headwaters to the mouth. Degradation alters those natural patterns and dynamics. Conditions at any particular point in the system reflect effects accumulated from all upstream parts of the watershed. (In some instances, as in the case of the lower Chinook, downstream or mains tern effects can also have significant impacts on a particular tributary reach.) Stream systems are intimately linked with the uplands in the headwater portions of the stream network. These linkages include ephemeral and intermittent stream channels, riparian zones, and adjacent hill slopes,

The suite of unique habitat types that occur in the watershed over time are the result of alternating transport and storage of sediment and organic matter from the hill slopes. The focus is on balance. The uplands cannot deliver more sediment to stream channels than streamflow can move through the system in a natural manner without disrupting the stream habitats within the watershed. The movement of sediment through the basin can be viewed as part of watershed "digestion": Sediment and food resources move from the hill slopes through the tributary streams and valley floors, eventually passing downstream through the mainstem.

Restoration priorities must be informed by an understanding of the salmon life-histories expressed in the basin now, and how these life-histories are linked with the current watershed conditions. As the name implies, a life-history strategy' is a plan, or strategy, that a group of fish share during their lifetime. A coho life history strategy in the Chinook river might include these instructions: (1) Remain in a particular pool in the Chinook River for approximately 18 months and then (2) migrate into the ocean in April and (3) travel to the west side of Vancouver Island. (4) Return to the Chinook River during September when 3 years old. (5) Spawn in November in the riffle above the pool it was born in. The general life-histories of the dominant salmon stocks in the Chinook basin are given on page 14. The stream habitat dictates which early life-history stages will be successful. Also, it is helpful to reconstruct the life histories historically present in the basin, audio understand how they were linked with watershed conditions. It is necessary to understand past and present life histories to set restoration priorities.

Strategic understanding and planning is as important as tactical understanding and planning. Put another way, being able to see a situation nested in its broader context is as important as analyzing parts of the situation. For example, knowing how each particular pool type (for example, a lateral scour pool) is constructed and maintained is important, but equally important is understanding how lateral scour pools fit within the distribution of other pool types within the basin, and how such pools are distributed spatially in natural and degraded watersheds.

Evaluation is central. Without it, the most carefully era fled restoration actions may actually speed watershed degradation. We need to evaluate components of the watershed for decades to make sure that changes are desirable and consistent with restoration objectives. Project goals must be examined and re-examined. Are the goals realistic, and are they ecologically sound?

Beschta, R.L. 1996. "Restoration of Riparian and Aquatic Systems for Improved Fisheries Habitat in the Upper Columbia" In: Strouder, Bisson, and Naiman, eds. Pacific Salmon and their Ecosystems. New York: Chapman and Hill.

Doppelt, R. et al. 1993. Entering the Watershed. Washington D.C.: Island Press.

Doppelt, R. et al 1993 (#l); Reeves, G. and J.R. Sedell. 1992. "An ecosystem approach to the conservation and management of freshwater habitat for anadromous salmonids in the Pacific Northwest." Trans. 57th Wildlife and Natural Resource Conference, WA.

Flagg, T.A., F.W. Waknitz, DJ. Maynard, G.B. Milner and C.V.N. Mahkhe. 1995. "The effect of hatcheries on native coho salmon populations in the lower Columbia River" Symposium 15, Uses and Effects of Cultured Fishes in Aquatic Ecosystems, Bethesda, MD: American Fisheries Society.

Frissell, C.A. and D. Bayles. 1996. "Ecosystem management and the conservation of aquatic biodiversity and ecological integrity" /. Am. Water Res. Assoc. 32(2): 229-240.

Gregory, S. and P. Bisson. 1996. "Degradation and loss of anadromous salmonid habitat in the Pacific Northwest" In: Stouder, DJ., P.A. Bisson, and R.J. Naiman, ed. Pacific Salmon and their Ecosystems.
New York: Chapman & Hill.

Independent Scienctific Advisory Group. 1996. Return to the River: Restoration of Salmonid Fishes in the Columbia River Basin. Draft. Oregon:
Northwest Power Planning Council.

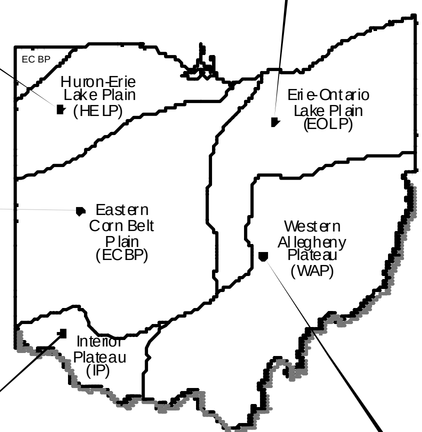
Stone, L. 1879. Report of operations at the salmon-hatching station on the Clackamas River, Oregon in 1877. Report of the Commissioner for 1877. Washington, D.C.: US Commission of Fish and Fisheries: Part II in Part 5.

Huron Erie Lake Plain (HELP)

Use	Size	IBI	MIwb	ICI
WWH	H	28	NA	34
	W	32	7.3	34
	B	34	8.6	34
MWH-C	H	20	NA	22
	W	22	5.6	22
	B	20	5.7	22
MWH-I	B	30	5.7	NA

Erie Ontario Lake Plain (EOLP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	34
	W	38	7.9	34
	B	40	8.7	34
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA



Eastern Corn Belt Plain (ECBP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	36
	W	40	8.3	36
	B	42	8.5	36
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Interior Plateau (IP)

Use	Size	IBI	MIwb	ICI
WWH	H	40	NA	30
	W	40	8.1	30
	B	38	8.7	30
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-I	B	30	6.6	NA

Western Allegheny Pleateau (WAP)

Use	Size	IBI	MIwb	ICI
WWH	H	44	NA	34
	W	44	8.4	34
	B	40	8.6	34
MWH-C	H	24	NA	22
	W	24	6.2	22
	B	24	5.8	22
MWH-A	H	24	NA	30
	W	24	5.5	30
	B	24	5.5	30
MWH-I	B	30	6.6	NA

Statewide Exceptional Warmwater Habitat (EWH) Biocriteria

Use	Size	IBI	MIwb	ICI
EWH	H	50	NA	46
	W	50	9.4	46
	B	48	9.6	46

Map 1. Ohio Biocriteria.