Appendix G. Phosphorus Target Development for the Mill Creek Basin

Target concentrations of total phosphorus (TP) selected for the Mill Creek watershed are selected to protect the respective aquatic life use designations in the basin. For Warmwater Habitat (WWH) designated headwater streams (drainage area < 20 mi^2) the target is 0.07 mg/l TP as a seasonal average for the summer to early fall low-flow period. For WWH wadeable segments (drainage area >20 - 200 mi^2) the target is 0.11 mg/l, and for Limited Resource Waters (LRW) segments the target is 0.58 mg/l. These target concentrations were obtained by analyzing relationships between the overall health of streams throughout the Eastern Cornbelt Plains (ECBP) as measured by the Index of Biotic Integrity (IBI), habitat quality as measured by the Qualitative Habitat Evaluation Index (QHEI) and a variety of water quality constituents including TP.

The Nature of Ecological Data
A variety of physical, chemical and biological factors determine the character of any given ecological community. In temperate warmwater streams of the eastern United States the two most critical of these factors, all other things being equal, are habitat and hydrology. The hydrology of a particular stream is governed by precipitation, geology, landuse and the stream's habitat. Habitat is determined by geology and landuse. As the level of anthropogenic stress increases in a particular watershed, other factors become increasingly important in determining the character of that watershed's streams. Trying to determine which factor or set of factors associated with anthropogenic stress are most influential is problematic because many of those factors tend to co-occur in proportion to the level of anthropogenic stress. For example, treated wastewater typically has higher than background concentrations of ammonia-nitrogen, nitrate-nitrogen and total phosphorus. Run-off from urban streets may contain high levels of metals, pesticides and nutrients. Also, where stream habitat is degraded by channelization for agricultural drainage or riparian removal, nitrate-nitrogen, total suspended solids and total phosphorus tend to become elevated relative to background levels. Ascertaining which factor(s) is most influential towards aquatic life for a particular stream involves examining all measured variables against background conditions, comparing measured variables to statistical associations from larger, regional data sets, and by examining multiple lines of evidence for a given site. For example, degradation associated with nutrient enrichment is often suspected when large fluctuations in dissolved oxygen concentrations are observed between night and day because of over-production of algae. Another line evidence comes from comparing IBI scores to measured water quality parameters, and by comparing the measured water quality parameters to background conditions.   And because poor habitat exacerbates the effects of nutrient enrichment, habitat quality is an important consideration. In short, because multiple factors, acting singly or in combination, influence the aquatic life of any given stream segment, examining the effect of any single factor on aquatic life will show considerable variability. Applied to nutrients, where high levels of TP and aquatic life use impairment co-occur, the relationship may be direct cause-and-effect, or the high levels of TP may be a surrogate for another factor or combination of factors that co-occur with TP. In either case, the remedial efforts needed to bring about aquatic life use restoration will be the same; therefore, a TP target can serve as a useful endpoint for water quality models of watershed restoration.

Biological Lines of Evidence

The distribution of IBI scores in relation to TP concentrations were plotted for headwaters and wadeable ECBP streams (Figure 1). A significant linear relationship was found, and the lines drawn through the data points in Figure 1 show the local relationship through the respective range of data. For wadeable streams (Figure 1, lower panel), the steepest slope is running through the middle portion of the data suggesting that effects from TP are strongest between a concentration of 0.06 and 0.2 mg/l. For headwater streams, the relationship is more continuous suggesting that effects from enrichment are evident at lower concentrations. Scatter plots for both headwaters and wadeable streams show wide variation and that some streams achieve IBI values consistent with the WWH aquatic life use (IBI > 36) across the entire range of TP concentrations measured. Notice, however, that data points corresponding to the fourth quartile of $\log_{10}$ transformed TP values are scattered over a wider range than the other three quartiles combined. When TP values are plotted using a probability plot, a strong departure from a normal distribution is evident with mean TP values skewed strongly beyond 0.25 mg/l. These data points for wadeable streams are shown in Figure 2 and are color coded by the narrative range of the IBI. Sites with Exceptional and Good IBI scores tend to have average TP concentrations an order of magnitude lower than Fair and Poor sites across three-quarters of the range of TP concentrations. For these site, TP is either directly responsible, or acting a surrogate for other factors, in controlling biology. At the tails of the distribution where the points converge factors other than TP (or TP as a surrogate) are controlling the biology. Comparisons of IBI scores by quartile of TP concentration (Figure 3)
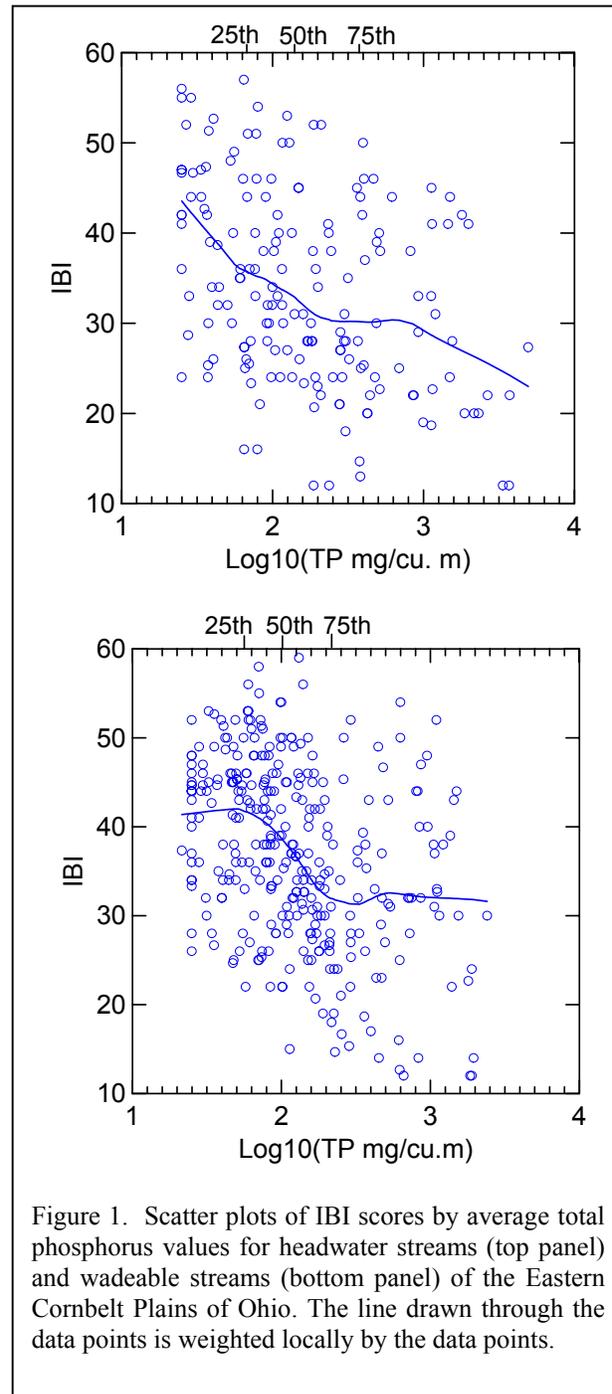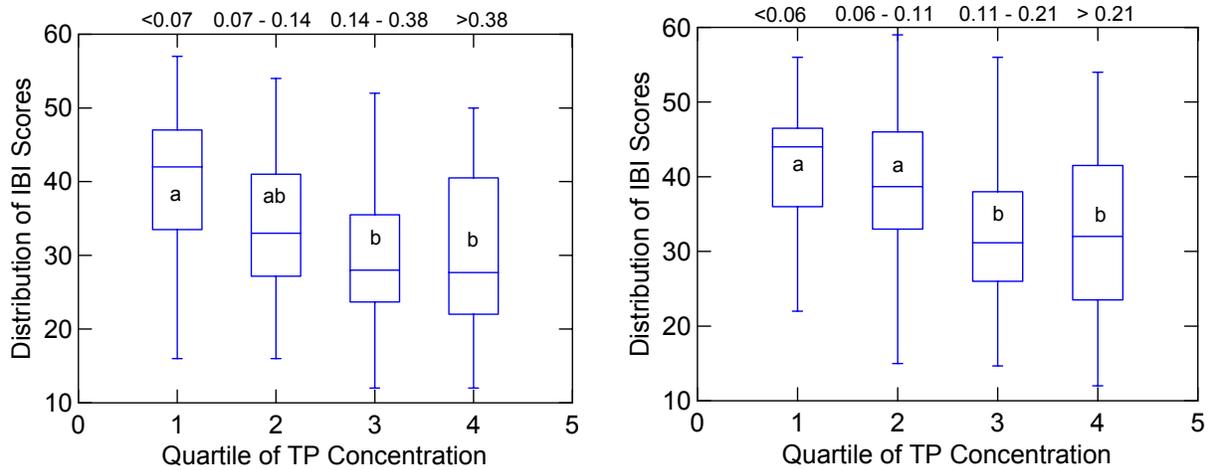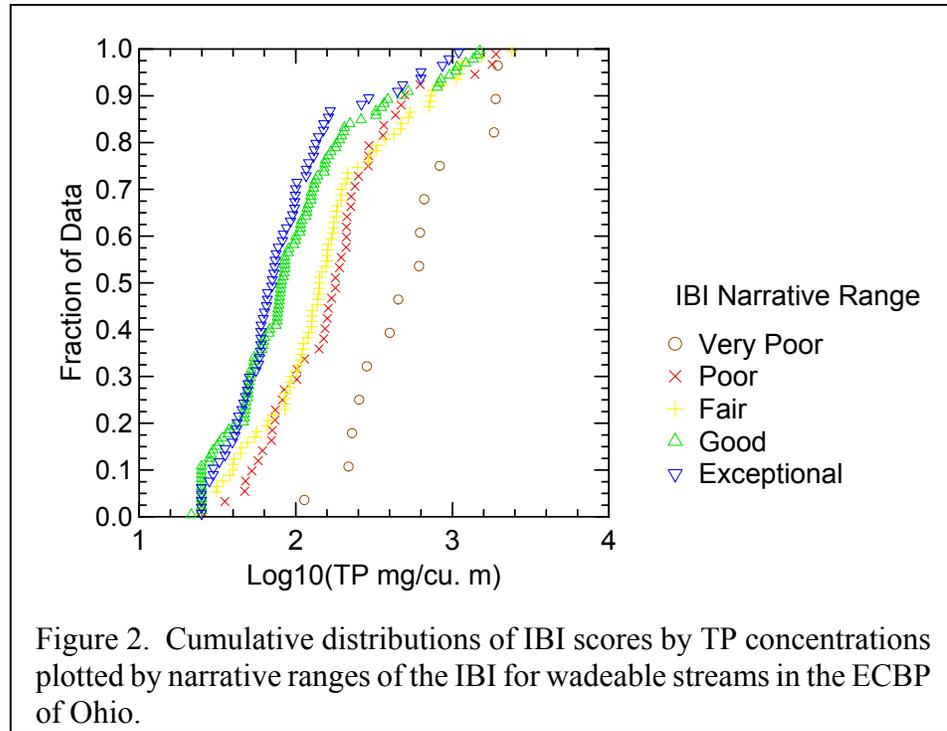

Figure 1. Scatter plots of IBI scores by average total phosphorus values for headwater streams (top panel) and wadeable streams (bottom panel) of the Eastern Cornbelt Plains of Ohio. The line drawn through the data points is weighted locally by the data points.

show that for headwater streams less than half the sites with TP concentrations exceeding the 25th percentile (>0.07mg/l) met the WWH criterion, and for wadeable streams less than half the sites with TP concentrations exceeding the 50th percentile (>0.11 mg/l) met the WWH criterion. These values

are reasonable target values for restoration of WWH aquatic life uses in the Mill Creek basin. The TP target value for LRW segments (0.58 mg/l) is the upper end of the normal data range.

Figure 2. Cumulative distributions of IBI scores by TP concentrations plotted by narrative ranges of the IBI for wadeable streams in the ECBP of Ohio.

Figure 3. Distributions of IBI scores by quartile range of TP concentrations for headwaters (left panel) and wadeable (right panel) ECBP streams in Ohio. Individual boxes sharing a common letter are similar.

Habitat

The inter-relationships between stream habitat and nutrient concentrations are complex and not completely understood. Basic research has shown the ability for streams to assimilate some levels of nutrients without impairing aquatic life. Natural stream systems with intact physical stream habitat and riparian buffers also work to trap and sequester nutrients before they reach the stream and during flood events when waters come into contact with their floodplains and point-bars.

Data from reference sites in Ohio, especially headwater and wading streams, show that total phosphorus during low flow is lower in stream sites with higher quality habitats as measured by the QHEI (Figure 2). The proportion of the phosphorus that is assimilated instream by improving habitat quality versus the proportion of nutrient load kept from reaching the stream compared to poor quality habitats is not known, but either way, better habitat will reduce instream total phosphorus concentrations and directly improve conditions for aquatic life.

Figure 4. Average total phosphorus concentrations for ECBP reference sites with less than 200 mi^2 drainage area. The line drawn through the plot is weighted locally to show the nature of the relationship through the range of data points.

Conclusion

The choice of total phosphorus target values for the Mill Creek basin are typical of other headwater and wadeable WWH streams in the Eastern Cornbelt Plains of Ohio, and are supported by the statistical association of IBI scores to the summer-early fall average total phosphorus concentrations in those streams. Remedial actions that achieve these target values should result in full restoration of aquatic life uses in the Mill Creek basin.
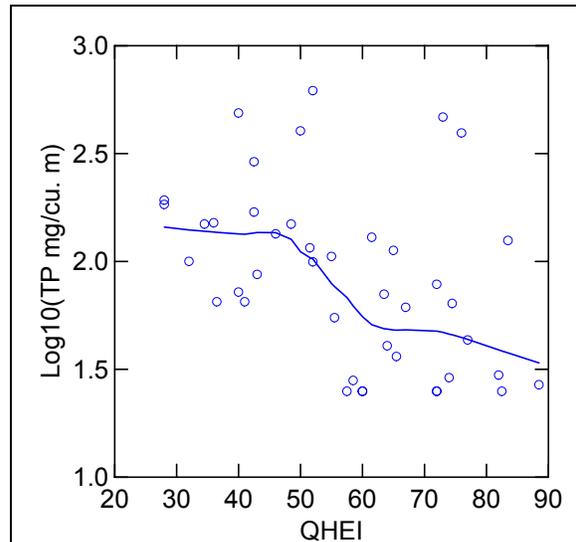
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