RIPARIAN VEGETATION STRUCTURE ALONG THE INDUSTRIALLY IMPACTED MAHONING RIVER, OHIO

By

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ABSTRACT

RIPARIAN VEGETATION STRUCTURE ALONG THE INDUSTRIALLY IMPACTED MAHONING RIVER, OHIO

Anna Stambolia-Kovach

The steel mills lining the banks of the lower Mahoning River in northeast Ohio once produced a full ten percent of our nation's steel. The incessant operation of the mills for nearly a century also produced tremendous amounts of toxic wastes and by-products, which were discharged directly into the Mahoning River. This historic industrialization has severely impaired the aquatic habitat and biota of the lower Mahoning River, but the biological impairment has not extended to the terrestrial component of the river. The riparian corridor flanking the severely degraded river boasts a healthy and diverse woodland, where tree basal area is dominated by native Eastern cottonwood, American sycamore, silver maple, and American elm. Statistical analysis revealed no correlation between riparian woodland structure and degree of industrialization or aquatic degradation. Multivariate ordination analysis instead identified land-use history and riverbank topography as factors most influential upon the localized structure and composition of the streamside community. Therefore, conservation of the intact native riparian woodland should be prioritized. Land use and development next to the river should be limited through legislation, and the proposed remediation of the lower Mahoning River must carefully avoid possible detrimental effects to this vital streamside ecosystem.

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I. INTRODUCTION

The Mahoning River arises in northeast Ohio and flows 174 km to empty into the Shenango River in western Pennsylvania. The upper 96 km of the river escaped heavy industrialization during the last century and a half, but the majority of the 60-km reach between the upper Mahoning River and the Ohio-Pennsylvania border was severely compromised by the continuous production of steel for over 70 years. First drawn to the area by large deposits of iron ore and limestone, the steel industry relied upon the Mahoning River to provide water and power to over 50 steel-related facilities (USACE 1999). Until 1970, the river also received vast quantities of untreated by-products and waste from the steel mills. The discharged materials included highly toxic compounds such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), and metals such as mercury. The insoluble contaminants quickly bound to the river sediment, and huge volumes of oil-soaked sediment remain impounded behind the low-head dams on the river. The steel industry that once made Youngstown, Ohio, one of the wealthiest cities in America also left the Mahoning River one of the most contaminated waterways in the world.

Current State of the Mahoning River Ecosystem

By 1988, the Ohio Environmental Protection Agency (OEPA) issued the first dermal contact advisory for the industrialized portion of the Mahoning River, urging citizens to avoid prolonged contact with the river sediment (OEPA 2005). The OEPA assessed the water quality and biological integrity of the Mahoning River in 1996, confirming that water and sediment in the lower industrialized portion of the river continued to carry dangerous amounts of residual toxic contaminants. A subsequent study on mercury, PAH, and PCB content of sport fish prompted the OEPA to issue in 1997 a public health advisory against any consumption of channel catfish and common carp caught from the lower reaches of the Mahoning River (2005). Neither advisory has been lifted, as contamination levels are unabated. Excessive exposure to PCBs and PAHs can result in immunological disorders, neurological dysfunction, reproductive failure, and cancer in humans and wildlife (ATSDR 2000).

The acute toxicity of Mahoning River sediment is very apparent in the aquatic ecosystem. In isolated places, as many as 24% of lower Mahoning River fish have displayed deformities, erosions, lesions, or tumors caused by the mutagenic contaminants in the water and sediment (USACE 1999). When pollution-intolerant macroinvertebrates (*Ephemeroptera*, *Plecoptera*, and *Trichoptera*) were sampled in the lower Mahoning River, the number of taxa present in some dam impoundments was zero, and averaged less than one third of the mean 6.4 taxa present in the upper reach of the river (Schroeder 1998). The impairment to aquatic life and damage to the physical aquatic habitat by industrialization of the Mahoning River has been found to be most acute in the impoundments of sediment behind each of the low-head dams (USACE 1999).

Proposed Remediation of the lower Mahoning River

In response to the 1996 OEPA report, the United States Army Corps of Engineers (USACE) selected the lower Mahoning River as one of five rivers to be considered for federal funding toward clean-up and restoration (USACE 1999).

The USACE issued a 1999 reconnaissance study that targeted for remediation the reach of the Mahoning River under OEPA dermal contact advisory, and the project is now in the feasibility phase. The stated goal of the remediation is to restore the aquatic ecosystem of the target area to conditions similar to those found upstream of the contact advisory (USACE 1999). The reference area is located upstream of the steel mills, in northern Warren and Leavittsburg, and has been determined to be environmentally safe and ecologically intact (USACE 1999).

The methods proposed to be most effective in restoring the aquatic ecosystem involve sediment dredging and low-head dam removal (USACE 1999). Recommended by the USACE is the intermediate-cost option of hydraulically dredging 247,000 m^3 (70%) of contaminated riverbed sediment, mechanically dredging 87,000 m^3 (30%) of contaminated bank sediment, and removing five of nine dams from the target area. These actions, supplemented by stabilization and the addition of new substrate to the riverbed and bank, promise to rapidly improve the health and integrity of the aquatic ecosystem. They will also modify the banks of the river, disrupt the interaction between the terrestrial and aquatic ecosystems, and permanently alter the riparian landscape. How injurious these sudden adjustments may be to the riparian vegetation remains to be seen.

The Riparian Corridor of the lower Mahoning River

Although the Mahoning River has been carefully examined and the damage to the aquatic ecosystem well-documented, the terrestrial component of the river has not received comparable attention from researchers. Bank sediment was found by the U.S. Fish and Wildlife Service (USFWS) to contain residual toxic hydrocarbons and heavy metals comparable to that found in riverbed sediment (USFWS 1999). While biological assessments have quantified the effects of riverbed sediment and water contamination on aquatic organisms, few studies have attempted to describe the effects of riverbank contamination and dam impoundment on species in the riparian corridor. At the advice of the USFWS (1999) to "fully address the impact [of remediation] to riparian vegetation", the USACE assembled a general list of plant species seen within the riparian corridor, as well as strategies for the preservation of the riparian vegetation during remediation of the river (1999). However, no detailed appraisal or analysis of the riparian habitat with respect to historic industrialization has been performed.

Goals and Objectives

The primary objective of this study was to identify spatial patterns in riparian ecosystem health and integrity along the lower Mahoning River. Multifaceted vegetation community analyses evaluate the impacts of industrialization, human disturbance, and land use on the structure and composition of the riparian ecosystem. In addition, the study quantitatively assesses the influence of low-head dams on the woodland community just beyond the water's edge. Three null hypotheses were addressed during the study: (1) the structure and composition of streamside woody vegetation in the portion of the lower Mahoning targeted for remediation does not differ from structure and composition along upstream reference area, (2) the structure and composition of riparian woodland immediately upstream of low-head dams does not significantly differ from woodland structure and composition just downstream of the dams, and (3) the structure and composition of the riparian woodland does not vary with proximity to the river itself when considering the twelve meters closest to the river.

This comprehensive account of the structure and composition of the streamside woodland surrounding five low-head dams encourages preservation of the riparian woodland, conservation of several important native species, and close observation of any deleterious effects of the proposed remediation. Broad-scale, qualitative description of trends in riparian health along the lower Mahoning River also provides insight on which factors may have been most influential on the structure, composition, and integrity of the streamside woodland along this urban waterway.

II. METHODS

Study Design

This study was designed to determine which riparian woodland community parameters may reflect the severe degradation to the aquatic habitat in the reach of the lower Mahoning River targeted for remediation. The data collected were used to assess the localized effect of low-head dams on riparian woodland, and to identify any changes in structure or composition relating to proximity with the river. Study sites were selected by degree of industrialization, as reflected by the health of the aquatic community. At each site, identical vegetation sampling schemes were applied above and below a low-head dam. Data were recorded with respect to distance from the low-water level, and the structure and composition of the woodland were described using seventeen community parameters.

Study Sites

The study area included the riparian woodland along the 60 km of the Mahoning River between the non-industrialized upper Mahoning (RK 78-174) and the Ohio-Pennsylvania border at RK 18 (Figure 1). Sediment and aquatic habitat quality remain within safe ranges upstream of RK 67 in Warren, Ohio, where the upper boundary of the contact advisory and remediation is set (OEPA 1996, USACE 1999). Below RK 18, no dams were built and there has been no direct discharge of contaminants, but the steel industry has adversely affected sediment and water quality in this Pennsylvania reach of the Mahoning River.

Each of six study sites (five of which centered on a low-head dam) comprised a tract of approximately 500 m of riparian corridor. Two sites (Leavittsburg and Lovers Lane) were chosen in the upstream reference area, three sites (Summit Street, Liberty Street, and Lowellville) were centered on dams and spanned the remediation target area, and one Undammed site was located downstream of the remediation area. More detailed descriptions of each study site can be found in Appendix A.

The five low-head dams were evaluated for localized influence upon riparian structure and composition. Two dams were in the minimally contaminated reference area, and the remaining three dams have been subject to varying degrees of industrialization. The Summit Street dam in Warren, Ohio, lies within 2 km of the upper boundary of the contact advisory area, and upstream of serious biological impairment. The Liberty Street dam in Girard is located in the reach of the river where industrialization and aquatic degradation have been most acute. The southernmost dam (Lowellville) is downstream of the heaviest industrial contamination, and was found to impound relatively small amounts of sediment that cause only moderate impairment to the aquatic habitat (USACE 1999). Details on the appearance, location, and construction of the five low-head dams addressed in this study can be found in Appendix B.

Among the six study sites, the width of the streamside woodland is spatially limited by roads, railways, or farmland, and ranges from 14 m to almost 100 m. Due to the degree of variation in this dimension, and in order to assess the vegetation most likely to be affected by remediation tactics, only the 12 m immediately adjacent to the river were sampled in this study.

Data Collection

At each study site, a 30-m length of streamside vegetation upstream of the dam was exhaustively sampled for woody plant species, and a second 30-m plot was sampled downstream of the dam (Figure 2A). Each upstream and downstream plot was partitioned into three zones: Zone A was 0-4 m from the low water level, Zone B was 4-8 m from the river, and Zone C was 8-12 m from the river. In each zone, the average depth of the litter layer was determined, and the amount of vegetative ground cover was visually estimated in a 2 m X 2 m quadrat placed at random coordinates (random.org). In order to accurately describe the structure and composition of the riparian woodland in each study plot, all woody plants over 0.5 m in height were counted and identified to species according to Gleason and Cronquist (1991). Vouchers of each species were obtained and deposited in the Herbarium of Youngstown State University (YUO). Nativity of each species to northeastern Ohio was preferably reported according to Braun (1989); nativity of species not reported by Braun was presented according to Gleason and Cronquist (1991).

All plants over 5 m in height comprise the tree layer and were measured for DBH (height = 1.4 m) to be used in tabulation of total basal area within each zone and plot. Tree basal area, calculated from all stem diameters greater than 3 cm, was used in this study to report species contributions in each of the study tracts. Canopy cover of the tree layer was estimated using a densiometer, and the height of the tree canopy was estimated using a Nikon® 400 laser rangefinder.

Woody plants 2.6-5.0 m in height comprise the upper shrub layer, where large upright shrubs and young trees dominate the flora. Shrubs and seedlings less than 2.5 m in height occupy the herbaceous layer of a woodland (Figure 2B), where they tend to sprawl or achieve rapid vertical growth to compete with forbs and grasses for resources (vertical stratification adapted from Mueller-Dombois and Ellenberg 1974). In each of these strata of the understory, the crown size of each woody plant was estimated as an ellipse, and the number of stems recorded. Total crown cover was reported for the herbaceous layer and for the upper shrub layer as a percentage of the total area sampled. The contribution of each growth form to the total crown cover was also determined.

A summary of the woodland parameters estimated with this sampling protocol is presented in Table 1. Each of the seventeen descriptive parameters was determined for the six study sites, for each of two study plots within each site, and for each of three zones within each plot. The total area sampled in all 12 study plots was 4230 m^2, which was adjusted by subtracting the area of a paved walkway bisecting the study plot downstream of the Summit Street dam.

Statistical Analysis

In order to describe changes in woodland structure moving downstream from the reference area to the area targeted for remediation, correlation analysis was used to identify patterns in five widely reported descriptors (Shannon-Wiener diversity indices for tree and shrub species, tree basal area, upper shrub layer cover, and herbaceous layer cover) that were associated with river kilometer (RK) (Zar 1999). There appears to be a trend in land use and development along the Mahoning River that corresponds with location within the study area. The upstream reference sites (Leavittsburg, Lovers Lane), and the Summit Street site are located in residentially developed areas where the streamside woodland has been selectively cleared or removed altogether. The downstream sites (Liberty Street, Lowellville, Undammed) remain more heavily industrialized, but the immediate riparian corridor has been less disturbed. Thus, RK is not used here as a controlling independent variable, but instead as a surrogate factor that reflects the gradient in land-use history seen along the lower Mahoning River.

In order to identify localized effects of the low-head dams on streamside vegetation, the same five widely reported descriptors were compared above and below the dams, and subjected to paired sample t-tests using the five dammed sites as replicates (Zar 1999).

Ordination by non-metric multidimensional scaling (NMDS) was also used to examine woodland structure and composition in the reference area and the target area (Glenn 1999). Ordination considers multiple community parameters in order to create a two-dimensional plot that represents the degree of dissimilarity among a set of samples, and can also identify the variables most significant in the differential placement of data points. In this analysis, NMDS ordination indicated which of the six study sites were similarly structured, based on seventeen provided descriptors. Once plotted, categorizing the study sites by independent variable revealed which factors had detectable influences on the overall structure of the sampled riparian woodland. NMDS was also used to illustrate how woodland structure and composition differed above and below low-head dams, or consistently varied with proximity to the river.

Species Diversity and Richness (SDR) software was used to calculate diversity and evenness indices, and NMDS was conducted using SPSS 11.0 software. The equations used by these software programs are presented along with the tabulated data in Appendix D.

III. RESULTS

A total of 44 woody plant species were identified, including 26 that typically grow in tree form (Table 2) and 16 that predominantly occur in shrub form (Table 3). One species (*Acer negundo*) was found to grow in both tree and shrub form in the area sampled, and the contribution of each growth form is noted in Tables 2 and 3. One tree (*Craetagus* sp.) and one shrub (*Rubus* sp.) were only identified to genus, due to the lack of distinguishing specific characters at the time of sampling. A complete list of the streamside woody flora found in this study of the lower Mahoning River can be found in Appendix C.

The parameters of the six riparian woodland study sites, and each plot and zone within each site, on the lower Mahoning River are given in Appendix D. Due to difficulty in measuring accurate tree height, canopy height was not used as a variable in the statistical analysis of Mahoning River riparian woodlands. Significant findings and trends based on the remaining seventeen woodland parameters will be discussed in the Structural Analysis of the woodland adjacent to the lower Mahoning River.

Within the study area, the riverbank supports a lush woodland with a tree basal area averaging 71 m^2/ha (calculated by pooling data from all twelve study plots). The trees along the length of the study area are dominated by *Acer saccharinum* (silver maple), with consistent contributions from *Ulmus americana* (American elm) and *Fraxinus americana* (white ash) (Table 2). Other trees that contribute significant basal area, but not at all study sites, are *Platanus occidentalis* (American sycamore), *Populus deltoides* (Eastern cottonwood), *Prunus serotina* (wild black cherry), *Quercus rubra* (red oak), and *Robinia pseudoacacia* (black locust). Nine additional tree species were identified at only one study site each.

Only three non-native tree species were identified during sampling, and their occurrence was very limited near the river. The invasive *Ailanthus altissima* (tree of heaven) and the cultivated *Ilex opaca* (American holly) were each found at only one site (Summit Street and Leavittsburg, respectively). The naturalized *Morus alba* (white mulberry) was found only at the Liberty Street site, where it grew along with the native *Morus rubra* (red mulberry). Tree basal area in the sampled woodland was 99.5% native.

Canopy height was consistent among the study sites, and averaged 20-25 m with emergent trees reaching heights of 30 m. Canopy cover of the woodland exceeded 90% at most sites (Table D3).

The understory layers (height < 5 m) of the riverbank riparian zone were occupied by a mixture of native and invasive shrub species. Most abundant was *Rosa multiflora* (multiflora rose), an invasive species, and second most common was *Euonymus atropurpurea* (Eastern wahoo), a shrub native to Ohio (Table 3). Shrubs restricted to the herbaceous layer provided 8.7% crown cover, while shrubs extending into the upper shrub layer provided 4.2% cover. Immature trees (DBH < 3 cm) contributed an additional 3.3% coverage in the herbaceous layer and 3.1% in the upper shrub layer (Tables D3 and D4). Trends in species occurrence will be addressed in the Compositional Analysis.

A parallel study assessed the avifauna at the same study sites, and a complete list of birds identified during a series of point counts at the sites is given in Appendix E. A list of large mammals frequenting the riverbank, either visually observed in the study area or identified by tracks left in the moist soil, is also included in Appendix E.

Structural Analysis: Location, Location, Location

Tree and shrub diversity values for the six study sites are visualized in Figure 3. Shannon-Wiener diversity indices for mature trees were highly variable along the length of the study area, ranging from 0.6718 in the Summit Street site to 1.4590 in the Lowellville site.

Shrub diversity (Shannon-Wiener) ranged from 1.6180 in the Leavittsburg site to 1.050 in the Lowellville site (Figure 3). Among the six study sites, there was a trend of decreasing shrub diversity moving downstream from the reference area through the target area. Shannon-Wiener diversity indices for shrub species were found to have a significant association (R=0.896, P=0.016) with river kilometer. Shrub diversity was highest in the residential northern sites.

Total basal area of streamside trees showed a significant inverse correlation (R = -0.828, P = 0.042) with river kilometer (Figure 4). Moving downstream along the lower Mahoning River, tree basal area tended to increase as the river became more industrialized. Conversely, total shrub layer cover steadily decreased from 37% at Leavittsburg to only 4% at Lowellville. The correlation between shrub diversity and river kilometer was not found to be significant due to a dense shrub layer in one plot at the Undammed site. These trends illustrate the dynamics between the shrub layer and the tree layer of a woodland. Sites that had well-developed tree layers with more basal area tended to have less developed shrub layers, while sites that showed higher shrub diversity and shrub cover often had a less mature tree layer with less basal area.

The ordination plot of the six study sites (Figure 5A) showed grouping of study sites according to the topography of the sampled riverbank. The Summit Street, Liberty Street, and Lowellville sites, placed through NMDS on the left half of the plot, were floodplains that are inundated frequently as the river rises in response to precipitation. The significant loading vectors suggested that these floodplains were characterized by a large tree basal area with a dense canopy closure (Figure 5B).

The northernmost and southernmost sites (Leavittsburg and Undammed, respectively) have terraced riverbanks, where inundation occurs far less frequently; only when the river rises to the height of the terrace. These two sites were placed by NMDS farthest to the right of the plot, but not near each other on the vertical axis. The Leavittsburg terrace had a dense shrub layer with far more stems, species, and herbaceous layer cover than the less disturbed Undammed site, which had 58.3 m^2/ha more basal area than Leavittsburg.

The Lovers Lane site had a riverbank that was steeply and evenly sloped, and this land was probably manipulated during construction of the city street (Lovers Lane) that parallels the river here. Flooding occurs at this site as a function of the river rising, but the steep slope limits the width of the flood. Lovers Lane had a lower basal area and denser shrub layer than the floodplains, but was not so distant from the floodplains in ordination space as were the two terraced sites. Land-use and disturbance history, suggested by river kilometer, appears to be an important factor in restricting the Leavittsburg and the sloped Lovers Lane site, to the upper right quadrant of the plot (Figure 5B).

The Liberty Street site, which holds many times the volume of contaminated sediment than other sites, is not isolated or divergent from the other industrialized sites in the ordination plot of riparian woodland structure (Figure 5A). Historic industrialization has uniquely impacted the aquatic habitat and ecosystem at the Liberty Street Site, but has not caused the streamside vegetation community to be structurally dissimilar from the other study sites.

Structural Analysis: Possible Effects of Low-head Dams

The effect of the low-head dams upon diversity was not uniform: four of five sites (all but Lovers Lane) showed higher tree diversity downstream of the dam (Table 4). Conversely, four of five sites (all but Summit Street) had higher shrub diversity upstream of the dam. When shrub diversity was higher upstream of the dam, the average difference in Shannon-Wiener diversity was 0.7180.

No consistent difference in tree basal area or upper shrub layer cover was found between upstream and downstream plots, but woody cover in the herbaceous layer of upstream plots was significantly higher (P = 0.037) than that found downstream of the dams (Table 5). Of the five diversity and density parameters thus evaluated, this was the only parameter found in this study to be consistently and significantly affected by the presence of a low-head dam.

NMDS produced an ordination graph (Figure 6A) that shows modest convergence of four out of five plots sampled downstream of dams. The most significant (P < 0.05) loading vectors are indicated in Figure 6B and allow qualitative description of the four homogenous downstream plots.

The woodland downstream of the Lowellville and Summit Street dams had more tree stems and less herbaceous cover than woodland upstream of these dams (green arrows). The litter depth was consistently lower downstream of these dams, suggesting less frequent inundation and less litter deposition.

The woodland downstream of the Liberty Street and Lovers Lane dams had fewer shrub stems and species, and less cover in both the herbaceous layer and the upper shrub layer than upstream woodland (blue arrows). The most divergent plots (not encircled) were in the Leavittsburg study site, which was used for recreation and timber purposes throughout the reign of the steel industry.

Structural Analysis: Proximity to the River

Litter depth in the region closest to the river, Zone A, was lower than or equal to that in the farthest, Zone C, with Zone B usually intermediate in value, in all twelve study plots. No other parameter showed a consistent trend moving away from the river. NMDS was applied to the seventeen descriptive community parameters for all 36 zones (three zones in each of twelve study plots). The resulting ordination plot (Figure 7) suggested modest homogeneity of Zone C, the farthest from the edge of the river, but the placement of the remaining data points was not informative. This study revealed no discernible changes in community structure or composition within the first twelve meters of riparian woodland along the lower Mahoning River.

Compositional Analysis

The riparian woodland along the lower Mahoning River is dominated by *Acer saccharinum* (silver maple), which comprises 55% of the total basal area sampled in this study with stems ranging from 3.2 to 93.9 cm in diameter. This native tree occurs along the study area at an average of 39 m^2/ha and constitutes 38-85% of the basal area among the six study sites.

A notable species making consistent contributions along the length of the study area is *Ulmus americana* (American elm), occurring along the study area at an average of 4.0 m^2/ha. Although *Ulmus americana* comprised only 5.6% of the total sampled basal area, it occurs at all of the six sampled sites and is the fourth most dominant species along the river. In addition to mature elm trees, *Ulmus americana* is present in the study area as seedlings, comprising 6.7% of all seedlings identified.

A third species occurring along the length of the study area is the native *Fraxinus americana* (white ash), which comprises 3.5% of total basal area. Although mature white ash is present at only 2.5 m^2/ha within the sampled sites, seedlings of this species were found to constitute a full 46% of all seedling stems. While *Acer saccharinum* is present at a slightly higher basal area in the four southernmost sites, *Ulmus americana* and *Fraxinus americana* are uniformly present along the length of the lower Mahoning River. Each of these three species is native to northeast Ohio.

Although *Platanus occidentalis* (American sycamore) is present at only three of six study sites, it comprises 15% of the total basal area sampled and is the second most abundant species along the lower Mahoning River. When calculated using the area sampled over all six study sites (4230 m^2), *Platanus occidentalis* occurs at a basal area of 11 m^2/ha. Sampling of the northern three sites identified no sycamore trees, while sampling of the southern three sites found increasing basal area of *Platanus occidentalis* moving downstream. The stem diameter of this species averaged 43 cm, and ranged from 17 to 96 cm.

The distribution of *Populus deltoides* (Eastern cottonwood) within the study area was similar to that of *Platanus occidentalis*; it was virtually absent from the northern sites while contributing significant basal area to the southern sites. *Populus deltoides* occurred at 5.5 m^2/ha within the length of the study area, making cottonwood the third most abundant species (7.8% of total basal area) along the lower Mahoning River. The size of the sampled cottonwood trees ranged from 28.6 cm to 148 cm in DBH. Like *Platanus occidentalis*, no immature seedlings of *Populus deltoides* were identified during sampling.

The contribution of the four dominant tree species (*Acer saccharinum, Platanus occidentalis, Populus deltoides*, and *Ulmus americana*) to site basal area is illustrated in Figure 8. These four native trees comprised over 90% of basal area in the three southernmost sites, but some species were largely replaced in the northern sites by pioneer, invasive, and cultivated species.

The Leavittsburg site exhibited 30% and 14% contribution to basal area by pioneer species *Prunus serotina* (wild black cherry) and *Robinia pseudoacacia* (black locust). The average DBH of these less mature trees were 16.1 cm and 31.8 cm, respectively. Also present among the trees at this site was the cultivated *Ilex opaca* (American holly). The shrubs of Leavittsburg included such non-native species as *Elaeagnus umbellata* (autumn olive), *Ligustrum vulgare* (common privet) and *Rubus* sp. (bramble), whose distributions are limited to the northern three sites.

Lovers Lane, with its steeply sloped riparian corridor, supported the only mature *Quercus rubra* (red oak), *Fagus grandifolia* (American beech), and *Nyssa sylvatica* (black tupelo) in the study area. These upland species contributed more basal area at this site than even silver maple. Present among the shrubs at this site were the only *Viburnum opulus* and *Staphylea trifolia* (bladdernut), both known to escape cultivation, to be identified during sampling.

The basal area at Summit Street was 85% *Acer saccharinum* with the presence of the pioneer *Robinia pseudoacacia* (black locust) and the invasive *Ailanthus altissima* (tree of heaven). The shrub species *Berberis thunbergii* (Japanese barberry) was found only at this site. In sum, the northern three sites supported ten tree and seven shrub species absent from the southern sites. Most conspicuous among these trees were pioneer species in Leavittsburg, and upland species at Lovers Lane. Shrubs found only in the north included several species that probably grow along the river as the result of escaped cultivation.

Only seven tree species were restricted to the southern sites; of these, *Platanus occidentalis* (American sycamore) and *Populus deltoides* (Eastern cottonwood) were easily the most informative. Two shrubs were restricted in occurrence to the southern sites: *Prunus virginiana* (chokecherry) was common among the three sites, while *Virburnum prunifolium* (black haw) was found only at the Undammed site. Both of these shrub species are native to northeast Ohio.

Since all sampling data were recorded with respect to the longitudinal zonation of the study plots, the occurrence of all 39 woody plant species was documented for each zone. Quantitative assessment of each species' occurrence revealed no trends in growth that correspond to proximity to the edge of the river (data not shown). No trends in woodland structure were identified, nor were any trends in composition recognized, that were related to the proximity to the river.

IV. DISCUSSION

Shrub diversity was found to be highest in the residential northern sites, where more recent development and the escape of cultivars may have fostered colonization by species not found in the southern sites. Tree basal area in these sites was lower than in the southern industrialized sites, which have remained largely unaltered since the original industrialization of the river. The NMDS ordination plot of the six study sites indicated that the mature tree layer creates a dense canopy closure in the southern sites that may restrict diversification in the shrub layers (Figure 5B). The riparian woodland of the southern sites appears to be more resistant to invasion by alien species than the woodland in the northern reference area.

Ordination analysis revealed that the study sites also differ from one another based upon landform, a healthy and natural response to change in topography. River kilometer, possibly reflecting a gradient in land-use history, also appeared to be associated with the varying structure of woodland along the lower Mahoning River. Specifically, the convergence of the Lovers Lane and Leavittsburg sites to the upper right quadrant of the ordination plot probably reflects the high degree of disturbance to the riparian woodland (Figure 5A). These two sites were located upstream of the contact advisory (in the reference area), but land use in these northernmost residential areas apparently has been most disruptive among the study sites. This was also reflected by the lower tree basal area, and by the more diverse and dense shrub layers, in these parcels of woodland.

Thus, the first null hypothesis was rejected; this study demonstrated that riparian structure and composition does significantly differ between the reference and target areas, likely due to variation in anthropogenic disturbance and land use patterns. Unlike the aquatic habitat of the river, the terrestrial ecosystem in the target area is notably healthy and mature. Ordination analysis revealed that the structure of the woodland also differed between study sites according to landform.

Structural analysis of streamside woodland surrounding the low-head dams revealed significantly less herbaceous layer cover downstream of each dam, which may be a direct result of less frequent inundation with river water. Dams create an upstream pool of water that flows over the riverbank more frequently than the more rapidly flowing tailwater downstream of the dam (Johnson 2002). Low-growing shrubs, as well as the young tree seedlings found in the herbaceous layer, respond to fluctuations in water supply more readily than larger shrubs and adult trees.

The occurrence of shrubs along the lower Mahoning River, as described in Table 3, provided some insight into the finding of lower shrub diversity downstream of four out of five dams. At least seven shrub species (*Elaeagnus umbellata*, *Lindera benzoin*, *Lonicera morrowii*, *Sambucus nigrum*, *Viburnum dentatum, Viburnum prunifolium*) were found only in upstream plots or in the Undammed site. Less frequent watering can reduce the optimality for seed germination and early woody growth, which may result in lower shrub diversity and less herbaceous layer cover adjacent to the tailwater. Possible impediment of seed movement across the dams may have also contributed to lower downstream shrub diversity (Andersson *et al.* 2000). Overall, the effect of the dams upon terrestrial vegetation structure is small and not detrimental, particularly with respect to that seen in the aquatic ecosystem of the river.

Based on the fact that at least one community variable (herbaceous layer cover) was consistently and significantly affected by the presence of low-head dams, the second null hypothesis was rejected. Low-head dams on the Mahoning River were found in this study to appreciably affect localized structure and composition of riparian woodland adjacent to the river.

No evidence was found that riparian woodland structure varies within the twelve meters closest to the water. The third null hypothesis was therefore accepted, with notation of the limitations of this study design to fully address the phenomenon.

The sampling for this study was performed near several of the low-head dams on the industrialized Mahoning River, where remediation is most likely to take place. Alteration to the boundaries of a river can result in drastic changes to the riparian vegetation, as large empty niches are exposed and existing flora is permanently submerged (Shafroth *et al.* 2002). Remediation of the degraded aquatic ecosystem could jeopardize the integrity of the healthy and native streamside woodland.

V. HEALTH AND INTEGRITY OF THE RIPARIAN ECOSYSTEM

The riparian woodland along the historically industrialized lower Mahoning River is highly functional and fittingly diverse. Much of the riverbank has been largely undisturbed by human activity since the initial industrial development of the river. While the seriously impaired aquatic ecosystem has labeled the Mahoning River as unsafe and marked it for remediation, the neighboring vegetation is largely intact and stands today as a fine exemplar of intact, native riparian woodland in northeast Ohio. Structural and compositional analyses at six study sites revealed virtually no negative impact of historic industrialization on the streamside vegetation. To the contrary, the woodland adjacent to the most heavily contaminated reach of the river has remained essentially free of human intrusion. Most of this land is considered brownfield, and would require costly clean-up efforts prior to construction or renovation. As a result, the brownfields left by the steel industry along the Mahoning River offer perhaps the best green space in the vicinity of Youngstown, Ohio.

Most significant among the findings of this study are the gradients in structure and composition seen along the length of the study area. Moving downstream within the 60-km study area, there is a clearly defined gradient in streamside vegetation from shrub-dominated black locust-black cherry-silver maple woodland in the northern sites to the more mature, native sycamore-cottonwood-silver maple woodland in the south. The woodland surrounding the Leavittsburg site is most disturbed among the vegetation sampled. The downstream plot here is a shrub-dominated community that more resembles a thicket than a woodland. Aside from silver maple, trees in this site are largely limited to black locust and wild black cherry, two species known to colonize recently cleared woodland. The study site lies just downstream of Canoe City, a recreation park that has been in operation since the early part of the twentieth century and utilizes the river by offering canoe rentals and fishing supplies. The steel industry did not severely contaminate the water and sediment in this area, and the river has remained safe for recreational use and adjacent residential development. In some areas near the study site, lawns of residents extend to the edge of a channelized river. Given the opportunity to enjoy an unindustrialized reach of the Mahoning River, citizens have done so, but with substantial effects on the health and integrity of the riparian woodland in Leavittsburg.

The region surrounding the Lovers Lane site is not so directly disturbed by human activity, with the exception of an encroaching residential area on the east bank of the river upstream of the dam. The woodland sampled in this study is located on the west bank between the river and a city road, and the steep terrain does not invite citizens to frequent the riverbank. A well-traveled road (Lovers Lane) and the adjacent residential neighborhood do impinge on the integrity of the riparian corridor, however. Landscape cultivars and invasive species have come to dominate the woodland nearest the road, and a tremendous amount of garbage has been discarded into the woodland from Lovers Lane. The landform of this riparian corridor is unnatural, and the flora is a mixture of native, invasive, and cultivated species. A few of the major species identified during sampling are unique to this site, as the slope permits the growth of red oak and American beech that would not tolerate the inundation that occurs elsewhere along the river. While the woodland near Lovers Lane is productive and functional, the general health and integrity of the ecosystem is questionable.

The reach of the river targeted for remediation includes the southern four study sites (Summit Street, Liberty Street, Lowellville, and Undammed). These sites support woodland that is, in general, more mature and less disturbed than the woodland in the northern sites. The Summit Street site is just within the northern boundary of the remediation area. The health of the aquatic ecosystem is marginal here, and the riparian woodland is only moderately disturbed. Upstream of the dam, the sampling plot is located behind an electrical power station, is not readily accessible, and appears to have remained undisturbed for decades. The downstream sampling plot is situated near a city park, where the woodland was partially cleared in 1997 for construction of the Riverwalk. The City of Warren has publicized the goal of increasing public appreciation of the Mahoning River, and the expansion of Perkins Park promises to serve that purpose. The manicured lawn, baseball diamonds, a newly constructed outdoor amphitheater and freshly paved sidewalks draw increasing numbers of citizens to visit the park along the river. Park officials have wisely chosen to leave intact a narrow (< 5 m) strip of riverbank vegetation, but the improvements recently made to the park have damaged the integrity of the streamside woodland. The new Riverwalk, extending northward out of the park and bisecting the downstream study plot, offers visitors a stroll by the river, but also provides immediate access to partially cleared woodland that was previously inaccessible and undisturbed. The two northernmost sites provide evidence that clearing, even selective, leaves a woodland vulnerable to colonization by pioneer, invasive, and cultivated species. Cottonwoods as large as 2.0 m in DBH are still maintained in the lawn of Perkins Park, and mature sycamores were noted in Perkins Park and near the Leavittsburg upstream site. This confirms that both *Populus deltoides* and *Platanus occidentalis* were once common near the northern sites, but have been reduced in occurrence by residential and commercial development. The Summit Street site is one of transition, marking the northern limit of the original native riparian woodland of the Mahoning River, and the southern boundary of historic human manipulation and recreational use of the riverbank.

The Liberty Street dam has been identified as the one impounding the largest volume of contaminated sediment in the Mahoning River. The majority of biological and physical indices determined for the ecosystem of the lower Mahoning River identify the river reach near this dam as the poorest in aquatic health and integrity, and the riverbank sediment remains soaked with oil to the surface. Nevertheless, the riparian woodland is robust and native, boasting the northernmost occurrence of streamside cottonwood found in this study. Here, the original state of the riparian woodland of the lower Mahoning River becomes apparent. Large, multi-stemmed silver maples arch over the river with huge cottonwoods and American elms dotting the riverbank. The shrubs that were so conspicuous in the northern sites become less dense here in the more mature woodland of the southern Mahoning River. The sampling plots are located on the east bank between the river and the railways that were once essential to the steel industry. Development is limited on this bank by the nearby railway and the steep slope that supports it, but residents encroach upon the river on the west bank downstream of the dam. Some are surely regretful to have done so, as the landform of the west bank is an unbuffered floodplain that regularly receives river water during heavy precipitation. In 2003, an estimated 50-year flood completely destroyed a number of homes here, and in many other areas along the Mahoning River.

Moving downstream to the Lowellville site, the woodland becomes even more impressive, with sycamore and cottonwood prevalent among the trees. Silver maple remains, as in most sites, dominant in basal area. The woodland is mature and largely undisturbed, and the shrub layer is less dense than in the Liberty Street site. Near the study site, residential areas have been developed adjacent to both banks of the river, but generally not so close as to disrupt the riparian woodland. Townspeople speak of opening a canoe rental business in the vicinity of the downstream study plot, and regularly clear the herbaceous flora in the area. They have sensibly left the woody flora intact, however, and one hopes that such an enterprise would not severely impinge on the integrity of the native woodland that grows there. As residents gain interest in recreational use of the river, measures should be taken to minimize the potentially deleterious effects of human disturbance.

The Undammed site, particularly the downstream plot, features what is by far the least disturbed and most impressive riparian woodland within the study area. The site is located in a rural setting just beyond the Ohio state line. While agricultural fields occasionally occupy the 100 m between the railway and a narrow strip of riparian corridor on the east bank (the upstream sampling plot was delimited by a corn field), much of the woodland remains largely intact and appears to have been undisturbed for hundreds of years. The west bank of the river is similarly intact, with untouched woodland extending away from the river. Sampling of the east riverbank identified mature cottonwood, silver maple, and American elm. Additional sampling in this area found a massive sycamore with DBH of 1.4 m. An accompanying expert who had visited all of the study sites suggested that, at upwards of 200 years, this tree may be among the oldest in the Mahoning River riparian corridor. Some selective clearing of this forest may have taken place in the distant past, but there is no evidence that the 100 m of unblemished riparian woodland behind the downstream plot has been altered by recent human activity. The woodland is so mature and functional that even the shrub layer has become well developed, benefiting from canopy gaps left in the overstory by trees that have aged and gradually succumbed. This region of intact woodland should undoubtedly serve as a reference for remediation of the dissembled riparian woodland found in the northern sites.

The low-head dams on the Mahoning River were previously found to have a profound negative effect on the health of the aquatic ecosystem. The low height of the dams renders them relatively insignificant to the hydrologic regime of the river, but they impounded highly contaminated sediment from over a century of industrialization. The resulting impoundments provide a dismal habitat for bottom-dwelling macroinvertebrates, altogether precluding their presence behind some dams. Even organisms not physically associated with the sediment (such as fish) have been drastically affected by the impounded sediment through their predation on bottom-dwellers.

In direct contrast to the aquatic ecosystem, the terrestrial component of the lower Mahoning River has not been severely impacted by the impoundment of contaminants behind low-head dams. Woody flora is remarkably resistant to soil contamination, and the woodland along the Mahoning River has not been compromised by sediment contamination. This is not unexpected, for trees have been used to effectively remove contaminants from soil in a practice called phytoremediation (Dickinson 2000). Animal life in the riparian corridor is also abundant and diverse. A parallel study analyzing the avifauna of the lower Mahoning River found a full 75 species of birds utilizing the riparian corridor at the same six study sites considered in this study (Blohm 2005). Species utilizing the streamside woodland include raptors, waterfowl, permanent residents, and migratory birds, and are indicative of a healthy, diverse habitat (Canterbury *et al.* 2000).

The USACE clearly stated in their reconnaissance study the goal of returning the southern industrialized portion of the river to conditions similar to that in northern Warren and Leavittsburg. The USACE and the OEPA both neglected to qualify the riparian woodland as an integral living feature of the Mahoning River. Had they done so, they may have recognized that the health and integrity of the streamside vegetation has been seriously compromised in the reach of the river used as their reference for optimal conditions. They may have added to their remediation objectives the goal of returning the conditions of the terrestrial ecosystem in their reference reach of the river to its native state. They may have emphasized the unique import of the relatively undisturbed, highly functional woodland that lies adjacent to the portion of the river they intend to remediate. They may have warned officials that remediation of the river, as proposed, threatens to destroy some of the finest riverside woodland remaining in northeast Ohio.

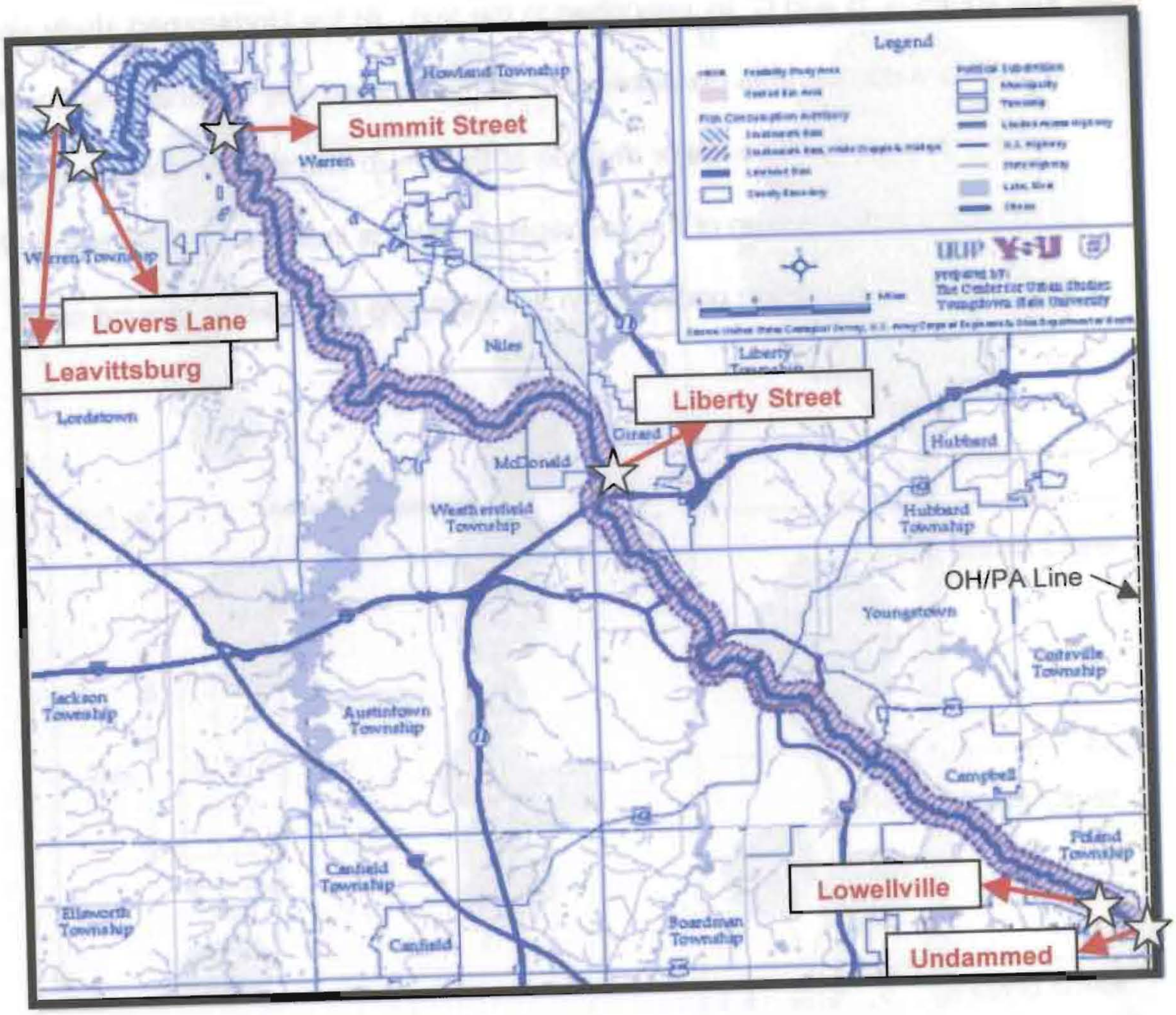
The quality of the terrestrial ecosystem is at least as important as the quality of the aquatic portion of the river. With native wetlands and riparian corridors disappearing from Ohio at an alarming rate, emphasis must be placed on conservation of the stable and functional woodland adjacent to the most industrialized reach of the lower Mahoning River. Remediation of the river is a noble and exciting prospect, but any actions that disrupt the riparian vegetation will likely reduce the quality of the woodland. The railway that runs parallel to the river at the three southern sites, as well as the road that parallels the Lovers Lane site, are lined with stands of the invasive tree of heaven. Thus far, the riparian corridor has largely withstood invasion by this and other exotic species, but even subtle alterations caused to the riverbank threaten to open niches to be readily colonized by invasives. The fact that the structure and composition of the woodland along the entire length of the study area respond to changes in riverbank topography and human activity far more than to changes in aquatic health or sediment quality underscores the stability, functionality, and autonomy of the ecosystem.

In addition, the presence of both mature and seedling American elm, even in the more recently disturbed northern sites, grants conservation of this riparian woodland precedence over aquatic remediation tactics that could disrupt the riverbank. The absence of cottonwood or sycamore seedlings along the river implies that removal of mature individuals would essentially eliminate these species from the landscape, leaving huge niches to be filled with any number of noxious and nonnative species. At what cost is the USACE willing to remediate the aquatic portion of the Mahoning River?

The information provided in this report should be carefully considered prior to any aquatic remediation efforts. This study, along with reports from the USACE and OEPA, provide a thorough snapshot of the current biological conditions of the lower Mahoning River. The success of any clean-up effort is sure to be documented for the riverbed sediment and the health of the aquatic ecosystem. If remediation does proceed in spite of the threat to the health and integrity of the riparian woodland, then the impact to the streamside vegetation can be clearly documented for consideration in remediation attempts elsewhere.

While the fitness of the aquatic ecosystem of the Mahoning River has been largely governed by historic industrialization, the wellbeing of the riverbank vegetation community was found in this study to be much more heavily influenced by the history of land use next to the river. The steel industry has come and gone from the Mahoning River, leaving a critically wounded riverbed and aquatic habitat. The woodland on the banks of the river survived the steel industry, however, and remains native and largely intact. The Mahoning River is reputed for its polluted water and sediment, and the health advisories issued as a result of the contamination. Rarely considered is the riparian vegetation community, which is yet to be ruined. This study demonstrates that the most immediate threat to the woodland is land use and human perturbation. While policymakers continue to ponder remediation of the Mahoning River, action must be taken to protect and conserve the riparian woodland of the river from disruption, invasion, and loss of integrity. It is truly the only part of the river that we have left.

Figure 1. The study area of the Mahoning River. The six study sites are named and indicated by red arrows. The 60-km reach of the Mahoning River considered in this study is the most heavily industrialized portion of the river. Purple hatching along the river corresponds with the reach targeted for remediation by the United States Army Corps of Engineers.



Summit Street
Lovers Lane
Leavittsburg
Liberty Street
OH/PA Line
Lowellville
Undammed
Legend
Howland Township
Warren
Warren Township
Lordstown
Niles
Liberty Township
Girard
McDonald
Hubbard
Hubbard Township
Weathersfield Township
Youngstown
Coitsville Township
Jackson Township
Austintown Township
Campbell
Poland Township
Canfield Township
Canfield
Ellsworth Township
Boardman Township

Figure 2. Schematic drawings of the study design (unscaled). (A) At each of five study sites, a 12m X 30m plot was sampled upstream of the dam and another was sampled downstream of the dam. Each of the plots was partitioned into zones A, B and C, as described in the text. At the Undammed study site, two plots a comparable distance apart were sampled. (B) Vertical stratification used in this study. The major division of the shrub and tree layers is indicated at 5 m, and the delineation of the herbaceous layer is indicated with a dashed line at 2.5 m. All vegetation under 0.5 m in height was considered ground cover.

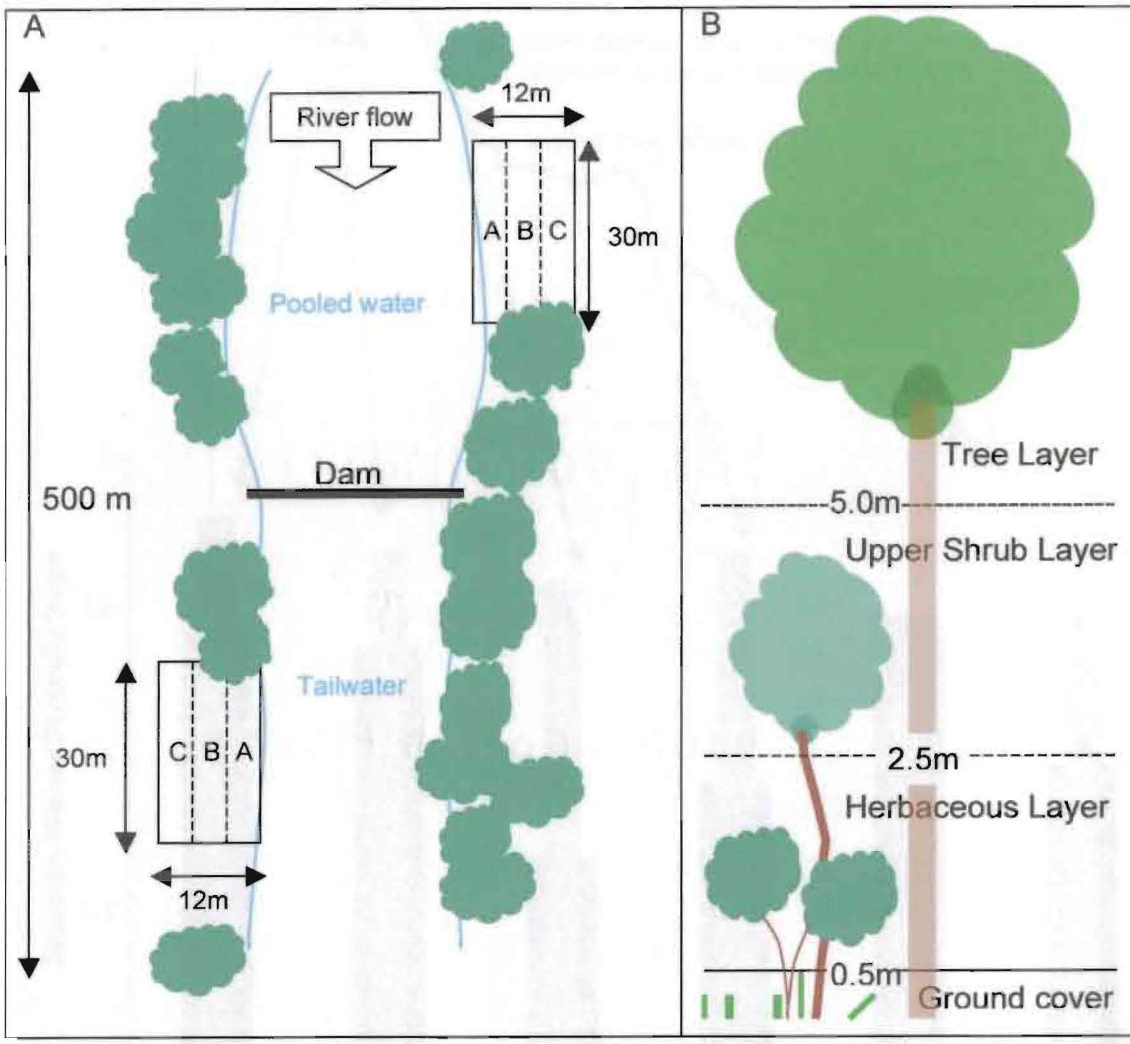

A
River flow
12m
A B C
30m
Pooled water
500 m
Dam
Tailwater
30m
C B A
12m
B
Tree Layer
5.0m
Upper Shrub Layer
2.5m
Herbaceous Layer
0.5m
Ground cover

Figure 3. Woody diversity in six tracts of riparian woodland along the lower Mahoning River. Tree diversity is variable along the length of the study area, while shrub diversity decreases with river kilometer.

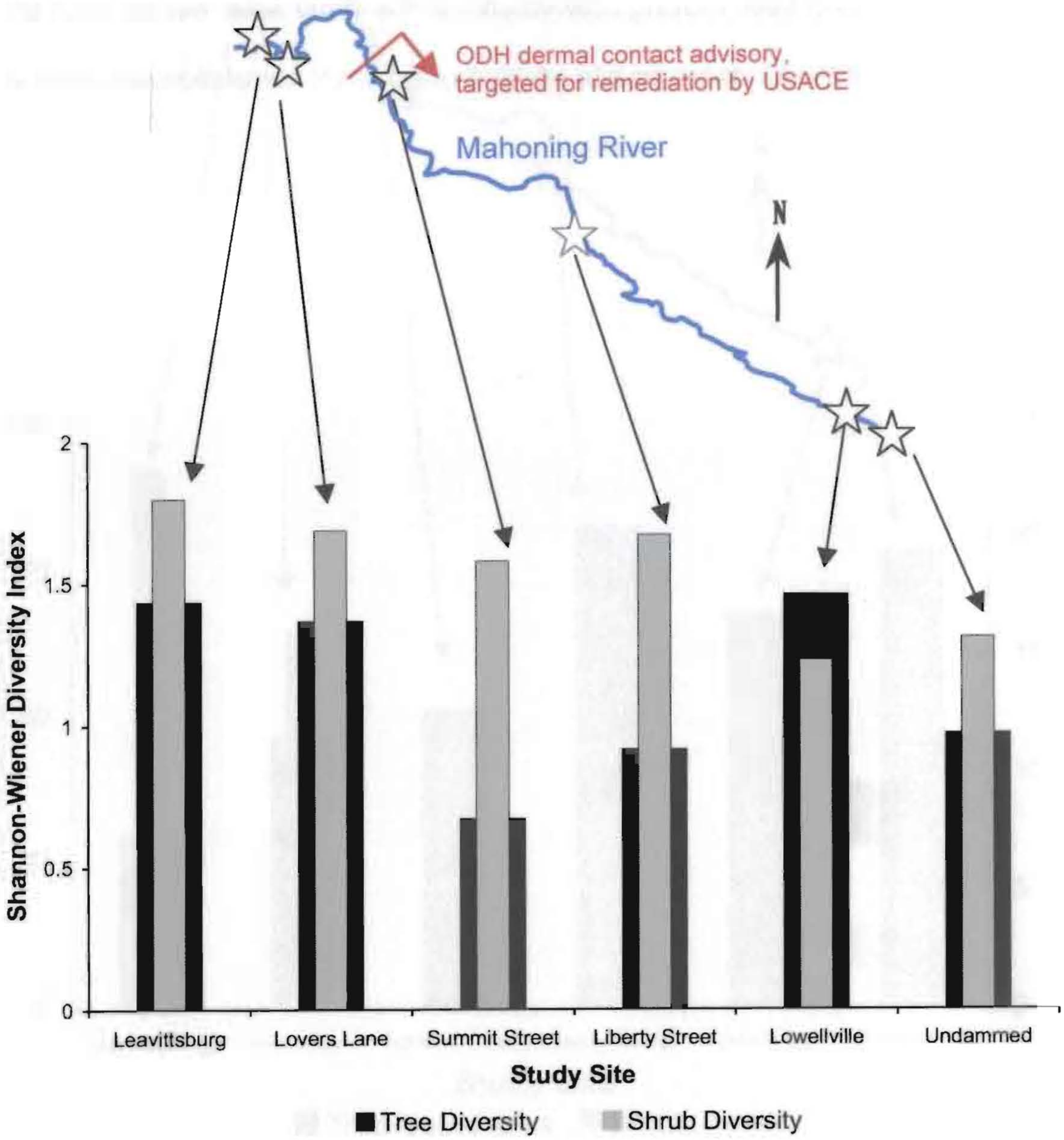

ODH dermal contact advisory, targeted for remediation by USACE
Mahoning River
N
Shannon-Wiener Diversity Index
2
1.5
1
0.5
0
Leavittsburg
Lovers Lane
Summit Street
Liberty Street
Lowellville
Undammed
Study Site
Tree Diversity
Shrub Diversity

Figure 4. Woody density in six tracts of riparian woodland along the lower Mahoning River. Tree basal area increases moving downstream and has a significant correlation (P = 0.042) with river kilometer. Shrub density (% cover) tends to decrease moving downstream in the study area, but the high shrub density at the Undammed site prevents significant correlation with river kilometer.

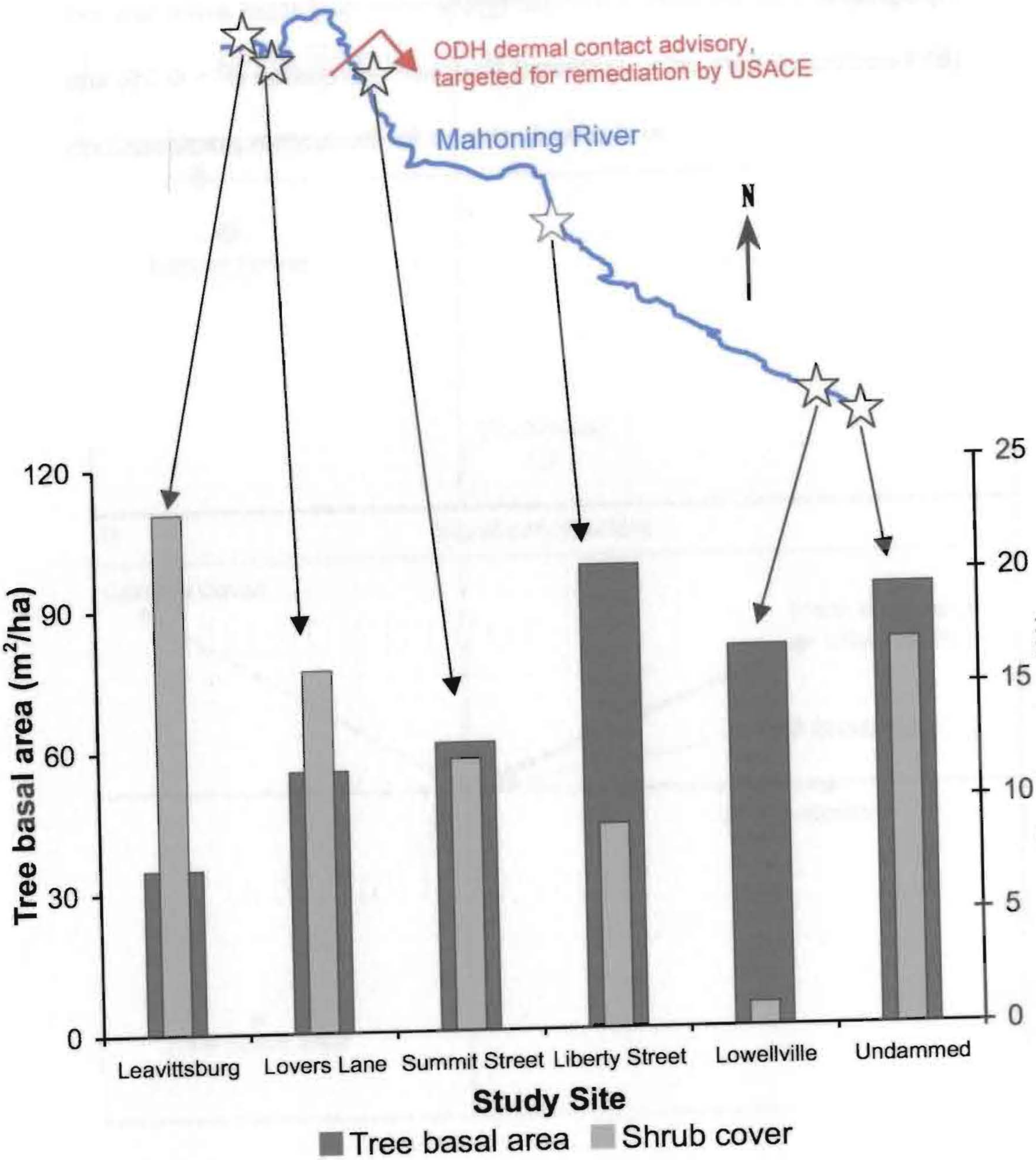

ODH dermal contact advisory, targeted for remediation by USACE
Mahoning River
N
120
90
60
30
0
Tree basal area (m²/ha)
25
20
15
10
5
0
Shrub cover (%)
Leavittsburg
Lovers Lane
Summit Street
Liberty Street
Lowellville
Undammed
Study Site
Tree basal area
Shrub cover

Figure 5. Ordination (multidimensional scaling) of six parcels of woodland along the lower Mahoning River. (A) For each dammed site, the riverbank topography and location of the site (Reference or Target area) are indicated. (B) Loading vectors with significant Pearson correlation ($P < 0.05$) with the horizontal axis. Tree basal area is shown for illustrative purposes only.

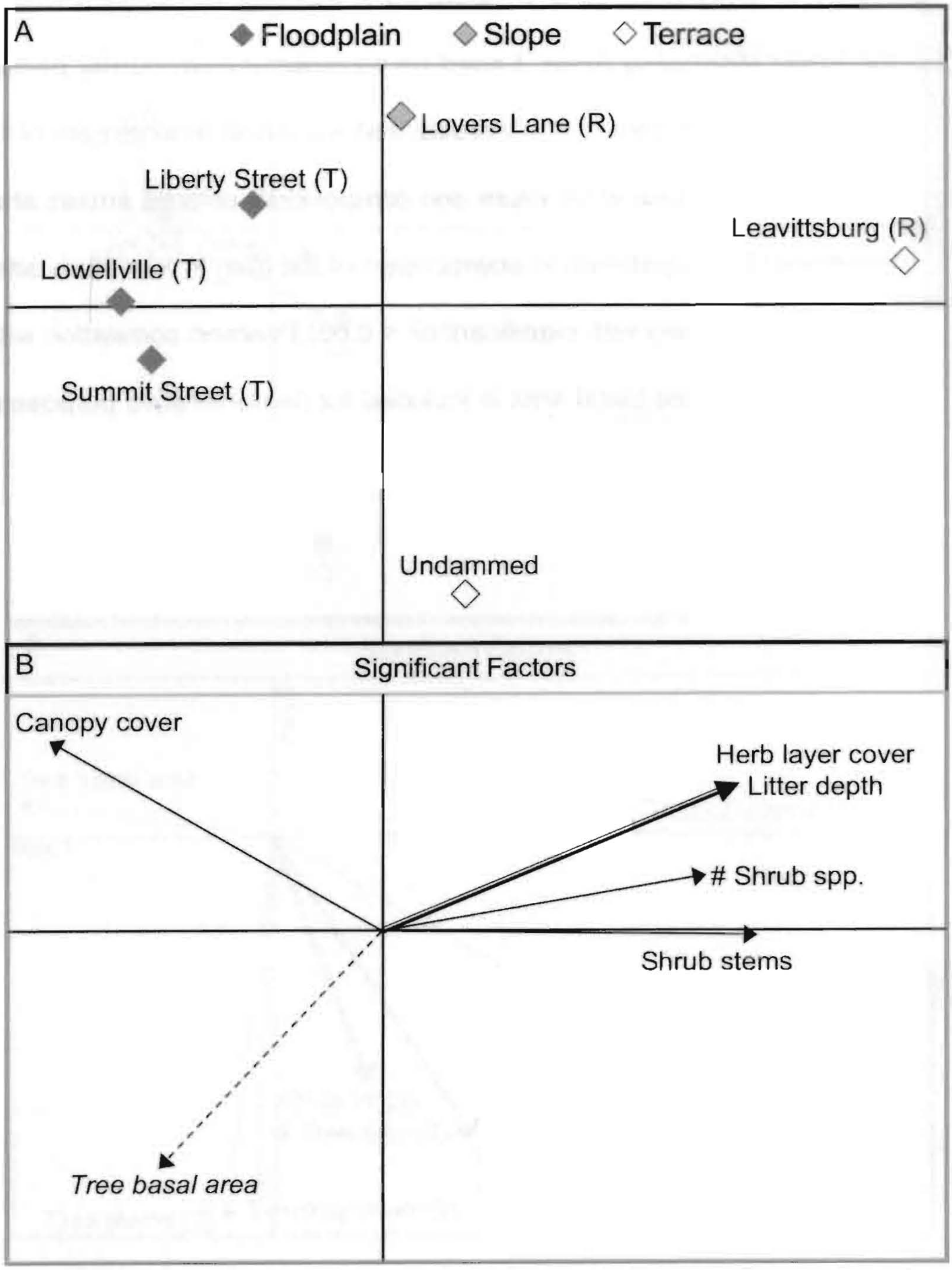

A
Floodplain
Slope
Terrace
Lovers Lane (R)
Liberty Street (T)
Leavittsburg (R)
Lowellville (T)
Summit Street (T)
Undammed
B
Significant Factors
Canopy cover
Herb layer cover
Litter depth
Shrub spp.
Shrub stems
Tree basal area

Figure 6. Ordination (multidimensional scaling) of twelve study plots along the lower Mahoning River, based on seventeen community parameters. (A) The encircled data points indicate that woodland downstream of four low-head dams is similar in structure and composition; colored arrows show movement from upstream to downstream of the dam in four study sites. (B) Loading vectors with significant ($P < 0.05$) Pearson correlation with the axis in parentheses. Tree basal area is included for demonstrative purposes.

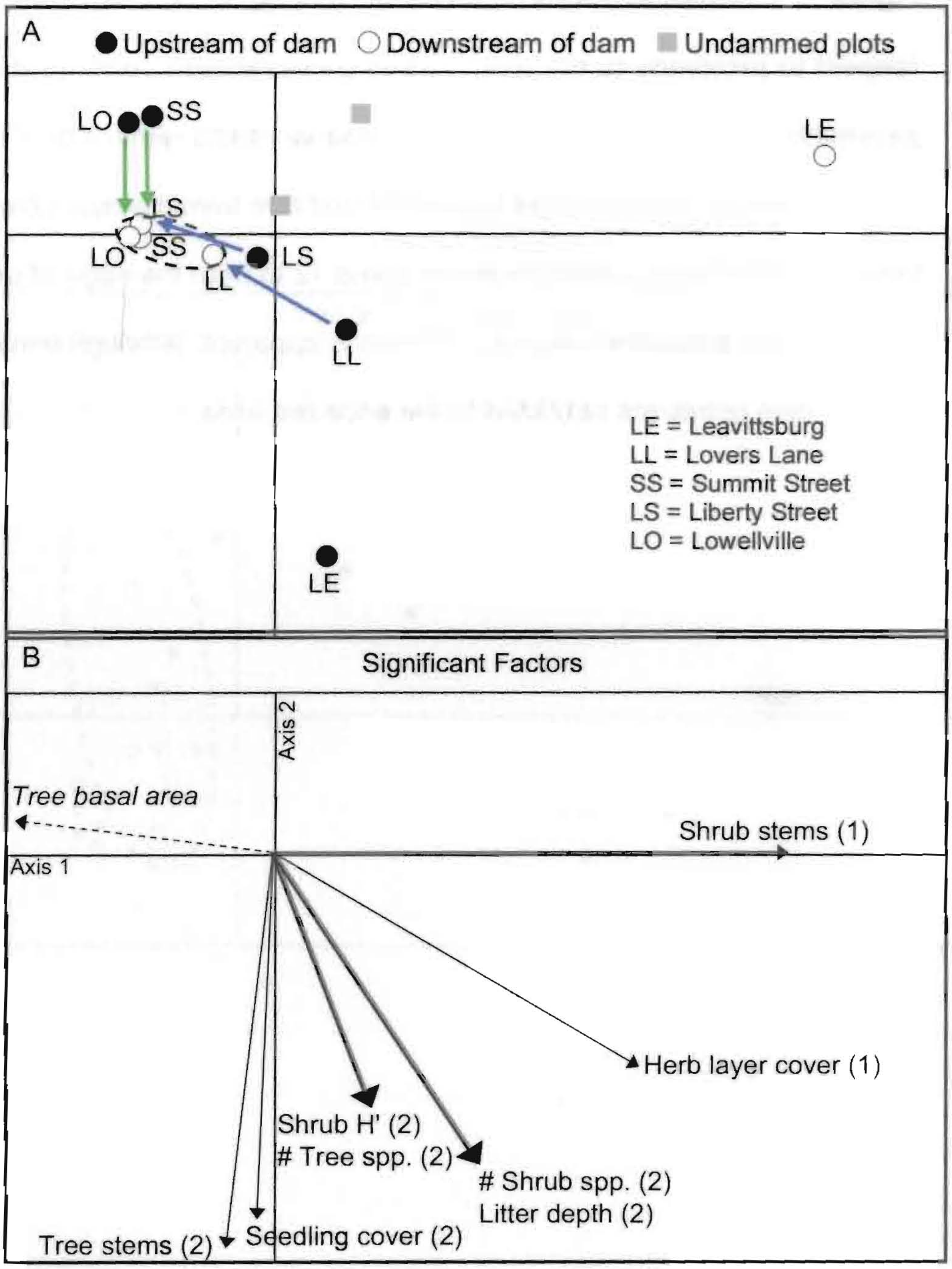

A
Upstream of dam
Downstream of dam
Undammed plots
LO
SS
LE
LS
LO
SS
LL
LS
LL
LE = Leavittsburg
LL = Lovers Lane
SS = Summit Street
LS = Liberty Street
LO = Lowellville
LE
B
Significant Factors
Axis 2
Tree basal area
Shrub stems (1)
Axis 1
Herb layer cover (1)
Shrub H' (2)
Tree spp. (2)
Shrub spp. (2)
Litter depth (2)
Tree stems (2)
Seedling cover (2)

Figure 7. Ordination (multidimensional scaling) of riparian woodland with respect to proximity to the river, based on seventeen community parameters. Data points include twelve riparian tracts within 4 m of the river (Zone A), twelve tracts located between 4 and 8 m from the river (Zone B), and twelve riparian tracts located between 8 and 12 m from the edge of the river (Zone C). No exclusive grouping of zones is apparent, although eleven of twelve Zone C data points are restricted to the encircled area.

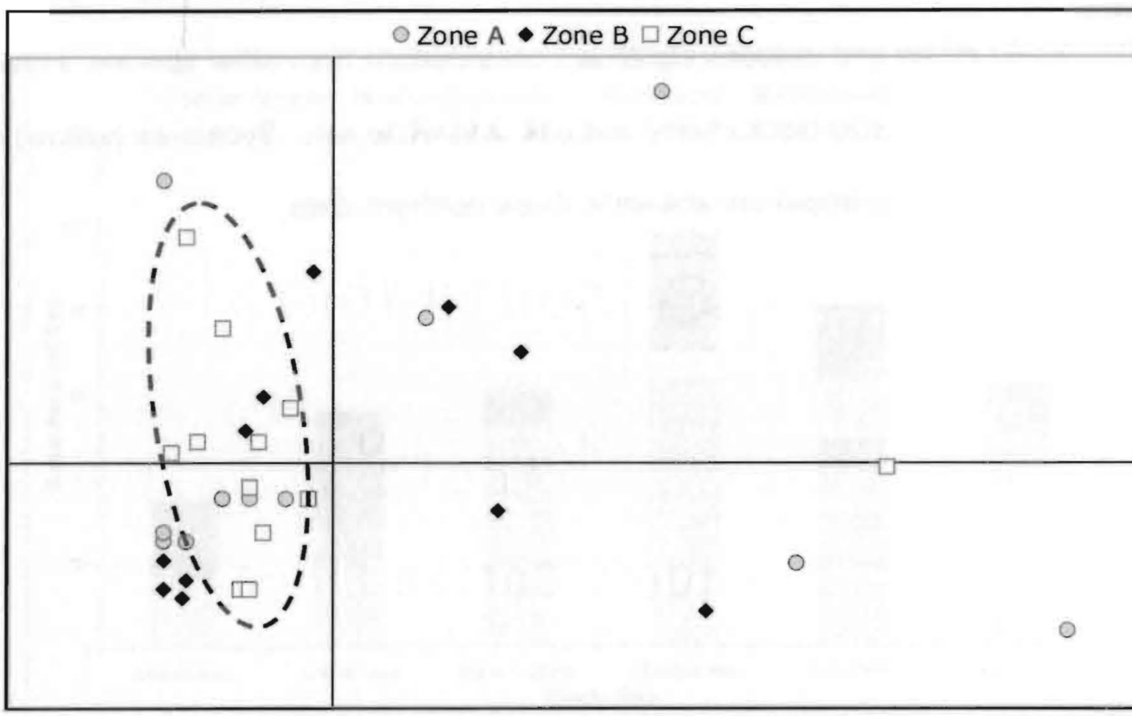
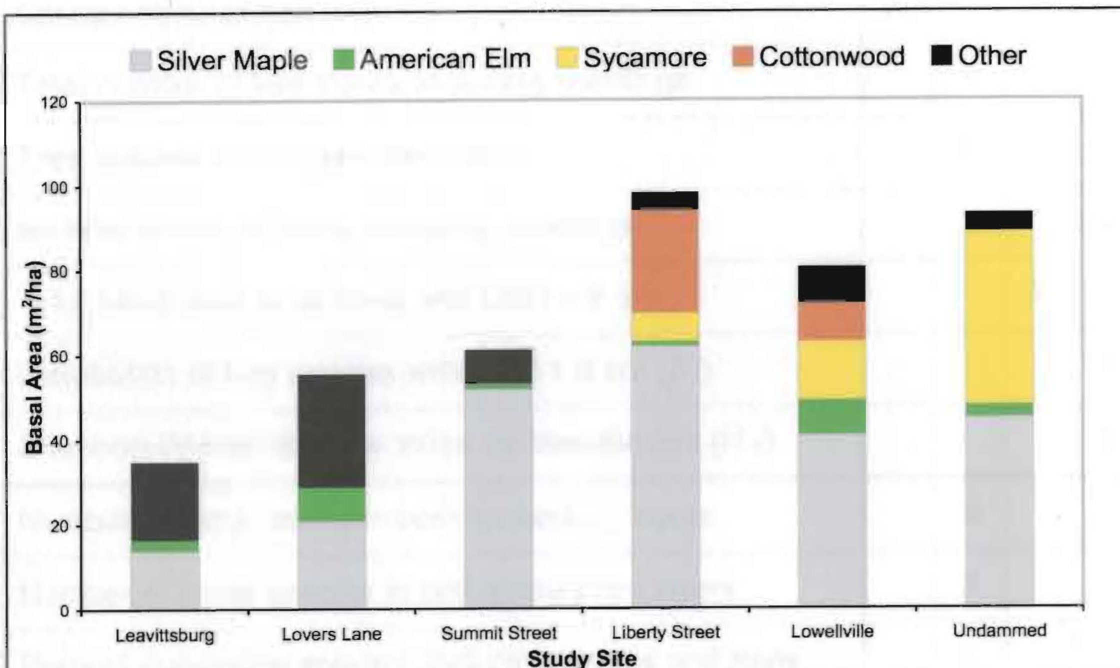

Zone A
Zone B
Zone C

Figure 8. Contribution of four dominant trees to total basal area in six woodland parcels along the lower Mahoning River. At Liberty Street, Lowellville, and the Undammed site, total basal area exceeds 80 m^2/ha and is comprised primarily of silver maple, American elm, sycamore, and cottonwood. At Leavittsburg, Lovers Lane, and Summit Street, total basal area ranges from 35-61 m^2/ha and includes significant contributions from other species, including black locust, wild black cherry, red oak, and white ash. Sycamore (yellow) and cottonwood (orange) are absent in these northern sites.



Silver Maple
American Elm
Sycamore
Cottonwood
Other
120
100
80
60
40
20
0
Basal Area (m²/ha)
Leavittsburg
Lovers Lane
Summit Street
Liberty Street
Lowellville
Undammed
Study Site

Table 1. Seventeen riparian woodland parameters determined for each parcel of streamside woodland. Distinction is made here between those estimated (**E**), those directly measured within the sampled plot or zone (**M**), parameters algebraically calculated from raw data obtained during sampling (**C**), and community indices determined using computer software (**I**).

Study Plot/Zone Parameter	E	M	C	I*
Percent vegetative ground cover	X			
Depth of litter layer	X			
Canopy cover of tree layer	X			
Total number of tree stems, including seedlings		X		
Tree species with largest basal area		X		
Number of tree species, including seedlings		X		
Total basal area of all trees with DBH > 3 cm			X	
Distribution of tree species with DBH > 3 cm (J'_T)				X
Shannon-Wiener diversity index for tree species (H'_T)				X
Number of shrub stems in both understory layers		X		
Number of shrub species in both understory layers		X		
Percent non-native species, including shrubs and trees		X		
Crown cover of woody plants in the herbaceous layer			X	
Crown cover of woody plants in the upper shrub layer			X	
Crown cover of only seedlings in both understory layers			X	
Distribution of shrub species (J'_S)				X
Shannon-Wiener diversity index for shrub species (H'_S)				X

*Equations used by computer software to calculate evenness and diversity indices are presented with the data in Appendix D.

Table 2. Streamside trees of the lower Mahoning River. Basal area (m^2/ha) for each species is given for each of the 12m X 30m plots sampled; those species represented only by small trees < 3 cm in DBH are noted (Y). The four species with the most basal area within the study area are indicated in bold. LE=Leavittsburg, LL=Lovers Lane, SS=Summit Street, LS=Liberty Street, LO=Lowellville, Und=Undammed; U=upstream woodland, D=downstream woodland. See Appendix B for details on the study sites and Appendix C for information on tree species.

Tree Species	LE		LL		SS		LS		LO		Und	
	U	D	U	D	U	D	U	D	U	D	U	D
Acer negundo	0.3	-	-	-	-	7.7	Y	0.3	Y	-	0.3	0.5
Acer saccharinum	**28.2**	**-**	**9.9**	**32.0**	**29.4**	**81.9**	**78.3**	**46.2**	**75.9**	**6.6**	**64.8**	**25.7**
Acer saccharum	-	-	0.3	-	1.0	-	-	-	-	Y	-	-
Ailanthus altissima	-	-	-	-	-	4.4	-	-	-	-	-	-
Carya cordiformis	Y	Y	Y	-	-	-	Y	-	-	-	Y	< 0.1
Catalpa speciosa	-	-	-	-	-	-	-	-	0.3	-	-	-
Crataegus sp.	Y	-	0.3	Y	Y	-	-	-	-	-	0.2	-
Fagus grandifolia	-	-	-	1.3	-	-	-	-	-	-	-	-
Fraxinus americana	1.0	4.6	10.9	3.9	Y	-	Y	7.0	Y	7.8	0.1	Y
Ilex opaca	Y	-	-	-	-	-	-	-	-	-	-	-
Juglans cinerea	-	-	-	-	-	-	-	-	-	-	-	6.9
Juglans nigra	-	-	-	-	-	-	-	-	-	-	-	Y
Morus alba	-	-	-	-	-	-	-	-	Y	-	-	-
Morus rubra	-	0.3	Y	-	-	Y	-	0.4	0.6	Y	-	-
Nyssa sylvatica	-	-	0.3	-	-	-	-	-	-	-	-	-
Ostrya virginiana	-	-	< 0.1	-	-	-	-	-	-	-	-	-
Platanus occidentalis	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**14.1**	**4.7**	**22.2**	**51.2**	**31.5**
Populus deltoides	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**47.8**	**-**	**17.3**	**-**	**-**
Prunus serotina	7.3	2.2	-	Y	-	-	-	-	-	-	-	-
Quercus rubra	Y	Y	36.8	Y	-	-	-	-	-	-	-	-
Robinia pseudoacacia	9.5	11.5	-	-	-	2.9	-	-	-	-	-	-
Sassafras albidum	-	-	Y	Y	-	-	-	-	-	-	-	-
Salix nigra	-	-	Y	-	-	-	-	-	9.2	-	-	-
Tilia americana	-	-	Y	< 0.1	1.5	-	-	-	-	-	-	-
Ulmus americana	**1.9**	**3.2**	**11.7**	**3.7**	**-**	**3.1**	**2.2**	**-**	**3.2**	**13.6**	**-**	**5.1**
Ulmus rubra	-	-	-	-	-	-	Y	-	-	-	-	-

Table 3. Streamside woody shrubs of the lower Mahoning River. Total crown cover of each species per unit area is given for each of the 12m X 30m plots sampled. Shrub species considered to be dominant within the study area are indicated in bold. LE=Leavittsburg, LL=Lovers Lane, SS=Summit Street, LS=Liberty Street, LO=Lowellville, Und=Undammed; 1=upstream woodland, 2=downstream woodland. See Appendix B for details on the study sites and Appendix C for information on shrub species.

Shrub Species	LE		LL		SS		LS		LO		Und	
	1	**2**	**1**	**2**	**1**	**2**	1	2	1	**2**	1	2
*Acer negundo***	0.004	-	-	-	-	0.213	0.005	0.075	0.051	-	0.042	0.002
Berberis thunbergii	-	-	-	-	-	0.008	-	-	-	-	-	-
Elaeagnus umbellata	0.007	-	-	-	-	-	-	-	-	-	-	-
Euonymus atropurpureus	**0.192**	**0.004**	**0.181**	**0.126**	-	**0.104**	-	-	**0.011**	-	**0.336**	-
Lindera benzoin	0.001	-	-	-	0.004	-	-	-	-	-	-	0.127
Ligustrum vulgare	-	0.013	0.038	-	-	-	-	-	-	-	-	-
Lonicera morrowii	0.048	-	-	-	-	-	0.216	-	-	-	-	-
Prunus virginiana	-	-	-	-	-	-	-	0.030	0.006	-	0.005	0.084
Rhamnus cathartica	0.012	-	0.132	-	-	0.261	0.163	-	-	-	-	-
Rosa multiflora	**0.337**	**0.553**	**0.164**	**0.024**	-	-	**0.120**	-	**0.023**	**0.023**	**0.023**	**0.520**
Rubus sp.	0.035	0.195	-	-	-	0.003	-	-	-	-	-	-
Sambucus nigra	0.027	-	-	-	-	-	0.007	-	-	-	-	-
Staphylea trifolia	-	-	0.163	0.090	-	-	-	-	-	-	-	-
Viburnum dentatum	0.113	-	-	-	0.227	-	-	-	-	-	-	-
Viburnum opulus				0.016								
Viburnum prunifolium	-	-	-	-	-	-	-	-	-	-	-	0.017

** *Acer negundo* occurs along the lower Mahoning River both in sprawling shrub form and in erect tree form. The contribution of each growth form is given in Tables 2 and 3.

Table 4. Diversity of the riparian woodland above and below five low-head dams of the lower Mahoning River. Shannon-Wiener diversity indices for trees with DBH > 3 cm (H'_T) and for all shrub species (H'_S) are reported.

Tree Diversity (H'_T)			
Study Site	**Upstream**	**Downstream**	**Difference**
Leavittsburg	1.156	1.235	+ 0.0790
Lovers Lane	*1.258*	*0.7487*	*- 0.5093*
Summit Street	0.3299	0.7104	+ 0.3805
Liberty Street	0.1263	1.061	+ 0.9347
Lowellville	0.7145	1.514	+ 0.7995
Average effect of dams upon tree diversity			**+ 0.3369**
Shrub Diversity (H'_S)			
Study Site	**Upstream**	**Downstream**	**Difference**
Leavittsburg	1.717	0.7832	- 0.9338
Lovers Lane	1.518	1.112	- 0.4060
Summit Street	*0.0817*	*1.116*	*+ 1.034*
Liberty Street	1.176	0.5977	- 0.5783
Lowellville	1.107	0	- 0.9538
Average effect of dams upon shrub diversity			**- 0.3676**

Table 5. Tree and shrub density above and below five low-head dams of the lower Mahoning River. Tree density is reported as total basal area (m^2/ha), and shrub density is reported as crown cover of all woody plants per unit area.

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Tree Basal Area			
Study Site	**Upstream**	**Downstream**	**Difference**
Leavittsburg	48.1	21.7	- 26.4
Lovers Lane	69.9	41.0	- 28.6
Summit Street	31.9	100	+ 68.1
Liberty Street	80.5	116	+ 35.5
Lowellville	93.8	67.4	- 26.4
Average effect of dams upon tree density			**+ 4.4**
Upper Shrub Layer Cover			
Study Site	**Upstream**	**Downstream**	**Difference**
Leavittsburg	0.18	0.01	- 0.17
Lovers Lane	0.15	0.06	- 0.09
Summit Street	0	0.22	+ 0.22
Liberty Street	0.12	0	- 0.12
Lowellville	0.02	0	- 0.02
Average effect of dams upon upper shrub layer cover			**- 0.04**
Herbaceous Layer Cover			
Study Site	**Upstream**	**Downstream**	**Difference**
Leavittsburg	0.28	0.25	- 0.03
Lovers Lane	0.20	0.16	- 0.04
Summit Street	0.10	0.02	- 0.08
Liberty Street	0.09	0.04	- 0.05
Lowellville	0.03	0.03	0
Average effect of dams upon herbaceous layer cover			**- 0.03**

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APPENDIX A:

Study Site Specifications

Table A1. Location and orientation of the study sites and plots sampled in this study.

Study Site	Study Plot	Location	Distance to Dam	Bank
Leavittsburg	Upstream	41°14.486' N 80°52.942' W	343 m	West
	Downstream	41°14.393' N 80°52.813' W	120 m	East
Lovers Lane	Upstream	41°14.474' N 80°51.807' W	85 m	West
	Downstream	41°14.604' N 80°51.830' W	136 m	West
Summit Street	Upstream	41°14.777' N 80°49.698' W	167 m	West
	Downstream	41°14.524' N 80°49.615' W	173 m	East
Liberty Street	Upstream	41°09.322' N 80°42.368' W	107 m	East
	Downstream	41°09.176' N 80°42.337' W	93 m	East
Lowellville	Upstream	41°02.315' N 80°32.414' W	147 m	East
	Downstream	41°02.195' N 80°32.243' W	205 m	East
Undammed (Ohio/PA Border)	Upstream	41°01.806' N 80°30.926' W	644 m apart	East
	Downstream	41°01.800' N 80°30.446' W		East

Table A2. Additional descriptions of the riparian corridor and riverbank topography at six study sites along the lower Mahoning River.
[d] The width of the riparian corridor was measured at either end of each plot and averaged.
[e] The slope of each study plot was measured at either end of the plot and averaged.

Study Site	Study Plot	Corridor Width[d]	Corridor Slope	Plot Slope[e]	Bank Topography
Leavittsburg	Upstream	52 m	< 5°	< 5°	2-m terrace
	Downstream	56 m	< 5°	< 5°	2-m terrace
Lovers Lane	Upstream	19 m	24°	24°	Steep slope
	Downstream	27 m	20°	20°	Steep slope
Summit Street	Upstream	97 m	< 5°	< 5°	Floodplain
	Downstream	29 m	23°	< 5°	Floodplain
Liberty Street	Upstream	33 m	16°	< 5°	Floodplain
	Downstream	44 m	20°	< 5°	Floodplain
Lowellville	Upstream	33 m	< 5°	< 5°	Floodplain
	Downstream	22 m	< 5°	< 5°	Floodplain
Undammed	Upstream	17 m	14°	< 5°	1.0-m terrace
	Downstream	59 m	< 5°	< 5°	1.5-m terrace

APPENDIX B:

Dam Specifications

Table B1. Location and construction of dams considered in this study.

Dam	RK[a]	Municipality, County	Dam Type	Ht (m)[b]
Leavittsburg[c]	(77)	Leavittsburg, Trumbull	Concrete run-of-river	---
Lovers Lane	74.3	Leavittsburg, Trumbull	Rock rubble mound	2.1
Summit Street	64.5	Warren, Trumbull	Concrete run-of-river	2.9
Liberty Street	43.4	Girard, Trumbull	Concrete run-of-river	2.2
Lowellville[c]	21.0	Lowellville, Mahoning	Concrete run-of-river	1.0

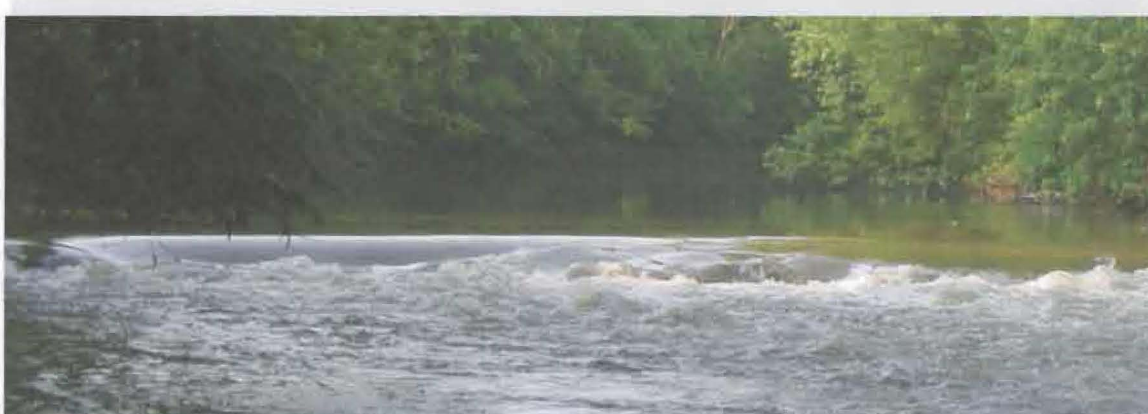
[a] River kilometer (RK) indicates the distance from the terminus of the river as determined by the USACE during their 1999 reconnaissance study. RK of the Leavittsburg dam is estimated.

[b] Height of dam, as reported by the USACE, from the crest to tailwater at low water.

[c] Dams not described by the USACE were estimated for river kilometer (Leavittsburg) and visually assessed for construction type (Leavittsburg and Lowellville).

<u>**Five low-head dams of the lower Mahoning River**</u>

Leavittsburg Dam, Leavittsburg OH



Lovers Lane Dam, Leavittsburg OH

Summit Street Dam, Warren OH

Liberty Street Dam, Girard OH

Lowellville Dam, Lowellville OH

Note: All photographs were taken by Anna Stambolia-Kovach during field reconnaissance in June 2004.

APPENDIX C:

Woody Plants of the lower Mahoning River

Table C1. Woody plants species of the lower Mahoning River (June 2004).

Family	Species Name	Common Name	Nat.
Aceraceae	*Acer negundo* L.	Boxelder	Y
	Acer saccharinum L.	Silver maple	Y
	Acer saccharum Marshall.	Sugar maple	Y
Anacardaiceae	*Toxicodendron radicans* (L.) Kuntze	Poison ivy	Y
Aquifoliaceae	*Ilex opaca* Aiton.	American holly	N
Berberidaceae	*Berberis thunbergii* DC.	Japanese barberry	N
Betulaceae	*Ostrya virginiana* (Miller) K. Koch.	Hop-hornbeam	Y
Bignoniaceae	*Catalpa speciosa* Warder.	Northern catalpa	Y
Caprifoliaceae	*Lonicera morrowii* A. Gray.	Honeysuckle	N
	Sambucus nigra L.	Eur. elderberry	N
	Viburnum dentatum L.	Arrowwood	Y
	Viburnum opulus var. *opulus* L.	Viburnum	N
	Viburnum prunifolium L.	Black haw	Y
Celastraceae	*Euonymus atropurpureus* Jacq.	Eastern wahoo	Y
Cornaceae	*Nyssa sylvatica* Marshall.	Black tupelo	Y
Elaeagnaceae	*Elaeagnus umbellata* Thunb.	Autumn olive	N
Fagaceae	*Fagus grandifolia* Ehrh.	American beech	Y
	Quercus rubra L.	Northern red oak	Y
Juglandaceae	*Carya cordiformis* (Wangenh.) K. Koch.	Bitternut hickory	Y
	Juglans cinerea L.	Butternut	Y
	Juglans nigra L.	Black walnut	Y
Lauraceae	*Lindera benzoin* (L.) Blume	Spicebush	Y
	Sassafras albidum (Nutt.) Nees.	Sassafras	Y
Leguminasae	*Robinia pseudoacacia* L.	Black locust	Y
Moraceae	*Morus alba* L.	White mulberry	N
	Morus rubra L	Red mulberry	Y
Oleaceae	*Fraxinus americana* L.	White ash	Y
	Ligustrum vulgare L.	Common privet	N
Platanaceae	*Platanus occidentalis* L.	Amer. sycamore	Y
Rhamnaceae	*Rhamnus cathartica* L.	Common buckthorn	N
Rosaceae	*Crataegus* sp. L.	Hawthorn	
	Prunus serotina Ehrh.	Wild black cherry	Y
	Prunus virginiana L.	Choke-cherry	Y
	Rosa multiflora Thunb. ex Murr.	Multiflora rose	N
	Rubus sp. L.	Bramble	
Salicaceae	*Populus deltoides* Marshall.	E. cottonwood	Y
	Salix nigra Marshall.	Black willow	Y
Simaroubaceae	*Ailanthus altissima* (Miller) Swingle.	Tree of heaven	N
Staphyleaceae	*Staphylea trifolia* L.	Bladdernut	Y
Tiliaceae	*Tilia americana* L.	Basswood	Y
Ulmaceae	*Ulmus americana* L.	American elm	Y
	Ulmus rubra L.	Slippery elm	Y
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper	Y
	Vitis riparia Michx.	Riverbank grape	Y

*****Nativity to Ohio according to Gleason and Cronquist 1991 and Braun 1989.***

APPENDIX D:

Woodland Community Parameters of the lower Mahoning River

Table D1. Depth of the litter layer (cm) in each zone sampled, as estimated by averaging seven transect measurements along each 30 m sampling plot.

Study Site	Zone	Upstream	Downstream
Leavittsburg **2.6 cm litter**	A	3.9	0.1
	B	2.7	1.2
	C	3.9	3.4
	PLOT	**3.5**	**1.6**
Lovers Lane **1.6 cm litter**	A	0	0
	B	2.1	0.2
	C	4.1	2.7
	PLOT	**2.1**	**1.0**
Summit Street **0.7 cm litter**	A	0.1	0.3
	B	0.9	0.4
	C	1.7	0.9
	PLOT	**0.9**	**0.5**
Liberty Street **1.1 cm litter**	A	0	0.8
	B	0.5	0.9
	C	2.1	2.1
	PLOT	**0.9**	**1.3**
Lowellville **0.4 cm litter**	A	0.3	0
	B	0.1	0
	C	1.2	0.5
	PLOT	**0.5**	**0.2**
Undammed **1.2 cm litter**	A	0.8	0.2
	B	1.7	0.9
	C	2.3	1.1
	PLOT	**1.6**	**0.7**

Table D2. Percent vegetative ground cover (<50 cm), as visually estimated in a randomly placed 2 m X 2 m quadrat within each sampled zone.

Study Site	Zone	Upstream	Downstream
Leavittsburg **46% vegetative ground cover**	A	50%	0
	B	60%	80%
	C	70%	15%
	PLOT	**60%**	**32%**
Lovers Lane **25% vegetative ground cover**	A	50%	10%
	B	50%	5%
	C	2%	30%
	PLOT	**34%**	**15%**
Summit Street **27% vegetative ground cover**	A	5%	50%
	B	30%	10%
	C	25%	40%
	PLOT	**20%**	**33%**
Liberty Street **30% vegetative ground cover**	A	5%	0
	B	30%	15%
	C	80%	50%
	PLOT	**38%**	**22%**
Lowellville **43% vegetative ground cover**	A	20%	25%
	B	25%	50%
	C	100%	35%
	PLOT	**48%**	**37%**
Undammed **59% vegetative ground cover**	A	35%	90%
	B	90%	10%
	C	35%	95%
	PLOT	**53%**	**65%**

Table D3. Canopy cover of the tree layer, as estimated using a densiometer, in each area sampled.

Study Site	Zone	Upstream	Downstream
Leavittsburg 89% canopy cover	A	93%	86%
	B	80%	92%
	C	92%	91%
	PLOT	**88%**	**90%**
Lovers Lane 95% canopy cover	A	93%	88%
	B	97%	97%
	C	98%	96%
	PLOT	**96%**	**94%**
Summit Street 95% canopy cover	A	92%	91%
	B	96%	95%
	C	98%	96%
	PLOT	**95%**	**94%**
Liberty Street 95% canopy cover	A	94%	95%
	B	95%	97%
	C	97%	91%
	PLOT	**95%**	**94%**
Lowellville 94% canopy cover	A	92%	95%
	B	90%	97%
	C	87%	98%
	PLOT	**90%**	**97%**
Undammed 92% canopy cover	A	94%	88%
	B	96%	90%
	C	92%	90%
	PLOT	**94%**	**90%**

Table D4. Tree basal area (m^2/ha) within each sampled area, which was obtained directly by summing the basal area of all trees with DBH > 3 cm.

Study Site	Zone	Upstream	Downstream
Leavittsburg 34.9 m^2/ha	A	34.3	4.8
	B	23.9	21.0
	C	86.1	39.4
	PLOT	**48.1**	**21.7**
Lovers Lane 55.5 m^2/ha	A	74.5	54.3
	B	24.1	42.9
	C	111.2	25.7
	PLOT	**69.9**	**41.0**
Summit Street 61.1 m^2/ha	A	69.9	97.3
	B	14.4	135.6
	C	11.5	69.1
	PLOT	**31.9**	**100**
Liberty Street 98.1 m^2/ha	A	26.2	73.1
	B	166.6	219.6
	C	48.7	54.6
	PLOT	**80.5**	**116**
Lowellville 80.6 m^2/ha	A	122.3	72.1
	B	12.1	36.2
	C	147.1	94.0
	PLOT	**93.8**	**67.4**
Undammed 93.2 m^2/ha	A	237.9	92.8
	B	34.7	61.1
	C	77.3	58.9
	PLOT	**117**	**70.9**

Table D5. Number of woody stems per hectare of sampled riparian woodland. Tree stems includes all trees, regardless of size.

Study Site	Zone	Upstream		Downstream	
		Shrubs	Trees	Shrubs	Trees
Leavittsburg	A	1.1 E4	4.9 E3	2.0 E4	1.7 E2
Shrubs = 1.0 E4	B	3.3 E3	3.3 E3	1.2 E4	3.3 E2
Trees = 2.3 E3	C	5.0 E2	3.6 E3	1.6 E4	1.6 E3
	PLOT	**4.9 E3**	**3.9 E3**	**1.6 E4**	**6.9 E2**
Lovers Lane	A	5.8 E3	2.9 E3	2.7 E3	1.3 E3
Shrubs = 3.8 E3	B	7.9 E3	2.6 E3	2.2 E3	2.2 E3
Trees = 2.0 E3	C	2.2 E3	1.0 E3	2.1 E3	1.8 E3
	PLOT	**5.3 E3**	**2.2 E3**	**2.3 E3**	**1.7 E3**
Summit Street	A	0	9.2 E2	1.3 E3	1.3 E3
Shrubs = 8.0 E2	B	5.0 E2	5.8 E2	0	5.0 E2
Trees = 1.1 E3	C	2.8 E3	2.1 E3	7.5 E2	1.8 E3
	PLOT	**9.2 E2**	**6.9 E2**	**6.7 E2**	**1.6 E3**
Liberty Street	A	5.0 E2	9.2 E2	0	1.0 E3
Shrubs = 2.0 E3	B	6.3 E3	3.0 E3	1.8 E3	1.9 E3
Trees = 1.6 E3	C	3.2 E3	1.3 E3	1.7 E2	1.7 E3
	PLOT	**3.3 E3**	**1.7 E3**	**6.7 E2**	**1.5 E3**
Lowellville	A	0	1.3 E3	0	1.4 E3
Shrubs = 4.1 E2	B	0	4.2 E2	0	7.5 E2
Trees = 1.2 E3	C	1.2 E3	5.0 E2	1.3 E3	2.8 E3
	PLOT	**3.9 E2**	**7.5 E2**	**4.2 E2**	**1.6 E3**
Undammed	A	1.9 E3	1.3 E3	1.4 E4	7.5 E2
Shrubs = 4.7 E3	B	7.4 E3	1.2 E3	0	5.0 E2
Trees = 9.4 E2	C	1.9 E3	1.4 E3	1.9 E3	5.0 E2
	PLOT	**3.8 E3**	**1.3 E3**	**5.6 E3**	**5.8 E2**

Table D6. Species identification and size (DBH in cm) of the largest stem within each sampled area.

Study Site	Zone	Upstream		Downstream	
		Species	DBH	Species	DBH
Leavittsburg Silver maple DBH = 85 cm	A	Black locust	37	American elm	27
	B	Black cherry	32	White ash	46
	C	Silver maple	85	Black locust	39
	PLOT	**Silver maple**	**85**	**White ash**	**46**
Lovers Lane Red oak DBH = 103 cm	A	Silver maple	46	Silver maple	43
	B	White ash	49	Silver maple	46
	C	Red oak	103	White ash	37
	PLOT	**Red oak**	**103**	**Silver maple**	**46**
Summit Street Silver maple DBH = 94 cm	A	Silver maple	51	Silver maple	46
	B	Silver maple	33	Silver maple	94
	C	Am. basswood	26	Tree of Heaven	34
	PLOT	**Silver maple**	**51**	**Silver maple**	**94**
Liberty Street E. cottonwood DBH = 148 cm	A	Silver maple	40	Silver maple	54
	B	Silver maple	60	E. cottonwood	148
	C	Silver maple	41	Am. sycamore	69
	PLOT	**Silver maple**	**60**	**E. cottonwood**	**148**
Lowellville Silver maple DBH = 141 cm	A	Silver maple	68	E. cottonwood	68
	B	American elm	34	E. cottonwood	50
	C	Silver maple	141	Am. sycamore	95
	PLOT	**Silver maple**	**141**	**Am. sycamore**	**95**
Undammed Am. Sycamore DBH = 95 cm	A	Silver maple	78	Am. sycamore	73
	B	Am. sycamore	39	Am. sycamore	95
	C	Am. sycamore	53	Silver maple	93
	PLOT	**Silver maple**	**78**	**Am. sycamore**	**95**

Table D7. Species richness of each zone and plot sampled, expressed in total number of species identified during sampling. Tree species include both mature trees and immature seedlings. Shrub species include all shrubs.

Study Site	Zone	Upstream		Downstream	
		Shrub	Tree	Shrub	Tree
<u>Leavittsburg</u> **11 Shrub spp.** **11 Tree spp.**	A	8	7	3	2
	B	4	6	2	3
	C	3	5	4	6
	PLOT	**10**	**11**	**4**	**7**
<u>Lovers Lane</u> **6 Shrub spp.** **15 Tree spp.**	A	4	6	1	3
	B	5	11	3	3
	C	4	7	1	8
	PLOT	**5**	**13**	**4**	**9**
<u>Summit Street</u> **7 Shrub spp.** **10 Tree spp.**	A	0	2	3	5
	B	2	2	0	3
	C	1	4	3	3
	PLOT	**2**	**5**	**5**	**6**
<u>Liberty Street</u> **6 Shrub spp.** **8 Tree spp.**	A	2	4	0	2
	B	2	4	1	5
	C	4	3	2	5
	PLOT	**5**	**5**	**2**	**6**
<u>Lowellville</u> **4 Shrub spp.** **10 Tree spp.**	A	1	5	0	4
	B	1	4	0	4
	C	3	2	1	5
	PLOT	**4**	**8**	**1**	**7**
<u>Undammed</u> **6 Shrub spp.** **9 Tree spp.**	A	1	2	3	4
	B	4	3	1	3
	C	2	5	2	5
	PLOT	**4**	**6**	**5**	**8**

Table D8. Evenness of tree basal area distribution, expressed as the Equitability J' (Sample) index for all trees with DBH > 3 cm and computed by SDR software.

Study Site	Zone	Upstream	Downstream
Leavittsburg $J'_T = 0.7379$	A	0.8624	0
	B	0.9993	0.9297
	C	0.04868	0.6428
	PLOT	**0.6454**	**0.7673**
Lovers Lane $J'_T = 0.5943$	A	0.6632	0.09549
	B	0.5876	0.1382
	C	0.034	0.6776
	PLOT	**0.6049**	**0.4652**
Summit Street $J'_T = 0.6718$	A	0	0.5385
	B	0	0.6582
	C	0.9892	0.7059
	PLOT	**0.3003**	**0.4414**
Liberty Street $J'_T = 0.9143$	A	0.2629	0.2094
	B	0.06372	0.8637
	C	0.4275	0.4775
	PLOT	**0.1822**	**0.592**
Lowellville $J'_T = 1.459$	A	0.6264	0.8857
	B	0.6026	0.7656
	C	0	0.6344
	PLOT	**0.3988**	**0.9407**
Undammed $J'_T = 0.9687$	A	0.6862	0.9626
	B	0	0.159
	C	0.1022	0.01545
	PLOT	**0.4487**	**0.6609**

*SDR uses the equation $J' = \frac{H'}{\log S}$,

where *H'* is the Shannon-Wiener diversity index
and *S* is the maximum number of species observed in any one sample.

Table D9. Tree diversity, expressed as the Shannon-Wiener diversity index for all trees with DBH > 3 cm (H'_T) and computed by SDR software using combined basal area of each species in each area sampled.

Study Site	Zone	Upstream	Downstream
Leavittsburg H'_T = 1.436	A	1.196	0
	B	0.6927	0.6444
	C	0.06749	0.8912
	PLOT	**1.156**	**1.235**
Lovers Lane H'_T = 1.368	A	0.7286	0.06619
	B	0.9458	0.09576
	C	0.04713	1.091
	PLOT	**1.258**	**0.7487**
Summit Street H'_T = 0.6718	A	0	0.7465
	B	0	0.7231
	C	1.087	0.7756
	PLOT	**0.3299**	**0.7104**
Liberty Street H'_T = 0.9143	A	0.1823	0.1451
	B	0.04417	0.5987
	C	0.2963	0.6619
	PLOT	**0.1263**	**1.061**
Lowellville H'_T = 1.459	A	0.8684	1.228
	B	0.6620	0.8411
	C	0	0.8795
	PLOT	**0.7145**	**1.514**
Undammed H'_T = 0.9687	A	0.4757	1.334
	B	0	0.1102
	C	0.1417	0.01071
	PLOT	**0.7222**	**1.184**

*SDR software uses the equation $H' = \log N - \frac{1}{N}\sum_{i=1}^{\infty}(p_i \log p_i)n_i$,

where N is the total number of species,
p_i is the proportion of individuals in the i^{th} species,
and n_i is the number of species with i individuals.

Table D10. Crown cover of woody plants in the herbaceous layer (all shrub and tree species 0.5-2.5 m in height) expressed per unit area sampled.

Study Site	Zone	Upstream		Downstream	
		Shrubs	Trees	Shrubs	Trees
Leavittsburg **Shrubs = 0.21** **Trees = 0.06**	A	0.30	0.15	0.32	0
	B	0.16	0.05	0.16	0
	C	0.01	0.17	0.28	0
	PLOT	**0.16**	**0.12**	**0.25**	**0**
Lovers Lane **Shrubs = 0.11** **Trees = 0.08**	A	0.10	0.05	0.12	0.04
	B	0.17	0.16	0.23	0.08
	C	0.09	0.03	0.02	0.08
	PLOT	**0.12**	**0.08**	**0.09**	**0.07**
Summit Street **Shrubs = 0.04** **Trees = 0.02**	A	0	0	0	0.02
	B	0.05	0	0	0
	C	0.18	0.03	0.02	0.03
	PLOT	**0.08**	**0.02**	**0**	**0.02**
Liberty Street **Shrubs = 0.04** **Trees = 0.03**	A	0	0.01	0	0
	B	0.06	0.03	0.03	0.01
	C	0.15	0.01	0	0.08
	PLOT	**0.07**	**0.02**	**0.01**	**0.03**
Lowellville **Shrubs = 0.01** **Trees = 0.02**	A	0	0.04	0	0
	B	0	0.01	0	0
	C	0.04	0	0.02	0.05
	PLOT	**0.01**	**0.02**	**0.01**	**0.02**
Undammed **Shrubs = 0.11** **Trees = 0.01**	A	0.04	0	0.21	0
	B	0.25	0.03	0	0
	C	0.07	0.01	0.09	0.01
	PLOT	**0.12**	**0.01**	**0.10**	**0**

Table D11. Crown cover of woody plants in the upper shrub layer (all shrub and tree species 2.6-5.0 m in height) expressed per unit area sampled.

Study Site	Zone	Upstream		Downstream	
		Shrubs	Trees	Shrubs	Trees
Leavittsburg Shrubs = 0.03 Trees = 0.07	A	0.11	0.12	0	0
	B	0.02	0.08	0	0
	C	0.01	0.18	0	0.03
	PLOT	**0.05**	**0.13**	**0**	**0.01**
Lovers Lane Shrubs = 0.05 Trees = 0.06	A	0.14	0.03	0	0
	B	0.05	0.10	0	0.03
	C	0.12	0.02	0	0.15
	PLOT	**0.10**	**0.05**	**0**	**0.06**
Summit Street Shrubs = 0.07 Trees = 0.03	A	0	0	0.37	0
	B	0	0	0	0
	C	0	0	0	0.17
	PLOT	**0**	**0**	**0.16**	**0.06**
Liberty Street Shrubs = 0.05 Trees = 0.01	A	0	0	0	0
	B	0.29	0.07	0	0
	C	0	0	0	0
	PLOT	**0.10**	**0.02**	**0**	**0**
Lowellville Shrubs = 0 Trees = 0.01	A	0	0.07	0	0
	B	0	0	0	0
	C	0	0	0	0
	PLOT	**0**	**0.02**	**0**	**0**
Undammed Shrubs = 0.06 Trees = 0.01	A	0	0	0.21	0
	B	0	0.02	0.14	0
	C	0	0	0.02	0.02
	PLOT	**0**	**0.01**	**0.12**	**0.01**

Table D12. Evenness of shrub distribution, expressed as the Equitability J' (Sample) index for all shrub species and computed by SDR software.

Study Site	Zone	Upstream	Downstream
Leavittsburg J'_S = **0.6746**	A	0.7804	0.6262
	B	0.9534	0.7909
	C	0.2512	0.7866
	PLOT	**0.7694**	**0.5649**
Lovers Lane J'_S = **0.8468**	A	0.7815	0
	B	0.8332	0.5161
	C	0.9203	0
	PLOT	**0.9432**	**0.8021**
Summit Street J'_S = **0.7295**	A	0	0.476
	B	0.3903	0
	C	0	0.0045
	PLOT	**0.1179**	**0.5219**
Liberty Street J'_S = **0.8384**	A	0.0685	0
	B	0.9918	0
	C	0.4798	0.0036
	PLOT	**0.8153**	**0**
Lowellville J'_S = **0.7968**	A	0	0
	B	0	0
	C	0.8682	0
	PLOT	**0.8682**	**0**
Undammed J'_S = **0.6562**	A	0	0.8850
	B	0.1722	0.9553
	C	0.0236	0.6223
	PLOT	**0.2782**	**0.6211**

*SDR uses the equation $J' = \frac{H'}{\log S}$,
where *H'* is the Shannon-Wiener diversity index,
and *S* is the maximum number of species observed in any one sample.

Table D13. Shrub diversity, expressed as the Shannon-Wiener diversity index for all shrub species (H'$_S$) and computed by SDR software using combined crown cover of each species in the sampled area.

Study Site	Zone	Upstream	Downstream
Leavittsburg H'$_S$ = **1.618**	A	1.623	0.6879
	B	1.322	0.5482
	C	0.2759	1.09
	PLOT	**1.717**	**0.7832**
Lovers Lane H'$_S$ = **1.517**	A	1.083	0
	B	1.341	0.567
	C	1.276	0
	PLOT	**1.518**	**1.112**
Summit Street H'$_S$ = **1.419**	A	0	0.523
	B	0.2705	0
	C	0	0.0049
	PLOT	**0.08172**	**1.116**
Liberty Street H'$_S$ = **1.502**	A	0.0475	0
	B	0.6875	0
	C	0.6652	0
	PLOT	**1.176**	**0.5977**
Lowellville H'$_S$ = **1.105**	A	0	0
	B	0	0
	C	0.9538	0
	PLOT	**1.107**	**0**
Undammed H'$_S$ = **1.176**	A	0	0.6135
	B	0.2387	1.049
	C	0.0163	1.049
	PLOT	**0.6085**	**0.8745**

*SDR software uses the equation $H' = \log N - \frac{1}{N}\sum_{i=1}^{\infty}(p_i \log p_i)n_i$,

where N = the total number of species,
p_i = the proportion of total cover in the i^{th} species,
and n_i = the number of species with i crown cover.

Table D14. Woodland nativity, expressed as percent native species (trees and shrubs combined) in each area sampled. Two plants not identified to species were not considered in this analysis.

Study Site	Zone	Upstream	Downstream
Leavittsburg **80% native**	A	67%	75%
	B	75%	75%
	C	100%	67%
	PLOT	**72%**	**70%**
Lovers Lane **81% native**	A	78%	100%
	B	73%	83%
	C	64%	88%
	PLOT	**76%**	**83%**
Summit Street **81% native**	A	100%	71%
	B	100%	67%
	C	100%	50%
	PLOT	**100%**	**67%**
Liberty Street **79% native**	A	80%	100%
	B	83%	80%
	C	57%	83%
	PLOT	**67%**	**86%**
Lowellville **93% native**	A	100%	100%
	B	75%	75%
	C	80%	83%
	PLOT	**82%**	**75%**
Undammed **94% native**	A	100%	86%
	B	83%	75%
	C	83%	86%
	PLOT	**88%**	**92%**

APPENDIX E:

Animal Species of the lower Mahoning River

Avifauna of the lower Mahoning River, Summer 2004

Species	Common Name
Ardea herodias	Great blue heron
Cathartes aura	Turkey vulture
Branta canadensis	Canada goose
Aix sponsa	Wood duck
Anas platyrhynchos	Mallard duck
Accipiter striatus	Sharp-shinned hawk
Accipiter cooperii	Cooper's hawk
Buteo lineatus	Red-shouldered hawk
Buteo jamaicensis	Red-tailed hawk
Meleagris gallopavo	Wild turkey
Charadrius vociferous	Killdeer
Actitis macularia	Spotted sandpiper
Columba livia	Rock dove
Chaetura pelagica	Chimney swift
Archilochus colubris	Ruby-throated hummingbird
Ceryle alcyon	Belted kingfisher
Melanerpes carolinus	Red-bellied woodpecker
Picoides pubescens	Downy woodpecker
Picoides villosus	Hairy woodpecker
Colaptes auratus	Northern flicker
Contopus virens	Eastern wood-pewee
Empidonax virescens	Acadian flycatcher
Empidonax minimus	Least flycatcher
Sayornis phoebe	Eastern phoebe
Myiarchus crinitus	Great crested flycatcher
Tyrannus tyrannus	Eastern kingbird
Vireo solitarius	Blue-headed vireo
Vireo flavifrons	Yellow-throated vireo
Vireo gilvus	Warbling vireo
Vireo olivaceus	Red-eyed vireo
Cyanocitta cristata	Blue jay
Corvus brachyrhynchos	American crow
Tachycineta bicolor	Tree swallow
Stelgidopteryx serripennis	Northern rough-winged swallow
Hirundo rustica	Barn swallow
Poecile atricapillus	Black-capped chickadee
Baeolophus bicolor	Tufted titmouse
Sitta carolinensis	White-breasted nuthatch
Thryothorus ludovicianus	Carolina wren
Troglodytes aedon	House wren
Polioptila caerulea	Blue-gray gnatcatcher
Sialia sialis	Eastern bluebird
Hylocichla mustelina	Wood thrush
Turdus migratorius	American robin
Dumetella carolinensis	Gray catbird
Mimus polyglottos	Northern mockingbird

Sturnus vulgaris	European starling
Bombycilla cedrorum	Cedar waxwing
Vermivora ruficapilla	Nashville warbler
Dendroica petechia	Yellow warbler
Dendroica pensylvanica	Chestnut-sided warbler
Dendroica coronata	Yellow-rumped warbler
Dendroica virens	Black-throated green warbler
Dendroica cerulea	Cerulean warbler
Mniotilta varia	Black-and-white warbler
Setophaga ruticilla	American redstart
Seiurus noveboracensis	Northern waterthrush
Geothlypis trichas	Common yellowthroat
Wilsonia citrina	Hooded warbler
Piranga olivacea	Scarlet tanager
Cardinalis cardinalis	Northern cardinal
Pheucticus ludovicianus	Rose-breasted grosbeak
Passerina cyanea	Indigo bunting
Pipilo erythrophthalmus	Eastern towhee
Spizella passerina	Chipping sparrow
Melospiza melodia	Song sparrow
Zonotrichia albicollis	White-throated sparrow
Agelaius phoeniceus	Red-winged blackbird
Sturnella magna	Eastern meadowlark
Quiscalus quiscula	Common grackle
Molothrus ater	Brown-headed cowbird
Icterus galbula	Baltimore oriole
Carpodacus mexicanus	House finch
Carduelis tristis	American goldfinch
Passer domesticus	House sparrow

Mammals of the lower Mahoning River, Summer 2004

Species	**Common Name**	**Identification**
Castor canadensis	Beaver	Visual
*Odocoileus virginianus**	White-tailed deer	Tracks only
Vulpes vulpes	Red fox	Visual
Marmota monax	Groundhog	Visual
Sylvilagus floridanus	E. cottontail rabbit	Visual
Procyon lotor	Raccoon	Visual
Didelphis virginiana	Opossum	Visual

* Species is suggested, as no visual identification of this animal was made. White-tailed deer is the only reported deer species in northeast Ohio.