Fact Sheet

Associations Between the Index of Biotic Integrity and Unionized Ammonia in Ohio Rivers and Streams: A Preliminary Analysis

The main purpose of an aquatic life-based chemical criterion is to protect the aquatic life of a stream, river, or lake in accordance with the goal of the designated use. Biocriteria are a direct measure of the aquatic community and as such represent a direct measure of designated aquatic life use attainment status. Having biocriteria provides the Ohio EPA with a unique method to examine whether existing and proposed chemical criteria are over or under-protective of designated aquatic life uses. Previous studies have attempted to evaluate chemical water quality criteria for certain parameters, such as heavy metals, by comparing instream concentrations with different measures of aquatic community health and well-being. However, no study yet has utilized a fully calibrated and standardized system of biological criteria and a statewide chemical water quality and biological database for this purpose.

Many studies have shown the toxic effects of unionized ammonia on aquatic macroinvertebrates and fish. In many instances in Ohio, negative effects to aquatic life have been strongly associated with exceedances of the Ohio EPA water quality criteria for unionized ammonia. Reductions in loadings of ammonia discharged from point sources has been observed throughout Ohio to be a key in the recovery of previously impaired aquatic life uses. While ammonia was a major cause of impairment in more than 1100 miles of rivers and streams in the 1988 Ohio Water Resource Inventory (305[b] report), this figure had shrunk to 150 miles by 1996.

The purpose of this fact sheet is to examine the association between one of the biological indices which comprises the Ohio EPA biological criteria, the IBI, and unionized ammonia to determine above which ammonia concentrations is aquatic life at risk. A scatter plot of unionized ammonia based on grab samples collected from Ohio rivers and streams versus the IBI yields a "wedge" of data points (Figure 1). The outer, sloped surface of points approximates the maximum concentrations that have been observed to coincide with a given level of aquatic community performance as portrayed by the IBI. A line drawn on the outer surface of the data points so that 95% of the points fall to the left or beneath the line is referred to as the "95% line of best fit." In the IBI and unionized ammonia example this represents the typically occurring maximum unionized ammonia concentrations at which a corresponding IBI value exists in the statewide database. Chi-square tests of independence were used to test whether or not the occurence of IBI scores are independent of unionized ammonia concentrations at the same sites. If the IBI is independent of the ammonia concentrations, then we can conclude that ambient concentrations of ammonia are not strongly affecting the IBI or the relationship is obscured by other environmental factors. If however, IBI and ammonia are statistically correlated, further analysis to determine the concentrations of unionized ammonia at which a reasonable risk of harm to aquatic life exists should take place.

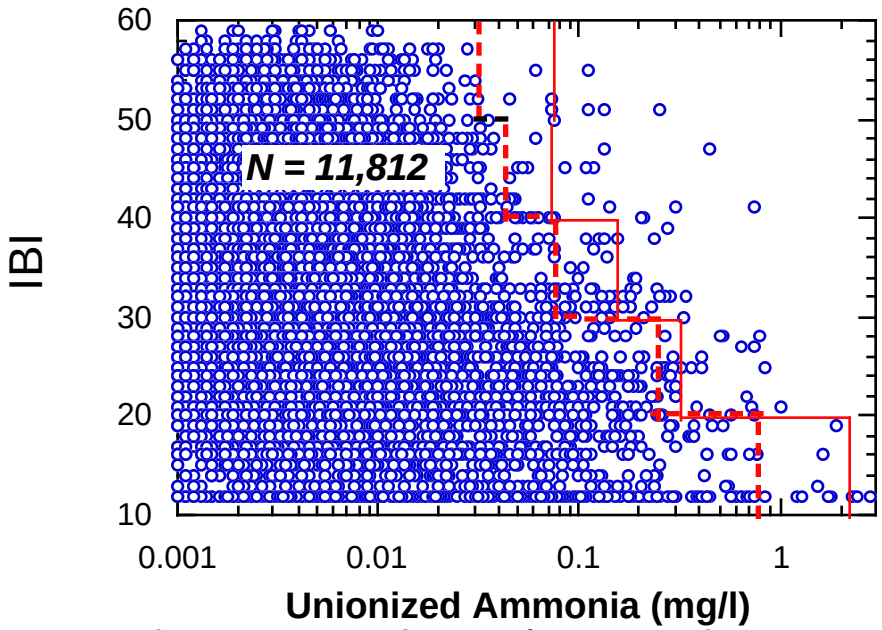

Figure 1. The IBI versus unionized ammonia from streams and rivers monitored by Ohio EPA between 1982 and 1994.

An alternative to generating a "continuous" 95th percentile regression line is to focus more on identifying outliers and extreme values (extreme percentiles) that represent an unacceptable risk to aquatic life. The method to identify outliers and extremes in the data is to cluster the distribution of the independent variable by ranges of IBI scores that correspond to narrative ratings of quality (*e.g.*, exceptional, good, fair, poor, very poor) and the tiered system of aquatic life use designations employed by Ohio EPA. The upper tenth percentile of the parameter concentration in each IBI category is used to identify the outliers and extremes in each distribution because the biological results at these sites are most likely affected by concentrations of that parameter. Box-and-whisker plots and percentile plots are then used to illustrate the

Table 1. Chi-square test of association between the IBI and unionized ammonia based on data collected in Ohio streams between 1982 and 1994 showing actual and expected (in parentheses) observations.

	Un-Ionized Ammonia (mg/l)				
IBI Range	<0.01	0.01-0.05	0.05-0.10	0.10-0.50	> 0.5
50-60	944 (815)	60 (148)	4 (22)	4 (23)	0 (3.3)
40-49	2464 (2203)	251 (401)	12 (61)	9 (63)	1 (9.0)
30-39	2912 (2765)	449 (504)	38 (76)	36 (79)	0 (11.3)
20-29	2377 (2583)	609 (471)	108 (71)	105 (73)	10 (10.6)
12-19	812 (1142)	363 (208)	100 (31)	116 (32)	28 (4.7)

$X^2 = 1135$; $P < 0.0001$

upper, empirically observed values for the independent variable compared to the narrative ranges of the IBI. Outliers in the data are those points that are greater than the upper quartile (UQ: 75th percentile) plus 1.5 times the interquartile range (distance between the 25th and 75th percentiles: UQ - LQ). The other statistic used to describe extreme values is the 99.5th percentile of all the data in an IBI category (illustrated as the 95th percentile of the upper 10 percent of the data in Figure 2). Where such data is strongly skewed the 99.5th percentile can be greater than the "maximum" value where outliers are excluded.

The ranges described above and illustrated in Figure 1 and

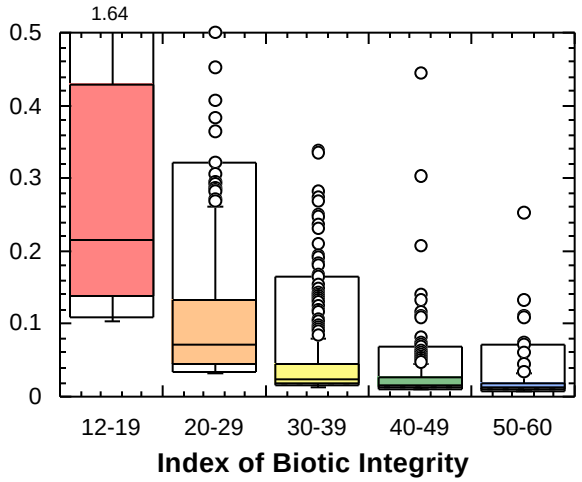

Figure 2. Box-and-whisker and percentile plot of the IBI versus unionized ammonia from streams and rivers monitored by Ohio EPA between 1982 and 1994. Data represent the upper ten percent of the unionized ammonia values within each IBI range. Shaded boxes represent the 25th, median, and 75th percentiles; open boxes the 5th and 95th percentiles; whiskers are the maximum and minimum values excluding outliers which are values greater than the upper (or lower) quartile plus (or minus) 1.5 times the interquartile range.

Table 2 can be used in a risk management approach for establishing water quality criteria, NPDES permit limits, or other water quality managment objectives. Water quality criteria which result in ambient unionized ammonia concentrations in the range of the maximum value, excluding outliers (upper whisker on the plot), and the 99.5th percentile values would be considered to pose an unacceptably high risk to aquatic life and, thus, a lower value should be chosen.

The scatterplot of unionized ammonia showed a well defined outer boudnary of data points which suggests a strong association with the IBI. The chi-square analysis confirms this association as highly significant (Table1). There were fewer sites that had IBI values >40 (good or WWH) and unionized ammonia concentrations >0.05 than expected (if there were no association) and more sites with low IBI values <30 (fair, reflects impairment) and unionized ammonia concentrations >0.05 than expected. The values listed in Table 2 can be used to validate water quality criteria derived by the traditional toxicological approaches. Tiered water quality criteria which correspond to the aquatic life uses developed by Ohio EPA have already been established. Other uses of the results presented here could include site-specific applications of the ammonia criteria in combination with the biological criteria. This would be most applicable where instream concentrations exceed the values in Table 2.

Table 2. Maximum unionized ammonia concentrations (excluding outliers) and 99.5th percentile unionized ammonia values by IBI narrative ranges and corresponding aquatic life uses.

Narrative Range	IBI Range	99.5th %tile Unionized Ammonia	Max. Unionized Ammonia
Exceptional (EWH)	50-60	0.073	0.031
Good (WWH[1])	40-49	0.070	0.045
Fair (WWH[2])	30-39	0.162	0.080
Poor (MWH)	20-29	0.321	0.262

1 excluding the Huron/Erie Lake Plain (HELP) ecoregion.
2 applies only within the HELP ecoregion.