# SURVEY FISH DIVERSITY: TESTING THE IMPACT OF VEGETATIVE ENCROACHMENT

Final Report to the Ohio Lake Erie Commission

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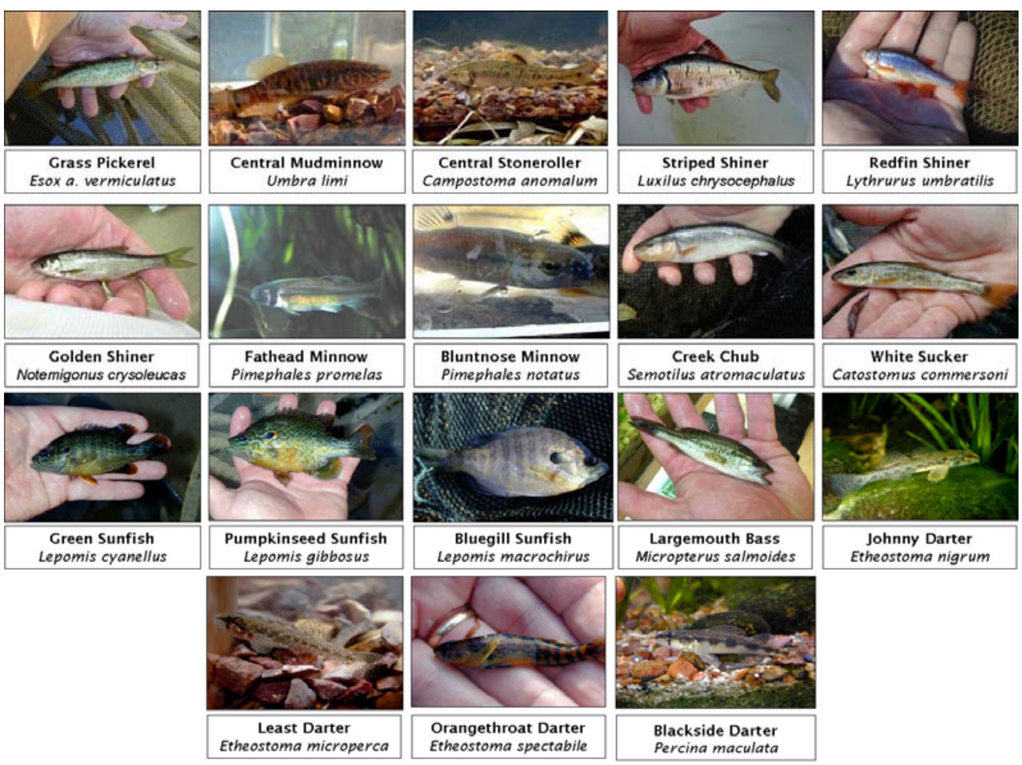

## Executive Summary

Colonization by wetland plants of channelized stream banks and the resulting fluvial geomorphology are surmised to produce more-stable channel cross-sections and improve water quality. We tested the impact of such colonization on the structure and composition of fish communities in farm ditches of the Ottawa River, a western Lake Erie tributary, by comparing twelve 20-m stream segments with and without plant intrusion (heterogeneous or Ht and homogeneous or Ho, respectively).

Fish communities were sampled by sweep and block seine in each segment eleven times between June 2005 and October 2006. Measurements of pH, temperature, turbidity, $DO_2$, conductivity, canopy cover and discharge were comparable between Ht and Ho segments at each sampling event.

A total of 10,501 fish representing 24 species were identified and released. Only 0.6% of the total catch belonged to non-native species. The average Shannon diversity, species richness and number of trophic guilds were significantly higher in Ht segments ($p=0.028$, $p=0.029$, $p=0.008$, respectively). Moreover, Ht segments appeared to host greater abundance (119.7 ± 32.2) than Ho sites (53.5 ± 13.8) although that difference was only significant at the $p=0.074$ level due to large inter-annual variability in fish abundance within each habitat type. The Index of Biological Integrity was not significant different between habitats (HT= 21.8 ± 0.1; HO=21.2 ± 0.2).

Our census included 1,615 least darters, *Etheostoma microperca*, a previously undocumented population and listed as a State Species of Concern in Ohio. Seines were an effective, non-lethal tool in our fish sampling protocol. These farm ditches showed a surprisingly robust, species-rich fish community that may be maintained by allowing wetland plant colonization along stream banks.

In spite of decades of continual disturbance by humans and a misinformed reputation for being little more than a culvert to drain excess water away from agriculture, the channelized and entrenched headwaters of the Ottawa River possess a developed fish community composition and structure that ranks “Fair” in comparison to statewide IBI assessments of streams. Although dominated by two tolerant species, the habitat is suitable for a large population of the State Species of Concern least darter, in addition to twenty other native species of fish. While present, three exotic species were an insignificant proportion of the fish community composition and structure.

Furthermore, within these streams, segments possessing a heterogeneous geomorphology host a significantly more rich, diverse and trophically-varied fish community than segments with less developed, homogeneous geomorphology. In the case of our study sites, colonization of plants contributes to the formation of the heterogeneous morphologies.

**Acknowledgements**
We would like to thank the Lake Erie Protection Fund for their support in funding this project (LEPF 251-05). Drs. Tramer and Martin Hayden provided valuable suggestions during the course of this study. This project would not have been possible without the competent field assistance from Ryan Argo, Blake Brown, Joshua Brown, Erika Buri, Cindy DeSaint-Victor, Kristin Gardner, Jeff Grabarkiewicz, Matt Nielson, Maria Tumeo, and Brian Zimmerman.

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# Introduction

Farm fields in the upper Midwest make extensive use of tiles, ditches and channelized headwater streams to drain excess water. In many cases, these ditched segments, or drains, serve as the headwater streams for their watersheds, and the management of these segments is a critical component of downstream water quality. Riparian plant restoration (woody and herbaceous) and best management practices (BMPs, such as no-till farming, grass buffer strips, two stage ditches) in these systems and the resulting fluvial geomorphological processes are surmised to improve water quality and produce a more stable cross section in the channel banks (Barila *et al*., 1981; Shields *et al*., 1994; Mecklenberg, 1998; Stauffer *et al*., 2000; Frothingham *et al*., 2002; Ward and Trimble, 2004; Zucker *et al*., 2004; Boody *et al*., 2005).

Information about the fish community structure and composition in rivers and streams is an important factor in understanding impacts of land use, as the community structure can be used as a metric for comparing the integrity or disturbance among stream segments that are subject to different impacts and management. The most popular method is the use of the Index of Biological Integrity model resulting from the work of Karr and Angermeier (Gorman and Karr, 1978; Angermeier and Karr, 1985; Angermeier and Schlosser, 1989; Karr 1991), and modeled specifically for Ohio streams by the Ohio EPA (OEPA 1988, 2006). Poff and Allan (1995) used community structure and species trophic guild "to describe habitat, trophic, morphological and tolerance characteristics" of fish assemblages in relation to hydrological regime.

**Figure 1.1 –** Wolfe Creek, Fulton County, OH

**Figure 1.2 –** Tenmile Creek, Fulton County, OH

Abundant literature is available on the response of fish community structure and composition to geomorphological changes in compromised woodland streams where agriculture now dominates (Schlosser, 1982; Jones *et al*., 1999; Stauffer *et al*., 2000; Scott 2006) or where these streams enter urban areas (Tramer and Rogers, 1973; Reash and Berra, 1987, Miltner *et al*., 2003) and receive point source pollution in addition to the non-point source pollution from agriculture. Literature is also being published on agricultural systems in the Great Plains Region (Taylor *et al*., 1993;

Zimmerman *et al.*, 2003; Vondracek *et al*., 2005), but these studies report primarily on larger segments of streams than the point of contact in the headwaters.

Very little, however, is known about fish community structure or hydrological variability in headwater streams in the agriculturally-dominated lake plain regions surrounding the Great Lakes. These heavily modified headwater streams, locally known as agricultural "ditches" or "drains", are assumed to serve a single purpose, one of removing surface water to maximize agricultural yields. As such, it is generally assumed by farmer and scientist alike, that these systems support a severely impoverished aquatic community and provide little ecological function. Only Wichert and Rapport (1998) specifically focused on agricultural streams, in their case along the northern coast of the lower Great Lakes in Canada in the Grand River, Ontario watershed. They compared land use practices from 1952 –1975 and 1975-1995 and examined the response of indicators of fish community composition (assemblage of species present) and structure (age at maturity, number of species, trophic guilds, etc.) with regard to stable or changing conditions on land adjacent to their test streams. They found a significant positive response in the fish community composition and structure with increased continuity of riparian vegetation and the use of conservation tillage. They also found a significant negative response to decreases in continuity of riparian vegetation, or practices such as allowing cattle access to streams. However, the study lacked data on the impact of vegetative colonization within the primary channel and the resulting stream morphology and hydrological regime on fish fauna in these systems.

Considering that these farm ditches are already degraded, and that an immediate response from a well-studied vertebrate community to such degradation is likely, this seems a good opportunity for research. In these systems, manipulations are possible without severe environmental repercussions as the systems are already heavily disturbed. Moreover, these agricultural drains constitute a large percentage of first and second order streams per watershed in the catchments of the lower Great Lakes, and may constitute the first line of action for improving water quality in the Great Lakes.

The Ottawa River, a 446 $km^2$ tributary watershed to western Lake Erie in northwest Ohio, offered a good opportunity to examine the effects of passive vegetative colonization and resulting fluvial geomorphology on the fish community structure and composition in farm ditches. The landscape, soils and land uses in this watershed are representative of a large portion of the headwater streams directly interfacing with agriculture throughout the Huron Erie Lake Plain ecoregion. Tramer and Rodgers (1973) and Tramer (1977) are the only published references in this watershed that characterized the fish community composition and structure in portions of Tenmile Creek, the largest tributary to the Ottawa River, as well as the Ottawa mainstem. In the 1973 samples at two sites in the upper reaches of Tenmile Creek, Tramer and Rodgers (1973) found a total of 13 species. A similar fish community was reported in Tramer's (1977) study of rapidly shrinking pools during drought. While the predominant land use in these study segments was agricultural, as it is today, no data were reported on the stream order, the stream morphology or the vegetative community in and along the stream.

In preliminary sampling of these systems for fish in 2002-2004 (Crail, unpubl.), we found that these ditches provided habitat for a remarkable fish community. We also noticed that certain stream segments seemed to host a richer and more abundant fish community than other segments, and that the more developed fish communities were found in segments that seemed more geomorphologically heterogeneous. This seemed similar to the Gorman and Karr (1978) comparison study of two second-order streams in Indiana. They compared Black Creek (Maumee River drainage), which had been severely channelized, and Indian Creek (Wabash River drainage), which was relatively intact. They found that Indian Creek maintained a more developed and seasonally stable fish community structure than Black Creek.

In preliminary sampling (Crail, unpubl.), we also noticed that the fish community seemed more temporally variable in certain stream segments than in others. Gorman (1986) also examined this question in a long-term study of Black Creek and other similar temporally-variable streams with regard to hydrology and fish community composition and structure. In this study, he examined the seasonal use of small streams by fishes migrating from stream segments or streams of a higher order. He noted that the smaller streams with greater geomorphological heterogeneity had a more stable fish community composition temporally, in spite of seasonal fluxes of fish from higher order stream segments. He also reported that little attention has been given to the fish community structure and composition in these variable environments.

Our third observation was that stream segments with a predominance of trees as the riparian vegetation hosted a much poorer fish community than segments without trees, or at times, no fish at all. This seemed inconsistent with the results from many of the previously cited studies, in which reforested segments showed a recovery of fish community composition and structure. We did notice, however, that these segments in our field observations remained channelized and incised. They only changed morphology where debris had become lodged forming jams in the course of the stream. In stream segments immediately downstream of these jams, we found a sudden appearance of a rich fish community similar to treeless sites. Landowners, however, generally remove these jams. As such, the response of the fish community appears immediately lost once the next sediment-moving storm pulse masks or reverses the developing geomorphology.

Our final observation was that in segments where plants were successfully colonizing the sides and channel of the stream (known as vegetative “benches”), these segments seemed to host a richer and more abundant fish community than other segments. The plant community and composition was typically that of old field weeds and grasses, which are shallow rooting, and would slough away during peak pulse events. These vegetative benches were also subject to “dip out” every decade or so, which is bench removal using heavy machinery by the landowners or county engineers to restore lost channel volume, thus forcing the channel back into an earlier stage of development. However, stabilization of the channel and the developing geomorphology seemed tied most directly to plant colonization, and thus, to the development of the more rich fish community structure and composition.

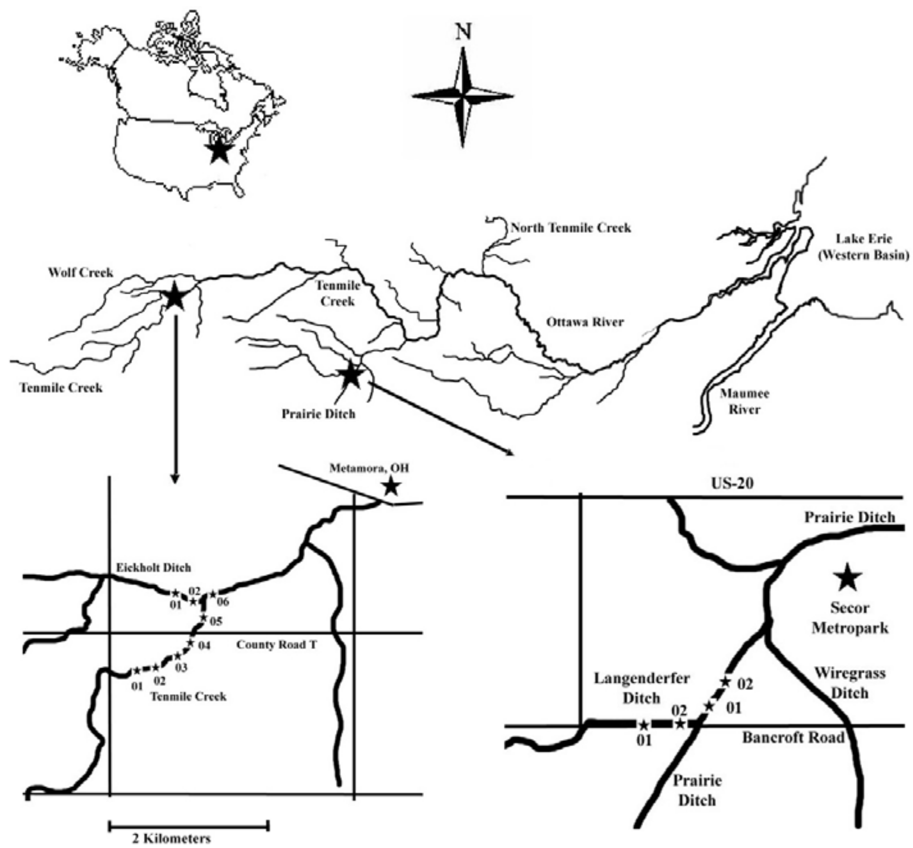
During the 2005 and 2006 field seasons, we evaluated the ecological impact of plant colonization by comparing the structure and composition of fish communities in twelve stream segments with and without such vegetative colonization in the headwaters of the Ottawa River, northwest Ohio. Based on our initial field observations, our goals were to develop a measure of the difference in the geomorphology of these stream segments that is linked to vegetative colonization, and quantify the effects of the different geomorphology on the development of fish community composition and structure. We also quantified a standard Index of Biological Integrity "reference reach" in Tenmile Creek within our test segment to compare the stream against other stream IBI scores statewide and to provide a context for the ranking of this system. Finally, we compared the list of species encountered in each of the two habitat types with data from the historical fish community composition (Trautman, 1981; Ted Cavender, Ohio State University Museum, pers comm.) to evaluate the current Ottawa River status within a historical context. We would expect that the current composition and structure is an extremely modified version of its historical fish community due to the massive changes in channel structure, land use and chemical contamination.

As such, our objectives for this study were to (1) contrast the fish community composition and structure over time between heterogeneous and homogenous stream segments, (2) contrast this community against other streams in Ohio using a traditional reference reach Index of Biological Integrity sample accounting for both types of stream segments, and (3) compare the current fish community to the historical fish community and discuss changes in the species composition through the 20$^{th}$ century.

# Methods

*Location*.
Twelve 20-meter stream segments were identified in the headwaters of the Ottawa River, a 446 $km^2$ (Benedict and Gottgens, 2006) tributary watershed flowing directly into western Lake Erie (Fig. 2.1) as a third order stream. The Ottawa River is a low-gradient (mean slope = 10.4 m/km) watershed consisting of agricultural, suburban and urban environments (Roberts *et al*., 2007) and is found on the United States Environmental Protection Agency "Area of Concern" list, included as a part of the Maumee River Area of Concern listing (http://www.epa.gov/glnpo/aoc/maumee.html). The surficial geology consists of glacio-lacustrine silt, clay, sand and gravel, left by the retreating glacier and Glacial Lake Maumee. Historically, the Ottawa originated on the Defiance Moraine as a clear woodland stream. The stream made way to the Oak Openings Region and Silica Monocline (an exposed area of bedrock) as a tannic, low gradient river, meandering through Great Lakes twig-rush prairies and oak savanna. Upon cresting the Silica Monocline, the stream resumed its woodland course through glacial lake deltas, and flowing into Lake Erie via the extensive western shore marshes.

**Figure 2.1 –** The Ottawa River watershed location with aspect to North America, and field sites in the Ottawa River watershed, northwest Ohio. Odd numbered sites represent heterogeneous sites, even numbered represent homogeneous sites.



The stream segments (Table 2.1) we used were first and second order streams in Fulton and Lucas counties flowing into Tenmile Creek, a tributary of the Ottawa River (Fig. 2.1). They were all within catchments of intense agricultural land use dominated by row cropping of corn and soybeans. In Fulton County, six sites were set on the Tenmile Creek mainstem (sites 01 - 06) between river kilometers 38 and 39.5, where the creek is a second order stream. Two additional sites were set on a second order tributary to Tenmile Creek that we named Eickholt Ditch (sites 01 and 02) joining Tenmile at river kilometer 38.5. In Lucas County, two sites were set on river kilometer 5 of Prairie Ditch (sites 01 and 02), a second order tributary joining Tenmile Creek at river kilometer 24, and two sites on Langenderfer Ditch (sites 01 and 02), a first order tributary to Prairie Ditch, also found at river kilometer 5.

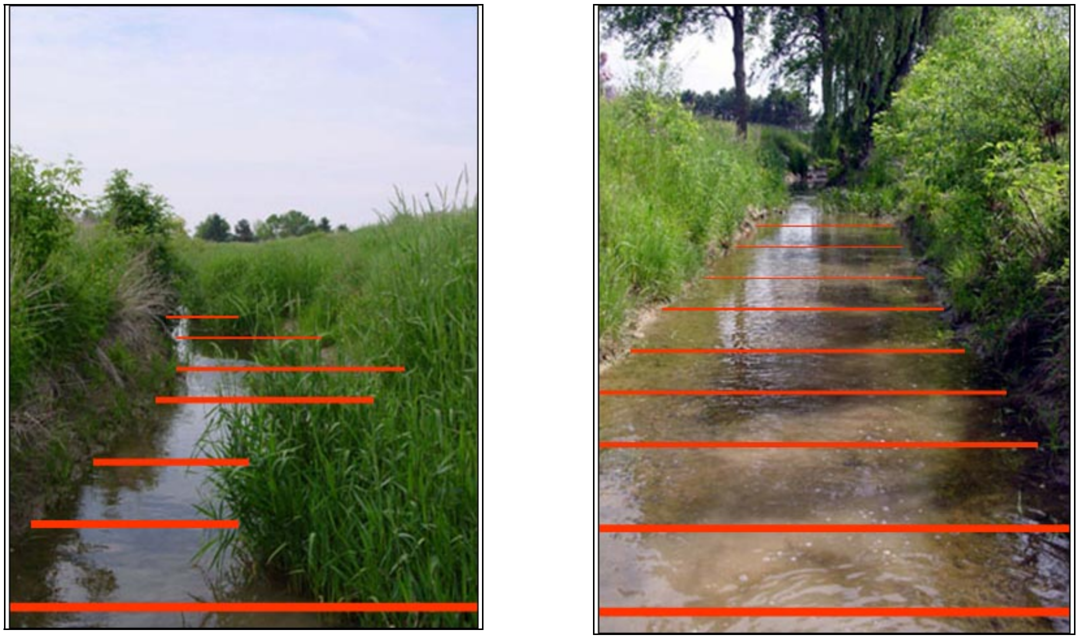
**Table 2.1** - Latitude and longitude of sample segments in the Ottawa River watershed, northwest Ohio.

| Site Name | Latitude | Longitude |
|---|---|---|
| Tenmile 01 | 41° 41' 48.98" N | 83° 56' 14.76" W |
| Tenmile 02 | 41° 41' 51.08" N | 83° 56' 09.25" W |
| Tenmile 03 | 41° 41' 52.60" N | 83° 56' 04.27" W |
| Tenmile 04 | 41° 41' 56.67" N | 83° 55' 58.92" W |
| Tenmile 05 | 41° 42' 07.25" N | 83° 55' 53.76" W |
| Tenmile 06 | 41° 42' 13.35" N | 83° 55' 52.48" W |
| Eickholt 01 | 41° 42' 13.66" N | 83° 56' 07.67" W |
| Eickholt 02 | 41° 42' 10.97" N | 83° 55' 59.13" W |
| Prairie 01 | 41° 39' 30.45" N | 83° 47' 54.67" W |
| Prairie 02 | 41° 39' 34.12" N | 83° 47' 51.37" W |
| Langenderfer 01 | 41° 39' 28.96" N | 83° 48' 08.86" W |
| Langenderfer 02 | 41° 39' 28.96" N | 83° 48' 01.03" W |

*Classification of Morphology*.

Twelve stream segments were classified in two habitat categories, i.e., morphologically heterogeneous and homogeneous segments. We quantified the amount of horizontal heterogeneity by measuring the bank-to-bank width of the channel in two-meter increments over the course of the twenty meters in each segment during base flow conditions. We then calculated the coefficient of variation for the eleven measurements to characterize the variation in stream widths at the surface along the stream segment. This measure of relative variability was used to quantify the degree of homogeneity of the width of the channel in each segment; higher values for coefficient of variation represented lower homogeneity.

**Figure 2.2 –** Pictorial representations of horizontal habitat profiles.



**Potentially Heterogeneous** **Potentially Homogeneous**

To describe the uniformity or lack of uniformity in the vertical profile, we quantified the amount of vertical heterogeneity by taking three evenly spaced depth measurements from bank to bank in four-meter intervals along the twenty-meter segments. The coefficient of variation was calculated among the three samples in the cross section and averaged for the entire 20-meter stream segment. Increasing values for the coefficient of variation again would represent lower homogeneity. Once classified, we will refer to sites as either heterogeneous (Ht) or homogeneous (Ho). All sites are part of a design wherein the Ht site is upstream and adjacent to the Ho site by no more than 150 meters distance, with most pairs within 50 meters of one another. This design allowed me to sample by moving upstream, leaving each new site undisturbed, from the farthest downstream site toward the farthest upstream site.

*Site Descriptions.*
The stream sediment texture was similar within and among sites (Table 2.2). We made field observations by sight and hand grabs, and listed substrates under qualitative categories of gravel, sand, clay and silt. At each site, we also characterized the submergent vegetation within the channel of the sample segment and emergent vegetation on the banks adjacent to the sample segment (Table 2.2). The dominant bank-line plant was reed canary grass, *Phalaris arundinacea*, an exotic plant colonizing wet areas commonly found surrounding agriculture, interspersed with a mix of native plants occurring with minimal frequency, such as arrowhead (*Sagittaria latifolia*), sneezeweed (*Helenium autumnale*), devil's beggar tick (*Bidens frondosa*), and blue lobelia (*Lobelia syphilitica*). In sample sites where submergent vegetation was found, the commonly seen species were small patches of *Elodea canadensis*, *Rotala* sp., and *Eleochris acicularis*. Many sites also had seasonally variable, thick patches

**Table 2.2** - Substrate and vegetation characterizations of sample segments in the Ottawa River watershed, northwest Ohio.

| Site Name | Substrate Characterization | Vegetation Characterization |
|---|---|---|
| Tenmile 01 | Clay, gravel, silt | Some submergent vegetation; Bordered by *Phalaris arundinacea.*, some *Solidago* sp. present. |
| Tenmile 02 | Clay, silt | Some submergent vegetation; Bordered by *Phalaris arundinacea.* |
| Tenmile 03 | Clay, gravel, silt | Some submergent vegetation; Bordered by *Phalaris arundinacea*, some *Solidago* sp. present. |
| Tenmile 04 | Clay, silt | Bordered by *Phalaris arundinacea.* |
| Tenmile 05 | Clay, gravel, silt | Some submergent vegetation; Bordered by *Phalaris arundinacea.* |
| Tenmile 06 | Clay, gravel | Some submergent vegetation; Bordered by *Phalaris arundinacea.* |
| Eickholt 01 | Clay, silt | Bordered by *Phalaris arundinacea* and some native forbs. |
| Eickholt 02 | Silt, clay | Bordered by *Phalaris arundinacea* and some native forbs. |
| Prairie 01 | Silt, sand, clay | Bordered by *Phalaris arundinacea* and instream cover dominated by *Cladophora* sp.. |
| Prairie 02 | Silt, sand, clay | Bordered by *Phalaris arundinacea* and instream cover dominated by *Cladophora* sp.. |
| Langenderfer 01 | Clay, sand | Bordered by *Phalaris arundinacea* and instream cover dominated by *Cladophora* sp.. |
| Langenderfer 02 | Clay, silt, sand | Bordered by *Phalaris arundinacea* and instream cover dominated by *Cladophora* sp.. |

of *Cladophora* sp. algae. The patch presence and densities corresponded to pulses of rainwater, and were assumed to develop from fertilizer inputs from the adjacent agriculture washing off in the subsurface drainage. During peak times for the development of *Cladophora* sp., the colonies were the dominant in-stream cover.

*Environmental Data.*

Environmental data were recorded during each sample event at the upper most portion of the stream segment after the fish sampling had been completed. These data were collected to assure similarity of environmental conditions among the Ht and Ho sites during a sample event. Variables for water temperature, pH, dissolved oxygen and conductivity were measured using the PASCO Passport Explorer PS-2000 multi-metric meter. Dissolved oxygen was only measured intermittently due to problems maintaining the probe in a calibrated state while in the field. Turbidity was measured using a modified Secchi disk application from a "Year of Clean Water 2002" Water Quality Monitoring kit, similar to the LaMotte “Earth Force Elementary Education Watershed Field Trip Kit” #5906. The Secchi was focused on the bottom of a 12.5 cm x 8 cm white cup that gave general characterization of the clarity of the water using a relative scale from 0 to 100 in 20-unit increments. Canopy cover was recorded for each site using a Forest Densiometer Spherical Model-A convex crown densiometer. Discharge was estimated by measuring the cross-section of the channel (in $m^2$) and the flow of the water (in m/sec) using a neutrally buoyant object. Multiplying both measurements yielded water discharge (in $m^3$/sec).

*Sampling Protocol.*

Each site was sampled by seining using two 3.7 meter seines with 6 millimeter mesh, one placed stationary as a blockade at the downstream end of the sample, and one moving from upstream down into and toward the stationary seine, with a 90 degree pivot turn with the downstream brail through the stationary seine to shore. The stationary seine was then turned on a 90-degree pivot rotation back through the sample area to capture any fish missed by the sweep seine. All fish were then identified to species in the field in accordance with identification characteristics in *Fishes of Ohio* (Trautman, 1981), aged into common size-age classes (adult, sub-adult, juvenile), assessed for spawning condition, and released downstream of a newly placed blockade upstream in the same sample site (*See Appendix 1*). The procedure was replicated in the upstream portion of the sample site to promote accurate sampling of the entire stretch, as a single sweep over the full 20-meter distance lent itself to problems with the seine, leading to escaped fish and error.

*Data Analysis.*

We used a simple t-test to compare the means of the coefficient of variation in the measurements of horizontal and vertical heterogeneity. Dependent variables calculated for each site during individual sampling events included species richness, abundance per species, the number of trophic guilds present, the Shannon Diversity Index (H’), and an Index of Biological Integrity. The Shannon Diversity Index was calculated according to:

$$H' = - \sum(p_i) * \ln(p_i)$$

Where $p_i$ represents the importance value for species *i*. Trophic guilds and the Index of Biological Integrity were calculated according to the Ohio Environmental Protection Agency's "Biological Criteria for the Protection of Aquatic Life" (Ohio Environmental Protection Agency, 1988, 2006).

From the site data for each sampling event, overall means and standard deviations of richness, abundance, number of trophic guilds, Shannon Diversity Index, and Index of Biologic Integrity were calculated with the data categorized by habitat type, Ht and Ho. We also calculated a modified Sorensen's Similarity Index for the entirety of the sample, again categorized by habitat type. Sorensen's Similarity Index was calculated as:

$$S = 1 - \sum |n_{i,Ht} - n_{i,Ho}| \div (N_{Ht} + N_{Ho})$$

Where $n_{i,Ht}$ and $n_{i,Ho}$ represent the number of the individuals for species *i* in the samples from Ht and Ho habitats, and $N_{Ht}$ and $N_{Ho}$ are the total number of fish from either habitat.

The means and standard error of richness, abundance, number of trophic guilds, Shannon Diversity Index, and Index of Biologic Integrity for each sample event were calculated over time for each habitat type. We used repeated measures ANOVA to test for significant differences in richness, trophic guilds, Shannon Diversity Index, and Index of Biologic Integrity calculated for Ht and Ho. We chose the repeated measures ANOVA as our statistical test because we took repeated measurements from the same sites. Such a design violates the assumption of the standard ANOVA that each observation is independent. Because the time interval between repeated measures in each site was relatively long (a minimum of four weeks), and because our fish sampling technique was non-destructive, the effect of dependency among measurements was minimized. We also calculated mean overall abundance for the Ht and Ho sites, and the mean Sorensen's Similarity Index.

*Reference Reach IBI.*
A reference reach Index of Biological Integrity was performed, comparing our stream stretch against existing EPA survey methods and standards, which determined how the Ottawa headwaters compared against streams statewide. We chose to run the IBI on the segment beginning at the head of Tenmile 04 Ho and ran continual blockade seine sweeps (as described in our sampling protocol earlier), advancing upstream as it went, and storing the catch in a floating "live well" made of 4" schedule 20 PVC wrapped in sewn-together panels of window screen, and permanently strapped using zip-ties. We stopped at the 105-meter mark, just short of Tenmile 03 Ht. The habitats within this segment were a mixture of Ht and Ho habitats, with canopy cover 0% on the upstream end, 100% on the downstream end, with half the segment predominantly open, and the other half predominantly shaded.

## Results & Discussion

*Classification of Habitats*
The difference in mean coefficient of variation (CV) grouped by "heterogeneous" or "homogeneous" was found to be highly significant (mean C.V. for Ht = 0.22; mean C.V. for Ho = 0.08; $p < 0.001$) using a simple t-test. Values for the various sites are found in Table 3.1.

**Table 3.1a** - Calculation of horizontal heterogeneity for Heterogeneous (Ht) sites using eleven bank-to-bank measurements to calculate the mean width, standard deviation and coefficient of variation of sample sites in the Ottawa River, northwest Ohio.

| Site Name | Mean Width (cm) | Standard Deviation (cm) | Coefficient of Variation |
|---|---|---|---|
| Tenmile 01 | 232.1 | 46.6 | 0.20 |
| Tenmile 03 | 229.1 | 51.1 | 0.22 |
| Tenmile 05 | 234.5 | 43.4 | 0.19 |
| Eickholt 01 | 151.5 | 54.7 | 0.36 |
| Prairie 01 | 251.2 | 42.6 | 0.17 |
| Langenderfer 01 | 168.7 | 27.5 | 0.16 |

**Table 3.1b** - Calculation of horizontal heterogeneity for Homogeneous (Ho) sites using eleven bank-to-bank measurements to calculate the mean width, standard deviation and coefficient of variation for sample sites in the Ottawa River, northwest Ohio.

| Site Name | Mean Width (cm) | Standard Deviation (cm) | Coefficient of Variation |
|---|---|---|---|
| Tenmile 02 | 280.8 | 18.1 | 0.06 |
| Tenmile 04 | 382.7 | 13.5 | 0.04 |
| Tenmile 06 | 299.7 | 23.2 | 0.08 |
| Eickholt 02 | 130.5 | 20.4 | 0.16 |
| Prairie 02 | 303.1 | 18.2 | 0.06 |
| Langenderfer 02 | 273.8 | 21.5 | 0.08 |

We found no significant difference in comparing the mean coefficient of variation (CV) of cross-sectional stream measurements between heterogeneous and homogeneous sites (mean C.V. for Ht = 0.18; mean C.V. for Ho = 0.16; $p = 0.23$). We also found that the Ht sites were not significantly deeper than Ho sites ($p = 0.20$). Values for the various sites are found in Table 3.2. This is not to say that the two habitat types are no different in their vertical profiles. Visually, the two habitat types are as different in this profile as they are along the horizontal plane, as heterogeneous segments have riffle, run and pool features that undulate the depth across the profile vs. homogeneous segments that are consistently trapezoidal. We feel the method we used to measure and quantify this visual difference was merely too coarse, and this morphological difference would be significant with a greater number of depth measurements than we used.

**Table 3.2a** - Calculations of vertical heterogeneity for Heterogeneous (Ht) segments using three cross section depth measurements along six transects to calculate the mean depth and coefficient of variation for sample sites in the Ottawa River, northwest Ohio.

| Site Name | Mean Depth (cm) | Coefficient of Variation |
|---|---|---|
| Tenmile 01 | 26.3 | 0.13 |
| Tenmile 03 | 22.4 | 0.31 |
| Tenmile 05 | 22.0 | 0.11 |
| Eickholt 01 | * | * |
| Prairie 01 | 39.3 | 0.10 |
| Langenderfer 01 | 26.3 | 0.26 |

* Result omitted due to change in elevation from toe stone insertion (see text for explanation).

**Table 3.2b** - Calculation of vertical heterogeneity for Homogeneous (Ho) segments using three cross section depth measurements along six transects to calculate the mean depth and coefficient of variation for sample sites in the Ottawa River, northwest Ohio.

| Site Name | Mean Depth (cm) | Coefficient of Variation |
|---|---|---|
| Tenmile 02 | 21.2 | 0.12 |
| Tenmile 04 | 15.2 | 0.26 |
| Tenmile 06 | 18.9 | 0.12 |
| Eickholt 02 | * | * |
| Prairie 02 | 27.7 | 0.11 |
| Langenderfer 02 | 27.0 | 0.21 |

* Result omitted due to change in elevation from toe stone insertion (see text for explanation).

Both Eickholt segments were omitted from the calculation of vertical heterogeneity. The stream characteristics of both sites were severely altered by the placement of gravel in the downstream portion of the Eickholt ditch during the July 2006 sample near the end of our study to improve the stream crossing for farm equipment. This changed Eickholt ditch into a pool that had an elevation greater than Eickholt 01, inundating both Eickholt sites. Our depth survey for all sites occurred in August 2006 after the gravel had been added, consequently depth measurements at Eickholt sites would be meaningless for this analysis. For the same reason, fish catch records from the August and September 2006 samples were omitted from the data.

*Environmental Data*

Means of environmental data recorded per habitat type showed no significant difference between the two types of habitat during each sample event (Table 3.3). The September 2005 pH difference was of note in that this was the sample with quickly drying pools, and the high pH value of the Ho sites was assumed to be due to the intense photosynthesis by *Cladophora* sp. algae. While the dissolved oxygen was not measured, it was assumed that the oxygen saturation in this situation would be in proportion to the oxygen deprivation that would typically occur at night once photosynthesis had ceased.

Percentage canopy cover was recorded during the growing season for peak canopy density using a crown densiometer. Most sites lacked canopy cover. Three Ho sites, however, did have some vegetative canopy cover, providing some shade for a portion of the day (Tenmile 02 Ho – 7.5%, Tenmile 04 Ho – 68.5%, and Eickholt 02 Ho – 49.0%). Typically, canopy cover is found to benefit the fish community, because it stabilizes bank structure, lowers erosion and maintains cooler water temperatures (Jones *et al.*, 1999). However, in our sites, the canopy cover is surmised to prevent colonization of herbaceous vegetation in the channel. This is one of the factors leaving the channel in an early state of geomorphological development, which we characterized as Ho.

Typically, in forested riparian zones, the prominence of woody debris in the stream would alter homogenous channel morphology. However, in these agricultural ditches, what little debris was found was typically removed by the landowner prior to development of any stabilized geomorphological features, masking any physical benefit canopy might have for the fish community composition and structure. In the case of our sample segments, the woody corridor was a single tree wide and composed of young trees, which did not create enough of an effect to cool the water. As well, the corridor was too narrow to stop sediment inputs from surface erosion, and was completely bypassed by sediment entering the channel through any subsurface drainage.

*Fish Community*

A total of 10,501 fish representing 24 species were captured, identified and released unharmed in our eleven sample events. The samples (summarized in Table 3.4) were dominated by two cyprinid species, the fathead minnow (*Pimephales promelas*) and the bluntnose minnow (*P. notatus*), representing 50.3% of the total catch (25.6% and 24.8% respectively). Both species are listed as highly tolerant, pioneering (Ohio Environmental Protection Agency, 1988) and are described as two of the most tolerant species of habitat degradation in Ohio (Trautman, 1981). A species of darter, the least darter (*Etheostoma microperca*), was also prevalent in the catch at 14.6%. The least darter presence was of note, and will be addressed separately further in the discussion of the results.

These three species will now be referred to as the "Alpha Group". A second group of species, the "Beta Group", consisted of the central stoneroller minnow (*Campostoma anomalum*) with 8.3%, johnny darter (*E. nigrum*) with 6.5%, orangethroat darter (*E. spectabile*) with 5.1%, creek chub (*Semotilus atromaculatus*) with 4.5%, and striped shiner (*Luxilus chrysocephalus*) with 4.4%. This group of species may be considered the secondary

**Table 3.3 –** Average temperature, pH, dissolved oxygen, conductivity, turbidity and discharge measurements recorded for all Ht and Ho segment classifications at each sample event from the Ottawa River, northwest Ohio, during eleven sample events. An "x" value indicates no measurements recorded for a sample event due to equipment failure. P values at the 95% confidence interval using a paired t-test listed in the right column. Error reported in standard deviation.

| | Sample Date | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 06/05 | 8/05 | 9/05 | 10/05 | 12/05 | 3/06 | 4/06 | 6/06 | 7/06 | 8/06 | 9/06 | p Value |
| Temperature (°C) | | | | | | | | | | | | |
| Ht | 25.6 ± 1.1 | 26.9 ± 3.5 | 23.8 ± 4.1 | 15.6 ± 1.0 | 1.4 ± 0.2 | 3.9 ± 1.7 | 16.1 ± 3.1 | 20.0 ± 2.2 | 25.4 ± 2.6 | 23.4 ± 1.2 | 16.6 ± 1.5 | 0.910 |
| Ho | 24.7 ± 1.3 | 28.7 ± 4.4 | 26.9 ± 2.8 | 16.1 ± 1.3 | 1.0 ± 0.2 | 3.7 ± 1.6 | 15.0 ± 3.2 | 19.3 ± 2.1 | 24.6 ± 2.4 | 23.3 ± 1.3 | 15.9 ± 1.1 | |
| pH | | | | | | | | | | | | |
| Ht | 7.8 ± 0.2 | 8.3 ± 0.4 | 8.6 ± 0.4 | 8.0 ± 0.4 | 8.0 ± 0.2 | 7.8 ± 0.3 | 8.4 ± 0.1 | 8.3 ± 0.3 | 8.0 ± 0.2 | 8.0 ± 0.1 | 8.1 ± 0.2 | 0.206 |
| Ho | 7.7 ± 0.3 | 8.3 ± 0.6 | 9.4 ± 0.5 | 8.1 ± 0.3 | 8.2 ± 0.2 | 7.8 ± 0.3 | 8.4 ± 0.1 | 8.3 ± 0.3 | 8.1 ± 0.2 | 8.0 ± 0.1 | 8.1 ± 0.2 | |
| Dissolved Oxygen (mg/L) | | | | | | | | | | | | |
| Ht | 8.2 ± 2.4 | x | 10.6 ± 4.7 | x | x | x | x | 6.2 ± 0.2 | 5.1 ± 0.4 | x | x | 0.378 |
| Ho | 7.0 ± 1.1 | x | 11.8 ± 4.4 | x | x | x | x | 5.9 ± 0.2 | 5.1 ± 0.7 | x | x | |
| Conductivity (mS $cm^{-1}$) | | | | | | | | | | | | |
| Ht | 894 ± 357 | 1045 ± 371 | 1158 ± 453 | 1162 ± 176 | 684 ± 146 | 636 ± 71 | 1090 ± 1100 | 676 ± 79 | 836 ± 98 | 783 ± 171 | 871 ± 73 | 0.811 |
| Ho | 917 ± 568 | 1122 ± 402 | 1320 ± 814 | 1001 ± 157 | 673 ± 147 | 599 ± 38 | 1054 ± 993 | 658 ± 112 | 842 ± 66 | 859 ± 256 | 857 ± 97 | |
| Turbidity (JTU) | | | | | | | | | | | | |
| Ht | 50 ± 17 | 21 ± 21 | 72 ± 67 | 68 ± 74 | 53 ± 42 | 60 ± 18 | 48 ± 18 | 27 ± 10 | 68 ± 41 | 127 ± 89 | 70 ± 33 | 0.848 |
| Ho | 50 ± 17 | 19 ± 19 | 37 ± 38 | 52 ± 38 | 67 ± 46 | 60 ± 32 | 60 ± 34 | 30 ± 17 | 75 ± 43 | 132 ± 88 | 73 ± 37 | |
| Discharge ($m^3$ / sec) | | | | | | | | | | | | |
| Ht | 0.03 ± 0.01 | No Flow | No Flow | No Flow | 0.13 ± 0.06 | 0.16 ± 0.06 | 0.09 ± 0.06 | 0.11 ± 0.08 | 0.08 ± 0.01 | 0.03 ± 0.01 | 0.04 ± 0.02 | 0.108 |
| Ho | 0.02 ± 0.01 | No Flow | No Flow | No Flow | 0.14 ± 0.01 | 0.12 ± 0.06 | 0.06 ± 0.03 | 0.10 ± 0.04 | 0.07 ± 0.01 | 0.02 ± 0.01 | 0.05 ± 0.03 | |

diversity in this system. A third group of species, the "Gamma Group" comprised species making less than 1.6% of the total catch, that were found in both habitats at two or more sample events and represent the rare, yet present, species in this system. This group included the yellow bullhead (*Ameiurus natalis*), white sucker (*Campostoma commersoni*), redfin shiner (*Lythrurus umbratilis*), green sunfish (*Lepomis cyanellus*), bluegill sunfish (*L. macrochirus*), grass pickerel (*Esox a. vermiculatus*), common goldfish (*Carassius auratus*), largemouth bass (*Micropterus salmoides*), and central mudminnow (*Umbra limi*).

Interestingly, three exotic species made up very little of the catch (66 individuals, or 0.6% of the total). The common goldfish (*Carassius auratus*), common carp (*Cyprinus carpio*), and mosquitofish (*Gambusia affinis*), the only exotics occurring in our samples, could be considered as rare in this part of the system. Further analysis revealed 54 of the exotic individuals were caught in Ht sites, giving Ht sites a higher percentage of exotics than Ho sites (0.5% Ht vs. 0.1% Ho of the total catch). However, the relative rarity of the exotic individuals was remarkable, considering the prevalence of exotics in other regional aquatic systems.

Contrasts between habitats emerged from the raw total catch numbers and percentages of total catch (Table 3.4). First, six species (in italics) were found in the Ht segments, but were absent from Ho segments. These species were poorly represented in the overall sample, represented by only 45 individuals, 0.4% of the total catch, or 0.6% of the total Ht catch. Although uncommon, the presence of these species was worth noting. Three of these species, the common carp, pumpkinseed sunfish (*Lepomis gibbosus*), and yellow perch (*Perca flavescens*), occurred during the July and August 2006 samples (Table 3.5), assumed to be the result of a flood pulse in July 2006 that will be discussed in detail later. The remaining three species, the golden shiner (*Notemigonus crysoleucas*), blackside darter (*Percina maculata*), and black bullhead (*Ameiurus melas*), appeared in the spring months with the exception of three golden shiner individuals caught in the September 2006 sample. This suggested, at least in the case of blackside darter and black bullhead, that these individuals were looking for appropriate spawning habitat, consistent with their life history patterns (Trautman, 1981), that were possibly found only in Ht habitats.

Further analysis of the Alpha Group by habitat type (Table 3.4) revealed additional differences. Mean abundances of fathead and bluntnose minnows in Ht segments were nearly double the number found in Ho segments. This is interesting, as the importance values were nearly the same for these two species (24.9% and 24.6% of the total Ht catch, respectively), compared to the Ho catch, (27.0% and 25.3% of the total Ho catch, respectively) (Tables 3.5 and 3.6). As well, the least darter had a larger mean abundance by nearly a factor of three (103 average individuals per sample event in Ht sites vs. 37 average individuals per sample event in Ho sites), but was also a similar percentage of the Ht catch (16.0%), compared to the percentage of the Ho catch (11.8%).

**Table 3.4** – Summary of total catch by habitat type, mean catch per sample event, and of the overall catch from the Ottawa River, northwest Ohio, during eleven sample events. Species present in Ht sites but absent from Ho sites in italics.

| | Total Catch Ht Sites | Mean catch per Event in Ht | Total Catch Ho Sites | Mean Catch per Event in Ho | % Total Catch Ht Sites | % Total Catch Ho Sites | Total Catch | % Total Catch |
|---|---|---|---|---|---|---|---|---|
| Fathead minnow | 1757 | 160 | 927 | 84 | 16.7 | 8.8 | 2684 | 25.6 |
| Bluntnose minnow | 1736 | 158 | 867 | 79 | 16.5 | 8.3 | 2603 | 24.8 |
| Least darter | 1133 | 103 | 405 | 37 | 10.8 | 3.9 | 1538 | 14.6 |
| Stoneroller | 551 | 50 | 318 | 29 | 5.2 | 3.0 | 869 | 8.3 |
| Johnny darter | 423 | 39 | 259 | 24 | 4.0 | 2.5 | 682 | 6.5 |
| Creek chub | 350 | 32 | 121 | 11 | 3.3 | 1.2 | 471 | 4.5 |
| Orangethroat darter | 325 | 30 | 169 | 15 | 3.1 | 1.6 | 494 | 4.7 |
| Striped shiner | 250 | 23 | 208 | 19 | 2.4 | 2.0 | 458 | 4.4 |
| Yellow bullhead | 120 | 11 | 43 | 4 | 1.1 | 0.4 | 163 | 1.6 |
| White sucker | 93 | 8 | 9 | < 1 | 0.9 | 0.1 | 102 | 1.0 |
| Redfin shiner | 76 | 7 | 24 | 2 | 0.7 | 0.2 | 100 | 1.0 |
| Green sunfish | 50 | 5 | 16 | 1 | 0.5 | 0.2 | 66 | 0.6 |
| Bluegill sunfish | 48 | 4 | 18 | 2 | 0.5 | 0.2 | 66 | 0.6 |
| Grass pickerel | 39 | 4 | 6 | < 1 | 0.4 | 0.1 | 45 | 0.4 |
| Common goldfish | 31 | 3 | 7 | < 1 | 0.3 | 0.1 | 38 | 0.4 |
| Largemouth bass | 22 | 2 | 12 | 1 | 0.2 | 0.1 | 34 | 0.3 |
| *Common carp* | 20 | 2 | 0 | 0 | 0.2 | 0.0 | 20 | 0.2 |
| Central Mudminnow | 17 | 2 | 18 | 2 | 0.2 | 0.2 | 35 | 0.3 |
| *Golden shiner* | 10 | < 1 | 0 | 0 | 0.1 | 0.0 | 10 | 0.1 |
| *Pumpkinseed sunfish* | 9 | < 1 | 0 | 0 | 0.1 | 0.0 | 9 | 0.1 |
| *Blackside darter* | 4 | < 1 | 0 | 0 | < 0.1 | 0.0 | 4 | < 0.1 |
| Mosquitofish | 3 | < 1 | 5 | < 1 | < 0.1 | < 0.1 | 8 | 0.1 |
| *Black bullhead* | 1 | < 1 | 0 | 0 | < 0.1 | 0.0 | 1 | < 0.1 |
| *Yellow perch* | 1 | < 1 | 0 | 0 | < 0.1 | 0.0 | 1 | < 0.1 |
| **Total:** | **7069** | | **3432** | | | | **10,501** | |

In fact, the mean number of individuals per sample event was higher for all species in Ht segments than Ho segments, and by a factor of two or greater for most species. The exception was the striped shiner (23 average individuals per sample event in Ht sites vs. 19 average individuals per sample event in Ho sites). This can be explained by life history, as the species is an opportunistic insectivorous feeder, preying on insect families that are allochthonous material to the system (Becker, 1983) and would have little dependence on the in-stream habitats for their food items.

However, despite these differences, the overall mean abundance was not significantly different ($p = 0.074$) in the repeated measures ANOVA analysis at the 0.05 $\alpha$ level (Table 3.7). This may be accounted for by the high variability in abundance over time within each habitat category over the course of the sampling, which may have been related to the widely varying amounts of water found in the system over the two seasons. On the other hand, richness, number of trophic guilds and SDI were significantly greater ($p = 0.029$, $p = 0.008$, $p = 0.028$ respectively) in Ht segments than Ho segments (Table 3.7). Even in a pair-wise comparison of these metrics per sample event, Ht segment means scored higher than Ho segments, with few outliers to this trend. Perhaps most striking was the highly significant difference in the trophic guild scores, as the number of trophic guilds is descriptive of how the fish community functions and uses resources. This was further reinforced by the significant difference in the Shannon Diversity Index, accounting for the evenness and richness of species, and thus removing the weight of species such as the *Pimephales* minnows. In the case of our sample, the significantly greater richness seemed more the factor driving the significantly greater SDI scores, while the overall low SDI scores are indicative of the unevenness in the species abundance values.

The qualitative metric that did not demonstrate a significant difference between habitats was the mean Index of Biological Integrity (IBI) (Table 3.7). Even though the Ht segments appeared to score higher than the Ho segments (means were $21.8 \pm 0.1$ vs. $21.2 \pm 0.2$), this difference was not found to be significant (repeated measures ANOVA, $p = 0.60$). Both mean IBI scores are listed as “poor” in the Revised 2006 Ohio IBI scoring for Huron Erie Lake Plain headwaters (Ohio Environmental Protection Agency, 2006). However, the mean values for each sample and habitat type were low in comparison to the reference IBI taken between Tenmile 03 Ht and Tenmile 04 Ho in October 2006. This will be discussed in a later section reviewing a reference reach IBI sample. In a pair-wise comparison over time, we noted some variance between the high and low scores in the “poor” rating. The July and August 2006 IBI values approached a “fair” rating, which were the highest of the sample period.

The “poor” rating is described as indicating “poor conditions due to extensive and severe impacts from WWTP, industrial sources, CSOs, urban development, low D.O., riparian & instream habitat degradation; recovery from these impacts has been minimal; some problems have worsened” (Yoder and Smith, 1999, Fig 2.5). “Fair” is described as “Few sites attain

**Table 3.5 –** Total catches in Ht segments by date from the Ottawa River, northwest Ohio, during eleven sample events. Samples for 8/06 and 9/06 are without catch information from Eickholt 01 and 02 segments due to change in pool depth with tractor crossing improvement. Species present in Ht segments but absent from Ho segments listed in italics.

| | **Sample Date** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6/05 | 8/05 | 9/05 | 10/05 | 12/05 | 3/06 | 4/06 | 6/06 | 7/06 | 8/06 | 9/06 | Total | **% Ht** |
| Fathead minnow | 138 | 25 | 88 | 99 | 17 | 34 | 242 | 243 | 104 | 267 | 500 | 1757 | **24.9** |
| Bluntnose minnow | 90 | 90 | 303 | 150 | 78 | 50 | 100 | 160 | 93 | 177 | 445 | 1736 | **24.6** |
| Least darter | 158 | 68 | 125 | 88 | 32 | 39 | 66 | 61 | 108 | 157 | 231 | 1133 | **16.0** |
| Stoneroller | 2 | 4 | 17 | 3 | 52 | 13 | 28 | 58 | 142 | 81 | 151 | 551 | **7.8** |
| Johnny darter | 9 | 23 | 7 | | 2 | 6 | 12 | 9 | 39 | 134 | 182 | 423 | **6.0** |
| Creek chub | 15 | 47 | 55 | 12 | 6 | 5 | 25 | 13 | 20 | 85 | 67 | 350 | **5.0** |
| Orangethroat darter | 44 | 14 | | 2 | 1 | 9 | 10 | 5 | 21 | 87 | 132 | 325 | **4.6** |
| Striped shiner | 1 | 1 | 2 | 10 | 15 | 13 | 16 | 61 | 55 | 38 | 38 | 250 | **3.5** |
| Yellow bullhead | | | | | | | | 1 | 14 | 74 | 31 | 120 | **1.7** |
| White sucker | 2 | 1 | | 1 | 1 | 1 | 1 | 1 | 15 | 39 | 31 | 93 | **1.3** |
| Redfin shiner | 1 | 8 | 3 | | 2 | | | 19 | | 30 | 13 | 76 | **1.1** |
| Green sunfish | 1 | 3 | 14 | 1 | | | 1 | 3 | 7 | 14 | 6 | 50 | **0.7** |
| Bluegill sunfish | | | | | | | | 2 | 2 | 40 | 4 | 48 | **0.7** |
| Grass pickerel | | | | | | | 1 | 5 | 16 | 15 | 2 | 39 | **0.6** |
| Common goldfish | | 1 | 2 | | | | 1 | | 14 | 6 | 7 | 31 | **0.4** |
| Largemouth bass | | 1 | | | | | | | | 18 | 3 | 22 | **0.3** |
| *Common carp* | | | | | | | | | | 20 | | 20 | **0.3** |
| Central Mudminnow | 1 | | | | | | 1 | 10 | 5 | | | 17 | **0.2** |
| *Golden shiner* | 5 | 2 | | | | | | | | | 3 | 10 | **0.1** |
| *Pumpkinseed sunfish* | | | | | | | | | 3 | 6 | | 9 | **0.1** |
| *Blackside darter* | 1 | | | | | | 3 | | | | | 4 | **0.1** |
| Mosquitofish | | | | 1 | | | | | | 2 | | 3 | < **0.1** |
| *Black bullhead* | | | | | | | 1 | | | | | 1 | < **0.1** |
| *Yellow perch* | | | | | | | | | | 1 | | 1 | < **0.1** |
| | | | | | | | | | | | **Total:** | **7069** | |

**Table 3.6 –** Total catches in Ho segments by date from the Ottawa River, northwest Ohio, during eleven sample events. Samples for 8/06 and 9/06 are without catch information from Eickholt 01 and 02 segments due to change in pool depth with tractor crossing improvement.

| | Sample Date | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6/05 | 8/05 | 9/05 | 10/05 | 12/05 | 3/06 | 4/06 | 6/06 | 7/06 | 8/06 | 9/06 | Total | **%Ho** |
| Fathead minnow | 28 | 25 | 5 | 2 | 11 | 10 | 50 | 307 | 102 | 202 | 185 | 927 | **27.0** |
| Bluntnose minnow | 65 | 206 | 45 | 20 | 32 | 12 | 21 | 131 | 66 | 151 | 118 | 867 | **25.3** |
| Least darter | 6 | 25 | 39 | 92 | 19 | 10 | 39 | 55 | 33 | 47 | 40 | 405 | **11.8** |
| Stoneroller minnow | | 1 | | | 4 | 3 | 3 | 66 | 111 | 78 | 52 | 318 | **9.3** |
| Johnny darter | 45 | 49 | 9 | 2 | 5 | 5 | 8 | 20 | 37 | 45 | 34 | 259 | **7.5** |
| Striped shiner | | 34 | 2 | 3 | 1 | | 6 | 33 | 33 | 48 | 48 | 208 | **6.1** |
| Orangethroat darter | 12 | 5 | | 6 | 1 | | 2 | 2 | 21 | 75 | 45 | 169 | **4.9** |
| Creek chub | 3 | 22 | | | 1 | | 1 | 6 | 10 | 41 | 37 | 121 | **3.5** |
| Yellow bullhead | | | | | | | | | 31 | 4 | 8 | 43 | **1.3** |
| Redfin shiner | 1 | 9 | | | 1 | | | 1 | | 6 | 6 | 24 | **0.7** |
| Central mudminnow | | | | | | | | 14 | 2 | 1 | 1 | 18 | **0.5** |
| Bluegill sunfish | | | | | | | | | 5 | 11 | 2 | 18 | **0.5** |
| Green sunfish | | 8 | | | | | 1 | 2 | 1 | | 4 | 16 | **0.5** |
| Largemouth bass | | | | | | | | | 5 | 7 | | 12 | **0.3** |
| White sucker | 2 | | | | | | | 6 | 1 | | | 9 | **0.3** |
| Common goldfish | | 1 | | | | | 1 | | 5 | | | 7 | **0.2** |
| Grass pickerel | | | | | | | | 3 | 3 | | | 6 | **0.2** |
| Mosquitofish | | | | | | | | | | | 5 | 5 | **0.1** |
| | | | | | | | | | | | **Total:** | **3432** | |

Warm Water Habitat criteria due to subbasin-wide riparian and instream habitat degradation, agricultural NPS, WWTP discharge, small industries, and/or acid mine drainage; some are in various stages of incomplete recovery from point source impacts" (*ibid.*).

While we expected to see a significant difference in the IBI scores between our habitat types, we find the similar IBI scores between habitats consistent with the purpose of the index, namely to compare a modified stream to an unmodified stream and detect gradations between these definitions. In essence, the IBI succeeds in comparing the fish community and structure of the upper Ottawa River watershed against streams statewide in a qualitative manner as it was designed to do. It fails, however, to see a difference between these two habitats in a dramatically modified warm-water stream where geomorphology is initially developing.

Sorensen's Similarity Index ranged from 0.27 in September of 2005 to more than 0.80 in June and July of 2006 (Figure 3.1) with an average score 0.54 and a standard deviation of ± 0.2. The relatively high standard deviation was due to the low values of the August and September 2005 samples, where the stream was rapidly condensing into a series of pools, and the high values for June, July and August 2006, that were taken immediately following peak pulse periods in the system. It is interesting to note that increased depth during the pulses would act as a "homogenizer" for the habitat classifications within the system, as the pulse would mask the primary channel and force fishes into other habitats to escape the heaviest flows. Similarly, scurrying for habitat at the stream's lowest, yet still-connected point in August 2005 may also appear as a "homogenizer" for the habitat classifications. It is also interesting to note that the two *least* similar samples occurred after these disturbances in September 2005 (dry) and September 2006 (wet).

**Figure 3.1** – Sorensen's Similarity Index comparing two habitat types (Ht and Ho) for eleven samples in the headwaters of the Ottawa River, northwest Ohio.

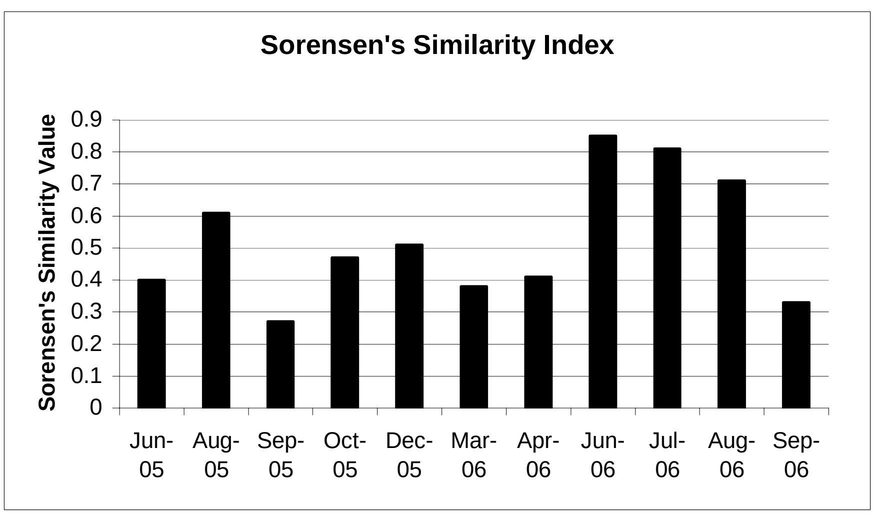


**Table 3.7** – Average richness, abundance, Shannon Diversity Index (SDI), number of trophic guilds, Index of Biological Integrity (IBI) and Sorensen's Similarity Index from the Ottawa River, northwest Ohio in eleven sample events.

| | Sample Date | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6/05 | 8/05 | 9/05 | 10/05 | 12/05 | 3/06 | 4/06 | 6/06 | 7/06 | 8/06 | 9/06 | Mean | Standard Error | p Value |
| **Richness** | | | | | | | | | | | | | | |
| Ht | 5.5 | 6.3 | 5.0 | 4.3 | 4.0 | 4.3 | 6.8 | 7.0 | 9.8 | 10.8 | 9.2 | **6.6** | **0.71** | **0.029** |
| Ho | 2.8 | 5.2 | 1.3 | 2.2 | 3.0 | 2.2 | 3.5 | 5.3 | 8.7 | 6.2 | 6.8 | **4.3** | **0.70** | |
| **Abundance** | | | | | | | | | | | | | | |
| Ht | 78.0 | 48.0 | 99.0 | 61.5 | 34.3 | 28.3 | 84.8 | 108.8 | 135.2 | 262.8 | 376.0 | **119.7** | **32.2** | **0.074** |
| Ho | 27.0 | 64.0 | 16.7 | 20.8 | 12.7 | 5.7 | 22.0 | 105.8 | 94.3 | 141.0 | 78.8 | **53.5** | **13.8** | |
| **SDI** | | | | | | | | | | | | | | |
| Ht | 1.04 | 1.26 | 1.16 | 0.92 | 0.81 | 1.03 | 1.47 | 1.54 | 1.94 | 2.07 | 1.58 | **1.35** | **0.12** | **0.028** |
| Ho | 0.68 | 1.02 | 0.41 | 0.49 | 0.72 | 0.57 | 0.81 | 0.98 | 1.83 | 1.17 | 1.45 | **0.92** | **0.13** | |
| **Trophic Guilds** | | | | | | | | | | | | | | |
| Ht | 2.5 | 3.3 | 3.0 | 2.8 | 2.3 | 2.0 | 3.7 | 3.7 | 3.7 | 4.2 | 3.8 | **3.2** | **0.2** | **0.008** |
| Ho | 2.0 | 2.5 | 1.0 | 1.3 | 1.7 | 1.3 | 2.0 | 2.8 | 3.8 | 3.0 | 2.7 | **2.2** | **0.3** | |
| **IBI** | | | | | | | | | | | | | | |
| Ht | 20.7 | 21.0 | 19.0 | 18.3 | 20.3 | 19.7 | 20.7 | 22.0 | 27.3 | 27.8 | 23.3 | **21.8** | **1.0** | **0.600** |
| Ho | 19.3 | 19.7 | 16.3 | 23.0 | 17.7 | 17.3 | 20.7 | 24.7 | 24.7 | 25.4 | 24.3 | **21.2** | **1.0** | |
| **Similarity** | | | | | | | | | | | | | | |
| | 0.40 | 0.61 | 0.27 | 0.47 | 0.51 | 0.38 | 0.41 | 0.85 | 0.81 | 0.71 | 0.33 | **0.52** | **0.06** | |

*Peak flood pulse and the effects on fish community composition*
The entire watershed, including our field sites, featured unusually high levels of water and flow during the 2006 sample period. 2006 marked the third wettest year in the history of Toledo and missed passing the second place record (1963) by only 0.53 cm (National Climatic Data Center, NOAA - http://www.ncdc.noaa.gov/oa/ncdc.html). As well, July 2006 was the wettest July on record, preceded by an intense storm June 21st, dropping 7.29 cm in the area in only a few hours (Toledo Blade, December 29, 2006.) For monthly historic average and actual precipitation amounts from April 2005 to October 2006, please refer to Table 3.8.

High water and flow conditions during most of 2006 provided an opportunity to monitor the stream in an exceptional situation to contrast the 2005 season. It also resulted in catches of fish we found exceptional when compared against long term monitoring we had done in the upper Ottawa River watershed (Crail, unpubl.). The first insight was catching a spawning cluster of three northern pike (*Esox lucius*), in Prairie Ditch just upstream from the confluence with Langenderfer Ditch during the March 23rd, 2006 sample (Fig. 3.2). While not taken within any of our sample segments, the catch is still impressive given the species and habitat in question. Nearly all March 2006 precipitation fell between the 9th and 13th, causing a high water pulse prior to our sample date, which may have led the fish into the ditches to spawn. The cluster was a large female followed by two smaller males, one on either side.

**Table 3.8 –** The historic average precipitation (1893 to 2006) and actual precipitation for 2005 and 2006 (National Climatic Data Center, NOAA).

| Month | Historic Average (cm) | Actual (cm) |
|---|---|---|
| April 2005 | 8.23 | 6.12 |
| May 2005 | 7.98 | 5.28 |
| June 2005 | 9.65 | 4.24 |
| July 2005 | 7.11 | 12.60 |
| August 2005 | 8.10 | 4.47 |
| September 2005 | 7.23 | 7.16 |
| October 2005 | 5.97 | 0.69 |
| November 2005 | 7.06 | 10.21 |
| December 2005 | 6.71 | 8.05 |
| January 2006 | 4.90 | 7.44 |
| February 2006 | 4.78 | 4.72 |
| March 2006 | 6.65 | 6.30 |
| April 2006 | 8.23 | 3.43 |
| May 2006 | 7.98 | 16.76 |
| June 2006 | 9.65 | 7.59 |
| July 2006 | 7.11 | 23.19 |
| August 2006 | 8.10 | 8.20 |
| September 2006 | 7.23 | 5.97 |
| October 2006 | 5.97 | 10.90 |
| **Total** | **138.64** | **153.32** |

Interestingly, Prairie Ditch is one of two major drains of the historic Irwin Prairie Great Lakes twig-rush marsh, which was historically a spawning habitat for Lake Erie northern pike (Trautman, 1981). We managed to catch one of the males, which measured 49.2 cm. The female was slightly longer and roughly twice the girth. We watched closely for juvenile northern pike when sorting catches of the closely related grass pickerel during the year, but were unable to retrieve any juveniles in our sample sites.

While temperatures and conditions during their capture in March 2006 were favorable for large, adult northern pike (mean temperature 3.8 degrees), the summer conditions noted in 2005 (mean temperature approximately 27.0 degrees) were near the upper incipient lethal temperature for sub-adult and adult northern pike (Wismer and Christie, 1987) and suggested these fish moved into this part of the system after September 2005. Curious to note is that the Secor Road dam (RK 18.2, 13 km downstream of the site) was flanked by floodplain streams during the same high water pulse event for a one-week period (March $9^{th}$ – $13^{th}$).

**Figure 3.2 –** Northern Pike, *Esox lucius*, caught in Prairie Ditch

Typically, this dam is the upstream barrier to any fish making migrations from the lake and lower reaches (Roberts *et al*., 2007). It is plausible that the northern pike were lake-run spawning fish that managed to pass the dam this particular spring due to coincidental conditions of migration and peak pulse. We look forward to testing this hypothesis after the removal of the dam, scheduled in 2007, when fish can move freely through the watershed.

A similar flanking of the Secor Dam occurred after the June $21^{st}$ storm, which we followed with the July $10^{th}$ and $11^{th}$ sample. The heavy rains resumed and were sustained through the end of July by consequent storms, allowing a similar set of conditions for our August $13^{th}$ sample. In these samples, we caught species we had never previously recorded, or had found only in extremely low abundances upstream of the dam in our monitoring of Langenderfer and Prairie ditches over the last five years, and the Ottawa River watershed over the last ten years (Crail, unpubl.). Not only were these species present, they were relatively abundant (56 "sport fish" individuals during the August 2006 sample at Langenderfer and Prairie ditches) and mainly composed of adult members. Typically these species are encountered only as juveniles in these parts of the system. The species of note were the bluegill sunfish (*Lepomis macrochirus*), pumpkinseed sunfish (*L. gibbosus*), largemouth bass (*Micropterus salmoides*), and yellow perch (*Perca flavescens*) and were sampled mostly in Ht sites. Until this point, we had never captured a perch upstream from Ottawa Hills, immediately adjacent to the pool behind the dam at RK 18.2, and had found only one pumpkinseed sunfish beyond that pool in 2002 at RK 32.0.

**Figure 3.3 –** Least Darter, *Etheostoma microperca*

*Characterization of the least darter, Etheostoma microperca, population in Tenmile Creek*. We sampled a large population of least darter (Fig. 3.3), which is a State Species of Concern in Ohio (Ohio Division of Wildlife, 2003). This population is currently represented by one specimen at one locality collected in 1930 by Trautman, in spite of listing multiple locality records for the Ottawa watershed in *Fishes of Ohio* (Trautman, 1981). The remaining localities for the Ottawa River represent vouchers received from the old State Fish Hatchery collection of Ed Wickliff, which Trautman regretfully disposed of due to the extremely poor condition of the specimens (Ted Cavender, pers. comm.). Repeated sampling of the watershed by the EPA since the mid-1980s failed to turn up any least darter and the population was thought lost. This notion was reinforced because the known extant populations of least darter occurred in much less disturbed systems with a more developed fish community structure and composition than was found in the Ottawa. However, we should point out that Tramer (1977) recovered nine dead specimens in his study of drying pools in the Ottawa River near Berkey, Ohio, downstream of our sample sites. While published, no vouchers were received by the Ohio State University Museum and, as such, these recoveries went unnoticed until recently.

A total 1,615 least darter were captured and released during our sample events (Table 3.9), making up 14.5% of the total catch over the seasons. The majority was caught at the Tenmile and Eickholt sites, with the exception of two specimens caught in Prairie 01 Ht at different times of the year. However, the April 2006 individual from this location was a gravid female. It is hoped this marks the start of their expansion downstream, as they had been undocumented in the Prairie ditch sub-watershed despite great effort on our part to find them there.

Abundances were temporally variable, with peak presence occurring at different times in the two seasons. However, Ht sites hosted a significantly larger population of least darter than Ho sites ($p = 0.007$ repeated measures ANOVA), representing a larger percentage of the catch within habitats (Ht – 16.0%, Ho – 11.8%) and having an average Ht abundance per sample event three times that of the Ho counterpart. Gravid females were documented in the June 2006 samples, yet were absent in the beginning samples in June 2005. It is also of note that the one sample event where Ho numbers exceeded those caught in Ht sites was during October 2005, when pools were weakly reconnected from the dry conditions of the August and September samples. We assume that the small size of the least darter allowed them to move about or away from predators and food limitation in concentrated pools.

**Table 3.9 –** Least darter, *Etheostoma microperca*, catch for all sites, by habitat during eleven samples events in the Ottawa River, northwest Ohio.

| | **Sample Date** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **6/05** | **8/05** | **9/05** | **10/05** | **12/05** | **3/06** | **4/06 *** | **6/06 *** | **7/06** | **8/06** | **9/06** |
| Ht | 158 | 68 | 125 | 88 | 32 | 39 | 66 | 61 | 108 | 164 | 240 |
| Ho | 6 | 25 | 39 | 92 | 19 | 10 | 39 | 55 | 35 | 61 | 85 |

* represents gravid females present in the sample

The least darter's small size is again worthy of note, as very few juveniles were recorded in our sampling. This is due to the miniscule size of the juvenile least darter, allowing it to swim through the mesh of the seine netting. Therefore, it would be inappropriate to use our sample method to acquire a true population estimate of least darter in this system as our records of least darter may represent underestimates. As well, the electrofishing method chosen by the OEPA as the standardized sampling method may completely overlook these tiny benthic fish, although in some cases they have recorded least darter in other systems using this method (Chris Yoder, pers comm.). It is recommended from the results of this survey, that samplers repeat the sample with seine netting once the standardized sample is completed in streams where the least darter historically occurred (or any other listed benthic species with rudimentary gas bladders).

*Reference Reach IBI Results*

In order to compare our sample segments in the Ottawa River system with other streams throughout Ohio using our sample method, a separate reference reach IBI sample was performed between the Tenmile 03 Ht and Tenmile 04 Ho sample sites in October 2006. This stretch was a representative segment of both Ht and Ho geomorphologies. 3,967 individuals representing 11 species were captured in our 105-meter segment between Tenmile 03 Ht and Tenmile 04 Ho resulting in an IBI score of 29 (Table 3.10). This is classified as "fair" for a Huron Erie Lake Plain headwater stream in the Revised 2006 Ohio IBI scoring (Ohio Environmental Protection Agency, 2006).

We stopped at the 105-meter mark when a good characterization of the stream's fish community and composition in an IBI sense was obtained, as distributions of species captured neither increased nor decreased with additional seine hauls. While other species may have been recorded if we had continued, we would have had to count a great deal more "Alpha Group" individuals to capture remaining "Gamma Group" species. Based on previous sampling at this site, the only expected species absent from this sample were the green sunfish and yellow bullhead, and these were found in low frequency throughout the study. Only one exotic individual (a goldfish) was captured during the event. Such low abundance of exotics was consistent with our findings on exotics in this system through the course of the study.

While showing some signs of recovery, the reference reach IBI sample demonstrated that the upper Ottawa River is a highly compromised system in comparison with other Ohio streams. A second conclusion from the reference reach IBI sample demonstrated that our regular sample event IBI scores were somewhat suppressed in comparison to an actual IBI sample. This is most likely related to the length of sample, which was 1/5$^{th}$ to 1/10$^{th}$ of the sample length of the traditionally run IBI sample (20 meters compared to 100 – 200 meters). However, it was also of note that in the months immediately prior to the reference reach sample, there was abundant water present (unlike 2005) and, while somewhat lower, the scores were more comparable to the reference reach IBI.

**Table 3.10** – Reference Reach Index of Biological Integrity results from a 105-m sample in the headwaters of the Ottawa River, northwest Ohio.

| Species | # Caught | Criteria | Result | Score |
|---|---|---|---|---|
| Bluntnose Minnow | 974 | # Total Sp | 11 | 3 |
| Fathead Minnow | 889 | # Darter Sp | 3 | 3 |
| Central Stoneroller | 523 | # Headwaters Sp | 0 | 1 |
| Striped Shiner | 184 | # Minnow Sp | 6 | 5 |
| Creek Chub | 146 | # Sensitive Sp | 0 | 1 |
| Redfin Shiner | 90 | % Tolerant Sp | 51.0% | 3 |
| White Sucker | 12 | % Omnivores | 47.3% | 1 |
| Johnny Darter | 140 | % Insectivores | 35.8% | 5 |
| Orangethroat Darter | 249 | % Pioneering | 60.4% | 1 |
| Least Darter | 759 | % Simple Lithophilic | 11.2% | 1 |
| *Goldfish* | 1 | % Lesions | 0.003% | 5 |
| **Total** | **3967** | | **IBI Score:** | **29** |

*Comparison to Historical Accounts of the Ottawa River Fish Community*

Comparison of our fish community data to the historical records found in *Fishes of Ohio* (Trautman, 1981) showed that the present-day Ottawa River has a very altered fish community. This would be expected with deforestation of the watershed and the prevalence of ditching and channelization of the entire system. The pre-1955 species distribution maps (*ibid.*) described the remnants of a stream with the highest water quality originating as segments of crystal clear prairie and woodland streams in the upper reaches to open, tannic, lentic marsh interfaces at the confluence with the Oak Openings Region.

Historically, in the upper reaches, intolerant species were recorded such as the hornyhead chub (*Nocomis biguttatus*), western creek chubsucker (*Erimyzon oblongus*), and moderately intolerant species such as the silverjaw minnow (*Notropis buccatus*), mimic shiner – (*N. volucellus*), stonecat madtom (*Noturus flavus*), greenside darter ( *Etheostoma blennoides*), rainbow darter (*E. caeruleum*), and fantail darter (*E. flabellare*). In the mid-reaches, pre-1955 records exist for moderately tolerant low velocity species such as the tadpole madtom – *Noturus gyrinus*, and blackstripe topminnow – *Fundulus notatus*. Swan Creek, a slightly larger watershed just to the south with similar geology, also has records of intolerant species such as the state extirpated pugnose minnow - *Opsopoeodus emiliae*, the bigeye chub – *Hybopsis amblops* and rosyface shiner – *Notropis rubellus*. Additionally, Swan Creek currently hosts viable populations of the moderately tolerant stonecat and tadpole madtom, blackstripe topminnow, spotted sucker and an abundant population of greenside darter. The latter was curiously absent from the Ottawa River system, despite kilometers of prime habitat as Tenmile Creek crests the Silica Monocline through Sylvania, Ohio.

This historical context is interesting, as it is applicable to future research in the watershed, should these historical species mentioned above, make their return to the Ottawa River. This is not out of the question, as a series of ditches connects Swan Creek and the Ottawa River watersheds through the Oak Openings Region of western Lucas county. Certain intolerant species have shown evidence of expanding their ranges from higher quality habitat in Michigan into Ohio. This includes, for example, a state endangered western banded killifish (*Fundulus diaphanous menona*), caught in the Maumee River during October 2006 (Crail, unpubl.).

However, many of the species mentioned will have no way to return to the watershed, either due to extirpation, a lack of connecting habitat, the presence of invasive species, or physical barriers such as dams (Harding *et al*. 1998, Roberts *et al*. 2007). What is more important for monitoring the recovery of the Ottawa River watershed are increases in extant species that were found as "Gamma Group" or rare species, such as the blackside darter, pumpkinseed sunfish and grass pickerel. Moreover, increasing abundances of moderately intolerant species such as the least darter, redfin shiner and striped shiner accompanied by abundance decreases of generalist species such as *Pimephales* minnows, would better reflect a reconstruction of the historic fish community composition and structure.

## Summary, Conclusions and Recommendations

In spite of decades of continual disturbance by humans and a misinformed reputation for being little more than a culvert to drain excess water away from agriculture, the channelized and entrenched headwaters of the Ottawa River possess a developed fish community composition and structure that ranks "Fair" in comparison to statewide IBI assessments of streams. Although dominated by two tolerant species, the habitat is suitable for a large population of the State Species of Concern least darter, in addition to twenty other native species of fish. While present, three exotic species are an insignificant proportion of the fish community composition and structure.

Furthermore, within these streams, segments possessing a heterogeneous geomorphology host a significantly more rich, diverse and trophically-varied fish community than segments with less developed, homogeneous geomorphology. In the case of our study sites, colonization of plants contributes to the formation of the heterogeneous morphologies. We found evidence of similar morphologies downstream of wood jams elsewhere in the watershed. A rich, diverse fish community composition and structure may also form, if these jams are left in place long enough.

Our data demonstrate that agricultural drainage ditches in the Ottawa River watershed serve as suitable habitat for fish while attaining their primary purpose of surface and sub-surface drainage necessary for successful agriculture in the Huron Erie Lake Plain ecoregion. In addition, we quantified significant development of fish community structure and composition in a very early state of channel evolution and development using a passive, naturally-occurring mechanism that neither shades nor encroaches on row cropping, the dominant land use in this portion of the watershed. The lost channel volume due to channel stabilization and sediment accumulation are easily regained by widening the ditch into a two-stage formation (Zucker *et al*., 2004), as opposed to dredging the bottom. This method provides a flood plain for the ditch by removing volumes of soil lateral to the main ditch channel, allowing the channel to stabilize by meandering. It stands to reason with each threshold of regained geomorphological heterogeneity, the fish community composition and structure will correspondingly improve. We have demonstrated this in a preliminary manner through our study.

Further research in these systems should examine fish community response to various treatments such as the two-stage formations, riparian plantings and in-stream modifications including intentional logjam placement. This may help to establish threshold values of geomorphology and the corresponding response in fish community composition and structure. Development of these values may then be used to determine costs of implementation, cost sharing between government and farmers and may even demonstrate lowered ditch maintenance costs for landowners after implementation. This leads to some recommendations for future projects that could lead to the development of threshold values and associated costs.

First, in the case of the two-stage ditch formation, one could examine the ratio of channel to floodplain to determine the ecological benefits based on the expense of removing spoil when widening the floodplain surrounding the stream's primary channel. Without question, a 1:20 channel to floodplain ratio is preferable from the perspective of wildlife or the long-term stability of the cross-section, but is outside the realm of possibility due to costs and lost agricultural productivity. In these low gradient systems, a 1:10 or 1:5 ratio may be acceptable for the majority of ditched segments.

In a second project, one could examine potential ecological benefits of various herbaceous riparian vegetation treatments. For example, comparing segments dominated by *Phalaris sp.* and other exotic field weeds to segments dominated by plantings of native grasses and forbs may prove relevant. The native plant community may have increased ecological benefits related to remnant animal communities (insects, birds, mammals). More prominently, native emergent plants may also increase stabilization beyond the benefits to channel development, due to deeper rooting compared to the shallow rooting *Phalaris sp.* and annuals typical of farm fields.

And in a third project, one could examine the fish community response to manually placed wood jams and compare these results against similar downstream morphologies formed by plant colonization. Analogously, comparing heterogeneous segments formed by woody debris against homogeneous segments without debris would be relevant for the management of these streams. While some resistance to this type of modification from landowners and county engineers may be expected, this is an aspect of recovering geomorphology that should be explored. Woody debris not only provides stabilization of channel morphology, but also serves as a substrate for many organisms that make up the trophic link between decomposition and a large part of the fish community's diet. As such, it is an important aspect that has historically been lost from these systems and may be the missing link in the further development of "Gamma Group" species in the fish community. This is particularly valid because all these species have life history aspects tied to decomposer insect larvae. For this reason alone, exploration of this type of implementation should be encouraged.

Finally, no widening of the floodplain around the stream's primary channel will occur unless agricultural landowners receive some incentive to take these narrow riparian zones out of production and unless these landowners are made aware of the potential for improvement of the fish community without loss of water conveyance or bank stability. We hope that the results of our work will be useful in a strategy to implement such incentive programs.

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# Appendix 1 – A sample data sheet from June 2005 sample.

## Sample 1 – June 10, 11 & 12, 2005

**Tenmile 01 HT**

| *6/11/2005 12:45* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| Bluntnose Minnow - O | 3 | 1 | 2 | 7 | | | | | 13 |
| Fathead Minnow - O | 7 | 4 | 3 | 1 | | | | | 15 |
| Green Sunfish - I | | | | | 1 | | | | 1 |
| Least Darter - I | 62 | 33 | | | | | | | 95 |
| Johnny Darter - I | 3 | 1 | | | | | | | 4 |
| Orangethroat Darter - I | 10 | 1 | 9 | 4 | | | | | 24 |
| | | | | | | **Total Individuals** | | | **152** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 27.2 | **Turbidity** | 50 | **Weather** | Overcast |
| **pH** | 8.1 | **Substrate** | Gravel, Firm Mud | **Riparian Veg** | Reed canary grass, Goldenrod |
| **Dissolved O2** | X | **Water Level** | Normal, Flowing | **Aquatic Veg** | Anacharis, Cladophora |
| **Conductivity** | 716 | **Discharge** | 0.03 m3/sec | | |

**Tenmile 02 HO**

| *6/11/05 11:45 AM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| Bluntnose Minnow - O | | | | | 2 | 2 | | | 4 |
| Fathead Minnow - O | | | | | 1 | | | | 1 |
| Johnny Darter - I | | | | | | 3 | | | 3 |
| Least Darter - I | | 1 | | | | 1 | | | 2 |
| | | | | | | **Total Individuals** | | | **10** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 27.2 | **Turbidity** | 50 | **Weather** | Overcast |
| **pH** | 8.1 | **Substrate** | Firm Mud | **Riparian Veg** | Reed canary grass, Some Natives |
| **Dissolved O2** | X | **Water Level** | Normal, Flowing | **Aquatic Veg** | Anacharis |
| **Conductivity** | 569 | **Discharge** | 0.02 m3/sec | | |

**Tenmile 03 HT**

| *6/11/05 10:30 AM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| Bluntnose Minnow - O | | 20 | 1 | 14 | | | | | 35 |
| Fathead Minnow - O | 12 | 25 | 3 | 28 | | | 2 | 4 | 74 |
| Redfin Shiner - I | | | | 1 | | | | | 1 |
| Creek Chub - G | | | | | | 2 | | | 2 |
| Stoneroller Minnow - H | | | | 1 | | | | | 1 |
| Central Mudminnow - I | | | | 1 | | | | | 1 |
| Least Darter - I | 12 | 8 | | | | | | | 20 |
| Johnny Darter - I | 2 | 1 | | | | | | | 3 |
| Orangethroat Darter - I | | 5 | | 2 | | | | | 7 |
| | | | | | | **Total Individuals** | | | **144** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 26.5 | **Turbidity** | 50 | **Weather** | Overcast |
| **pH** | 8.0 | **Substrate** | Gravel, Firm Mud | **Riparian Veg** | Reed canary grass, Some Natives |
| **Dissolved O2** | 6.2 | **Water Level** | Normal, Flowing | **Aquatic Veg** | Anacharis, Sagitaria |
| **Conductivity** | 768 | **Discharge** | 0.02 m3/sec | | |

**Tenmile 04 HO**

| *6/11/05 9:15 AM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| Creek Chub - G | | | | | 1 | 1 | | | 2 |
| White Sucker - O | | | | | | 2 | | | 2 |
| Johnny Darter - I | | | | | 20 | 22 | | | 42 |
| Least Darter - I | 1 | 1 | | | | | | | 2 |
| | | | | | | **Total Individuals** | | | **48** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 24.1 | **Turbidity** | 40 | **Weather** | Clear |
| **pH** | 7.8 | **Substrate** | Gravel, Firm Mud | **Riparian Veg** | RCG, Some Natives |
| **Dissolved O2** | 6.0 | **Water Level** | Normal, Flowing | **Aquatic Veg** | Hornwort, Potomogeton |
| **Conductivity** | 668 | **Discharge** | 0.03 m3/sec | | |

**Tenmile 05 HT**

| *6/10/05 10:00 AM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| Bluntnose Minnow - O | | 5 | | 12 | 1 | 8 | | | 26 |
| Fathead Minnow - O | | 3 | | 19 | | 1 | | | 23 |
| Creek Chub - G | | | | 1 | | 2 | | | 3 |
| Striped Shiner - I | | | | 1 | | | | | 1 |
| Least Darter - I | 4 | 31 | | | | | | | 35 |
| Johnny Darter - I | | 1 | | 1 | | | | | 2 |
| Orangethroat Darter - I | 1 | 1 | 4 | 4 | | 2 | | | 12 |
| | | | | | | **Total Individuals** | | | **102** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 25.3 | **Turbidity** | 40 | **Weather** | Overcast |
| **pH** | 7.7 | **Substrate** | Gravel, Firm Mud | **Riparian Veg** | RCG, Some Natives |
| **Dissolved O2** | 7.4 | **Water Level** | Normal, Flowing | **Aquatic Veg** | Hornwort, Potomogeton |
| **Conductivity** | 660 | **Discharge** | 0.03 m3/sec | | |

**Tenmile 06 HO**

| *6/10/05 9:00 AM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| Bluntnose Minnow - O | | | | | | 8 | | 8 | 16 |
| Least Darter - I | | 1 | | | | | | | 1 |
| Orangethroat Darter - I | | 1 | 8 | | | 2 | | | 12 |
| | | | | | | **Total Individuals** | | | **29** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 23.3 | **Turbidity** | 40 | **Weather** | Overcast |
| **pH** | 7.2 | **Substrate** | Gravel, Firm Mud | **Riparian Veg** | RCG, Some Natives |
| **Dissolved O2** | 7.0 | **Water Level** | Normal, Flowing | **Aquatic Veg** | Hornwort, Potomogeton |
| **Conductivity** | 688 | **Discharge** | 0.03 m3/sec | | |

**Eickholt 01 HT**

| *6/10/05 11:30 AM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| Fathead Minnow - O | 1 | | 11 | | 10 | 2 | 1 | | 25 |
| Golden Shiner - I | | | | | 1 | | | | 1 |
| Least Darter - I | 4 | 4 | | | | | | | 8 |
| Orangethroat Darter - I | | 1 | | | | | | | 1 |
| | | | | | | | **Total Individuals** | | **35** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 25.8 | **Turbidity** | 50 | **Weather** | Clear |
| **pH** | 7.5 | **Substrate** | Firm Mud | **Riparian Veg** | RCG, some natives |
| **Dissolved O2** | 10.9 | **Water Level** | Normal, Flowing | **Aquatic Veg** | Rotala |
| **Conductivity** | 747 | **Discharge** | 0.01 m3/sec | | |

**Eickholt 02 HO**

| *6/10/05 11:00 AM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| Bluntnose Minnow - O | | 1 | | 4 | | 34 | | | 39 |
| Fathead Minnow - O | | 5 | | 5 | | 17 | | | 27 |
| Least Darter - I | | 1 | | | | | | | 1 |
| | | | | | | | **Total Individuals** | | **67** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 24.8 | **Turbidity** | 50 | **Weather** | Clear |
| **pH** | 7.4 | **Substrate** | Soft Mud | **Riparian Veg** | RCG, some natives |
| **Dissolved O2** | 8.1 | **Water Level** | Normal, Flowing | **Aquatic Veg** | None |
| **Conductivity** | 718 | **Discharge** | 0.01 m3/sec | | |

**Prairie 01 HT**

| *12/2/05 2:45 PM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| | ***NO FISH*** | | | | | | | | 0 |
| | | | | | | | **Total Individuals** | | **0** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 24.3 | **Turbidity** | 30 | **Weather** | Overcast |
| **pH** | 7.6 | **Substrate** | Soft Mud, Sand | **Riparian Veg** | RCG, Polygonum |
| **Dissolved O2** | X | **Water Level** | Normal, Non-Flowing | **Aquatic Veg** | Cladophora, Potomogeton |
| **Conductivity** | 1094 | **Discharge** | 0.04 m3/sec | | |

**Prairie 02 HO**

| *12/2/05 3:00 PM* | Adult | Adult | Sub | Sub | Juv | Juv | Gravid | Gravid | Total |
|---|---|---|---|---|---|---|---|---|---|
| | ***NO FISH*** | | | | | | | | 0 |
| | | | | | | | **Total Individuals** | | **0** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 24.3 | **Turbidity** | 30 | **Weather** | Overcast |
| **pH** | 7.9 | **Substrate** | Soft Mud, Sand | **Riparian Veg** | RCG, Bindweed |
| **Dissolved O2** | X | **Water Level** | Normal, Non-Flowing | **Aquatic Veg** | Potomogeton, Cladophora |
| **Conductivity** | 791 | **Discharge** | 0.03 m3/sec | | |

**Langenderfer 01 HT**

| *6/12/05 10:35 AM* | **Adult** | **Adult** | **Sub** | **Sub** | **Juv** | **Juv** | **Gravid** | **Gravid** | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| Bluntnose Minnow - O | | 7 | 3 | 4 | 2 | | | | 16 |
| Creek Chub - G | | 1 | 2 | 4 | 3 | | | | 10 |
| Fathead Minnow - O | | | | | 1 | | | | 1 |
| Golden Shiner - I | | 3 | | | 1 | | | | 4 |
| White Sucker - O | | | | 1 | 1 | | | | 2 |
| Central Stoneroller - H | | 1 | | | | | | | 1 |
| Blackside Darter - I | | | | | 1 | | | | 1 |
| | | | | | | | **Total Individuals** | | **35** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 24.6 | **Turbidity** | 30 | **Weather** | Overcast |
| **pH** | 7.7 | **Substrate** | Firm Mud, Sand | **Riparian Veg** | RCG, Bindweed |
| **Dissolved O2** | X | **Water Level** | Normal, Non-Flowing | **Aquatic Veg** | Cladophora |
| **Conductivity** | 947 | **Discharge** | 0.02 m3/sec | | |

**Langenderfer 02 HO**

| *6/12/05 9:45 AM* | **Adult** | **Adult** | **Sub** | **Sub** | **Juv** | **Juv** | **Gravid** | **Gravid** | **Total** |
|---|---|---|---|---|---|---|---|---|---|
| Bluntnose Minnow - O | | | 3 | | | 3 | | | 6 |
| Creek Chub - G | | | 1 | | | | | | 1 |
| Redfin Shiner - I | | | 1 | | | | | | 1 |
| | | | | | | | **Total Individuals** | | **8** |

| | | | | | |
|---|---|---|---|---|---|
| **Temp** | 24.4 | **Turbidity** | 40 | **Weather** | Overcast |
| **pH** | 7.5 | **Substrate** | Soft Mud, Sand | **Riparian Veg** | RCG, Bindweed |
| **Dissolved O2** | X | **Water Level** | Normal, Non-Flowing | **Aquatic Veg** | Cladophora |
| **Conductivity** | 781 | **Discharge** | 0.02 m3/sec | | |