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Life history and ecology of *Megarcys signata* (Plecoptera: Perlodidae), Mill Creek, Wasatch Mountains, Utah

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LIFE HISTORY AND ECOLOGY OF *MEGARCYS SIGNATA* (PLECOPTERA: PERLODIDAE), MILL CREEK, WASATCH MOUNTAINS, UTAH[1]

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Abstract.— During an investigation of some of the stoneflies (Plecoptera) of Mill Creek, Wasatch Mountains, Utah, *Megarcys signata*, a large omnivorous stonefly, was found to have a univoltine life history and a slow seasonal life cycle.

Temperature appears to affect the growth rate of *Megarcys signata*. Warmer stream temperatures accompany the acceleration of the growth rate, whereas cooler stream temperatures apparently retard the growth rate.

Periods of maximum absolute growth rate correspond with maximum carnivorous feeding from August to September and March to April. Chironomidae, Ephemeroptera, and Plecoptera, in that order, were the most abundant prey in the foreguts. Young nymphs ingested considerable amounts of diatoms, filamentous algae, and detritus but not as much animal matter as did older nymphs.

Megarcys signata was uniformly distributed throughout Mill Creek, except at the lowest station, where few nymphs were found.

Emergence occurred in May and June, the peak occurring in June. The mean size of females and males decreased as emergence progressed.

This report is part of an eighteen-month study of some of the stoneflies of Mill Creek, Wasatch Mountains, Utah. Because a detailed description of the study area and the methods and materials is given in another paper (Cather and Gaufin 1975, only a summary is included here.

Mill Creek Canyon is located 11 km southeast of Salt Lake City, Utah, in the Wasatch Mountains of the Middle Rocky Mountain Province. Six stations were selected along a 12 km length of the stream in the Wasatch National Forest with elevations ranging from 1,605 to 2,280 m. The sampling stations were numbered consecutively, Station I denoting the highest elevation. The three lower stations (1,605-1,785 m) are easily accessible all year, but the three upper stations (1,995-2,280 m) are accessible only in the summer and fall. Average minimum and maximum daily flows were 0.3 m^3/sec and 1.2 m^3/sec, respectively, during the study period. Depth averaged 11-45 cm, and current averaged 0.2-0.7 m/sec during the fall when measurements were taken. The substrate of the sampling area at all stations ranged from coarse sand to small cobbles. Minimum water and air temperatures recorded during adult emergence were 3 C and 9 C, respectively. Maximum water and air temperatures during this period were 13 C and 26 C, respectively. Water chemistry was similar at all stations. Dissolved oxygen ranged from 6.0 to 8.5 mg/l (70-120 percent saturation), calcium bicarbonate 109-189 mg/l, calcium carbonate 0-2.4 mg/l, pH 7.5-8.3, total hardness 100-340 mg/l, and conductivity 312-859 mhos/cm.

Methods and Materials

Nymphs of *Megarcy signata* were collected at least monthly from June 1971 to December 1972 at each of six stations. Additional nymphs were collected in spring 1973 for food habit studies. Handscreens of mesh sizes 7 and 9 sq/cm were used, the smaller handscreen being used during the majority of the study in an attempt to collect the smaller instars. An area of about 80 cm^2 of the stream bottom was disturbed in an attempt to collect at least 100 nymphs monthly. All nymphs were preserved in 80 percent ethanol.

Adults were collected weekly throughout the emergence period and biweekly during peak emergence using a sweep net and handpicking from vegetation, rocks, and bridges. All adults were preserved in 80 percent ethanol.

The interocular distance of all nymphs and adults was measured to the nearest 0.1 mm using an ocular micrometer in a dissecting microscope for determining growth rates and to see if the mean size of the adults decreased as emergence progressed. The nymphs were identified as males and females when possible.

Foregut analyses were conducted on 200 nymphs collected from the field. Nymphs were selected from an upper (I) and a

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lower (IV) station during each season (Station V had to be substituted for Station I during winter and spring). The method used followed Swapp (1972). All prey animals were enumerated and identified to order except where family or generic determination was possible. Three types of the family Chironomidae were recognized and designated as species a, b, and c (based on morphology of head capsule). These are discussed under results and discussion but are not separated in Table 1. All algae were determined to genus where possible. Percentage compositions of algae and detritus were estimated when present, and dominant items were recorded. A volume analysis was not conducted.

Identification of nymphs and adults followed Gaufin et al. (1966), and nomenclature followed Illies (1966) and Zwick (1973).

Results and Discussion

The only systellognathan stonefly present in Mill Creek in numbers large enough for analysis is *Megarcys signata.* This species exhibits a slow seasonal type of life cycle. Emergence and oviposition occur in May and June with hatching soon after. Small nymphs (0.5 mm interocular distance) appear in July at the lower stations. Nymphs of comparable size generally appear for the first time in August, September, and October at the upstream stations. Rapid growth occurs from August to emergence (Figs. 1a, b, c). The size

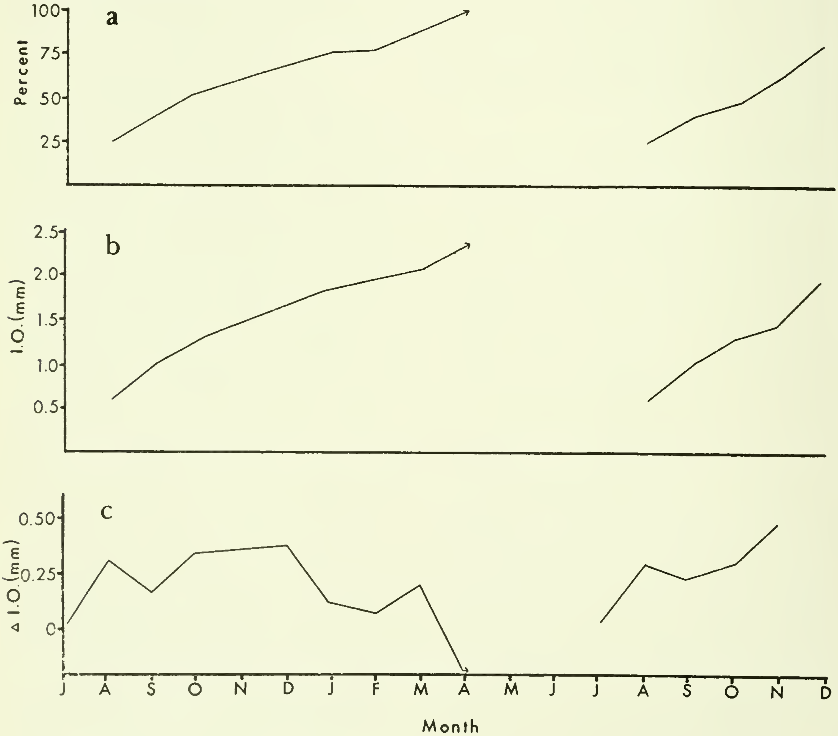

Fig. 1. Growth of *Megarcys signata.* Arrows indicate emergence. I. O. indicates interocular distance: (a) Monthly mean size as a percentage of total mean size at Station IV; (b) Monthly mean cumulative growth at Station IV; (c) Monthly mean absolute growth rate (data pooled from all stations). Δ indicates change in I. O. distance.

frequencies of nymphs and the mean cumulative growth at each station are shown in Figs. 2 and 3, respectively.

A comparison of the cumulative growth at all stations reveals that the most rapid growth occurs at the lowest (warmest) stations (Fig. 4). Thus, there seems to be a direct correlation between growth and temperature. Baumann (1967) found no direct correlation in this species in Mill Creek. Seasonally the most rapid growth occurs during the fall and early winter (September-January). Growth apparently slows, but does not stop, during the winter (January-March), increases from March to April, and then decreases from April to May, prior to emergence. Sheldon (1972) reported similar results in his study on the *Arcynopteryx* species complex he studied in California. However, Schwarz (1970) reported no growth at times during the winter in other Systellognatha. The correlation between growth and food habits will be discussed later.

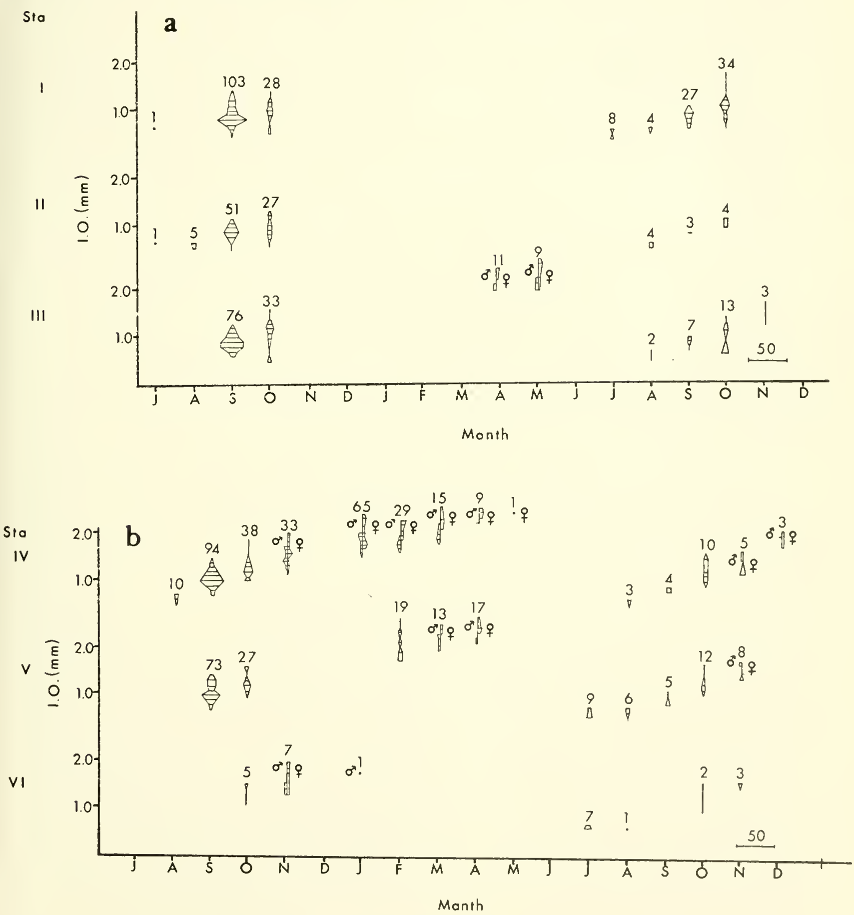

Fig. 2. Frequency distribution of nymphal size classes of *M. signata*. Number of individuals shown above each polygon; males and females as indicated: (a) Stations I, II, and III; (b) Stations IV, V, and VI.

Megarcys signata seems to show no preference for either the upstream or downstream stations. This species is evenly distributed throughout the stream except at Station VI. Here the substrate is almost entirely cemented. Where the water is deep enough for this large insect, the current is too slow; where the current is fast enough, the water is too shallow and the substrate too homogeneous. More individuals were collected at Station IV than at any other station.

The emergence of *M. signata* began in early May at the lower stations and lasted until late June at the higher stations (Fig. 5). Peak emergence was in June. Baumann (1967) found this species emerging from late April to mid-July in Mill Creek. Emergence is progressively later as the elevation increases. Baumann (1967), Hynes (1970), and Nebeker (1971) reported similar results. They were first collected at Stations III and V in early May, when the water tempera-

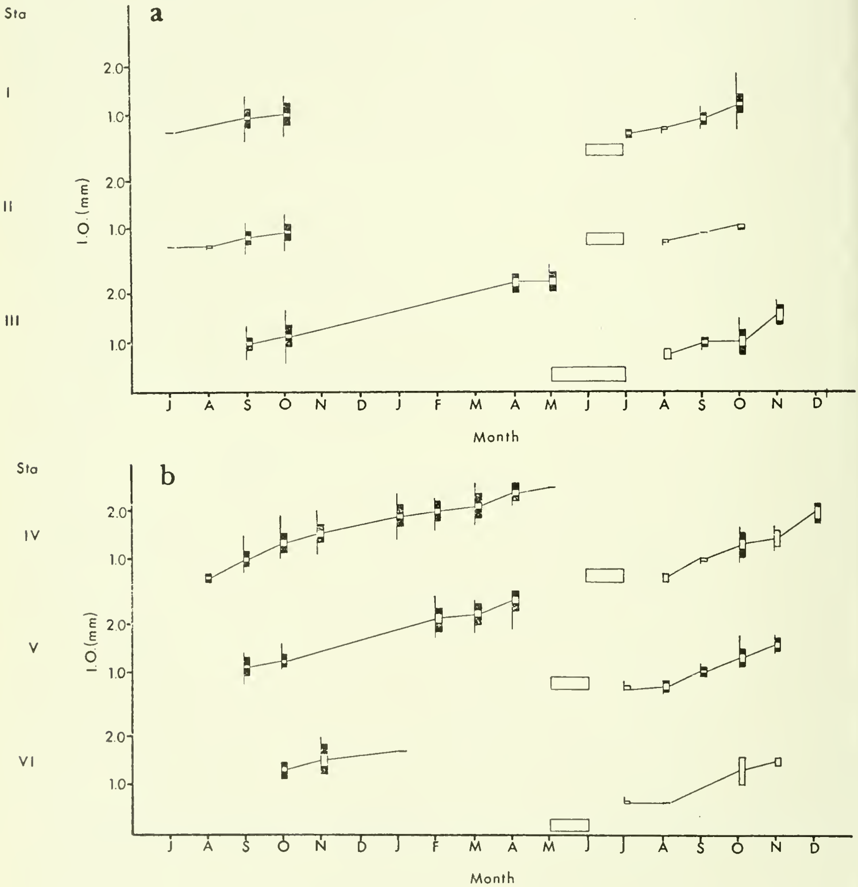

Fig. 3. Mean cumulative growth of nymphs of *M. signata*. Vertical line represents size range of nymphs; shaded area represents standard deviation; unshaded area represents standard error of the mean; solid line connects means; rectangle represents emergence period: (a) Stations I, II, and III; (b) Stations IV, V, and VI.

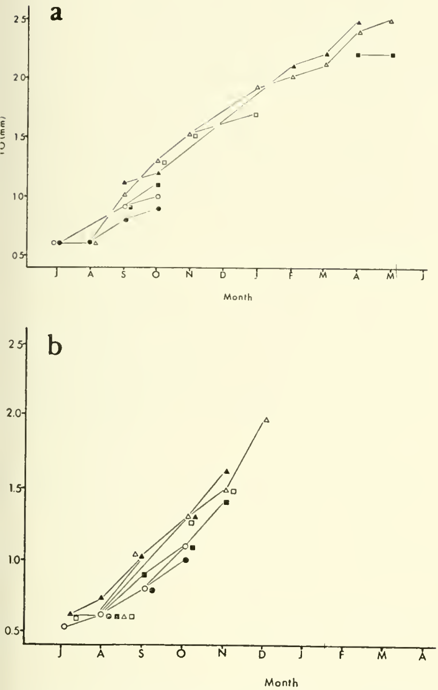

Fig. 4. Comparison of mean cumulative growth of nymphs of (□) *M. signata* at Stations I-V. Station I represented by (o); Station II by (●); Station III by (■); Station IV by (Δ); Station V by (▲); and Station VI by (□): (a) July, 1971 through June, 1972; (b) July, 1972 through December, 1972.

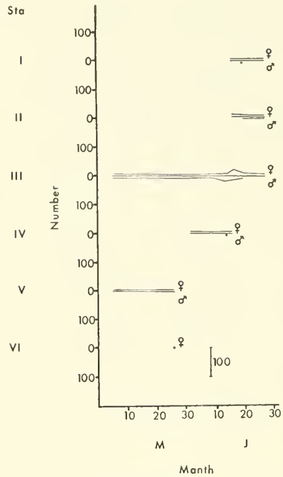

Fig. 5. Emergence at each station of *M. signata.*

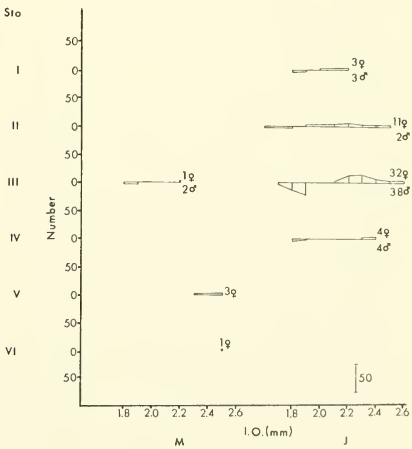

Fig. 6. Frequency distribution of adults of *M. signata.* Number of individuals shown above each polygon.

tures were 3 C and 5 C, respectively. Emergence ended in late May (water temperature 9 C) at Station V, but lasted until mid-June (12 C) at Station IV and late June (5.5-7 C) at the three upper stations. *Megarcys signata* is a secretive insect that hides in cracks under bridges or among vegetation to escape warm summer temperatures. Clusters of these stoneflies usually containing one female and several males were often collected in these hiding places. Brinck (1949) reported the same phenomenon in related species. The collection data probably reflect this secretive habit in that *M. signata* should have been collected earlier at Station IV.

Females and males generally emerged together in a 1:1 ratio. Harper and Pilon (1970) reported similar findings. Only 55 females and 49 males were collected. Females outnumbered males in both May and June (Fig. 6). There was no size overlap between the females and males. The mean size of females and males decreased as emergence progressed from May to June at all stations (data pooled). Khoo (1968), Schwarz (1970), and Sheldon

(1972) reported a similar phenomenon. The mean size of females decreased from 2.4 mm to 2.3 mm, while that of males decreased from 1.9 mm to 1.8 mm (Fig. 7). The data were rather inconclusive because only small numbers of adults were collected in May. More intensive collecting may reveal this trend more strongly. Sheldon (1972) reported similar results in the *Arcynopteryx* species complex he studied and suggested that the decrease in mean size also influenced fecundity; that is, the smaller females carried fewer eggs. Warmer stream temperatures and increasing photoperiod may act as emergence cues before growth and egg development are completed (Khoo 1968, Hynes 1970).

A total of 200 nymphs of *M. signata* were dissected and the foreguts examined for a preliminary food-habit analysis. The nymphs were selected from upper and lower stations and from each season of the year. Table 1 gives the results of this analysis. Of those foreguts examined, 39 were empty (some of these stoneflies were beginning to molt; others had just molted). Chironomids seemed to be the preferred food item. Three types of chironomids based on differences in the head capsules were recognized. Of these three types, one was much more frequently found in the foreguts. A total of 442 were found in 39 percent of the insects examined. The other two types were found only occasionally. Mayflies were the second most abundant food item ingested (37 percent of all individuals). *Baetis* spp. were most frequently recognized. Stoneflies, notably chloroperlids, comprised a considerable portion of the gut contents, also (27 percent of the individuals). Rich-

Table 1. Percentage of dissected nymphs of *Megarcys signata* containing specific food items.

Season	Summer	Fall	Winter	Spring
Date	7/20/72 9/8/72	10/15/71	2/4/72 2/18/72	3/17/73
Station No.	I	I	V	V
Head Capsule Size Range for Sample (mm)	0.4-1.1	0.5-1.4	1.7-2.6	1.9-2.5†
No. Foreguts Examined	25	25	19	31
Empty Foreguts (%)	12	8	26	13
Class Insecta				
Ephemeroptera	5	0	21	63
Plecoptera	9	4	29	49
Trichoptera	4	0	0	3
Diptera				
Chironomidae	32	17	79	26
Other Diptera	0	0	0	0
Unidentified	0	0	7	7
Division Cyanophyta				
Oscillatoria (?) spp.	4;9*	9	0	0
Division Chlorophyta		0	0	0
Mougeotia spp.	0	30;35*	14;21*	0
Enteromorpha spp.	18;14			
Desmids				
Closterium spp.	9	4	0	0
Division Chrysophyta				
Diatoms				
Navicula spp.	100	69;17*	71;21	22
Gomphonema spp.	18	26	29;14*	0
Cymbella spp.	64	39	0	0
Fragilaria spp.	4	22;4*	0	0
Nitzschia spp.	14	43	0	0
Synedra spp.	0	9	0	0
Surirella spp.	23	0	0	0
Diatoma spp.	0	0	0	0
Misc. diatoms	27	48	0	0
Unidentified sp. 1	81;9*	35;65*	43;7*	0
Unidentified sp. 2	50	0	7	0
Unidentified filamentous algae	14	0	0	0
Unidentified plant fragments	0	0	0	0
Detritus (sand grains, silt, plant remains, diatom frustules)	4;77*	4;26*	43;29*	85

†Measurements from 3/17/72
*Dominant

Table 1 (Continued)

Season	Summer	Fall	Winter	Spring	
Date	8/3/72 8/11/71 9/1/71	10/8/71 10/15/71	1/7/72	3/12/73 3/17/73	
Station No.	IV	IV	IV	IV	X
Head Capsule Size Range for Sample (mm)	0.5-1.2	1.0-1.5	1.4-2.3	1.8-2.6†	
No. Foreguts Examined	25	25	25	25	
Empty Foreguts (%)	12	36	36	16	20
Class Insecta					
Ephemeroptera	58	19	75	48	37
Plecoptera	9	19	81	29	27
Trichoptera	0	0	13	0	2
Diptera					
Chironomidae	45	4	88	81	44
Other Diptera	0	0	13	0	1
Unidentified	18	13	4	4	7
Division Cyanophyta					
Oscillatoria (?) spp.	0	38*	0	0	2;5*
Division Chlorophyta					
Mougeotia spp.	23	0	0	0	3
Enteromorpha spp.	0	0	0	0	8;9*
Desmids					
Closterium spp.	4	4	0	0	3
Division Chrysophyta					
Diatoms					
Navicula spp.	0	75*	63*	0	33;22*
Gomphonema spp.	0	50	38	0	20;2*
Cymbella spp.	0	4	0	0	15
Fragilaria spp.	0	0	13	4	6;0.5*
Nitzschia spp.	0	0	0	0	8
Synedra spp.	0	0	0	0	1
Surirella spp.	0	0	0	0	3
Diatoma spp.	0	0	13	0	1
Misc. diatoms	0	0	0	19	12
Unidentified sp. 1	0	19	31	0	25;11*
Unidentified sp. 2	0	0	0	0	7
Unidentified filamentous algae	0	0	0	0	2
Unidentified plant fragments	4	0	0	19	3
Detritus (sand grains, silt, plant remains, diatom frustules)	14	63;4*	0	19	30;17*

†Measurements from 3/17/72
*Dominant

ardson and Gaufin (1971) determined that *M. signata* fed primarily on Ephemeroptera, Chironomidae, and Simuliidae. In his study, Swapp (1972) found that the similar species, *M. subtruncata* (Hanson) and *Skwala parallela* (Frison), ingested mayflies and chironomids and that *S. parallela* ingested caddisflies as well. However, he found only one *S. parallela* of 200 specimens that contained other stoneflies. The food habits of *M. signata* are similar to those of *Skwala curvata* (Hanson) as investigated by Sheldon (1972), with the exception of the number of Trichoptera eaten. In Mill Creek *M. signata* ingested very few caddisflies.

Filamentous algae, diatoms, and detritus also composed a significant percentage of the gut contents. Richardson and Gaufin (1971), Sheldon (1972), and Swapp (1972) report that all the Isogeninae species they studied are herbivores to a considerable extent. Hynes (1941) and Brinck (1949) agree that so-called carnivorous species also feed on vegetable matter. There is no way to determine if these items are actively ingested, present in the prey stomachs, or eaten in the search for prey. The corollary, that the prey species may have been ingested while *M. signata* were grazing on periphyton, may also be true (Sheldon 1972). *Navicula* spp. and an unidentified species of a filamentous diatom were the most numerous of the algae found in the guts. Detritus in the form of sand grains, silt,

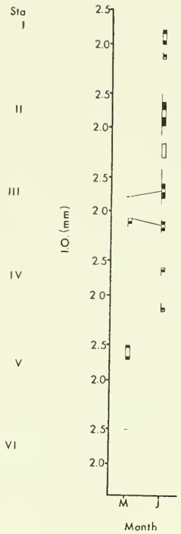

Fig. 7. Size range of adults of *M. signata*.

diatom frustules, leaf fragments, and other plant remains were found in 30 percent of the insects examined. Other diatoms encountered were *Gomphonema* spp., *Cymbella* spp., and *Nitzschia* spp. These are common stream dwellers of Mill Creek, occurring on the rocks in shallow water.

There are some significant seasonal differences in the food items found in the guts. In the summer (July-early September) significantly more *M. signata* (58 percent) ingested mayflies than in the fall at Station IV, but at Station I the numbers feeding on Ephemeroptera were low (5 percent). Stoneflies were found in only 9 percent of the guts examined at Stations I and IV. Chironomids, on the other hand, were present in 32 and 45 percent of the guts at Stations I and IV, respectively. The number of chironomid head capsules found was also greater than in the fall. At Station IV diatoms were notably lacking in the gut contents, although mayflies and chironomids were present. This could be because the swift current dislodges the algae from the substrate and because the deeper water and suspended solids from spring runoff shut out sufficient light. However, at Station I, where the water was shallower, diatoms were found in the majority of the guts examined (*Navicula* spp. were found in all stoneflies examined). Filamentous algae and detritus were also present in many guts. *Enteromorpha* spp., a filamentous green algae, was the dominant plant material in 14 percent of the guts, while detritus was the dominant item in 77 percent of the guts. This herbivorous material may have come from the stomachs of the chironomid prey (mayflies present in only 5 percent of the stoneflies) since Oliver (1971) states that some chironomids feed on algae and detritus. However, many guts contained detritus as the dominant material without chironomids being present. It is conceivable that during the summer the newly hatched nymphs of *M. signata* could feed at least partially on diatoms, filamentous algae, and detritus. At this stage they are probably not as effective a predator as at later life stages. Coffman, Cummins, and Wuycheck (1971) found a similar pattern in other groups of insects, in that young individuals consumed primarily detritus but shifted to algal or animal ingestion as they matured. The lowest absolute growth rate occurs in the summer from July to August despite increased carnivorous feeding. Growth increases sharply from August to September, however.

In the fall (mid-October) at the two stations analyzed, Ephemeroptera were found in 19 percent of the guts at Station IV and in none of the guts at Station I. This can probably be explained on the basis of emergence of many of the mayfly species. One mayfly adult was found ingested, however. Plecoptera were also relatively rare in the fall, many having emerged already. Many summer and fall emergers may still be in the egg stage or too small to be prey. Chironomidae were least numerous at this time of year also (present in only 17 percent of the insects examined). Diatoms and detritus were the most numerous items found in the guts during the fall. Since *M. signata* emerges mostly in the summer, the fall specimens represent some of the smaller sizes. They would not require as much food and thus are adapted to the relative paucity of prey species. At Station IV even diatoms except *Navicula* spp. were not numerous in those stoneflies examined. The swift current could be a factor in removing many from the substrate. At this station more individuals had fed on mayflies and stoneflies than at Station I. Another difference was that more empty foreguts were found in those stoneflies dissected from Station IV (maximum number reached) than at Station I (9 vs. 2). The lack of sufficient prey could be a limiting factor. However, the period October-November represents one of the highest absolute growth rates during the year. The growth rate data were obtained by pooling all samples from all stations, however.

During the winter (January-February) mayflies, stoneflies, caddisflies, and chironomids in the guts increased significantly. Sheldon (1972) reported similar results in some of the *Arcynopteryx* species complex he studied. In the winter at Station IV, there were prey species present in more of the guts than at any other time during the year. This represents an increase in the absolute growth rate but a decrease from the previous month. The calculated absolute growth rates from November to December and from December to January are questionable, since only 3 *M. signata* nymphs were collected in December. This increase in growth rate is probably correlated with the availability of food, because only the family Capniidae are emerging. Chironomids were the most numerous, being present in 88 percent of the guts examined. These slower-moving insects would be easier prey than the faster mayflies and stoneflies. Stoneflies also increased dramatically in the guts despite the fact that the numbers available decreased due to winter emergence. By winter, however, the summer and fall emergers, such as the family Chloroperlidae, may have attained a sufficient size to be suitable prey. Surprisingly, the increase in numbers of prey found in the guts also coincides with one of the periods of the least amount of growth. The low winter-stream temperature could stress the nymphs enough that some growth may be sacrificed even though an adequate food supply may be available. The number of diatoms and other algae decreased significantly, probably due to the decreased water temperature and lack of sufficient solar radiation. Nevertheless, *Navicula* spp. and *Gomphonema* spp. were still numerous. *Enteromorpha* spp. were dominant in 21 percent of the guts examined during this period. The stoneflies dissected from Station V were collected in February, however, when stream temperatures were beginning to warm slightly and solar radiation was increasing. Detritus was present in 43 percent of the guts and comprised the dominant item in 29 percent of those examined. The number of empty foreguts increased to a maximum again during this time.

The early spring (March) was also a time of increased carnivorous feeding. This also coincides with a significant increase in the absolute growth rate. At this time many stoneflies and mayflies are approaching their maximum size prior to emergence. The quiescent stage just before emergence may also make them easier prey. The percentage of mayflies and stoneflies in the guts increased at Station V but decreased at Station IV. One explanation for this may be that during spring runoff, the water level is deeper at Station IV than at Station V. However, the occurrence of chironomids decreased significantly at Station V but remained high at Station IV. The reason for this was not determined. Some emergence could have occurred at Station V, but because the stations are in close proximity this would not seem to be the answer. Sheldon (1972) stated that mature nymphs of the *Arcynopteryx* species complex he studied decrease their consumption of animal food in the spring (April). At this time *M. signata* in Mill Creek undergoes a noticeable decrease in absolute growth rate prior to emergence. Diatoms and other algae were still relatively rare in the guts examined. Presumably spring runoff created spates which might have removed these forms from the substrate. Detritus was found in 85 percent of the guts at Station V. Increased runoff due to snow melt contributed large amounts of allochthonous detritus to the stream. The greater depth of water at Station IV may have prevented the concentration of detritus and effectively removed it. On the other hand, at Station V the channel is wide enough that shallow areas are available for detritus to collect.

In discussing food habits it is important to remember that the partitioning of resources is accomplished by the wide distribution in size range, which decreases intraspecific competition (Hartland-Rowe, 1964; Radford and Hartland-Rowe, 1971). In most samples a difference in interocular measurement of *M. signata* averaged 0.6-1.0 mm from the smallest to largest individuals. This was a significantly larger size range than in the euholognathan species studied.

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