THE INFLUENCE OF DAMS ON AVIAN COMMUNITIES WITHIN DISTURBED RIPARIAN HABITAT

By

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Submitted in Partial Fulfillment of the Requirements

For the Degree of

Master of Science

in the

Biological Sciences

Program

YOUNGSTOWN STATE UNIVERSITY

May, 2005

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ABSTRACT

An avian community study was conducted along a 55.2 km portion of the lower Mahoning River located in western Pennsylvania and northeast Ohio, U.S.A. Low-head dams have created alternating series of free-flowing and impounded segments of water, altering the natural riverine habitat of the lower Mahoning River. The goal of this study was to examine the effects of low-head dams on the avian community and habitat structure within riparian forest.

In the spring and summer of 2004, avian point counts and habitat characterization was conducted at study plots downstream and upstream of low-head dams that were at least 200 m apart (n=12). Birds were placed into habitat assemblages, as well as foraging and nesting substrate guilds. The Shannon-Weiner index (H') of diversity and the Bird Community Index (BCI) were used to evaluate avian communities in study plots. Principal Component Analysis was used to detect differences in habitat structure between study plots.

At the Leavittsburg study site, the upstream study plot had a more diverse avian community than the downstream study plot. Study plots with a high H', BCI score, and percent mature forest bird species were associated with habitat more indicative of mature forest. Foraging and nesting substrate guilds did not appear to be influenced by low-head dams. Ordination revealed no differences in habitat structure between study plots. Results from this study appear to indicate that the presence of low-head dams in the lower Mahoning River have a minimal effect on avian diversity. Instead, downstream and upstream study plots with high diversity and BCI scores appeared to be influenced by habitat characteristics typical of mature forest.

ACKNOWLEDGMENTS

I would like to thank my thesis advisor, Dr. Courtenay Willis, for opening my eyes and ears to the wonderful world of Ornithology. I thank her for her field assistance with bird identification, guidance, advice, expert editing skills, and for simply being a good friend. I will always keep a look out for the "Terror Crane". I thank Dr. Tom Diggins for all of his help with statistical analysis. I sincerely thank Professor Carl Chuey for keeping my geographical maps as accurate and readable as possible. I would also like to thank Anna Stambolia-Kovach for designing the habitat sampling method, assistance in measuring habitat along the Mahoning River and providing her car for the transport of field equipment. Mom and Dad, thank you for being the greatest parents on earth and for being supportive of my endeavors. I would especially like to thank Laura Blohm, my sister-in-law, for inspiring me to attend college. Dawn Amolsch, thank-you for lending me your ears when I needed to vent my frustrations. Tom Bucco, thank-you for always being there to help me with computer woes. I do appreciate all of the help and support you have given me. This research was funded in part by a grant from the Youngstown State University PACER (Presidential Academic Center for Education and Research) program and a small grant from the Ohio Biological Survey.

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INTRODUCTION

Industry and low-head dams have historically contributed to human disturbances along the lower Mahoning River (USACE 1999). Contamination of sediments and the construction of low-head dams have created an alternating series of free-flowing and impounded segments of water (OEPA 1996), thus altering the natural riverine habitat of the lower Mahoning River (USACE 1999). Increased sediment build-up and impoundment of water upstream of low-head dams is thought to have a negative impact on the ecological health of the river and may be responsible for habitat degradation (USACE 1999).

In 1996, a survey was undertaken by the Ohio Environmental Protection Agency to evaluate habitat quality of the lower Mahoning River. The survey concluded that the free-flowing segments of the Mahoning River, downstream of low-head dams, supported a "healthier" habitat than impounded segments of pooled water, upstream of low-head dams. Their conclusion suggests that habitat quality tends to be influenced by alterations in river flow characteristics caused by low-head dams. Alterations in habitat quality upstream of low-head dams include drowning of riffles and runs, entrapment of contaminated sediment which buries a more favorable riverine substrate, and depressed levels of dissolved oxygen in the water.

While the effects of contaminated sediment and altered riverine flow caused by low-head dams are known to limit fishery potential and cause aquatic degradation (USACE 1999), relatively little is known of the effects of low-head dams on terrestrial organisms, such as birds, and habitat structure within the riparian forest adjacent to the lower Mahoning River. Many avian species utilize riparian habitat (Parkinson *et al.*

2002); therefore, the effects of low-head dams on avian species diversity and habitat structure was the primary focus of this study.

Goals and Objectives

The purpose of this study was to examine the influence of low-head dams on avian species and the surrounding habitat within the riparian forest adjacent to the lower Mahoning River. My objectives were to determine if low-head dams influence (1) the diversity and abundance of avian species, (2) avian habitat assemblages (mature forest, shrubland, forest edge, and habitat generalist) and avian diet and nesting substrate guilds, (3) and habitat structure.

Relevance of Riparian Habitat to Avian Species

Riparian habitat is used by more species of breeding birds than any other habitat type in North America given that riparian habitat contains fertile alluvial soil, an abundant water supply, has a low fire incidence, and provides avian species with food, sites for nesting, and protection from predators (Douglas *et al.* 1992, Kozlowski 2002). Riparian habitat can be regarded as a transitional zone between terrestrial and an aquatic ecosystem (Iwata *et al.* 2003), which can provide important habitat for both aquatic and woodland bird species (Parkinson *et al.* 2002). Regardless of the importance of riparian ecosystems to biodiversity, riparian ecosystems continue to be degraded by anthropogenic activities (Rottenborn 1999).

Influence of Habitat Structure on Avian Diversity

Habitat structure is an important factor affecting avian species diversity and abundance (Larison 2001). Examination of avian-habitat relationships often incorporate aspects of vegetative structure, plant species composition, and local resource availability which can then be correlated with the diversity and abundance of avian species found within a habitat (MacArthur and MacArthur 1961, Stauffer and Best 1980, Douglas *et al.* 1992). The distribution and abundance of avian species within a habitat may be influenced by ecological attributes of the habitat at different spatial scales, such as the structural diversity of vegetation (Stauffer and Best 1980, Scott *et al.* 2003) and the pattern and composition of vegetation within the surrounding landscape (Scott *et al.* 2003). Plant species richness, percentage of vegetation cover, and variations in local habitat structure can all affect habitat complexity which may influence the local diversity of avian communities (James 1971).

Effects of Dams on Birds and Riparian Habitat

Riparian zones are generally viewed as having high productivity and species diversity (Whitaker and Montevecchi 1999). Dams represent one type of human disturbance affecting the lower Mahoning River (USACE 1999), and disturbance is well known to influence species diversity and abundance (Cardinale *et al.* 2000). Alterations in riparian habitat caused by dams can negatively impact river ecology. Dams disrupt the flow of water, sediment, nutrient energy and biota altering these important ecological processes (Ligon *et al.* 1995). Dams can also alter riparian structure and function by causing disturbances in the hydrology, geomorphology, and vegetation structure in riparian habitat which can influence aquatic and riparian fauna (Bryce *et al.* 2002).

Extensive damming and engineering projects have altered many of North America's major rivers and their adjacent riparian habitat in which a number of avian species depend upon. For example, due to the alteration of riparian forest brought on by damming the Colorado River , many riparian-dependent bird species in the southwest are expected to disappear from the region (Askins 2000), such as the Southwestern Willow Flycatcher (*Empidonax traillii*) (Graf *et al.* 2002). Likewise, avian species living within the lower Mississippi River riparian woodlands are declining due to habitat loss caused by engineering efforts to control flooding with dams and the conversion of floodplain into agricultural land (Scott *et al.* 2003). Declines in avian species numbers may be attributed to the loss of large tracts of riparian forest which is thought to be the cause of the possible extinction of the Ivory-billed Woodpecker (*Campephilus principalis)* (Scott *et al.* 2003). As a consequence, habitat disturbance caused by dams has been associated with adversely affecting individual avian species living along these rivers. Conversely, water bird's living within riparian habitat has been known to increase due to reservoir formation upstream of dams in response to the creation of new habitat and resource availability (Stevens *et al.* 1997).

Upstream Effects

Dams modify riparian habitat by raising water levels upstream resulting in an inundation and eventual loss of terrestrial habitat caused by reservoir formation (Nilsson and Berggren 2000). Prolonged inundation of water can be very harmful to riparian vegetation due to oxygen deprivation experienced by certain plants (Kozlowski 2002). Oxygen deficiency in inundated soil is caused by an increase in anaerobic organisms, which consume residual soil oxygen, and is associated with a massive loss of plant biomass, suppression of vegetative and reproductive growth, death and decay of roots, and tree mortality (Kozlowski 2002).

The loss of riparian vegetation can result in a decline of arthropods which may be detrimental to insectivorous bird species that rely on arthropods, which are usually abundant in riparian vegetation along river banks, as an important food resource (Yard *et al.* 2004). Loss of vegetation in riparian habitat can also reduce the number of nesting cavities and nesting sites for many resident and Neotropical migrant bird species (Farley *et al.* 1994). Vegetation loss can affect avian diversity by reducing the amount of habitat used as stop-over sites for long-distance migrant birds, resident birds or species with restricted breeding habitats. Once specific vegetation types are eliminated from a region, the associated avifauna often disappears as well (Farley *et al.* 1994).

Downstream Effects

Riparian habitat downstream of dams can also experience changes that can affect avian species diversity. Reduced or regulated water flow can alter the transport and deposition of sediments resulting in physical changes in riparian habitat (Graf *et al.* 2002). Floods are the most important natural disturbance in riparian ecosystems (Poff *et al.* 1997) and dams are often constructed for the purpose of flood control and reduce both the peak and frequency of water inundation in floodplains (Kozlowski 2002). Flooding in riparian areas control important physical and biological processes, such as creating seed beds for riparian vegetation, aiding in the dispersal of seed propagules, redistributing nutrients, and causing river channels to relocate and meander (Graf *et al.* 2002). Reduced water flow caused by dams tend to straighten river channels and decrease the groundwater supply beneath rivers leading to lowered ecosystem productivity and species diversity (Pollock *et al.* 1998). Reductions in the amount of stream flow and groundwater cause riparian vegetation to undergo physiological stress resulting in lowered productivity and possibly death (Graf *et al.* 2002).

Reductions in stream flow may adversely affect insects with aquatic larval forms (Graf *et al.* 2002). These insects may become stressed when there is less surface flow, resulting in a lower abundance of insects, which may decrease the food available to insectivorous birds (Graf *et al.* 2002). Also, Iwata *et al.* (2003) found that insectivorous birds tended to be more diverse and abundant in rivers and streams that meander. This is presumably due to an increase in the amount of stream edge and stream surface that support a higher number of insects in meandering rivers than rivers that have straightened channels caused by dam modifications in river flow and habitat.

Assessing Effects of Habitat Disturbance on Avian Community Structure

Avian species are considered to be the most useful and most practical indicators of terrestrial disturbances. Most birds can be observed easily, may be vocally identifiable when not seen, and birds have been well studied in their behavioral and life history traits (Verner 1984). When evaluating the effects of environmental disturbance on avian species, ecological information must be obtained to relate patterns of avian species to the amount of available habitat and resources, degree of habitat fragmentation and the amount of anthropogenic disturbance in a particular habitat (Bryce *et al.* 2002). Once ecological information on habitat characteristics is obtained, patterns or thresholds may be observed that allow some avian species to persist while other species disappear within areas of disturbed habitat (Bryce *et al.* 2002). Differences in species abundance and diversity are frequently thought to signify changes in habitat, and ecological guilds are important as they may reflect changes in vegetation structure and disturbance (Lindsay *et al.* 2002). The presence or absence of a single species may or may not indicate degraded habitat. However, if species richness within a particular guild is low, it may reflect lowered ecological integrity of an area (Bishop and Myers 2005).

The use of faunal guilds, such as birds, can serve as indicators of disturbance within a particular habitat (Croonquist and Brooks 1991). A guild is a group of organisms that exploit the same type of environmental resource in a similar manner (Root 1967). Placing avian species into guilds should allow for a relatively accurate and quantifiable prediction of environmental impact which can be used to assess both quantitative and qualitative components of avian species inhabiting disturbed ecosystems (Severinghaus 1981). It is thought that disturbances that affect environmental resources or habitat will also affect the members of the guilds using those resources or habitat (Szaro 1986). Avian guilds can be formed according to their foraging strategies, nesting substrate, or habitat preference, to name just a few examples. The use of an avian guild concept for the evaluation of environmental impacts on avian communities may allow for the determination of a cause and effect relationship between the disturbance to the environment and the environmental conditions in which avian communities reside (Severinghaus 1981).

Avian habitat assemblages, in particular, have been found to be useful indicators of biointegrity because habitat assemblages may allow for a more direct evaluation of community response to changes in vegetative structure and habitat brought about by disturbance (Canterbury *et al.* 2000). Avian habitat assemblages can be formed by placing species according to their tolerance to disturbance within a habitat. Avian species sensitive to disturbance are found mainly in mature forest; species more tolerant to disturbance are found typically in forest edge or shrubland, and habitat generalist species are those species which can be found in a wide variety of habitat types (Canterbury *et al.* 2000).

The use of avian species, avian habitat assemblages, or guilds has all been used to quantify bird responses to habitat disturbance in previous studies. Canterbury *et al.* (2000) used avian habitat assemblages to develop a Bird Community Index (BCI), which was used to evaluate the effect of habitat disturbance on avian habitat assemblages. By placing avian species into habitat assemblages and comparing them against various levels of habitat disturbance, they found that there was an association between the presence of a particular habitat assemblage and the amount of disturbance in the area in which it was found. Canterbury *et al.* (2000) concluded that by placing birds into habitat assemblages, birds could be used as indicators to assess the amount of disturbance placed upon individual species constituting a particular habitat assemblage.

METHODS

Study Design

This study was designed to test if the presence of low-head dams influences the diversity of avian species, the avian community and habitat structure within the riparian forest along the lower portion of the Mahoning River. Five low-head dams and an undammed study site, serving as a reference, were investigated along the lower portion of the Mahoning River.

To evaluate the influence of low-head dams on avian diversity, a 50m fixed radius point count protocol (Huff *et al.* 2000) was used to survey avian species at established downstream (n=6) and upstream (n=6) study plots. To evaluate habitat structure, 30m x 12m sampling plots were established adjacent to the river bank within the area where the 50m fixed radius point counts were conducted at each study plot to assess vegetation and habitat characteristics.

To evaluate the influence of low-head dams on the avian community within the riparian habitat along the lower portion of the Mahoning River, the avian species observed in point counts were classified into guilds according to preferential habitat, such as mature forest species, forest edge species, shrubland species, or habitat generalist species (Canterbury *et al.* 2000). In addition, avian species were also classified by their diet type and preferred nesting substrate. BCI, H', species richness, and the percentage of avian species within guilds were compared against habitat variables to evaluate the effects, if any, of habitat structure on the avian community.

This study was designed to test the following null hypotheses:

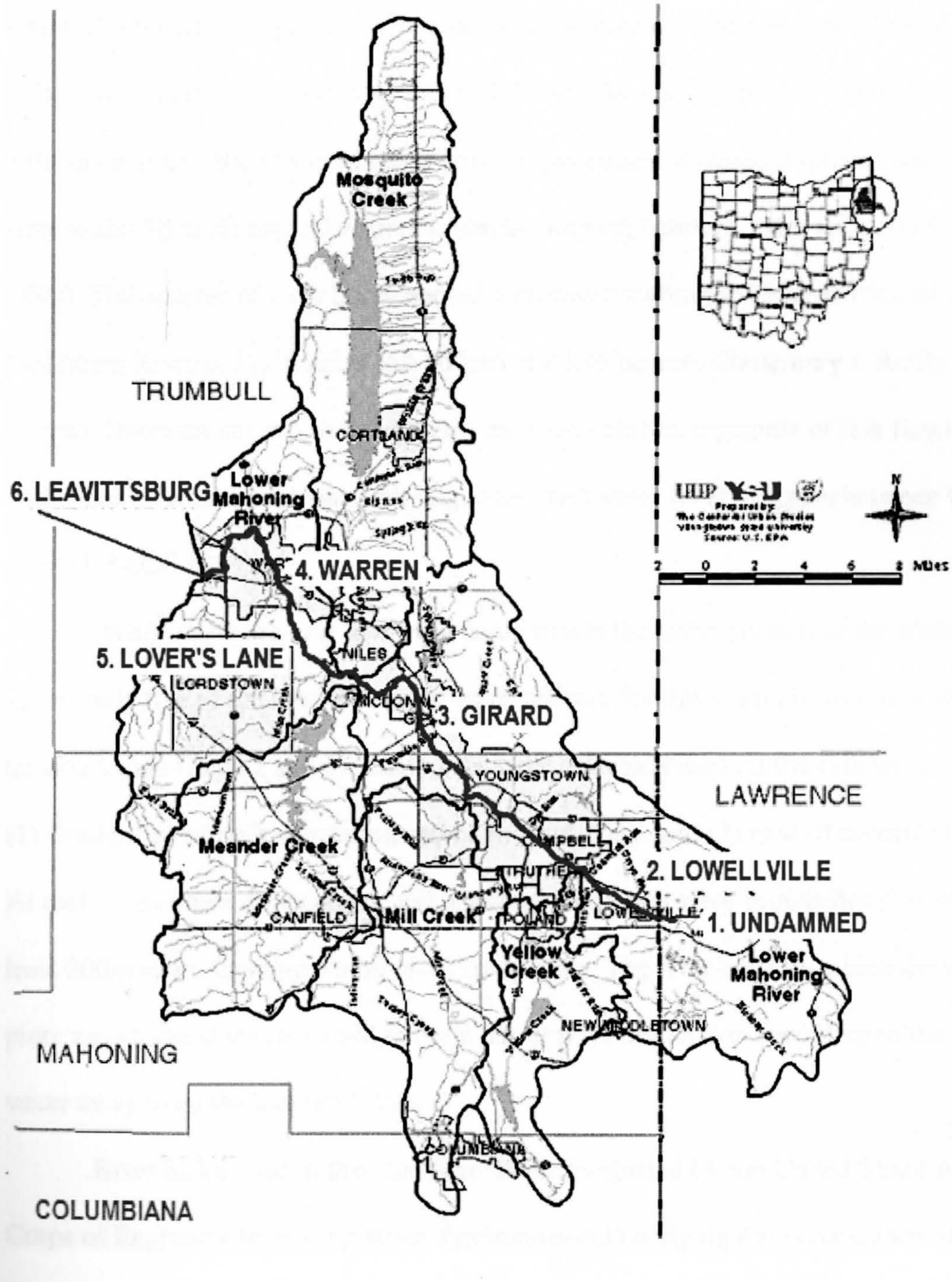
1) Diversity and abundance of avian species will not differ above and below low head dams.
2) Diversity and abundance of avian species will not differ between low head dam study sites.
3) Presence or absence of avian guild types will not differ between low head dam study sites.
4) Habitat Structure will not differ above and below low head dams.

Study Area

The lower Mahoning River was chosen for this study because low-head dams represent one type of disturbance that may affect avian communities and habitat. The area studied extends from Leavittsburg, Ohio through an area just east of the Ohio/Pennsylvania state border located in Lawrence County, Pennsylvania, USA. The lower Mahoning River passes through industrial, residential, and undeveloped areas (USACE 1999) (Fig 1).

Although the lower Mahoning River has been extensively developed, it does support abundant riparian vegetation throughout most of this stretch of river (USACE 1999). The study area encompasses 34.33 river miles (55.24 km) of the lower Mahoning River (USACE 1999). Within this stretch of river, nine low-head dams have created a

Figure 1. The highlighted area indicates the portion of the Mahoning River examined in this study. Low head dams are depicted numerically: (1) Undammed study site (2) Lowellville study site (3) Girard study site (4) Warren study site (5) Lovers Lane study site and (6) Leavittsburg study site.



Mosquito Creek
TRUMBULL
CORTLAND
6. LEAVITTSBURG
Lower Mahoning River
4. WARREN
5. LOVER'S LANE
LORDSTOWN
NILES
3. GIRARD
YOUNGSTOWN
LAWRENCE
Meander Creek
CAMPBELL
2. LOWELLVILLE
CANFIELD
Mill Creek
POLAND
1. UNDAMMED
Yellow Creek
Lower Mahoning River
NEW MIDDLETOWN
MAHONING
COLUMBIANA
COLUMBIANA
Miles

series of impounded segments of pooled water upstream of the low-head dams causing river flow to decrease in velocity (USACE 1999). As a result, pooled segments of the river upstream of the low head dams have deepened and widened, typically increasing the river width 10 to 20 percent with river depths varying between 2.4m to 3m (USACE 1999). The number of river miles pooled with water within the lower portion of the Mahoning River is 37.16 miles (59.86 km) or 83.19 percent (Rosemary J. Reilly pers. comm). Downstream of low-head dams, the river exhibits segments of free flowing water with smaller natural pool and riffle sequences and water levels varying between 0.6m to 1.8m (USACE 1999).

While there are nine low-head dams within the lower portion of the Mahoning River, only five of the low head dams were selected for this study, as well as a study site lacking a dam (Figs. 2 and 3). Study sites were selected based on the following criteria: (1) similarities of both vegetation and habitat structure, and (2) ease of accessibility. At each study site a downstream and upstream study plot were established that were at least 200m apart, creating a total of 12 study plots. The river bank on which the study plots were located was assigned either a left or right orientation according to the flow of water away from the low head dam.

River miles used in this study are those designated by the United States Army Corps of Engineers Mahoning River Environmental Dredging Reconnaissance Study taken in 1999. In this designation, river miles increase from east to west, with river mile zero (0 km) being at the Mahoning River's discharge point into the Shenango River located in Lawrence County, Pennsylvania. Calculated values for pooled segments of

Figure 2. Aerial views of each study site with the approximate locations of study plots downstream and upstream of low-head dams. (a) Undammed study site, (b) Lowellville study site (c) Girard study site, (d) Warren study site, (e) Lover's Lane study site, and (f) Leavittsburg study site. Aerial photographs were taken in 2000, courtesy of Kimberly D. Mascarella.

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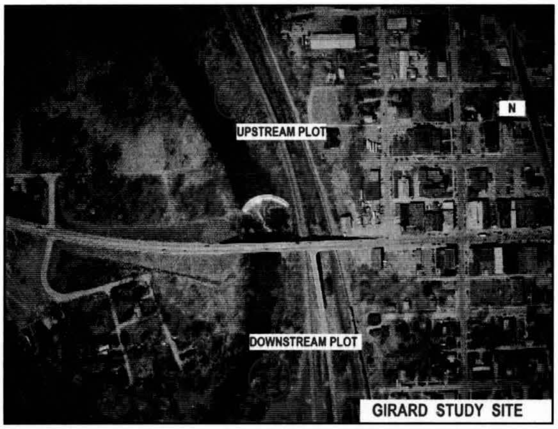

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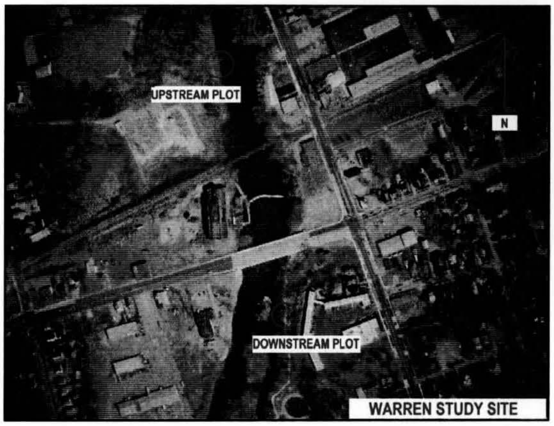

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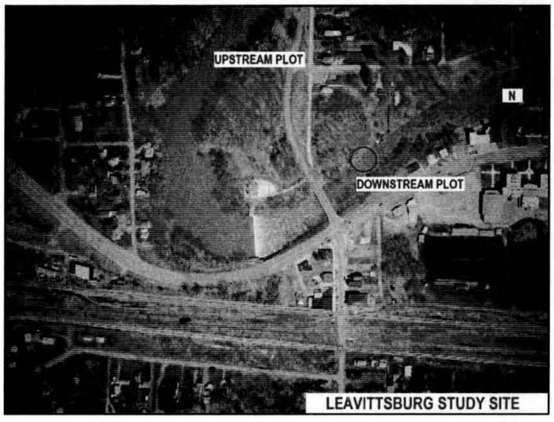

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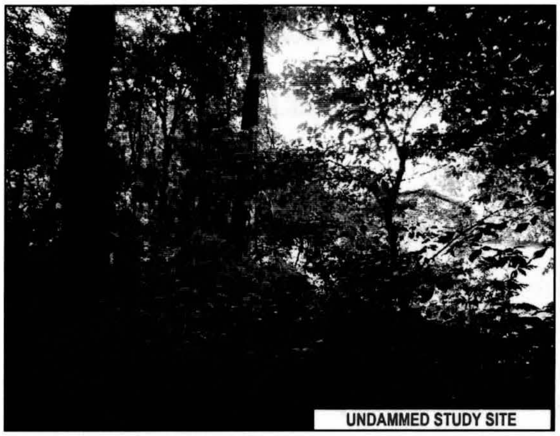
Figure 3. Photographs of each study site along the lower Mahoning River. (a) Undammed study site, (b) Lowellville study site, (c) Girard study site, (d) Warren study site, (e) Lover's Lane study site, and (f) Leavittsburg study site. Photographs were taken during May and June 2004 courtesy of Anna Stambolia-Kovach.



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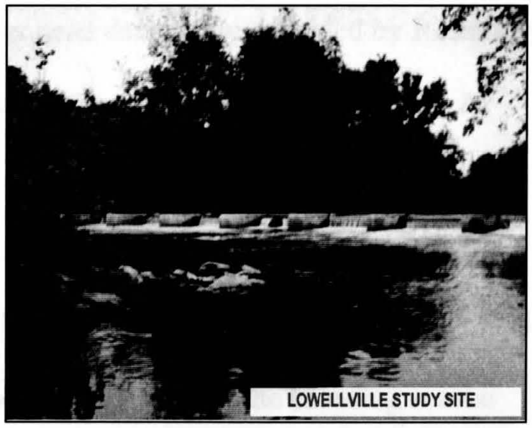

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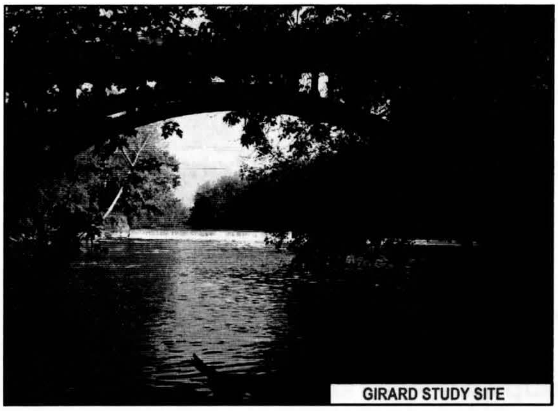

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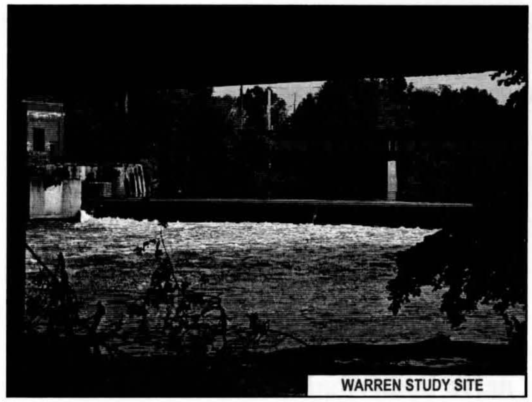

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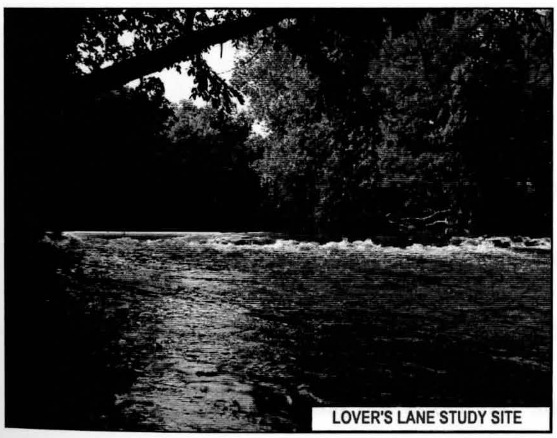

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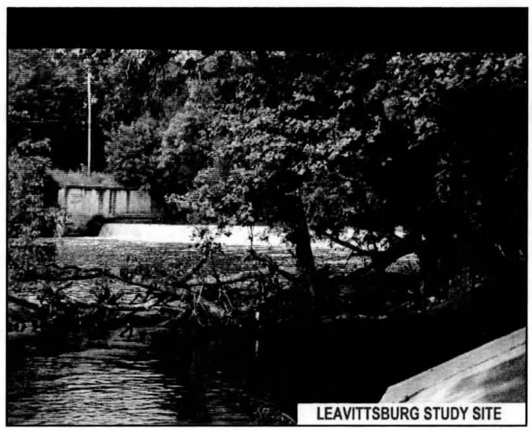

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water at low flow conditions upstream of the low head dams were provided by Rosemary J. Reilly of the USACE. Descriptions of each study site can be found in Appendix A.

Avian Point Counts

Avian point counts were conducted at all study plots from May 3 - June 16, 2004 to coincide with the peak period of bird migration and the start of the breeding season (Appendix B). A systematic approach was used to determine the order in which study plots were visited to perform avian point counts. A systematic approach ensured that each of the study plots was visited at different times of the morning during the four-hour avian point count period (0600-1000h). This reduced bias in the identification of avian species during the sampling period.

A Habitat-Based Point Count protocol for Terrestrial Birds was used to monitor avian species. Point counts allow for a quantification of the number of individual avian species and abundance of individual birds observed at a fixed location during repeated observations (Huff *et al.* 2000). At each study plot, seven 10 min. avian point counts were conducted over a seven week period. Point counts were taken at the center of a 50m fixed radius area located within study plots located downstream and upstream of low head dams. Point counts were conducted between 0600-1000 h and only under fair weather conditions. Avian species seen or heard within the 50m fixed radius areas were used in the analysis so that the surveyed data could be effectively compared to local habitat conditions (Canterbury *et al.* 2000). The 50m fixed radius areas were at least 200m apart. At least two observers were present during the point counts to minimize bias in avian identification. All questionable avian songs or calls heard during point counts were confirmed with the use of audio field guides, such as Petersons Field Guide to Eastern Bird Songs™ and Stokes Field Guide to Bird Songs®.

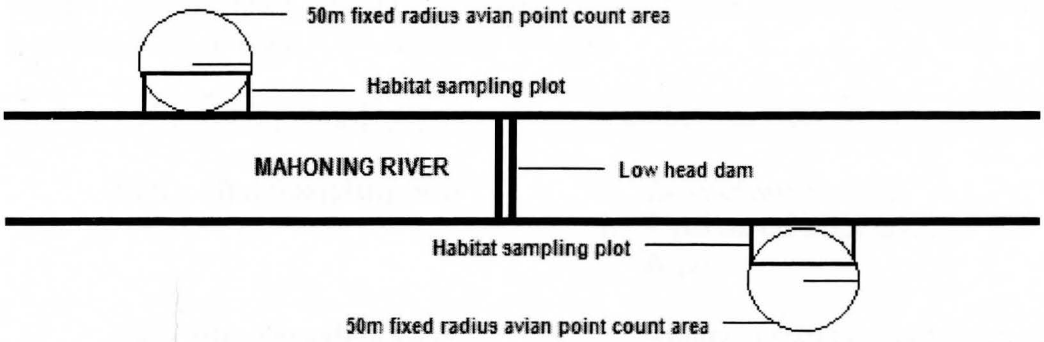
Measuring Habitat Characteristics

Habitat characteristics were measured according to a combination of a BBIRD (Breeding Biology and Research Database) protocol (Martin *et al.* 1997) and methods of habitat analysis used by Canterbury *et al.* (2000). A BBIRD protocol was incorporated into the habitat analysis because point counts were conducted during the breeding season and it was necessary to examine habitat characteristics that may influence potential avian nesting substrates. A total of 6 downstream and 6 upstream study plots were characterized from late June to mid-August 2004. The habitat sampling plot design was described by Greig-Smith (1983) and Mueller-Dombois and Ellenberg (1974) and was modified by Anna Stambolia-Kovach (pers. comm).

At each downstream and upstream study plot, a 12m x 30m sampling plot was established adjacent to the river bank within the 50m fixed radius area used to conduct avian point counts. The 12m x 30m sampling plot was divided further into three 4m x 12m zones with zone A being nearest the river shore, zone C being furthest from the river shore, and zone B being between. Within each zone, a 2m x 2m sub- sampling plot was randomly assigned to measure microhabitat variables (Fig 4).

A detailed list of habitat variables measured within each 12m x 30m sampling plot, 4m x 12m sampling zone and 2m x 2m sub-sampling plot is given in Table 1. Within each sampling plot, trees with a DBH greater than 3cm were measured, recorded and combined to obtain a total tree basal area. Crown measurements of all shrubs were

Figure 4. Schematic of a 12m x 30m habitat sampling plot. Sampling plots were situated within 50m fixed radius areas used to conduct avian point counts adjacent to the Mahoning River. Each sampling plot was divided into three smaller sampling zones measuring 4m x 30m. Zones are labeled A, B, and C, respectively, with zone A being nearest the river shore. Within each sampling zone, 2m x 2m sub-sampling plots were randomly selected to obtain ground cover measurements.


50m fixed radius avian point count area
Habitat sampling plot
MAHONING RIVER
Low head dam
Habitat sampling plot
50m fixed radius avian point count area

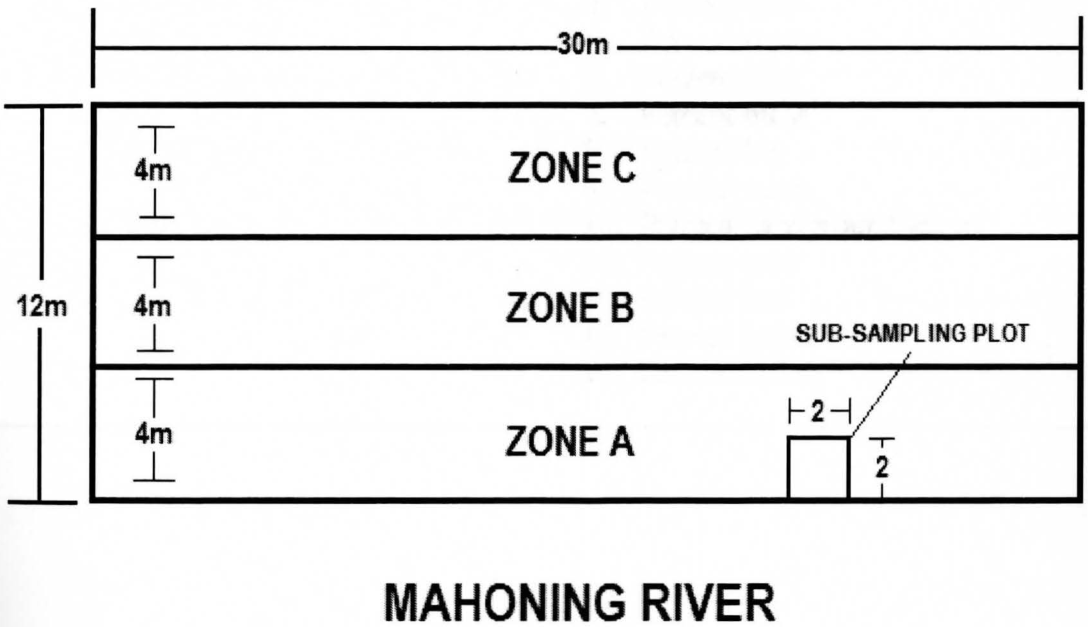

30m
12m
4m
ZONE C
4m
ZONE B
SUB-SAMPLING PLOT
4m
2
ZONE A
2
MAHONING RIVER

Table 1. List of habitat variables measured in each 12m x 30m sampling plot, 4m x 12m sampling zone, and 2m x 2m sampling sub-plot.

Sampling Plot/Zone	Habitat Variable Measured
12m x 30m Sampling plot	1. River channel width
	2. Riparian corridor width
	3. Aspect
4m x 30m Sampling zone	1. Number of all tree and shrub stems
	2. Trees with a DBH greater than 3cm
	3. Shrub crown
	4. Canopy cover
	5. Litter depth (mm)
2m x 2m sampling plot	1. Percent green ground cover
	2. Percent grass
	3. Percent sedge
	4. Percent forb
	5. Percent shrub
	6. Percent fern
	7. Percent moss
	8. Percent log
	9. Percent water
	10. Percent bare ground/gravel
	11. Percent rock
	12. Percent leaf
	13. Percent brush
	14. Percent marsh

recorded and combined to obtain a percentage of the total area covered by shrubs. Canopy height was obtained with the use of an extendable meter pole or range finder. A spherical densitometer was used to measure canopy cover. A clinometer was used to measure corridor slope. A range finder was used to measure river channel width. Riparian corridor width was measured with the use of a range finder and/or metric measuring tape.

Evaluating Avian Communities

In this study, avian species were grouped into three guilds in order to examine the impact of low-head dams on avian communities. Avian species were grouped according to their preferential habitat type, diet type, and preferred nesting substrate. Avian guild classifications (Appendix C) were determined based on the life history traits of avian species (e.g. Ehrlich *et al.* 1988; Earnst and Andres 1996; Croonquist *et al.* 2000; Peterjohn 2001). Avian species were classified into one of four habitat assemblages: disturbance-sensitive species that are typically found in areas of mature forest (MF) habitat, disturbance-tolerant species that are typically found in forest-edge (FE) habitat or shrubland (SL) habitat, and generalist species that are typically found in a wide variety of non-disturbed and disturbed habitat types (Canterbury *et al.* 2000).

The Bird Community Index (BCI) (Canterbury *et al.* 2000) was used to contrast disturbance-sensitive species against disturbance-tolerant species in a given habitat. The number of each species observed in the aforementioned habitat assemblages within downstream and upstream study plots and study sites along the Mahoning River, except for those species classified as habitat generalists, were placed into the formula $(\ln(MF + 1) - \ln(SL + FE + 1))$. Study plots and study sites dominated by disturbance-sensitive avian species are expected to yield positive values, whereas, study sites dominated by disturbance-tolerant avian species are expected to yield negative values.

Statistical Analysis

Avian diversity and Abundance

To examine if avian species diversity differed between study plots, avian point counts were used to estimate Shannon-Weiner diversity (H') (Species Diversity and Richness III, version 3.0). The mean abundance (N) of avian species at all downstream and upstream study plots was calculated by averaging the daily number of individual birds recorded at each study plot during the seven week point count period. Levene's test was used to test for homogeneity of variances and indicated that mean abundance data was normally distributed among study plots. A Student's *t*-test used to compare mean abundances of birds between downstream and upstream study plots (SPSS, version 11.0). In addition, species richness (S), evenness index (E), and maximum diversity (H'max) were also calculated (Zar 1999).

To examine if avian species diversity differed between study sites, point-count data collected at downstream and upstream study plots at each site was pooled to give one H' per site. The mean abundance (N) of avian species at study sites was calculated by averaging the daily number of individuals from both the downstream and upstream study plots during the seven week point count period. Levene's test was used to test for homogeneity of variances and indicated that mean abundance data was normally distributed among study sites. A One-way ANOVA was used to compare mean abundances of birds between study sites (SPSS, version 11.0). In addition, species richness (S), evenness index (E), and maximum diversity (H'max) were also calculated. A one-sided Randomization test was used to test for differences in H' between study plots and study sites (Solow 1993; Species Diversity and Richness III, version 3.0).

Avian Guilds and Habitat Structure

Avian species observed in downstream and upstream study plots were combined at each study site and categorized into habitat assemblage, diet, and nesting guilds. Avian species grouped into habitat assemblages, which included mature forest, forest edge, and shrubland, were placed into the Bird Community Index (BCI) (Canterbury *et al.* 2000) to assess whether downstream and upstream study plots were dominated by disturbance-tolerant or disturbance-intolerant avian species. Furthermore, all observed mature forest, forest edge, and shrubland species observed at both study plots per study site were combined to obtain a BCI value for each study site.

To examine if habitat and avian communities differ between downstream and upstream study plots, a Principle Component Analysis (PCA) was performed to detect habitat variables displaying variability between downstream and upstream study plots (SPSS, version 11.0). PCA determines which habitat variables are interrelated and reduces large sets of variables, such as habitat characteristics, into a smaller group of meaningful variables that aid in ecological analysis (MacKenzie and Sealy 1981). Habitat variables producing a high factor loading within each downstream and upstream study plot were used to create an ordination plot, describing the habitat variables that best explain the structure of the over all bird community (Rottenborn 1999). In order to create the ordination plot, BCI scores were divided into four data ranges (< -1, < -.5, < -.25, and

< 0). Similarly, Shannon-Weiner index values were divided into three data ranges (< 3.300, 3.301- 3.299, and > 3.300). A bi-plot was added to correlate the information obtained on habitat variables from the PCA to study plots (De Bartolomeo *et al.* 2004). The direction of the arrows of the bi-plot relative to the axes indicates how well the environmental variable is related with each axis. The location of each study plot relative to the arrows indicates the habitat variable associated with each study plot (Rottenborn 1999). Multiple linear regression analysis of factor loadings on habitat variables from PC1, PC2, PC3, and PC4 (Appendix D) was performed to test if a relationship existed between habitat and H', BCI scores, species richness and avian guilds.

RESULTS

Avian Diversity and Abundance

Analysis of avian community diversity between upstream and downstream study plots is based on the identification of 1,651 individuals representing 66 species from 29 families, which were observed between May 3 - June 16, 2004. A total of 850 individuals were counted at the downstream plots (n=6) and 801 individuals were counted at the upstream plots (n=6). Only the Leavittsburg study site had a more diverse avian community upstream compared to downstream (one-sided Randomization Test, p=0.0041) (Table 2). Species richness varied from 41 species at the undammed downstream study plot to 23 species at both the Girard and Lover's Lane downstream study plots. The Warren downstream study plot had the highest mean abundance of birds ($\bar{x}$=26 ± SD) and the Lover's Lane downstream study plot had the lowest mean abundance of birds ($\bar{x}$=13 ± SD)(Table 3).

Analysis of avian community diversity between the six study sites showed that the undammed study site had the highest diversity and the Lover's Lane study site had the lowest diversity (Table 4). The undammed study site had the highest species richness, with 52 observed species, while the Girard study site had the lowest species richness with 32 species observed. The Warren study site had the highest mean abundance of birds ($\bar{x}$=23 ± SD), while the Lover's Lane study site had the lowest mean abundance of birds ($\bar{x}$=15 ± SD) (Table 4).

In comparing differences in diversity between study sites using a one-sided Randomization Test, the undammed study site was more diverse than study sites

Table 2. One-sided Randomization Test results comparing differences in diversity between downstream and upstream study plots.

Study Site	(H') Downstream Plot	(H') Upstream Plot	P value
Undammed	3.386	3.311	0.7835
Lowellville	3.049	3.148	0.1678
Girard	2.778	2.974	0.0522
Warren	3.119	3.097	0.4455
Lover's Lane	2.766	2.867	0.3033
Leavittsburg	**2.957**	**3.224**	**0.0041**

Table 3. Richness (S), mean abundance ($\bar{x}$ ± SD)(N), Shannon-Diversity Index (H'), maximum diversity ($H_{max'}$), evenness (E), and Bird Community Index for avian communities at downstream and upstream study plots. Values were calculated from pooling data acquired during the seven week point count period.

Study Plot	S	N	H'	$H_{max'}$	E	BCI
Undammed Down	41	20.1 ± 4.6	3.386	3.713	0.8053	-0.207
Undammed Up	40	22.0 ± 2.6	3.311	3.689	0.7874	-0.154
Lowellville Down	32	20.5 ± 5.0	3.049	3.466	0.7250	-0.287
Lowellville Up	32	18.4 ± 4.8	3.148	3.466	0.7486	-0.105
Girard Down	23	18.7 ± 6.4	2.778	3.135	0.6606	-1.099
Girard Up	27	15.8 ± 6.2	2.974	3.296	0.7008	-0.693
Warren Down	38	26.0 ± 12.1	3.119	3.638	0.7417	-0.167
Warren Up	32	20.7 ± 3.9	3.097	3.466	0.7365	-1.099
Lover's Lane Down	23	13.8 ± 2.8	2.766	3.315	0.6579	-0.288
Lover's Lane Up	25	16.2 ± 2.8	2.867	3.219	0.6819	-0.693
Leavittsburg Down	29	21.5 ± 2.8	2.957	3.367	0.7033	-0.357
Leavittsburg Up	33	21.1 ± 2.7	3.224	3.497	0.7667	-0.619

Table 4. Richness (S), mean abundance ($\bar{x}$ ± SD)(N), Shannon-Diversity Index (H'), maximum diversity ($H_{max'}$), evenness (E), and Bird Community Index for avian communities at study sites. Values were calculated from pooling data acquired during the seven week point count period.

Study Site	S	N	H'	$H_{max'}$	E	BCI
Undammed	52	21.3 ± 3.6	3.516	3.951	0.8899	+0.061
Lowellville	41	19.5 ± 4.8	3.255	3.713	0.8766	0
Girard	32	17.2 ± 6.2	3.005	3.466	0.8720	-0.875
Warren	48	23.3 ± 9.0	3.277	3.871	0.8466	-0.460
Lover's Lane	33	15.0 ± 4.0	2.970	3.497	0.8493	-0.539
Leavittsburg	40	21.3 ± 3.3	3.249	3.689	0.8807	-0.762

possessing a dam (Appendix D). There were no differences in the mean abundance of birds detected when comparing downstream and upstream study plots. However, when mean abundance of birds present during point counts were compared between study sites, mean abundance differed significantly from Leavittsburg, Warren, and the undammed study sites (One-way ANOVA, F=4.27, p=0.002) (Appendix D).

Avian Community

The highest percentage of mature forest species was observed at the undammed study site (30%), while the Girard study site had the lowest percentage of mature forest species (13%). The Lover's Lane study site had the highest percentage of forest edge species (30%) while the Lowellville study site had the lowest percentage of forest edge species (17%). The Warren and Leavittsburg study sites both had the highest percentage of shrubland species (10%). The Lover's Lane study site had the lowest percentage of shrubland species (3%) (Fig. 5). Avian species classified as insectivores made up the highest average percentage of foragers within the diet guild at all six study sites (63%), followed by omnivores (22%), seed (7%), carnivores and nectivores (3%), frugivores (2%), and carrion (.3%) (Fig. 6). Avian species classified as canopy nesters comprised the highest average percentage of nesters across all study sites (36%), followed by cavity nesters (24%), shrub nesters (20%), ground nesters (12%), anthropogenic structures (5%), parasite nesters (2%) and reed (1%) (Fig. 7).

Figure 5. Proportions of habitat guild types present at each study site (n=6).

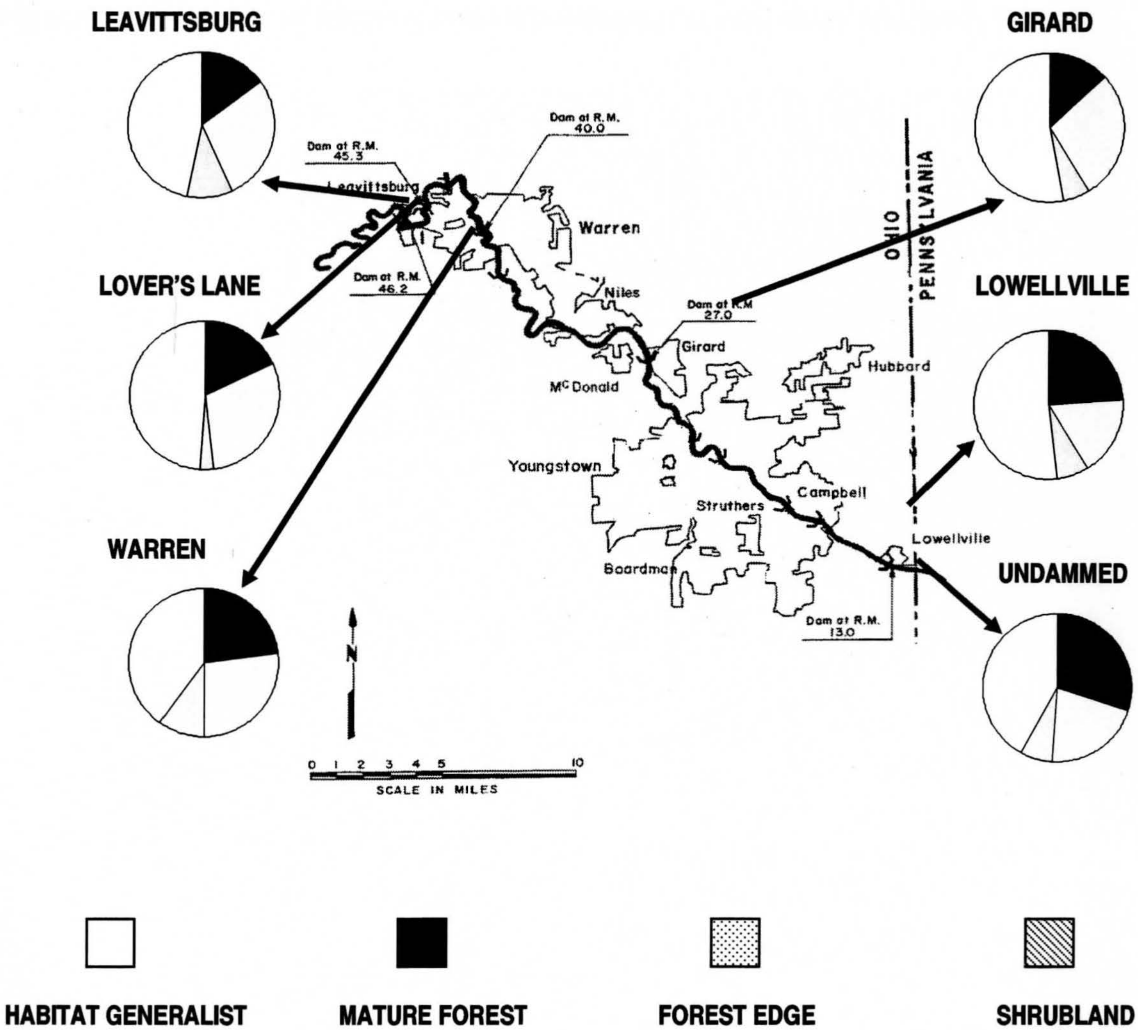

LEAVITTSBURG
GIRARD
LOVER'S LANE
LOWELLVILLE
WARREN
UNDAMMED
Dam at R.M. 40.0
Dam at R.M. 45.3
Dam at R.M. 46.2
Dam at R.M. 27.0
Dam at R.M. 13.0
Leavittsburg
Warren
Niles
Girard
Hubbard
McDonald
Youngstown
Struthers
Campbell
Lowellville
Boardman
OHIO
PENNSYLVANIA
N
0 1 2 3 4 5 10
SCALE IN MILES
HABITAT GENERALIST
MATURE FOREST
FOREST EDGE
SHRUBLAND

Figure 6. Proportions of foraging guild types present at each study site (n=6).

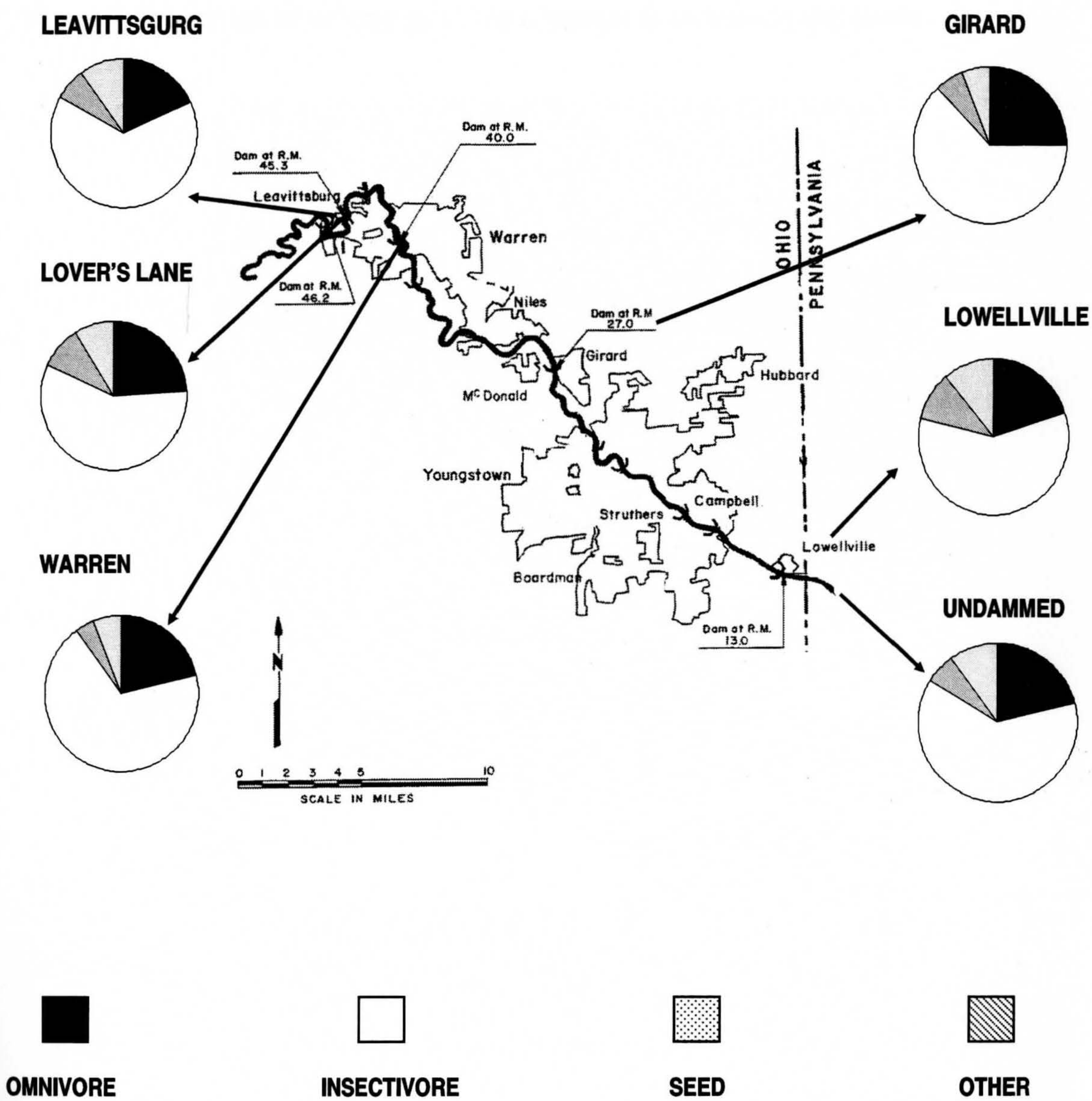
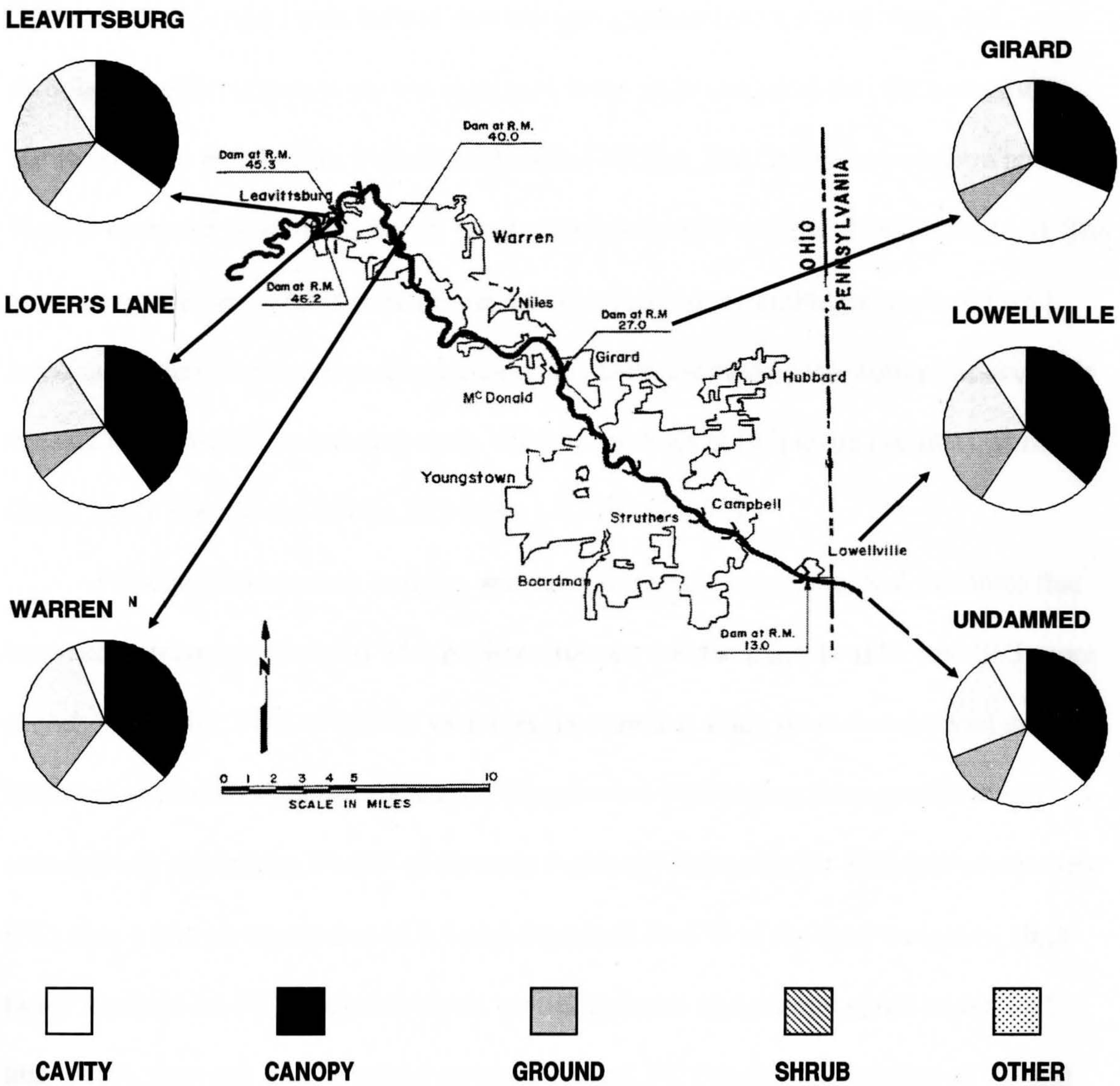

LEAVITTSGURG
LOVER'S LANE
WARREN
GIRARD
LOWELLVILLE
UNDAMMED
Dam at R.M. 45.3
Dam at R.M. 40.0
Dam at R.M. 46.2
Dam at R.M 27.0
Dam at R.M. 13.0
Leavittsburg
Warren
Niles
Girard
McDonald
Hubbard
Youngstown
Campbell
Struthers
Lowellville
Boardman
OHIO
PENNSYLVANIA
N
0 1 2 3 4 5 10
SCALE IN MILES
OMNIVORE
INSECTIVORE
SEED
OTHER

Figure 7. Proportion of nesting guild types present at each study site (n=6).

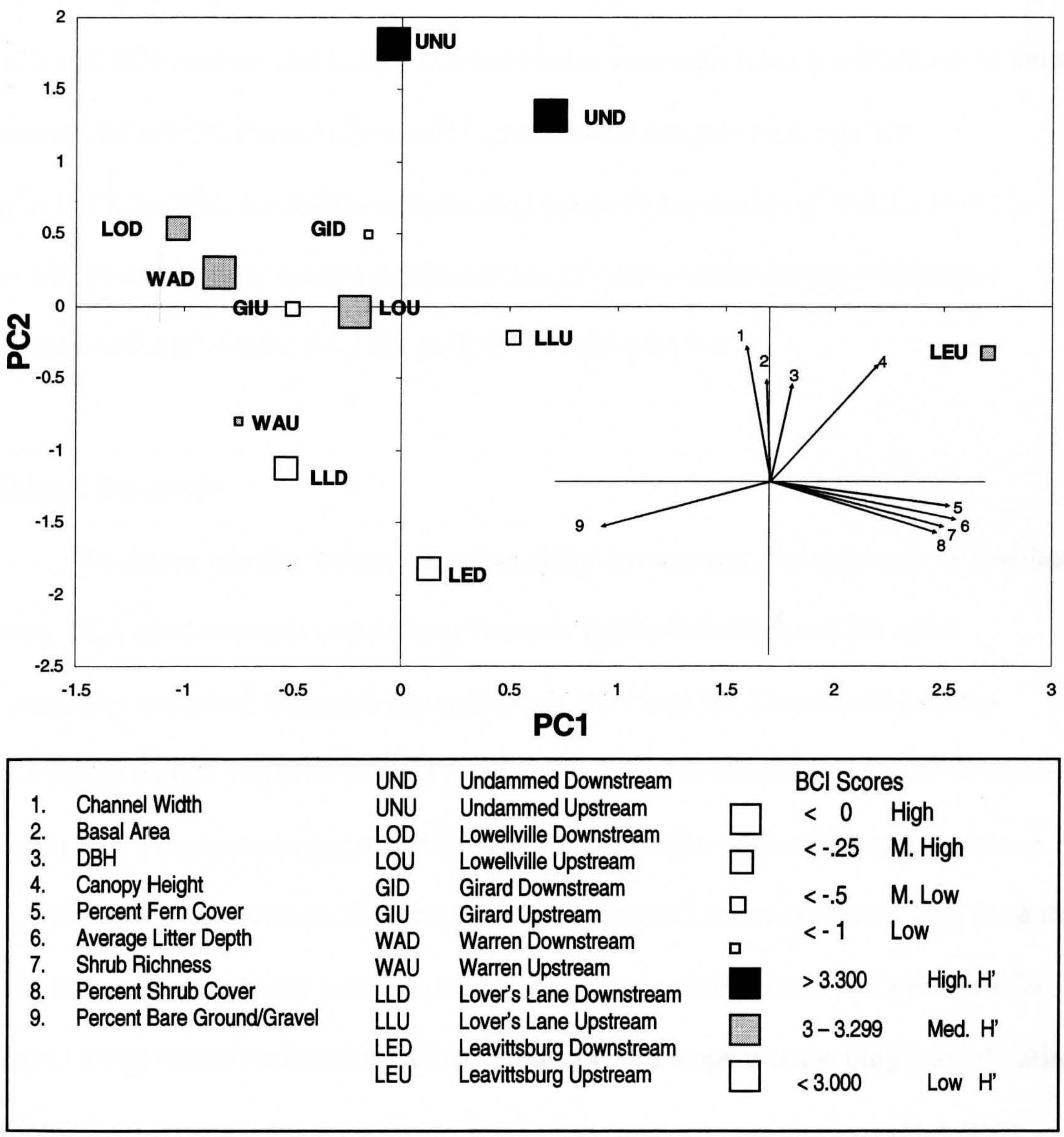


LEAVITTSBURG
GIRARD
LOVER'S LANE
LOWELLVILLE
WARREN
UNDAMMED
Dam at R.M. 45.3
Dam at R.M. 40.0
Dam at R.M. 46.2
Dam at R.M 27.0
Dam at R.M. 13.0
Leavittsburg
Warren
Niles
Girard
McDonald
Hubbard
Youngstown
Struthers
Campbell
Boardman
Lowellville
OHIO
PENNSYLVANIA
N
0 1 2 3 4 5 10
SCALE IN MILES
CAVITY
CANOPY
GROUND
SHRUB
OTHER

BCI analysis of avian forest habitat assemblages (mature forest, forest edge, and shrubland) within downstream and upstream study plots indicated that the Lowellville upstream study plot had the highest BCI value (-0.105). The Girard downstream and Warren upstream study plots tied in having the lowest BCI values (-1.099) (Table 3). The combining of avian species constituting the forest habitat assemblages (mature forest, forest edge, and shrubland) in downstream and upstream study plots within the six study sites indicate that the undammed study site had the highest BCI score (+0.061) while the Girard study site had the lowest BCI score (-0.875) (Table 4).

Principal Component analysis was used to identify environmental variables that were most strongly correlated with habitat structure and the calculated H' and BCI score at each study plot. PCA of habitat variables measured at study plots downstream and upstream of low-head dams produced 6 eigenvectors with eigenvalues greater than 1, cumulatively explaining 89.0 % of the total variance (Appendix D). Principal component (PC) axes 1 had an eigenvalue of 6.1 and explained 26.6 % of the total variance. High factor loadings on PC 1 included shrub species richness and percent shrub cover, leaf litter depth, fern and bare or gravel covered ground. PC 2 had an eigenvalue of 4.0 and explained 17.6% of the total variance. High factor loadings on PC 2 included corridor slope and percent near ground shrub cover. Ordination of factor loadings on habitat variables from PC 1 and PC2 revealed clustering of study plots with a medium to high Shannon-Weiner index value and a medium to high BCI score. A biplot indicated that habitat variables, such as channel width, basal area, DBH, and canopy height, tended to be correlated to study plots with high H' and BCI scores (Fig. 8).

Figure 8. Ordination of habitat variables at downstream and upstream study plots. Symbols of different size were used to indicate Bird Community Index (BCI) scores and Shannon-Weiner index values are indicated by differences in shading. A biplot indicated that study plots with a high BCI score and Shannon-Weiner index value were correlated with channel width, basal area, DBH and canopy height.



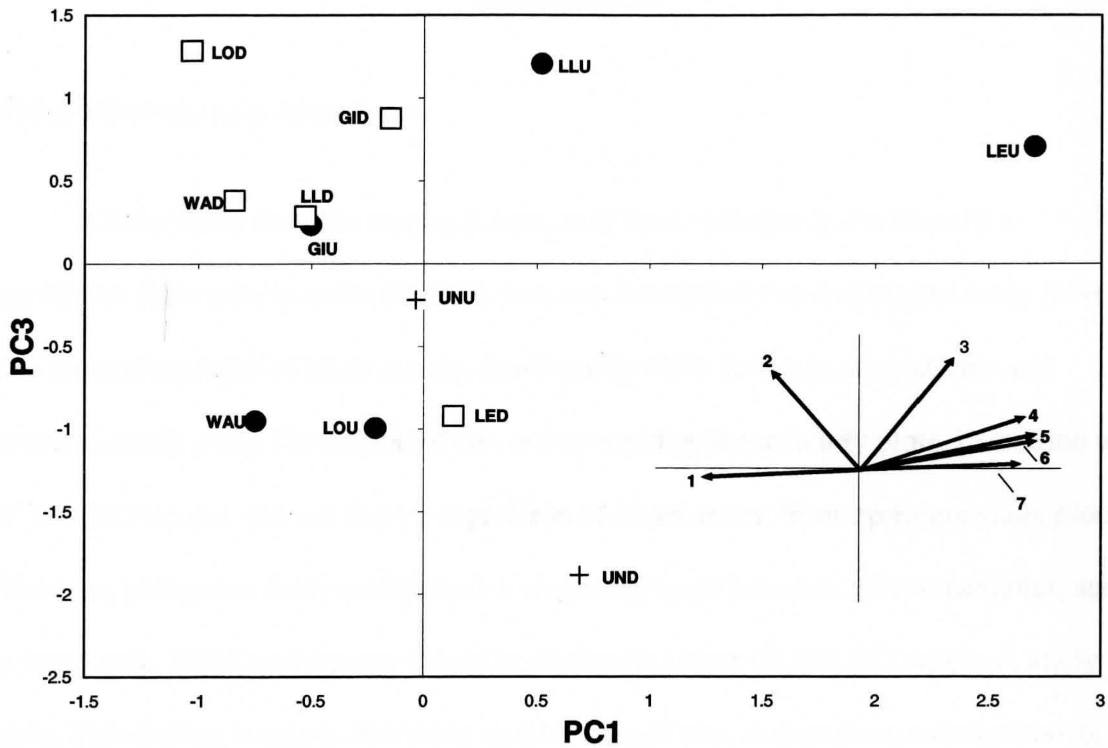
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
PC2
PC1
UNU
UND
LOD
GID
WAD
GIU
LOU
LLU
LEU
WAU
LLD
LED
1
2
3
4
5
6
7
8
9
1. Channel Width
2. Basal Area
3. DBH
4. Canopy Height
5. Percent Fern Cover
6. Average Litter Depth
7. Shrub Richness
8. Percent Shrub Cover
9. Percent Bare Ground/Gravel
UND Undammed Downstream
UNU Undammed Upstream
LOD Lowellville Downstream
LOU Lowellville Upstream
GID Girard Downstream
GIU Girard Upstream
WAD Warren Downstream
WAU Warren Upstream
LLD Lover's Lane Downstream
LLU Lover's Lane Upstream
LED Leavittsburg Downstream
LEU Leavittsburg Upstream
BCI Scores
< 0 High
< -.25 M. High
< -.5 M. Low
< - 1 Low
> 3.300 High. H'
3 – 3.299 Med. H'
< 3.000 Low H'

Multiple linear regression analysis of factor loadings of habitat variables from PC1, PC2, PC3, and PC4 showed that habitat characteristics were significantly correlated to avian diversity ($r^2 = 0.78$, $F = 6.37$, $p = 0.017$), percent habitat generalist species ($r^2 = 0.77$, $F = 5.92$, $p = 0.021$) and percent insectivorous species ($r^2 = 0.77$, $F = 5.85$, $p = 0.022$). In addition, species richness tended to show a relationship with habitat characteristics ($r^2 = 0.69$, $F = 3.89$, $p = 0.057$) (Appendix D).

Habitat Structure

To assess whether habitat variables differ downstream and upstream of low-head dams, PCA used to assess correlations between habitat variables and the avian community was used. To create the ordination, PC 1 and PC 3 were used because loadings of habitat variables on PC1 and PC 3 produced a clustering trend of downstream study plots. Principal component (PC) axes 1 had an eigenvalue of 6.1 and explained 26.6 % of the total variance. PC 3 had an eigenvalue of 3.6 and explained 15.9 % of the total variance. High factor loadings on PC 3 included corridor slope and percent near ground shrub cover. Ordination indicated that corridor slope was the only habitat variable correlated to downstream study plots (Fig 9). Further examination of corridor slope between downstream and upstream study plots revealed that the average corridor slope at downstream study plots was 17 degrees. At upstream study plots the average corridor slope was 8 degrees. However, habitat variables that also loaded highly on PC 1 and PC3, such as percent near ground shrub cover, shrub species richness, average litter depth, percent fern, and the percentage of in plot shrub cover were not correlated with either the downstream or upstream study plots.

Figure 9. Ordination of downstream and upstream study plot habitat variables produced a clustering trend of downstream study plots. A biplot indicated that corridor slope was correlated to downstream study plots.



1. Percent Bare Ground/Gravel
2. Corridor Slope
3. Percent Near Ground Shrub Cover
4. Shrub species Richness
5. Average Litter Depth
6. Percent Fern
7. Percent Shrub Cover

UND	Undammed Downstream
UNU	Undammed Upstream
LOD	Lowellville Downstream
LOU	Lowellville Upstream
GID	Girard Downstream
GIU	Girard Upstream
WAD	Warren Downstream
WAU	Warren Upstream
LLD	Lover's Lane Downstream
LLU	Lover's Lane Upstream
LED	Leavittsburg Downstream
LEU	Leavittsburg Upstream

DISCUSSION

Avian Diversity and Abundance

Of the study sites possessing a dam, only the Leavittsburg site showed a significant difference in avian diversity between downstream and upstream study plots. The mean abundance of birds did not significantly differ between downstream and upstream study plots. Ordination of downstream and upstream study plots, in relation to H' and BCI scores, did not show a separation of downstream from upstream study plots. However, ordination analysis did show a clustering trend between habitat variables, such as basal area, DBH, and canopy height in relation to larger H' and BCI scores at study plots. This finding suggests that dams exhibit little, if any, influence on avian diversity and abundance downstream and upstream of low-head dams. However, differences in habitat between study sites appeared to play a more important role in the diversity and abundance of avian species than did the presence of dams.

Unlike the remaining five study sites, the undammed study site is located in a stretch of the Mahoning River that is, at least qualitatively, less impacted by anthropogenic disturbance and is surrounded by more continuous forest. The undammed study site had the greatest species richness, highest percentage of bird species preferring a mature forest habitat, and the highest Shannon-Weiner index value and BCI score. In addition, avian species sensitive to disturbance and habitat fragmentation, such as the Cerulean Warbler (*Dendroica cerulea*) and Wood Thrush (*Hylocichla mustelina*), were observed at this site, presumably due to the presence of more mature forest. This finding is supported by Farley *et al.* (1994) who found that mature riparian plant communities in the southwestern United States contain a larger number of height classes, structural forms, and greater plant species diversity producing a more heterogeneous environment that correlated positively with bird species diversity.

The Lowellville, Girard, Warren, Lover's Lane, and Leavittsburg study sites are all affected by some degree of urbanization and/or relatively narrow riparian corridors. Rottenborn (1998) found that broad riparian corridors better maintain bird species richness than narrow corridors. Both riparian corridor width (Groom and Grubb 2002) and urbanization (Rottenborn 1998) are known to influence the occurrence and diversity of avian species. These factors may be responsible for the lower H' values and BCI scores associated with study plots at these sites. Despite the fact that low levels of disturbance associated with urban development may lower species diversity, the Warren, Lowellville, and Leavittsburg sites had the highest H' values, next to the undammed site. In addition, sites such as Warren and Leavittsburg equaled or surpassed the mean abundance of birds at the undammed study site. This finding is supported by Beissinger and Osborne (1982), who stated that although bird species richness may decline in urban areas, bird communities of residential and urban areas often contain higher bird densities than outlying natural areas. One possible explanation for this trend is that low to moderate levels of disturbance may provide artificial roosting or nesting sites and may provide anthropogenic food resources (Rottenborn 1998).

Avian Guilds

All study plots were dominated by disturbance-tolerant species typical of landscapes altered for human use. However, when species at downstream and upstream study plots were combined at each study site, the undammed study site produced the only positive BCI score, indicating that this site is dominated by disturbance-sensitive mature forest species. In addition, the highest percentage of mature forest species was observed at the undammed study site. The Lowellville study site, which was located 2 km upstream of the undammed study site, produced neither a positive or negative BCI score. This indicated that it was neither dominated by disturbance-tolerant or disturbance-intolerant species. The Lowellville study site also had the second highest percentage of mature forest species and was also shown to exhibit mature forest habitat characteristics. The remainder of the study sites had negative BCI scores indicating that they were all dominated by disturbance-tolerant species. As with bird diversity and abundance, the low-head dams did not appear to influence the presence or absence of avian species categorized into the habitat assemblage guilds above and below low head dams.

Ordination analysis indicated that habitat characteristics more conducive of mature forest, such as DBH, basal area, and canopy height were related to high H' and BCI scores at the undammed and Lowellville study sites. Diaz *et al.* (2005) offered an explanation for increased avian diversity associated with habitat characteristic of large trees. They found that large trees can benefit birds by offering additional nesting sites for cavity and canopy nesters, and large trees may support a greater abundance of resources for birds such as arthropods in bark and leaves.

The dominant foraging guild was insectivory across all of the study sites, followed by omnivores, and seed foragers. The carnivores, frugivores, nectivores, and birds that forage on carrion made up only small proportions, or were entirely absent, at study sites. Multiple linear regression revealed that insectivorous birds were significantly related to habitat variables, such as corridor slope, percent near ground shrub cover, DBH, tree richness, percent grass cover, and percent log cover. Findings in previous studies have found that arthropods of aquatic and terrestrial origin found on vegetation adjacent to rivers are important food resources to insectivorous birds in aquatic habitats (Yard *et al.* 2003). This may be why insectivorous birds made up the highest proportion of foragers at study sites along the Mahoning River. Proportions of foraging guilds were similar at all study sites and the presence of low-head dams did not appear to influence their distributions.

Canopy nesters made up the largest proportion of nesters across all study sites, followed by cavity, shrub and ground nesters. The proportion of birds constituting the anthropogenic structure, parasite, and reed nesting guilds made up only small proportions, or were entirely absent, at study sites. As mentioned previously, although portions of the riparian corridor along the Mahoning River are relatively narrow, the riparian corridor is continuous. The average percent of canopy cover at all twelve upstream and downstream study plots was 89% or greater. The high percentage in canopy cover and continuous forest may be responsible for the high percentage of canopy and cavity nesters. Conversely, ground nesters made up the smallest proportion of the significant nesting substrate guilds, especially at the Girard and Lover's Lane study sites. Lindsay *et al.* (2002) found that increased numbers of nest predators within urbanized areas, such as raccoons (*Procyon lotor*) and the domestic cat (*Felis domesticus*), in association with landscape maintenance, may be responsible for a decline of ground-nesters in anthropogenically disturbed areas.

Multiple linear regression showed no significant relationship between the percentage of canopy, cavity, shrub and ground nesting species and habitat at downstream and upstream study plots. These findings suggest that neither habitat characteristics nor the presence of low-head dams significantly affected the distribution of nesting guilds across the lower Mahoning River.

Habitat Structure

Ordination of habitat variables measured downstream and upstream of low-head dams did not show a discernable separation of upstream and downstream study plots. A biplot revealed only one habitat variable, corridor slope, that was correlated with downstream study plots. The Lowellville, Girard, Warren, and Leavittsburg downstream study plots had a greater degree of corridor slope than their upstream counterparts.

As stated in the 1999 United States Army Corp of Engineers reconnaissance study of the lower Mahoning River, pooled segments of the river upstream of low-head dams have deepened and widened, typically increasing the river width 10 to 20 %. Widening and deepening of the river upstream of low-head dams may be responsible for the decrease in corridor slope, possibly as a result of water pooling upstream of the dam. Habitat variables also included in the ordination such as percent near ground shrub cover, shrub species richness, percent fern, and percent in sampling plot shrub cover were not correlated to either downstream or upstream study plots. Ordination indicated no trend in differences in these habitat variables downstream and upstream of dams.

This finding does not support studies that have examined downstream and upstream affects of dams on riparian habitat. Previous studies done on the effects of habitat upstream and downstream of dams suggest that the presence of dams can disrupt the flow of water decreasing downstream forest productivity (Kozlowski 2002). Also, dams have been shown to increase the volume of water upstream inundating riparian areas leading to a loss of vegetation and habitat (Nilsson and Berggren 2000). However, these studies focused on large-order rivers, such as the Colorado River, which have large dams, that create large reservoirs, drowning out large areas of habitat upstream, resulting in significant reductions of water flow downstream. Low-head dams located within the lower Mahoning River were not built for the purpose of reservoir formation and therefore may not produce the same changes in habitat created by larger dams. Results from this study indicate that low-head dams within the lower Mahoning River did not appear to influence habitat characteristics downstream and upstream of low head dams.

Conclusion

At the time of this study, The United States Army Corps of Engineers is currently working on efforts to restore the ecological integrity of the lower 73km of the Mahoning River. As part of the proposed restoration project, plans are underway to dredge contaminated river and bank sediments. If this plan takes effect, care should be taken to minimize disturbance to the riparian corridor, especially in Warren near Perkins Park, Lowellville, and sections of the Mahoning River east of Lowellville that exhibit a more mature forest characteristic, higher avian species diversity, and a greater proportion of birds requiring mature forest.

Although this study focused primarily on the riparian habitat directly adjacent to the lower Mahoning River, it is important to consider that other habitat types were in close proximity to our study sites. For example, the undammed study site had an abundance of thicket running parallel to a set of rail road tracks about 200 m from the river. Yellow Warbler (*Dendroica petechia*), which prefers to nest in shrubs near waterways (Harrison 1975), were consistently observed during all point counts at this site only. In addition, the highest mean abundance of Yellow Warbler was observed at the undammed site. This observation is in sharp contrast to the Lover's Lane study site, which had little or no thicket, and where Yellow Warbler was not detected. It is important to recognize that not all avian species depend upon the same habitat types.

Results of this study indicate that low-head dams do not appear to influence avian species diversity and abundance. Rather, it appears that habitat structure has a greater influence on avian species diversity and community structure. Restoration efforts of the Mahoning River should reach beyond the dredging of river sediments within and on the riverbank of the Mahoning River. A total of 66 bird species were identified within the riparian woodland along the lower portion of the Mahoning River, each of which uses its own habitat type. If the ecological integrity of the lower Mahoning River is to be preserved, care should be taken to preserve all habitat types, not just the most mature habitat with the highest avian species diversity.

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APPENDIX A

STUDY SITE DESCRIPTIONS

Table A1. Descriptions of study sites along the Mahoning River.

Undammed Study Site: Lawrence County, PA **River Mile: 11.85** **19.07 km**

Length of pooled segment water upstream of dam (in kilometers): 0

Downstream Plot		**Upstream Plot**	
GPS Coordinates:	41° 01.800' N 80° 30.446' W	GPS Coordinates:	41° 01.806' N 80° 30.926' W
Distance from upstream site:	644m	Distance from downstream site:	644m
Orientation on riverbank:	Left	Orientation on river bank:	Left
Avg. riparian corridor width:	59m	Avg. riparian corridor width:	17m
Average river channel width:	56m	Average river channel width:	57m

Lowellville Dam Study Site: Mahoning County, OH **River Mile: 13.05** **21.01 km**

Length of pooled segment of water upstream of dam (in Kilometers):3.7

Downstream Plot		**Upstream Plot**	
GPS Coordinates:	41° 02.164' N 80° 32.243' W	GPS Coordinates:	41° 02.315' N 80° 32.414' W
Distance from Dam:	205m	Distance from dam:	147m
Orientation on riverbank:	Right	Orientation on river bank:	Left
Avg. riparian corridor width:	22m	Avg. riparian corridor width:	33m
Average river channel width:	61m	Average river channel width:	46m

Girard Dam Study Site: Trumbull County, OH **River Mile: 26.98** **43.42 km**

Length of pooled segment of water upstream of dam (in kilometers): 15.8

Downstream Plot		**Upstream Plot**	
GPS Coordinates:	41° 09.176'N 80° 42.337'W	GPS Coordinates:	41° 09.322'N 80° 42.368'W
Distance from dam:	93m	Distance from dam:	107m
Orientation on riverbank:	Left	Orientation on river bank:	Left
Avg. riparian corridor width:	32m	Avg. riparian corridor width:	33m
Average river channel width:	57m	Average river channel width:	53m

Table A1 (cont.). Descriptions of study sites along the Mahoning River.

Warren Dam Study Site: Trumbull County, OH **River Mile: 40.95** **65.90 km**

Length of pooled segment of water upstream of dam (in Kilometers): 4.6

Downstream Plot		**Upstream Plot**	
GPS Coordinates:	41° 14.524' N 80° 49.615' W	GPS Coordinates:	41° 14.777' N 80° 49.698' W
Distance from dam:	173m	Distance from dam:	167m
Orientation on riverbank:	Left	Orientation on river bank:	Right
Avg. riparian corridor width:	29m	Avg. riparian corridor width:	97m
Average river channel width:	76m	Average river channel width:	49m

Lover's Lane Dam Study Site: Trumbull County, OH **River Mile: 45.13** **72.63 km**

Length of pooled segment of water upstream of dam (in kilometers): 0.7

Downstream Plot		**Upstream Plot**	
GPS Coordinates:	41° 14.604'N 80° 51.830' W	GPS Coordinates:	41° 14.474' N 80° 51.807' W
Distance from dam:	136m	Distance from dam:	85m
Orientation on riverbank:	Right	Orientation on river bank:	Right
Avg. riparian corridor width:	27m	Avg. riparian corridor width:	19m
Average river channel width:	40m	Average river channel width:	43m

Leavittsburg Dam Study Site: Trumbull County, OH **River Mile: 46.18** **74.32 km**

Length of pooled segment of water upstream of dam (in kilometers): 13.9

Downstream Plot		**Upstream Plot**	
GPS Coordinates:	41° 14.393' N 80° 52.813' W	GPS Coordinates:	41° 14.486' N 80° 52.942' W
Distance from dam:	120m	Distance from dam:	343m
Orientation on riverbank:	Left	Orientation on river bank:	Right
Avg. riparian corridor width:	56m	Avg. riparian corridor width:	52m
Average river channel width:	33m	Average river channel width:	61m

APPENDIX B

AVIAN POINT COUNTS

Table B1. Undammed Study Site: Downstream Plot

Species Observed Common Name	Number of Individuals Observed in Week						
	5/3 – 5/7	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/7 - 6/11	6/14 - 6/18
Canada Goose	1	1					
Wood Duck	1	1	2		1		1
Mallard					1		
Wild Turkey							1
Mourning Dove		1					
Belted Kingfisher		1					
Red-bellied Woodpecker		1	1		1	1	1
Hairy Woodpecker	1	1					
Northern Flicker						2	2
Eastern Wood-Pewee					1	1	2
Acadian Flycatcher			1	1		3	2
Eastern Phoebe	1						1
Eastern Kingbird		1					
Yellow-throated Vireo						1	
Warbling Vireo						1	2
Red-eyed Vireo			1	1	1		1
Blue Jay	3						
American Crow			1				
Black-capped Chickadee		1	1				1
Tufted Titmouse					1		3
Carolina Wren					1	1	
Blue-gray Gnatcatcher					1		
Wood Thrush						1	
American Robin	2	2	1	2	2	2	1
Gray Catbird	1	2	1		1		2
Cedar Waxwing			1	1			
Yellow Warbler	5	3	1	1	1	2	4
Chestnut-sided Warbler				1			
Yellow-rumped Warbler	1						
Cerulean Warbler					1		
American Redstart					1	3	1
Common Yellowthroat		1			1		
Northern Cardinal		1	1				
Rose-breasted Grosbeak	2				1	1	
Indigo Bunting		1	1	1	1		1
Eastern Towhee		1	1	1			
Song Sparrow	1	2	1	1	2	1	2
Common Grackle			1			1	
Brown-headed Cowbird	2			2			1
Baltimore Oriole		1	1	1			
American Goldfinch	2				1	1	
Total	23	22	17	11	20	22	1

Table B2. Undammed Study Site: Upstream Plot

Species Observed Common Name	Number of Individuals Observed in Week						
	5/3 - 5/7	5/10 - 5/14	5/17 - 5/21	5/24 - 5/28	5/31 - 6/04	6/7 - 6/11	6/14 - 6/18
Great Blue Heron					1	1	
Turkey Vulture		3					
Canada Goose		2					
Wood Duck			3				
Wild Turkey							1
Chimney Swift		2			3		
Ruby-throated Hummingbird					1		
Red-bellied Woodpecker					1		
Downy Woodpecker	1						
Northern Flicker	2					1	1
Eastern Wood-Pewee			1				1
Acadian Flycatcher					1	1	2
Eastern Kingbird					1		
Blue-headed Vireo		1					
Yellow-throated Vireo		1			1	1	
Warbling Vireo		1	2		1	1	1
Red-eyed Vireo			1				1
Blue Jay	1	1				1	
Black-capped Chickadee			1		1		
Tufted Titmouse					1		
American Robin	2		1	5		2	2
Gray Catbird			1	1			3
European Starling			1				
Cedar Waxwing			1	4	2	6	3
Yellow Warbler	4	1	1	1	1	2	2
Yellow-rumped Warbler	1						
American Redstart						1	
Common Yellowthroat				1			
Hooded Warbler				1			
Northern Cardinal	1	2		1	1	3	2
Rose-breasted Grosbeak		1			2	1	1
Indigo Bunting					1		
Song Sparrow	1	2	1	1	1		1
Red-winged Blackbird	1	1	1			1	
Eastern Meadowlark				2			
Common Grackle	1		3	1	1		1
Brown-headed Cowbird				2			
Baltimore Oriole	1	1	1	1	2		
American Goldfinch	1	5	1	1	1	1	1
House Sparrow							1
Total	17	24	20	22	24	23	22

Table B3. Lowellville Study Site: Downstream Plot

Species Observed Common Name	Number of Individuals Observed in Week						
	5/3 – 5/7	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Great Blue Heron			1			1	
Canada Goose						7	3
Mallard		1			1	2	
Spotted Sandpiper		1					
Rock Dove				2			
Mourning Dove	1						
Chimney Swift				4			
Ruby-throated Hummingbird						1	
Downy Woodpecker				1		2	
Hairy Woodpecker					2		
Eastern Phoebe		2			1	1	
Blue-headed Vireo*	1						
Warbling Vireo	2	2	2		1	1	1
Red-eyed Vireo			1		1		
Blue Jay	2		1				
Northern Rough-winged Swallow		4	2				
Black-capped Chickadee					1		
Tufted Titmouse							1
Carolina Wren		1					
American Robin	2	1	5	4	2	3	2
Gray Catbird	1	1	1	2	1	2	
European Starling	3				1		
Cedar Waxwing	2	2		4		4	3
Yellow Warbler		1	1	2	2	2	1
Northern Cardinal	2	1	1	1			
Indigo Bunting							1
Eastern Towhee					1		
Song Sparrow	3	1	3	2	3	1	1
Common Grackle		1				3	1
Baltimore Oriole	1	1					
American Goldfinch						1	1
House Sparrow							1
Total	20	3	18	22	17	1	16

Table B4. Lowellville Study Site: Upstream Plot

Species Observed Common Name	Number of Individuals Observed in Week						
	5/03 – 5/07	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Canada Goose			3			1	
Sharp-shinned Hawk	1						
Chimney Swift							2
Ruby-throated Hummingbird						1	1
Belted Kingfisher				1			
Red-bellied Woodpecker							1
Downy Woodpecker			1				
Hairy Woodpecker				1			1
Eastern Wood-Pewee				2	1	1	2
Eastern Phoebe		1					
Warbling Vireo		2	1		1	1	
Red-eyed Vireo				1	1		1
Blue Jay			1				
American Crow	1						
Black-capped Chickadee				1			1
Tufted Titmouse	1		1	1			
House Wren			1				
Wood Thrush			2		1	1	1
American Robin	2	1	1	2	3	3	1
Gray Catbird		1	1	1			2
European Starling	7					1	
Cedar Waxwing				2		3	
Yellow Warbler		1	2	2		2	2
Yellow-rumped Warbler	3						
Northern Cardinal	1	2	2	2	1	2	2
Indigo Bunting				2	2	1	1
Song Sparrow	3	2	1	1	2	2	1
Common Grackle						1	
Brown-headed Cowbird				2			1
Baltimore Oriole	1		1				
American Goldfinch	2	1	1				2
House Sparrow				1		1	
Total	22	11	19	22	12	21	22

Table B5. Girard Study Site: Downstream Plot

Species Observed Common Name	Number of Individual Observed in Week						
	5/3 – 5/7	5/24 – 5/28	5/10 – 5/14	5/17 – 5/21	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Canada Goose						1	
Spotted Sandpiper			2	2			
Chimney Swift		3	2	2	3		
Ruby-throated Hummingbird					1		
Red-bellied Woodpecker				1			
Red-eyed Vireo						1	
Blue Jay			1	1	1		1
Black-capped Chickadee			1				
White-breasted Nuthatch			1				
Carolina Wren		2		1			
American Robin	1	3	2	1	5	2	2
Gray Catbird		1		1		2	
European Starling			5	1	3	2	
Cedar Waxwing		2			3		3
Yellow Warbler	2				1		
Northern Cardinal	2	2	2	1			3
Indigo Bunting					1		
Song Sparrow	2	2	1	1	1	3	2
Common Grackle		4		2	6	1	2
Brown-headed Cowbird		1					1
Baltimore Oriole	1		1	1			
American Goldfinch	1	1	3	1	1	1	1
House Sparrow			1	2	3		3
Total	9	21	22	18	4	1	18

Table B6. Girard Study Site: Upstream Plot

Species Observed Common Name	**Number of Individuals Observed in Week**						
	5/3 – 5/7	**5/10 – 5/14**	**5/17 – 5/21**	**5/24 – 5/28**	**5/31 - 6/04**	**6/07 - 6/11**	**6/14 - 6/18**
Chimney Swift		**2**		**2**	**2**	**2**	**1**
Ruby-throated Hummingbird			**1**				
Red-bellied Woodpecker		**1**					
Downy Woodpecker			**1**	**1**			
Hairy Woodpecker					**2**		
Acadian Flycatcher						**1**	
Warbling Vireo					**1**		
Red-eyed Vireo			**1**		**1**	**1**	
Blue Jay			**2**		**1**		
American Crow					**1**	**1**	
Black-capped Chickadee	**1**		**1**	**1**		**2**	
Tufted Titmouse				**1**			
Carolina Wren	**1**						
House Wren		**1**					
American Robin	**2**	**5**	**1**	**2**	**2**	**2**	**1**
Gray Catbird			**2**	**2**	**1**		**3**
European Starling			**1**				
Cedar Waxwing				**1**	**8**		
Northern Cardinal	**1**	**2**	**1**	**1**	**1**	**2**	**2**
Rose-breasted Grosbeak	**1**				**2**		
Indigo Bunting			**1**	**3**	**2**		**1**
Song Sparrow	**1**	**2**	**1**	**1**	**1**	**1**	**1**
White-throated Sparrow	**3**						
Common Grackle			**1**		**2**		
Baltimore Oriole					**1**		
American Goldfinch	**1**	**1**	**1**	**1**	**1**	**1**	**1**
House Sparrow			**2**				**1**
Total	**11**	**14**	**17**	**16**	**29**	**1**	**11**

Table B7. Warren Study Site: Downstream Plot

Species Observed Common Name	Number of Individuals Observed in Week						
	5/3 – 5/7	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Great Blue Heron					1		
Canada Goose		2					
Mallard			1	1		2	
Chimney Swift		2	20		2		2
Ruby-throated Hummingbird							1
Red-bellied Woodpecker	2						
Downy Woodpecker	1				1		
Hairy Woodpecker			1		1		1
Eastern Wood-Pewee			1	1			
Eastern Phoebe					1		
Great Crested Flycatcher				1			
Blue-headed Vireo*	1						
Yellow-throated Vireo	2						
Warbling Vireo					1		
Red-eyed Vireo		1	1	2			1
Blue Jay			1				
American Crow	1						
Northern Rough-winged Swallow					12	1	3
White-breasted Nuthatch				1	1		
House Wren		1		1		1	
American Robin	3	2	3	2	2	2	1
Gray Catbird		2	2	2	2	1	1
European Starling		1			1	1	1
Cedar Waxwing			1				
Nashville Warbler				1			
Yellow Warbler			1				
Yellow-rumped Warbler	9						
Black-throated Green Warbler		1					
Blackpoll Warbler			10				
Black-and-white Warbler	1		2				
Scarlet Tanager	1						
Northern Cardinal		1	3	1	1	2	1
Indigo Bunting							1
Song Sparrow	2	1		2	1	1	1
Common Grackle		1			2		1
Brown-headed Cowbird				1		1	
American Goldfinch	2	1		6	3	1	1
House Sparrow		2	3		1	1	4
Total	25	18	50	22	33	15	20

Table B8. Warren Study Site: Upstream Plot

Species Observed Common Name	Number of Individuals Observed in Week						
	5/3 – 5/7	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Canada Goose	6						
Wood Duck	1						
Killdeer			1				
Chimney Swift		3	2	2	3	2	2
Red-bellied Woodpecker		1	1	1			1
Hairy Woodpecker			1		1	1	
Eastern Wood-Pewee			1				
Eastern Phoebe					1		
Great Crested Flycatcher				1	1		
Red-eyed Vireo				1		2	
Blue Jay	1				1		
Northern Rough-winged Swallow		2	2	1			4
Black-capped Chickadee				1			
Tufted Titmouse	1						
Carolina Wren	1	1	1	1	1	1	2
House Wren		1		1	1		2
American Robin	1	1	2	3	2	2	3
Gray Catbird		1	2	2	1	1	2
European Starling			1		1		
Cedar Waxwing			1		2	3	
Yellow Warbler		1			1	1	1
Chestnut-sided Warbler		1		1			
Common Yellowthroat							1
Northern Cardinal		3	3	2	2	2	2
Rose-breasted Grosbeak						1	
Indigo Bunting						1	1
Eastern Towhee					1		
Song Sparrow	2	1	1	1	2	2	3
Brown-headed Cowbird	1		1			1	
Baltimore Oriole			1	1			
American Goldfinch	1	1	1		1	1	2
House Sparrow			2			1	
Total	15	17	24	19	22	22	26

Table B9. Lover's Lane Study Site: Downstream Plot

Species Observed Common Name	Number of Individuals observed in Week						
	5/3 – 5/7	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Great Blue Heron							1
Mallard		1	4	2	5	3	1
Spotted Sandpiper					1		
Chimney Swift				2	4	2	
Red-bellied Woodpecker	1	1					
Eastern Wood-Pewee					1		
Eastern Phoebe	1	1		1			
Blue-headed Vireo*			1				
Red-eyed Vireo						1	
Blue Jay	1		1				
American Crow				2			
Northern Rough-winged Swallow			1	2	4		
Tufted Titmouse		1	1			1	1
White-breasted Nuthatch						1	
American Robin	2	2	3	1	2	1	1
Gray Catbird	1				1		
European Starling		1		1			
Cedar Waxwing			1	1			3
Yellow-rumped Warbler	10						
Northern Cardinal		1	1			2	1
White-throated Sparrow	1						
Brown-headed Cowbird		1		1	1	1	1
American Goldfinch	1	1			1	1	1
Total	18	10	13	13	20	13	10

Table B10. Lover's Lane Study Site: Upstream Plot

Species Observed Common Name	Number of Individuals Observed in Week						
	5/3 – 5/7	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Mallard	2	2		1	1	8	1
Spotted Sandpiper		1					
Mourning Dove	1						
Chimney Swift		2		3	3	2	2
Ruby-throated Hummingbird						1	
Red-bellied Woodpecker		1	1	2			
Hairy Woodpecker							1
Northern Flicker					1	1	
Eastern Phoebe	1					1	1
Red-eyed Vireo						1	1
Blue Jay	3		1				
Northern Rough-winged Swallow	2	3	1	2	3		
Black-capped Chickadee				2			
American Robin	2	2	2		2	2	2
Gray Catbird			1				1
European Starling		1	2	1	1	1	
Cedar Waxwing				4	2		
Northern Cardinal	1	1	3	1		2	1
Rose-breasted Grosbeak	1						
Song Sparrow					1		1
Common Grackle				1	1		
Brown-headed Cowbird			2			1	
Baltimore Oriole		1					
American Goldfinch		1	1		1		1
House Sparrow	1	3		1			2
Total	14	18	14	18	16	20	14

Table B11. Leavittsburg Study Site: Downstream Plot

Species Observed Common Name	Number of Individuals observed in Week						
	5/3 – 5/7	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Great Blue Heron					1		1
Mallard							1
Killdeer		1					
Spotted Sandpiper			1				
Mourning Dove						1	
Chimney Swift		2	4	5	3	2	2
Red-bellied Woodpecker							1
Downy Woodpecker		1					
Hairy Woodpecker			1				
Eastern Wood-Pewee			1	1		1	1
Red-eyed Vireo		1				1	1
Blue Jay	1	3					
Northern Rough-winged Swallow			6	5	3		1
Barn Swallow				1			
Carolina Wren		1	1		1	1	1
American Robin	5	4		1	2	2	3
Gray Catbird		2	1	2	2	1	3
European Starling		1	1	1	1		1
Cedar Waxwing			4	2			
Yellow-rumped Warbler	3						
Blackpoll Warbler			1				
Northern Cardinal	1	1		1	2	2	1
Indigo Bunting			1		1		1
Song Sparrow	3	1	1	2	2	2	
White-throated Sparrow	2						
Common Grackle					5	4	1
Baltimore Oriole		1					
American Goldfinch	1	1	3	1			1
House Sparrow	1			3	1		2
Total	17	20	26	25	24	17	22

Table B12. Leavittsburg Study Site: Upstream Plot

Species Observed Common Name	Number of Individuals observed in Week						
	5/3 – 5/7	5/10 – 5/14	5/17 – 5/21	5/24 – 5/28	5/31 - 6/04	6/07 - 6/11	6/14 - 6/18
Great Blue Heron	1					1	
Mallard			4	2	4		
Chimney Swift		2	2	2	2	2	2
Ruby-throated Hummingbird							1
Red-bellied Woodpecker	2	1	1	1	2	1	
Downy Woodpecker	1	1				1	
Hairy Woodpecker							2
Northern Flicker		1	1				
Great Crested Flycatcher				1	1		1
Eastern Kingbird	1						
Red-eyed Vireo				1		1	
Blue Jay		2	1			1	
Black-capped Chickadee			1		1		
Tufted Titmouse	1	1					
White-breasted Nuthatch			1				
Carolina Wren	1			2	2	2	1
American Robin		1	1	3	2	3	1
Gray Catbird	2	1		1	1		2
European Starling			1	1	1		4
Cedar Waxwing			2	1			2
Yellow-rumped Warbler	1						
Blackpoll Warbler			2				
Northern Cardinal			3	1	2	1	2
Rose-breasted Grosbeak	1					1	
Eastern Towhee		1					
Song Sparrow		1	1	1	1	1	2
White-throated Sparrow	5						
Red-winged Blackbird	1		1		1		
Common Grackle			1	1	1		1
Brown-headed Cowbird					1		
Baltimore Oriole		2	1	1	1		
American Goldfinch	1			1	1		
House Sparrow		4	2	2		3	1
Total	18	18	26	22	24	18	22

APPENDIX C

AVIAN SPECIES LIST

Table C1. Common name, scientific name (American Ornithologists' Union 1998), and membership in habitat, diet, and nesting assemblages for avian species observed along the Mahoning River May and June 2004.

Species Name	Scientific Name	Habitat Assemblage	Diet	Nesting Substrate
Great Blue Heron	*Ardea herodias* Linnaeus	Mature Forest	Carnivore	Canopy
Turkey Vulture	*Cathartes aura* (Linnaeus)	Mature Forest	Carrion	Ground
Sharp-shinned Hawk	*Accipiter striatus* Vieillot	Mature Forest	Carnivore	Canopy
Wild Turkey	*Meleagris gallopavo* (Linnaeus)	Mature Forest	Omnivore	Ground
Red-bellied Woodpecker	*Melanerpes carolinus* (Linnaeus)	Mature Forest	Insectivore	Cavity
Hairy Woodpecker	*Picoides villosus* (Linnaeus)	Mature Forest	Insectivore	Cavity
Acadian Flycatcher	*Empidonax virescens* (Vieillot)	Mature Forest	Insectivore	Canopy
Blue-headed Vireo*	*Vireo solitarius* (Wilson)	Mature Forest	Insectivore	Canopy
Warbling Vireo	*Vireo gilvus* (Vieillot)	Mature Forest	Insectivore	Canopy
Red-eyed Vireo	*Vireo olivaceus* (Linnaeus)	Mature Forest	Insectivore	Canopy
Blue-gray Gnatcatcher	*Polioptila caerulea* (Linnaeus)	Mature Forest	Insectivore	Canopy
Wood Thrush	*Hylocichla mustelina* (Gmelin)	Mature Forest	Insectivore	Shrub
Yellow-rumped Warbler	*Dendroica coronata* (Linnaeus)	Mature Forest	Insectivore	Canopy
Blackpoll Warbler	*Dendroica striata* (Forster)	Mature Forest	Insectivore	Canopy
Cerulean Warbler	*Dendroica cerulea* (Wilson)	Mature Forest	Insectivore	Canopy
Black-and-White Warbler	*Mniotilta varia* (Linnaeus)	Mature Forest	Insectivore	Ground
Hooded Warbler	*Wilsonia citrina* (Boddaert)	Mature Forest	Insectivore	Shrub
Scarlet Tanager	*Piranga olivacea* (Gmelin)	Mature Forest	Insectivore	Canopy
Killdeer	*Charadrius vociferous* Linnaeus	Shrubland	Insectivore	Ground
Gray Catbird	*Dumetella carolinensis* (Linnaeus)	Shrubland	Insectivore	Shrub
Common Yellowthroat	*Geothlypis trichas* (Linnaeus)	Shrubland	Insectivore	Shrub
Indigo Bunting	*Passerina cyanea* (Linnaeus)	Shrubland	Insectivore	Shrub
Eastern Towhee	*Pipilo erythrophthalmus* (Linnaeus)	Shrubland	Insectivore	Ground
Eastern Wood-Pewee	*Contopus virens* (Linnaeus)	Forest Edge	Insectivore	Canopy
Great Crested Flycatcher	*Myiarchus crinitus* (Linnaeus)	Forest Edge	Insectivore	Canopy
Eastern Kingbird	*Tyrannus tyrannus* (Linnaeus)	Forest Edge	Insectivore	Canopy
Yellow-throated Vireo	*Vireo flavifrons* (Vieillot)	Forest Edge	Insectivore	Canopy
White-breasted Nuthatch	*Sitta carolinensis* Latham	Forest Edge	Insectivore	Cavity
House Wren	*Troglodytes aedon* Vieillot	Forest Edge	Insectivore	Cavity
Cedar Waxwing	*Bombycilla cedrorum* Vieillot	Forest Edge	Frugivore	Canopy
Nashville Warbler	*Vermivora ruficapilla* (Wilson)	Forest Edge	Insectivore	Ground
Chestnut-sided Warbler	*Dendroica pensylvanica* (Linnaeus)	Forest Edge	Insectivore	Shrubs
American Redstart	*Setophaga ruticilla* (Linnaeus)	Forest Edge	Insectivore	Shrubs
Rose-breasted Grosbeak	*Pheucticus ludovicianus* (Linnaeus)	Forest Edge	Omnivore	Shrubs
Song Sparrow	*Melospiza melodia* (Wilson)	Forest Edge	Insectivore	Shrubs
White-throated Sparrow	*Zonotrichia albicollis* (Gmelin)	Forest Edge	Insectivore	Shrubs
Common Grackle	*Quiscalus quiscula* (Linnaeus)	Forest Edge	Omnivore	Canopy
Brown-headed Cowbird	*Molothrus ater* (Boddaert)	Forest Edge	Insectivore	Parasitic
Baltimore Oriole	*Icterus galbula* (Linnaeus)	Forest Edge	Insectivore	Canopy
Canada Goose	*Branta canadensis* (Linnaeus)	Wetland	Omnivore	Ground
Wood Duck	*Aix sponsa* (Linnaeus)	Wetland	Omnivore	Cavity
Mallard	*Anas platyrhynchos* Linnaeus	Wetland	Omnivore	Ground
Spotted Sandpiper	*Actitis macularia* (Linnaeus)	Wetland	Insectivore	Ground

Table C1. Cont. Common name, scientific name (American Ornithologists' Union 1998), and membership in habitat, diet, and nesting assemblages for avian species observed along the Mahoning River May and June 2004.

Species Name	Scientific Name	Habitat Assemblage	Diet	Nesting Substrate
Rock Dove	*Columba livia* Gmelin	Habitat Gen.	Seeds	Antho.
Mourning Dove	*Zenaida macroura* (Linnaeus)	Habitat Gen.	Seeds	Canopy
Chimney Swift	*Chaetura pelagica* (Linnaeus)	Habitat Gen.	Insectivore	Anthro.
Ruby-throated Hummingbird	*Archilochus colubris* (Linnaeus)	Habitat Gen.	Nectar	Canopy
Downy Woodpecker	*Picoides pubescens* (Linnaeus)	Habitat Gen.	Insectivore	Cavity
Northern Flicker	*Colaptes auratus* (Linnaeus)	Habitat Gen.	Insectivore	Cavity
Eastern Phoebe	*Sayornis phoebe* (Latham)	Habitat Gen.	Insectivore	Anthro.
Blue Jay	*Cyanocitta cristata* (Linnaeus)	Habitat Gen.	Omnivore	Canopy
American Crow	*Corvus brachyrhynchos* Brehm	Habitat Gen.	Omnivore	Canopy
NorthernRough-winged Swallow	*Stelgidopteryx serripennis* (Audubon)	Habitat Gen.	Insectivore	Ground
Barn Swallow	*Hirundo rustica* Linnaeus	Habitat Gen.	Insectivore	Anthro.
Black-capped Chickadee	*Poecile atricapillus* (Linnaeus)	Habitat Gen.	Insectivore	Cavity
Tufted Titmouse	*Baeolophus bicolor* (Linnaeus)	Habitat Gen.	Insectivore	Cavity
Carolina Wren	*Thryothorus ludovicianus* (Latham)	Habitat Gen.	Insectivore	Cavity
American Robin	*Turdus migratorius* (Linnaeus)	Habitat Gen.	Omnivore	Canopy
European Starling	*Sturnus vulgaris* Linnaeus	Habitat Gen.	Omnivore	Cavity
Yellow Warbler	*Dendroica petechia* (Linnaeus)	Habitat Gen.	Insectivore	Shrubs
Black-throated Green Warbler	*Dendroica virens* (Gmelin)	Habitat Gen.	Insectivore	Canopy
Northern Cardinal	*Cardinalis cardinalis* (Linnaeus)	Habitat Gen.	Insectivore	Shrubs
Red-winged Blackbird	*Agelaius phoeniceus* (Linnaeus)	Habitat Gen.	Insectivore	Reeds
American Goldfinch	*Carduelis tristis* (Linnaeus)	Habitat Gen.	Seeds	Shrubs
House Sparrow	*Passer domesticus* (Linnaeus)	Habitat Gen.	Seeds	Cavity

APPENDIX D

STATISTICAL TESTS

Table D1. Randomization Test results comparing Shannon-Weiner index diversity between the undammed study site and the remaining five study sites.

Randomization Test
Solow, 1993 J. Anim. Ecol, 62, 191-193
Using a Shannon Wiener index with 10000 random partitions

Observed Diversity, 1st sample - Undammed = 3.516
Observed Diversity, 2nd sample - Lowellville = 3.255
Delta = 0.261231

Simulation Results
1. Two sided test - Diversity different between sites
Number of Simulated |delta| > Observed |delta| = 19
Estimated Probability (that diversities are equal) = 0.0019

2. One sided test
Number of Simulated delta > Observed delta = 13
Estimated Probability (that Sample 1 (Undammed) <= Sample 2 (Lowellville)) = 0.0013
Sample 1 (Undammed) is more diverse then Sample 2 (Lowellville) at 5% Level

Randomization Test
Solow, 1993 J. Anim. Ecol, 62, 191-193
Using a Shannon Wiener index with 10000 random partitions

Observed Diversity, 1st sample - Undammed = 3.516
Observed Diversity, 2nd sample - Girard = 3.005
Delta = 0.511666

Simulation Results
1. Two sided test - Diversity different between sites
Number of Simulated |delta| > Observed |delta| = 0
Estimated Probability (that diversities are equal) = 0

2. One sided test
Number of Simulated delta > Observed delta = 0
Estimated Probability (that Sample 1 (Undammed) <= Sample 2 (Girard)) = 0
Sample 1 (Undammed) is more diverse then Sample 2 (Girard) at 5% Level

Randomization Test
Solow, 1993 J. Anim. Ecol, 62, 191-193
Using a Shannon Wiener index with 10000 random partitions

Observed Diversity, 1st sample - Undammed = 3.516
Observed Diversity, 2nd sample - Warren = 3.277
Delta = 0.239475

Simulation Results
1. Two sided test - Diversity different between sites
Number of Simulated |delta| > Observed |delta| = 29
Estimated Probability (that diversities are equal) = 0.0029

2. One sided test
Number of Simulated delta > Observed delta = 9
Estimated Probability (that Sample 1 (Undammed) <= Sample 2 (Warren)) = 0.0009
Sample 1 (Undammed) is more diverse then Sample 2 (Warren) at 5% Level

Table D1. (Continued) Randomization Test results comparing Shannon-Weiner index diversity between the undammed study site and the remaining five study sites.

Randomization Test

Solow, 1993 J. Anim. Ecol, 62, 191-193
Using a Shannon Wiener index with 10000 random partitions

Observed Diversity, 1st sample - Undammed = 3.516
Observed Diversity, 2nd sample - Lover's Lane = 2.97
Delta = 0.546815

Simulation Results
1. Two sided test - Diversity different between sites
Number of Simulated |delta| > Observed |delta| = 0
Estimated Probability (that diversities are equal) = 0

2. One sided test
Number of Simulated delta > Observed delta = 0
Estimated Probability (that Sample 1 (Undammed) <= Sample 2 (Lover's Lane)) = 0
Sample 1 (Undammed) is more diverse then Sample 2 (Lover's Lane) at 5% Level

Randomization Test
Solow, 1993 J. Anim. Ecol, 62, 191-193
Using a Shannon Wiener index with 10000 random partitions

Observed Diversity, 1st sample - Undammed = 3.516
Observed Diversity, 2nd sample - Leavittsburg = 3.249
Delta = 0.267702

Simulation Results
1. Two sided test - Diversity different between sites
Number of Simulated |delta| > Observed |delta| = 3
Estimated Probability (that diversities are equal) = 0.0003

2. One sided test
Number of Simulated delta > Observed delta = 0
Estimated Probability (that Sample 1 (Undammed) <= Sample 2 (Leavittsburg)) = 0
Sample 1 (Undammed) is more diverse then Sample 2 (Leavittsburg) at 5% Level

Table D2. Principal Component Analysis of habitat variables measured at downstream and upstream study plots (n=12).

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.132	26.661	26.661	6.132	26.661	26.661
2	4.059	17.648	44.309	4.059	17.648	44.309
3	3.662	15.923	60.233	3.662	15.923	60.233
4	3.283	14.276	74.508	3.283	14.276	74.508
5	2.219	9.648	84.156	2.219	9.648	84.156
6	1.122	4.878	89.034	1.122	4.878	89.034
7	.953	4.145	93.180			
8	.861	3.744	96.924			
9	.338	1.468	98.392			
10	.236	1.027	99.419			
11	.134	.581	100.000			
12	6.523E-16	2.836E-15	100.000			
13	4.414E-16	1.919E-15	100.000			
14	3.853E-16	1.675E-15	100.000			
15	9.989E-17	4.343E-16	100.000			
16	4.284E-17	1.862E-16	100.000			
17	-7.78E-17	-3.384E-16	100.000			
18	-1.67E-16	-7.263E-16	100.000			
19	-2.27E-16	-9.873E-16	100.000			
20	-3.04E-16	-1.321E-15	100.000			
21	-3.78E-16	-1.642E-15	100.000			
22	-5.15E-16	-2.238E-15	100.000			
23	-1.01E-15	-4.377E-15	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix [a]

	Component					
	1	2	3	4	5	6
SHRCOV	.796	-.261	4.597E-02	-.189	-.344	-.125
BA	-.103	.837	.125	.282	-.242	.296
SNAG	6.850E-02	.525	.147	-.554	-.434	.275
DBH	.102	.602	.119	.694	.192	.160
CANCOVR	-.626	.190	.579	-.248	-9.28E-02	-.232
CANHGT	.511	.720	.246	.122	5.083E-02	-.247
CORWIDTH	.143	-.364	-.594	-.352	.317	-.198
CHANWIDT	-8.29E-03	.615	.280	-.306	.231	.204
CORSLOPE	-.424	.112	.730	.102	-.453	-.135
TREERICH	.388	.160	9.484E-02	.786	-8.70E-03	-.329
SHRURICH	.819	-.238	.396	-9.23E-02	-.132	-5.59E-02
LITTER	.872	-.178	.262	-.108	-.213	1.346E-02
GREEN	.611	.564	-.315	-3.28E-02	.157	.188
GRASS	9.346E-02	-.178	-.603	.664	8.088E-02	.235
FORB	.152	.715	-.551	-.359	-1.20E-02	1.503E-02
SHRUB	.460	-.120	.824	5.255E-02	.228	-4.27E-02
FERN	.852	-.103	.222	-.277	.250	.203
MOSS	-.578	7.812E-02	.202	1.587E-02	.686	2.354E-02
LOG	3.289E-02	-.203	6.027E-02	.854	-.267	6.027E-02
BAREGRAV	-.772	-.224	-5.58E-02	-.185	-.385	.190
ROCK	-.324	.168	.405	-7.63E-02	.680	-.161
LEAF	.487	.521	-.469	-.129	-7.62E-02	-.481
BRUSH	.648	-.421	.298	-2.27E-02	.281	.400

Extraction Method: Principal Component Analysis.

a. 6 components extracted.

Table D3. One-way ANOVA for differences in mean abundance (N) of birds between study sites (n=6).

Test of Homogeneity of Variances

VAR001

Levene Statistic	df1	df2	Sig.
1.794	5	78	.124

ANOVA

VAR001

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	646.060	5	129.212	4.273	.002
Within Groups	2358.929	78	30.243		
Total	3004.988	83			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) VAR002	(J) VAR002	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
VAR001	1.00	2.00	1.8571	2.07855	.947	-4.2159	7.9302
		3.00	4.0714	2.07855	.375	-2.0016	10.1445
		4.00	-2.0000	2.07855	.928	-8.0730	4.0730
		5.00	6.2857*	2.07855	.038	.2127	12.3588
		6.00	.0000	2.07855	1.000	-6.0730	6.0730
	2.00	1.00	-1.8571	2.07855	.947	-7.9302	4.2159
		3.00	2.2143	2.07855	.894	-3.8588	8.2873
		4.00	-3.8571	2.07855	.437	-9.9302	2.2159
		5.00	4.4286	2.07855	.283	-1.6445	10.5016
		6.00	-1.8571	2.07855	.947	-7.9302	4.2159
	3.00	1.00	-4.0714	2.07855	.375	-10.1445	2.0016
		2.00	-2.2143	2.07855	.894	-8.2873	3.8588
		4.00	-6.0714	2.07855	.050	-12.1445	.0016
		5.00	2.2143	2.07855	.894	-3.8588	8.2873
		6.00	-4.0714	2.07855	.375	-10.1445	2.0016
	4.00	1.00	2.0000	2.07855	.928	-4.0730	8.0730
		2.00	3.8571	2.07855	.437	-2.2159	9.9302
		3.00	6.0714	2.07855	.050	-.0016	12.1445
		5.00	8.2857*	2.07855	.002	2.2127	14.3588
		6.00	2.0000	2.07855	.928	-4.0730	8.0730
	5.00	1.00	-6.2857*	2.07855	.038	-12.3588	-.2127
		2.00	-4.4286	2.07855	.283	-10.5016	1.6445
		3.00	-2.2143	2.07855	.894	-8.2873	3.8588
		4.00	-8.2857*	2.07855	.002	-14.3588	-2.2127
		6.00	-6.2857*	2.07855	.038	-12.3588	-.2127
	6.00	1.00	.0000	2.07855	1.000	-6.0730	6.0730
		2.00	1.8571	2.07855	.947	-4.2159	7.9302
		3.00	4.0714	2.07855	.375	-2.0016	10.1445
		4.00	-2.0000	2.07855	.928	-8.0730	4.0730
		5.00	6.2857*	2.07855	.038	.2127	12.3588

*. The mean difference is significant at the .05 level.

Table D4. Multiple linear regression of H' and habitat.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.886[a]	.785	.661	.11571

a. Predictors: (Constant), PC4, PC3, PC2, PC1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.341	4	.085	6.373	.017[a]
	Residual	.094	7	.013		
	Total	.435	11			

a. Predictors: (Constant), PC4, PC3, PC2, PC1

b. Dependent Variable: DIVERSIT

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.054	.033		91.430	.000
	PC1	6.507E-02	.035	.327	1.865	.104
	PC2	.112	.035	.562	3.204	.015
	PC3	-.106	.035	-.532	-3.031	.019
	PC4	-5.59E-02	.035	-.281	-1.601	.153

a. Dependent Variable: DIVERSIT

Table D5. Multiple linear regression of percentage of habitat generalist species and habitat.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.879[a]	.772	.642	4.99042

a. Predictors: (Constant), PC4, PC3, PC2, PC1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	590.337	4	147.584	5.926	.021[a]
	Residual	174.330	7	24.904		
	Total	764.667	11			

a. Predictors: (Constant), PC4, PC3, PC2, PC1

b. Dependent Variable: HG

Coefficients[a]

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	48.333	1.441		33.551	.000
	PC1	-1.726	1.505	-.207	-1.147	.289
	PC2	-1.919	1.505	-.230	-1.275	.243
	PC3	6.449	1.505	.773	4.286	.004
	PC4	2.328	1.505	.279	1.547	.166

a. Dependent Variable: HG

Table D6. Multiple linear regression of percentage of insectivorous species and habitat.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.877[a]	.770	.638	2.92834

a. Predictors: (Constant), PC4, PC3, PC2, PC1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	200.890	4	50.223	5.857	.022[a]
	Residual	60.026	7	8.575		
	Total	260.917	11			

a. Predictors: (Constant), PC4, PC3, PC2, PC1

b. Dependent Variable: INS

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	61.083	.845		72.259	.000
	PC1	.331	.883	.068	.375	.719
	PC2	-.247	.883	-.051	-.280	.787
	PC3	-3.096	.883	-.636	-3.507	.010
	PC4	-2.916	.883	-.599	-3.303	.013

a. Dependent Variable: INS

Table D7. Multiple linear regression of richness and habitat.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.831[a]	.690	.513	4.31411

a. Predictors: (Constant), PC4, PC3, PC2, PC1

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	289.969	4	72.492	3.895	.057[a]
	Residual	130.281	7	18.612		
	Total	420.250	11			

a. Predictors: (Constant), PC4, PC3, PC2, PC1

b. Dependent Variable: RICHNESS

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.250	1.245		25.093	.000
	PC1	.744	1.301	.120	.572	.585
	PC2	3.657	1.301	.592	2.811	.026
	PC3	-3.001	1.301	-.486	-2.307	.054
	PC4	-1.851	1.301	-.299	-1.423	.198

a. Dependent Variable: RICHNESS

APPENDIX E

PERCENTAGE AND NUMBER OF AVIAN GUILDS

Table E1. Number and percentage of avian species in habitat guilds.

Habitat Guilds	**Undammed**		**Lowellville**		**Girard**		**Warren**		**Lover's Lane**		**Leavittsburg**	
	#	%	#	%	#	%	#	%	#	%	#	%
Mature Forest	16	**30**	10	**24**	4	**13**	11	**23**	6	**18**	6	**15**
Forest Edge	11	**21**	7	**17**	9	**28**	13	**27**	10	**30**	11	**28**
Shrubland	4	**7**	3	**7**	2	**6**	5	**10**	1	**3**	4	**10**
Habitat Gen.	22	**42**	21	**52**	17	**53**	19	**40**	16	**49**	19	**47**

Table E2. Number and percentage of avian species in foraging guilds.

Foraging Guilds	Undammed		Lowellville		Girard		Warren		Lover's L.		Leavittsburg	
	#	%	#	%	#	%	#	%	#	%	#	%
Omnivore	11	**21**	8	**20**	8	**25**	10	**21**	8	**24**	7	**18**
Carnivore	2	**4**	3	**7**	0	**0**	1	**2**	1	**3**	1	**2**
Insectivore	33	**63**	24	**59**	20	**63**	33	**69**	19	**58**	26	**65**
Nectivore	1	**2**	1	**2**	1	**3**	1	**2**	1	**3**	2	**5**
Frugivore	1	**2**	1	**2**	1	**3**	1	**2**	1	**3**	1	**2**
Seed	3	**6**	4	**10**	2	**6**	2	**4**	3	**9**	3	**8**
Carrion	1	**2**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**

Table E3. Number and percentage of avian species in nesting guilds.

Nesting Guilds	**Undammed**		**Lowellville**		**Girard**		**Warren**		**Lover's Lane**		**Leavittsburg**	
	#	%	#	%	#	%	#	%	#	%	#	%
Canopy	19	**37**	15	**37**	10	**31**	18	**37**	13	**40**	14	**35**
Cavity	10	**19**	9	**22**	10	**31**	11	**23**	8	**24**	10	**25**
Ground	7	**13**	6	**15**	2	**7**	7	**15**	3	**9**	5	**13**
Shrub	12	**23**	7	**17**	8	**25**	9	**19**	6	**18**	7	**18**
Parasite	1	**2**	1	**2**	1	**3**	1	**2**	1	**3**	1	**2**
Reed	1	**2**	0	**0**	0	**0**	0	**0**	0	**0**	1	**2**
Anthropogenic Structure	2	**4**	3	**7**	1	**3**	2	**4**	2	**6**	2	**5**