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The Effects of Agricultural Land Use on Benthic Macroinvertebrate Communities and the Applicability of Family Level Bioassessment Metrics in Southern Illinois Headwater Streams

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ABSTRACT

Benthic macroinvertebrates were sampled from fifteen headwater streams, covering a gradient from five to eighty percent agricultural watershed land use/land cover (LULC), in Jersey County, Illinois. A sub-sample of invertebrates was identified to the family taxonomic level. Communities were analyzed in conjunction with LULC distributions calculated at three spatial scales: watershed, 150m stream buffer, and 50m stream buffer. Most streams exhibited similar invertebrate community composition, characterized by low diversity, an absence of pollution intolerant taxa, and a dominance of hydropsychid caddisflies and gammarid amphipods. Exceptions to this trend included three streams, which displayed communities consisting of almost all non-insectan taxa, and one stream, which had a notable population of Perlodidae (Plecoptera). Hilsenhoff's family biotic index (FBI), Shannon-Weiner diversity, and taxa richness and evenness were also calculated to assess stream degradation. None of these bioassessment metrics correlated with LULC. However, percent agriculture was significantly correlated with percent Hydropsychidae (Trichoptera) and percent Gammaridae (Amphipoda). This suggests that while agricultural development alters benthic communities in the Middle Mississippi Border natural division (MMBD) in Jersey County, the family level bioassessment metrics may either be ineffective in this region, or lack the taxonomic resolution to detect agricultural impacts in regional streams. Percent Hydropsychidae had the strongest relationship with agriculture, and may be the best metric for assessing the impacts of agricultural degradation in moderately cultivated regions of the MMBD in west central Illinois.

Keywords: bioassessment, benthic macroinvertebrate, headwater streams, land use, agriculture, biotic index, Illinois.

INTRODUCTION

Agricultural expansion has severely altered the Illinois landscape. Almost 75 percent of pre-settlement forests and 90 percent of the state's historic prairies have been converted to agriculture (Iverson 1988), and it is estimated that Illinois contributes 15 percent of the nitrogen (N) and 10 percent of the phosphorous (P) that cause the hypoxic zones in the Gulf of Mexico (Gentry et al. 2000; Alexander et al. 2008). In addition to its downstream impacts, agricultural development degrades the quality of freshwater systems.

The negative impacts of agricultural development on headwater streams includes: (1) increased sedimentation; (2) greater flow variation, disrupting biological communities and processes; (3) loss of high quality habitat; (4) contamination from pesticides, and (5) increases in surface water N and P concentrations (Allan 2004; Herringshaw et al. 2011). These stressors can lead to decreased biotic diversity and altered trophic dynamics, which impact functional feeding group (FFG) distributions, organic matter transport, and overall stream function throughout the continuum of lotic systems (Cummins 1973; Vannote et al. 1980; Allan 2004; Burcher et al. 2007).

Because macroinvertebrate communities assimilate long-term disturbance and stress trends in freshwater ecosystems, community metrics and biotic indices of macroinvertebrate communities reflect the effects of anthropogenic stressors on food web dynamics, biodiversity, and organic matter transport in stream systems (Cummins 1973; Vannote et al. 1980). Bioassessment metrics provide insights into the health of riverine systems while avoiding the complexity, costliness, and dramatic daily and seasonal variance that accompanies traditional water quality testing (Hilsenhoff 1987; Lenat 1993; Barbour et al. 1999; Bode et al. 2002; Rawer-Jost et al. 2000; Allan 2004). Hilsenhoff's macroinvertebrate index, which was developed to assess stream quality response to organic and nutrient pollution, and its derivatives, have been used extensively by the Illinois Natural History Survey and in other statewide studies (Hilsenhoff 1982-1987; Lenat 1993; Chirhart 2003; Pond et al. 2003; Miller 2004, Sangunett 2005, Stone et al. 2005). Additionally, family and order level macroinvertebrate indices are commonly used in citizen-science stream monitoring programs (Miller 2004; Marchal 2005).

Studies suggest that agricultural development tends to have a net negative impact on invertebrate diversity and community structure when agriculture exceeds 30-40 percent of watershed land use/land cover (LULC) (Genito et al. 2002; Stone et al. 2005; Kratzer et al. 2006; Niyogi et al. 2007). However, the spatial distribution of agricultural development within a watershed, and the specific types of agricultural use both have the potential to strongly influence the impacts that agricultural development have on stream quality (Allan 2004; Stone et al. 2005; Kratzer et al. 2006; King et al. 2005).

The health of stream systems and applicability of macroinvertebrate-based bioassessment has been well documented in agricultural watersheds across Illinois (Genito et al. 2002; Heatherly et al. 2007; Sangunett 2005; Stone et al. 2005). However the impacts of moderate agricultural development in more diverse regions of the state have been less thoroughly studied. Because of its many protected natural areas, hilly karst topography, and riverside bluffs, the southwestern half of Jersey County, Illinois is a mosaic of forested ravines and upland agriculture, boasting nearly twice as much contiguous forest (proportionately) as the rest of the state (Joselyn & Brown 1996; Krohe 1997). In contrast, the northeastern half of Jersey County resembles the typical Illinois landscape, dominated by row-crop agriculture. The diversity in LULC distributions among headwater catchments in Jersey County, from pristine forestland to mixed LULC and heavily cultivated regions, while representative of the diversity found across the state, has yet to be studied as thoroughly as other regions of Illinois.

The purpose of this study was to investigate the relationships among agricultural land use and benthic macroinvertebrate communities in Jersey County's headwater streams. Secondarily, we aimed to evaluate the use of various macroinvertebrate community indices and metrics calculated at the family taxonomic level as means of assessing regional stream quality. It was hypothesized that benthic community structure would be correlated with percent upstream agricultural LULC at the watershed, 150m radial buffer, and 50m radial buffer scales. We expected the correlation to be strongest for the 50m buffers and weakest at the watershed scale. Additionally, it was hypothesized that Shanon-Weiner diversity, evenness, and richness would be negatively correlated with percent agricultural land use and that Hilsenhoff's (1988) family biotic index (FBI) scores would be positively correlated with percent agriculture at all spatial scales.

METHODOLOGY

Study Area

This study was conducted in Jersey County, Illinois within, or on the border of, the Middle Mississippi Border Division (MMBD). The MMBD is one of 14 Illinois natural divisions, first described by Shwegmann et al. (1973). This region stretches from Rock Island County to St. Clair County along the Mississippi River and is characterized by highly dissected karst topography with riverside bluffs, deciduous forests covering the hills and ravines, and cultivated crops in the floodplains and ridge top plateaus (Schwegman et al. 1973; Panno et al. 1997). The MMBD covers the southwestern half of Jersey County and contains most of the county's spring-fed, and high gradient streams (Krohe 1997; Wetzel & Webb 2007).

Stream Selection

We sampled fifteen headwater streams with watershed areas less than 10 km^2. All streams maintained surface flow through riffle sections during the semi-drought conditions of Fall 2013, and are assumed to be perennial. Suitable watersheds were identified using ArcMap (Version 10.2, ESRI, Redlands, CA). Final stream selections were made after conferring with regional experts and making preliminary site visits. Although the initial goal of the study was to sample streams from all regions of Jersey County, only streams in the MMBD met the selection criteria (perennial, headwater streams with riffle habitats). Once qualifying streams were delineated, sample sites were selected based on upstream catchment size (<10km^2), stream access (land-owner permission and roadside proximity), and LULC distributions so that all streams fell on a gradient from low to high upstream agricultural development (Table 1). Sites in close proximity to roads were sampled upstream of any bridges or culverts.

ArcMap was then used (with Hydrology Tool in Spatial Analyst) to delineate watersheds upstream of the sample reaches, along with 50m and 150m radial buffers for each stream. LULC distributions were calculated for each watershed and stream buffer class using the NLCD 2006 dataset. Agricultural LULC included row crop and pasture hay classifications. LULC was calculated considering these cover types individually and combined.

Sample Reach Characterization

Sixty meter reaches were delineated at each sample site. All reaches had at least five meters of riparian vegetation on one bank. Substrates were primarily small cobble and gravel intermixed with silt or bedrock substrates. Riffle velocity was measured at a representative riffle in each reach. Discharge was calculated at channelized areas with uniform flow, which were often transition zones between riffle and pool habitats. Stream width was measured at representative riffle, pool, and channel cross-sections. Additionally, 10 habitat quality indicators (epifaunal substrate/available cover, embeddedness, velocity/depth combinations, sediment deposition, channel flow status, channel alteration, riffle frequency, bank stability, bank vegetation, and riparian zone vegetation) were visually assessed on a scale from 1-20 (least to most) following the protocols outlined by the US EPA (Barbour et al., 1999). Temperature, pH, conductivity, total solids, and dissolved oxygen were measured using the YSI 556 water quality probe (YSI Incorporated, Yellow Springs, OH).

Table 1. The global positioning system (GPS) coordinates (Lat/Lon), distributions of upstream agriculture, forest, and urban land use (LULC) for all sampled streams at the watershed, 150m buffer, and 50m buffer spatial scales.

Site	Lat./Lon. Cooridinates	% Ag Watershed	%Ag 150m	%Ag 50m	%Forest Watershed	%Forest 150m	%Forest 50m	%Urban Watershed	%Urban 150m	%Urban 50m
1	38.9655, -90.3263	56.7	48.2	32.6	36.7	47.4	63.2	6.2	3.7	2.7
2	39.0264, -90.5271	4.7	8.4	12.5	92.3	89.4	84.6	3.0	2.2	2.9
3	39.0761, -90.5132	11.3	4.5	2.2	87.1	95.5	97.8	0.7	0.0	0.0
4	39.0849, -90.5528	33.9	26.3	16.7	59.7	66.7	73.7	6.3	6.8	9.2
5	39.0789, -90.4282	72.5	54.6	35.6	23.0	41.9	60.7	4.4	3.6	3.7
6	39.1082, -90.5563	50.6	36.3	21.4	46.0	60.6	73.3	3.4	3.1	5.3
7	39.1354, -90.5536	32.9	14.2	4.0	63.6	82.2	88.9	3.5	3.6	7.1
8	39.1647, -90.5294	45.4	39.1	22.5	49.8	55.7	68.5	4.6	5.0	8.4
9	39.1635, -90.5298	25.7	9.0	2.8	72.6	90.9	97.2	1.6	0.0	0.0
10	39.1428, -90.5006	48.6	25.7	11.0	46.9	69.8	38.5	4.5	4.5	3.4
11	39.0006, -90.2828	72.4	63.5	37.0	24.6	34.1	61.6	3.0	2.3	1.4
12	38.9957, -90.2835	71.4	75.8	63.7	15.6	19.7	32.6	12.6	4.0	2.6
13	39.0085, -90.2758	80.2	75.6	64.4	8.6	14.0	26.2	10.1	8.3	5.3
14	39.0586, -90.4680	17.5	8.3	2.8	78.2	90.4	96.7	4.2	1.3	0.5
15	38.9722, -90.3951	27.5	19.5	6.5	70.1	78.6	93.5	2.5	1.9	0.0
Mean		**43.4**	**33.5**	**22.4**	**51.7**	**62.5**	**70.5**	**4.7**	**3.4**	**3.5**

Macroinvertebrate Sampling

Benthic macroinvertebrates were sampled during base-flow conditions between 15 September and 16 October 2013. A 0.09m^2 Surber sampler, mesh size 500 µm, was used to sample riffle habitats (shallow, fast water habitats with stream flow rates >0.02 m s^{-1}). Between two and five samples were collected in representative riffles at each reach by disturbing, kicking, rubbing, and upturning the substrate for one minute. Large sticks and leaves were removed, and all macroinvertebrates and remaining detritus were transferred into mason jars and mixed with 95 percent ethanol. The net was rinsed and picked for remaining macroinvertebrates (>3mm) for roughly five minutes.

Upon return to the lab, jars were drained and filled with 70 percent ethanol. At least 150 invertebrates were picked from each sample by evenly spreading the sample across two gridded pans and picking all invertebrates from randomly selected grids. Individuals were identified to family (or the next lowest taxonomic level, if the family could not be identified) and stored in 70 percent ethanol or isopropyl alcohol.

Analysis

Shannon Diversity (H'), family richness, evenness, and taxa and functional feeding group (FFG) distributions were calculated to assess community structure. For FFG analysis, taxa were divided into five groups: shredders, scrapers, collector-filterers, collector-gatherers, and predators (Cummins 1973; Voshell 2002; Cummins et al. 2005). Hilsenhoff's FBI was also calculated to estimate the effects of organic and nutrient pollution (Hilsenhoff 1982-1988).

Pearson's correlations were run among the explanatory variables — LULC distributions, macroinvertebrate abundances, and community metrics — using the SPSS statistical software package (Version 19, IBM, New York, NY). Correlations were considered significant at $p<0.1$. A Principal Components Analysis (PCA) was also determined using PCOrd (Version 6, MjM Software, Gleneden Beach, OR) to investigate multivariate patterns in the family-level and the FFG data as well as to identify the strongest explanatory variables of those patterns (McCune & Grace 2002).

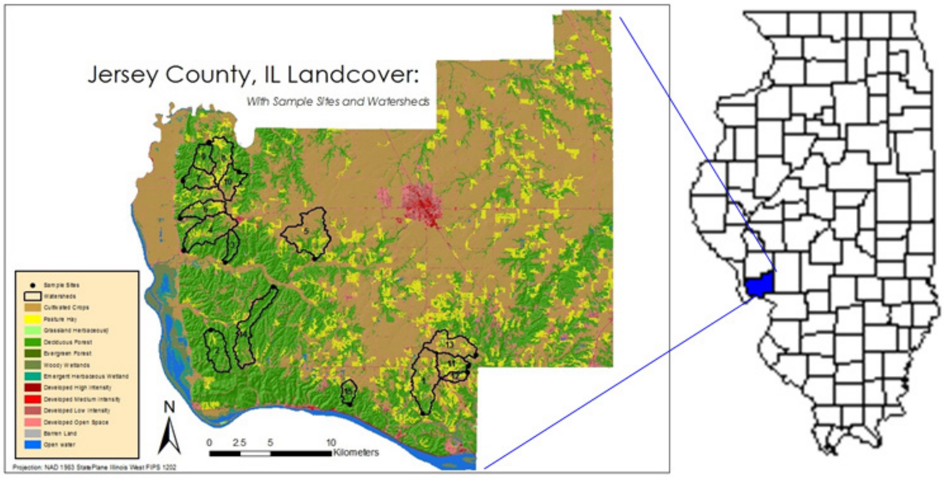

Figure 1. Map of Illinois showing the location of Jersey County and the specific Land Use/ Land Cover (LULC) for Jersey County (NLCD 2006) with sampled locations and corresponding watersheds.

RESULTS

Land Use

The LULC of Jersey County, including the sampled watersheds, is shown in Fig. 1. Agricultural LULC ranged from 4.7 to 80.2 percent among sampled watersheds. Cultivated crops composed roughly 66% of total agriculture among the sampled watersheds, and pasture hay accounted for the remaining 33 percent (Table 1). Forest cover ranged from 8.6 to 92.3 percent at the watershed scale, and was inversely correlated with agriculture at all spatial scales (r^2=0.99 for the watershed and 150m buffers; r^2=0.72 for the 50m buffers). In light of this negative correlation, forest cover and agricultural cover do not functionally serve as separate independent variables in our analysis. Urban development in the sampled watersheds was negligible (<13% with 4.7 percent average for all sampled streams). All surveyed streams had at least 26 percent forest cover within their 50m buffers (Table 1). Additionally, the ratio of agriculture to forest cover was lowest in the 50m buffers (0.32) and highest at the watershed scale (0.84), indicating that agricultural development tended to occur away from the riparian zones.

Stream Characteristics

Average discharge was 0.019 m^{3}s^{-1}. The wetted width at riffle sections ranged from 0.5 to 2.7 m. Channel width ranged from 3.5 to 13.3 m. Habitat Assessment (HA) scores ranged from 110 to 167, out of 200. Substrate, embeddedness, channel flow status, and vegetative protection displayed the most variation in visual assessment scores among sampled streams. HA scores correlated with forest cover at all spatial scales, with the strongest correlation occurring for the 50 m buffers (r=0.72, p=0.002).

Dissolved oxygen ranged from 6.14 mg L^{-1} to 10.17 mg L^{-1} and had a negative correlation with agricultural land use at the watershed (r=-0.45, p=0.09), 150m buffer (r=-0.52, p=0.05), and 50 m buffer (r=-0.45, p=-0.01) scales. All sampled streams were slightly acidic, averaging a pH of 5.90. Stream 5 had an abnormally low pH of 4.66. Conductivity ranged from 0.514 to 0.728 MS s^{-1}.

Macroinvertebrate Community Structure

Eighteen families and two classes of benthic invertebrates were identified (Table 2). Hydropsychidae and Gammaridae were co-dominant accounting for 39% and 28% of invertebrates, respectively. Ninety-four percent of all invertebrates identified were distributed among the five most common families (Table 2).

The distribution of FFGs varied from 100 percent shredders at stream 2, to predominately collector-filterers at stream 13 (Fig. 2). In the PCA, axis 1 accounted for 55 percent of the variance and axis 2 accounted for 19.2 percent of the variance (Fig. 3). Axis 1 covered a gradient from shredder

Table 2. The distribution of collected and identified taxa, in percent, for each sampling site.

Site #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hydropsychidae	49.7		16.6	58.8	43.2	50.3	5.2	42.6	71.8		55.5	69.1	81.2	33.7	
Gammaridae	18.4	98.7	56.1	10.1	8.6	14.9	37.2	22.2	3.4	49.4	15.5	5.5	7.8	7.1	90.2
Asellidae	12.8	1.3	24.8	12.7	35.2	24.1	36	17.0	4.0	50.0	15.5	16.4	1.3	43.8	5.5
Chironomidae	6.1			0.9	1.9	0.5	11.6	2.3	1.7		1.9	3.6	1.9		
Tipulidae	1.1			2.2		5.6	0.6		7.3				0.6	3.0	
Simuliidae				4.8				1.7	2.3					0.6	
Dixidae									0.6						
Tabanidae											0.6				
Calopterygidae				0.4									1.3	0.6	
Veliidae	4.5			0.4	0.6						2.6		1.3	0.6	
Baetidae	0.6		0.6	9.2	10.5	4.1	7.6	9.7	8.5	0.6	1.9	4.2		5.3	
Heptageniidae								1.1			0.6	1.2	0.6		
Physidae	0.5										0.6			0.6	3.0
Planorbidae															0.6
Elmidae	5.6							1.7			1.3		2.6	0.6	
Psephenidae											1.3				0.6
Coleoptera									0.6						
Oligochaeta	0.6		0.6								2.6				
Hirudinea			0.6												
Turbellaria			0.6	0.4		5.1		1.7					1.3	0.6	
Perlodidae														3.6	
Unidentified							1.7								

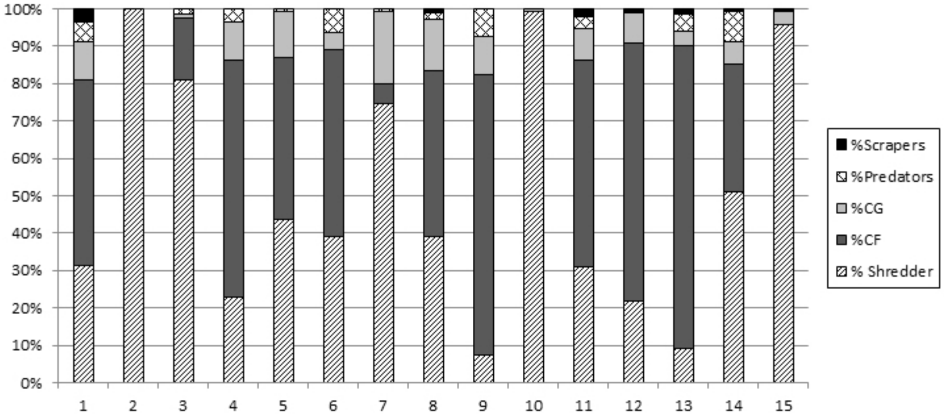

Figure 2. Functional feeding group (FFG) distributions for all streams.

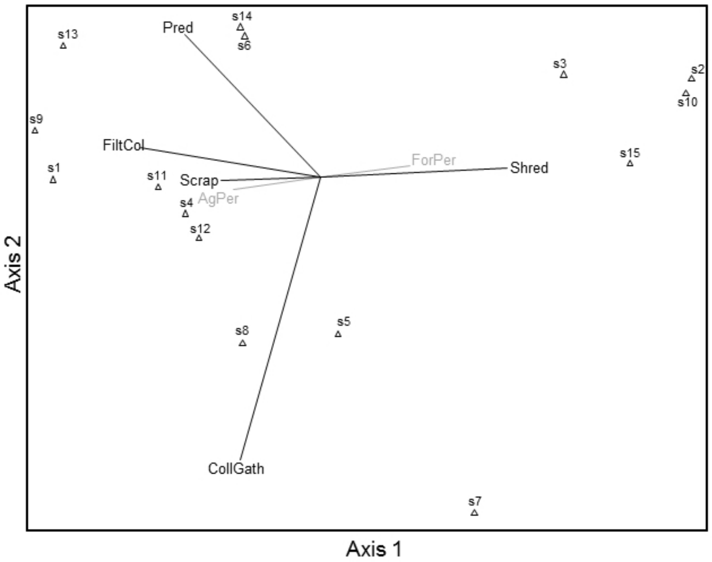

Figure 3. Principal Components Analysis (PCA) showing Axis 1 and Axis 2, which accounted for 74.2% of the variance. Sampled streams are shown as points. FFG and land use gradients are shown in the ordination space.

dominance on the right to scraper and collector-filterer dominance on the left. Axis 2 followed a gradient from collector-gatherers on the bottom to predators on the top. The streams separated into three main groupings in the ordination space with shredder dominated communities on the far right, mixed communities in the center and collector-filterer dominated communities on the left. Watershed scale agriculture and forest cover had strong loadings on axis 1 (Fig. 3).

Functional Feeding Group Analysis

Pearson's correlation coefficients and *p*-values are shown for the five FFGs and LULC variables at all spatial scales in Table 3. Shredders were positively correlated with forest cover and negatively correlated with agriculture at the watershed and 150m buffer scales and positively correlated with agriculture for all three spatial scales. Collector-filterers and scrapers were positively correlated with agriculture and negatively correlated with forest cover. Correlations for these three FFGs were significant at all three spatial scales for agriculture and significant at only the watershed and 150m buffers for forest cover. Collector-gatherers were positively correlated with urban land-cover in the 50m buffers. Predators were not correlated with LULC or any explanatory variables (Table 3).

Family-Level Relationships

Pearson's correlation coefficients and *p*-values for the five dominant families and LULC variables at all spatial scales are shown in Table 4. Gammaridae were negatively correlated with agriculture and positively correlated with forest cover. Hydropsychidae were positively correlated with agriculture and negatively correlated with forest cover. Correlations were significant for all spatial scales except forest in the 50m buffers (Table 4). The strongest correlation was with Hydropsychidae and agriculture within the 50m buffers (Fig. 4).

Community Metrics

Hilsenhoff's FBI scores ranged from 4.0 to 6.0 (Table 5). Shannon-Weiner family diversity (H') ranged from 0.07 to 1.57 (Table 5). Family richness ranged from 2 to 12 with an average richness of 7. Family evenness ranged from 0.10 to 0.72 (Table

Table 3. Pearson's correlations and *p*-values in parentheses among the functional feeding groups (FFGs) and land use/land cover (LULC); n=15 (**significant at p<0.05; *significant at p<0.1, NS = not significant).

	%Agriculture Watershed	%Agriculture (150m)	%Agriculture (50m)	%Forested Watershed	%Forested (150m)	%Forested (50m)
Gammaridae	-0.58 (0.03)**	-0.57 (0.03)**	-0.57 (0.03)**	0.57 (0.03)**	0.58 (0.02)**	NS
Asellidae	0.57 (0.02)**	0.61 (0.02)**	0.63 (0.01)**	-0.59 (0.02)**	-0.61 (0.02)**	NS
Hydropsychidae	NS	NS	NS	NS	NS	NS
Baetidae	0.49 (0.07)*	0.57 (0.03)**	0.52 (0.048)**	-0.50 (0.06)*	-0.56 (0.03)**	NS
Chironomidae	NS	NS	NS	NS	NS	NS

Table 4. Pearson's correlations and *p*-values in parentheses among the five most dominant families and land use/land cover (LULC); n=15 (**=significant at p<0.05; *=significant at p<0.1, NS=not significant).

	%Agriculture Watershed	%Agriculture (150m)	%Agriculture (50m)	%Forested Watershed	%Forested (150m)	%Forested (50m)
Gammaridae	-0.58 (0.02)**	-0.50 (0.056)*	-0.45 (0.095)*	0.59 (0.02)**	0.50 (0.057)*	NS
Asellidae	NS	NS	NS	NS	NS	NS
Hydropsychidae	0.58 (0.02)**	0.64 (0.01)**	0.65 (0.01)**	-0.62 (0.01)**	-0.64 (0.01)**	NS
Baetidae	NS	NS	NS	NS	NS	NS
Chironomidae	NS	NS	NS	NS	NS	NS

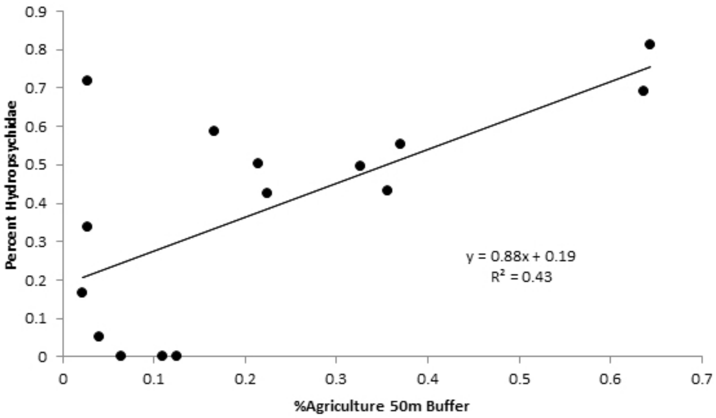

Figure 4. Regression line and r^2 values for percent Hydropsychidae and percent agriculture in the 50m buffers.

Table 5. Hilsenhoff's family biotic index (FBI), Shannon-Weiner diversity (H’), richness, and evenness for all sampling sites.

Site	FBI	H’	Richness	Evenness
1	4.4	1.53	9	0.67
2	4.1	0.07	2	0.10
3	4.9	1.10	6	0.56
4	4.6	1.37	8	0.59
5	5.4	1.28	6	0.72
6	4.9	1.32	7	0.68
7	5.6	1.37	6	0.70
8	4.7	1.57	9	0.71
9	4.1	1.09	8	0.50
10	6.0	0.73	3	0.66
11	4.4	1.46	12	0.59
12	4.7	1.02	6	0.57
13	4.0	0.83	9	0.38
14	5.6	1.48	12	0.59
15	4.1	0.42	5	0.26
Mean	4.8	1.11	7	0.55

5). Neither FBI, H’, nor taxa richness and evenness showed a significant correlation with any LULC variables. Shannon-Weiner diversity was positively correlated with channel width (*r*=0.54, *p*=0.04), indicating possible relationship between diversity and stream size. Evenness also was positively correlated with channel width (*r*=0.47, *p*=0.08).

DISCUSSION

Community Structure

The dominance of shredders and collector-filterers found in the Jersey County streams sampled in this study is comparable to what one would expect for healthy, heterotrophic, headwater streams. Additionally, the FFG distributions indicate normal patterns of organic matter transport through Jersey County's headwater systems (Vannote et al. 1980). The shredder Gammaridae and collector-filterer Hydropsychidae, however, overwhelmingly dominated these two FFGs. The importance of these two families suggests that they are responsible for fulfilling key ecological roles in the regions headwater systems. While the consistent co-dominance of these taxa was unique to this study, many of the taxa more commonly observed among our streams (Table 2), including Hydropsychidae, Baetidae, Chironomidae, Elmidae, Simuliidae, and Sub-Class Oligochaeta, have been commonly found in streams throughout the state (Heatherly et al. 2007).

However, Illinois streams in watersheds with predominately agricultural and urban LULC have been shown to exhibit functionally different communities dominated by collector-gatherers and pollution tolerant families including Chironomidae, Ceratopogonidae, and non-insectan taxa such as Oligochaeta (Gorman 1987, Sangunett 2005, Stone et al. 2005, Heatherly et al. 2007). In contrast, collector gatherers, Ceratopogonidae and Oligochaetes were uncommon among our streams. Chironomidae, while more consistently observed, was never present in large populations (Table 2). Regional differences, differences in methodology, and innate community differences for low gradient, ephemeral streams—which were sampled in many comparable studies—may partially explain these differences. Still, similar taxa have been linked with agriculturally degraded and organically polluted streams throughout the country, and in high gradient, perennial streams, regardless of sampling methodology (Heatherly et al. 2007, Heringshaw et al. 2011, Kratzer et al. 2006).

Despite these differences, the absence of diverse Ephemeroptera, Trichoptera, and Plecoptera (EPT) taxa in this study suggests that the region's agriculture has moderately degraded stream quality. Percent EPT is a common bioassessment metric, and EPT taxa are traditionally considered indicators of good water quality (Barbour et al. 1999). Nutrient and sediment pollution, which are derivatives of agricultural development, have been consistently linked with decreases in the diversity and range of EPT populations (Griffith et al. 2001, Chirhart 2003, DeWalt 2003, Sangunett 2005, Lenat & Penrose 1996). Although EPT richness varies regionally throughout Illinois, most streams throughout the state have displayed higher EPT richness than that observed in this study (DeWalt 2003, Miller 2004).

Hydropsychidae (Trichoptera), which represented 39 percent of all invertebrates and were present at 12 of the 15 sampled streams, was the most common EPT taxa collected. Although percent EPT has been shown to decrease in agriculturally stressed streams, many genera of Hydropsychidae have a high tolerance for agricultural pollution. Some Hydropsychidae such as *Cheumatopsyche*, a genus common in Illinois, have been shown to exhibit hyper-dominance in response to nutrient enrichment and organic pollution (Pond et al. 2003, Heatherly et al. 2007). The high proportion of Hydropsychidae present among the streams sampled in this study likely indicates a moderate base level of agricultural induced nutrient enrichment in streams throughout the county.

Furthermore, of all the families, Hydropsychidae had the strongest correlation with percent agriculture, the FFGs, and bioassessment metrics. While significant at all spatial scales, the correlation was strongest for the 50m buffers and weakest at the watershed scale. This suggests that the negative impacts of agriculture decrease the further the development is from a stream's riparian zone. Stream 9, which exhibited a Hydropsychidae dominated community (Table 2) despite having only 2.8 % riparian agriculture (50m buffer), is an exception to this trend. The disproportionately high amount of upland agriculture in this watershed may contribute to the community dynamics in this stream.

Community Anomalies

Although Gammaridae were consistently collected at all sampled streams, stream numbers 2, 10, and 15 displayed unique, non-insectan communities overwhelmingly dominated by Gammaridae and Isopoda (Table 2). Additionally, these three streams were the only locations where Hydropsychidae was not collected. The apparent uniqueness of these communities is supported by the PCA, which grouped these three streams together in ordination space along with stream 3, as a solitary cluster.

Illinois streams with proximal hard-water spring inputs have been shown to have benthic communities dominated by amphipods and other non-insectan taxa (Webb et al. 1995; Wetzel & Webb 2007). We hypothesize that the benthic communities in these three streams, and potentially stream 3, are strongly influenced by upstream hard-water springs, which are common in the MMBD. The potential for certain streams to exhibit significantly different, non-insectan communities, even in pristine or heavily forested watersheds, should be considered when using macroinvertebrate bioassessment to compare the organic and nutrient pollution among streams in this region.

The presence of Perlodidae (Plecoptera) at stream 14, a highly forested and relatively pristine watershed with negligible development, was also unique among surveyed streams. The presence of a notable population of Perlodidae (6 percent) suggests that historically, EPT richness may have been higher throughout Jersey County. This is especially noteworthy given that Plecoptera have experienced high rates of extinction/extirpation in Illinois (DeWalt 2004). Interestingly, stream 14 was also home to a large population of Isopoda, which are often associated with organic pollution (Williams 1976, Heatherly et al. 2007). This complicates any conclusions may could be drawn about the water quality at stream 14.

Bioassessment Metrics

The bio-assessment metrics failed to show any significant relationships between streams and the LULC variables. The collective failure of all the tested metrics to differentiate among sampled streams suggests that stream quality may not vary significantly throughout the study area. The rarity of watersheds with over 60 % cultivated croplands—which contribute to the nitrification and sedimentation of streams more than pasture hay—and the spatial distribution of agricultural lands in the region may explain the lack of correlation between water quality and percent agriculture, based on the bioassessment metrics.

However, the correlation between Hydropsychidae and percent agriculture, along with the PCA, indicate that stream quality was degraded enough in this study's most agricultural catchments to stimulate shifts in community structure. Although having been widely accepted as effective bioassessment tools, these metrics may be less successful in regions that have a small range in environmental conditions (Kratzer et al. 2006). Additionally, DeWalt (2003) and Sangunett (2005) found that Hilsenhoff's index (and its derivative indices) scores varied little across the state and may not be effective tools for statewide bioassessment.

SUMMARY

Our assessment of streams in the MMBD portions of Jersey County was consistent with a study done by DeWalt (2004), who found that despite being characterized by low diversity, the MMBD exhibited generally healthy stream communities. Most streams in this survey were dominated by two families, Gammaridae and Hydropsychidae, and displayed similarly structured communities with low diversity and an absence of pollution intolerant taxa. Similar traits are often associated with streams suffering from the impacts of agricultural development (Voshell 2002, Pond et al., 2003, Heatherly et al. 2007, Lenat & Penrose 1996, Stone et al. 2005, Song et al. 2009). However, compared to studies of highly polluted agricultural and urban watersheds, the benthic communities in our streams were more indicative of a moderate deterioration in stream quality than they were of a highly degraded, and functionally altered ecosystem (DeWalt 2004, Vinikour & Anderson 1984; Sangunett 2005; Stone et al. 2005).

Agricultural development in the surveyed watersheds generally occurred on ridge top plateaus, leaving forested riparian zones. Nonetheless, percent agriculture was correlated with changes in community structure. Percent Hydropsychidae was the most effective metric for gauging the impacts of regional agricultural development. H', richness, evenness, and Hilsenhoff's FBI showed no correlation with the LULC data, suggesting that these metrics may not be effective in monitoring the impacts of moderate agricultural development on streams in this region.

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