ISSN 0096-7807

Vol. 10, No. 4, July-August, 1979

March, 1980

SJECAH 10(4) 271-368 (1979)

THE SOVIET JOURNAL OF

ECOLOGY

ЭКОЛОГИЯ/ÉKOLOGIYA

TRANSLATED FROM RUSSIAN

CONSULTANTS BUREAU, NEW YORK

THE SOVIET JOURNAL OF

ECOLOGY

A translation of *Ékologiya*

March, 1980

Volume 10, Number 4 July-August, 1979

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(continued)

Engl./Russ.

The Russian press date (podpisano k pechati) of this issue was 7/19/1979. Publication therefore did not occur prior to this date, but must be assumed to have taken place reasonably soon thereafter.

METHODS OF DETERMINATION OF DISTANCE DRIFTED BY BENTHIC INVERTEBRATES (AS EXEMPLIFIED BY THE BUREYA RIVER)

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UDC 577.472(28)

Known methods of determining the mean drift distance L of benthic invertebrates can be used on water courses with low water velocity and a small flow. For rivers with a large flow it is suggested that L should be calculated from the formula $L = N_d \cdot l/N$. A formula for calculating the mean time T spent by benthic organisms in suspension in the water and their L for a particular time of day is given. It is shown that in the Bureya River, with a water velocity of 0.22 m/sec near the bank, 23% of the *Heptagenia soldatovi* Tshern. larvae ($T \approx 15$ min, L 200 m) and 7% of the Capniidae gen. sp. juv. ($T \approx 3$ min, $L \approx 35$ m) are involved in the drift in the course of 24 h.

There are two methods of determining drift distance, which can be used only for brooks or small rivers with a small flow and water velocities of not more than 0.2-0.3 m/sec (Waters, 1965; McLay, 1970; Elliott, 1971).

A method of determining the drift distance of benthic invertebrates for the conditions of large rivers was devised and tested on the Bureya River near the settlement of Chekunda (Verkhnebureinskii District, Khabarovsk Province). The width of the river at this point is about 300 m, the maximum depth at average level is 6 m, and the bottom is composed of pebble and gravel. The mean water velocity in the main stream is 1-1.5 m/sec. The river is free of pollution of human origin. For the investigations we selected a stretch about 1 km long and 0.2-0.3 m deep. The mean water velocity was 0.22 m/sec, and the mean diameter of the pebbles on the bottom was about 10 cm. The observations were made over a 24-h period – from 1800 h on August 31 to 1800 h on September 1, 1976.

SAMPLING METHODS

At the beginning and end of the experiment we determined the numbers and biomass of the benthos per m^2 of bottom. For this purpose we took eight stones from the stretch. Each of them was removed from the water in a net and was then washed in a basin. The area of projection of the stones was determined by weighing and then the number of organisms washed off was expressed per m^2 of bottom.

During the 24-h period we determined the downstream drift of the animals. They were trapped by a net of No. 23 silk gauze with an entrance opening of 0.25×0.25 m^2 and a depth of 1 m; every two hours during the day, and every hour at night. During the day the net was set for 10 min, and at night two five-minute samples of the drift were taken every hour and pooled. Thus, the total time for which the net was set was also 10 min. The true volume of the water filtered by the net was determined by calibration with a GR-2M current meter.

Hydrobionts migrating upstream were determined on a 0.5×2.0 m^2 area of bottom that had been artificially cleared of animals. This area was protected from invertebrates drifting down from above by a net of No. 23 gauze fitted on a cone of aluminum wire. To prevent the net becoming clogged with coarse debris the cone was placed with its point upstream. The wire with the net was attached to side wooden frames consisting of two vertical stakes and upper and lower crossbars. Close-woven cloth was nailed to the frames to prevent migrating animals entering the area from the side. On the cone side the cloth was sewn to the net. The frame was embedded in the bottom by the stakes. Stones were laid on the bottom free part of the cloth and gauze net to ensure that there was no gap at the bottom. Thus, this area was accessible only to animals capable of moving against the current. Owing to filtration by the

Pacific-Ocean Institute of Geography, Far-Eastern Scientific Center, Academy of Sciences of the USSR. Translated from Ekologiya, No. 4, pp. 82-88, July-August, 1979. Original article submitted September 9, 1977.

gauze net the water velocity within the isolated area was only a third of that outside. Animals that settled in the area during the 24-h period were collected by the method indicated above. The animals were washed from 21 stones.

Alongside the first area we prepared a similar control area, but in its lower part we installed an additional net blocking the path of invertebrates migrating upstream. Filtration by the two nets reduced the flow within the second area almost to zero. Animals were washed from 29 stones. In comparing the results obtained for the experimental and control areas we assumed that the species migrating upstream were those whose numbers and biomass in the first case were several times greater than on the control area.

A third natural area was isolated in a similar way for a count of the animals drifting out of unit area in the 24-h period. The invertebrates were collected from nine stones after 24 h. The reduction of the number of organisms on the area in comparison with bottom samples, plus the number of animals which arrived in the area due to upstream drift (data for areas 1 and 2), indicated the downstream drift of particular groups of animals from the area. Since the water velocity on the third area as on the first, was only a third of that on the stretch, the drift obtained for the third area was probably greater than the natural drift, since it is known that a sharp change in current enhances the migration of benthic invertebrates (Hughes, 1970).

However, if we rule out the grazing down of drifting organisms by fish, we can assume that the number of organisms entering the water flow is equal to the number arriving on the bottom of the area, and the number of aquatic invertebrates involved in the drift is given by the number of animals arriving on the bottom. This count was made with the aid of stones cleared of organisms and marked with a glass pencil and placed on the bottom for the 24-h period. To prevent invertebrates crawling onto the stones a circular area of approximately 30 cm in diameter around them was cleared of animals.

On the stretch of river we measured the water temperature with a temperature gauge every hour over the 24-h period. The water level in the river was determined at the gauge post of the Chekunda meteorological station, situated 0.3 km below the site of the experiment. A GR-2M water gauge was used to measure the mean water velocity in the evening and morning.

All the samples were fixed in 4% formalin solution. The fixed animals were weighed on a torsion balance. Mayfly larvae were identified by O. Ya. Boikova, a scientific worker in the Pacific-Ocean Institute of Fisheries and Oceanography, and stonefly larvae by L. A. Zhil'tsova, a scientific worker in the Zoological Institute of the Academy of Sciences of the USSR; we express our thanks to them.

METHODS OF CALCULATING DRIFT DISTANCE OF BENTHIC ORGANISMS

To calculate the drift distance of benthic organisms we assume that the total period of drift of the animals is 24 h. If drift samples are taken every hour, i.e., $t = 1$ h, the number of samples will be 24. The time taken to collect each i-th sample is τ sec, and we assume that the results of the i-th sample are constant for the whole interval t_i.

It is obvious that the drift distance of an animal is equal to the product of the mean water velocity and the time for which the animal is suspended in the water. The mean drift time of the animal during the interval t_i can be calculated as

$$T_i = \frac{N_{si}}{N_{ti}} t_i, \tag{1}$$

where N_{si} is the number of animals contained in a water column whose base area is S and whose height is equal to the depth h_i of this part of the river; N_{ti} is the number of animals rising into the water from a part of the bottom of area S.

The value of N_{si} is easily determined in terms of the cross-sectional area S_n of the net, the time τ for which it is set in the interval t_i, the water velocity v_{ni} at the entrance to the net, and the number of animals n_i caught in time τ:

$$N_{si} = \frac{n_i}{v_{ni} \cdot \tau \cdot S_n} S h_i. \tag{2}$$

If we assume that the drift time T_i does not vary from hour to hour during the 24-h period, then the number of animals rising into the water in an hour divided by the number of animals N_s rising into the water in 24 h is equal to the number caught in this hour by the net divided by the total number caught in 24 h, i.e.,

$$\frac{n_i}{\sum n_i} = \frac{N_{ti}}{N_s}, \text{ whence } N_{ti} = N_s \frac{n_i}{\sum n_i}. \qquad (3)$$

Substituting expressions (2) and (3) in formula (1) we obtain

$$T_i = t_i S h_i \sum n_i / \tau v_{ni} S_n N_s. \qquad (4)$$

Recalling that the mean drift distance L_i is $T_i v_i$, where v_i is the mean water velocity in the course of the i-th hour, we obtain

$$L_i = \frac{v_i \cdot S \cdot h_i t_i \sum n_i}{\tau v_{ni} S_n N_s}. \qquad (5)$$

To calculate the mean drift distance L of benthic organisms in 24 h we can use the simplified formula:

$$L = \frac{N_d \cdot l}{N}, \qquad (6)$$

where N_d is the number of organisms passing during the drift period through an elementary cross-sectional area of width l and height equal to the depth h; N is the number of invertebrates settling on an area of bottom equal to l^2 during the drift period, i.e., $N \equiv N_s$.

RESULTS OF OBSERVATIONS

At depths of 0.2-0.3 m on the stretch of the Bureya River the mean number of benthic animals in the period of our observations was about 5000 per m² with biomass 1.2 g/m². Chironomid larvae were most numerous (60% of the total benthos), followed by stonefly larvae (27%), then mayfly larvae (7%). Water mites, oligochetes, and caddis fly larvae were occasionally found. Mayfly larvae dominated in biomass (65% of the total weight of animals), followed by stonefly larvae (25%); chironomid larvae constituted only 9% of the biomass.

Active drifting in the Bureya occurred at night and lasted for 9 h (from 2030 to 0530 h). The passive daytime drift accounted for only a small part of the total drift (17% in numbers and 5% in biomass). During the 24-h period 167,900 animals with a biomass of 32.9 g drifted through 1 m² of cross section of the river. A comparison of the numbers of the main groups of animals in the drift with the composition of these groups on the bottom of the stretch revealed considerable differences. In number and biomass the drift consisted mainly of mayfly larvae (51% in number, 49% in biomass), followed by chironomid larvae (18% each), and stonefly larvae (15 and 14%).

The drift contained all the mayfly and stonefly species found on the bottom: the larvae of nine species of mayfly – *Heptagenia soldatovi* Tshern., *Heptagenia* sp., *Pseudocloeon fenestratum* Kazl., *Rhithrogena lepnevae* Br., *Ephemerella aurivillii* Bengtss., *Baetis bioculatus* Piktet., *Baetis* sp. (gr. *bioculatus*), *Baetis* sp., *Baetis sibiricus* Bajk., and of seven species of stonefly – Capniidae gen. sp. juv., *Perlodidae* gen. sp. juv., *Diura* sp., *Phasganophora* sp., *Skwala* sp., *Chloroperlidae* gen. sp. juv., and *Nemoura* sp. Larvae of the mayfly *H. soldatovi* and the stonefly Capniidae gen. sp. juv. were selected for investigation, since they were the most numerous representatives of the benthic fauna. *Heptagenia soldatovi* constituted 5% in number and 65% in biomass of the total number of bottom animals; the corresponding figures for the drift were 28% and 30%. The migrations of this species occurred only at night. Early-instar larvae were most active in the drift. Levanidova (1968) regarded larvae more than 3 mm long as large. In the population that we investigated such larvae comprised 55% of the total number, but only 5% in the drift (Fig. 1).

The results obtained on marked stones showed that 23% of the *H. soldatovi* larvae were involved in the 24-h drift. On the third area, however, the drift contained 40% of the mayfly larvae. We attribute this large drift to reduction of the water velocity due to filtration by the upper net.

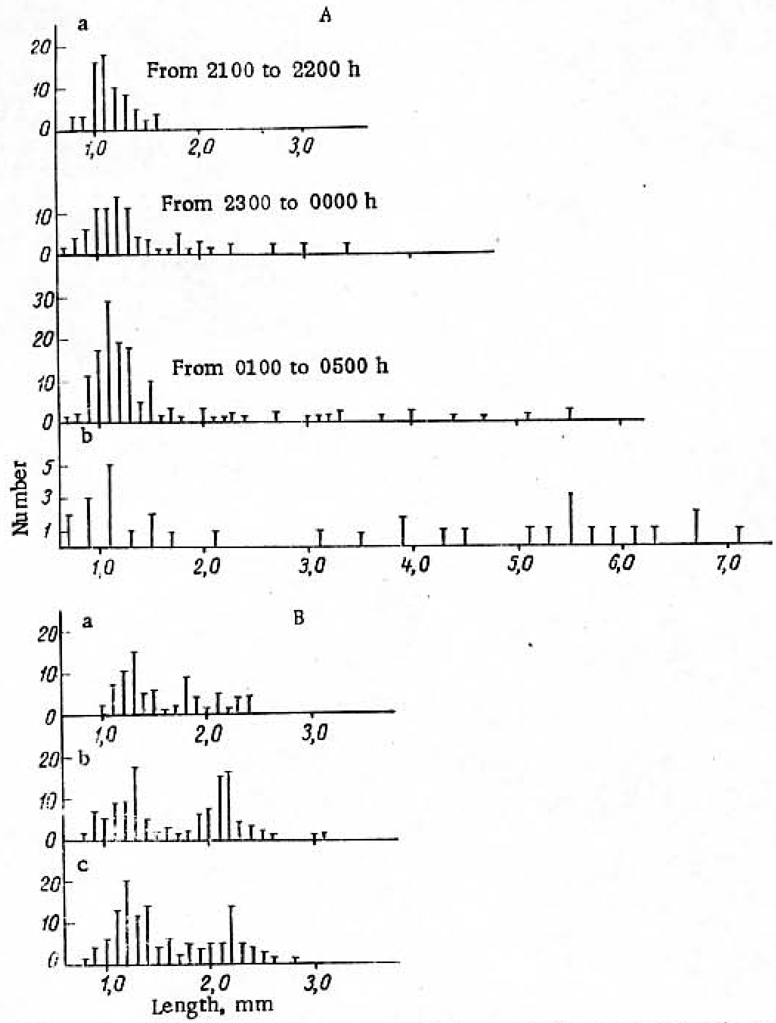

Fig. 1. Size vs age composition of *H. soldatovi* (A) and Capniidae gen. sp. juv. (B) in the Bureya River: a) drift; b) bottom sample; c) third area after drift.

Figure 2 shows that at night there were two peaks of ascent of *H. soldatovi* larvae into the water. These ascents were not due to fluctuations of the temperature or level of the water, since there were no great changes during the night (Fig. 3). The first peak was reached at 2200 h, i.e., 1.5 h after the start of the drift. Only early-instar larvae were involved in the migrations (see Fig. 1). The second peak occurred at the hour of the night when the biomass reached its peak, since full-grown individuals migrated at this time.

Heptagenia soldatovi was the only species which migrated upstream. The number of larvae on the first area after 24 h was 2.4 times greater, and the biomass 3.6 times greater, than on the control area. Subtracting the number and biomass of the larvae on the control area from the number and biomass of the larvae on the first area we found that 24 *H. soldatovi* larvae of biomass 0.08 g settled on the first area as a result of migration against the current. The number of larvae migrating against the current in relation to the total drift was small (0.4%).

Calculation of the drift distance, for 2200 h, for instance, showed that the mean drift time of each larva was 880 sec. The mean water velocity was 0.22 m/sec and, hence, the mean drift distance for *H. soldatovi*, calculated from the equation, was approximately 200 m. Since the mean water velocity during the period of active drift was practically constant, then L_i for any time of the day was constant.

Since the water level only varied slightly the value of N_d for *H. soldatovi* was 12,030 per day. Of them 60 larvae settled on 1 m^2 of bottom per day. Since the number of larvae migrating upstream relative to the total drift was very small, we can assume that the bottom

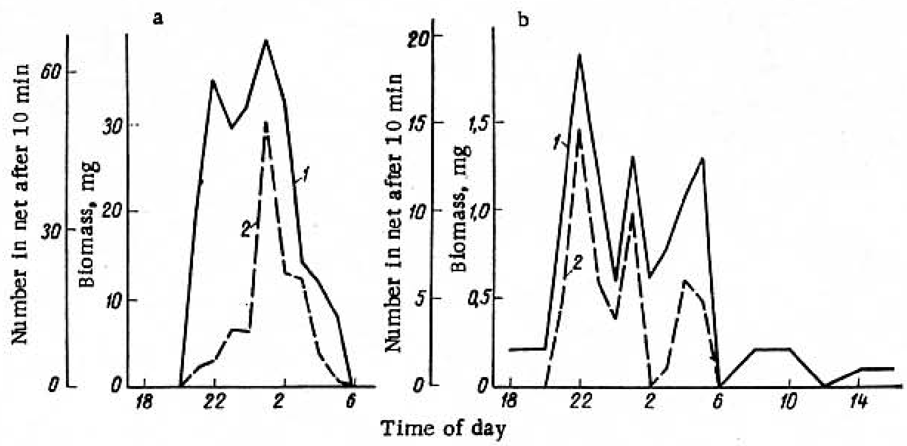

Fig. 2. Drift of *H. soldatovi* (a) and Capniidae gen. sp. juv. (b) in the Bureya River. 1) Number; 2) biomass.

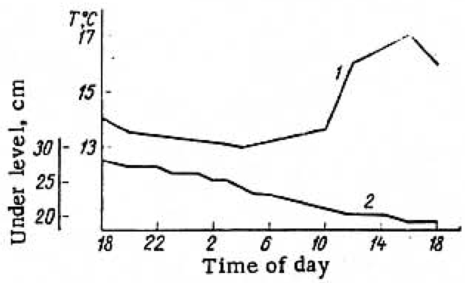

Fig. 3. Variation of temperature (1) and water level (2) in the Bureya River.

was colonized only by downstream-migrating larvae. Then

$$L = \frac{12030 \times 1\,\text{m}}{60} \approx 200\ \text{m}.$$

Larvae of Capniidae gen. sp. juv. constituted 26% in number and 9% in biomass of the total number of benthic organisms and 9% and 2%, respectively, in the drift. Larvae of this species constituted 96% in number and 35% in biomass of the total stonefly larvae, and 58 and 15%, respectively, of stonefly larvae in the drift.

In the course of the 24-h period 7% of the Capniidae gen. sp. juv. larvae were involved in the drift. The point distribution of species on the bottom did not allow us to assess the drift of larvae on the third area. The migration occurred mainly during the night. The daytime drift of the larvae was only 15% of the 24-h drift. Figure 2 shows that during the night Capniidae gen. sp. juv. made three ascents into the water. The highest peak occurred at 2200 h. At midnight there was a second ascent of larvae, followed by a drop until 0200 h, and a third peak at 0500 h. Subsequently, when the sun rose, the number of migrants dropped sharply.

Histograms of the size vs age composition (Fig. 1) show that the stonefly population consisted of two age groups; the largest larvae did not exceed 3 mm in length. It is impossible to say with confidence which age groups participated more actively in the drift. No migration of capniid larvae against the current was detected. In the calculation of the drift distance of stonefly larvae at 2300 h, for instance, the mean time spent by the larvae in the body of the water was 155 sec. During this time they traveled a distance of 35 m.

When the varying water level was taken into account N_d for stonefly larvae was 3700 per day. During this time 110 larvae settled on 1 m^2 of bottom, whence

$$L = \frac{3700 \times 1\text{m}}{110} \approx 35\,\text{m}.$$

COMPARISON OF RESULTS WITH PUBLISHED DATA

There are only three investigations in which the drift distance of some species of benthic invertebrates has been experimentally determined. According to the data of Waters (1965) the mean drift distance in small streams in Minnestoa (USA) is 50 m for *Baetis* sp. and 60 m for *Gammarus* sp. McLay (1970), who recalculated Waters' data, showed that the drift distance of *Baetis* sp. could be 100 m, and that of *Gammarus* sp. could be 130 m. He reported that in New Zealand rivers the mean drift distance of various mayfly species as 0.5-19.3 m, and the maximum distance is 45.7 m. According to Elliott's data (1971), the mean drift distance in English rivers for *Baetis* sp. and *Gammarus* sp. is 20 m.

Thus, our calculated mean drift distance of 200 m for *H. soldatovi* is the highest value given in the literature. On the main bed of a large river the drift distance of some species of invertebrates can possibly be even higher.

The mean drift distance for Capniidae gen. sp. juv., equal to 35 m, is practically the same as those cited for other species.

It should be noted that, in comparison with *H. soldatovi*, the percentage of Capniidae gen. sp. juv. larvae participating in migrations was very low. Stonefly larvae were present in the body of the water for a short time and moved through a distance of only approximately one-sixth of the distance traversed by mayfly larvae. Such differences are probably due to the fact that the living conditions on the stretch of river are more suitable for Capniidae gen sp. juv. than for *H. soldatovi*.

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