

Mayflies (Insecta: Ephemeroptera) of the Kiamichi River Watershed, Oklahoma

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ABSTRACT: The biodiversity of Ephemeroptera in the Kiamichi River watershed is described. Fifty-six species, 29 genera, and 11 families of Ephemeroptera are documented in the Kiamichi River watershed. The family Baetidae accounts for almost one-third of the total number of species collected. Fourteen species are reported for the first time from the Interior Highlands, and thirty species represent new state records for Oklahoma. Seventy-five percent of the mayfly species collected from this watershed have strong affinities with eastern North America.

Introduction

Distributional studies of mayflies, like many other insects in North America, have usually focused on political regions rather than natural boundaries. Regulatory and conservation agencies have recognized that a more comprehensive approach based on watersheds is needed to maintain and restore our waters. Extensive inventories of aquatic insects occurring in North American temperate freshwaters has never been undertaken (Schindler, 1989). The Nationwide Rivers Inventory estimated a total of 5,200,000 km of streams in the contiguous 48 states but only 2% are of sufficient quality to be worthy of federal protection status (Benke, 1990). It is reasonable to assume that man's increasing demands on water resources will result in even greater degradation of surface water and loss of aquatic species. Documentation of the biodiversity of North American aquatic insects will be another tool to evaluate our efforts to protect ecosystems (Allan and Flecker, 1993; Benke, 1990; Hughes and Noss, 1992; McCafferty et al., 1993; Schindler, 1989). This paper presents a comprehensive survey of the Ephemeroptera of the Kiamichi River watershed in southeastern Oklahoma. Documentation of mayfly diversity and distribution within the Kiamichi watershed provides a baseline that will be useful in evaluating future changes in water quality and provides a model for comparison to other streams in the geographical region.

The objectives of this study were to: (1) document the diversity of mayflies within the Kiamichi River watershed, a major river in the Interior Highlands (2) contribute to a better understanding of distribution of mayflies in North America and (3) increase our understanding of the variation of morphological characteristics used to identify North American mayflies.

Study Area

The Kiamichi River, situated in southeastern Oklahoma, is the major watershed in the Kiamichi Mountains (Fig. 1). The river, approximately 275 km long, drains an

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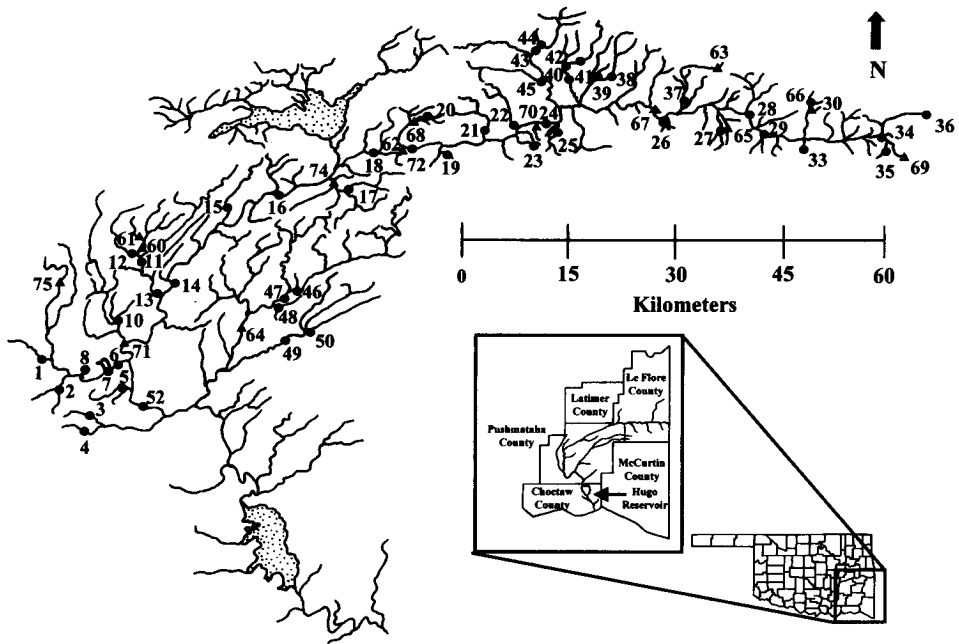


Fig. 1. The Kiamichi Watershed in Oklahoma. The closed circles represent regular collection sites and the triangles represent records from sites that were occasionally sampled.

area of 4740 km². Most of the upper Kiamichi River watershed lies within the Ouachita Mountain physiographic region of the Interior Highlands of North America. The lower portion of the watershed is situated within the Red River Plains geographic region. The watershed is dominated by mixed forest containing hardwoods such as oak (*Quercus* spp.) and hickory (*Carya* spp.), and softwoods such as pine (*Pinus* spp.). Prairies, used primarily for cattle grazing, are common within the watershed. Elevation ranges from 140 to 340 meters above sea level. Stream temperatures range from 6°C during the winter months to near 26°C during the summer months.

Materials and Methods

Monthly collecting trips of three to four days were made February through November 1993. A total of 48 potential collection sites were established throughout the Kiamichi River watershed (Fig. 1). Before each sampling trip, 20 sites were randomly selected from these sites using a stratified random block design. This study design provided seasonal and unbiased representative coverage of streams in the watershed. Ephemeral habitats in the watershed were visited during periods when water was present, usually spring and early summer.

Larvae were collected with a dip net (mesh size 1 mm) and by hand-picking from substrates at each collection site. Adults were collected using aerial nets and portable ultra-violet lights. These lights were operated for a minimum of 30 minutes after sunset during the spring, summer, and fall, when the air temperature was expected to exceed 15°C. Adult mayflies were also collected from a white sheet illuminated

with an ultra-violet light. This technique made possible the collection of undamaged adults.

Mature live larvae collected in the field were placed in "six-pack" Styrofoam coolers, and then packed in an ice chest containing ice. Those adults that did not emerge in the field were transferred to rearing chambers containing gravel, and placed in a Frigid Units Living Stream maintained at a stream-simulated photoperiod and water temperature. Adults that emerged were placed in sub-imago containers for their final molt and their associated larval cast skin collected.

We have followed the classification of McCafferty (1996). All identifications were confirmed by recognized authorities. Voucher specimens were deposited at the following institutions: Colorado State University, Florida A&M University, Purdue University, University of Missouri, Southern Connecticut State University, and University of Texas at Edinburg. A reference collection is maintained at the University of North Texas.

Results

A total of 9400 mayfly specimens from over 200 collections in the Kiamichi River watershed were examined. Based upon current understanding of mayfly systematics, 56 species distributed among 11 families and 29 genera (Table 1) have been identified from the Kiamichi watershed. The greatest diversity is found within the family Baetidae (17 species), which accounts for 30% of the total number of species. The next three most diverse families are Heptageniidae (20%), Leptophlebiidae (16%), and Caenidae (12.5%). The remaining 12 species are distributed among the remaining six families. Of the three mayflies known to be endemic in the Interior Highlands, only *Habrophlebiodes annulata* (Traver) was found within the Kiamichi River watershed.

Many of the species identified during this study were expected, based on previous published distribution records. However, a number of the species that were noteworthy because they possess unusual morphological characteristics or represent significant range extensions are discussed below.

Family Baetidae

Acerpenna macdunnoughi (IDE): This species is reported for the first time in the Interior Highlands. Previous collection records are from scattered localities in eastern and northeastern North America (Burian and Mack, 1990; Burks, 1953; Ide, 1937; Morihara and McCafferty, 1979). *Acerpenna macdunnoughi* occurred throughout much of the watershed, mainly in smaller headwater creeks.

Baetis intercalaris MCDUNNOUGH: An uncommon nymphal variant of this species was collected in the watershed and is discussed by Waltz et al. (1996).

Centroptilum alamance (TRAVER): This eastern North American species is known throughout the Appalachian Mountain region as far west as south-central Missouri (Sarver and Kondratieff, 1997). Its presence in the Kiamichi River watershed represents a major south-western range extension. *Centroptilum alamance* was collected only once during the study from the extreme headwaters of the Kiamichi River at an elevation of 370 meters.

Heterocloeon curiosum (MCDUNNOUGH): This widely distributed eastern North American species is reported for the first time in the Interior Highlands.

Plauditus futilis (MCDUNNOUGH): *Plauditus futilis* was previously known only from the type locality (Alberta, Canada) and central Texas (Baumgardner et al.,

Table 1. Mayfly species collected within the Kiamichi River drainage, and their associated collection sites.

FAMILY BAETIDAE	
<i>Acentrella turbida</i> (McDunnough):	07, 10, 11, 13, 15–17, 19, 20–23, 25, 27–30, 33–35, 37, 41, 43, 44, 46, 50, 62, 65 (larvae, reared adults).
² <i>Acerpenna macdunnoughi</i> (Ide):	02–06, 24, 39 (larvae).
<i>A. pygmaea</i> (Hagen):	02, 04, 05, 24, 33, 39, 41–43, 47, 49, 61 (larvae).
<i>Baetis flavistriga</i> McDunnough:	06, 33, 34, 41, 50, 63 (larvae).
<i>B. intercalaris</i> McDunnough:	14, 33, 34, 62 (larvae, reared adults).
<i>Callibaetis floridanus</i> Banks:	46 (adult).
¹ <i>Centroptilum alamance</i> (Traver):	36 (adults).
<i>Diphetero hageni</i> (Eaton):	27, 29, 30, 33–35, 37, 63 (larvae).
² <i>Heterocloeon curiosum</i> (McDunnough):	13, 14 (larvae).
¹ <i>Plauditus dubius</i> (Walsh) 1862:	05, 06, 10, 16, 17, 19, 23, 24, 26, 27, 34, 37, 41, 43, 49, 60 (larvae).
² <i>P. futilis</i> (McDunnough):	18 (adults).
¹ <i>P. parvulus</i> (McDunnough):	04–06, 13, 16, 28, 46, 47, 50 (larvae).
¹ <i>P. punctiventris</i> (McDunnough):	14 (larvae).
² <i>Procloeon minor</i> (McDunnough):	10, 33, 67 (adults).
² <i>P. pennulatum</i> (Eaton):	64 (reared adults, larvae).
<i>P. rubropictum</i> (McDunnough):	19 (reared adults).
² <i>P. texanum</i> McCafferty & Provonsha:	39 (adult).
FAMILY BAETISCIDAE	
<i>Baetisca lacustris</i> McDunnough:	14, 24 (larvae).
FAMILY CAENIDAE	
¹ <i>Brachycercus flavus</i> Traver:	13, 14 (adults).
<i>Caenis amica</i> Hagen:	07, 14, 16, 21, 24, 33, 37, 43 (adults, larvae).
<i>C. anceps</i> Traver:	10, 28, 30, 33, 37, 65, (adults).
² <i>C. diminuta diminuta</i> Walker:	24 (adults).
<i>C. hilaris</i> (Say):	10, 11, 13–16, 18, 21, 24, 28, 30, 33, 37, 39, 40, 47, 60, 61, 65, 67 (larvae, adults).
<i>C. latipennis</i> Banks:	02, 05, 13, 16, 21–25, 33, 34, 37, 45, 46, 48 (adults, larvae).
<i>C. punctata</i> McDunnough:	11, 37, 61 (adults).
FAMILY EPHEMERELLIDAE	
<i>Eurylophella bicolor</i> (Clemens):	34, 35 (adults).
¹ <i>E. funeralis</i> (McDunnough):	23 (larvae).
¹ <i>E. temporalis</i> (McDunnough):	02, 05, 35, 41 (larvae).
¹ <i>Serratella frisoni</i> (McDunnough):	61 (larvae).
² <i>Timpanoga simplex</i> (McDunnough):	61 (larvae).
FAMILY EPHEMERIDAE	
<i>Hexagenia limbata</i> Guerin:	13, 16, 21, 63, 70, 73 (adults).
FAMILY HEPTAGENIIDAE	
¹ <i>Leucrocota aphrodite</i> (McDunnough):	10, 13, 16, 28, 30, 33, 34, 37, 39, 60, 61, 66 (adults).
² <i>L. juno</i> (McDunnough):	15, 16, 30, 34, 35, 63, 66, 69 (adults).
<i>L. maculipennis</i> (Walsh):	07, 10, 12, 16, 18, 24, 30, 33, 34, 37, 39, 44, 63, 65, 69, 70 (adults).
<i>Nixe perfida</i> (McDunnough):	05, 17, 20, 23, 30, 34, 35, 46, 50, 60, 62, 64 (larvae, adults).
<i>Stenacron interpunctatum</i> (Say):	01–06, 08, 10, 12, 13, 15–18, 21, 23, 24, 28, 33–35, 37–41, 44, 46, 48, 50, 61, 63, 65, 67, 70, 75 (adults, larvae).
¹ <i>Stenonema exiguum</i> Traver:	06, 14, 28, 30, 33, 37, 72 (reared adults, larvae).
<i>S. femoratum</i> (Say):	01, 02, 04, 05, 07, 08, 10–24, 27–30, 33–35, 37–50, 60, 61, 64, 65, 67, 68, 70–72, 74, 75 (larvae, adults).
¹ <i>S. mexicanum integrum</i> (Ulmer):	24, 61 (adults).
<i>S. modestum</i> (Banks):	13, 37, 46, 49, 50 (adults).
¹ <i>S. pulchellum</i> (Walsh):	13, 24, 33, 37 (larvae).
<i>S. terminatum terminatum</i> (Walsh):	24, 33, 37, 70 (adults, larvae).

Table 1. Continued.

FAMILY ISONYCHIIDAE	
<i>Isonychia rufa</i> (McDunnough): 06, 10, 12, 14, 16, 18, 21, 24, 28, 33, 34, 37, 50, 61, 65 (adults, larvae).	
FAMILY LEPTOHYPHIDAE	
² <i>Leptohyphes robacki</i> Allen: 24 (larvae).	
¹ <i>Tricorythodes allectus</i> (Needham): 14, 33, 39, 46, 67 (larvae, adults).	
FAMILY LEPTOPHLEBIIDAE	
<i>Choroterpes basalis</i> (Banks): 10–13, 15–18, 21–24, 26, 28, 33, 37, 39–41, 60–62, 65, 67, 68 (adults, larvae).	
<i>Habrophlebiodes annulata</i> Traver: 15, 19, 23, 26, 30, 33, 66 (adults).	
¹ <i>Leptophlebia cupida</i> (Say): 30 (larva).	
² <i>L. intermedia</i> (Traver): 02, 03, 05, 23, 25, 26 (larvae, adults).	
² <i>Paraleptophlebia adoptiva</i> (McDunnough): 19 (larva).	
² <i>P. debilis</i> (Walker): 05, 07, 36, 41, 43, 47, 60 (larvae).	
<i>P. guttata</i> McDunnough: 34, 66 (larvae, adult).	
<i>P. mollis</i> (Eaton): 30, 34, 35, 63 (larvae).	
² <i>P. volitans</i> McDunnough: 23, 29, 34, 37 (adults).	
FAMILY POLYMITARCYIDAE	
¹ <i>Ephoron album</i> (Say): 14, 15, 18, 24, 65, 67 (adults, larvae).	
FAMILY POTAMANTHIDAE	
¹ <i>Anthopotamus myops</i> (Walsh): 14, 16, 18, 21, 28, 33, 37, 40, 65, 67, 70, 72 (adults, larvae).	

¹ New state record for Oklahoma.
² New record for the Interior Highlands and Oklahoma.

1997). Berner (1977) also reported it from southern Mississippi; however, our re-examination of the male imagoes that established this record indicated they were misidentified.

Procloeon minor (MCDUNNOUGH): Previous to this study, this species had only been reported from its type locality in Canada. Its presence in the Kiamichi River watershed represents a major range extension to the south. *Procloeon minor*, collected only three times from widely separated localities, appears to have a broad distribution in the watershed. All three collection sites were headwater streams at elevations above 225 meters surrounded by mixed forest.

Procloeon pennulatum (EATON): Previously known in North America only from North Carolina and southern Canada, this species is widespread in Europe (McCafferty, 1993). Its presence in the Kiamichi River watershed represents the first record in the Interior Highlands.

Procloeon texanum MCCAFFERTY AND PROVONSHA: This species was previously known only from its type locality in south central Texas (McCafferty and Provonsha, 1993). Its presence in the Kiamichi watershed extends its known range northward into the Interior Highlands.

Family Caenidae

Caenis anceps TRAVER: Provonsha (1990) describes adult tergites of this species as "entirely pale". However, tergites of several adult specimens examined from the Kiamichi River watershed were moderately brown-tinged. This species is widely dis-

tributed in larger second and third-order streams in the upper region of the Kiamichi watershed.

Caenis diminuta diminuta WALKER: This species is widespread in the southeastern United States, where it tends to be the most common *Caenis* (Provonsha, 1990). Its occurrence in the Interior Highlands is the first record for this region and extends the known range westward.

Caenis hilaris (SAY): Adults of *C. hilaris* collected within the Kiamichi watershed displayed the same purplish shading between the lateral ocelli as reported by Provonsha (1990) for populations in the mountainous regions of Arkansas. This was the most commonly collected and widely distributed species of *Caenis* within the watershed. Adults were collected from a wide variety of sampling stations located on second through fifth-order streams.

Family Ephemerellidae

Timpanoga simplex (MCDUNNOUGH): Known from throughout eastern North America (Allen and Edmunds, 1962; Berner and Pescador, 1988), this is the most widely distributed species in the genus *Timpanoga*. Its presence in the Kiamichi River watershed represents the first record of it in the Interior Highlands.

Family Heptageniidae

Leucrocuta juno (MCDUNNOUGH): *Leucrocuta juno* is known from scattered localities in the eastern United States (Faulkner and Tarter, 1977; Kondratieff and Harris, 1986; Kondratieff and Voshell, 1983; Traver, 1937). Its presence in the Kiamichi River watershed is the first report from the Interior Highlands. Adults were found to be widely distributed in the Kiamichi watershed in the vicinity of small, shallow first, second, and third-order streams with cobble and boulder substrate.

Family Leptohyphidae

Leptohyphes robacki ALLEN: The Kiamichi River watershed represents a significant western range extension for *L. robacki*, which was previously known only from the Potomac River in Maryland, and the Savannah River on the South Carolina-Georgia border (Allen, 1967).

Family Leptophlebiidae

Leptophlebia intermedia (TRAVER): This is a common and widely distributed species in the southeastern United States (Berner, 1975), with its northern limits in Connecticut (Burian and Bednarik, 1994). Its presence in the Kiamichi River watershed represents the first record in the Interior Highlands, and extends its known range west. *Leptophlebia intermedia* was found widely distributed in the Kiamichi River watershed. Larvae were collected from among plant roots and detritus in undercut banks of small second and third order streams.

Paraleptophlebia adoptiva (MCDUNNOUGH): Although widely reported in northeastern North America (Burks, 1953; Leonard and Leonard, 1962; Burian and Bednarik, 1994), *P. adoptiva* is considered rare in the southeast (Berner, 1975). This is the first record in the Interior Highlands, and extends its known range to the southwest.

Paraleptophlebia debris (WALKER): This is a common northern transcontinental species that ranges across North America from California to South Carolina (Berner, 1975; Harper and Harper, 1986). Berner (1975) reports it as rare in North and South Carolina, while Kondratieff and Harris (1986) collected it from a single county in

northern Alabama, its previous most-southern record. Collection records of *P. debilis* in the Kiamichi River watershed represent its southern limit, and first record in the Interior Highlands. This species is widely distributed in the watershed, with collection records from the upper headwaters to the lower reaches of the watershed. Larvae were collected from 1st–3rd order creeks.

Paraleptophlebia volitans (MCDUNNOUGH): Known from Ontario to Florida and west to east Texas (Berner and Pescador, 1988; Baumgardner et al., 1997), this is a common eastern North American species. Its presence in the Kiamichi River watershed represents a new record for the Interior Highlands.

Discussion

It is known that there is considerable range in the seasonal occurrence and spatial distribution of various mayfly species and genera (Edmunds et al., 1976). This study, by surveying a major portion of the Kiamichi watershed over a ten month period, increases the probability that those mayflies with restricted seasonal and spatial distributions will be represented. Fourteen species are reported for the first time from the Interior Highlands (Table 1). Thirty species are reported as new state records for Oklahoma. These new records expand the total number of mayfly species known in Oklahoma from 59 to 89.

Seventy-five percent of the mayfly species collected within the Kiamichi River watershed have eastern North American affinities. This is typical of creeks and rivers in the Interior Highlands which contain faunal assemblages similar to those of eastern North America (Ross and Ricker, 1971; McCafferty and Provonsha, 1978). It is hypothesized that many aquatic species dispersed into the Interior Highlands during the Pleistocene glacier advance through the unglaciated Illinois Ozark corridor that connected the Cumberland Plateau-Appalachian region with the Interior Highlands (McCafferty and Provonsha, 1978). Those mayflies in the Kiamichi watershed with an Illinois-Ozark distribution include *Acerpenna pygmaea*, *Anthopotamus myops*, *Choroterpes basalis*, *Nixe perfida*, *Serratella frisoni*, *Leucrocuta aphrodite*, *Stenacron interpunctatum*, *Stenonema femoratum*, and *Paraleptophlebia guttata*. Only *Brachycercus flavus*, *Caenis diminuta*, *Paraleptophlebia volitans*, and *Leptophlebia intermedia* have a continuous distribution through the Gulf Coast Corridor with the Kiamichi River watershed. Species with disjunct populations in the watershed are *Acerpenna macdunnoughi*, *Centroptilum almance*, *Heterocloeon curiosum*, *Timpanoga simplex*, *Leucrocuta juno*, *Leptohyphes robacki*, and *Paraleptophlebia adoptiva*. Additional surveys are necessary to determine whether these species are truly disjunct or have populations that have been overlooked due to insufficient collecting.

Other species collected from the Kiamichi River watershed have widespread, largely transcontinental distributions. These include *Acentrella turbida*, *B. flavistriga*, *Diphetero hageni*, *Plauditus parvulus*, *Caenis amica*, *Caenis latipennis*, *Hexagenia limbata*, and *Paraleptophlebia debilis*. No species of mayflies were found within the Kiamichi River watershed that had exclusively western or southwestern affinities. *Ephoron album*, which is considered primarily a western species, also ranges into the central United States.

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