Wing Pad and Tergite Growth of Mayfly Nymphs in Winter

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Wing Pad and Tergite Growth of Mayfly Nymphs in Winter[1]

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ABSTRACT: Growth rates of nymphal wing pads and tergites of *Epeorus* (Ephemeroptera) during the winter from a West Virginia stream were established. The average specific growth rate of the wing pad was 0.193 mm/week/mm and the average growth rate of the tergite was 0.017 mm/week. The pre-emergent tergite growth is slower in contrast to the rapid increases of wing pad size. The effect of temperature on the rate of growth appeared to be minimal, as the growth rates were achieved during periods of lowest water temperature.

Most stream bottom fauna studies have been conducted under warm temperature conditions. Little information concerning the winter ecology of stream benthos is available. Some abundant species appear as early instars in the autumn and undergo a spring emergence. A study of the characteristics of physical growth during the period of low temperatures is important for an understanding of the life cycles of aquatic insects. Brown (1953) found that freezing temperatures seemed to have little effect on certain aquatic organisms providing the water immediately surrounding them is not frozen. There is a lack of agreement as to the effect of winter conditions on the growth of the Ephemeroptera. Macan (1957) was unable to determine if the growth rate was affected by temperature, but recognized some nymphal growth during the winter. Illies (1952) found that *Rhithrogena* sp. did not grow during the winter.

The objective of this investigation was a winter study of physical growth in *Epeorus* (Ephemeroptera). This genus constituted 30 per cent of the total bottom fauna sampled.

MATERIALS AND METHOD

Epeorus nymphs were collected from Roaring Creek, located in Preston Co., West Virginia at an elevation of 2,060 feet above sea level. The stream bed consists of boulders, rubble and coarse gravel. A dense cover of mixed hardwoods and laurel lines the stream banks.

Field work extended over a 30-week period from 31 October 1959 to 15 May 1960. Collections of aquatic organisms were made with a modified Fish and Wildlife Service sampler, consisting of a rectangular metal frame of 0.1 square meter area and a net. Fifty-six bottom fauna samples were taken during the collection period. Water temperatures were recorded weekly by a Sixes type maximum-minimum thermometer. The thermometer was enclosed in an aluminum cage and permanently submerged in the stream during the collection period.

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Growth of *Epeorus pleuralis* and *E. fragilis* nymphs was based on measurements made with a binocular microscope with a calibrated micrometer eyepiece. Methods for growth determinations were modified from techniques used by Ide (1935). Nymphs were placed between two ordinary glass slides when measured. Measurements included counts of antennal segments, over-all length, wing pad length and the ninth abdominal tergite length. Approximately 2,000 individual nymphs were measured.

RESULTS

The populations discussed in this paper are organisms trapped in the sampler net, so in effect are a "net population." The term "recruits" is applied to young *Epeorus* nymphs with barely apparent wing pads, less than 0.1 mm in length. The total body lengths of these recruits varied from 2 to 4 mm. The specimens were just large enough to be retained by the mesh of the sampler net. Recruitment of young nymphs into the net population is a major factor governing the seasonal standing crop pattern. In Table I the effect of recruitment on the total population is shown. The March peak in the total population is directly related to the accumulated entrance of small nymphs into the population. The reduction of the total population in the spring corresponds to a reduction in the rate of recruitment.

There is an unknown but probably high nymphal mortality rate, since the accumulation of young recruits should give a larger total population than is actually the case. The reduction in numbers of larger nymphs reflects probable effects of predation and flood flow.

TABLE I.—The effect of numbers of *Epeorus* recruits* on the total *Epeorus* population

Period in weeks	Date	Number of recruits	Total population	% Recruits
0	10-31-59	64	67	95
2	11-14-59	95	117	81
4	11-28-59	33	75	44
6	12-12-59	9	24	36
8	12-26-59	73	207	35
10	1- 9-60	55	139	39
12	1-25-60	75	204	37
14	2- 6-60	103	197	53
16	2-20-60	......	......	....
18	3- 5-60	120	264	45
20	3-19-60	75	319	23
22	4- 2-60	33	65	51
24	4-16-60	51	233	22
26	4-29-60	11	132	8
28	5-14-60	8	46	17

* Young *Epeorus* nymphs with wing pads less than 0.1 mm in length.

Further population reduction is due in part to movement of large nymphs with well-developed wing pads from the riffles. The number of nymphs reaching the large pre-emergent size is a small per cent of the total number appearing initially as recruits in the population. Large numbers of recruits are responsible for the numerical dominance of *Epeorus* in the Roaring Creek benthos.

Measurements showed definite growth in the body size and wing pad length. Recruitment of young nymphs presented difficulties in growth analysis. Determinations based on the entire population would show unbalance due to the large numbers of small nymphs. Division of the sample into growth units appeared to be the most convenient logical approach. In Figure 1 growth units through the collection periods were established by graphical methods. Macan (1957) has stated that by looking at the size of the largest specimen in each successive collection period it is possible to gain a rough idea of the growth rates. The growth units in this paper are a refinement of that idea.

Growth Unit I was determined by selecting a group of nymphs with wing pads of maximum length which appeared during the 20th collection period. Wing pad lengths in this group had a range of 0.5 mm and were the basis for establishing Unit I in the rest of the collection periods. Units II, III, and IV were established by similar methods although variations were necessary to conform to natural breaks in the data. It is realized this selection of growth units may

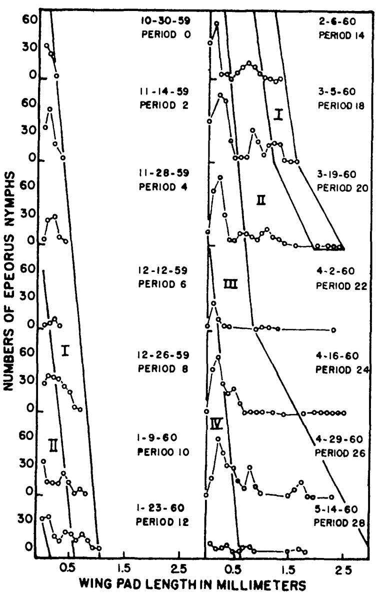
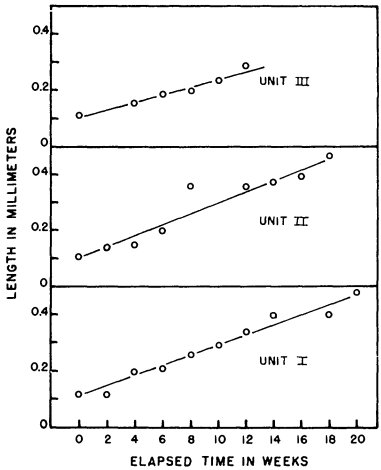


Fig. 1.—Total *Epeorus* nymphs collected during each period as a function of wing pad length. Note establishment of Growth Units I, II, III and IV by utilizing natural breaks in the data.



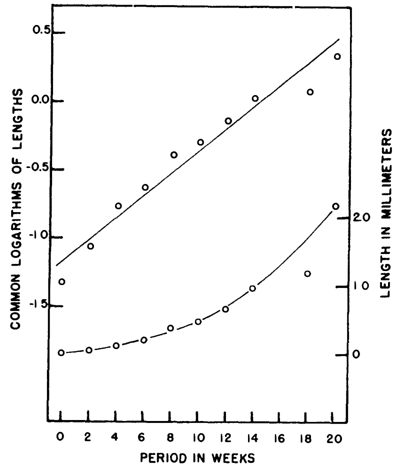
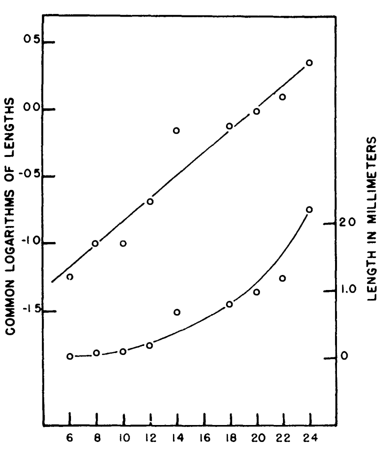


Fig. 2 (left).—Tergite length as a function of time for Growth Units I, II, and III. Calculated standard growth rates for Unit I = 0.018 mm/week; Unit II = 0.020 mm/week; Unit III = 0.014 mm/week.

Fig. 3 (right).—Wing pad length as a function of time for Growth Unit I. Calculated specific growth rate = 0.186 mm/week/mm.



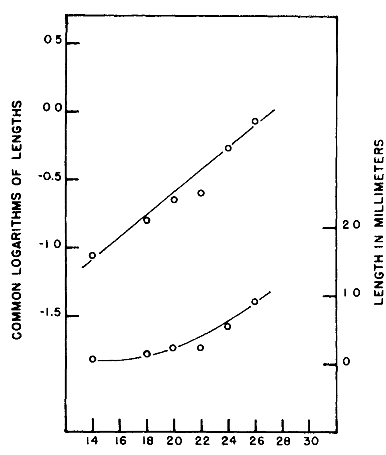


Fig. 4 (left).—Wing pad length as a function of time for Growth Unit II. Calculated specific growth rate = 0.198 mm/week/mm.

Fig. 5 (right).—Wing pad length as a function of time for Growth Unit III. Calculated specific growth rate = 0.194 mm/week/mm.

TABLE II.—Summary of *Epeorus* 9th tergite growth rate values

Growth unit	Standard growth rate mm/week All tergite lengths	Specific growth rate mm/week/mm 0.1 mm tergite	0.4 mm tergite
I	0.018	0.180	0.045
II	0.020	0.200	0.050

not be an entirely accurate reflection of nymphal growth. However, this method is an attempt to quantify growth data in the absence of existing methods.

In Figures 2, 3, 4, and 5 growth curves were constructed for wing pad and tergite length increases for Units I, II and III. The regression equation $Y = a + bX$ from Snedecor (1946) was derived to determine the exact position of the curves. The tergite curve is a straight line for all three plotted growth units. The regression coefficient yields the "standard growth rate" per millimeter of length. The similar rates for the three units indicate some degree of validity for the method of selecting growth units. In Table II "specific growth rates" were determined by division of the standard growth rate by tergite size. The standard growth rate indicates a uniform increase in tergite length independent of tergite size. In this sense a steady arithmetic growth pattern is maintained. However, growth as a function of

TABLE III.—Growth rates of *Epeorus* for each collection period by growth units.*

Dates	Period (weeks)	Growth of wing pad mm/week	Growth of tergite mm/week	Temperature C Min.	Max.
		Unit I			
10-31-59 to 11-14-59	0 to 2	0.019	0.000	4.4	11.7
11-14-59 to 11-28-59	2 to 4	0.041	0.035	1.7	9.4
11-28-59 to 12-12-59	4 to 6	0.031	0.012	1.7	6.7
12-12-59 to 12-26-59	6 to 8	0.088	0.030	1.1	7.2
12-26-59 to 1- 9-60	8 to 10	0.052	0.009	2.8	7.8
1- 9-60 to 1-23-60	10 to 12	0.109	0.024	1.1	7.8
1-23-60 to 2- 6-60	12 to 14	0.179	0.035	0.6	5.6
2- 6-60 to 3- 5-60	14 to 18	0.022	0.000	0.0	6.7
3- 5-60 to 3-19-60	18 to 20	0.500	0.039	0.0	3.3
		Unit II			
12-12-59 to 12-26-59	6 to 8	0.025	0.014	1.1	7.2
12-26-59 to 1- 9-60	8 to 10	0.000	0.005	2.8	7.8
1- 9-60 to 1-23-60	10 to 12	0.154	0.012	1.1	7.8
1-23-60 to 2- 6-60	12 to 14	0.252	0.081	0.6	5.6
2- 6-60 to 3- 5-60	14 to 18	0.019	0.000	0.0	6.7
3- 5-60 to 3-19-60	18 to 20	0.105	0.016	0.0	3.3
3-19-60 to 4- 2-60	20 to 22	0.090	0.009	0.0	7.2
4- 2-60 to 4-16-60	22 to 24	0.528	0.039	2.8	12.2

* Growth units were established by graphical methods. See Fig. 1.

tergite length shows a decrease per unit length. In this latter sense tergite growth drops off as the nymph matures.

The wing pad curve plotted as periods versus logarithms of the wing pad lengths yields a straight line indicating the geometric nature of wing pad growth. Specific growth rates for wing pads were calculated as $\log_e 10$ times the regression coefficient. Growth rates of wing pads and tergites as determined independently for each collection period are shown in Table III. The following formula from Simpson and Roe (1939) yields growth in terms of millimeters per week.

$$A = \frac{Yt - Yo}{t}$$

Where Yo = the initial size of the wing pad.
A = the growth rate.
t = the time elapsed.
Yt = the size of the wing pad or tergite at the end of this time.

Growth rates of tergites and wing pads show a fundamental difference between growth patterns of these structures. Ratios of wing pad to tergite length provide a demonstration of the growth differential accompanying nymphal maturation. The rapid increase of wing pad over tergite length after the fourth week is indicated by geometrically increasing ratios.

DISCUSSION

The maintenance of growth throughout the winter is evident by the data presented. This is in contrast to *Rhithrogena* sp. which,

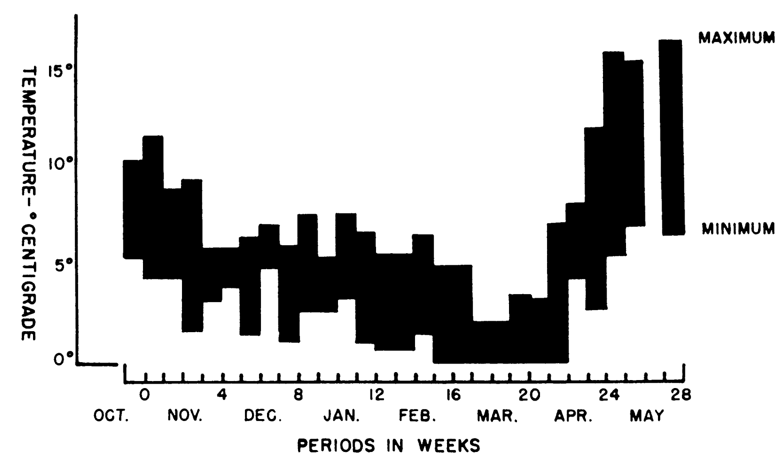


Fig. 6.—Maximum and minimum water temperatures of Roaring Creek during the fall, winter and spring.

according to Illies (1952), does not show any growth during the winter. Macan (1957) has recorded some nymphal growth in Ephemeroptera during the winter, but was unable to determine if the growth rate was affected by temperature. The *Epeorus* population is evidently well adapted to low temperatures since growth was maintained despite low water temperatures shown in Figure 6. Effect of temperature on changes in growth rates cannot be clearly demonstrated for *Epeorus*. However, the most spectacular growth occurs in the final period in Units I and II during the lowest winter temperatures. This may appear to be contrary to well-established facts concerning the relationship of metabolic activity to temperature. Physiological growth is undoubtedly involved in the early stages of wing pad development. However, in the later phases of enlargement physical expansion rather than metabolic processes may play the primary role. Size increases in this phase are nevertheless of considerable significance as an intrinsic part of the maturation sequence.

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