

The nymphal development of *Paraleptophlebia adoptiva* (McDunnough) and *Paraleptophlebia mollis* (Eaton) (Ephemeroptera: Leptophlebiidae) and the possible influence of temperature

LYNDA D. CORKUM¹

Department of Zoology, Erindale College, University of Toronto, Mississauga, Ont., Canada L5L 1C6

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Nymphal development of *Paraleptophlebia adoptiva* (McDunnough) and *Paraleptophlebia mollis* (Eaton) was studied in the West and East branches of the Credit River, Peel County, Ontario. Nymphs of *P. adoptiva* were found only in the cooler water of the West branch; they continued to grow during winter months and had a short emergence period in mid-May. *Paraleptophlebia mollis* nymphs occurred in both branches, nymphs in the West branch being significantly smaller than those of the East. No growth was observed for *P. mollis* nymphs in winter and a protracted emergence period for this species throughout June was evident. Both mayfly species are univoltine.

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Le développement larvaire de *Paraleptophlebia adoptiva* (McDunnough) et de *Paraleptophlebia mollis* (Eaton) a été étudié dans les branches ouest et est de la rivière Credit, comté de Peel, en Ontario. Les larves de *P. adoptiva* n'habitent que les eaux plus fraîches de la branche ouest; elles continuent leur croissance durant les mois d'hiver et ont une courte période d'émergence au milieu de mai. Les larves de *P. mollis* habitent les deux branches de la rivière et celles de la branche ouest sont de taille significativement moindre que celles de la branche est. Il ne semble pas y avoir de croissance chez les larves de *P. mollis* en hiver; la période d'émergence de l'espèce se prolonge durant tout le mois de juin. Les deux espèces sont univoltines.

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Introduction

Paraleptophlebia adoptiva (McDunnough) and *Paraleptophlebia mollis* (Eaton) are distributed throughout eastern Canada and northeastern, southeastern, and central United States (Edmunds *et al.* 1976). Although Traver (1937) collected both species in South Carolina, Berner (1975) considers them rare in the southeastern United States. Despite the similarity in geographical distribution, water temperature requirements have been shown to segregate these species within a single stream (Ide 1935).

This study examines the seasonal development of *Paraleptophlebia adoptiva* and *P. mollis* at one location in the West and East branches of the Credit River, Peel County, Ontario.

Materials and Methods

The Credit River, which flows through farmland and mixed deciduous forests, is generally a fast-flowing stream (up to 1 m per second) at the study area near the Forks of the Credit River, Peel County, Ontario (43°48' N; 79°59' W). The West and East branches of the Credit meet near the village of Belfountain.

Samples were taken from the West branch immediately upstream from the confluence and from the East, 200 m upstream from the confluence. The stream bed at both sites is composed of boulders, cobbles, gravel, scattered logs, and the occasional fallen tree. Stream widths varied between 14 and 16 m and water depth was variable with a maximum of 0.5 m.

Both sites were sampled for *P. adoptiva* and *P. mollis* nymphs from April 1974 to June 1975. Weekly visits were made from April to October; but between November and March, when nymphal growth slowed, samples were taken biweekly. Nymphs were hand picked from all substrate types and immediately preserved in 70% ethanol. Nymphs were also collected using a modified Hess sampler (Waters and Knapp 1961) (mesh size: 0.432 mm). Water temperatures were taken at the time of collection with a pocket thermometer at the two sites within 15 min of each other.

Paraleptophlebia adoptiva and *P. mollis* nymphs were distinguished according to the following criteria: (1) Since *P. adoptiva* nymphs are larger than those of *P. mollis*, representatives, which are collected at the same time and place, can be readily distinguished by size. (2) *Paraleptophlebia adoptiva* nymphs have a pair of pale strokes (paramedial) at the anterior border of the 10th abdominal tergum. This character is lacking in *P. mollis* (Ide, personal communication). (3) Both sexes of *P. adoptiva* nymphs are pigmented over the entire abdominal tergum. Female *P. mollis* nymphs possess dark-pigmented areas near the gill origin and along the lateral edges of the abdominal terga only. Male *P. mollis* nymphs lack these abdominal pigmented areas. Representative nymphs were reared to imago for positive identification.

¹Present address: Department of Zoology, University of Alberta, Edmonton, Alta., Canada T6G 2E9.

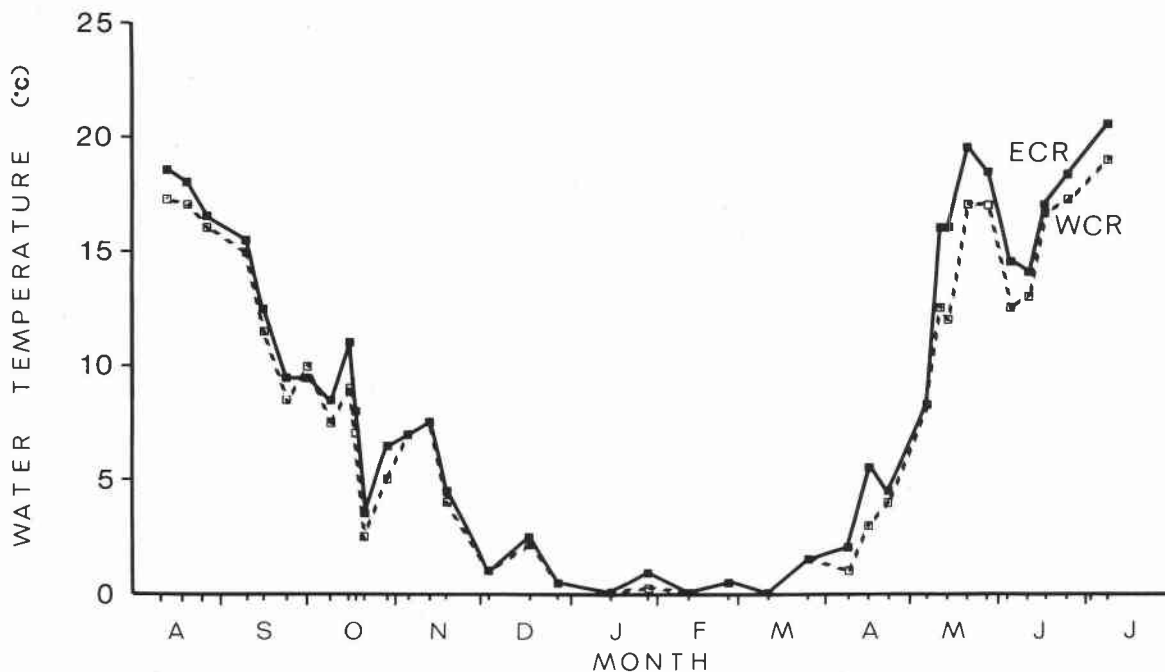


FIG. 1. Seasonal changes in water temperature for the West (---; WCR) and East (—; ECR) branches of the Credit River.

Male nymphs of both species were recognized by the presence of 'double' compound eyes. Using abdominal pigmentation, nymphs of *P. mollis* could be sexed at an earlier developmental stage than is possible with eye formation.

All nymphs were measured under a dissecting microscope at 40 \times with the aid of an ocular micrometer. Initially, three growth parameters were measured for each specimen: wing-pad length, ratio of wing-pad length to the length of the seventh abdominal tergite, and head capsule width (HCW). Coefficients of variation were calculated to determine the parameter with the least variability over a sampling period of 2 months. For both species, HCW measurements were least variable and they alone were subsequently used to determine size distributions.

Results and Discussion

The 37 samples collected during 1974–1975 yielded 489 nymphs of *P. adoptiva* and 3315 of *P. mollis*. These numbers do not reflect the relative abundance of each species in the river. *Paraleptophlebia adoptiva* nymphs were found only in the West branch of the Credit, whereas *P. mollis* nymphs were found in both branches. This still appears to be the case after 3 years of sampling in the area. Both species are univoltine. From field observations, it was assumed that food sources were not limiting in either branch.

Wilcoxon's signed-ranks test for two groups arranged as paired observations (Sokal and Rohlf 1969) was used to determine if differences in water temperature existed between the two sample areas. The water temperatures were significantly higher ($p < 0.001$) in the East branch than in the West (Fig. 1).

Paraleptophlebia adoptiva nymphs, most of which possessed gills, were first collected in September. Since early instars of mayfly nymphs lack gills, this species must have been overlooked in earlier collections at the site. These earlier instars may have occupied interstitial spaces within the stream bed (Coleman and Hynes 1970a; Bishop 1973; Williams and Hynes 1974).

Based on HCW measurements, immature *P. adoptiva* nymphs grow rapidly from September until December at which time water temperatures vary between 2.5 and 1°C (Fig. 2). The nymphs continue to grow throughout the winter months, but at a slower rate. Once temperatures increase, rapid growth resumes with the nymphs emerging by the 2nd week of May.

Paraleptophlebia adoptiva emergence in the West Credit River is confined to a short period in mid-May when the maximum water temperatures reach about 15°C. This species is one of the first mayflies to emerge in the spring (Gordon 1933; Leonard and Leonard 1962). Leonard and Leonard (1962) note that the peak emergence of *P. adoptiva* is during the first 3 weeks of May in Michigan, yet imagos continue to appear until July 8. Gordon (1933) collected subimagos and imagos in flight on May 5 in a New York stream and by June 17, no more were found.

Paraleptophlebia mollis nymphs collected in early August lacked gills, indicating that they were

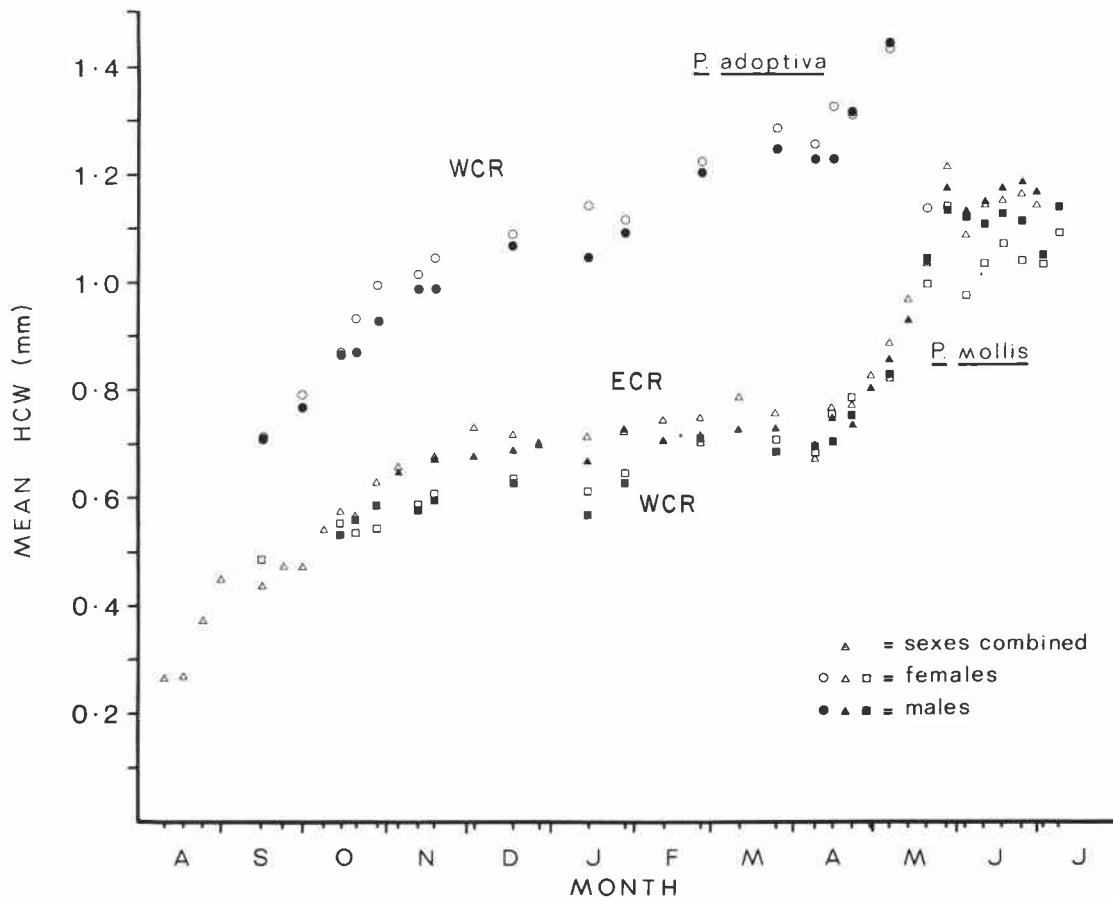


FIG. 2. Seasonal changes in mean head capsule width (HCW) for nymphs of *P. adoptiva* (●, ○) in the West Credit River (WCR) and for *P. mollis* in the East (▲, △; ECR) and West (■, □) branches of the Credit.

in very early instars. Hatching, therefore, occurred about this time. Populations in both branches exhibited growth in the autumn and showed no growth during the winter months (December–March). Once water temperatures increased in the spring (at about 5°C), growth resumed until June (Fig. 2). This pattern of *P. mollis* development agrees with the study by Coleman and Hynes (1970b) in the Speed River, Ontario. From a life history study on the Pigeon River, Michigan, Kovalak (1978) reported that *P. mollis* nymphs grew slowly between August and March, but rapidly between April and July.

Water temperatures may significantly influence the relative size of *P. mollis* nymphs in the two branches. Two-way ANOVA paired comparison tests (Sokal and Rohlf 1969) were used to test for differences in mean male and female HCW between sample sites. Although growth patterns were similar (increased growth in the autumn and spring with no growth in the winter), the mean HCW of both males and females was greater in the warmer East branch than the West ($p < 0.001$).

The frequency distribution of HCW of *P. mollis* with time is illustrated in more detail in Fig. 3 for the East branch. Samples differ between years for May (1975) and June (1974), but after testing overlapping sample populations (Student's *t*-test), no significant difference ($p > 0.05$) in HCW was found. Some *P. mollis* individuals overwintered as 'large' nymphs, i.e. the lengths of the mesothoracic wing pads were greater than the distance between them. During April, however, many nymphs could be still classed as immatures with lengths of the mesothoracic wing pads less than the distance between them (note the large range of HCWs in April, Fig. 3). This might be a consequence of delayed hatching as well as a precursor to an expanded emergence. Throughout June, the HCW of *P. mollis* nymphs changed little. Mature *P. mollis* nymphs with black wing pads were first observed on May 28. Other nymphs continued to grow and were found until the end of June. These individuals, however, did not attain the ultimate size of the larger overwintering nymphs. High water temperatures in late June (20°C) probably forced the emergence of the smallest nymphs. Cole-

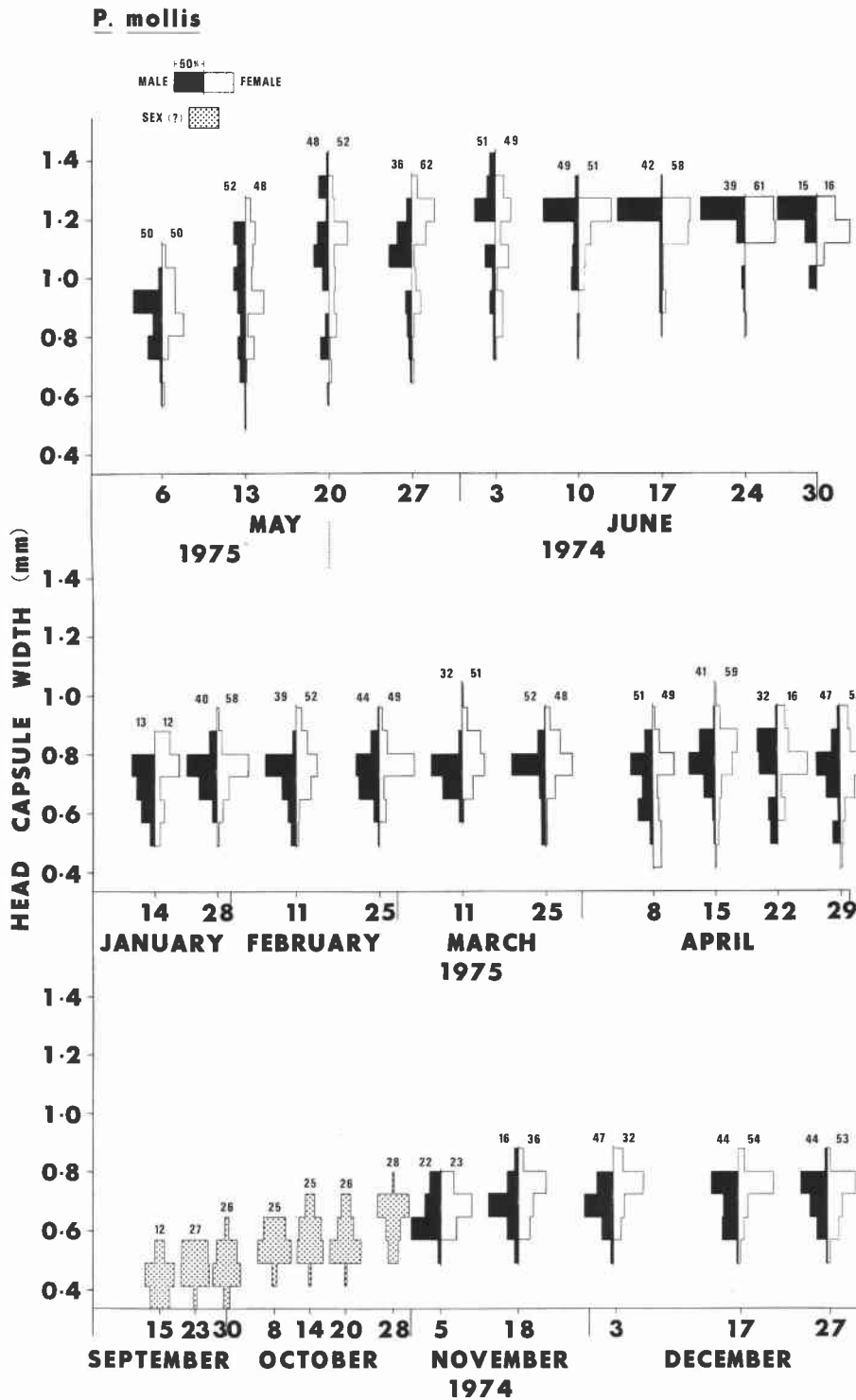


FIG. 3. Frequency distribution of head capsule widths for *P. mollis* nymphs in the East branch of the Credit River. Number of nymphs collected is associated with each histogram.

man and Hynes (1970b) also showed that nymphal size at maturity appeared to decrease as the emergence season progressed. In the West branch, *P. mollis* nymphs were found up until July 8 when

water temperatures at that time were 20°C. This temperature appears to be the upper threshold for emergence within this species.

The emergence period of *P. mollis* in southern

Ontario closely resembles that reported by Gordon (1933) in New York State. She indicates that the earliest collection of a subimago in the field occurred on May 30. Although the emergence period extended through June, the peak occurred early in the month. Leonard and Leonard (1962) agree with this time of peak emergence for *P. mollis*, but indicate that emergence extends until August 23. A long emergence period of from mid-May until mid-August was reported by Coleman and Hynes (1970b). Examples of expanded emergence in other species of mayflies are also known: *Ameletus inopinatus* (Gledhill 1959), *Baetisca rogersi* (Pescador and Peters 1974), *Epeorus pleuralis* (Ide 1935; Minshall 1967), and *Leptophlebia cupida* (Clifford 1970).

Ide (1940) demonstrated that *P. mollis* emerging from Costello Creek, Algonquin Park, Ontario, came from two overlapping, segregated populations. Based on egg counts of female subimagos, he separated *P. mollis* A, emerging from the 1st to the 3rd week of June, from *P. mollis* B, emerging from the 3rd week of June to the end of the 1st week of July. Ide (personal communication) now considers these to be distinct species.

I visited Costello Creek on June 6 and again on June 28, 1977, and sampled a 200-m stretch of riffle at the outflow of Costello Lake. *Paraleptophlebia mollis* nymphs were present on the earlier sampling date (water temperature: 18°C); however, on the second visit, I found only two nymphs after an hour's search (water temperature: 25°C). The exceptionally warm temperatures that month must have forced an earlier emergence.

Despite the wide range of nymphal size at any one time in the Credit River, there was no clear evidence of bimodality. Egg counts, however, were not made. This problem of heterogeneity within a species could be examined using electrophoresis on samples of nymphs or imagos throughout the expanded emergence period.

The above evidence suggests that water temperature may be an important factor in maintaining microdistributional differences between congeneric species. The distinguishing features of *P. adoptiva* development (occurrence in cooler water, continued growth, earlier and shorter emergence period) suggest that this species would extend into more northerly latitudes, higher elevations, or farther upstream than *P. mollis*. Ide (1935) reported that in one Ontario river supporting both *P. adoptiva* and *P. mollis*, *P. adoptiva* extends farther upstream towards the source where lower water temperatures prevail.

Continuously low water temperatures, i.e. those

below the emergence level of *P. mollis*, would eliminate this species from a river.

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- BERNER, L. 1975. The mayfly family Leptophlebiidae in the southeastern United States. *Fla. Entomol.* **58**: 137-156.
- BISHOP, J. E. 1973. Observations on the vertical distribution of the benthos in a Malaysian stream. *Freshwater Biol.* **3**: 147-156.
- CLIFFORD, H. F. 1970. Variability of linear measurements throughout the life cycle of the mayfly *Leptophlebia cupida* (Say) (Ephemeroptera: Leptophlebiidae). *Pan-Pac. Entomol.* **46**: 98-106.
- COLEMAN, M. J., and H. B. N. HYNES. 1970a. The vertical distribution of the invertebrate fauna in the bed of a stream. *Limnol. Oceanogr.* **15**: 31-40.
- . 1970b. The life histories of some Plecoptera and Ephemeroptera in a southern Ontario stream. *Can. J. Zool.* **48**: 1333-1339.
- EDMUNDS, G. F., JR., S. L. JENSEN, and L. BERNER. 1976. The mayflies of North and Central America. University of Minnesota Press, Minneapolis.
- GLEDHILL, T. 1959. The life history of *Ameletus inopinatus* (Siphonuridae, Ephemeroptera). *Hydrobiologia*, **14**, 85-89.
- GORDON, E. L. 1933. Notes on the Ephemeroptera genus *Leptophlebia*. *Bull. Brooklyn Entomol. Soc.* **28**: 116-134.
- IDE, F. P. 1935. The effect of temperature on the distribution of the mayfly fauna of a stream. *Publ. Ont. Fish. Res. Lab.* **50**: 1-76.
- . 1940. Quantitative determination of the insect fauna of rapid water. *Publ. Ont. Fish. Res. Lab.* **59**: 1-24.
- KOVALAK, W. P. 1978. Relationships between size of stream insects and current velocity. *Can. J. Zool.* **56**: 178-186.
- LEONARD, J. W., and F. A. LEONARD. 1962. Mayflies of Michigan trout streams. Cranbrook Institute of Science, Bloomfield Hills.
- MINSHALL, J. D. 1967. Life history and ecology of *Epeorus pleuralis* (Banks) (Ephemeroptera: Heptageniidae). *Am. Midl. Nat.* **78**: 369-388.
- PESCADOR, M. L., and W. L. PETERS. 1974. The life history and ecology of *Baetisca rogersi* Berner (Ephemeroptera: Baetiscidae). *Bull. Fla. State Mus., Biol. Sci. Ser.* **17**: 151-209.
- SOKAL, R. R., and F. J. ROHLF. 1969. *Biometry*. W. G. Freeman and Co., San Francisco.
- TRAYER, J. R. 1937. Notes on mayflies of the southeastern states (Ephemeroptera). *J. Elisha Mitchell Sci. Soc.* **53**: 27-86.
- WATERS, T. F., and R. J. KNAPP. 1961. An improved stream bottom fauna sampler. *Trans. Am. Fish. Soc.* **90**: 225-226.
- WILLIAMS, D. D., and H. B. N. HYNES. 1974. The occurrence of benthos deep in the substratum of a stream. *Freshwater Biol.* **4**: 233-255.