8-1-2012

LATE SPRING SURVEY AND RICHNESS ESTIMATION OF THE AQUATIC BENTHIC INSECT COMMUNITY IN THE UPPER PORTION OF THE LUSK CREEK WATERSHED

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by

Jacqueline M. Turner

B. S., Southern Illinois University, 2001

A Thesis
Submitted in Partial Fulfillment of the Requirements for the
Master of Science Degree

Department of Zoology
in the Graduate School
Southern Illinois University Carbondale
August 2012

THESIS APPROVAL

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in the field of Zoology

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AN ABSTRACT OF THE THESIS

JACQUELINE M. TURNER, for the Master of Science degree in Zoology, presented on 30 April 2012, at Southern Illinois University Carbondale.

TITLE: LATE SPRING SURVEY AND RICHNESS ESTIMATION OF THE AQUATIC BENTHIC INSECT COMMUNITY IN THE UPPER PORTION OF THE LUSK CREEK WATERSHED

MAJOR PROFESSOR: Dr. J. E. McPherson

The Lusk Creek Watershed, located in Pope County, IL, long has been recognized as a high quality area and as biologically significant. Yet, surveys of the macroinvertebrate fauna have been limited. Thus, a survey of the benthic insect community in the upper portion of Lusk Creek was conducted from May 2003 to April 2005. Eleven sites were selected and characterized by physical properties and water chemistry. Insect distribution patterns, abundance, and diversity (richness, evenness) were examined.

A total of 20,888 specimens, mostly immatures, were examined during the study and represented eight orders. The Diptera, by far, was the most common order, with 18,590 specimens, almost all of which were members of the Chironomidae and Simuliidae. The EPT (Ephemeroptera, Plecoptera, Trichoptera) combined were common with 1,550 specimens but paled in comparison to the Diptera. The Coleoptera was represented by 647 specimens, almost all of which were members of *Stenelmis* (n = 612). The Shannon diversity index (H') showed that the H' values for individual sites were similar to those reported for other relatively undisturbed streams. Analyses of richness suggested that as many as 37 taxa were unobserved, indicating the survey was incomplete.

DEDICATION

I dedicate this research to Drs. Richard R. and Jean W. Graber, who inspired my appreciation of all living things and encouraged me to return to school to study insects, and to my parents, Bill and Bea Turner, who taught me to love animals.

ACKNOWLEDGMENTS

I thank Dr. J. E. McPherson, my major professor and co-chair of my graduate committee, for his advice, support, and encouragement during my undergraduate and graduate studies including my thesis. I could have not completed this paper without his guidance and assistance. I am indebted to him for his work on my behalf.

I would like to thank Dr. Matt R. Whiles, also co-chair of my graduate committee, for his advice and counsel during my graduate studies including my research and the writing of this paper. His ecological expertise was needed and appreciated.

I am grateful to the other members of my graduate committee, Drs. R. Edward DeWalt (Illinois Natural History Survey, University of Illinois, Champaign) and Brooks M. Burr (Department of Zoology). Dr. DeWalt was the inspiration for this research project. His guidance with site selection, sampling, and insect identification was needed and appreciated. Dr. Burr always was supportive and a grounding influence.

I thank Ms. Pat McNeil (Graduate School) for her unwavering belief in me. Her kindness and support have sustained me during my entire time as a graduate student.

I would like to thank those who have generously donated their time and expertise. Dr. John D. Reeve (Department of Zoology) provided many hours of statistical insight. From the Morris Library Geospatial Resources, Kevin Davie provided many hours of mapping assistance, and Nathan Rahe assisted with figures.

I would like to thank the USFS and IDNR staff for their support. John Taylor, USFS, gave me permission to sample on the Shawnee National Forest. Kris Twardowski, USFS, provided National Natural Area mapping assistance. Jody Shimp, IDNR, provided permitting guidance and grant assistance. He helped me obtain Illinois Department Natural Resources Wildlife Preservation Fund Grant #04-30W and provided grant administrative support. Tara Kieninger, IDNR, provided Illinois Natural Area Inventory information.

I have many to thank in the Department of Zoology for their efforts on my behalf. Dr. William L. Muhlach helped me obtain Federal Work Study matching funds for my two undergraduate student workers, Angela Defore and Kristi Magraw. I thank them both for their invaluable assistance. Angela spent weeks, and Kristi months picking through samples, a tedious task. Dr. Frank M. Wilhelm and Mike Venarsky in the Limnology Laboratory and Tom Heatherly, Scott Peterson, and Mandy Stone in the Stream Ecology Laboratory provided technical assistance and support. Judy Rains and Karen Gibson provided administrative assistance and support. Shannon Voss, Rachel Shurtz, and Denise Walther provided support and encouragement.

Finally, I would like to thank my husband, Dr. Joseph M. Glisson, for his support and counsel of me and my educational pursuits.

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CHAPTER 1

INTRODUCTION

Illinois, known unofficially as the prairie state (Shankle 1938), has undergone major landscape changes during the last 200 years, primarily because of agricultural and industrial development. Not unexpectedly, these anthropogenic changes have been concentrated in the highly populated regions of northern Illinois (IDENR 1994a) and the heavily farmed areas of central Illinois (IDENR 1994b).

Prior to intensive European settlement, over half of Illinois was prairie (21.6 million acres) with the reminder primarily forest (13.8 million acres), which often was concentrated along rivers (Anderson 1970, Iverson et al. 1989). In 1800, the United States census indicated there were 2,458 people in Illinois (Boggess 1908). By 1820, the population had increased to just over 55,000 (Telford 1926), with most individuals residing in the southern forests (Anderson 1970). From 1830 to 1840, 300,000 settlers moved into the central prairie region and developed all but a small fraction of this area (Telford 1926).

By 1924, the total forest acreage of Illinois had been reduced to just over 3 million acres (Telford 1926). By 1967, Klopatek et al. (1979) estimated that only 11% of Illinois' natural vegetation still remained. By 1990, over 80% of Illinois was farmland, with 2/3 in corn and soybeans, and less than 2,400 acres of high quality prairie remained (IDENR 1994b). In less than 200 years, therefore, almost all of the prairie and most of the original forest had been converted to agricultural land.

SOUTHERN ILLINOIS AND POPE COUNTY

In 1820, the southern portion of Illinois was covered almost completely by forest (Anderson 1970, Iverson et al. 1989). At that time, Pope County had 236,300 acres of forest (Iverson et al. 1989) and a human population of 2,610. By 1890, the population had reached its peak of 14,017 (Pope County Historical Society 1986). By the early 1900s, most of the forest cover of the Shawnee Hills, which included much of Pope County, had been removed, and most land was being farmed "intensively" (Kandl 1990).

By 1924, the forested area of Pope County had been reduced to 65,259 acres (Telford 1926). By the beginning of the Depression the land was no longer profitable for farming and much of it had been "forfeited" (i.e., foreclosed). As a result, the eastern Shawnee Hills region was selected as the site of a national forest (Soady 1965). By 1980, the population had decreased to 4,250 (Pope County Historical Society 1986). By 1985, forest acreage in the county had increased to 149,200 acres (Iverson et al. 1989).

BASELINE STUDIES AND REFERENCE CONDITIONS

Studies of anthropogenic changes, both biological and physical, ideally would include baseline studies preceding human influence for comparison. As that generally is not possible, baseline studies of systems with limited human influence generally are used to establish reference points for assessing ecological integrity (Metzeling et al. 2006).

White (1978) surveyed Illinois natural areas and found, based on 1,089 sites, only 25,723 acres of high quality natural communities. Large areas of the state had no high quality sites, including the former central prairies that had been almost completely farmed; other areas had clustered sites that were located near the western and southern borders of Illinois along rivers and bluffs. The 11 southernmost counties had 396 sites, including Pope County with 88 sites, of high quality natural communities (White 1978); T. G. Kieninger (personal communication) stated that the 396 and 88 sites included 5,274 and 319 acres, respectively. This high number of sites and large amount of high quality acreage in southern Illinois reflects the lower degree of anthropogenic impacts in this region.

LUSK CREEK

Southern Illinois contains a variety of aquatic and semi-aquatic habitats, including small and large streams. One of the smaller systems is Lusk Creek, which lies entirely within Pope County (Figs. 1A and B). Draining north to south, it is ca. 40-km in length. The Lusk Creek watershed has high topographic relief (Fig. 2), which apparently has protected the major stream valleys from human impact (Hudak 1979).

The Lusk Creek watershed has received several designations and ratings that recognize the high quality of the area. In 1970, Lusk Creek Canyon (LCC) was designated an Illinois Nature

Preserve (INPC 2008). In 1980, a portion of the Lusk Creek watershed and its stream, including LCC, was designated a National Natural Landmark (NPS 2009). K. Twardowski (personal communication) provided a map that showed the portion of the stream included from south of Dog Hollow to just north of Ramsey Branch. In 1989, Lusk Creek from Manson Ford to Little Lusk Creek was rated as a "Unique Aquatic Resource (Class A)" stream (Hite and Bertrand 1989). In 1990, a portion of Lusk Creek and the adjacent watershed (from the Lusk Creek/Dog Hollow confluence to Ramsey Branch [USFS 1996]) were designated a National Wilderness Area, which is a federal land designation where natural processes dominate the landscape and the human presence is "substantially unnoticeable" (United States Congress 1990). In 1992, Lusk Creek from Flick Branch to Quarrel Creek and from Manson Ford to Little Lusk Creek and Copperous Branch were rated as "Biologically Significant Streams" (Page et al. 1992). In 1993, Lusk Creek from Copperous Branch to just upstream of Ramsey Branch was rated as a "Unique Aquatic Resource" (Class A stream), and the remaining upstream and downstream portions of Lusk Creek and the entire length of Little Lusk Creek were rated as a "Highly-valued Aquatic Resource" (Class B stream) (Bertrand et al. 1996).

A WATERSHED AND ITS STREAM

Watershed area increases geometrically in relation to stream order (Smith and Smith 2001). Stream size is a function of watershed area (Leopold 1997). As the watershed area increases, the volume of stream flow generally increases (Brooks et al. 2003). Base flow is the amount of flow that is present year-round and results from water stored in the watershed (Newbury 1984). In temperate regions, small streams may become dry during the summer as the water table drops (Feminella 1996).

The watershed governs the stream environment (Hynes 1975). The vegetational composition is influenced by climate (Voigt and Mohlenbrock 1964) and geology (Wetzel 2001); both influence the soil type (Smith and Smith 2001). Climate, geology, and vegetation combine to control the hydrology, physical structure, substrata, and water chemistry (Townsend et al. 1997).

Precipitation, obviously, is the ultimate source of water in streams (Hynes 1970). Through evaporation and transpiration, forest cover decreases the amount of precipitation that immediately reaches the stream. However, forest cover contributes to a more constant inflow by reducing runoff and maintaining soil moisture (Hynes 1970). Forested watersheds that have rapid percolation allow the subsurface movement of most of the precipitation (Brooks et al. 2003). The soils present in a watershed govern the rate of water release to a stream (Hynes 1975).

Drainage density and hillside slope have a continuous influence on flood-producing characteristics of a stream. Runoff occurs when the precipitation rate surpasses soil percolation rate (Brooks et al. 2003). A vegetated landscape retains precipitation that, in turn, decreases runoff and increases percolation (Hynes 1970). Watersheds with drainage density values less than1-km/km^2 have high permeability and low runoff potential (Pidwirny 2006). As the watershed hillslope increases, the runoff potential increases (Brooks et al. 2003).

The stream sinuosity ratio is a physical characteristic that reflects aquatic habitat complexity. Lower values are associated with straighter channels and more habitat uniformity. Higher values have more meanders and, consequently, more habitat diversity (IEPA 1994). Generally, channel width and depth increase downstream (Beschta and Platts 1986) with width increasing faster than depth (Leopold et al. 1964).

BENTHIC INVERTEBRATES

Three important factors affecting benthic invertebrates in streams are substrata, current velocity (flow), and temperature (Hynes 1970). In natural streams, substrate and flow are so interrelated that it is difficult to separate the effects of each component (Minshall 1984).

The substrata are comprised of two types of materials, inorganic and organic. Geologic parent material is the source of inorganic material, whereas the watershed and stream provide the organic material. The substrata of a stream affect insects in two ways: by directly providing the surface on which they live and indirectly by altering the environment in which they live (Minshall 1984). In turn, variation in flow results in dynamic substrata composition. For a stream to be stable, the magnitude of the shear stress must be equal to the stress capacity of inorganic substrata materials (Hynes 1970).

Water temperature can vary or remain fairly constant. However, annual fluctuations can be predictable in some systems (Sweeney 1984). For spring-fed streams, the daily temperature remains more constant near the source and may show little variation if the stream continues to receive groundwater along its course (Hynes 1970).

An additional factor, among others, affecting benthic invertebrates is stream canopy cover, which controls the amount of sunlight that reaches the stream. Canopy cover, or lack thereof, can greatly influence stream temperature (Brown and Krygier 1970, Burton and Likens 1973, Moore et al. 2005) and ultimately control primary production (IEPA 1994, Zimmerman and Death 2002).

Alternating riffle and pool habitats are found in streams dominated by coarser substrata (Hynes 1970). Insect communities in riffle/run or “erosional sub-habitats” generally are more diverse, but sometimes with lower abundance, than pool or “depositional sub-habitats” (Minshall 1984). Roy et al. (2003) found that the riffle habitat community was more sensitive to in-stream changes resulting from watershed land-use alterations than bank or pool habitats. However, they observed that bank habitat served as a refuge for riffle insects when riffles were impacted by sedimentation.

Conductivity and pH also influence the benthic invertebrate community. For most aquatic biota, the ideal range for pH is 6.5–8.0, and the normal range for conductivity is 150–500-µS/cm (USEPA 2011).

RIVER CONTINUUM CONCEPT (RCC)

Vannote et al. (1980) predicted that habitat heterogeneity is greater in medium-sized streams (orders 3–5) than in headwater streams (orders 1–2) or larger streams (order 6 or >) and, consequently, invertebrate diversity would be highest in medium-sized streams. They noted that as stream order increases, energy inputs change, which in turn results in a change in invertebrate communities. In headwaters, streams are heavily shaded, riparian vegetation provides the major energy inputs into the stream, and invertebrate communities are co-dominated by shredders and collectors, which feed on detritus. In mid-order streams, shading is reduced, and the relative energy input moves toward in-stream primary production causing invertebrate communities to shift to more collector and grazer species. In larger streams, deep channels limit in-stream primary production, and upstream processing of detritus provides the energy input in the form of exported particulates. Collectors are the dominant group in higher-order streams. Unlike primary consumers, predators tend to be equally represented along the continuum.

LOSS OF AQUATIC HABITAT

In the U. S., the loss of aquatic habitat has been dramatic. In 1982, the National Park Service for the Nationwide Rivers Inventory reported that of the 5,200,000 km of streams that the agency evaluated, only 99,300 km (1.9%) were considered high quality (Benke 1990). In 2006, the U. S. Environmental Protection Agency reported the results of the Wadeable Streams Assessment. Nationwide, based on the Macroinvertebrate Index (MI), 42% of streams were in poor biological condition, 25% in fair condition, 28% in good condition, and 5% not accessed (USEPA 2006).

In the 1930s, there was a dramatic increase in the utilization of waterways for flood control, water supply, transportation, and hydropower. In the continental US (excluding Alaska), all rivers of 1,000 km in length or greater have been changed dramatically for navigation and hydropower, the one exception being the Yellowstone River in Montana. Only 42 rivers of 200 km or greater in length are free flowing, which is “the strongest testimony of overwhelming exploitation" (Benke 1990).

Most Illinois streams have been altered, with major manipulations including channelization and construction of impoundments. Channelization has occurred primarily for agricultural practices (IDENR 1994b) with 22.7% of streams in the state affected (Mattingly and Herricks 1991). Impoundments have been constructed for transportation, flood control, water supplies, and recreation (IDENR 1994b).

Channelization dramatically alters the stream and adjacent riparian area (IDENR 1994b) and degrades stream habitat (Brooker 1985). This, in turn, reduces stream biodiversity (Henegar and Harmon 1971). Channelization increases stream slope and causes width and depth to increase, which in turn results in bank instability and erosion (Emerson 1971). Increased width disrupts riffle-pool habitat sequences (Keller 1976). The associated removal of streamside trees can affect the average stream temperature and disrupt the daily and seasonal temperature patterns and associated biological processes (Wiederholm 1984).

Impoundments replace natural streams with man-made reservoirs and result in regulated streams (Ward 1984). As with channelization, impoundments reduce habitat and species diversity (IDENR 1994b). Man-made reservoirs trap sediments that cause them to fill-in over time and disrupt downstream sediment transport and deposition (Leopold 1997). The release of reservoir water can disrupt seasonal cues in aquatic insect life cycles. Relatively warm winter water release can inhibit the cold-triggered break in diapause. Spring release can obscure the rapid temperature increase that triggers egg hatching. Relative cool summer release can prevent number of warm days that triggers adult development and emergence (Ward 1984).

CHANGES IN DIVERSITY OF STREAM FAUNA

The Nature Conservancy and others in the 1980s and 1990s evaluated the conservation status of over 30,000 terrestrial and aquatic species and subspecies with existing state natural heritage database information. Fourteen groups of plants and animals, representing 20,900 species, had enough associated information to evaluate the entire taxonomic assemblage (Master et al. 2000). Of the 14, four groups of freshwater animals comprised the highest proportion of species at risk (i.e., presumed/possibly extinct, critically imperiled, imperiled, and vulnerable). These included mussels, crayfish, stoneflies, and fish with 69%, 51%, 43%, and 37% at risk, respectively. Apparently not enough data were available to evaluate the conservation status of mayflies or caddisflies (Master et al. 2000).

As with the national trends, the diversity of Illinois stream fauna also has declined as evidenced by decreases in the same four groups noted above. Of 79 mussel species, 17 (22%) are extinct or extirpated (INHS 2012a) and 25 (32%) are endangered or threatened (Mankowski 2010, INHS 2012a). Of the 22 crayfish species, one (5%) has disappeared (IDENR 1994b) and four (18%) are endangered (IDENR 1994b, Mankowski 2010). Of the 77 stonefly species, 22 (29%) are extinct or extirpated, including two Illinois endemics, and 19 (25%) are “critically imperiled” (DeWalt et al. 2005). Of the 187 original fish species, 11 (6%) species have disappeared (IDENR 1994b, Mankowski 2010) and 31 (17%) are threatened or endangered (Mankowski 2010).

Smith (1971) attributed the richness of Illinois fishes to the high number of streams and the associated diversity of habitats. However, he identified seven factors that have reduced Illinois fish diversity. They include impoundments, drainage of wetlands and headwaters, desiccation during drought, siltation, temperature disruption, pollution, and species interaction and introduction. Page (1991) agreed with Smith (1971) and suggested that these same factors were major threats to stream biodiversity in general.

Stone et al. (2005) investigated agriculturally dominated streams in southwestern Illinois. They found that the benthic invertebrate communities in these systems were dominated by pollution-tolerant taxa and identified siltation as the major human impact affecting biological integrity. They also found that the insect portion of the community increased as riparian buffers increased in width.

Heatherly et al. (2007) investigated streams across Illinois that represented the major natural divisions and a land-use continuum. They found that physical habitat quality and nutrient concentrations were correlated with macroinvertebrate community metrics. They also found that forested streams, such as Lusk Creek, had the richest macroinvertebrate communities.

PAST WORK AND NEED FOR FURTHER STUDY

The Illinois Environmental Protection Agency (IEPA) and the Illinois Natural History Survey (INHS) have conducted limited biological investigations of Lusk Creek. The IEPA and the Illinois Department of Conservation (IDOC), now Illinois Department of Natural Resources (IDNR), are responsible for assessing stream quality and stream fisheries, respectively (Hite and Bertrand 1989). As part of a continued statewide effort, IEPA biologists periodically have sampled the benthic macroinvertebrate community in Lusk Creek to monitor stream quality (Hite et al. 1990).

The INHS is responsible for recording Illinois' biological diversity (INHS 2008a). Since the 1930s, INHS scientists have sampled Lusk Creek sporadically, focusing on the Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (EPT) fauna as part of a statewide inventories program (INHS 2008b), and have documented 65 EPT species, making it the most EPT-rich stream in the state (Thomas 2001).

Lusk Creek and its watershed represent a high-quality remnant of the original southern Illinois landscape. Its forested streams support an exceptionally high diversity of a benthic insect community. However, most studies of the drainage have been systematic in nature (e.g., Frison 1935, Ross 1944, Burks 1953, Poulton and Stewart 1991, Moulton and Stewart 1996) or have been conducted as part of statewide monitoring (e.g., Hite et al. 1990, Shasteen et al. 2003). Thus, a more thorough baseline study of the stream invertebrates and habitat features of this system would be valuable for comparison with future surveys and for establishing regional reference conditions for Illinois streams.

Identification of appropriate reference sites and reference conditions is important in the development of stream biological assessment programs and, thus, is a major focus of the USEPA and other agencies (USEPA 1995). Lusk Creek is important in this regard in that it provides the rare opportunity to examine physical and biological attributes of a relatively unimpaired drainage within a highly disturbed Illinois landscape.

STUDY OBJECTIVES

The objectives of this investigation were to: (1) survey the aquatic insects within the upper portion of the Lusk Creek system, (2) examine variation in the physical and chemical properties of the upper portion, (3) use landscape features to explain patterns of insect distributions among sites, and (4) use observed taxa richness to estimate watershed-scale richness.

CHAPTER 2

MATERIALS AND METHODS

This study was conducted from May 2003 to April 2005 in the upper portion (from Dog Hollow to Copperous Branch) of the Lusk Creek watershed. This watershed lies within the Shawnee Hills Natural Division (SH) of Illinois and is divided into the Greater SH and Lesser SH (Fig. 2). The Greater SH has sandstone geology with high topographic relief, and the Lesser SH has limestone and sandstone geology with lower topographic relief (Schwegman 1973). (For further information, see discussion of Lusk Creek in introduction).

SITE SELECTION

In May 2003, potential study sites were identified using the United States Geological Survey National Land Cover Data Set (NLCDS) (Vogelmann et al. 2001), which delineates vegetation types found in the Lusk Creek watershed. Streams with watersheds that were predominately forested were selected for further investigation. These sites were located with a compass and 7.5" series quadrangle maps (USFS 1996). On-site evaluation criteria included the presence of riparian forest, stable banks, and embedded substrata, all of which were considered representative of high quality stream habitat by Barbour et al. (1999). I also included the absence of filamentous algae and insects as dominant taxa in my evaluation.

Originally, eight sites were selected. One was on Lusk Creek, itself (i.e., near Dog Hollow [L@DH]); six were on Lusk Creek tributaries (i.e., Bear Branch [BB], Copperous Branch [CB], Dog Hollow [DH], Little Bear Branch [LBB], Ramsey Branch [RB], and Little Lusk Creek, upstream of the confluence with East Fork [LL@EF]); and one was on East Fork [EF], a Little Lusk Creek tributary) (Fig. 3). All sites were first- or second-order streams.

Three additional sites, higher-order segments, were added subsequently (i.e., Lusk Creek, downstream of the Lusk Creek Canyon Nature Preserve [L@LL] [third-order]; Little Lusk Creek, tributary of Lusk Creek, downstream of Martha's Woods [LL@L] [third-order]; and Lusk Creek at the Eddyville Blacktop [L@Rd] [fourth-order] (Fig. 3), this latter site because earlier collections by J.E. McPherson and R.E. DeWalt suggested high insect diversity.

The 11 study sites were located in the upper portion of the Lusk Creek stream system, nine in the Greater SH and two (CB, L@Rd) in the Lesser SH (Figs. 2 and 3).

WATERSHED AND STREAM FEATURES

A digital map of the Lusk Creek watershed and its stream was used in conjunction with GIS ArcView 3.2 (ESRI 1999) to determine various features of the study area. The map included NLCDS, the National Elevation Data Digital Elevation Model with a 10-m resolution (NED) (Gesh et al. 2002), and USGS National Hydrography Dataset (NHD) (USGS 2003). Specifically, the NED was used to determine the watershed boundaries and watershed areas; the NLCDS and watershed boundaries were used to determine acreage by land cover type; the watershed areas and land acreage to determine watershed land cover composition; and the NHD was used to determine stream order, drainage density, and main channel sinuosity. Stream order was assigned according to Strahler (1963).

The NHD divides the stream system into segments. All upstream segments of a study site were combined to determine total stream system length and main channel length. Drainage density (km/km^2) was calculated by dividing the total stream system length by the total watershed area and main channel sinuosity by dividing the main channel length by the main channel distance (a straight line from the study site to the stream origin). The main channel distance was measured three times to obtain an average.

The main channel distance and 7.5" series quadrangle maps (USFS 1996) were used to determine the main channel hillside slope. The main channel distance represented the hypotenuse of a right triangle. Using the 7.5" series quadrangle map (USFS 1996), the difference in elevation of the main channel distance end points was determined and represented one leg of a right triangle (rise). The hypotenuse and leg were used to calculate the length of the remaining leg (run). Main channel hillside slope was the ratio of rise/run.

REACH FEATURES

Hydrologic status was based on field observations. Sites that had only isolated pools or were completely dry in September 2003 were considered intermittent; those with flow at this time were considered perennial.

Baseflow discharge was measured in September 2003 at sites with flowing water. The width and depth for discharge calculations were measured along one transect using a 100-m tape and meter stick. Velocity was measured at the same location using the neutrally-buoyant object procedure following Kaufmann (1988).

Water chemistry measurements were taken at 4–6-week intervals from June 2003 to April 2004. Temperature (^{o}C), and conductivity (µS/cm), were measured with an YSI® 85 meter and pH with a water quality meter (U21EX, Horiba, Lmt.). Readings were taken at the top of run or pool habitats with little or no turbulence and at various times of the day.

During April 2005**,** wetted stream width, depth, and canopy cover were measured; and substrata composition and percent riffle/run and pool were estimated. A 100-m reach that contained most of the sampled area was measured and flagged in 25-m increments along the right bank beginning downstream. At each flag, a tape measure was stretched across the stream perpendicular to the flow to delineate the transect line. Wetted stream width was recorded, and depth was measured at 0.1, 0.3, 0.5, 0.7, and 0.9 width to determine average depth.

Canopy cover and substrata were measured at 100 random points along the 100-m reach. The size of the substrata material was estimated visually using a simplified Illinois Environmental Protection Agency (IEPA) scale: bedrock/boulder (>25.0 cm), cobble (25.0–6.0 cm), gravel (6.0–0.2 cm), and sand (0.2 cm or less) (IEPA 1994*)*; other substrata also were recorded (i.e., silt, leaves). The absence or presence of canopy cover was determined using a densitometer. The percent riffle**/**run and percent pool were estimated visually at the 25-m intervals of the 100-m reach (IEPA 1994).

INVERTEBRATE SAMPLING

Benthic samples were collected during June 2003 with 10 sampling units per site. The sampling effort was proportional to the percentages of riffle and bank habitat present, which were estimated visually. If undercut bank habitat represented less than 10% of the habitat area at a site (10 of 11 sites), then only riffle habitats were sampled. For the eleventh site (LL@EF), riffles represented 90% and bank 10% of the total habitat, so riffle and bank habitats were sampled proportionally. All riffle sampling units were collected at approximately 10-meter increments.

Riffle habitats were sampled based on Hauer and Resh (2007) using a Surber sampler with a 363-micron mesh and a 0.09-m^2 frame. The sampler frame was placed on the substrata, and large, moveable rocks were washed in front of the sampler and then set outside the frame. The remaining substrata were disturbed thoroughly. The contents of the sampler were placed in a 34 X 25-cm white tray, rinsed with 95% ethanol to remove most of the sediments and placed in 95% ethanol. At each site, all riffle sample units were combined into one sample and represented a variety of substrate types and flow regimes.

At the LL@EF site, the undercut bank habitat was sampled using a 0.3-m wide standard D-frame net with a 500-micron mesh. The net was placed under the bank and a 0.09-m^2 area was disturbed thoroughly. Disturbed roots were cut and placed in the net. The net contents were placed in a 34 X 25-cm white tray and transferred to 95% ethanol. For this site, the bank sample was kept separate from the combined riffle sample.

Each of the combined riffle samples for the 10 sites and the riffle and bank samples for the LL@EF site were labeled per site and kept separate. Within 24 hours and again in 2 weeks, the preservation fluid was replaced with 95% ethanol.

SAMPLE PROCESSING

For examination and analyses, two slightly different subsamples were collected. For the 10 sites consisting only of a combined riffle sample, the subsample comprised one half of the combined sample. For the LL@EF site, the subsample comprised 4/9ths of the combined sample plus the undercut bank sample.

To obtain a subsample, the material was drained of alcohol using a sieve with a 250-micron mesh and rinsed in tap water. For sites with 10 combined riffle samples, the material was placed in a 37 X 21-cm white metal tray with a 5 X 2 grid drawn on the bottom and spread evenly over 10 sections. For the site with nine combined riffle samples, the material was spread over nine sections. The contents on each grid section were placed in a pint mason jar with 95% ethanol. Each grid section corresponded to a number, one through ten. To obtain the riffle subsample, numbers were selected randomly. If ten riffles were sampled, five numbers were selected; if nine, four were selected.

For each subsample, a small amount of material was placed in a dish half-filled with 70% ethanol, and the animals were removed using a microscope with 10X magnification or, if needed, up to 45X magnification. Animals were separated by order and placed in additional dishes filled with 70% ethanol.

Most insect taxa subsequently were identified to the generic level following Merritt and Cummins (1996) and functional feeding groups were assigned following Merritt et al. (2008). However, chironomids (Diptera) were identified only to subfamily or tribe and dytiscids, hydrophilids (Coleoptera), and dolichopodids (Diptera) only to family. Once identified, the insects were placed in vials with 70% ethanol.

DIVERSITY MEASUREMENTS AND NONPARAMETRIC STATISTICS

Biological diversity is the number of taxa as well as their relative abundance in the community (Lloyd and Ghelardi 1964). The number of taxa also is known as richness (McIntosh 1967). The relative abundance of each taxon describes the degree of community evenness (i.e., the more equal the value, the higher the evenness) (Smith and Smith 2001). Many investigators have used the term diversity to mean only richness. Therefore, it is important to understand how the term is being used (Hayek and Buzas 1997). For the present study, biological diversity refers to richness and evenness.

All taxonomic units and all individuals were treated as equals, and abundance measurements were made consistently. Samples were assumed to represent continuous distributions. Nonparametric diversity indices and richness estimators were used to describe the aquatic insect community.

The Shannon diversity index (H') was used as a measure of diversity and determined using the equation $H' = -\sum p_i \ln p_i$, where p is the proportion for the ith taxa (Magurran 2004). H' was calculated for each site. Variance was determined following Hayek and Buzas (1997).

The first-order jackknife was used to estimate taxa richness (observed and unobserved) from a single data set (following Manly 1997). This procedure was used because the number of taxa in a sample is usually an underestimate of the true taxa richness (Manly 1997). Palmer (1990, 1991) found the first-order jackknife to be the most precise and least (Palmer 1990) or less

(Palmer 1991) biased of nonparametric diversity estimators.

$Chao_1$ has been used to estimate the true taxa richness (Colwell and Coddington 1994). It was developed to estimate the total the number of classes (observed and unobserved) (Chao 1984). For this study, $Chao_1$ was calculated for all sites combined following Colwell and Coddington (1994). $Chao_1$ is equal to $S_{obs} + ((F_1^2)/(2F_2))$, where S_{obs} is the observed number of taxa, F_1 represents the singletons (one individual), and F_2 represents the doubletons (two individuals) (Colwell and Coddington 1994). Variance was calculated following Chao (1987).

An alternative form, $Chao_2$, uses presence/absence information (Colwell and Coddington 1994). $Chao_2$ was calculated for all sites combined following Colwell and Coddington (1994). $Chao_2$ is equal to $S_{obs} + ((Q_1^2)/(2Q_2))$, where S_{obs} is the observed number of taxa, Q_1 represents the uniques (found at only one site) and Q_2 represents the duplicates (found at two sites) (Colwell and Coddington 1994). Variance was calculated following Chao (1987).

Sampling at the LL@EF site included both riffle and undercut bank habitats. For all other sites, only riffles were sampled. Therefore, LL@EF was not comparable to other sites and was not included in the analyses; the collection data from this site are given in Appendix A.

Presented here are the results of the insect survey of Lusk Creek supplemented with published life history information for selected taxa and preliminary analyses of the species richness based on this survey.

CHAPTER 3

RESULTS AND DISCUSSION

WATERSHED ENVIRONMENT

Watershed area, and base flow generally, increased as stream order increased (i.e., watershed: 2.07–110.91 km^2 [Table 1]; base flow: no flow to 131.6 m^3/sec [Table 1]). All first-order streams (LBB, RB, DH) were intermittent, and, with one exception (CB), all higher-order streams (2–4) were perennial (Table 1).

Forest was the dominant watershed land cover type followed by grassland and row crop (Table 2). Most sites had more than 75% forest cover and less than 20% grassland cover and 7% row crop. RB was the only site with less than 50% forest cover and more than 20% row crop.

Generally, the study sites had low flood potential. Drainage density values were low, ranging from 1.20 to 2.04 km/km^2, and indicated watersheds with high permeability and low runoff potential (Table 3). Hill slope values ranged from 1 to 15% (Table 3), and most sites had 3% or less indicating low runoff potential.

Drainage density is a measure of stream network complexity (Pallard et al. 2009) and reflects how quickly water moves through the stream system (Brooks et al. 2003). The low values in the present study (Table 3) are typical of forested watersheds.

Hillslope contributes to water movement through the watershed. Steeper slopes move water faster (Brooks et al. 2003). The hillside slope values reflected the Lusk Creek watershed topography and stream order (Table 3). The three first-order streams (LBB, RB, DH) and the smallest second-order stream (BB) had the highest slopes and are located in the steep northwest portion of the Lusk Creek watershed.

STREAM ENVIRONMENT

A meandering stream has a sinuosity value of 1.5 or greater (Ritter 2006) and a strongly meandering stream, a value of 4 or greater (IEPA 1994). Stream sinuosity values in the present study ranged from 1.17 to 3.36 in first- to third-order streams and 4.96 in the only fourth-order stream (L@Rd) (Table 3).

Stream bed surfaces fluctuate vertically as evidenced by riffles and pools and fluctuate laterally as evidence by meanders. In straight channels, lateral movement is not apparent although it may be present (Leopold et al. 1964). The low sinuosity values of first- and second-order streams in this study (Table 3) indicate no apparent lateral movement, whereas increasing values in third- and fourth-order streams demonstrate lateral movement downstream.

All sites had substrata dominated by cobble and gravel, comprising 67–91% of all materials combined. All sites, with one exception (L@Rd), had bedrock/boulder as the third most common substratum; L@Rd had sand (Table 4).

In an alluvial valley, the downstream movement of water transports and distributes stream bed materials (Bisson et al. 2007). These materials decrease in size downstream, rapidly at first and then slowly (Leopold et al. 1964). All first- to third-order streams had similar substrata. Compared to the other streams, L@Rd, the only fourth-order stream, had more sand and less bedrock, indicating a change in the stream environment at this site**.**

Canopy cover ranged from 9 to 72%, and eight sites had values ranging from 28 to 45% (Table 4). LBB, a first-order stream, had the highest value and was the only heavily shaded site. L@Rd had the lowest value (Table 4).

Channel width and depth generally increased as stream order increased (Table 1). First- and second-order streams had similar values**,** which were lower than those for third- and fourth-order streams (Table 1).

Riffle/run generally represented a higher percentage of the stream habitat than pool, the exceptions being LL@EF and RB, with 46 and 28%, respectively (Table 5). In LL@EF and RB, the riffle/run habitat was separated by elongated pools.

WATER CHEMISTRY

Temperature, pH, and conductivity can vary during the diurnal cycle (Hynes 1970). In the present study, those measurements were taken at various times of the day and, therefore, sites could not be compared. However, some generalizations are possible.

All sites roughly followed the same temperature trend during the 11-month period (Table 6). The warmest temperatures generally were recorded during August 2003, the coldest during January/February 2004.

Most pH measurements fell within the ideal range for aquatic insects (i.e., 6.5–8.0; USEPA 2011), ranging from 5.78 (DH, August 2003) to 8.12 (CB, February 2004) (Table 7). Eight (19%) measurements were below 6.5.

Although some of the conductivity measurements were within the ideal range for aquatic biota (i.e., 150–500 µS/cm; USEPA 2011), most were not. Measurements ranged from 51.9–487.2 µS/cm, with 50 (81.0%) measurements below 150 µS/cm (Table 8).

INSECT DISTRIBUTIONS

A total of 20,888 specimens, mostly immatures, were examined during the study and represented eight orders (Table 9). The Diptera, by far, was the most common order, with 18,590 specimens (89.0%), almost all of which were members of the Chironomidae and Simuliidae. The EPT (Ephemeroptera, Plecoptera, Trichoptera) combined were common with 1,550 specimens (7.4%) but paled in comparison to the Diptera. The Coleoptera was represented by 647 specimens, almost all of which were members of *Stenelmis* (n = 612; 94.6%).

The order Ephemeroptera was represented by at least 12 taxa in 11 genera and five families: Baetidae, Caenidae, Heptagenidae, Isonychiidae, and Leptophlebiidae (Table 9). Of the 11 genera, naiads of *Acerpenna* (Baetidae), *Plauditus* (Baetidae), and *Habrophlebiodes* (Leptophlebiidae) were the most numerous (Table 9).

Acerpenna (formerly *Baetis* [McCafferty and Waltz 1990, McCafferty 1996]) is widespread in North America (Waltz and Burian 2008) and represented by three species (Purdue University 2011). The species occur in erosional lotic habitats and are both swimmers and clingers, and collector-gatherers (Waltz and Burian 2008).

Two species occur in Illinois [i.e., *A. macdunnoughi* (Ide), *A. pygmaea* (Hagen)] (Morihara and McCafferty 1979, Randolph and McCafferty 1998). Burks (1953), in his study of Illinois mayflies, stated that *A. pygmaea* prefers “small rivers or creeks with fairly rapid flow, such as Salt Fork River and Lusk Creek.” He reported *A. pygmaea* from a branch of Clear Creek (Union

County) and the town of Herod (Pope County). *A. macdunnoughi* now also is known from Lusk Creek (INHS 2012b).

A total of 242 naiads of *Acerpenna* (primarily *A. macdunnoughi*) was collected with most found at L@Rd (n = 190, 78.5%) and L@LL (n = 40, 16.5%) (Table 9), a fourth- and third-order perennial stream, respectively (Table 1). L@Rd and L@LL have riffle areas of 90 and 88%, respectively (Table 5), and abundant cobble/gravel substrata (Table 4). The distributional pattern of the naiads among the sites (Table 9) showed a distinct preference for the downstream reach of the third-order (L@LL) sites and fourth-order (L@Rd) site.

Plauditus (formerly *Pseudocloeon*, then *Baetis* [McCafferty and Waltz 1990, Lugo-Ortiz and McCafferty 1998]) is widespread in North America and represented by 10 species (Waltz and Burian 2008). The species occur in lotic habitats (erosional and depositional) and are both swimmers and clingers and collector-gatherers (Waltz and Burian 2008). Edmunds et al. (1976) reported that *Pseudocloeon* naiads are found in all stream sizes but predominately shallow, fast water, often riffles.

Three species occur in Illinois [i.e., *P. armillatus* (McCafferty and Waltz), *P. dubius* (Walsh), *P. punctiventris* (McDunnough)] and two in southern Illinois (i.e., *P. dubius*, *P. punctiventris*) (Burks 1953, Randolph and McCafferty 1998). Burks (1953) stated that *P. dubuis* and *P. punctiventris* prefer “small rivers or creeks with fairly rapid flow, such as Salt Fork River and Lusk Creek.” He reported *P. punctiventris* from Hutchins Creek (Union County) and *P. dubuis* from Hutchins Creek and Lusk Creek.

A total of 295 naiads of *Plauditus* was collected from all sites except LBB and BB with most found at LL@L (n = 89, 30.2%) and L@DH (n = 72, 24.4%) (Table 9), a third- and second-order perennial stream, respectively (Table 1). LL@L and L@DH have riffle areas of 79 and 89%, respectively (Table 5), and abundant cobble/gravel substrata (Table 4). The distributional pattern of the naiads among the sites (Table 9) showed a broad tolerance of stream order ranging from first-order to fourth-order sites.

Habrophlebiodes is found in the eastern and midwestern United States and represented by four species (Waltz and Burian 2008). The species occur in lotic habitats (erosional and depositional); are swimmers, clingers, and sprawlers; and scrapers and collector-gatherers (Waltz and Burian 2008). They occur in streams with slow to moderately fast current and may be found in riffles although they occur more typically with submerged plants and woody debris (Edmunds et al. 1976).

One species, *H. americana* (Banks), occurs in Illinois (Burks 1953, Randolph and McCafferty 1998). Burks (1953) reported that *H. americana* prefers “small, temporary pools, usually along stream margins, which have greatly reduced or no current,” and reported it from the town of Herod (Pope County).

A total of 142 naiads of *Habrophlebiodes* was collected from all sites except LBB, RB, and L@Rd (Table 9) with most found at BB (n = 52, 36.6%) and L@DH (n = 46, 32.4%) (Table 9), both second-order perennial streams (Table 1). BB and L@DH have riffle areas of 59 and 89%, respectively (Table 5), and abundant cobble/gravel substrata (Table 4). The distributional pattern of the naiads among the sites, including a few specimens from two intermittent streams (DH and CB) (Table 9), showed a broad tolerance of stream order but differs in that no specimens were collected at L@Rd.

The order Plecoptera was represented by at least five taxa in four genera and four families: Capniidae, Leuctridae, Nemouridae, and Perlidae (Table 9). Of the four genera, naiads of *Allocapnia* (Capniidae) and *Perlesta* (Perlidae) were the most numerous (Table 9).

Allocapnia is found in eastern North America and represented by 47 species (DeWalt et al. 2012). The species are clingers and shredder-detritivores (Stewart and Stark 2008). Naiads of some species avoid summer temperatures by burrowing and entering diapause. They can be found at a depth of 10–20 cm and difficult to find (Harper and Hynes 1970).

Eight species occur in Illinois [i.e., *A. forbesi* Frison, *A. granulata* (Claassen), *A. mytica* Frison, *A. nivicola* (Fitch), *A. recta* (Claassen), *A. rickeri* Frison, *A. smithi* Ross and Ricker, *A. vivipara* (Claassen)] (DeWalt et al. 2005), and five of the eight are found in the Shawnee Hills (i.e., *A. vivipara, A. rickeri, A. mytica, A. forbesi,* and *A. smithi*) (Ross and Ricker 1971, Webb 2002, DeWalt et al. 2005). *A. vivipara* is the most common Illinois winter stonefly, whereas *A. rickeri* is one of the most common in the Shawnee Hills. *A. mytica, A. forbesi, and A. smithi* are restricted to the Shawnee Hills with the latter two found only on the eastern side (Webb 2002). *A. vivipara* is found in a variety of stream sizes and conditions, including organic enrichment, whereas the other four species are found in clear, cool, typically spring-fed streams with course substrata (Ross and Ricker 1971). *A. forbesi* can be found in streams that may experience summer drying (Ross and Ricker 1971). *A. vivipara* is known to undergo naiadal diapause (Harper and Hynes 1970).

A total of 117 naiads of *Allocapnia* was collected in June from all sites except LL@L. They were small and in diapause with the head bent over the body as described by Harper and Hynes (1970). They were collected at all sites except LL@L with most found at L@LL (n = 75, 64.1%) and LL@EF (n = 21, 17.9%) (Table 9), a third- and second-order perennial stream, respectively (Table 1). L@LL and LL@EF have riffle areas of 88 and 46%, respectively (Table 5), and abundant cobble/gravel substrata (Table 4). The distributional pattern of the naiads among the sites, including occurrence in both intermittent and perennial streams (Table 9), showed a broad tolerance of stream order but a distinct preference for the downstream reach of the third-order sites (L@LL).

Perlesta is widespread in North America and represented by 30 species (DeWalt et al. 2012). Most species occur in lotic habitats (erosional and depositional), are clingers, and are listed as predators and facultative collector-gatherers (primarily in early instars) (Stewart and Stark 2008).

Nine species occur in Illinois [i.e., *P. cinctipes (*Banks), *P. decipiens* (Walsh), *P. golconda* DeWalt & Stark, *P. lagoi* Stark, *P. ouabache* Grubbs and DeWalt, *P. shawnee* Grubbs & Stark, *P. shubuta* Stark, *P. teaysia* Kurchner and Kondratieff, *P. xube* Stark & Rhodes)] (DeWalt et al. 2011, DeWalt and Grubbs 2011), four of which have been reported from Pope County (i.e., *P. golconda, P. lagoi, P. shawnee, P. xube*) (DeWalt et al. 2001, Grubbs 2005). *P. golconda* typically is found in large rivers (DeWalt et al. 2001, 2005). *P. lagoi* is the second most common species in Illinois (*P. decipiens* is the most common) and found throughout the state in small streams (DeWalt et al. 2001). *P. shawnee* is restricted to the southern unglaciated region of the state (DeWalt et al. 2001, 2005). *P. xube* is uncommon and found in small forested streams that may be reduced to pools in the summer (DeWalt et al. 2001). None of the species can be identified to species as naiads.

A total of 227 naiads of *Perlesta* was collected from all sites with most found at LBB (n = 54, 23.8%), DH (n = 36, 15.9%), and EF (n = 36, 15.9%), and (Table 9), the first two sites, first-order intermittent streams, the third site, a second-order perennial stream (Table 1). LBB, DH, and EF have riffle areas of 58, 69, and 85%, respectively (Table 5), and abundant cobble/gravel substrata (Table 4). The distributional pattern of the naiads among the sites (Table 9) showed a broad tolerance of stream order but no obvious preference for any one site.

The order Megaloptera was represented by at least three taxa in three genera and two families: Corydalidae and Sialidae (Table 9). Of the three genera, larvae of *Nigronia* (Corydalidae) were the most numerous (Table 9).

Nigronia is found in eastern and central North America and represented by two species (Flint et al. 2008), *N. fasciatus* (Walker) and *N. serricornis* (Say) (Tarter et al. 1976). The species occur in lotic habitats (erosional and depositional), are clingers and climbers, and are predators (Flint et al. 2008).

Nigronia fasciatus and *N. serricornis* occur in Illinois (Tarter et al. 1976). Neunzig (1966) reported that *N. fasciatus* is restricted to "small, cool woodland streams," whereas *N. serricornis* inhabits "larger woodland streams and certain portions of rivers." Tarter et al. (2006) found *N. fasciatus* most often in first-order streams and *N. serricornis* in second- to fourth-order streams but sometimes found the two species together. They reported the names of those streams but not the stream order.

A total of 89 larvae of *Nigronia* (including at least five *N. serricornis*) was collected from all sites except LBB, RB, and DH (Table 9). Therefore, they were found only in second- to fourth-order streams (Table 1) with most found at LL@EF (n = 22, 24.7%) (Table 9). LL@EF has a riffle area of 46% (Table 5) and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae among the sites (Table 9) showed a broad tolerance for stream order but no obvious preference for any one site.

The order Trichoptera was represented by at least 12 taxa in 11 genera and eight families: Glossosomatidae, Hydropsychidae, Hydroptilidae, Leptoceridae, Philopotamidae, Polycentropodidae, Rhyacophilidae, and Uenoidae (Table 9). Of the 11 genera, larvae of *Cheumatopsyche* (Hydropsychidae) and *Chimarra* (Philopotamidae) were the most numerous (Table 9).

Cheumatopsyche is widespread in North America and represented by 44 species (Morse and Holzenthal 2008). The species occur in lotic erosional habitats, particularly in warmer streams and rivers, are clingers (net-spinners) that build fixed retreats, and are collector-filterers (Morse and Holzenthal 2008). They are found in moderate currents and build nets with intermediate mesh sizes (Wiggins 1996, 2004). In the Interior Highlands, streams may contain several congeners (Moulton and Stewart 1996).

Nine species occur in Illinois [i.e., *C. analis,* (Banks), *C. aphanta* Ross, *C. burksi* Ross, *C. campyla* Ross, *C. lasia* Ross, *C. oxa* Ross, *C. pasella* Ross, *C. sordida* (Hagen), *C. speciosa* (Banks)] (Ross 1944), including three that occur in the Illinois Ozarks of the Interior Highlands (i.e., *C. analis*, *C. campyla*, *C. oxa*) (Moulton and Stewart 1996). *C. campyla* is found in a variety of environmental conditions (Moulton and Stewart 1996) including those not tolerated by other caddiflies (Ross 1944). It prefers larger streams (Ross 1944). *C. analis* is the most common species in the Interior Highlands (Moulton and Stewart 1996) and also tolerates degraded water quality (Ross 1944). *C. oxa* is found in small to medium streams (Moulton and Stewart 1996), particularly in small, spring-fed streams (Ross 1944).

A total of 251 larvae of *Cheumatopsyche* was collected from all sites with most found at L@LL (n = 80, 31.9%) (Table 9), a third-order perennial stream (Table 1). L@LL has a riffle area of 88% (Table 5) and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae among the sites (Table 9) showed a broad tolerance of stream order but a distinct preference for the downstream reach of the third-order sites (L@LL).

Chimarra is widespread in North America and represented by 21 species (Morse and Holzenthal 2008). The species occur in erosional lotic habitats and are clingers (saclike, silk net makers) and obligate collector-filterers (Morse and Holzenthal 2008). As with other philopotamids, *Chimarra* spp. are restricted to flowing waters (Wiggins 2004) that serve to inflate their silken filtering nets (Wiggins 1996). They use their membraneous labrum to remove fine particles from the inside of the net (Wiggins 2004).

Four species occur in Illinois [i.e., *C. aterrima* Hagen, *C. feria* Ross, *C. obscura* (Walker), *C. socia* Hagen] (Ross 1944), including two in the Illinois Ozarks in the Interior Highlands (i.e., *C. feria* , *C. obscura*) (Moulton and Stewart 1996). *C. feria* and *C. obscura* are common species in the Interior Highlands and often collected together (Moulton and Stewart 1996). *C. feria* is common in clear fast streams in southern Illinois, where it tolerates summer drying by seeking refuge in damp conditions under rocks (Ross 1944). *C. obscura* also prefers clear fast streams (Ross 1944).

Both *C. feria* and *C. obscura* were collected in the present study, *C. feria* being the most common (Table 9). For *C. feria,* 69 larvae were collected with most found at LL@L (n = 39, 56.5%) (Table 9); for *C. obscura* (Walker)*,* 19 larvae were collected with most found at L@LL (n = 11, 57.9%) (Table 9). LL@L and L@LL are third-order perennial streams (Table 1). LL@L and L@LL have riffle areas of 79 and 88%, respectively (Table 5), and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae of *C. feria* among the sites (Table 9) indicates a broad tolerance of stream order, although the larvae of both *C. feria* and *C. obscura* showed a distinct preference for the downstream reach of the third-order sites (see above).

The order Coleoptera was represented by at least six taxa in four genera and five families: Dryopidae, Dytiscidae, Elmidae, Hydrophilidae, and Psephenidae (Table 9). Of the four genera, individuals of *Stenelmis* (Elmidae) were the most numerous (Table 9).

Stenelmis is widespread in North America and represented by 33 species (White and Roughley 2008). The species occur in erosional lotic habitats with coarse sediments and detritus and are clingers and both scrapers and collector-gatherers (White and Roughley 2008). Several species may be found together (Sanderson 1953).

Three are found in Illinois [i.e., *S. crenata* (Say), *S. decorata* Sanderson, and *S. vittipennis* Zimmermann] (Brown 1983). In Wisconsin, *S. crenata* adults inhabit a variety of stream types and *S. decorata* adults inhabit medium to large streams (Hilsenhoff and Schmude

1992). In Indiana, *S. vittipennis* is found in a variety of stream sizes (McMurray and Newhouse 2006). *S. crenata* has been reported from Lusk Creek (Shasteen et al. 2003).

A total of 612 larvae and adults of *Stenelmis* was collected from all sites with most found at L@LL (n = 185, 30.2%) and L@Rd (n = 120, 19.6% (Table 9), a third-order and fourth-order perennial stream, respectively (Table 1). L@LL and L@Rd have riffle areas of 88 and 90%, respectively (Table 5), and abundant cobble/gravel substrata (Table 4). The general increase in numbers moving downstream showed a distinct preference for the downstream reach of the third-order (L@LL) and fourth-order (L@Rd) sites (Table 9).

The order Diptera was represented by at least 20 taxa in 15 genera and nine families: Ceratopogonidae, Chironomidae, Culicidae, Dixidae, Dolichopodidae, Empididae, Psychodidae, Simuliidae, and Tipulidae (Table 9). Of the nine families, larvae in the Ceratopogonidae, Chironomidae, Simuliidae, and Tipulidae were the most numerous (Table 9).

CERATOPOGONIDAE

In the present study, this family was represented by three genera. Of the three genera, larvae of the *Bezzia* complex were the most numerous. This complex includes at least *Bezzia* and *Palpomyia*. There is difficulty in separating these two genera (Courtney and Merritt 2008), but the species appear to occur in different habitats (Merritt and Webb 2008). Thus for this discussion, they are treated separately.

Bezzia is widespread in North America and represented by 52 species (Merritt and Webb 2008). The species are found in lentic (littoral, profundal, and sometimes limnetic) and lotic (in hot springs [algal mats]) habitats. They are burrowers and occasionally planktonic (swimmers) and engulfing predators (Merritt and Webb 2008).

Palpomyia is widespread in North America and represented by 31 species (Merritt and Webb 2008). The species are found in lotic (erosional and depositional [detritus]) and lentic (littoral, profundal, sometimes limnetic) habitats. They are burrowers, occasionally planktonic (swimmers**)**, and predators (engulfers) and collector-gatherers (Merritt and Webb 2008).

A total of 101 larvae of the *Bezzia* complex was collected at all sites combined with most found at LL@EF (n = 30, 29.7%) (Table 9), a second-order perennial stream (Table 1). Their preference for lotic habitats more closely resembles that of *Palpomyia* than of *Bezzia*. LL@EF has a riffle area of 46% (Table 5) and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae among the sites (Table 9) showed a broad tolerance of stream order but no obvious preference for any one site.

CHIRONOMIDAE

This family was represented by four taxa (i.e., Tanypodinae, Orthocladinae, Chironomini, and Tanytarsini), the larvae of which were numerous (Table 9).

Species of Tanypodinae are widespread in NA and represented by 46 genera (Ferrrington et al. 2008). They occur in all lentic and lotic habitats and generally are sprawler-swimmers and burrowers and are predators (engulfers and piercers) (Ferrington et al. 2008).

A total of 420 larvae of Tanypodinae was collected at all sites with the most found at L@DH (n = 160, 38.1%) (Table 9), a second-order perennial stream (Table 1). L@DH has a riffle area of 89% (Table 5) and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae among the sites (Table 9) showed a broad tolerance of stream order with a distinct preference for the L@DH site.

Species of Orthocladiinae are widespread in North America, especially in the North**,** and represented by 85 genera (Ferrington et al. 2008). The subfamily is diverse and, consequently, species are found in a variety of habitats (Epler 2001). Larvae occur primarily in lotic habitats, but many occur in lentic habitats (primarily oligotrophic lakes) and generally are burrowers (tube-builders) and collector-gatherers or scrapers (Ferrington et al. 2008). They dominate in streams with coarse substrates and colder waters, typically low-order, headwater streams (Pinder 1995).

A total of 8,473 larvae of Orthocladiinae was collected at all sites with most found at L@DH (n = 1,693, 20.0%) (Table 9), a second-order perennial stream (Table 1). L@DH has a riffle area of 89% (Table 5) and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae among the sites (Table 9) showed a broad tolerance of stream order but a distinct preference for the BB, L@DH, and L@LL sites, all second- and third-order perennial streams.

Species of Chironomini are widespread in North America and represented by 50 genera (Ferrington et al. 2008). They generally occur in lentic (littoral and profundal) and lotic (depositional) habitats and usually are burrowers and collectors (gatherers, shredders, and filterers) (Ferrington et al. 2008).

A total of 3,072 larvae of Chironomini was collected at all sites with most found at L@DH (n = 1,281, 41.7%) (Table 9), a second-order perennial stream (Table 1). L@DH has a riffle area of 89% (Table 5) and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae among the sites (Table 9) showed a broad tolerance of stream order but a distinct preference for the L@DH site.

Species of Tanytarsini are widespread in North America and represented by 18 genera (Ferrington et al. 2008). They generally occur in lotic (erosional and depositional) and lentic (littoral) habitats and usually are burrowers or clingers (tube-builders) and collectors (gatherers and filterers) (Ferrington et al. 2008).

A total of 1,601 larvae of Tanytarsini was collected at all sites with most found at L@LL (n = 385, 24.1%) (Table 9), a third-order perennial stream (Table 1). L@LL has a riffle area of 88% (Table 5) and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae among the sites (Table 9) showed a broad tolerance of stream order.

SIMULIIDAE

This family was represented by only *Simulium* in the present study, the larvae of which were numerous (Table 9).

Simulium is widespread in North America and represented by 154 species (Alder and Currie 2008). The species occur in lotic and lentic erosional habitats and are clingers and collector-filterers (Alder and Currie 2008). Although simuliids usually are found in moderate-sized streams, they can be found in smaller or larger streams (Crosskey 1990).

A total of 4,686 larvae of *Simulium* was collected at all sites with most found at L@Rd (n = 1,837, 39.2%) (Table 9), a fourth-order perennial stream (Table 1). L@Rd has a riffle area of 90% (Table 5) and abundant cobble/gravel substrata (Table 4). The general increase in numbers moving downstream showed a preference for third- and fourth-order sites (Table 9).

TIPULIDAE

This family was represented by at least six species in six genera in the present study. Of the six genera, the larvae of *Dicranota* were the most numerous (Table 9).

Dicranota is widespread in North America and represented by 55 species (Byers and Gelhaus 2008). The species are found in lotic (erosional and depositional [detritus]) and lentic (littoral [detritus]) habitats and along margins of both habitats. They are sprawler-burrowers and engulfing predators (Byers and Gelhaus 2008).

A total of 92 larvae of *Dicranota* was collected at all sites except LBB and L@Rd with most found at EF (n = 29, 31.5%) and DH (n = 25, 27.2%) (Table 9), a second-order perennial and first-order intermittent stream, respectively (Table 1). EF and DH have riffle areas of 85 and 69, respectively (Table 5), and abundant cobble/gravel substrata (Table 4). The distributional pattern of the larvae among the sites (Table 9) showed a broad tolerance of stream order with a distinct preference for the DH, EF, and LL@EF sites, the first a first-order intermittent stream and the latter two, second-order perennial streams.

INSECT DISTRIBUTION PATTERNS

The number of taxa per site ranged from 20 to 33 (Table 10). Comparing sites overall, there was a relationship between stream order, hydrologic status, and taxa richness. Generally, as stream order increased, streams transitioned from intermittent to perennial and taxa richness increased (Table 10). Perennial streams generally had more EPT taxa than intermittent streams, a pattern not evident in Diptera, the only other well-represented group (Table 10).

When stream conditions remain stable, habitat becomes more stable and stream biota more diverse (Hynes 1970). Feminella (1996) found that richness, both overall and the EPT, was related to hydrologic status, and more permanent streams had increased numbers of taxa. In this investigation, higher-order perennial streams had increased richness. Compared to intermittent streams, perennial streams would provide more stable hydrologic conditions that would allow for greater diversity.

In the present study, species of the Chironomidae comprised three of the four most commonly collected taxa, with the fourth being *Simulium*; thereafter, there was a sharp decrease in specimens collected (Table 11). Of those taxa identified to genus, the Tipulidae was the most diverse, with six genera (Table 9). Undoubtedly, the Chironomidae would have far exceeded six had the specimens been identified to genus. Based on the number of specimens collected for all taxa (Table 11), the Orthocladinae (n = 8,473; 40.6%), Chironomini (n = 3,072; 14.7%), and Tanytarsini (n = 1,601; 7.7%) were among the most commonly collected taxa, representing almost 63% of all taxa collected. Further, the abundance of specimens within the Orthocladiinae far exceeded that within the other subfamilies, supporting Tokeshi's (1995) statement that the Orthocladiinae is the most abundant subfamily of the chironomids in temperate streams of the Northern Hemisphere.

The RCC prediction of higher diversity in medium-sized streams compared to headwater streams (Vannote et al. 1980) was moderately supported by this investigation, as most medium-sized reaches had higher diversity than the smaller headwater reaches (Table 1).

In general, patterns of functional feeding structure supported RCC predictions for first- to fourth-order streams (Vannote et al. 1980). Of the 60 taxa collected (Table 9), 32 were represented by one feeding group and included six collector-filterers, four collector-gatherers, 15 predators, four scrapers (grazers), and three shredders; the remaining taxa were combinations of these categories (Table 12). Functional feeding groups were distributed among all stream orders (Table 13).

BIOLOGICAL DIVERSITY (RICHNESS and EVENNESS)

The combined insect richness for the 11 sites was 60 taxa representing eight orders (Table 10). The combined EPT richness was 29 taxa (12 Ephemeroptera, 5 Plecoptera, and 12 Trichoptera [Table 9]). The richness of each order comprising the EPT was actually less than that of the Diptera with 20 taxa. The remaining four orders (i.e., Coleoptera, Megaloptera, Hemiptera, and Odonata) were represented by six taxa or less and had a combined richness of 11 (Tables 9 and 10).

Species richness will be underestimated if specimens are not identified to species as genera and families may contain more than one species (Rosenberg et al. 2008). For this investigation, only 13 taxa were identified to the species level, 36 to the generic level, and the remaining 11 to tribe, subfamily or family level (Table 9). Unique taxa may be undetected at the generic level or higher. Therefore, the observed taxa richness may have been underestimated.

The benthic insect taxa richness can be used to infer habitat quality (Barbour et al. 1999). The EPT richness is used to evaluate stream health (Lenat 1988). Heatherly et al. (2007) found that Lusk Creek and other forested Illinois streams with low nutrient levels had higher insect taxa richness than non-forested Illinois streams with high nutrient levels. For impaired streams in the Kaskaskia River system, Stone et al. (2005) found 11 insect taxa and only four EPT taxa (three tolerant ephemeropterans, no Plecoptera, and one trichopteran represented by two specimens). When compared to Stone et al. (2005), the results of this study indicate that Lusk Creek is a high quality stream with a rich benthic insect community.

Delucchi (1988) categorized taxa as abundant (>10%), common (1% ≤10%), or rare (<1%) based on total number of specimens collected. Using these same categories for the 60 taxa in the present study, there were three abundant, seven common, and 50 rare taxa (Tables 9 and 11). Biological communities typically are comprised of a few abundant species, some common species, and a majority of rare species (Magurran 2004). The observed results in the present study follow that general pattern and reflect low evenness.

Longino et al. (2002) used different collection methods in various habitats to assess the richness of a tropical ant community. When they compared collecting techniques, they found that typically a single method yielded fewer taxa and high numbers of rare ones, some of which might be common elsewhere. In the present study, only one habitat in one season was sampled using one method. Of the 50 rare taxa, some may have been common in other habitats. For example, in the present study, one specimen of *Anopheles* was collected in the riffle at the BB site, but several were collected in the supplemental bank samples (author's personal observation). Also, one specimen of *Neophylax* was collected in the riffle at the L@DH site but several were observed in the spring.

The Shannon diversity index gave *H'* values for individual sites ranged from 1.07 to 2.01 (Table 14). Sites with the lowest (RB, 1.07) and the highest (EF, 2.01) values had low richness (Tables 9 and 10). Therefore, the *H'* value difference was due to a change in evenness. This can be observed in the relative abundances of the four most common taxa (Tables 11 and 15). RB had one dominant and one moderately dominant taxon, whereas EF had three moderately dominant taxa; therefore, EF had a higher evenness (Table 15).

Increases in richness and evenness will cause *H'* values to increase (Lloyd and Ghelardi 1964). Therefore, differences among sites may be related to changes in richness, evenness, or both. The proportion of each taxon determines its influence on the index value. The dominant taxa contribute less than moderately dominant taxa, and the maximum contribution occurs at 36.8% (Hayek and Buzas 1997). When sites have the same number of taxa, evenness can be compared (Hayek and Buzas 1997). In the present study, LBB and DH had 20 taxa, CB and EF had 23 taxa, and L@DH and L@LL had 30 taxa (Tables 9 and 10). All paired sites had different *H'* values (Table 14) indicating differences in evenness (Table 15).

Lusk Creek results were similar to other investigations of relatively undisturbed streams. Allan (1975) examined a Colorado stream from June to August and calculated *H'* values from Surber sampling results for EPT and Coleoptera. He excluded Diptera and reported values of 0.962 to 1.983. He did not note the log base used for his calculations. Initially, log base 2 was used and now the trend is to use the natural log (Magurran 2004). Wu and Legg (2007) investigated two Wyoming stream systems in summer and fall and reported *H'* values of 1.33 to 2.10 using the natural log for their calculations.

The three richness estimators, first-order jackknife, $Chao_1$, and $Chao_2$, were compared. The first-order jackknife estimate (Manly 1997) was 74.40 (Tables 16 and 17) and predicted approximately 14 unobserved taxa. The $Chao_1$ estimate (Colwell and Coddington 1994) was 97.50 (Table 17) and predicted approximately 37 unobserved taxa (13 more than the first-order jackknife estimate). The $Chao_2$ estimate (Colwell and Coddington 1994) was 70.67 (Table 17) and predicted approximately 10 unobserved taxa (4 less than the jackknife estimate and 27 less than the $Chao_1$).

The observed number of taxa is the lowest possible estimate of the true richness (Smith and Pontius 2006). Usually, a taxonomic survey does not account for all taxa that are present (Chao 2005). Therefore, the observed taxa richness often is an underestimate (Longino et al.

2002). Methods, including first-order jackknife, $Chao_1$, and $Chao_2$, have been used to estimate the true richness from random samples (Colwell and Coddington 1994). These nonparametric richness estimators do not assume the frequency that new species will be encountered (Chao 2005). However, the community distribution does influence the estimated richness (Colwell and Coddington 1994).

The first-order jackknife estimate is driven by unique taxa (i.e., those found at one site only) (Heltshe and Forrester 1983). Therefore, for a given site, as the number of unique taxa increases, the pseudo-value increases. The jackknife estimate is the mean of the pseudo-values (Manly 1997). Reporting the results of a simulation experiment, Manly (1997) noted that the jackknife reduced the bias of the estimate but did not perform well in the calculation of the standard error.

$Chao_1$ utilizes abundance information (Magurran 2004). The $Chao_1$ estimator is calculated using taxa represented by one (singletons) or two (doubletons) specimens (Colwell and Coddington 1994). As the number of singletons increases relative to doubletons, the estimate increases in value (Chazdon et al. 1998). $Chao_1$ should not be used when there are major ecological differences among sites (Magurran 2004). Because $Chao_1$ utilizes abundance information, it is sensitive to non-random distributions (Chazdon et al. 1998).

$Chao_2$ utilizes occurrence information (Colwell and Coddington 1994) and is calculated using taxa that are found at one (unique) or two (duplicate) sites (Chazdon et al. 1998). Using seed bank data, Colwell and Coddington (1994) compared six nonparametric estimators and found that for small samples (12), $Chao_2$ had a high degree of accuracy. Chazdon et al. (1998) found that $Chao_2$ was tolerant of small sample size and moderate non-randomness. When comparing estimators, Silva and Coddington (1996) noted that $Chao_2$ may be “the most practical.” As with $Chao_1$, $Chao_2$ should not be used when there are major ecological differences among sites (Magurran 2004).

First-order jackknife, $Chao_1$, and $Chao_2$ are limited because they have maximum values (Silva and Coddington 1996). For the first-order jackknife, the maximum value is approximately two times the observed number (Colwell and Coddington 1994). For $Chao_1$ and $Chao_2$, the maximum value is approximately half of the observed number squared (Colwell and Coddington 1994). Therefore, the first-order jackknife is more affected by undersampling (Silva and Coddington 1996).

The Chao and jackknife estimators have been compared to other methods and found to perform well. Using a well-known bird community, Walther and Martin (2001) compared 19 estimators and found that the Chao methods were the most precise and least bias followed by the jackknife methods. In their review of numerous studies and several different estimators, Walther and Moore (2005) found the jackknife and Chao estimators generally were the most accurate.

Determining richness estimates with different methods is recommended (Walther and Moore 2005). The first-order jackknife yields a conservative estimate. Therefore, if other estimators yield similar results, that would suggest “a robust estimate” (Silva and Coddington 1996).

The performance of the first-order jackknife and the Chao methods have been evaluated by other investigators and their assessments reported here. In the present study, three richness estimators were calculated using a real data set. The actual performance of each richness estimate was not tested. Although confidence intervals were determined, those for the jackknife estimate are known not to perform well, and others have improved performance as sample size increases. Because the first-order jackknife and Chao estimators reflect the data, they may not always produce good estimates (Walther and Moore 2005). Therefore, the actual performance of the estimators in the present study is unknown.

The difference in the number of individuals between sites is a potential source of sampling error. For the present study, the samples were standardized by area, which resulted in a different number of individuals per site. Most sites had between 1,000 and 3,500 individuals (Table 9). The exceptions were LBB with almost 400 individuals and L@DH with more than 4,000 individuals (Table 9). Because the observed richness often is correlated with sample size (Lande et al. 2000), if present, LBB and L@DH jackknife results should have been affected by this error because the jackknife estimate is an average of pseudo-values (Table 16). However, LBB and L@DH had one and two unique taxa, respectively, which were typical values (Table 16; Appendix B).

Chazdon et al. (1998) found that a non-random distribution or “patchiness” can be detected by comparing the number of singletons to uniques and the number of doubletons to duplicates. When they are similar, the distribution is random. For the present study, non-randomness was not apparent in comparing the 15 singletons to the 16 uniques. However, the same was not true for the 3 doubletons and 12 duplicates, which indicates a nonrandom or patchy distribution. The edge explanation of rareness, which results in a high number of singletons, may have countered the non-randomness of the singletons compared to the uniques.

Richness estimates were calculated using a small sample (10 sites), and the distribution exhibited some degree of patchiness. The $Chao_2$ has been shown to be accurate with small samples and tolerant of moderate patchiness. Of the three estimators, it produced the most conservative estimate of unobserved taxa. In addition, it was similar to the jackknife estimate, and agreement among estimators suggests a robust result. However, given the small number of samples, these results most likely represent an underestimate.

All sites were ecologically similar, which is a requirement of $Chao_1$ and $Chao_2$. However, he $Chao_1$ estimate was larger than the other two estimators. This result may be due to the patchy distribution, as the $Chao_1$ is known to be sensitive to patchiness. As mentioned earlier, the number of doubletons was small relative to the number of duplicates. This would seem to be indicative of clumping.

When many individuals of all taxa are collected after extensive sampling, it would seem that the survey is complete (Coddington et al. 1996). However, rare taxa will persist even after extensive collecting (Mao and Colwell 2005). For the present study, the results represent a small number of samples using one collection method from one habitat in one season. Given the limitations of this study and the high number of rare taxa, it would seem the results indicate an incomplete survey.

SUMMARY AND CONCLUSIONS

Of the eleven sites selected, stream order ranged from 1 to 4; all first-order streams were intermittent, the remainder, with one exception (CB), perennial. Watershed area, channel width and depth, and base flow generally increased as stream order increased. The sites were heavily forested and the stream substrata dominated by cobble and gravel. Temperatures generally were higher during August and lowest during January/February. The pH generally fell within the ideal range for aquatic insects but conductivity measurements did not.

Eight orders of insects were collected, five of which (i.e., Ephemeroptera [n = 760 specimens], Plecoptera [n = 394], Trichoptera [n = 396], Coleoptera [n = 647], Diptera [n = 18,590]) were common.

The Ephemeroptera was represented primarily by *Acerpenna*, *Plauditus*, and *Habrophlebiodes*, with specimens comprising 89.3% of the total. Although common, they differed in their distributions. *Acerpenna* showed a distinct preference for the third- and fourth-order sites, whereas *Plauditus* and *Habrophlebiodes* were more broadly distributed, ranging from first- to fourth-order sites.

The Plecoptera was represented primarily by *Allocapnia* and *Perlesta*, with specimens comprising 87.3% of the total. Both genera were broadly distributed, ranging from first- to fourth-order sites, but differed in that *Allocapnia* showed a distinct preference for the L@LL site, the downstream reach of the third-order stream.

The Trichoptera was represented primarily by *Cheumatopsyche* and *Chimarra*, with specimens comprising 85.8% of the total. Although *Cheumatopsyche* showed a broader distribution among the sites, ranging from first- to fourth-order sites, both genera showed a distinct preference for the third-order sites (LL@L, L@LL).

The Coleoptera was represented primarily by *Stenelmis*, with specimens comprising 94.6% of the total. The general increase in numbers moving downstream showed *Stenelmis* had a distinct preference for the reach of the third-order (L@LL) and fourth-order (L@Rd) sites.

The Diptera was represented primarily by the Chironomidae and Simuliidae, with specimens comprising 98.2% of the total.

The four taxa comprising the Chironomidae (i.e., Tanypodinae, Orthocladiinae, Chironomini, Tanytarsini) combined were broadly distributed, ranging from first- to fourth-order (L@LL) sites. Generally, and not unexpectedly, the lowest numbers were associated with the first-order sites.

The Simuliidae, represented only by *Simulium*, also was broady distributed, ranging from first- to fourth-order sites. However, the general increase in numbers moving downstream showed a preference for the third- and fourth-order sites.

The number of taxa per site ranged from 20 to 33. Overall, the numbers roughly increased as stream order increased and streams transitioned from intermittent to perennial.

Of all taxa collected, the four most common included only two families, the Chironomidae (i.e., Orthocladiinae, Chironomini, Tanytarsini) and the Simuliidae; thereafter, there was a sharp decrease in specimens collected.

As would be expected, the diversity in taxa collected (e.g., eight orders, 35 families) was reflected in the diversity of the functional feeding habits. Of the 60 taxa collected, 32 were represented by one feeding group (e.g., predator, collector-filterer), the remainder by combinations of feeding groups (e.g., collector-gatherer/ scraper). The distribution of the feeding groups among stream orders was variable.

Biological diversity (richness and evenness) was estimated using the Shannon diversity index with H' values for individual sites ranging from 1.07 (RB) to 2.01 (EF); both sites had low richness so the difference was due to a difference in evenness.

Analyses with the first-order jackknife, $Chao_1$, and $Chao_2$ predicted 14, 37, and 10 unobserved taxa, respectively, indicating the survey was incomplete.

To date, this study is the first comprehensive investigation of the Lusk Creek spring/summer aquatic insect community and supports its recognition as a high quality and biologically significant area. However, much work remains to be done. Similar studies should be conducted during the summer and fall months and for more than 1 year to provide a more complete picture of the richness of the Lusk Creek community. This proposed study should be conducted soon because the high quality of the area, undoubtedly, is going to be subjected to further anthropogenic influences.

Table 1. Selected physical properties and watershed area of sites used in 2003 insect survey of Lusk Creek in Pope County

Study Site[a]	Stream Order	Channel Width (m)[b]	Channel Depth (m)[b]	Base flow (m^3/sec)[c]	Hydrologic Status[d]	Watershed Area (km^2)[e]
LBB	1	5.11	0.09	no flow	Intermittent	2.07
RB	1	5.15	0.09	no flow	Intermittent	4.15
DH	1	7.34	0.16	no flow	Intermittent	4.98
BB	2	3.85	0.09	30.1	Perennial	8.18
CB	2	6.65	0.12	no flow	Intermittent	10.70
EF	2	4.22	0.11	29.3	Perennial	11.91
L@DH	2	5.42	0.12	58.7	Perennial	18.87
LL@EF	2	7.76	0.12	63.2	Perennial	21.13
LL@L	3	10.71	0.19	131.6	Perennial	41.22
L@LL	3	10.38	0.20	105.6	Perennial	44.80
L@Rd	4	13.55	0.21	91.0	Perennial	110.91

[a]**BB** = Bear Branch, **CB** = Copperous Branch, **DH** = Dog Hollow, **EF** = East Fork (Little Lusk Creek tributary), **LBB** = Little Bear Branch, **LL@EF** = Little Lusk Creek at East Fork (upstream of confluence with East Fork), **LL@L** = Little Lusk Creek at Lusk Creek (downstream of Martha's Woods), **L@DH** = Lusk Creek at Dog Hollow (upstream of Dog Hollow), **L@LL** = Lusk Creek at Little Lusk Creek (downstream of Lusk Creek Canyon Nature Preserve), **L@Rd** = Lusk Creek (at Eddyville Blacktop), and **RB** = Ramsey Branch (See Fig. 3).
[b]Measured during April 2005.
[c]Measured during September 2003.
[d]Intermittent = no flow on day of base flow measurement.
[e]Determined with a digital map and GIS.

Table 2. Land cover percentages of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Landcover (%)[a]				
Study Site[b]	Forest[c]	Grass[d]	Row Crop[e]	Water[f]	Other[g]
LBB	78.01	16.58	5.19	0.22	0.00
RB	46.44	29.56	22.65	0.20	1.15
DH	91.95	5.46	2.58	0.02	0.00
BB	67.04	19.01	13.65	0.21	0.10
CB	69.39	19.44	11.07	0.10	0.00
EF	83.43	12.10	4.26	0.20	0.01
L@DH	63.53	29.66	6.62	0.10	0.09
LL@EF	89.32	7.76	2.92	0.01	0.00
LL@L	87.62	9.07	3.22	0.09	0.00
L@LL	76.26	17.64	5.92	0.12	0.05
L@Rd	79.45	14.44	5.93	0.11	0.07

[a]Determined with a digital map and GIS.
[b]See Table 1 for complete names and stream order.
[c]Includes deciduous, evergreen, mixed, and woody wetland.
[d]Includes grassland, pasture/hay, urban parklike, and herbaceous wetland.
[e]Includes row crop and small grain.
[f]Includes all open water.
[g]Includes low residential and commercial/industrial/transportation areas.

Table 3. Watershed drainage density, hillside slope, and main channel sinuosity values of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

Study Site[a]	Drainage Density (km/km^2)[b]	Hillside Slope%[c]	Main Channel Sinuosity[d]
LBB	1.47	15	1.17
RB	1.23	8	1.36
DH	1.33	6	1.22
BB	1.20	10	1.64
CB	1.87	2	1.68
EF	2.04	3	1.31
L@DH	2.01	1	1.30
LL@EF	1.46	1	1.44
LL@L	1.71	1	2.18
L@LL	1.65	3	3.36
L@Rd	1.71	1	4.96

[a]See Table 1 for complete names and stream order.
[b]Calculated with digital map and GIS and derived by dividing total stream system length by area
[c]Calculated with digital map, topographic maps, and GIS and derived by dividing elevation (rise) by run and multiplying by 100.
[d]Calculated with digital map and GIS and derived by dividing main channel length by main channel distance.

Table 4. Percent canopy cover and stream bed substratum composition of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Substratum (%)[a]					
Study Site[b]	Cobble	Gravel	Bedrock /Boulder	Sand	Other	Canopy (%)[a]
LBB	31	48	17	1	3	72
RB	53	36	9	2	0	41
DH	35	46	13	3	3	40
BB	42	36	22	0	0	40
CB	35	56	9	0	0	14
EF	43	47	8	0	2	45
L@DH	58	25	15	0	2	28
LL@EF	38	43	10	9	0	28
LL@L	54	23	16	6	1	37
L@LL	41	26	29	3	1	44
L@Rd	32	46	2	17	3	9

[a]Measured during April 2005.
[b]See Table 1 for complete names and stream order.

Table 5. Percent riffle/run and pool estimated visually for sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

Study Site[a]	Riffle/run (%)[b]	Pool (%)[b]
LBB	58	43
RB[c]	28	73
DH	69	31
BB	59	41
CB	64	36
EF	85	15
L@DH	89	11
LL@EF[c]	46	54
LL@L	79	21
L@LL	88	13
L@Rd	90	10

[a]See Table 1 for complete names and stream order.
[b]Measured during April 2005.
[c]Riffles separated by elongated pools.

Table 6. Water temperature during June 2003–April 2004 of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Month(s)					
	Jun	Aug	Sept	Nov	Jan/Feb	Apr
Study Site[a]	Water Temperature (^{o}C)					
LBB	18.8	21.5	15.4	9.3	2.3	18.9
RB	20.3	Dry	Dry	Dry	1.6	14.5
DH	20.5	20.6	17.0	11.7	4.1	13.2
BB	21.6	22.7	16.7	9.3	3.4	20.9
CB	23.8	25.2	20.7	11.9	3.0	12.3
EF	20.1	20.4	16.6	7.5	2.8	14.1
L@DH	23.6	23.0	17.5	7.3	4.2	13.8
LL@EF	21.1	21.4	17.5	7.4	3.1	13.3
LL@L	23.1	23.6	17.8	10.0	1.9	12.2
L@LL	22.6	23.5	18.6	10.9	1.1	16.2
L@Rd	24.9	26.5	19.1	10.9	1.2	12.1

[a]See Table 1 for complete names and stream order.

Table 7. pH during August 2003–April 2004 of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Month			
Study Site[a]	Aug	Nov	Feb	Apr
LBB	5.99	6.22	6.67	6.46
RB	Dry	Dry	7.82	7.30
DH	5.78	6.22	6.49	6.39
BB	6.69	7.00	7.46	6.86
CB	7.36	7.36	8.12	7.88
EF	7.06	6.97	6.69	6.63
L@DH	7.18	6.99	6.69	6.52
LL@EF	7.15	6.81	6.50	6.57
LL@L	6.73	6.85	6.98	6.46
L@LL	6.61	7.06	7.08	6.66
L@Rd	6.96	6.93	7.07	6.67

[a]See Table 1 for complete names and stream order.

Table 8. Conductivity during June 2003–April 2004 of sites used for 2003 insect survey of Lusk Creek in Pope County, Illinois

	Month(s)					
	Jun	Aug	Sept	Nov	Jan/Feb	Apr
Study Site[a]	Conductivity (µS/cm)					
LBB	65.9	73.9	105.5	78.9	51.9	65.1
RB	472.5	Dry	Dry	Dry	181.7	340.0
DH	58.5	65.0	72.0	77.5	62.1	65.7
BB	109.8	148.9	123.8	159.5	90.9	136.0
CB	338.8	440.6	417.5	487.2	189.2	301.0
EF	124.3	121.5	93.4	221.2	----[b]	93.0
L@DH	95.6	97.0	98.3	110.0	108.8	115.6
LL@EF	81.3	82.5	85.3	104.0	81.9	79.5
LL@L	97.7	85.6	97.6	123.2	60.8	90.1
L@LL	98.9	89.3	108.8	168.9	71.1	104.9
L@Rd	121.4	86.5	91.0	116.8	87.8	112.6

[a]See Table 1 for complete names and stream order.
[b]Unable to obtain reading from meter.

Table 9. Number of specimens per taxon collected from riffle habitats of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Study Sites[a]											
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
Taxon[def]	No. Specimens											Total[g]
Ephemeroptera												
Baetidae												
Acerpenna spp.							2	4	6	40	190	242
Baetis flavistriga									1			1
McDunnough												
B. intercalaris										11	2	13
McDunnough												
Plauditus spp.		10	16		14	8	72	28	89	27	31	295
Procloeon spp.									1		3	4
Caenidae												
Caenis spp.								1		1		2

Table 9. Continued

Taxon[def]	Study Sites[a]											Total[g]
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
	No. Specimens											
Heptageniidae												
Leucrocuta spp.				1			1		14	9		25
Stenacron spp.							1	1		2		4
Stenonema												
femoratum (Say)				4			2			17	1	24
Isonychiidae												
Isonychia spp.									1	5		6
Leptophlebiidae												
Habrophlebiodes												
spp.			1	52	2	13	46	11	10	7		142
Paraleptophlebia												
spp.			1			1						2
Odonata												
Coenagrionidae[h]										1		1

Table 9. Continued

	Study Sites[a]											
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
Taxon[def]	No. Specimens											Total[g]
Plecoptera												
Capniidae												
Allocapnia spp.	5	1	1	1	3	1	7	21		75	2	117
Leuctridae[h]	2		10	2			1					15
Nemouridae												
Amphinemura ssp.				1				1				2
Perlidae												
Neoperla spp.				1	4		3	2	7	12	4	33
Perlesta spp.	54	1	36	29	3	36	22	11	18	11	6	227
Hemiptera												
Veliidae												
Microvelia spp.	1	2		1		1				1	1	7

Table 9. Continued

	Study Sites[a]											
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
Taxon[def]	No. Specimens											Total[g]
Megaloptera												
Corydalidae												
Corydalus												
cornutus (L.)											1	1
Nigronia spp.				18	2	13	16	22	3	11	4	89
Sialidae												
Sialis spp.	1						2					3
Trichoptera												
Glossosomatidae												
Agapetus illini							1					1
Ross												
Hydropsychidae												
Cheumatopsyche												
spp.	3	7	3	14	14	6	45	15	39	80	25	251

Table 9. Continued

	Study Sites[a]											
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
Taxon[def]	No. Specimens											Total[g]
Hydroptilidae												
Hydroptila spp.					1						2	3
Neotrichia spp.									3			3
Leptoceridae[h]										1		1
Philopotamidae												
Chimarra feria												
Ross				1		4	11		39	12	2	69
C. obscura												
(Walker)									1	11	7	19
Wormaldia												
shawnee (Ross)					1				1			2
Polycentropodidae												
Polycentropus												
spp.		2		6		4	5	1	3	9		30

Table 9. Continued

	Study Sites[a]											
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
Taxon[def]	No. Specimens											Total[g]
Rhyacophilidae												
Rhyacophila												
fenestra Ross			1									1
R. glaberrima												
Ulmer	5	3				1	4		2			15
Uenoidae												
Neophylax												
concinnus												
McLachlan							1					1
Coleoptera												
Dytiscidae[h]						1						1
Dryopidae												
Helichus spp.	3		2	1			1	4	1		1	13

Table 9. Continued

	Study Sites[a]											
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
Taxon[def]	No. Specimens											Total[g]
Elmidae												
Stenelmis spp.	4	11	11	70	23	32	33	60	63	185	120	612
Hydrophilidae[h]	1	4		1	8				1			15
Psephenidae												
Ectopria thoracica												
(Ziegler)	1											1
Psephenus												
herricki (DeKay)										4	1	5
Diptera												
Ceratopogonidae												
Atrichopogon spp.		4			1							5
Bezzia complex	6	4	2	7	15	9	5	30	3	14	6	101
Dasyhelea spp.		5			4	1		1				11

Table 9. Continued

	Study Sites[a]											
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
Taxon[def]	No. Specimens											Total[g]
Chironomidae												
Tanypodinae[h]	20	17	30	29	52	19	160	12	17	38	26	420
Orthocladiinae[h]	242	891	747	1039	505	199	1693	658	628	1136	735	8473
Chironominae[h]												
Chironomini[h]	15	26	103	70	146	177	1281	377	337	350	190	3072
Tanytarsini[h]	13	197	33	61	173	60	245	76	132	385	226	1601
Culicidae												
Anopheles sp.				1								1
Dixidae[h]			1									1
Dolichopodidae[h]	1	2										3
Empididae												
Chelifera spp.		3	40					1			1	45
Hemerodromia spp.					11		2	1	4	7	4	29

Table 9. Continued

	Study Sites[a]											
	LBB[b]	RB[b]	DH[b]	BB[c]	CB[b]	EF[c]	L@DH[c]	LL@EF[c]	LL@L[c]	L@LL[c]	L@Rd[c]	
Taxon[def]	No. Specimens											Total[g]
Psychodidae												
Psychoda sp.		1										1
Simuliidae												
Simulium spp.	10	32	9	355	216	273	577	141	570	666	1837	4686
Tipulidae												
Dicranota spp.		6	25	6	2	29	3	16	2	3		92
Hexatoma spp.	1					3	1	5	8		1	19
Limonia spp.		2		1	2							5
Molophilus sp.										1		1
Pilaria spp.	1									1		2
Tipula spp.			1	3	2	2	9	3	1	1		22
Total no. specimens	389	1231	1073	1775	1204	893	4252	1503	2005	3134	3429	20,888
Total taxa[i]	20	22	20	26	23	23	30	26	30	33	27	60

[a]See Table 1 for complete names and stream order.

[b]Intermittent stream.
[c]Perennial stream.
[d]Specimens collected during June 2003.
[e]All specimens were immatures (i.e., naiads, nymphs, larvae) except for Hemiptera and Coleoptera as follows: Veliidae, adults and nymphs; Dryopidae, adults; Dytiscidae, adult; Elmidae, adults and larvae; Hydrophilidae, larvae; and Psephenidae, larvae.
[f]For purpose of this table, spp. treated as one taxon.
[g]Total number of specimens per taxon.
[h]Unidentified genus or genera.
[i]Minimum number of taxa per site and for all sites combined.

Table 10. Stream order and number of taxa collected from riffle habitats of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

			Taxa[a]						
Study Site[b]	Stream Order	Hydrologic Status[c]	No.Taxa/ Per site	EPT	D	C	M	H	O
LBB[d]	1	I	20	5	9	4	1	1	0
DH[d]	1	I	20	8	10	2	0	0	0
RB[d]	1	I	22	6	13	2	0	1	0
CB[d]	2	I	23	8	12	2	1	0	0
EF[d]	2	P	23	9	10	2	1	1	0
LL@EF[e]	2	P	26	11	12	2	1	0	0
BB[d]	2	P	26	11	10	3	1	1	0
L@Rd[d]	4	P	27	12	9	3	2	1	0
L@DH[d]	2	P	30	16	10	2	2	0	0
LL@L[d]	3	P	30	16	10	3	1	0	0
L@LL[d]	3	P	33	17	11	2	1	1	1
Total[f]			60	29	20	6	3	1	1

[a]EPT = Ephemeroptera, Plecoptera, Trichoptera; D = Diptera; C = Coleoptera; M = Megaloptera; H = Hemiptera; O = Odonata.
[b]See Table 1 for complete names.
[c]I = intermittent, P = perennial.
[d]Riffle comprised entire sample.
[e]Riffle and undercut bank sampled.
[f]Number of different taxa for all sites combined (see Table 9).

Table 11. Abundant (>10%), common (1% to ≤10%), and rare (<1%) taxa collected from riffle habitats of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

Taxon	Total No of Specimens	Overall Proportion (%)
Orthocladiinae	8,473	40.6
Simulium spp.	4,686	22.4
Chironomini	3,072	14.7
Tanytarsini	1,601	7.7
Stenelmis spp.	612	2.9
Tanypodinae	420	2.0
Plauditus spp.	295	1.4
Cheumatopsyche spp.	251	1.2
Acerpenna spp.	242	1.2
Perlesta spp.	227	1.1
Habrophleboides spp.	142	0.7
Allocapnia spp.	117	0.6
Bezzia complex	101	0.5
Dicranota spp.	92	0.4
Nigronia spp.	89	0.4
Chimarra spp. (n = 2)	88	0.4
Other rare taxa (n = 43)	380	1.8
Total	20,888	100.0

Table 12. Order, family, subfamily, tribe, genus, or species and functional feeding group for taxa collected from riffle habitats of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

Order	Family or Subfamily	Tribe, Genus or Species[a]	Functional Feeding Group[b]	Stream Order[c]
Ephemeroptera	Baetidae	*Acerpenna* spp.	Cg	2–4
		Baetis flavistriga	Cg/Sc(facultative)	3
		Baetis intercalaris	Cg/Sc(facultative)	3–4
		Plauditus spp.	Cg	1–4
		Procloeon spp.	Cg/Sc	3–4
	Caenidae	*Caenis* spp.	Cg/Sc	2–3
	Heptageniidae	*Leucrocuta* spp.	Sc/Cg	2–3
		Stenacron spp.	Sc/Cg(facultative)	2–3
		Stenonema femoratum	Sc/Cg(facultative)	2–4
	Isonychiidae	*Isonychia* spp.	Cf/Pe	3
	Leptophlebiidae	*Habrophlebiodes* spp.	Sc/Cg	1–3
		Paraleptophlebia spp.	Cg/Sh(facultative)	1–2
Odonata	Coenagrionidae		Pe	3
Plecoptera	Capniidae	*Allocapnia* spp.	Sh	1–4
	Leuctridae		Sh	1–2

Table 12. Continued

Order	Family or Subfamily	Tribe, Genus or Species[a]	Functional Feeding Group[b]	Stream Order[c]
Plecoptera	Nemouridae	*Amphinemura* sp.	Sh/Cg(facultative)	2
	Perlidae	*Perlesta* spp.	Pe/Cg(facultative)	1–4
		Neoperla spp.	Pe	2–4
Hemiptera	Veliidae	*Microvelia* spp.	Pp	1–4
Megaloptera	Corydalidae	*Corydalus cornutus*	Pe	4
		Nigronia spp.	Pe	2–4
	Sialidae	*Sialis* spp.	Pe/Cg(one species)	1–2
Trichoptera	Glossosomatidae	*Agapetus illini*	Sc/Cg(facultative)	2
	Hydropsychidae	*Cheumatopysche* spp.	Cf	1–4
	Hydroptilidae	*Hydroptila* spp.	Pc/Sc(facultative)	2, 4
		Neotrichia spp.	Sc	3
	Leptoceridae		Cg/Cf/Sh/Sc/Pe	3
	Philopotamidae	*Chimarra feria*	Cf(obligate)	2–4
		Chimarra obscura	Cf(obligate)	3–4
		Wormaldia shawnee	Cf(obligate)	2–3

Table 12. Continued

Order	Family or Subfamily	Tribe, Genus or Species[a]	Functional Feeding Group[b]	Stream Order[c]
Trichoptera	Polycentropodidae	*Polycentropus* spp.	Pe/Cf/Sh	1–3
	Rhyacophilidae	*Rhyacophila fenestra*	Pe/Sc/Cg/Sh	1
		Rhyacophila glaberrima	Pe/Sc/Cg/Sh	1–3
	Uenoidae	*Neophylax concinnus*	Sc(obligate)	2
Coleptera	Dytiscidae		Pe	2
	Dryopidae	*Helichus* spp.	Sc/Sh	1–4
	Elmidae	*Stenelmis* spp.	Sc/Cg	1–4
	Hydrophilidae		Pe[d]	1–3
	Psephenidae	*Ectopria thoracica*	Sc	1
		Psephenus herricki	Sc	3–4
Diptera	Ceratopogonidae	*Atrichopogon* spp.	Cg/?Sc	1–2
		Bezzia complex	Pe	1–4
		Dasyhelea spp.	Cg/Sc	1–2
	Chironomidae			
	Tanypodinae		Pe/Pp	1–4
	Orthocladiinae		Cg/Sc	1–4

Table 12. Continued

Order	Family or Subfamily	Tribe, Genus or Species[a]	Functional Feeding Group[b]	Stream Order[c]
Diptera	Chironominae			
		Chironomini	Cg	1–4
		Tanytarsini	Cf/Cg	1–4
	Culicidae	*Anopheles* sp.	Cf	2
	Dixidae		Cg/?Cf	1
	Dolichopodidae		Pp	1
	Empididae	*Chelifera* spp.	Pp	1–2, 4
		Hemerodromia spp.	Pp	2–4
	Psychodidae	*Psychoda* spp.	Cg	1
	Simuliidae	*Simulium* spp.	Cf	1–4
	Tipulidae	*Dicronota* spp.	Pe	1–3
		Hexatoma spp.	Pe	1–4
		Limonia spp.	Sh	1–2
		Molophilus sp.		3
		Pilaria spp.	?Pe	1, 3

Table 12. Continued

Order	Family or Subfamily	Tribe, Genus or Species[a]	Functional Feeding Group[b]	Stream Order[c]
Diptera		*Tipula* spp.	Sh(obligate)/Cg/ Sc(facultative)	1–3

[a]For purpose of this table, each spp. treated as one taxon.
[b]As defined and listed by Merritt et al. (2008), generally at generic level: **Cf** = collector-filterer; **Cg** = collector-gatherer; **Pc** = plant piercer; **Pe** = predator-engulfer; **Pp** = predator-piercer; **Sc** = scraper; and **Sh** = shredder.
[c]Indicates stream order(s) in which given taxa were found.
[d]Merritt et al. (2008) listed functional feeding group for adults and larvae; only larvae collected in present study.

Table 13. Number of functional feeding groups by stream order for taxa collected from riffle habitats of sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Stream Order											
	1	2	3	4	1 –2[b]	1–2,4 [c]	1, 3[d]	1–3[e]	1–4[f]	2–3[g]	2–4[h]	3–4[ii]
Functional Feeding Group [i]												
Collector-filterers	0	1	0	0	0	0	0	0	2	1	1	1
Collector-gatherers	1	0	0	0	0	0	0	0	2	0	1	0
Predators	1	1	1	1	0	1	1	2	4	0	3	0
Scrapers	1	1	1	0	0	0	0	0	0	0	0	1
Shredders	0	0	0	0	2	0	0	0	1	0	0	0

[a]First- to second-order streams.
[b]First- to second- and fourth-order stream.
[c]First- and third-order streams.
[d]First- to third-order streams.
[e]First- to fourth-order streams.
[f]Second- to third-order streams.
[g]Second- to fourth-order streams.
[h]Third- to fourth-order streams.
[i]Excludes combined feeding groups (see Table 12).

Table 14. Shannon diversity index (H') for taxa collected from riffle habitats of 10 of 11 sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

Study Site[ab]	H'[c]	SE	Lower CI	Upper CI
RB	1.07	0.04	0.99	1.15
DH	1.28	0.05	1.19	1.37
L@Rd	1.34	0.02	1.29	1.38
LBB	1.49	0.07	1.34	1.63
BB	1.46	0.03	1.40	1.53
L@DH	1.64	0.02	1.60	1.67
CB	1.79	0.03	1.73	1.86
LL@L	1.88	0.03	1.83	1.93
L@LL	1.93	0.02	1.88	1.97
EF	2.01	0.04	1.94	2.09

[a]See Table 1 for complete names and stream order.
[b]LL@EF was not included (see text).
[c]$\{-\sum p_i \ln p_i\}$, p_i = proportion of the *i*th taxon.

Table 15. Percentages of selected taxa that were dominant (10% or more) at all or some sites for taxa collected from riffle habitats of 10 of 11 sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Taxon[a]			
Study Site[bc]	Orthocladiinae	*Simulium* spp.	Chironomini	Tanytarsini
RB	72.4	2.6	2.1	16.0
DH	69.6	0.8	9.6	3.1
L@Rd	21.4	53.6	5.5	6.6
LBB	62.2	2.6	3.9	3.3
BB	58.5	20.0	3.9	3.4
L@DH	39.8	13.6	30.1	5.8
CB	41.9	17.9	12.1	14.4
LL@L	31.3	28.4	16.8	6.6
L@LL	36.2	21.3	11.2	12.3
EF	22.3	30.6	19.8	6.7
All Sites[d]	40.6	22.4	14.7	7.7

[a]Total number of individuals of selected taxon divided by total number of individuals for the site (e.g., 891/1,231 = 72.4%; see Table 9). These percentages indicate amount of evenness and influence Shannon diversity index values.
[b]See Table 1 for complete names and stream order.
[c]LL@EF was not included (see text).
[d]Total number of individuals of selected taxon for all sites divided by total number of individuals collected (e.g., 8,473/20,888 = 40.6%; see Table 9).

Table 16. Partial estimate totals and pseudo-values used in jackknife calculations for taxa collected from riffle habitats of 10 of 11 sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Study Sites[ab]									
	LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd
Partial Estimate[c]	59	59	58	58	60	59	58	58	56	59
Pseudo-value[d]	69	69	78	78	60	69	78	78	96	69

[b] See Table 1 for complete names and stream order.
[a] LL@EF was not included (see text).
[c] Total taxa (60 [see Table 11]) minus total number of unique taxa (i.e., number of times partial estimate equaled zero for site).
[d] {n**S*-((n-1)**S-j*)} ,n = 10, *S* = 60, *S-j* = partial estimate total.

Table 17. Jackknife, $Chao_1$ and $Chao_2$ estimators used to estimate richness from the taxa collected from riffle habitats of 10 of 11 sites used in 2003 insect survey of Lusk Creek in Pope County, Illinois

	Estimate[a]	SD	SE	Lower CI	Upper CI
Jackknife[b]	74.40	9.67	3.06	67.49	81.31
$Chao_1$[c]	97.50	29.69	9.39	79.10	115.90
$Chao_2$[d]	70.67	6.97	2.20	63.35	74.99

[a]LL@EF was not included (see text).
[b]Mean of the pseudo-values (Table 16), standard deviation (SD), standard error (SE), and confidence intervals (CI).
[c]$\{S_{obs}+(F_1^2/2F_2)\}$, $S_{obs} = 60$, $F_1 = 15$, $F_2 = 3$, standard deviation (SD), standard error (SE), and confidence intervals (CI).
[d]$\{S_{obs}+(L^2/2M)\}$, $S_{obs}= 60$, $L = 16$, $M = 12$, standard deviation (SD), standard error (SE), and confidence intervals (CI).

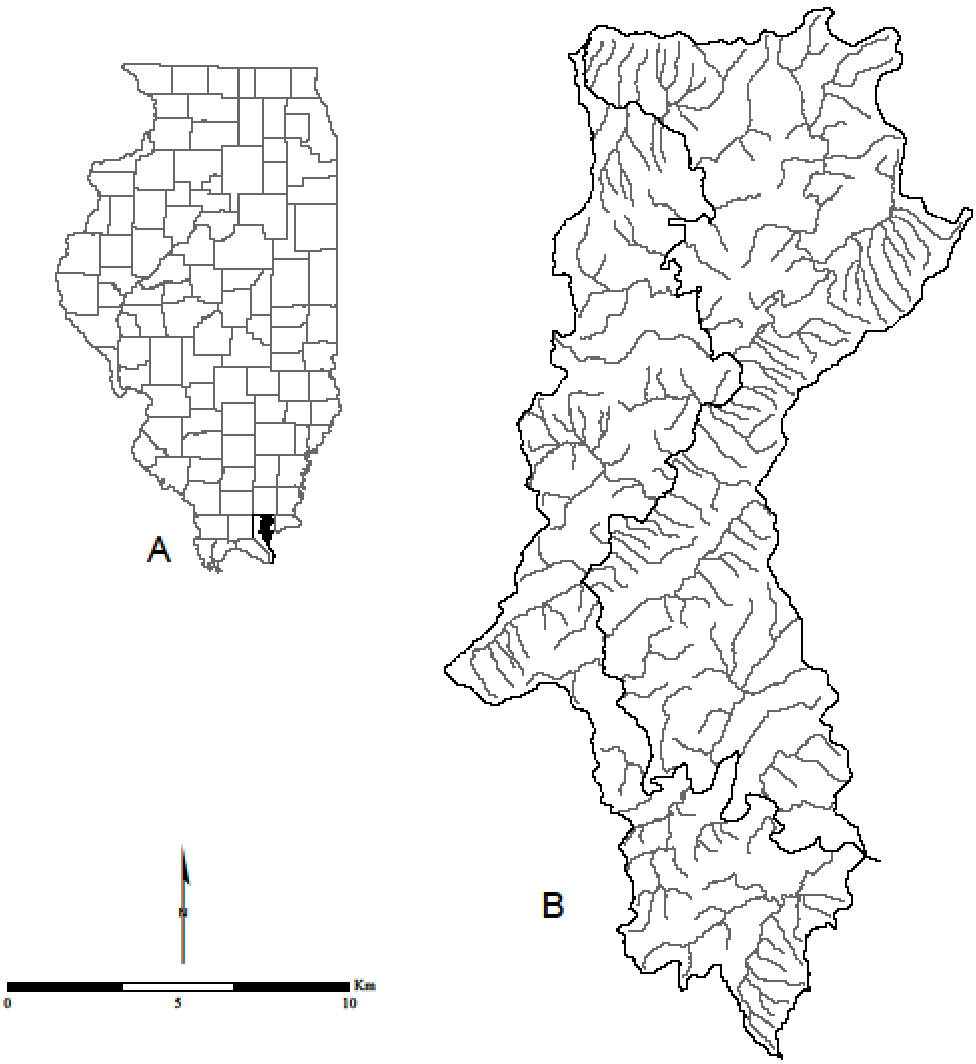

Figure 1. Location of Lusk Creek and watershed in Pope County, Illinois. A, location of watershed. B, location of Lusk Creek.

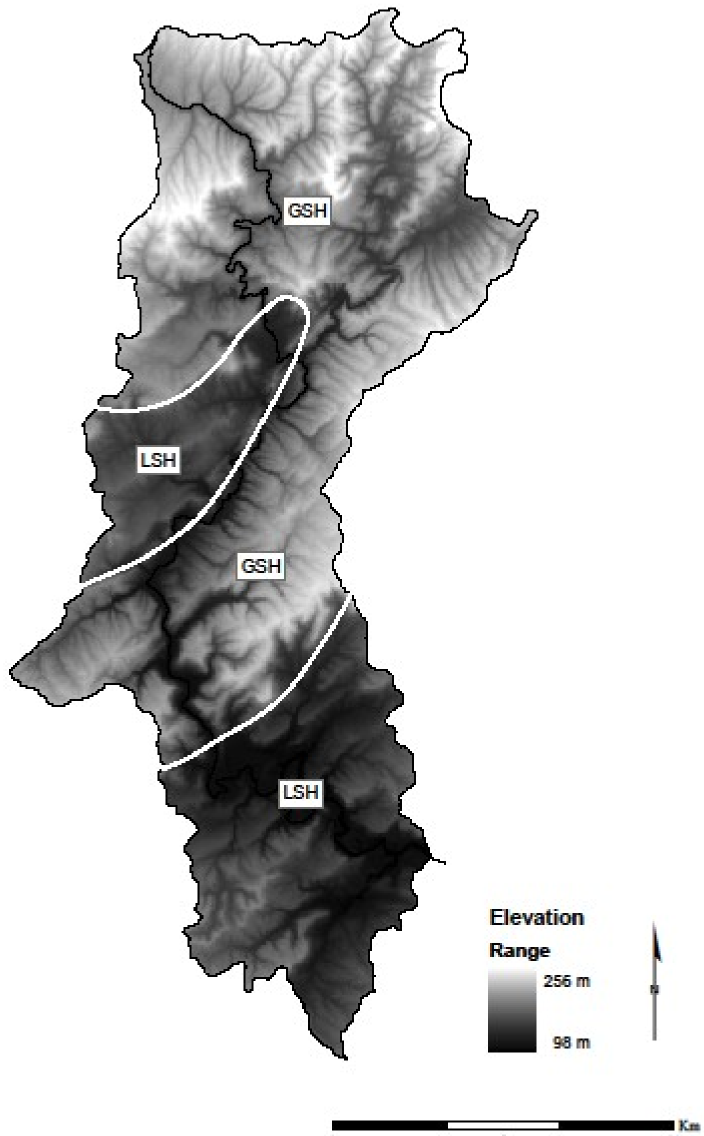

Figure 2. Lusk Creek watershed within Shawnee Hills Illinois Natural Division (SH), subdivided into Greater SH (GSH) and Lesser SH (LSH). Shown here is range of elevation (GSH = 104–256 m and LSH = 98–207 m).

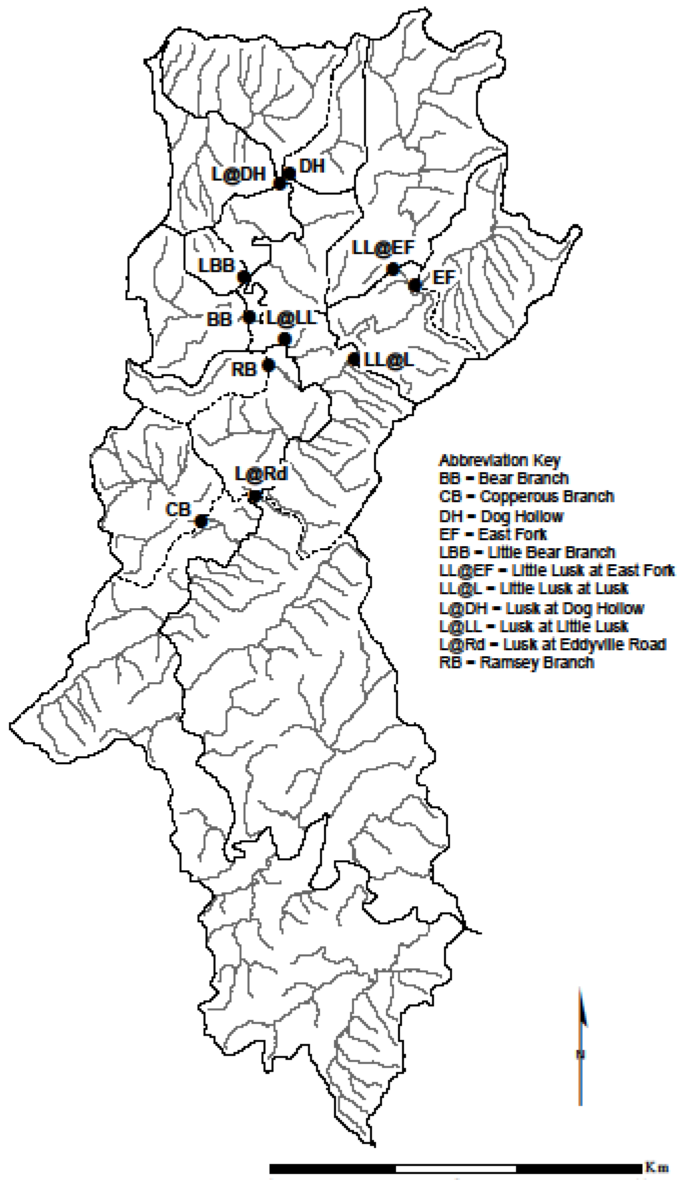

Figure 3. Lusk Creek watershed with sampling sites and their subbasins in upper portion from Dog Hollow to Copperous Branch.

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APPENDICES

Appendix A. Taxa collected from bank or riffle and bank habitats at Little Lusk Creek at East Fork in 2003 insect survey of Lusk Creek in Pope County

Taxon[abc]	Riffle	Bank
Ephemeroptera		
Baetidae		
Plauditus spp.	28	1
Caenidae		
Caenis spp.	1	1
Leptophlebiidae		
Habrophleboides spp.	11	7
Paraleptophlebia spp.		10
Plecoptera		
Perlidae		
Perlesta spp.	11	1
Megaloptera		
Corydalidae		
Nigronia spp.	22	3
Sialidae		
Sialis sp.		1
Trichoptera		
Lepidostomatidae		
Lepidostoma sp.		1
Coleoptera		
Dryopidae		
Helichus spp.	4	1
Dytiscidae [d]		1
Elmidae		
Stenelmis spp.	60	2

Appendix A. Continued

Taxon[abc]	Riffle	Bank
Hydrophilidae [d]		3
Diptera		
Ceratopogonidae		
Bezzia complex	30	4
Foricpomyia sp.		1
Chironomidae		
Tanypodinae [d]	12	19
Orthocladinae [d]	658	266
Chironominae		
Chironomini [d]	377	111
Tanytarsini [d]	76	162
Tipulidae		
Tipula spp.	3	2

[a] Specimens collected during June 2003.
[b] For purpose of this table, each spp. treated as one taxon.
[c] All specimens were immatures (i.e., naiads, nymphs, larvae) except for Hemiptera and Coleoptera as follows: Veliidae, adults and nymphs; Dryopidae, adults; Dytiscidae, adult; Elmidae, adults and larvae; Hydrophilidae, larvae; and Psephenidae, larvae.
[d] Unidentified genus or genera.

Appendix B. Presence (1) or absence (0) of each of 60 taxa collected in riffle habitats from sites used in 2003 insect survey of Lusk Creek in Pope County, IL. Row total equals the number of sites where a taxon was observed

	Study Sites[a]										
Taxon[bc]	LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd	Row Total
Ephemeroptera											
Baetidae											
Acerpenna spp.	0	0	0	0	0	0	1	1	1	1	4
Baetis flavistriga	0	0	0	0	0	0	0	1	0	0	1
B. intercalaris	0	0	0	0	0	0	0	0	1	1	2
Plauditus spp.	0	1	1	0	1	1	1	1	1	1	8
Procloeon spp.	0	0	0	0	0	0	0	1	0	1	2
Caenidae											
Caenis spp.	0	0	0	0	0	0	0	0	1	0	1
Heptageniidae											
Leucrocuta spp.	0	0	0	1	0	0	1	1	1	0	4
Stenacron spp.	0	0	0	0	0	0	1	0	1	0	2
Stenonema femoratum	0	0	0	1	0	0	1	0	1	1	4

Appendix B. Continued

Taxon[bc]	Study Sites[a] LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd	Row Total
Isonychiidae											
Isonychia spp	0	0	0	0	0	0	0	1	1	0	2
Leptophlebiidae											
Habrophlebiodes spp.	0	0	1	1	1	1	1	1	1	0	7
Paraleptophlebia spp.	0	0	1	0	0	1	0	0	0	0	2
Odonata											
Coenagrionidae[d]	0	0	0	0	0	0	0	0	1	0	1
Plecoptera											
Capniidae											
Allocapnia spp.	1	1	1	1	1	1	1	0	1	1	9
Leuctridae[d]	1	0	1	1	0	0	1	0	0	0	4
Nemouridae											
Amphinemura ssp.	0	0	0	1	0	0	0	0	0	0	1

Appendix B. Continued

	Study Sites[a]										
Taxon[bc]	LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd	Row Total
Perlidae											
Neoperla spp.	0	0	0	1	0	0	1	1	1	1	5
Perlesta spp.	1	1	1	1	1	1	1	1	1	1	10
Hemiptera											
Veliidae											
Microvelia spp.	1	1	0	1	0	1	0	0	1	1	6
Megaloptera											
Corydalidae											
Corydalus cornutus	0	0	0	0	0	0	0	0	0	1	1
Nigronia spp.	0	0	0	1	1	1	1	1	1	1	7
Sialidae											
Sialis spp.	1	0	0	0	0	0	1	0	0	0	2

Appendix B. Continued

	Study Sites[a]										
Taxon[bc]	LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd	Row Total
Trichoptera											
Glossosomatidae											
Agapetus illini	0	0	0	0	0	0	1	0	0	0	1
Hydropsychidae											
*Cheumatopsyche*spp.	1	1	1	1	1	1	1	1	1	1	10
Hydroptilidae											
Hydroptila spp.	0	0	0	0	1	0	0	0	0	1	2
Neotrichia spp.	0	0	0	0	0	0	0	1	0	0	1
Leptoceridae[d]	0	0	0	0	0	0	0	0	1	0	1
Philopotamidae											
Chimarra feria	0	0	0	1	0	1	1	1	1	1	6
C. obscura	0	0	0	0	0	0	0	1	1	1	3
Wormaldia shawnee	0	0	0	0	1	0	0	1	0	0	2

Appendix B. Continued

Taxon[bc]	Study Sites[a]										Row Total
	LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd	
Polycentropodidae											
Polycentropus spp.	0	1	0	1	0	1	1	1	1	0	6
Rhyacophilidae											
Rhyacophila fenestra	0	0	1	0	0	0	0	0	0	0	1
R.glaberrima	1	1	0	0	0	1	1	1	0	0	5
Uenoidae											
Neophylax concinnus	0	0	0	0	0	0	1	0	0	0	1
Coleoptera											
Dytiscidae[d]	0	0	0	0	0	1	0	0	0	0	1
Dryopidae											
Helichus spp.	1	0	1	1	0	0	1	1	0	1	6
Elmidae											
Stenelmis spp.	1	1	1	1	1	1	1	1	1	1	10

Appendix B. Continued

Taxon[bc]	Study Sites[a]										Row Total
	LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd	
Hydrophilidae[d]	1	1	0	1	1	0	0	1	0	0	5
Psephenidae											
Ectopria thoricica	1	0	0	0	0	0	0	0	0	0	1
Psephenus herricki	0	0	0	0	0	0	0	0	1	1	2
Diptera											
Ceratopogonidae											
Atrichopogon spp.	0	1	0	0	1	0	0	0	0	0	2
Bezzia complex	1	1	1	1	1	1	1	1	1	1	10
Dasyhelea spp.	0	1	0	0	1	1	0	0	0	0	3
Chironomidae											
Tanypodinae[d]	1	1	1	1	1	1	1	1	1	1	10
Orthocladiinae[d]	1	1	1	1	1	1	1	1	1	1	10
Chironominae											
Chironomini[d]	1	1	1	1	1	1	1	1	1	1	10
Tanytarsini[d]	1	1	1	1	1	1	1	1	1	1	10

Appendix B. Continued

Taxon[bc]	Study Sites[a]										Row Total
	LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd	
Culicidae											
Anopheles sp.	0	0	0	1	0	0	0	0	0	0	1
Dixidae[d]	0	0	1	0	0	0	0	0	0	0	1
Dolichopodidae[d]	1	1	0	0	0	0	0	0	0	0	2
Empididae											
Chelifera spp.	0	1	1	0	0	0	0	0	0	1	3
Hemerodromia spp.	0	0	0	0	1	0	1	1	1	1	5
Psychodidae											
Psychoda sp.	0	1	0	0	0	0	0	0	0	0	1
Simuliidae											
Simulium spp.	1	1	1	1	1	1	1	1	1	1	10
Tipulidae											
Dicranota spp.	0	1	1	1	1	1	1	1	1	0	8
Hexatoma spp.	1	0	0	0	0	1	1	1	0	1	5

Appendix B. Continued

Taxon[bc]	Study Sites[a] LBB	RB	DH	BB	CB	EF	L@DH	LL@L	L@LL	L@Rd	Row Total
Tipulidae											
Limonia spp.	0	1	0	1	1	0	0	0	0	0	3
Molophilus sp.	0	0	0	0	0	0	0	0	1	0	1
Pilaria spp.	1	0	0	0	0	0	0	0	1	0	2
Tipula spp.	0	0	1	1	1	1	1	1	1	0	7

[a] See Table 1 for complete names and stream order.
[b] For purpose of this table, each spp. treated as one taxon.
[c] All specimens were immatures (i.e., naiads, nymphs, larvae) except for Hemiptera and Coleoptera as follows: Veliidae, adults and nymphs; Dryopidae, adults; Dytiscidae, adult; Elmidae, adults and larvae; Hydrophilidae, larvae; and Psephenidae, larvae.
[d] Unidentified genus or genera.

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Major Professor: J. E. McPherson