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The Qualitative Habitat Evaluation Index [QHEI]: Rationale, Methods, and Application

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Introduction

The presence and abundance of stream fishes is strongly related to the physical and chemical characteristics of a stream (Gorman and Karr 1978; Schlosser 1982). With changes in nutrients and habitat, changes such as those that occur with increasing stream size, obvious shifts in fish community structure and function occur (e.g., River continuum concept: Vannote et al. 1980; Minshall et al. 1985) . Although these changes in stream systems are often viewed as gradual or forming a "continuum", in reality there can often be much variability in local lithology and stream morphology that can affect fish communities (Minshall et al. 1985). Such variability has been increased by human activities; channel dredging and agricultural modification of watersheds can alter nutrient cycling patterns, and, in turn, fish community structure. If such altered streams enter more natural watersheds (e.g., wooded) they often regain more natural habitat and chemical characteristics (Marsh and Luey 1982). Much of the degradation observed in fish communities related to habitat disturbance is strongly influenced by the extent of modifications. As the extent of modifications increase the probability of local extinctions increase and a more disturbed community results.

Regulatory activities under the Federal Water Pollution Control Act of 1972 and its 1977 and 1987 amendments require knowledge of the potential fish or biological community that can be supported in a stream or river (termed aquatic life "use designations") for setting "benchmarks" of community expectations to compare against actual instream performance.[1] A procedure for relating stream potential to habitat quality would provide some insight into how habitat might affect biological expectations in a given waterbody.

To help with this problem we have developed an index of macro-habitat quality, the Qualitative Habitat Evaluation Index (QHEI). This index is designed to provide a measure of habitat that generally corresponds to those physical factors that affect fish communities and which are generally important to other aquatic life (e.g., invertebrates). The QHEI was developed within several constraints associated with the practicalities of conducting a large-scale monitoring program, i.e., we desired to construct an index that would work reliably for our purposes yet require few additional resources to use. Specifically, (1) the index needed to be easy to record in a minimal amount of time and with a minimum of field measurements, (2) the index should take advantage of the field experience of our field biologists (indeed, it was the realization that the subjective habitat evaluations of our

[1]In actual practice few States measure aquatic community performance directly but rely on chemical surrogates to measure performance. See OhioEPA (1987a) for shortfalls of this approach *alone*.

staff were often quite accurate which spurred development of this index), (3) the index should include all of the important variables that could influence fish communities (maximize explanatory power of index), (4) the index should have acceptable reproducibility among different workers, and 5) obviously, the index needed to be useful enough to separate the relative effects of habitat vs water quality on fish community structure or at a minimum determine the baseline community that could be expected in a particular habitat. The index is based on six interrelated metrics: substrate, instream cover, channel morphology, riparian and bank condition, pool and riffle quality, and gradient. These attributes have been shown to be correlated with stream fish communities (Table 1).

This document discusses (1) the relationship between the QHEI and its metrics with the IBI in minimally impacted (by chemical water quality) stream reaches in Ohio, (2) the importance of basin and subbasin landuse and stream modification and the limiting effects of "average" habitat conditions on the QHEI as a predictive tool, (3) guidelines for use of the QHEI for determining aquatic life use designations of flowing waters, and (4) the variability that can be expected in the calculation of the QHEI by different biologists.

Table 1. Literature citations describing correlations between fish communities or populations and the physical factors used as metrics in the QHEI.

Metric	Citation
General	Gorman and Karr (1978), Schlosser (1982a), Platts *et al.* (1983), Karr et al. (1983a)
Substrate	Lyons *et al.* (1988), Berkman and Rabeni (1987)
Cover	Angermeier and Karr (1984), Benke *et al.* (1984, 1985), Marzolf (1978)
Stream Channel	Griswold *et al.* (1978), Portt *et al.* (1986), Trautman (1939), Trautman and Gartman (1974), Schlosser (1982a,b)
Riparian Quality	Schlosser and Karr (1981), Dudley and Karr (1977), Karr and Schlosser (1977)
Pool/Riffle Quality	Schlosser (1982a; 1987),
Gradient	Trautman (1941; 1981), Hocutt and Stauffer (1975),

Background

Physical habitat in streams has been measured and quantified by a multitude of workers; however, for our purposes the methodologies are either too time consuming and costly (e.g. Habitat Suitability Indices; Terrell 1984 or Habitat Quality Index; Binns and Eiserman 1979) or do not encompass a wide enough range of physical attributes (Habitat Diversity Index; Karr and Gorman 1979). The QHEI is composed of an array of metrics that describe attributes of physical habitat that may be important in explaining the species presence, absence, and composition of fish communities in a stream. We envision the QHEI filling a gap between completely subjective habitat descriptions and more labor intensive Habitat Suitability Indices developed for each species in a fish community. Although it may not have the resolution to predict the abundance of each individual species in a stream, it should be useful in explaining shifts in the general composition and ecological function of lotic fish communities. This paper will primarily present data on the most recent form of the QHEI (OhioEPA 1989). Some reference will be made to an older form of the QHEI which is compared to the current form in Table 2 (see Ohio EPA 1989a); these references will generally explain the rationale for changes to the original structure of the QHEI. For convenience sake the current index will be referred to as the QHEI and the past effort the "Old" QHEI.

Scale

The influence of habitat on biological organisms and communities can be examined from several scales depending on an investigators purpose. The QHEI is a macro-scale approach that measures emergent properties of habitat (sinuosity, pool/riffle development) rather than the individual factors that shape these characters (current velocity, depth, substrate size).

Scoring

The field procedures and scoring criteria for the QHEI are described in Ohio EPA (1989). The field sheet for the QHEI consists of lists of qualitative descriptors that are checked as appropriate. Highest scores were assigned to the habitat parameters that have been shown to be correlated with streams that have high biological diversity and biological integrity with progressively lower scores assigned to less desirable habitat features. For example, the widest riparian width, > 50m, was assigned a 4 and narrower categories of riparian width were assigned progressively lower scores down to a score of zero for no riparian vegetation.

Table 2. Metrics and scoring ranges for the old version and the new version of the QHEI.

"Old " QHEI		"New" QHEI	
Substrate	15 pts	*Substrate*	20 pts
1) Type	2-14	1) Type	0-20
2) Quality	-2-2	2) Quality	-5-3
Instream Cover	15 pts	*Instream Cover*	20 pts
1) Type	0-8	1) Type	0-9
2) Amount	1-7	2) Amount	1-11
Channel Quality	15 pts	*Channel Quality*	20 pts
1) Sinuosity	1-4	1) Sinuosity	1-4
2) Development	1-4	2) Development	1-7
3) Channelization	1-4	3) Channelization	1-6
4) Stability	1-3	4) Stability	1-3
Riparian/Erosion	15 pts	*Riparian/Erosion*	10 pts
1) Width	0-5	1) Width	0-4
2) Floodplain Quality	1-5	2) Floodplain Quality	0-3
3) Bank Erosion	1-5	3) Bank Erosion	1-3
Pool/Riffle	15 pts	*Pool Riffle*	20 pts
1) Max. Depth	0-3	1) Max Depth	0-6
2) Cover Quality	0-3	2) --	- -
3) Current Available	-2-4	3) Current Available	-2-4
4) Pool Morphology	0-2	4) Pool Morphology	0-2
5) Riffle/Run Depth	1-3	5) Riffle/Run Depth	0-4
6) Riffle Substrate Stability	0-1	6) Riffle Substrate Stab.	0-2
7) Riffle Embeddedness	0-1	7) Riffle Embeddedness	-1-2
Drainage Area	0-15 pts	*Drainage Area*	*Not included*
Gradient	0-10 pts	*Gradient*	0-10 pts
Total Score	0-100 pts.	Total Score	0-100 pts.

Methods

Three groups of data were used to examine the behavior of the QHEI, (1) data from streams throughout Ohio that represent sites minimally impacted by chemical water quality or habitat ["warmwater" reference sites], (2) sites from streams that contain areas that have relatively unimpacted chemical water quality but have documented habitat impacts ["modified" reference sites], and (3) examples from within stream basins where we have used the QHEI in some water quality management decision. Data in groups one and two are the same that were used to generate Ohio's biocriteria; their selection and use is described in OhioEPA (1987b). All sites were sampled with one of three electrofishing methods (see OhioEPA 1989) which is based on the size and characteristics of the stream or river[2]. Data here are analyzed by site types: headwater sites (< 20 sq mi drainage area), wading sites (20-554 sq mi drainage area), and boat sites (90-6471 sq miles drainage area). A QHEI was calculated over the exact length of stream that was sampled by electrofishing: 150-200 m for headwater and wading sites and 500 m for boat sites. Calculation of the Index of Biotic Integrity (IBI) is explained in detail in Karr (1981), Karr *et al.* (1986), and OhioEPA(1987b). Some analyses were done by ecoregion. Descriptions of Ohio ecoregions and the rationale for their influence in Ohio is found in Whittier *et al.* (1987) and Ohio EPA (1989b,c).

Statistical Analysis

The influence of habitat data on stream fish communities was examined with simple linear and exponential regressions and frequency analyses of combined and individual components of QHEI metrics in relation to the IBI. Chi-square was used, by site type, to determine whether the frequency of sites with a given habitat characteristic in an IBI range differed substantially from the hypothetical population frequency based on the IBI distribution at all sites. Where expected frequencies were less than 5 for an IBI range they were combined with the adjacent IBI range. Data was insufficient to calculate chi-square by ecoregion within site types, however, ecoregions are distinguished on frequency plots. All tests were considered statistically significant at $P > 0.05$.

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[2]Boat and wading sites overlap somewhat in drainage area range because stream depth and other habitat features dictate the type of equipment that can be used. These features vary with physiography in Ohio (e.g., very deep streams with small drainage areas.that must be sampled with boats in WAP).