AN ABSTRACT OF THE THESIS OF

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in Biology presented on 3 May 1982

Title: Some Aspects of Mayfly (Ephemeroptera: Stenonema) Ecology in a Neosho River Riffle, Lyon County, Kansas

Abstract approved: Carl W. Prophet

A study was conducted to determine the *Stenonema* species inhabiting a riffle of the Neosho River near Emporia, Kansas, and to observe strategies employed by the species present to reduce competition. For benthic sampling purposes, three substrate zones were recognized within the study reach, according to median particle diameter. MdØ (median diameter in phi units) of the zones were: Zone I, -3.38, Zone II, -4.75, and Zone III, -6.25. Zone II comprised approximately 50% of the study reach, with Zones I and III comprising approximately 25% each. From 11 June 1980 to 10 October 1980 water temperature ranged from 17.5°C to 32.0°C, dissolved oxygen ranged from 6.0 ppm to 8.9 ppm, and pH ranged from 7.89 to 8.33. Quantitative benthos samples were taken from 20 March 1980 to 24 September 1980. In addition, *Stenonema* nymphal and adult stages were collected qualitatively during the same period. Four species were collected: *S. terminatum*, *S. femoratum*, *S. exiguum*, and *S. integrum*. The objective to characterize resource partitioning strategies was not realized due to unexpectedly low population densities of all species present except *S. terminatum*. Populations of *S. femoratum*, *S. exiguum*, and *S. integrum* were too sparse for reliable substrate preference and life cycle analyses. The maximum estimated density of *S. terminatum* nymphs within the study reach of 68.9 nymphs/m^2 on 2 July

1980. There was no significant preference for any substrate zone by *S. terminatum* nymphs. Analyses of adult light trap data and measurements of nymphal head capsule width indicated that *S. terminatum* produced two generations during the summer of 1980 and a third, fall generation which would mature in the spring of 1981. Known habitat requirements of *S. femoratum*, *S. exiguum*, and *S. integrum* were compared with conditions at the Emporia study reach. In each case, at least one requirement was lacking.

Some Aspects of Mayfly (Ephemeroptera: *Stenonema*)
Ecology in a
Neosho River Riffle, Lyon County, Kansas

A Thesis
Submitted to
the Division of Biological Sciences
Emporia State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
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May 1982

Carl W. Prophet

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ACKNOWLEDGEMENTS

I would like to thank Dr. Carl Prophet for his patient guidance as my major advisor. My thanks to Dr. John Ransom and Dr. Thomas Eddy for serving on my graduate committee. Mr. Kenneth Fuller and Mr. Orville Hoch kindly allowed me to conduct this study on their properties. I would also like to thank the Division of Biological Sciences of Emporia State University for providing financial support. I express my sincere appreciation to my wife, Becky, for her faith and support.

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INTRODUCTION

The need to monitor environmental quality has generated interest in benthic communities. Henderson (1949) and Patrick (1953) were among the first to recognize the value of sampling benthic organisms in order to assess effects of pollution. Cummins (1974) stressed the need for more information about benthic organisms at the species level to increase our understanding of the structure and function of lotic ecosystems.

There are 17 families, 61 genera and approximately 600 species of mayflies (Ephemeroptera) inhabiting the fresh waters of North America (Edmunds et al., 1976). Immature mayflies (nymphs) are benthic insects which usually require three to six months for growth and development, but the terrestrial adult's lifespan is rarely longer than one week (Needham et al., 1935). With a few exceptions, mayfly nymphs feed on detritus and diatoms and are an important component of many benthic food webs (Cummins, 1973). Adult mayflies do not feed. Their sole purpose is reproduction.

The mayfly genus Stenonema Traver (Heptageniidae) is common in riffle areas of streams and rivers in eastern North America. Stenonema nymphs are adapted morphologically and behaviorally to lotic habitats. They are flattened dorso-ventrally and provide little resistance to water current as they cling to the undersides of stones with relatively long, curving tarsal claws (Cummins, 1978). Stenonema nymphs avoid light, seeking food and shelter in crevices within the substrate (Edmunds, Jensen and Berner, 1976). Their primary food is often particles of allochthonous detritus, the particle size utilized depending on the size of the nymph (Coffman, Cummins and Wuycheck, 1971).

Many Stenonema species are widely distributed and exhibit a variable morphology according to local conditions (Spieth, 1947). The majority of studies concerning Stenonema have been restricted to relatively small geographic areas and do not provide a reliable guide to the taxonomy and ecology of this genus in other localities (Burks, 1953; Flowers and Hilsenhoff, 1978; Leonard and Leonard, 1962, and Lewis, 1974). Recently, Bednarik and McCafferty (1979) revised the taxonomy of Stenonema using characters drawn from specimens collected throughout its known range.

Recent stream surveys in Kansas list Stenonema nymphs as one of the more abundant and consistently present members of the riffle, benthic fauna (Nulty, 1974; Prophet and Edwards, 1973, and Ransom and Prophet, 1974). Liechti (1978), listed nine species of Stenonema as occurring in the state and briefly discussed the distribution and ecology of each species. According to Bednarik and McCafferty (1979), four of the species listed by Liechti are synonyms, thus reducing to five the number of Stenonema species known to occur in Kansas.

I collected four species of Stenonema nymphs from a Neosho River riffle near Hartford, Kansas, during 1975. Congeneric coexistence obviously depends upon mechanisms which reduce competition, since two closely related species normally cannot occupy the same niche. I believed that a situation such as was observed at the Hartford riffle presented an excellent opportunity to study adaptations utilized by the four Stenonema species for resource partitioning.

A study was initiated during the 1980 spring to determine the species of Stenonema nymphs inhabiting a large riffle area on the Neosho River near Emporia, Kansas, and to observe strategies employed by the species present to reduce competition.

METHODS AND MATERIALS

Description of the Study Area

The Neosho River originates in the Flint Hills upland of east central Kansas, flowing southeast to its confluence with the Arkansas River in eastern Oklahoma. The channel length is 540 km, and its gradient averages 2.8 m/km in the upper reaches (Schoewe, 1951). Over the 13 year period 1963-1976, the flow rate of the upper Neosho River averaged approximately 0.90 m^3/s, exceeding 0.25 m^3/s about 50% of the time (Kansas Water Resources Board, 1978). During the same period water temperatures ranged from 0°C to 32°C. The upper Neosho River usually transports 250-500 ppm total dissolved solids and sediment in a range from 1,300-2,000 ppm (Kansas Water Resources Board, 1967).

A portion of a Neosho River riffle two km northeast of Emporia, Lyon County, Kansas, was selected for study because of its proximity to Emporia State University. The study reach was 50 m long, approximately 35 m wide and 25 cm deep. At this location, the river is flanked on both sides by riparian forest with a maximum width of approximately 50 m. The primary woody taxa comprising this forest are *Celtis*, *Acer*, *Fraxinus*, and *Ulmus*. Beyond the forest, the land surrounding the study area is cultivated.

Substrate Analysis

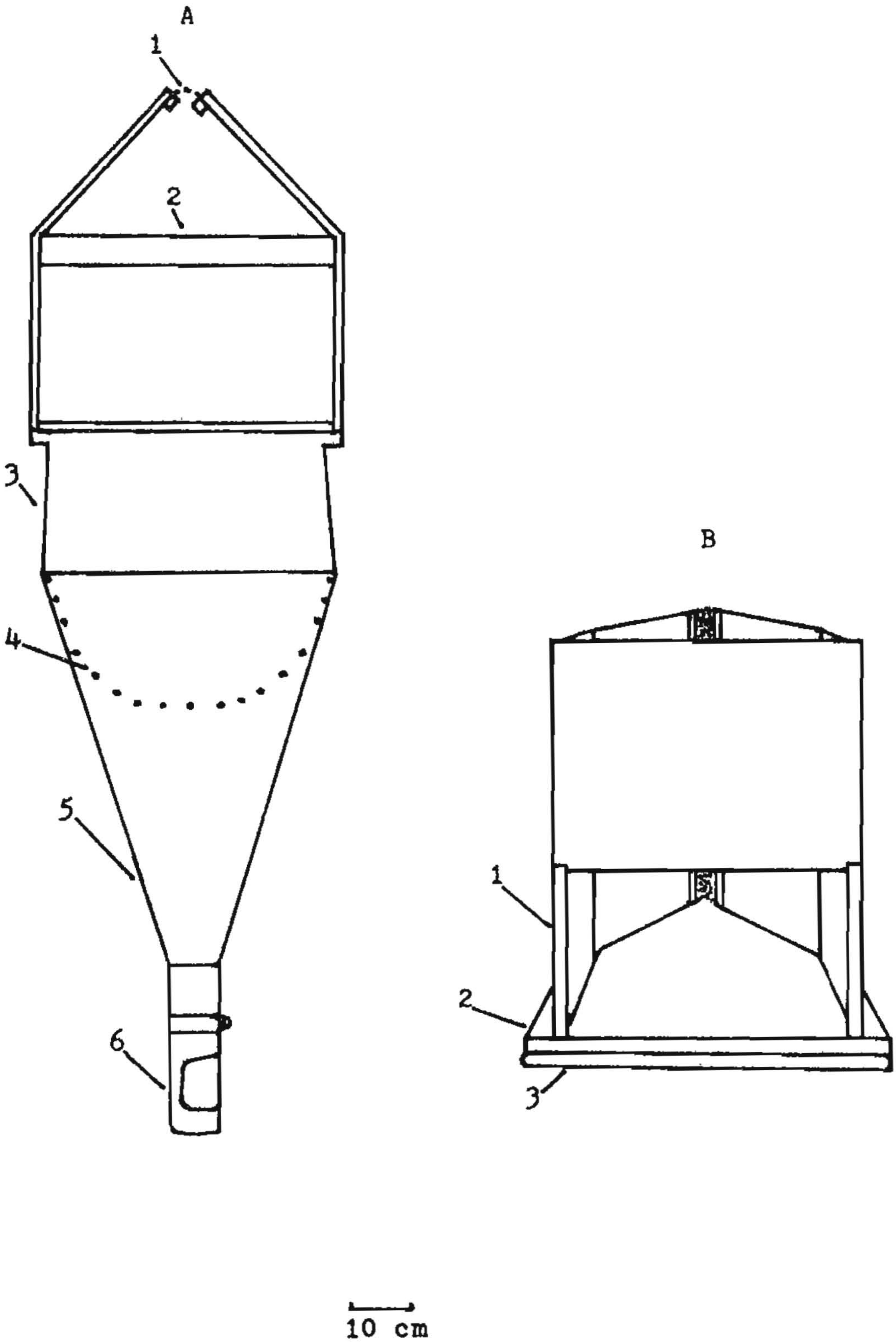
The substrate of the study area was composed of a variety of particle sizes. For sampling purposes the stream bed in the study area was divided into three substrate zones: gravel, cobble, and boulder. A preliminary quantitative sample was taken in March 1980 to determine the median particle diameter for each zone. As recommended by Cummins (1962) the phi scale was used in substrate analysis.

Three subsamples were collected at random from each of the three substrate zones using a pentagonal shaped benthos sampler (Fig. 1) modified from Mundie (1971). Each subsample was thoroughly washed and the benthos sorted out and preserved. Substrate particles smaller than 0.04 mm (phi 4) were processed by retaining the water used to wash the subsample, allowing the sediment to settle for 48 hours, decanting the surface water, and evaporating the remainder at 105°C in a drying oven. This sediment was then dried another 24 hours, allowed to cool to room temperature, and weighed on a Mettler B balance. Particles with a diameter equal to or greater than 0.04 mm but less than 25 mm (phi -4) were separated by wet sieving, air dried and weighed on an Ohaus 2610 balance beam. Those particles 25 mm or larger were measured individually, air dried and weighed on an Ohaus 2610 balance beam.

Quantitative Sampling

Quantitative benthic samples were taken approximately once each month from March 1980 through September 1980. Each sample consisted of three subsamples randomly taken from each of the three substrate zones with the pentagonal benthos sampler. Benthos contained in each subsample were taken to the laboratory in separate containers, sorted and all heptagenid mayfly nymphs were preserved. Stenonema nymphs were identified to species when possible; head width, head length and body length were measured with a compound microscope fitted with an ocular scale. The primary taxonomic references were; Biosystematic Revision of the Genus Stenonema (Bednarik and McCafferty, 1979) and Taxonomy and Ecology of Stenonema Mayflies (Heptageniidae; Ephemeroptera) (Lewis, 1974).

Figure 1. Quantitative sampler design. The back, sides and front of the sampler are made of 12 mm plywood. A. Top view: 1) aluminum screen (one mm mesh) across inlet gap, 2) wooden cross brace, 3) canvas net sleeves (inner net sleeve nests inside outer net sleeve), 4) inner nytex net (571 u mesh), 5) outer nytex net (64 u mesh), 6) removable catch bucket. B. Back view with nets removed: 1) aluminum angle attached to sampler side and extended beyond the back edge to accept net frames, 2) wooden base, 3) closed cell foam seal.


A
1
2
3
4
5
6
B
1
2
3
10 cm

Qualitative Sampling

Qualitative samples were collected at approximately weekly intervals from 20 March to 10 October by washing rocks over a bucket and by using a surber type stream sampler. The living nymphs were returned to the laboratory where some of the more mature Stenonema nymphs were transferred to rearing containers; the remaining specimens were preserved and used for identification purposes.

Adult mayflies were collected from spider webs along the stream bank and by sweeping adjacent vegetation with an insect net. Peak periods of adult activity were detected by taking black light samples biweekly from May through September. A 25x35 cm white enameled pan containing a solution of alcohol and water was placed in front of a battery powered flourescent lamp fitted with an ultraviolet tube on a gravel bar near the center of the study area. Starting at dusk, the light was turned on for five minutes and then off for fifteen minutes until mayfly response ceased. Mayflies attracted to the light were trapped in the pan, collected after the light was turned off and placed in a jar of 90% alcohol. A few individuals were picked from the surface of the lamp and placed in ventilated jars so the living colors of the insect could be observed.

Rearing

For taxonomic purposes the most valuable specimens are those that have been reared to adulthood. Stenonema nymphs were reared in individual glass jars containing river water and a few pebbles. A twig or pebble was placed above the water so the newly emerged mayfly would have a place to rest. Each jar was covered with plastic screen and placed in a warm location, but not in direct sunlight. No aeration or food was provided.

Physicochemical Conditions

Approximately twice each month, from June through October, certain physicochemical conditions in the river were measured and recorded. Temperature was measured with a mercury thermometer. Dissolved oxygen was estimated by the Winkler method. A water sample was taken and transported to the laboratory where pH was measured with a Fisher Accumet model 610 pH meter. In addition, on each quantitative sampling date air temperature, water temperature and time of sampling were recorded. Depth at the center of each subsample location was measured with a meter stick and recorded.

RESULTS

Physicochemical Conditions

In March 1980, the study reach of the Neosho River was a continuous riffle approximately 35 m across at its widest point, 50 m long and with a maximum depth of 42 cm. Water level and flow rate decreased throughout the study period. By the middle of May 1980, the study area consisted of three pools separated by shallow riffles. On 24 September 1980, when quantitative sampling was terminated, the maximum width of the study reach was 15 m, and maximum depth in the riffle areas was less than 10 cm. Total area of stream bed within the study reach available to benthos decreased from an estimated 1750 m^2 on 20 March 1980 to approximately 320 m^2 on 24 September 1980.

During the period 20 March 1980 through 10 October 1980, water temperature ranged from 12.0°C to 32.0°C. D. O. ranged from 6.0 ppm to 8.9 ppm and pH ranged from 7.89 to 8.33 (Table 1).

Substrate Analysis

For sampling purposes three substrate zones were recognized within the study area, based on substrate particle size (Fig. 2). The MdØ (median particle diameter in phi units) of Zone I was -3.38 (approximately 12 mm), Zone II had a MdØ of -4.75 (approximately 28 mm) and Zone III had a MdØ of -6.25 (approximately 82 mm). Relative amounts of each substrate zone remained the same throughout the study period, with approximately 50% of the study reach classified as Zone II, approximately 25% classified as Zone I and approximately 25% classified as Zone III.

Composition of *Stenonema* Fauna

Four *Stenonema* species were identified from benthos samples collected from the study reach. These four species were: *Stenonema terminatum*

Table 1. Water temperature, pH and D. O. in a Neosho River riffle from 3 March to 10 October 1980.

Date	Water temperature °C	pH	D. O. ppm
3-20	12.0		
4-20	17.5		
5- 5	18.0		
5-22	21.0		
5-26	25.0		
6-11	30.0		
6-17	29.0		7.1
6-28	32.0		
7- 2	32.0	7.89	7.0
7-17	30.0	8.13	6.0
7-22	30.0		
7-25	27.0	8.10	7.2
7-29	32.0		
8- 7	31.0	8.00	6.3
8-13	29.0		
8-19	31.0	8.33	7.0
8-21	27.0		
8-29	29.5		
9- 3	32.0	8.32	7.5
9-10	24.8		
9-12	27.5		
9-21	27.5		
9-25	17.5	7.95	7.3
10- 8	22.5		
10-10	19.0	8.07	8.9

(Walsh), *Stenonema femoratum* (Say), *Stenonema exiguum* Traver and *Stenonema integrum* (McDunnough). Mature nymphs and adults of each species were collected within the study reach.

Figure 2. Substrate zone map of the study reach near Emporia, Kansas. The Mdϕ of each zone is: 1, -3.38 (12 mm), 2, -4.75 (28 mm) and 3, -6.25 (82 mm).

UPSTREAM

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2  333333333333333333333333333333333333  2222222222222
22  3333333333333333333333333333333333  22222222222222
222  33333333333333333333333333333333   22222222222222
2222  333333333333333333333333333333  2222222222222222
22222  33333333333333333333333333333  2222222222222222
222222  333333333333333333333333333  22222222222222222
222222  33333333333333333333333333  222222222222222222
2222222  333333333333333333333333  2222222222222222222
22222222  3333333333333333333333  22222222222222222222
222222222  33333333333333333333  222222222222222222222
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22222222222  3333333333333333  22222222222222222222222
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1                           22222222222222222222222222
1111111111111111  222222222222222222222222222222222222
111111111111111  2222222222222222222222222222222222222
11111111111111  22222222222222222222222222222222222222
111111111111111  2222222222222222222222222222222222222
111111111111111  2222222222222222222222222222222222222
11111111        22222
11111111  22222222222  3333333333333333333333333333333
111111111  22222222222  333333333333333333333333333333
111111111  22222222222  333333333333333333333333333333
1111111111  22222222222                 33333333333333
11111111111  22222222222222222222222222
11111111111  22222222222222222222222222222222222222222
111111111111  2222222222222222222222222222222222222222
1111111111111  222222222222222222222222222222222222222
11111111111111  22222222222222222222222222222222222222
1111111111111  222222222222222222222222222222222222222
1111111111111  22           22222222222222222222222222
1111111111111  22  333333333  222222222222222222222222
11111111111111   33333333333  222222222222222222222222
111111111111111   3333333333  222222222222222222222222
111111111111111  333333333333  22222222222222222222222
111111111111111  33333333333  222222222222222222222222
111111111111111   333333333  2222222222222222222222222
11111111111111  2  3333333  22222222222222222222222222
 11111111111111  2  33333  222222222222222222222222222
   11111111111  222       2222222222222222222222222222
        111111  22222222222222222222222222222222222222
         111  2222222222222222222222222222222222222222
             22222222222222222222222222222222222222222
         222222222222222222222222222222222222222222222
        2222222222222222222222222222222222222222222222
       22222222222222222222222222222222222222222222222
       2222222222
       222222     111111111111111111111111111111111111
              1111111111111111111111111111111111111111
       3333  11111111111111111111111111111111111111111
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Stenonema terminatum

S. terminatum was the most abundant and prevalent *Stenonema* species inhabiting the study reach. On each collection date more than 90% of identifiable *Stenonema* nymphs collected were *S. terminatum*. The highest density of *S. terminatum* nymphs observed was on 2 July 1980 when an estimated 68.9 nymphs/m^2 inhabited the study area (Fig. 3).

The density of *S. terminatum* nymphs in each of the three substrate zones was compared to determine any possible substrate preferences. For each quantitative sampling date the average number of nymphs collected from each substrate zone was compared to the average number of nymphs collected from the other two substrate zones using the F test (d.f.=2/6, P=0.05). The average frequencies of *S. terminatum* nymphs on all quantitative sampling dates for each substrate zone were also analyzed using the F test (d.f.=2/18, P=0.05). According to these analyses *S. terminatum* nymphs did not show a significant preference for any of the substrate zones.

Head capsule width data for *S. terminatum* nymphs collected quantitatively are presented in Figure 4. Nymphs with head capsules 1.9 mm or wider are mature and would emerge as adults before the next sampling date.

Mature *S. terminatum* nymphs tended to move to the edge of the river and emerge as adults in shallow water. Nymphs of all sizes avoided areas of strong current, regardless of substrate type underlying them. This behavior is apparently typical of all *Stenonema* nymphs (Leonard and Leonard, 1962).

Stenonema terminatum also constituted most of the *Stenonema* adults

Figure 3. Density estimates of *Stenonema* nymphs inhabiting a Neosho River riffle near Emporia, Kansas.

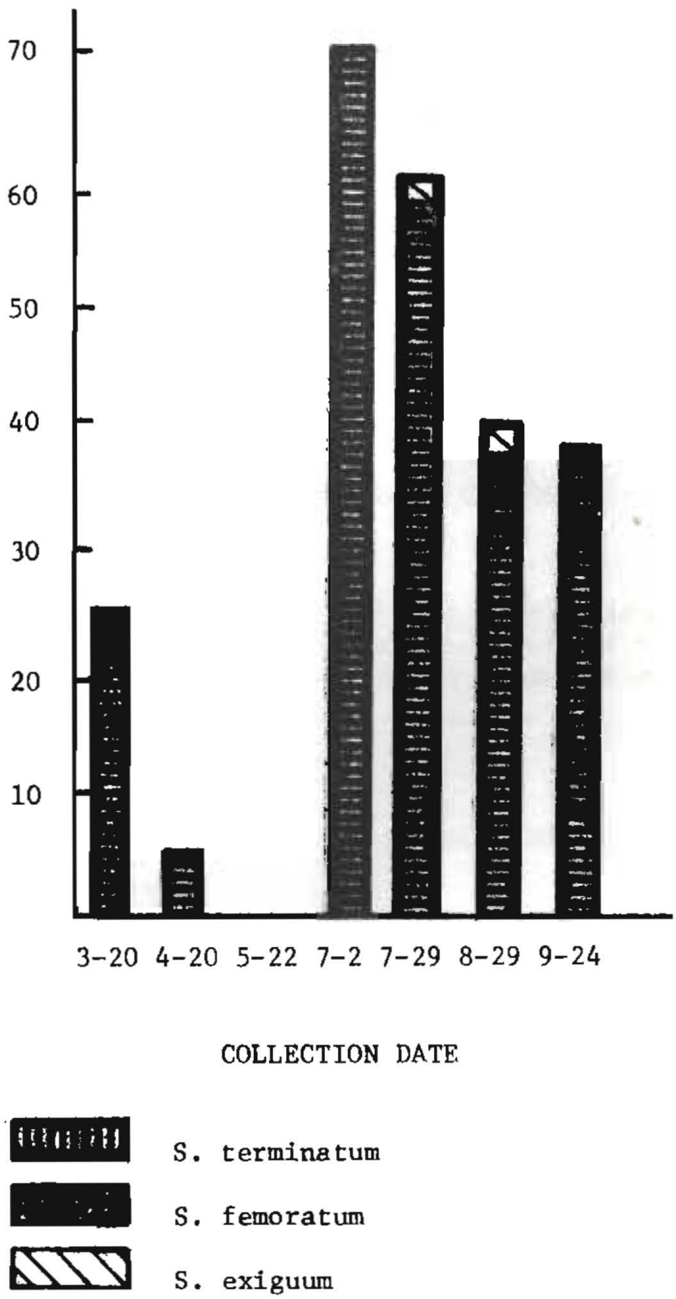
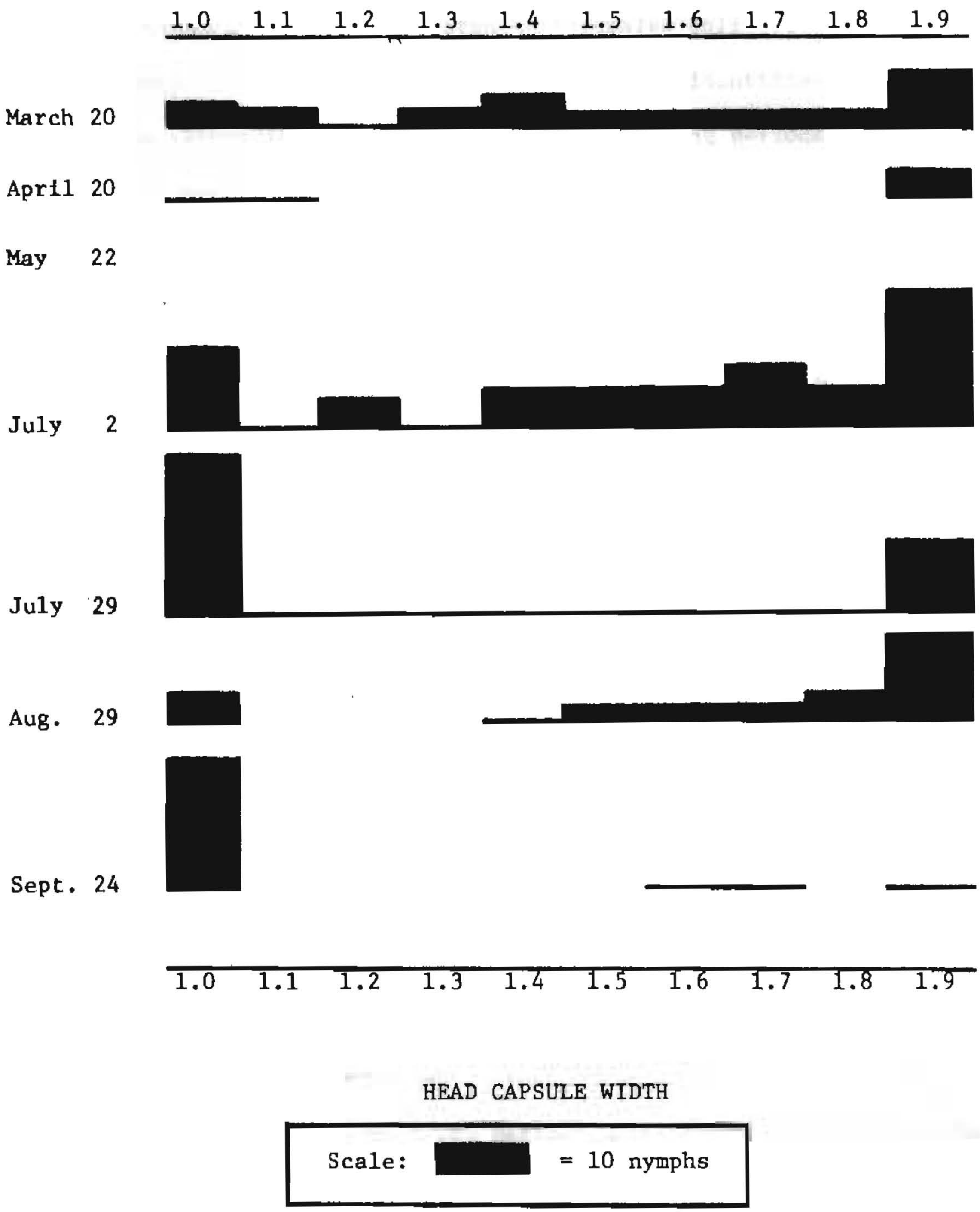

70
60
50
40
30
20
10
3-20 4-20 5-22 7-2 7-29 8-29 9-24
COLLECTION DATE
S. terminatum
S. femoratum
S. exiguum

Figure 4. Life cycle of _Stenonema terminatum_ represented by width of nymphal head capsules. Nymphs with head capsules 1.9 mm or wider are mature.


1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9
March 20
April 20
May 22
July 2
July 29
Aug. 29
Sept. 24
1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9
HEAD CAPSULE WIDTH
Scale: = 10 nymphs

collected. Males of this species responded in the greatest numbers to ultraviolet light on two occasions, 26 May and 22 July (Table 2). Table 2 does not include the number of *Stenonema* females collected because many *Stenonema* female adults can not be positively identified to species at this time (Bednarik and McCafferty, 1979). During periods of emergence, *S. terminatum* adults came to ultraviolet light as darkness fell, but within one hour all activity ceased for the night. Swarming was most intense over shallow riffles.

Stenonema femoratum

S. femoratum adults and nymphs were collected sporadically throughout the study (Fig. 5). An estimated population of 2.0 nymphs/m^2 inhabited the study reach in the spring and late summer of 1980 (Fig. 3). Small numbers of adults were attracted to ultraviolet light on each date that *S. terminatum* adults were collected, except for 21 August, when no *S. femoratum* adults were collected (Table 2). On 22 July and 21 September, *S. femoratum* adults were collected after *S. terminatum* response to the light had stopped, indicating that *S. femoratum* may have no longer activity period or perhaps multiple activity periods throughout the night. Insufficient numbers of *S. femoratum* nymphs were collected for reliable analysis of substrate preference.

Stenonema exiguum

Mature *S. exiguum* nymphs were collected in the late spring and early summer of 1980 (Fig. 5). The maximum density of *S. exiguum* nymphs within the study reach was estimated to be less than 2.0 nymphs/m^2 (Fig. 3). Adults were collected at the light trap on one occasion, 21 August (Table 2).

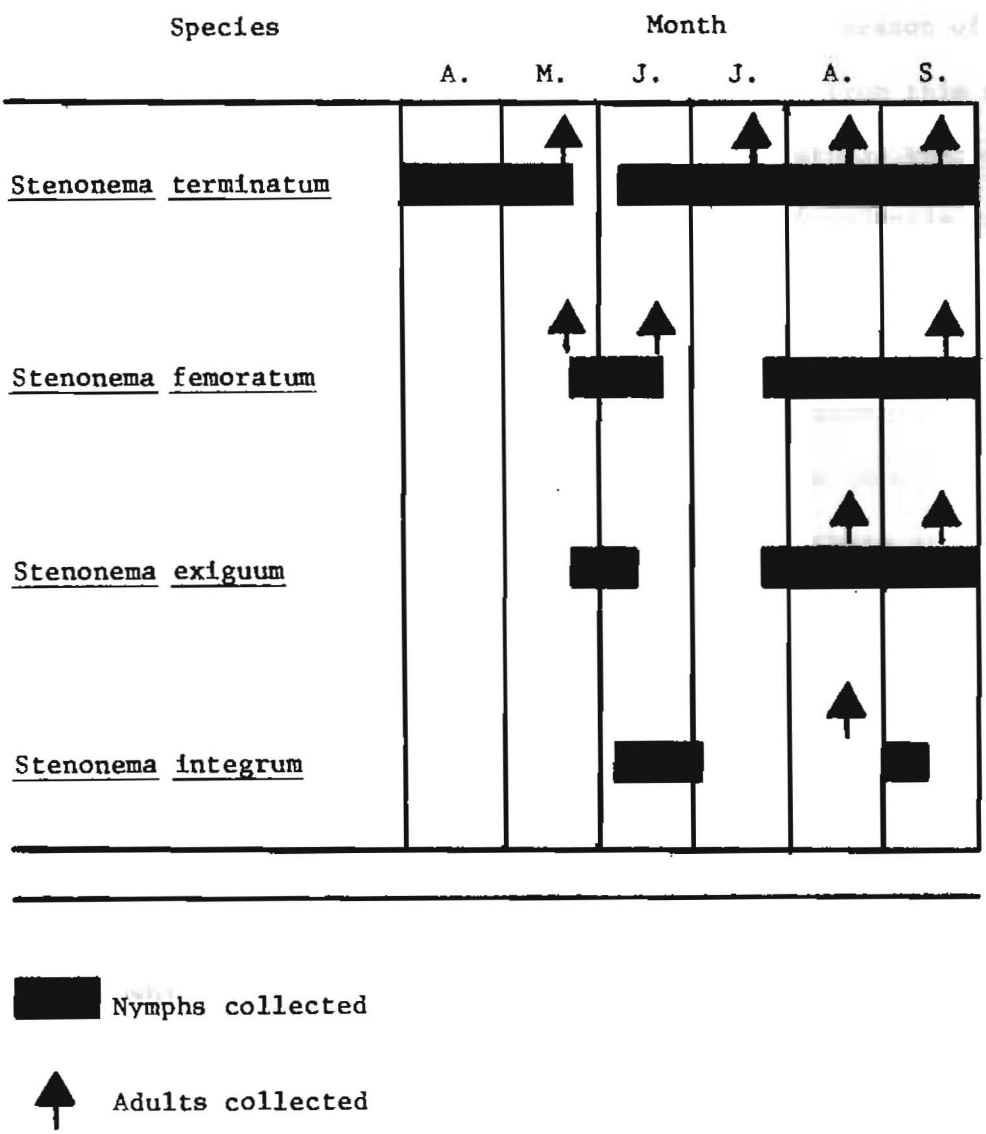
Table 2. Response rate of adult male *Stenonema* mayflies to ultraviolet light during the spring and summer of 1980.

Date	Individuals collected/minute			
	S. terminatum	*S. femoratum*	*S. exiguum*	*S. integrum*
4-10	0	0	0	0
5- 5	0	0	0	0
5-26	9.5	0.2	0	0
6- 6	0	0	0	0
6-19	0	0	0	0
6-28	0	0	0	0
7-22	7.4	0.2	0	0
8- 1	0	0	0	0
8-21	0.2	0	1.2	0.4
9-10	0	0	0	0
9-12	1.8	0.2	0	0
9-21	0.2	0.4	0	0
10- 8	0	0	0	0

Stenonema integrum

Stenonema integrum nymphs were not present in any of the quantitative samples taken, but two mature nymphs were collected in June and one in September by qualitative means. Three adults were collected on 21 August by light trapping. As with *S. femoratum* and *S. exiguum*, too few *S. integrum* nymphs were collected for substrate preference analysis

Figure 5. Occurrence of Stenonema mayflies in a Neosho River riffle, spring and summer 1980.


Species
Month
A.
M.
J.
J.
A.
S.
Stenonema terminatum
Stenonema femoratum
Stenonema exiguum
Stenonema integrum
Nymphs collected
Adults collected

DISCUSSION

Research Objective

My original objective was to study resource partitioning among coexisting congeneric *Stenonema* mayfly nymphs. Based on past observations, I expected to find two or three dominant species within the study reach each separated from the others by either season of occurrence, substrate preference, or both factors. Data from this study indicate there was one dominant species (*S. terminatum*), the other three species were present at densities too low for reliable analyses of habitat preference or life cycle types.

Life Cycle of *S. terminatum*

Mayfly life cycles may be classified into two general types, univoltine (one generation per year) and polyvoltine (more than one generation per year). Within each life cycle type there are two types of development, synchronous (the individuals of each generation develop and grow at the same rate during the same time span) and asynchronous (the individuals of each generation grow and develop at different rates). A mayfly population developing synchronously would exhibit an emergence period of intense activity and relatively short duration each time a generation matures, as all adults mate and die. A population exhibiting asynchronous development is represented at any given time by individuals in several stages of development. Asynchronously developing generations often overlap and emergence periods are relatively long and of low intensity.

Since adult mayflies do not usually live more than one week (Needham et al., 1935), the presence of *S. terminatum* adults over long periods of time during this study (Fig. 5) suggests that this species was either polyvoltine or univoltine with asynchronous development. Available data indicate that S. terminatum produced two generations during the summer of 1980 and another generation would complete its life cycle in the spring of 1981. Table 2 shows peaks of response to ultraviolet light on 26 May, 22 July, and 12 September indicating the presence of mating swarms. Each mating swarm was preceded and followed by approximately three weeks of little or no adult activity (Table 2). These short, isolated emergence periods are characteristic of synchronous development. When Table 2 and Figure 4 are compared, emergence periods coincide with times when the majority of the nymphal population was mature, and the next benthic sample taken after an emergence period shows relatively large numbers of nymphs in the smallest size class. The 22 May benthic sample (Fig. 4) did not contain any S. terminatum nymphs because it was taken during an emergence period and only adults and eggs were present at that time. I interpret these data to mean that each emergence period marks the end of a generation. Adults collected on 26 May (Table 2) developed from eggs laid in the late summer of 1979. The adults present in late May 1980 produced a fast growing summer generation which matured in late July and produced another summer generation which matured in September. The progeny of the second summer generation grew slowly through the winter and matured in the spring of 1981.

Reports of polyvoltinism in Stenonema species are uncommon. However, many of the studies of Stenonema ecology have been done in areas with a cooler climate than Kansas (Flowers and Hilsenhoff, 1978; Leonard and Leonard, 1962; Lewis, 1974; Richardson and Tarter, 1976). Water temperature influences the growth and development of benthic insects (Hynes, 1970). McCafferty and Huff (1978) found that Stenacron interpunctatum (Heptageniidae) nymphs held at 22-24°C grew faster than those held at lower temperatures.

Lewis (1974) considered extended exposure to a water temperature of 25°C to be intolerable for Stenonema nymphs. My results do not support this hypothesis, since stream temperatures during my study exceeded 24°C from 26 May through 25 September (Table 1) and Stenonema nymphs were present. There were other indications that the species present in the study riffle were adapted to warm water conditions. I did not observe or collect any Stenonema adults before water temperature reached 20°C in the spring or after it fell below 20°C in the fall. This adaptation to relatively high water temperatures allows S. terminatum to produce five generations every two years.

Stenonema terminatum's Dominance

All four Stenonema species collected during this study are widespread in the eastern U. S. (Bednarik and McCafferty, 1979) and tolerant to a range of habitats and environmental conditions (Lewis, 1974). Each of these species has been reported previously from Kansas (Liechti, 1978), and they are the same four species I observed in 1975 inhabiting another riffle of the Neosho River located approximately 28 km downstream from the Emporia study reach.

Stenonema terminatum was the only Stenonema species in the area exploiting the study reach under the existing conditions. The degree of competition among the Stenonema species present is unknown. There are indications that habitat availability was the primary determinant of Stenonema relative abundance. The study area probably would not support large populations of S. femoratum, S. exiguum or S. integrum even if S. terminatum were not present, because each of these species has habitat requirements which are lacking at the study reach.

Riffles are marginal habitat for S. femoratum, it is usually most abundant in lakes and river pools with rocky bottoms (Flowers and Hilsenhoff, 1978; Bednarik and McCafferty, 1979). Pools do not exist in the study reach except after extended periods of low rainfall. Pools upstream from the study area may serve as refugia for S. femoratum and provide a source of drifting nymphs which continually colonize the riffle.

The coexistence of S. exiguum with S. terminatum in other areas has been reported (Flowers and Hilsenhoff, 1978; Lewis, 1974) suggesting that competition between them is not severe. Also, according to Lewis (1974) and Flowers and Hilsenhoff (1978) S. exiguum prefers large streams and rivers with sandy bottoms. The study reach did not include sandy substrate.

A few S. integrum nymphs may be found in any stream, but they prefer large deep rivers where they are most abundant below sewage outfalls (Flowers and Hilsenhoff, 1978; Lewis, 1974). The deep water habitats S. integrum prefers are not available in or near the study area for most of the year.

In order to test the hypothesis that lack of suitable habitat in the study reach limited the populations of S. femoratum, S. exiguum and S. integrum, a follow-up sample was taken in August 1981 (Table 3). One set of four subsamples was randomly taken at the study reach near Emporia, Kansas, and another set of four subsamples was taken at random

Table 3. Density estimates of Stenonema nymphs inhabiting two riffles of the Neosho River. The Hartford sample was taken on 17 August 1981 and the Emporia sample was taken on 19 August 1981. Reported as nymphs/m^2.

	S. terminatum	S. femoratum	S. integrum
Hartford	10.68	1.34	4.01
Emporia	12.02	0	0

approximately 28 km downstream at the riffle I studied in 1975 near Hartford, Kansas. S. terminatum was the most abundant Stenonema species at both locations and the only Stenonema species collected at the Emporia riffle. The 1981 Hartford sample also contained S. femoratum and S. integrum nymphs (Table 3).

The absence of S. exiguum at both locations in August 1981 may be due to sample error. High water conditions existed in July and early August, scouring the bottom and reducing benthos density. The density estimate of S. terminatum nymphs at the Emporia riffle for August 1981 (Table 3) is lower than the comparable estimate for 1980 (Fig. 3). A small population of nymphs, scattered by flood waters, probably would not be represented in a small set of samples. This is also the case for S. femoratum and S. integrum, which were not present in the 1981 Emporia sample but were collected a few days later by qualitative means.

The Cottonwood River, a major tributary, joins the Neosho River approximately midway between Emporia and Hartford. As a result, the river at Hartford is larger and offers a greater variety of depth, current velocities and substrate composition. The 1981 comparison survey indicates that the Hartford riffle supports a larger population of S. integrum nymphs than the Emporia study area (Table 3). Since there was no significant difference between the numbers of S. terminatum nymphs collected at Hartford and Emporia in August 1981 (t test, d.f=6 p=0.05), the apparently small population of S. integrum at the Emporia riffle is suppressed by factors in addition to competition with S. terminatum. I suggest that lack of suitable habitat is an important limiting factor of S. integrum population density at the Emporia reach.

SUMMARY

1). A study was conducted to determine the Stenonema species inhabiting a riffle of the Neosho River near Emporia, Kansas, and to observe strategies employed by the species present to reduce competition.

2). For benthic sampling purposes three substrate zones were recognized within the study reach, according to median particle diameter. Md∅ (median diameter in phi units) of the zones were: Zone I -3.38, Zone II -4.75, and Zone III -6.25. Zone II comprised approximately 50% of the study reach, with Zones I and III comprising approximately 25% each.

3). From 11 June 1980 to 10 October 1980 certain physicochemical parameters of the study reach were measured and recorded. Water temperature ranged from 17.5°C to 32.0°C. Dissolved oxygen ranged from 6.0 to 8.9 ppm, and pH ranged from 7.89 to 8.33.

4). Quantitative benthos samples were taken from 20 March 1980 to 24 September 1980. In addition, Stenonema nymphs and adults were collected qualitatively during the same time period. Four Stenonema species were collected: *S. terminatum*, *S. femoratum*, *S. exiguum*, and *S. integrum*.

5). The original objective to study resource partitioning was not realized due to unexpectedly low population densities of all Stenonema species except *S. terminatum*. Populations of *S. femoratum*, *S. exiguum*, and *S. integrum* were too low for reliable substrate preference and life cycle analyses.

6). The maximum estimated of *S. terminatum* nymphs was 68.9 nymphs/m^2 on 2 July 1980. There was no significant preference for any substrate

zone by S. terminatum nymphs.

7). Analyses of adult light trap data and measurements of nymphal head capsule width indicate that S. terminatum produced two complete generations during the summer of 1980, and a third, fall generation which would mature in the spring of 1981.

8). Reported habitat requirements of S. femoratum, S. exiguum, and S. integrum were compared with conditions at the Emporia study reach. In each case at least one requirement was lacking.

9). A follow-up study was conducted in August 1981, comparing the relative abundance of Stenonema nymphs at the Emporia study reach with another Neosho River riffle approximately 28 km downstream near Hartford, Kansas. The results of the follow-up study support the hypothesis that lack of suitable habitat suppressed the populations of S. femoratum, S. exiguum and S. integrum at the Emporia study reach.

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