

**Change in Growth of a Mayfly Nymph,
Ephemera japonica, along the Stream
Length and Thermal Effect on It**

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Change in Growth of a Mayfly Nymph, *Ephemera japonica*, along the Stream Length and Thermal Effect on It

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Abstract

The growth and life cycle of *E. japonica* in the upper, the middle and the lower regions of the Kazuradani Creek, Kagawa Prefecture were compared. The beginning of emergence is one month earlier in the lower region than in the others. And the recruitment of next generation is one month earlier in the lower and the middle regions than in the upper. The average growth rate of the early-stage nymphs from August to January is higher in the lower region than in the others, and this results in the size difference after spring. The difference in growth rate can be explained fairly well by the difference in water temperature among the regions. The biomass of nymphs increases toward the upper stream where the adult size and fecundity must be the smallest. The fact indicates that the maximum adult size and fecundity do not always coincide with the greatest sub-population biomass; it is contrary to the thermal equilibrium hypothesis.

Introduction

Four species of *Ephemera*, burrowing mayflies, are distributed in Japan. The nymphs of *E. japonica*, *E. strigata* and *E. orientalis* inhabit upper, middle and lower regions, respectively, in a lot of streams except in the Okinawa Islands where *E. formosana* is distributed (KUWADA 1955, 1958, MIZUNO & GOSE 1972, WATANABE 1985). This general tendency holds good also in the Kazuradani Creek, Kagawa Prefecture (KURODA et al 1984). The distribution range of *E. japonica*, however, spreads to the lower region of the creek and the nymphal size in each month seems to be different in the regions along the stream length. Therefore, we describe in this paper the differences in growth and life cycle of *E. japonica* nymphs among the three regions of the Kazuradani Creek and examine the thermal effect on them based on the same data as in KURODA et al (1984).

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Materials and methods

The Kazuradani Creek, a tributary of the Kasuga River, is a first-order stream and originates 310 m above sea level in the Sanuki mountains. The sampling points of *E. japonica* are shown in Fig. 1. Station 1 is 230 m and St. 8 is 45 m in altitude, and the distance between the two points is about 3.8 km. The substrata are mainly sandy all over the stream. The stream width is less than 2 m from St. 1 to St. 7 and 2-5 m at St. 8 with seasonal fluctuations.

Monthly samplings were made at each of the eight points from February 19th, 1982 to January 11th, 1983 although St. 7 and St. 8 were omitted in February.

A kind of box sampler, a metal frame (30 cm × 30 cm bottom and 53 cm height) covered the sides with canvas, was used. The sampler was pushed down and fixed to the bottom surface. The substratum inside the sampler was stirred with a small rake and floating organisms were swept with a hand net of 38 mesh (0.471 mm opening). The stirring and sweeping were repeated until no organism was found. Three samples were taken at each of the points every month. The water and air temperature, and the stream width were recorded at the same time.

Ephemera nymphs were sorted out from the samples and preserved in 70 % ethanol solution. The three species were identified by the colour pattern of head and of dorsal abdomen (KURODA & WATANABE, 1984). The nymphs were determined the sex by the presence of male external genitalia and measured their body length and pronotum width using a binocular microscope.

Results and Discussion

Fig. 2 shows the average water temperature in each region at the monthly samplings. The water temperature is generally the highest in the lower, and the lowest in the upper regions with a few exceptions. The difference of temperature among the regions, however, is a little; the greatest (4.5°C) in March and less than 2°C in most

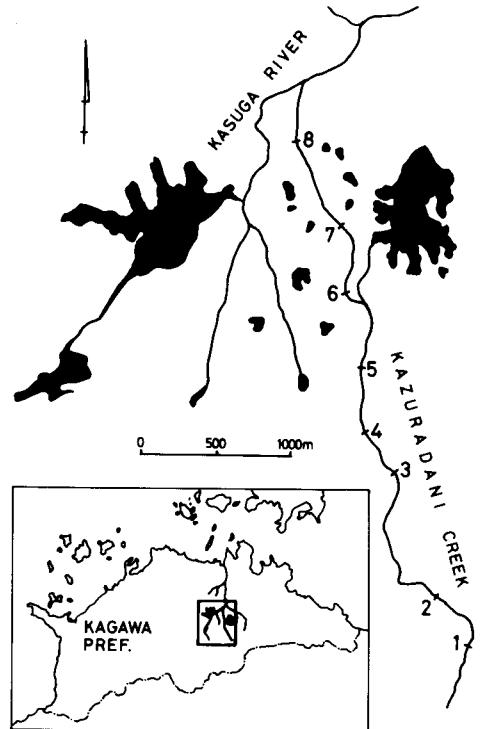


Fig. 1 Map of the Kazuradani Creek showing the sampling points.

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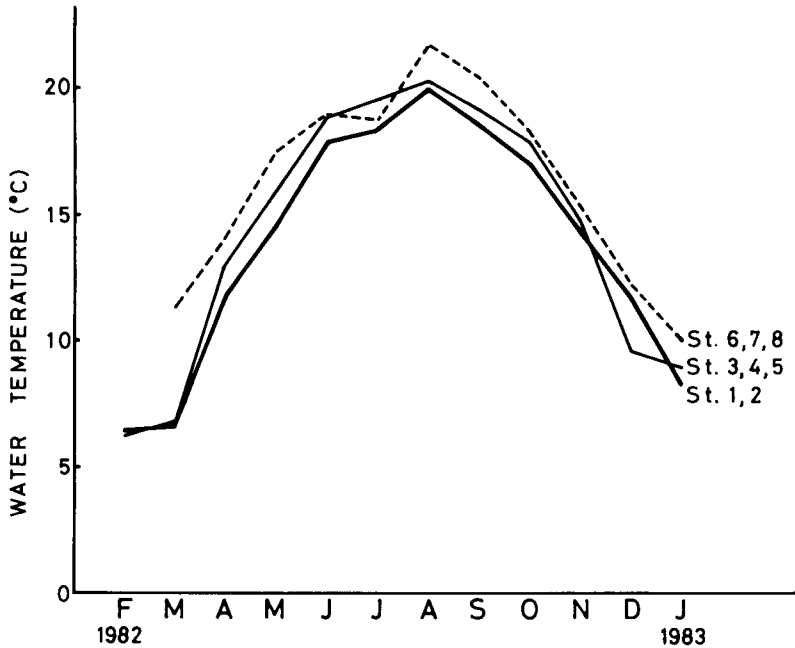


Fig. 2 Monthly water temperature in each region.

months.

The frequency distribution of the pronotum widths in the three regions are shown in Fig. 3 with the records of emergence. In the upper and the middle regions, the emergence was found in June, August and September. We cannot decide whether the absence of adults in July is something meaningful or it is owing only to the inadequate searching effort. In any case, the emergence begins in June in both regions. The nymphs smaller than 0.8 mm in pronotum width are abundant in September, but only a few in August in the upper region, although they are abundant also in August in the middle region. In the lower region, the emergence occurs in May, and the small nymphs first recruit in August. Therefore, the emergence is about one month earlier in the lower region than in the upper and the middle regions, and the recruitment of small nymphs begins about one month later in the upper region than in the others. Considering the long sampling intervals, both the times of emergence and recruitment of the next generation seem gradually to become earlier from the upper to the lower stream.

KURODA et al (1984) found that *E. japonica* nymphs were absent or very few in June and July in the lower region of the Kazuradani Creek. Fig. 3 suggests that this phenomenon is not due to the seasonal migration but to the gaps of life cycle among the regions. In the lower region, the emergence has almost finished and the next generation does not recruit yet in June and July. ULFSTRAND (1968) reported that *Baetis rhodani*

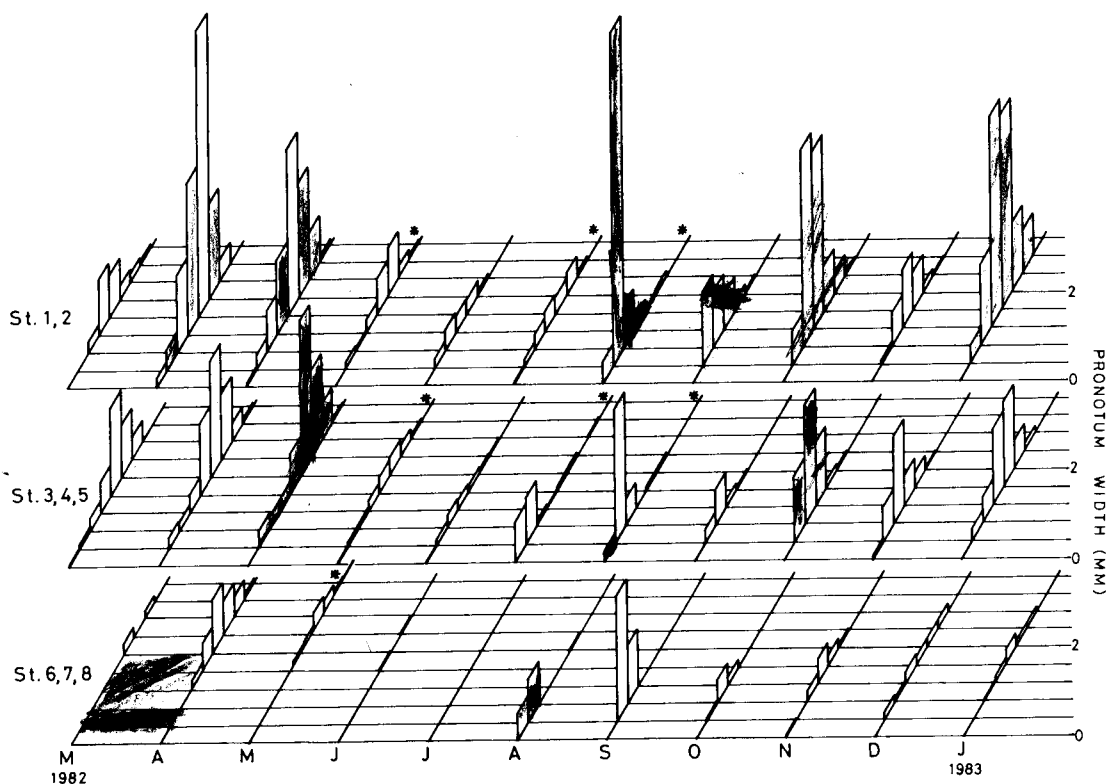


Fig. 3 Seasonal change in size-frequency distribution of *E. japonica* nymphs in each region. The asterisks show the months when adult mayflies were found.

nymphs disappeared in summer at the outlets with a high water temperature although they occurred at the other localities, and he explained this fact by the same reason as above.

The maximum nymphal size decreases in the later emergence season (August and September in the upper and the middle regions). The gradual decrease in adult body size during a emergence period has been reported in many mayflies (GLEDHILL 1959, FREMLING 1973, PLESKOT 1961, HARVEY et al 1980). The decrease in the maximum nymphal size of *E. japonica* suggests the decrease also in adult size in the later emergence period.

Fig. 4 shows the growth in the average pronotum width of *E. japonica* nymphs in each of the regions. By CASSIE's (1954) probability paper method, the major group was separated from the size distribution in each month and approximated to a normal distribution, and its mean pronotum width was obtained. The nymphs larger than 1.2 mm in pronotum width can be determined the sex, in general. The large females and males from March to August are shown separately (Fig. 4a,b). Both sexes of small nymphs from August to January are shown together even if they could be distinguished (Fig. 4c),

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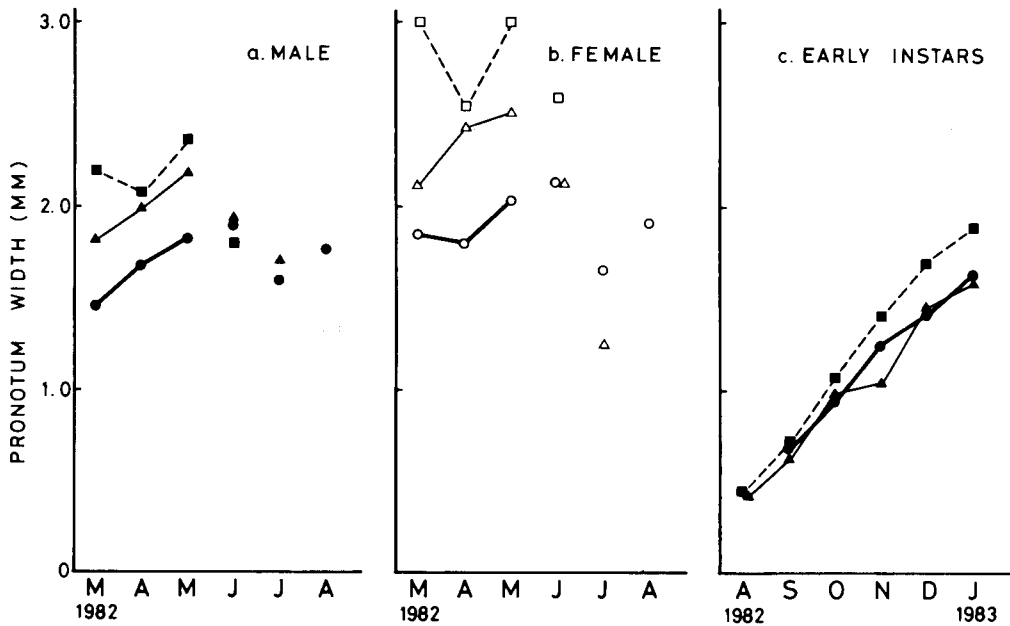


Fig. 4 Mean pronotum width every month. Circles, triangles and squares show the upper, the middle and the lower region, respectively.

because they do not differ in size. From the figure, the female nymph is larger than the male from spring to summer, and the sizes of both sexes decrease from the lower to the upper regions every month. The small nymphs from August to January in the lower region are larger than those in the upper and the middle regions, although the size difference between the upper and middle regions is not distinct with an unusual small value of November in the middle region. The size difference of small nymphs between the upper region and the others increases as the time goes: it indicates that the difference of growth rate in the earlier stage results in the size difference after spring.

The average monthly growth rates in the earlier stage for the upper and the lower regions are shown as a function of both initial size and water temperature on a three-dimensional scale in Fig. 5. The water temperature is indicated as the average value of the two successive months from which the growth rate was calculated. The size naturally increases as the water temperature decreases because the figure is concerned with the period from August to January. The growth rate decreases as the size increases, and it is higher in the lower region with higher temperatures than in the upper region. The nymphal size in the lower region is 0.2-0.4 mm greater than that in the upper region at the imaginary same temperature by interpolations. This size difference, however, seems not to affect much the growth rate, which is similar in both regions at a given temperature. The growth rate, accordingly, can be indicated as a

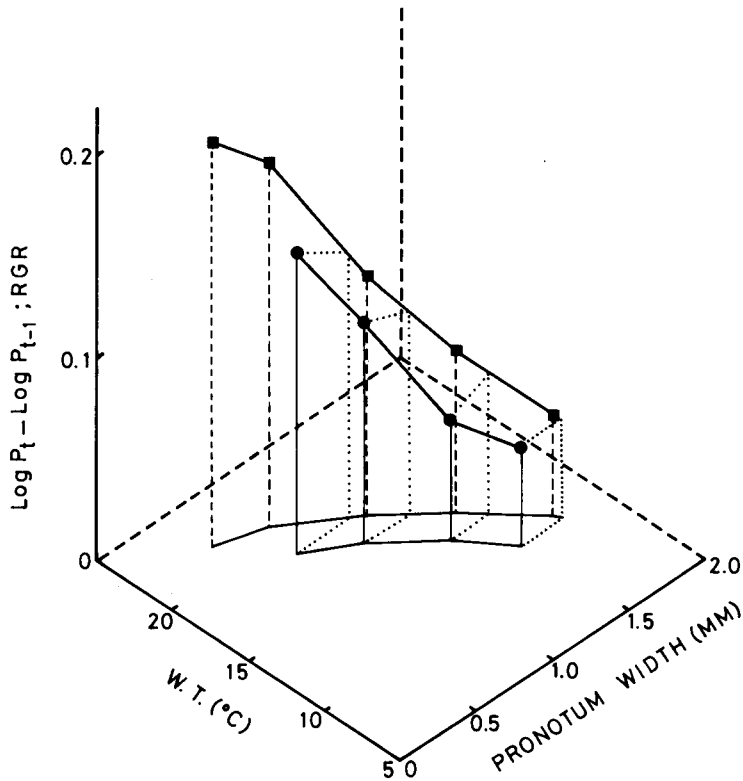


Fig. 5 Relative growth rates in each of the upper (●) and lower (■) region shown as a function of both temperature and initial size on a three-dimensional scale.

function of water temperature alone (Fig. 6). The middle region also is included in the figure. The growth rate increases with the increasing water temperature, and the upper and the lower regions are not clearly distinguishable in this relationship. The values of the middle region vary widely, especially two points deviate from the others. As shown in Fig. 4, this deviations are due to the unusually small pronotum width in November which results in the very low growth from October to November, and the very high growth from November to December. The reason for the unusual

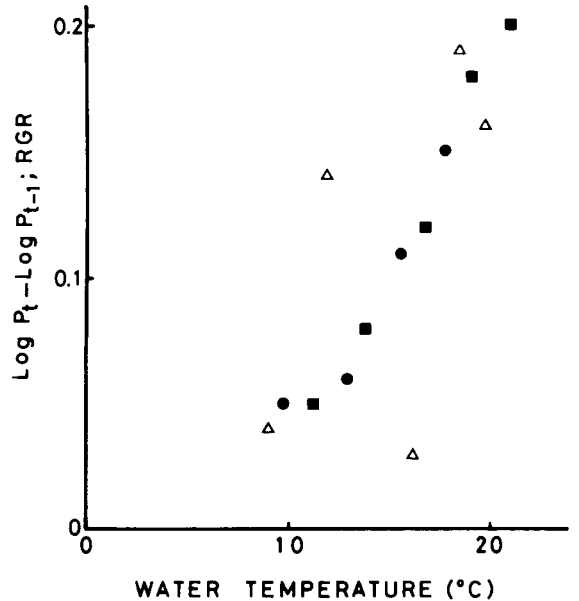


Fig. 6 Relationship between relative growth rate and water temperature. Symbols are the same as in Fig. 4.

small size in November is not clear. Without the two points, the growth rate-temperature relationships hardly differ among the three regions. Therefore, the greater part of the difference in growth rate among the regions can be explained by the difference in water temperature.

SWEENEY & SCHNACK (1977) and SWEENEY (1978) reported that the intraspecific variations in adult size or fecundity of aquatic insects were affected by the diurnal and seasonal fluctuations of water temperature. Besides, SWEENEY & VANNOTE (1978) and VANNOTE & SWEENEY (1980) proposed the hypothesis that an equilibrium location, the geographic region where both individual weight and fecundity are maximized, coincides closely with the location of the greatest subpopulation biomass.

The present paper is based on a preliminary survey of *E. japonica* life history, and some errors are probably included in the estimates such as nymphal size and density. Rough comparisons of the regions, however, are possible. In the Kazuradani Creek, the nymphal growth rate in the lower region with high temperature is higher than that in the upper region with low temperature. The nymphal maximum size in the emergence period becomes larger downstream; it suggests the difference of adult size among the regions.

CLIFFORD & BOERGER (1974) found that the fecundity of mayfly increased with adult size, and the size-fecundity relationship gave a single curve regardless of species except *Leptophlebia cupida*. The fecundity of *E. japonica* increases with adult size regardless of the regions and the days during a emergence period also in the Kazuradani Creek (MIYOSHI & WATANABE, unpublished). The lower region where both adult size and fecundity are greater, accordingly, is expected to be a better thermal condition and to be a greater biomass than the upper region by the hypothesis of SWEENEY & VANNOTE (1978) and VANNOTE & SWEENEY (1980). KURODA et al (1984), however, reported that the density of *E. japonica* was always much higher in the upper region than in the lower region. Moreover, rough estimates of biomass are always much greater in the upper region than in the lower; the biomass was calculated from the data of density, individual body length and the length-weight relationship which is roughly expressed as $W = L^{2.9}$ based on a small samples ($n = 12$). The fact proves that the maximum adult size and fecundity do not always coincide with the greatest sub-population biomass.

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