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CHANGES IN FISH ASSEMBLAGES OF KILLBUCK CREEK AND PIPE CREEK, DELAWARE COUNTY, INDIANA

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ABSTRACT. To accurately determine the sources of impairment on downstream bodies of water, headwaters and tributaries must first be evaluated on temporal and longitudinal changes. Fish assemblage assessments in Killbuck Creek and Pipe Creek were conducted in 1978 and replicated in 2008. Distinct changes in the fish assemblage include the absence of pirate perch in Killbuck Creek from the 2008 sample while they were fairly abundant in 1978. Killbuck Creek is now characterized by populations of bluegill (*Lepomis macrochirus*) and grass pickerel (*Esox americanus vermiculatus*) and Pipe Creek is now characterized by steelcolor shiner (*Cyprinella whipplei*), rock bass (*Ambloplites rupestris*), bluegill, and white suckers (*Catostomus commersonii*). Species diversity has increased at nearly all sites on both creeks. A total of eight new species was found in each stream. New records of sensitive species such as golden redhorse (*Moxostoma erythrurum*), logperch (*Percina caprodes*), northern hog sucker (*Hypentelium nigricans*), and smallmouth bass (*Micropterus dolomieu*) were documented in Killbuck and Pipe Creek. Longitudinal variability of the fish assemblage was found to be attributed primarily to habitat. For example, the headwaters of both creeks have been dredged, straightened, and denuded of riparian vegetation while much of the lower stretches of both rivers have been left intact.

Keywords: Rivers, fish assemblage, diversity, habitat

An estimated 87% of wetlands have been lost in Indiana from the 1780s to the 1980s (Dahl 1990). Much of this loss was primarily due to agricultural activities (Frayer et al. 1983). Agricultural practices such as dredging, straightening of stream channels, and clear-cutting of riparian vegetation have been listed as the sources of impairment in over 40% of the impaired waters in the United States (U.S. EPA 2009). However, there has been a minor reversal in this trend of wetland loss. Since 1998 there has been an increase of 32,000 wetland acres (13,000 ha) annually (Dahl 2006). Promoting the change of these agricultural practices include federal funding and local recognition programs. For example, farmers who successfully manage their property for wildlife and farming are eligible for programs such as the "Indiana Conservation Farmer of the Year" and "River Friendly Farmer".

Sustainable land use practices (e.g., buffer strips) promote ecological integrity of both the immediate and downstream reaches (Vought et al. 1995; Gomi et al. 2002). The impact of headwater streams on the physical, chemical, and biological integrity of downstream waters has been widely studied (Lowe & Likens 2005; Alexander et al. 2007; Meyer et al. 2007; Wipfli et al. 2007). For example, a natural buffer strip of woody vegetation, grasses, and shrubs will reduce sediment, nitrates, and pesticides before they enter the stream as well as stabilize channel banks (Pearce et al. 1998; Patty et al. 1999; Simon & Collison 2002; Cooper 2005).

One of the first biological studies conducted by the Muncie Bureau of Water Quality (BWQ) was an evaluation of the fish assemblage in Killbuck and Pipe Creek in 1978. The purpose of that investigation was to determine baseline fish assemblage data in the White River watershed. The objectives of this study were: (1) to describe changes in the fish assemblages in Killbuck Creek and Pipe Creek from samples collected in 1978 and 2008 and (2) to evaluate the relationship between the current fish assemblage and habitat.

METHODS

Study area.—Killbuck Creek and Pipe Creek are located in East Central Indiana. The headwaters of both streams originate in rural Delaware County and flow south-west into Madison County. Killbuck Creek joins White River at Anderson, and Pipe Creek enters further downstream (Fig. 1). Both headwaters have been heavily manipulated to facilitate

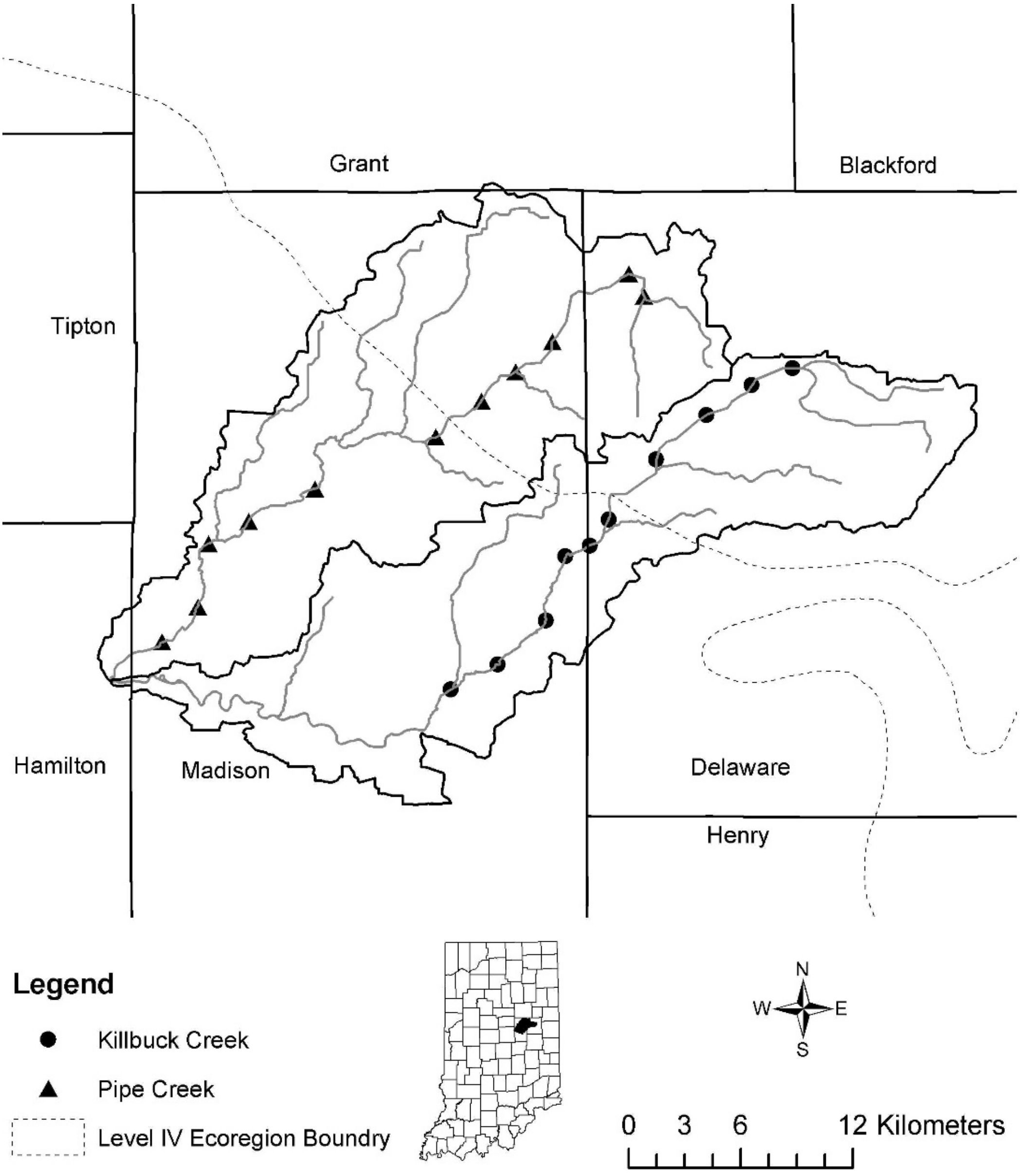

Figure 1.—Killbuck and Pipe Creek fish sampling sites. The surrounding counties are indicated.

efficient agricultural field drainage and have the potential to substantially influence White River. In 2008, the BWQ biology section replicated a 1978 survey to compare fish assemblages after a 30-year period. Study sites were located in Delaware and Madison County (Fig. 1). Sampling took place from June through September.

Fish collection.—In 1978, twenty-one sites were sampled from Pipe Creek and Killbuck Creek with a backpack electrofishing unit or an electric seine. Field data sheets from 1978 do not provide specifics of the gear used. The same sites were resampled in 2008 using only a model 12-B POW Smith Root, Inc. backpack electrofisher (60Hz pulse, 4ms wide and 300 volts).

Sample distances were identical for both collections and ranged from 27–200 m.

All fish were identified to species and enumerated. Relative species abundance by site was used to allow for fish assemblage comparisons between different gear types (Tejerina-Garro et al. 1998). For each species at each site and year relative species abundance was calculated as:

$$C_x = N_x / TN$$

where C is relative species abundance for species X, N is the total number of species X sampled, and TN is the total number of all individuals collected.

For example, the relative abundance of species *x* at site *j* in year *y* was calculated as total number of species *x* sampled at site *j* in year *y* divided by total number of individuals sampled at site *j* in year *y*.

Habitat.—Limited habitat information from 1978 prevents definitive conclusions on how habitat was structuring the fish population. Habitat changes and current land use practices were qualitatively evaluated from 1978 field datasheets and aerial photographs of Madison County (1998 and 2008) and Delaware County (1967, 1979, 1988, 1998, and 2008). In 2008, habitat was assessed with the Qualitative Habitat Evaluation Index (QHEI) (Rankin 1989) to provide information on how habitat is currently affecting the fish assemblage. The QHEI is a multimetric index that summarizes the available habitat at an individual sample site to determine the influence of habitat on fish communities. The index is comprised of six metrics describing substrate, instream cover, riparian characteristics, channel characteristics, pool and riffle quality, and gradient and drainage area.

Statistics.—Detrended Correspondence Analysis (DCA) was used to summarize the multivariate species assemblage data for both years combined for each stream separately (McCune & Grace 2002). DCA axes were correlated with individual fish species proportional abundance to determine which species trends were represented by the axis values. Repeated measures Analysis of Variance (ANOVA) was used to detect temporal (year collected as repeated measure) and longitudinal (river kilometer as the dependent variable) influences on the fish assemblages as represented by DCA axis scores. Indicator Species Analysis (ISA) was used to identify which species were more indicative of each sample year (Dufrene & Legendre 1997; McCune & Grace 2002). ISA is a multivariate statistical technique used to identify taxa that would indicate a specified group based on disturbance levels, habitat types, or other categorical environmental variable. In addition, species diversity was analyzed using the Shannon Wiener index (H') (Shannon & Weaver 1949). Temporal and spatial trends in H' were analyzed using repeated measures ANOVA with years collected as repeated measure and river kilometer as the dependant variable.

To evaluate the relationship between habitat and fish assemblages at Killbuck Creek and Pipe Creek I applied DCA to the dual matrix of fish data and QHEI metric scores for 2008 only. Correlation analysis was used to relate QHEI metrics to DCA axes scores.

DCA and ISA were performed with PC-ORD 5.0 while all other statistics used SAS 9.2. Prior to analysis relative abundance values were arcsine square root transformed in PC-ORD. Rare species were down-weighted to reduce their influence during the ordination (McCune & Grace 2002). Statistical significance was set at 0.05.

RESULTS

Killbuck Creek.—The total numbers of species captured at 10 sites were 27 (1978) and 33 (2008), while the total numbers of individuals captured were 352 (1978) and 976 (2008). DCA indicated three axes explained 54% of the cumulative variation in the fish assemblages. Axis-1 represents a gradient of green sunfish (*Lepomis cyanellus*), creek chub (*Semotilus atromaculatus*), grass pickerel (*Esox americanus*), bluegill (*Lepomis macrochirus*), and northern hog sucker (*Hypentelium nigricans*) ($R^2 = 0.41$); Axis-2 represents pirate perch (*Aphredoderus sayanus*), mottled sculpin (*Cottus bairdii*), and grass pickerel ($R^2 = 0.09$); and Axis-3 represents black bullhead (*Ameiurus melas*), blackstripe topminnow (*Fundulus notatus*), and pumpkinseed sunfish (*Lepomis gibbosus*) ($R^2 = 0.04$). The plot of DCA Axis-1 and Axis-2 shows that there were two clusters represented by sample period (1978 *vs.* 2008) (Fig. 2). The fish assemblage summarized by Axis-1 was significantly different between sample periods ($F(1,8) = 12.62$; $P = 0.008$) and was related to river kilometer

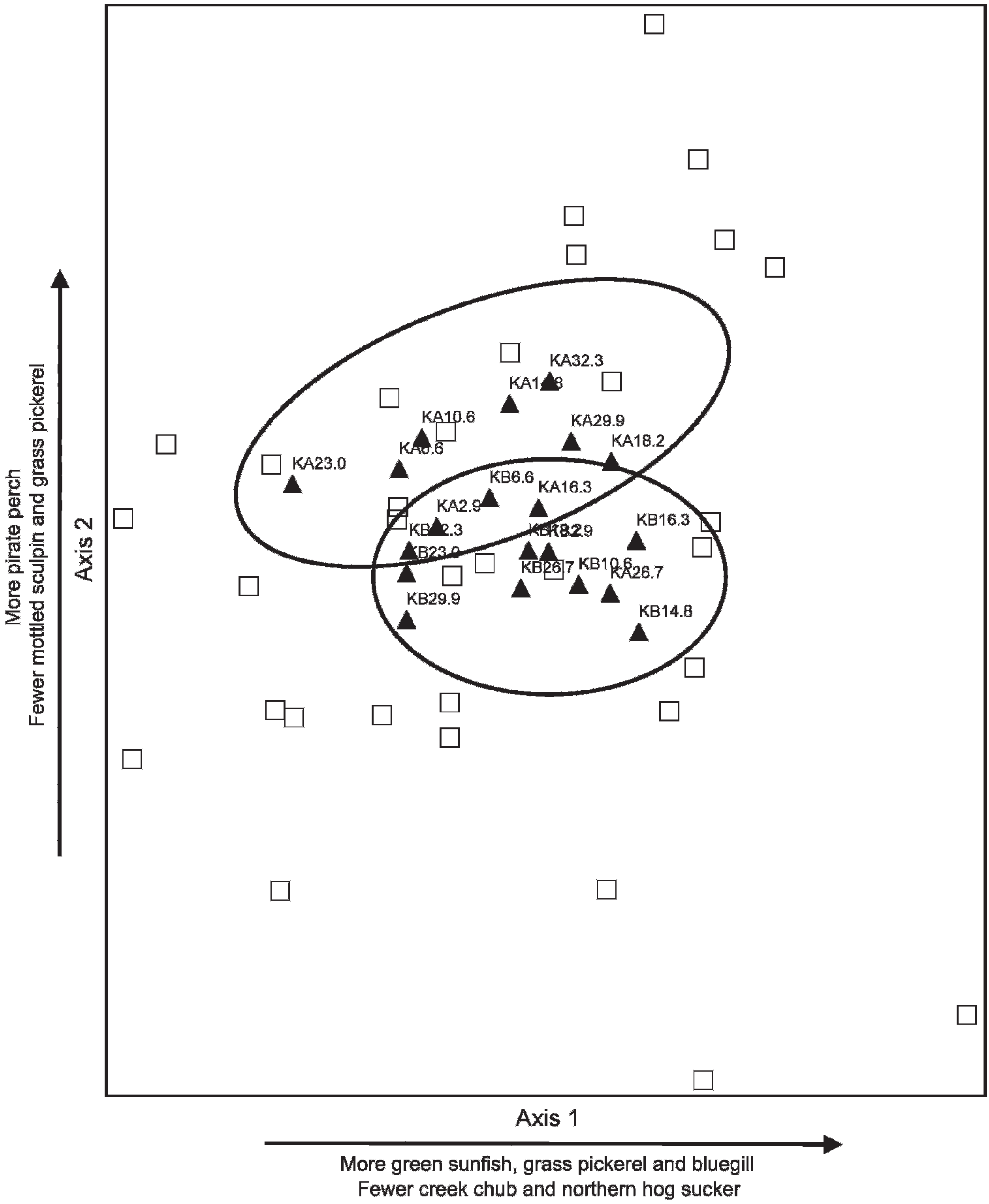

Figure 2.—Detrended Correspondence Analysis axes for Killbuck Creek. Triangles represent site scores and squares represent species scores. Clusters in enclosures indicate similar fish assemblage by year (KA = 1978 & KB = 2008).

($F(1,8) = 12.66$; $P = 0.007$). The remaining axes were not significantly related to sample periods or river kilometer. ISA revealed pirate perch were indicative of the fish assemblage in 1978 while grass pickerel and bluegill were indicative of the 2008 fish assemblage (Table 1).

Shannon Wiener indices ranged from 0.27 to 2.33 in 1978 and 0.72 to 3.57 in 2008. The diversity increased at all sites sampled on

Table 1.—Results of Indicator Species Analysis on Killbuck Creek and Pipe Creek. Only significant Indicator Values are shown.

Species	Decade	Indicator value	*P*-value
Killbuck Creek			
Pirate perch	1978	70.0	0.003
Bluegill	2008	72.1	0.007
Grass pickerel	2008	71.3	0.004
Pipe Creek			
Green sunfish	1978	64.7	0.032
Greenside darter	1978	57.8	0.012
Bluegill	2008	87.8	< 0.001
White sucker	2008	64.2	0.014
Rock bass	2008	56.0	0.047
Blackstripe topminnow	2008	54.5	0.011
Northern hog sucker	2008	45.5	0.033

Killbuck Creek (Fig. 3). Thirteen new species were collected including three sensitive species: golden redhorse (*Moxostoma erythrurum*), rainbow darter (*Etheostoma caeruleum*), and silver shiner (*Notropis photogenis*) (Table 2). Overall, the mean diversity index significantly increased from 1978 (0.96) to 2008 (1.90) ($F(1,8) = 5.73$; $P = 0.044$), and the change was consistent regardless of the river kilometer ($F(1,8) = 0.10$; $P = 0.758$).

Riparian habitat differed the most in the headwaters located in Delaware County. The predominant alteration was clear-cutting and dredging at three of the five sites located in Delaware County. In contrast, the downstream section of Killbuck Creek has never been approved for alteration by the Madison County Drainage Board (pers. comm. 9/18/2009). As such, the riparian zone of the lower reaches in Madison County is comprised of woody vegetation.

QHEI scores ranged from 26 "very poor" to 66 "fair". With the exception of the two sites near the headwaters that scored 26, Killbuck Creek did not vary substantially. QHEI scores averaged 60 "fair" at the four most downstream sites and 37 "poor" at the four most upstream sites. The Pool/Current score was the only QHEI metric that was correlated with DCA Axis-1 (Table 3). No QHEI metric was

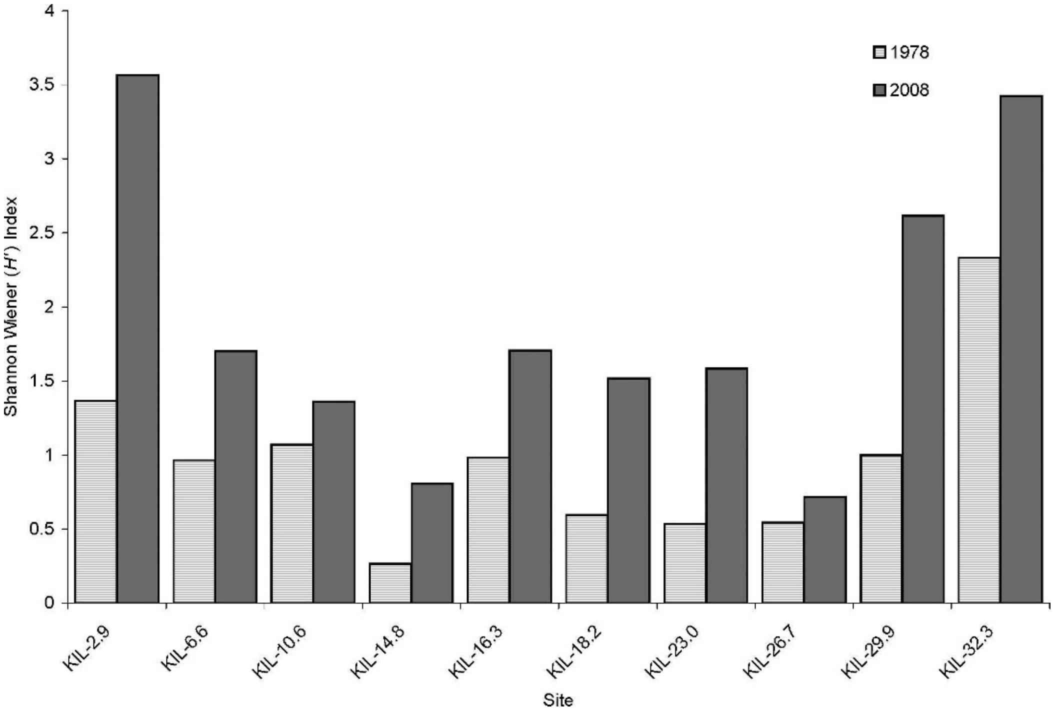

Figure 3.—Shannon Wiener Index (H') at each Killbuck Creek sample site, 1978 and 2008 (Number in site label indicates river kilometer).

significantly correlated with Axis-2 or Axis-3. However, the relationship between Channel score and DCA Axis-2 was marginally significant ($r = 0.62$; $n = 10$; $P = 0.056$). The Riffle/Run score was the only QHEI metric significantly correlated with diversity (Table 3).

Pipe Creek.—The total numbers of species captured at 11 sites were 25 (1978) and 32 (2008), while the total numbers of individuals captured were 820 (1978) and 860 (2008). DCA indicated three axes explained 69% of the cumulative variation in the fish assemblages. Axis-1 represents a gradient of grass pickerel, blackstripe topminnow, yellow bullhead (*Ameiurus natalis*), and largemouth bass (*Micropterus salmoides*) ($R^2 = 0.45$); Axis-2 represents steelcolor shiner (*Cyprinella whipplei*) and rock bass (*Ambloplites rupestris*) ($R^2 = 0.17$); and Axis-3 represents black bullhead ($R^2 = 0.08$). The plot of DCA Axis-1 and Axis-2 indicated there were four clusters represented by sample period (1978 *vs.* 2008) and river kilometer (Fig. 4). The fish assemblage represented by all three axes was significantly different between sample periods (Axis-1, $F(1,9) = 9.17$, $P = 0.014$; Axis-2, $F(1,9) = 20.54$, $P = 0.001$; Axis-3, $F(1,9) = 33.21$, $P < 0.001$) while only Axis-1 and Axis-3 were influenced by river kilometer ($F(1,9) = 29.02$, $P < 0.001$; $F(1,9) = 34.54$, $P < 0.001$; respectively). ISA revealed green sunfish and greenside darter (*Etheostoma blennoides*) were indicative of the fish assemblage in 1978 while bluegill, white sucker (*Catostomus commersonii*), rock bass, blackstripe topminnow, and northern hog sucker were more indicative of the fish assemblage in 2008 (Table 1).

Shannon Wiener indices ranged from 0.37 to 2.80 in 1978 and 0.70 to 3.39 in 2008. Four sites were either similar or decreased from 1978 while the remaining sites increased (Fig. 5). Sixteen new species were collected in 2008 including six sensitive species, logperch (*Percina caprodes*), northern hog sucker, smallmouth bass (*Micropterus dolomieu*), sand shiner (*Notropis ludibundus*), golden redhorse, and silver shiner (Table 2). Overall, the difference in diversity index from 1978 to 2008 was marginally significant ($F(1,9) = 4.97$; $P = 0.052$). Sites near the confluence of White River were generally more diverse than the headwaters; however, river kilometer location was not significant ($F(1,9) = 2.04$; $P = 0.187$).

No visible habitat alteration occurred in Delaware County or Madison County prior to 1998. However, minimal alteration of the riparian zone in Madison County has occurred since 1998. In contrast, two headwater sites in Delaware County have been clear-cut and dredged.

QHEI values on Pipe Creek ranged from 36 "poor" to 72 "good". The highest QHEI values were associated with the confluence with White River. Likewise the Substrate, Cover, Channel, Riparian, and Gradient score were also higher near the confluence of White River. QHEI scores precipitously declined with river kilometer with an average QHEI of 61 "fair" at the four most downstream sites and 37 "poor" at the four most upstream sites. The Pool/Current and Riffle/Run score were the only two individual QHEI metrics that were not significantly correlated to DCA-1 (Table 3). DCA Axis-2 and Axis-3 were not significantly correlated to any QHEI categories. Diversity of the fish assemblage was significantly and positively correlated with three of the individual QHEI metrics (Channel score, Riparian score, and Gradient score).

DISCUSSION

The fish assemblage of Killbuck Creek in 2008 was markedly different from 1978. The significant increase in Shannon Weiner index indicates an improvement in the physical and/or chemical water quality. Increased species diversity in response to improved physical and chemical water quality have also been documented in other areas of Indiana as well as Illinois (Gammon et al. 2003; Gorman & Karr 1978; Schlosser 1982). However, relative abundance of tolerant species at some sites (e.g., green sunfish) also increased. In addition, longitudinal changes in the fish assemblage were detected, agreeing with other studies which found a significant longitudinal effect with species richness (Grenouillet et al. 2004).

Of particular note was the absence of pirate perch in the 2008 samples from Killbuck Creek. Their absence is likely due to clear-cutting that has taken place since the survey in 1978. There remains a possibility that pirate perch still inhabit Killbuck Creek, as potential habitat remains in scattered patches (Trautman 1981). Clear-cutting has also likely led to an increase

Table 2.—Checklist of species sampled at Killbuck Creek and Pipe Creek in 1978 and 2008.

	Killbuck Creek		Pipe Creek	
Family, *species*, common name	1978	2008	1978	2008
APHREDODERIDAE				
Aphredoderus sayanus, Pirate perch	*		*	
CATOSTOMIDAE				
Erimyzon oblongus, Creek chubsucker	*		*	
Moxostoma erythrurum, Golden redhorse		*		*
Hypentelium nigricans, Northern hog sucker	*	*		*
Carpiodes cyprinus, Quillback carpsucker			*	
Minytrema melanops, Spotted sucker		*		*
Catostomus commersonii, White sucker	*	*	*	*
CENTRARCHIDAE				
Lepomis macrochirus, Bluegill	*	*	*	*
Lepomis cyanellus, Green sunfish	*	*	*	*
Lepomis spp., Hybrid sunfish		*		*
Micropterus salmoides, Largemouth bass		*		*
Lepomis megalotis, Longear sunfish	*	*	*	*
Lepomis humilis, Orangespotted sunfish			*	
Lepomis gibbosus, Pumpkinseed	*		*	*
Ambloplites rupestris, Rock bass	*	*	*	*
Micropterus dolomieu, Smallmouth bass	*	*		*
Pomoxis annularis, White crappie		*		*
COTTIDAE				
Cottus bairdii, Mottled sculpin	*	*	*	*
CYPRINIDAE				
Rhinichthys atratulus, Blacknose dace		*		
Pimephales notatus, Bluntnose minnow	*	*	*	*
Campostoma anomalum, Central stoneroller	*	*	*	*
Cyprinus carpio, Common carp	*	*	*	*
Semotilus atromaculatus, Creek chub	*	*	*	*
Notemigonus crysoleucas, Golden shiner				*
Nocomis biguttatus, Hornyhead chub				*
Lythrurus umbratilis, Redfin shiner	*	*	*	*
Notropis ludibundus, Sand shiner	*	*		*
Notropis photogenis, Silver shiner		*		*
Ericymba buccata, Silverjaw minnow		*		*
Cyprinella spiloptera, Spotfin shiner				*
Notropis hudsonius, Spottail shiner	*			
Cyprinella whipplei, Steelcolor shiner		*		*
Luxilus chrysocephalus, Striped shiner			*	
ESOCIDAE				
Esox americanus vermiculatus, Grass pickerel	*	*	*	*
FUNDULIDAE				
Fundulus notatus, Blackstripe topminnow	*	*		*
ICTALURIDAE				
Ameiurus melas, Black bullhead	*		*	*
Ameiurus nebulosus, Brown bullhead			*	
Noturus gyrinus, Tadpole madtom		*		
Ameiurus natalis, Yellow bullhead		*	*	*
POECILIIDAE				
Gambusia affinis, Mosquitofish		*		

Table 2.—Continued.

Family, *species*, common name	Killbuck Creek 1978	Killbuck Creek 2008	Pipe Creek 1978	Pipe Creek 2008
PERCIDAE				
Percina maculata, Blackside darter	*	*	*	*
Percina copelandi, Channel darter	*			
Etheostoma blennioides, Greenside darter	*	*	*	*
Etheostoma nigrum, Johnny darter	*	*	*	*
Percina caprodes, Logperch	*			*
Etheostoma spectabile, Orangethroat darter	*	*	*	*
Etheostoma caeruleum, Rainbow darter		*		

in the average water temperature through sun exposure, imposing additional stress to the headwater fish assemblages (Bartholow 2000).

The fish assemblage of Pipe Creek has experienced a more substantial change than that of Killbuck Creek. The longitudinal gradient which has been shown to structure fish assemblages was more pronounced in Pipe Creek (Angermeier & Schlosser 1989; Belliard et al. 1997; Grenouillet et al. 2004). This effect was also detected in the relationship between the Gradient score of the QHEI, which reflects stream size, with DCA Axis-1 and H'. The influence of stream size could be a reflection of the River Continuum Concept (Vannote et al. 1980). However, Pipe Creek remains a third order stream until it reaches White River. This relationship may also be a product of other factors since the drainage area variablity within the Pipe Creek drainage basin is still relatively uniform when compared to the variability in other studies (Grenouillet et al. 2004). In addition, four of the six most upstream sites have a similar or lower H' while the remaining sites have increased (Fig. 5). This is likely due to the cumulative impact of the recent clear-cutting and dredging that has taken place in Delaware County. Evaluation of historic aerial photographs indicates clusters created by the Pipe Creek DCA axes scores align with the transition from a recently channelized agricultural ditch with virtually no riparian zone to a recovering stream with variable patches of riparian woody vegetation. This relationship was also suggested by the significant correlation between the Channel score and Riparian score of the QHEI with DCA-1 and H'. In addition, the separation of DCA axes values aligns with the transition of Level IV ecoregions, the Clayey, High Lime Till Plains and Loamy, High Lime Till Plains. The Clayey, High Lime Till Plains typically contain soil which has less efficient natural drainage than the Loamy, High Lime Till Plains leading to the increased artificial drainage and channelization (Woods et al. 1998). Therefore, habitat and land use are likely the primary mechanisms structuring the fish assemblage of Pipe Creek.

Fish communities in all Pipe Creek sites were uniform in 1978. Currently there are greater longitudinal differences, most likely due to the observed clear-cutting of the riparian zone and dredging that has occurred in the headwaters since 1998.

Table 3.—Pearson's correlation matrix of DCA axes and H' with QHEI metrics from Killbuck and Pipe Creek, 2008. Significant relationships ($P < 0.05$) are in brackets.

	DCA-1	DCA-2	DCA-3	H'
Killbuck Creek				
Substrate Score	0.16	−0.02	0.42	0.55
Cover Score	−0.59	−0.14	0.14	0.16
Channel Score	−0.38	0.62	0.25	0.18
Riparian Score	−0.56	−0.09	0.29	0.11
Pool/Current Score	[−0.65]	−0.20	0.19	0.06
Riffle/Run Score	0.51	−0.31	0.44	[0.64]
Gradient Score	−0.34	0.01	−0.08	0.03
Pipe Creek				
Substrate Score	[−0.74]	0.11	0.89	0.50
Cover Score	[−0.71]	0.18	−0.29	0.21
Channel Score	[−0.71]	0.24	0.19	[0.63]
Riparian Score	[−0.67]	0.11	0.37	[0.70]
Pool/Current Score	−0.01	−0.12	0.03	0.04
Riffle/Run Score	−0.37	−0.15	0.17	0.39
Gradient Score	[−0.78]	0.52	0.26	[0.82]

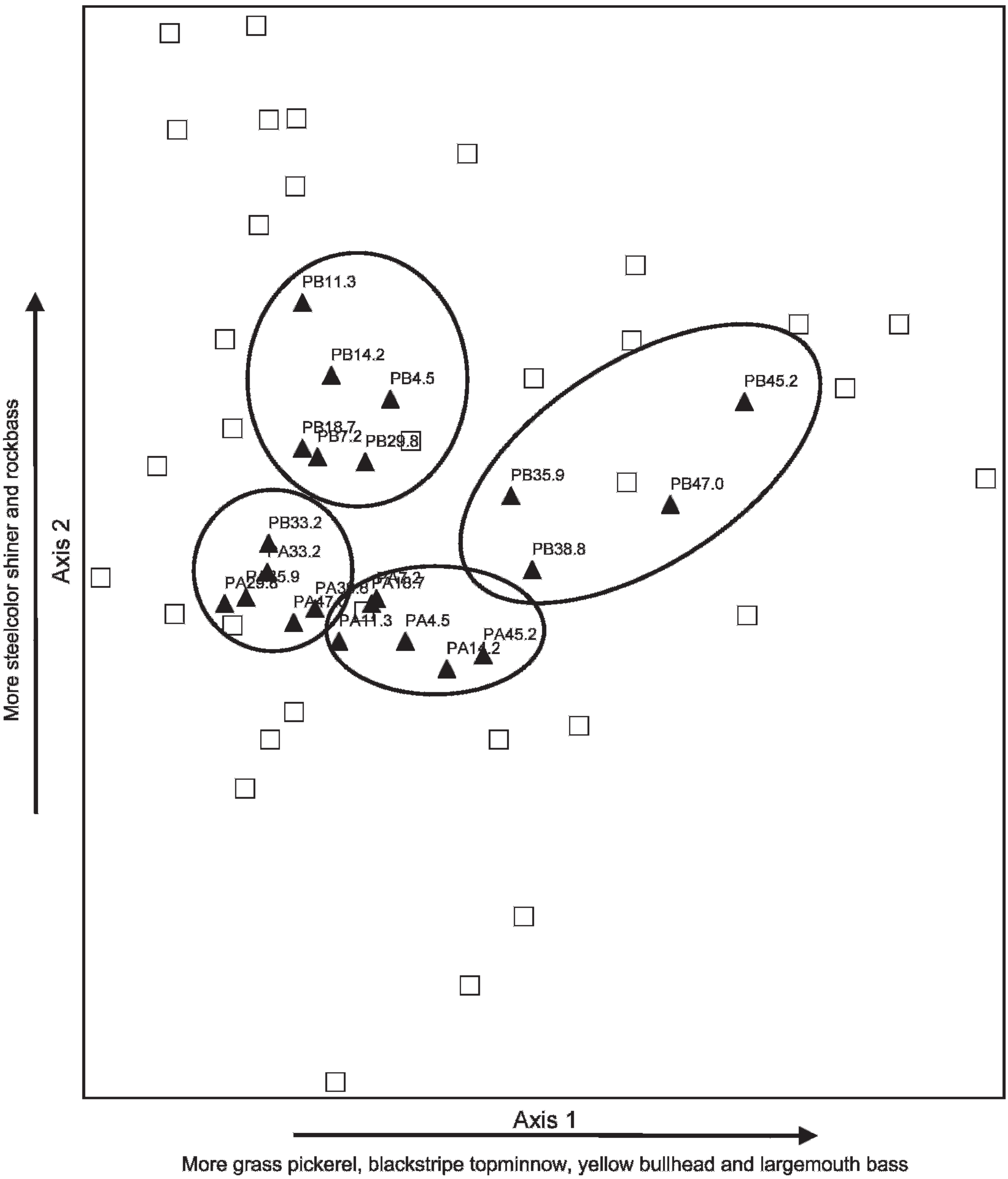

Figure 4.—Detrended Correspondence Analysis axes for Pipe Creek. Triangles represent site scores and squares represent species scores. Clusters in enclosures indicate similar fish assemblage by year (PA = 1978 & PB = 2008) and river kilometer (site numbers).

The role of tributaries and headwater streams in influencing the physical, chemical, and biological integrity of the downstream waters is important with regards to the jurisdiction of the Clean Water Act (CWA) (Nadeau & Rains 2007). To date, the scientific literature suggests a strong link between the two systems (Piccolo & Wipfli 2002; Alexander et al. 2007; MacDonald & Coe 2007). Headwater streams contribute to increased biodiversity in downstream bodies of water by providing refuge from thermal and flow extremes,

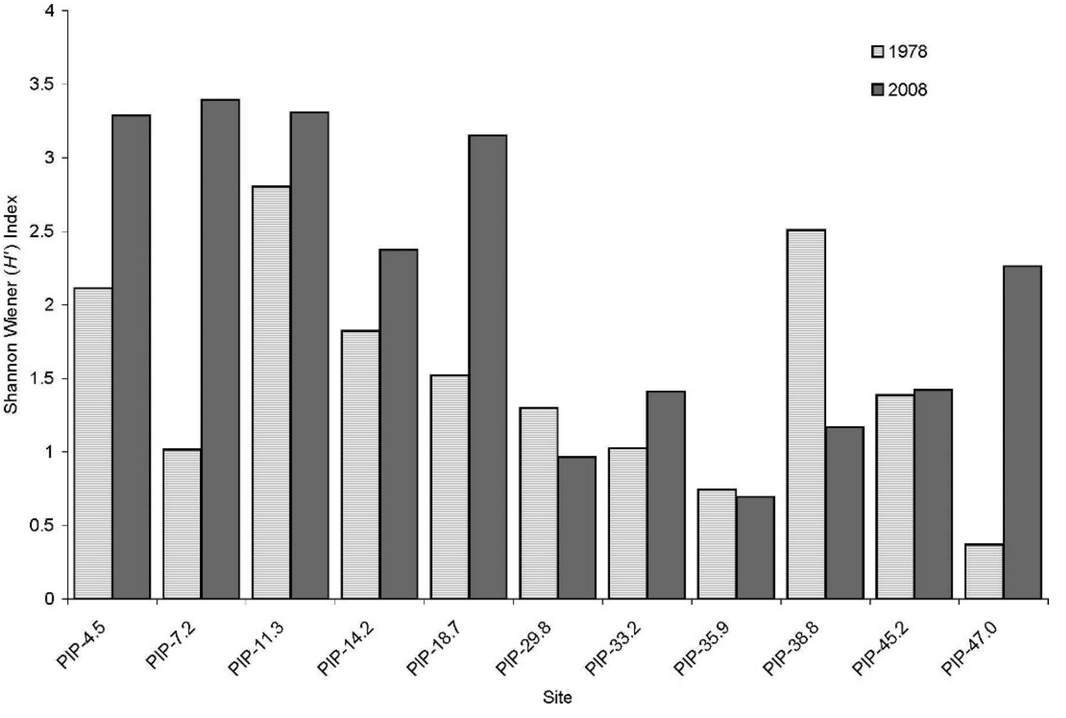

Figure 5.—Shannon Wiener Index (H') at each Pipe Creek sample site, 1978 and 2008 (Number in site label indicates river kilometer).

competitors and predators, as well as providing spawning and rearing sites (Meyer et al. 2007).

It is concluded that the fish assemblages at Killbuck Creek and Pipe Creek have slightly improved since 1978 based on the increased H' and increased sensitive species abundance. However, they do continue to exhibit signs of stress. Both creeks are likely negatively influencing White River. The headwaters of Killbuck and Pipe Creek would benefit from vegetated buffer strips.

Future management & restoration goals.—Conservation practices exist which are capable of improving the quality of these headwaters, such as the installation of riparian buffer strips. Implementation of proper buffer strips comprised of woody vegetation would result in reduced erosion, sediment load, nitrogen, and phosphorus (Vought et al. 1995; Pearce et al. 1998; Simon & Collison 2002; Barling & Moore 1994). Moreover, buffer strips of woody vegetation would allow the streams to return to a cooler thermal regime and provide a source of organic material (Burton & Likens 1973; Hewlett & Fortson 1982).

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