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EMERGENCE OF MAYFLIES (EPHEMEROPTERA) FROM STREAMS OF ERIE CO., PA[1]

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ABSTRACT

Comparisons were made of mayfly species composition and emergence patterns from two first order streams in northwestern Pennsylvania over one and two year periods using emergence traps of 15m² and 4m². Eighteen species of mayflies emerged from two streams in Erie County, Sixmile Creek (SMC 1980) and Fourmile Creek (FMC 1989-1990). Fourteen species, representing five families, were collected at SMC; and 10 species in 1989 and 8 species in 1990, representing four families, were collected at FMC. Emergence at both locations extended 27 weeks from mid-April to late October at SMC and from early-April to mid-October at FMC. *Paraleptophlebia moerens* was the most abundant species at both streams. *Baetis flavistriga* was common at both SMC and FMC. The parthenogenetic mayflies, *Ameletus lineatus,* and *Diphetor hageni* were present at SMC and *Ameletus ludens* at FMC. *Epeorus pleuralis*, *Leucrocuta thetis* and *Nixe perfida* were collected only at SMC. *Paraleptophlebia strigula* and *Habrophlebiodes americana* were taken only at FMC. At both locations peak emergence of bisexual congeners was temporally separated.
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INTRODUCTION

Emergence traps have been used to examine a number of aspects of aquatic insect biology, for example, species composition and diversity (Judd, 1967), productivity (Illies, 1971), energy and nutrient export (Paasivirta, 1975) temperature effects (Nordlie and Arthur, 1981), relative abundance and flight period (Anderson, et al., 1978; Masteller, 1991; Masteller and Flint 1980 a, b, 1983, Masteller and Wagner, 1984; Wagner and Masteller, 1992) and diurnal variations of emergence (Morgan and Waddell, 1961 b; Harper et al., 1983).

Phenology is an important component of aquatic insect life histories (Sweeney, 1984) but for many nearctic species little information regarding this is available. Some data on emergence seasonality of Nearctic Ephemeroptera can be found in a number of life history investigations (Clifford et al., 1979; Coleman and Hynes, 1970; Flowers and Hilsenhoff, 1978; Gibbs, 1973; Gibbs and Mingo, 1985; Kondratieff and Voshell, 1980; Lauzon and Harper, 1986; Minshall, 1967; and Voshell, 1982).

Many life history studies have concentrated on nymphal growth and development and paid little attention to phenology related to emergence. Notable exceptions are studies of Britt (1962), Boerger and Clifford (1975), Harper and Magnin (1971), Harper and Harper (1982, 1984), Lauzon and Harper (1988), Peters and Peters (1977), Sweeney (1978), Peters et al. (1987), Sweeney and Vannote (1981), and Vannote and Sweeney (1980). Newbold et al. (1994) presented a model that reproduced the univoltine life histories and accounted for variation in emergence over a range of latitudes for six species of mayflies.

The purpose of this study was to determine the species composition of mayflies and their emergence patterns for two streams in northwestern Pennsylvania.

STUDY SITES

The study streams are first order tributaries of Sixmile Creek (SMC) and Fourmile Creek (FMC) which flow into Lake Erie approximately 7 km downstream. Both streambeds are in steep gorges of Devonian-Girard shale. The Phi scale for the tributaries of Sixmile Creek were and Fourmile Creek as follows: (first percentage is SMC, the second is FMC with size classifications of -6 small

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cobble, -5 pebbles and -3 to -1 gravel) -6 (25%-20%), -5 (17%-18%), -3 (8%-14%), -2 (17%-13%), -1 (8%-12%). The drainage basin area in square miles of the sites is 12.1 for FMC and 18.9 for SMC.

Riparian vegetation is primarily beech, maple and hemlock. Details of the sites are in Masteller and Flint (1980 a) for SMC and Adler et al. (1982) for FMC. SMC is intermittent in flow during years of low precipitation.

METHODS

Emergence traps were constructed of Lumite^{R} special screen shade cloth (Masteller, 1977). The trap at SMC covered an area of 15m^2 and at FMC 4m^2. "Adults", as referred to in this paper, include subimagos and imagos. The trap at SMC was monitored from 3 January to 17 December 1980. At FMC the trap was monitored for the entire year from 1 January to 31 December in 1989 and 1990. Data for emergence was plotted on a weekly scheme developed by Taylor and French (1972). This week scheme allows display of data on a comparable basis for consecutive years as long as Feb. 29 and Dec. 31 are eliminated. Collections were made three times a week throughout the year. Plastic petri dishes were used to collect subimagos which were taken back to the laboratory and placed in a moist chamber for molting. Adults were aspirated into collection tubes at the trap. At the time of collection the air and water temperatures were measured using a standard hand-held thermometer accurate to 0.1°C. Stream temperatures at FMC varied from 1.0 to 19.5°C in 1989 and 2.0 to 20°C in 1990. At SMC water temperatures ranged from 0 to 20.5°C (Figure 1, average weekly water temperatures). Voucher specimens have been deposited in the Aquatic Insect Museum, Entomology and Biological Control, Florida A&M University, Tallahassee, FL 32307.

RESULTS AND DISCUSSION

Eighteen species of mayflies in five families were collected at two streams in Erie County. These species occurred in 1655 specimens at SMC in 1980 and from 770 and 605 specimens at FMC in 1989 and 1990, respectively. Of these only five were common to both streams (Table 1). During 1990, unseasonable warm temperatures occurred early in March causing quite different emergence patterns from those of 1989 at FMC. The SMC data provides comparisons for those comparable species.

Paraleptophlebia moerens was the most abundant species in both streams (Table 2). A total of 398 ♂ and 750 ♀ were collected at SMC while 396 and 133 individuals (sex not determined) were collected at FMC. Coleman and Hynes (1970) reported that emergence of this species in southern Ontario began shortly after spring thaw (April) and ended about mid-June. In this study the first emergence occurred 15 May 1980 at SMC, while at FMC initial emergence was on 29 May 1989 and 4 April 1990. Final emergence lasted until 16 September at SMC and at FMC until 15 September 1989 and 3 August 1990 (Table 2). The earlier emergence of mayflies in 1990, which occurred for species in other orders also, was, we believe, due to elevated spring water temperatures (Figure 1). In 1990, following the initial early emergence event, there was a cessation of emergence for about 24 days. This 24 day period coincided with the attainment of a period of stable late spring/early summer water temperatures (Figure 1). Emergence returned to more normal numbers in late May, and continued through normal completion of emergence, although in 1990 for *P. moerens* emergence was completed about a month earlier than usual. This effect of elevated temperatures on the emergence of mayflies has been well documented by Brittain (1976, 1979), Sweeney (1978), Vannote and Sweeney (1980), Sweeney and Vannote (1981) and Peters et al. (1987).

Paraleptophlebia debilis displayed the greatest degree of temporal segregation at both streams (Figures 2-3). Emergence was restricted to late summer and autumn. The first emergence at SMC was 23 July 1980 and at FMC on 4 August 1989 and 14 August 1990, with final emergence at SMC on 17 October, 1980 and at FMC on 25 September 1989 and 29 August 1990 (Table 2). Emergence was not continuous over this period at SMC but at FMC *P. debilis* had the shortest emergence period of any mayfly (15 days in 1990). This could be a response to completion of the life cycle before the onset of cooler autumn temperatures. The period of emergence agrees with Burian and Gibbs(1991) in Maine and Harper and Harper (1986) in northern Canada.

Paraleptophlebia strigula has been infrequently reported in eastern North America (Burian and Gibbs 1991) and was collected only at the FMC site in numbers of 15 and 39 for the two year period (Table 2). This is the first record of the life cycle of this species. The early emergence peak in 1990 may be attributed to warmer spring water temperatures and may not be typical for this species, but gives an indication of the earliest possible time of initiation of emergence. Despite the early pulse in 1990, the period of maximum emergence was similar for both 1989 and 1990 (Figure 2). In both years emergence decreased rapidly after June.

Habrophlebiodes americana occurs commonly throughout eastern North America although in this study it was taken only at FMC (Table 2). Little is known about the biology of this species. Harper and Harper (1984) studied the phenology of this species in southern Ontario and reported peak emergence between late June and early July. Burian and Gibbs (1991) observed adults in Maine flying from June-August. At FMC the majority of specimens were collected from June-August with a peak in July which was not typical of the other leptophlebiids in

this study (Figure 2). In 1990 *H. americana* continued emergence two weeks longer than in 1989.

Only one specimen of *Leptophelebia cupida*, a female was collected in this study on 21 April 1989 at FMC. Burian and Gibbs (1991) reported emergence of *Leptophlebia* species in northern New England from April through early June.

The Heptageniidae were much more common at SMC (Table 1) with 6 of the 7 species collected at both streams. *Stenacron gildersleevei* initiated emergence on 21 May 1980 at SMC and ceased on 2 August 1980 (Figure 3). There was continuous emergence over this 11 week period. Peak emergence occurred during the first 2 weeks of its emergence in May and gradually tapered off in late June.

Epeorus fragilis was collected over a four-week period at SMC from 19 May 1980 to 4 June 1980 while at FMC it was collected only in 1990 and 17 of 18 specimens were obtained on 21 May (Table 2). Little information exists on its life history, but our results indicate

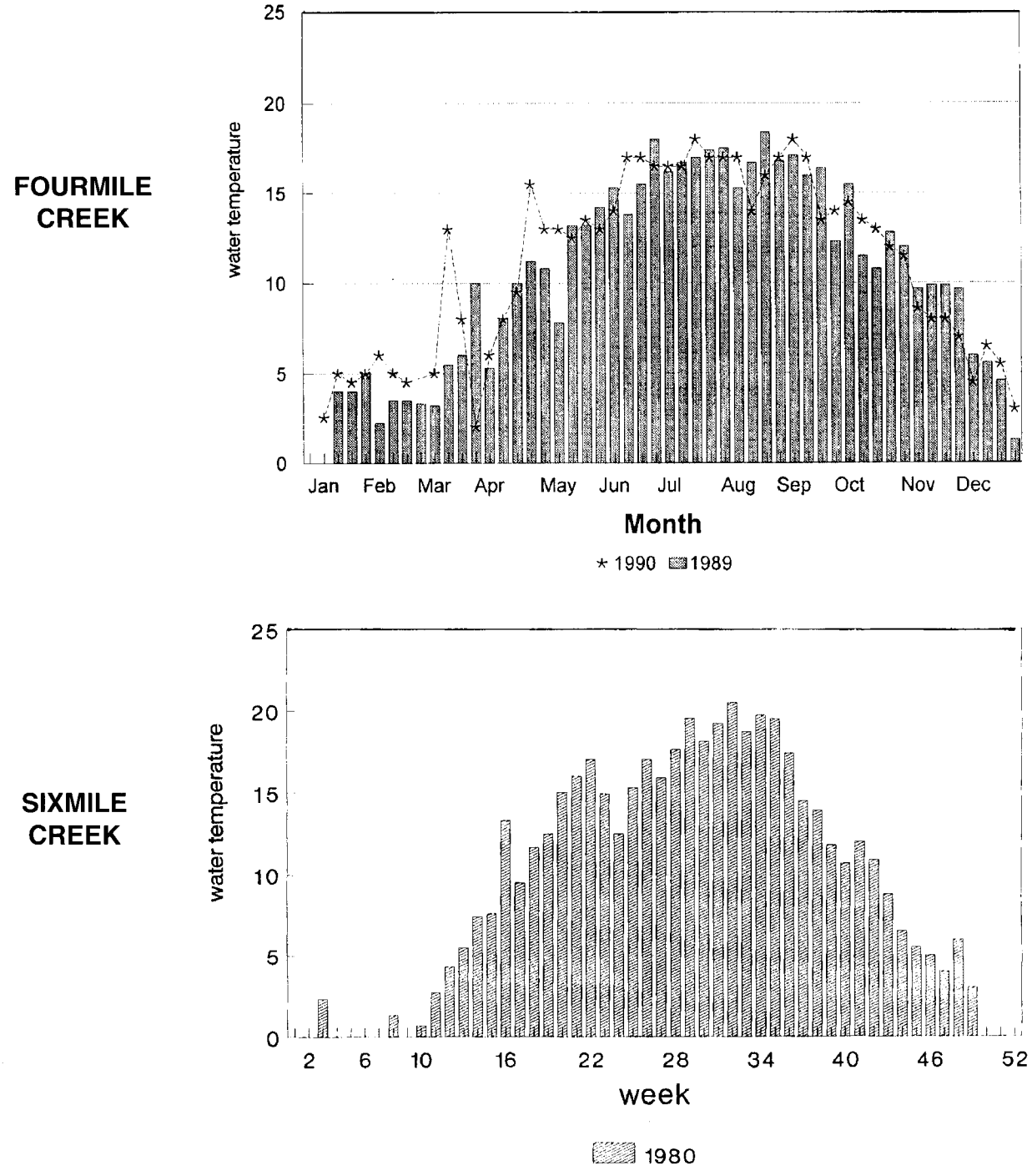

FIGURE 1. Mean weekly water temperatures during 1980 at Sixmile Creek and 1989-1990 for Fourmile Creek, Erie County.

TABLE 1. Species list of mayflies occurring at Sixmile Creek (1980) and Fourmile Creek (1989-1990) in Erie County.

	Sixmile Cr.	Fourmile Cr.	
SPECIES	1980	1989	1990
AMELETIDAE			
Ameletus lineutus Traver	173		
Ameletus ludens Needham		1	23
Ameletus sp.		7	
BAETIDAE			
Baetis flavistriga McDunnough	52	22	31
Baetis tricaudatus Dodds	13	96	31
Baetis sp.		140	172
Centroptilum alamance (Traver)	1		
Diphetor hageni (Eaton)	24		
EPHEMERELLIDAE			
Eurylophella funeralis (McDunnough)	1		
Eurylophella sp.			2
HEPTAGENIIDAE			
Epeorus fragilis (Morgan)	33		18
Epeorus pleuralis (Banks)	22		
Leucrocuta thetis (Traver)	11		
Leucrocuta umbratica (McDunnough)	1		
Nixe perfida (McDunnough)	11		
Stenacron gildersleevei (Traver)	116		
Stenonema sp.		1	
LEPTOPHLEBIIDAE			
Habrophleboides americana (Banks)		25	37
Leptophlebia cupida (Say)		1	
Paraleptophlebia debilis (Walker)	59	9	9
Paraleptophlebia moerens (McDunnough)	1148	396	113
Paraleptophlebia strigula (McDunnough)		15	39
Paraleptophlebia sp.		57	101

this species is likely univoltine (Figure 2-3). *Epeorus pleuralis* was collected over a six-week period from 23 April 1980 to 28 May 1980 with peak emergence near mid-May and is apparently also univoltine.

Leucrocuta thetis had a unique discontinuous pattern of emergence with an initial emergence for 2 weeks starting 23 May 1980 followed by a 2-week period with no specimens and then a final week of emergence starting 18 June 1980 and ending on 25 June 1980. Only one male of *Leucrocuta umbratica* was collected (27 July 1980) but from other years of collections it was observed to emerge from July through early September.

Nixe perfida emerged over a short period (1 week) only at SMC, 18-25 June 1980. This species has been collected by McDunnough (1926) in Ontario during June and Burks (1953) collected it in May-June in Illinois. Burian and Gibbs (1991) collected this species in July in western Maine.

Baetidae were common at both streams with two species dominating. The emergence of *Baetis flavistriga* at SMC lasted 6-weeks from 28 May to 4 July 1980, while at FMC in 1989 emergence started on 7 June with incidental specimens until the final emergence on 28 August when half of the specimens were collected (Table 2). In 1990 at FMC an early emergence took place on 16 April with 26 of the 31 specimens emerging over an 11 day period from 2-13 June (Figure 2). At SMC a distinct male peak was present during the first week of emergence. Ide (1935) in his study of *B. flavistriga* (=*B. cingulatus*) in Ontario described emergence

TABLE 2. Fourteen species of mayflies are described in reference to date of first emergence, final emergence, 50% emergence date of peak emergence along with the peak emergence number and the total collected. Eighty refers to the Sixmile Creek and 89, 90 refer to the Fourmile Creek site.

	A. lineatus	*A. ludens*		*B. flavistriga*			*B. tricaudatus*		
Year	80	89	90	80	89	90	80	89	90
Init. Emerg.	24 Apr	17 Apr	9 Apr	28 May	7 Jun	20 Apr	20 Apr	1 may	11 Apr
Final Emerg.	13 Jun	17 Apr	18 Jun	4 Jul	28 Aug	6 Aug	24 Jun	16 Oct	3 Sep
50% Emerg.	15 May	-	25 Apr	30 May	2 Aug	8 Jun	4 May	23 Jun	9 May
Peak Emerg.	20	1	16	12	11	14	4	27	5/5*
Date of Peak	2 May	17 Apr	25 Apr	30 May	28 Aug	8 Jun	20 Apr	21 Jun	25 May-10 Jun*
No. Coll.	173	1	23	20	22	31	19	96	31

	D. hageni	*E. fragilis*		*E. pleuralis*	*N. perfida*	*S. gildersleevei*	*L. thetis*
Year	80	80	90	80	80	80	80
Init. Emerg.	3 May	19 May	21 May	23 Apr	18 Jun	21 May	23 May
Final Emerg.	11 Sep	4 Jun	6 Jun	28 May	25 Jun	2 Aug	25 Jun
50% Emerg.	4 Jun	26 May	21 May	9 May	24 Jun	18 Jun	26 May
Peak Emerg.	3	7	17	5	5	14	5
Date of Peak	4.30 May*	26 May	21 May	9 May	25 Jun	30 May	26 May
No. Coll.	24	33	18	22	11	116	11

	H. americana		*P. debilis*			*P. moerens*			*P. strigula*	
Year	89	90	80	89	90	80	89	90	89	90
Init. Emerg.	21 may	16 Apri	23 Jul	4 Aug	14 Aug	15 May	29 May	4 Apr	7 Jun	2 Apr
Final Emerg.	2 Aug	16 Aug	17 Oct	25 Sep	29 Aug	16 Sep	15 Sep	14 Aug	7 Aug	2 Jul
50% Emerg.	30 Jun	29 Apr	17 Aug	22 Sep	22 Aug	24 Jun	14 Jul	30 May	19 Jun	16 Jun
Peak Emerg.	6	8	11	4	3	123	44	22	4	13
Date of Peak	30 Jun	29 Apr	29 Aug	22 Sep	17 Aug	18 Jun	26 Jul	18 Apr	14 Jun	6 Jun
No. Coll.	25	37	59	9	9	1148	396	113	15	39

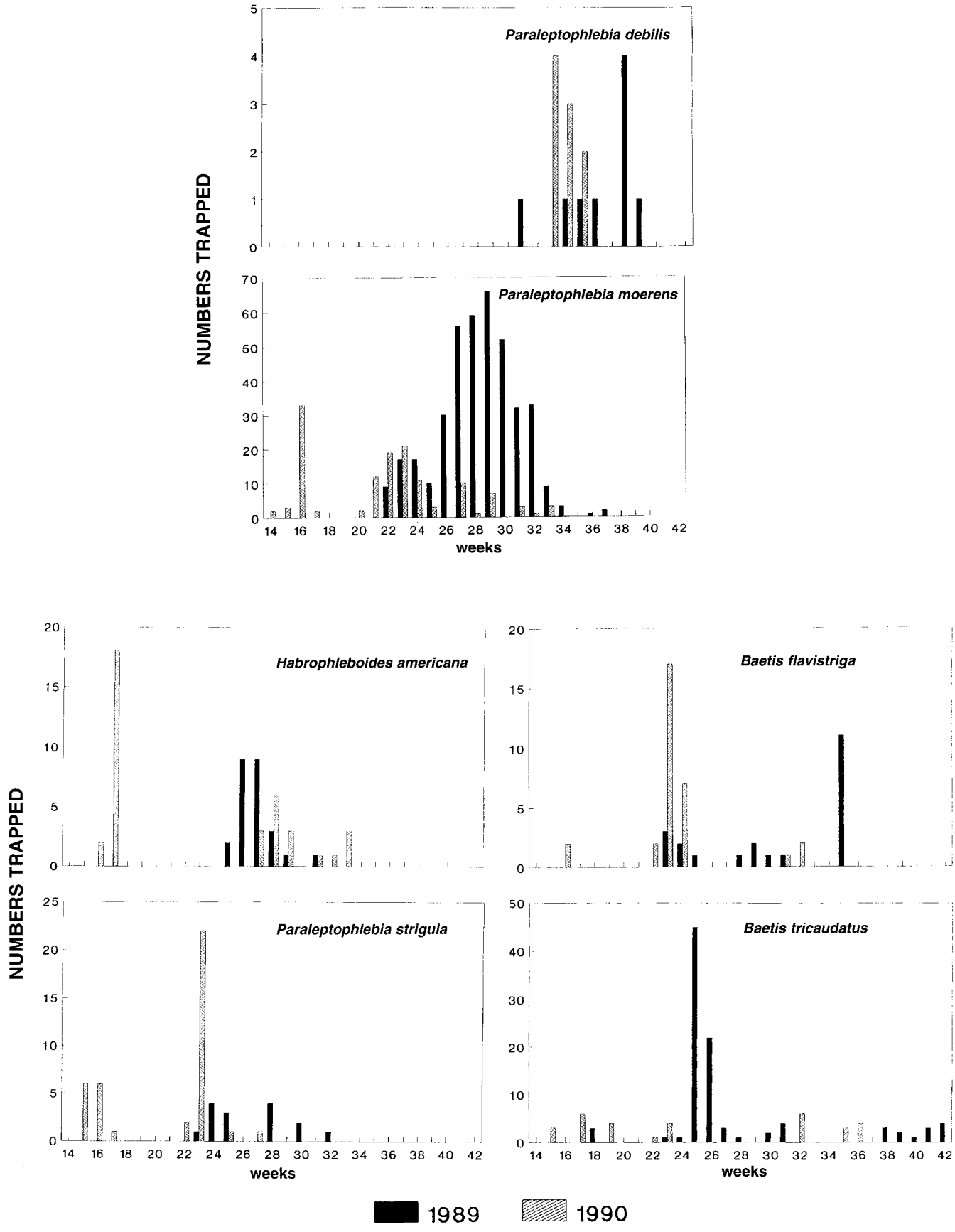

FIGURE 2. Emergence phenology for six representative mayflies collected at Fourmile Creek.

from mid-June through September with a break in August, possibly indicating two generations. Bergman and Hilsenhoff (1978) collected adults (as *B. levitans* and *B. phoebus*) from late May through November in Wisconsin which they thought was either a long emergence period or two overlapping generations. At FMC it appears there are two generations which may also be present at SMC (Figure 2-3).

Baetis tricaudatus emerged very early with emergence beginning at SMC on 20 April 1980, followed by intervals in emergence, with final emergence on 24 June 1980 (Table 2). At FMC in 1989 emergence began on 1 May 1989 with a peak of 27 out of 96 specimens collected on 21 June and the last emergence on the 16 of October. In 1990 at FMC emergence began on 11 April and continued in every month, except July, until 3 September (Figure 2). Clifford (1982) in his review of mayfly life cycles reported that *B. tricaudatus* was multivoltine. Bergman and Hilsenhoff (1978) collected adults (=*B. vagans*) from April to May for a short spring emergence and late June to mid-October which they interpreted as an extended autumn emergence. Our results support a multivoltine life history.

One female of *Centroptilum alamance* was collected on 22 July 1980. Other years of our collections indicate that this species occurs from June through September and may have several generations.

Diphetor hageni was collected only at SMC and appeared to be parthenogenetic. It was taken sporadically from 3 May 1980 to 11 September 1980 (Figure 3). This was the longest period of emergence of any mayfly at either site. Minshall (1968) observed long emergence for *D. hageni* (=*B. herodes*) in Kentucky from April to October as did Lehmkuhl and Anderson (1972) in Oregon. A bivoltine life history was present but may eventually be interpreted as multivoltine.

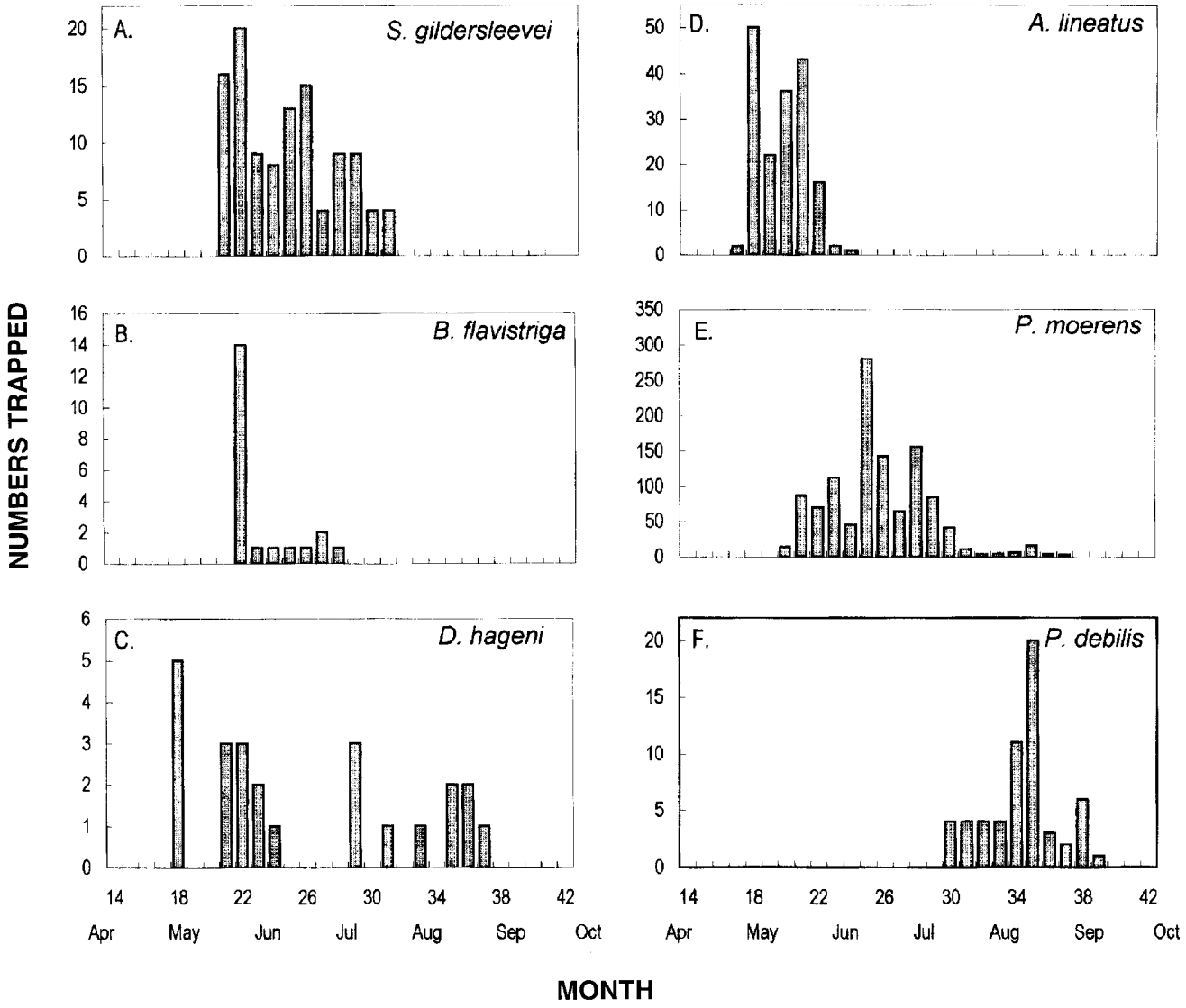

FIGURE 3 Emergence phenology for six representative mayflies collected at Sixmile Creek during 1980.

Few Ephmerellidae were collected at these streams. A male of *Eurylophella funeralis* was collected at SMC on 28 May 1980 but from other years of our collections it occurs from May through June. An unidentified *Euryophella* sp. was collected on 1 June 1990 at FMC.

Ameletus lineatus, a parthenogenetic species, was collected at SMC. An intersex was taken on 6 May 1989 (Grant and Masteller 1987). The initial emergence of *A. lineatus* was 24 May 1980 and final emergence on 13 June 1980 (Table 2). This eight week emergence suggested a univoltine life cycle. Burks (1953) collected adults of this species in early April in Illinois. *Ameletus ludens*, also parthenogenetic, was collected at FMC primarily during 1990 with emergence from 9 April through 18 June with 16 of 23 specimens emerging on 25 April also suggesting a univoltine life history (Figure 3).

Emergence is the visible endpoint of life history processes of aquatic insects. Timing of emergences and year to year variation is reflective of the current adaptive limits of populations for local habitat and climatic gradients. Data presented in this study indicate that large variation can exist at the extreme limits of emergence for some species of mayflies. Pronounced early emergence peaks occurred at FMC for *Habrophleboides americana*, *Paraleptophlebia moerens*, and *P. strigula*. Actually the majority of the populations were less responsive. Sweeney et al. (1992) and Newbold et al. (1994) have shown with experimental modeling that mayflies can rapidly adjust to new conditions.

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