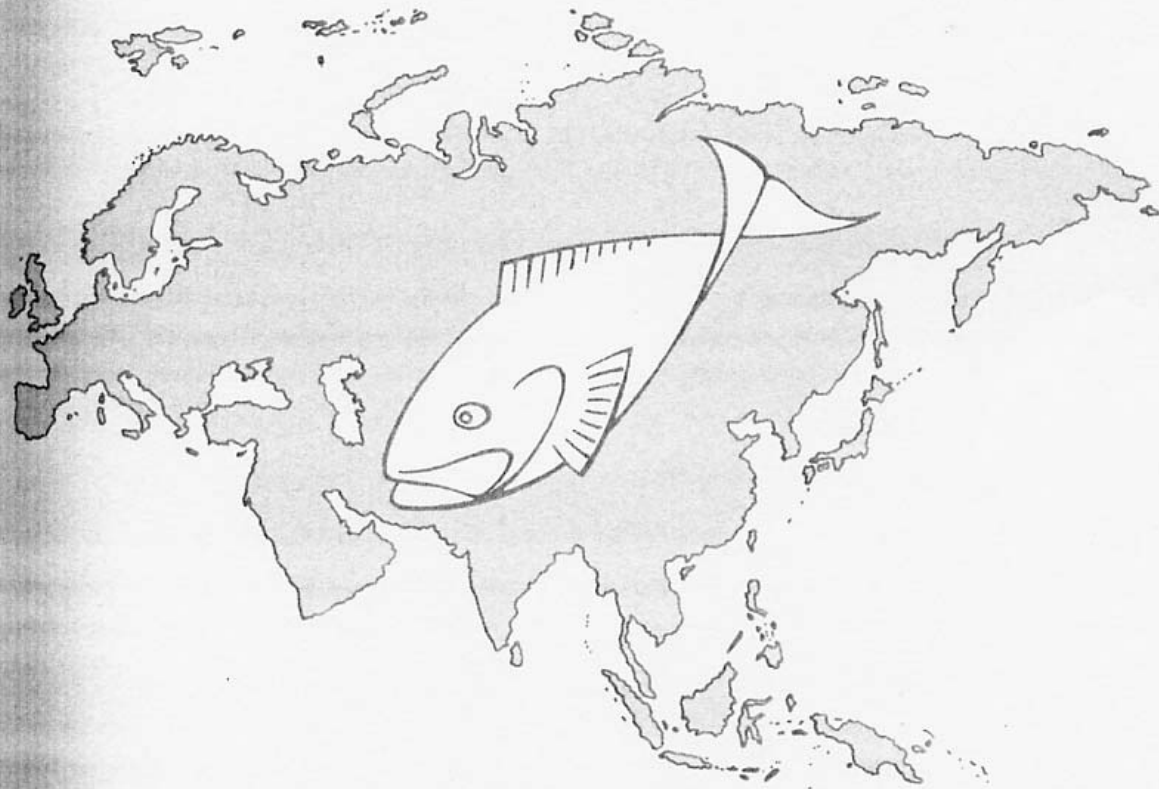


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## A Method of Calculating Migratory Activity and Drift Distance of Benthos in Large Rivers

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In a previous paper I demonstrated that the daily drift of organisms in river benthos  $N_d$  is determined by their migratory activity ( $N$ ), which is measured by the number or biomass of individuals passing into the water column from a unit bottom area  $L^2$  per day and the drift distance ( $L$ ) of the hydrobionts [1]:

$$N_d = ML/l, \quad (1)$$

where  $N_d$  is the number or biomass of organisms per day passing through a cross section of a stream of width  $l$  and depth  $h$ . It is important that  $L$  is in turn related to the depth-averaged flow rate ( $V$ ) by the function

$$L = aV^b, \quad (2)$$

where  $a$  and  $b$  are constants and  $b$  does not differ significantly from unit [4]. In this case  $a$  will indicate the time spent by invertebrates in the water column ( $T$ ). Then,

$$L = TV, \quad (3)$$

and hence

$$T = L/V. \quad (4)$$

In large rivers,  $L$  and  $N$  cannot be determined by existing methods [1, 4-6] because of the great area and flow. Here we propose a new method of calculating these characteristics which has been developed especially for large rivers.

We know that in large, and sometimes small, rivers, the net catches of drift organisms are greater in the surface layer than the bottom layer [2, 3, 6]. We therefore assume that in the period of active drift of animal forms, the near-bottom water mass is not a zone of active drift transport and a bottom net samples organisms which are rising to the surface or descending to the bottom, or are being borne along passively.

To calculate the migratory activity of benthic organisms we assume that the numbers  $n_1$  of invertebrates in the near-bottom layer and  $n_2$  of invertebrates in the surface layer are caught in time  $\tau$  by a net with an intake area of  $l \times l \text{ m}^2$ . We need to find out how many individuals actively swimming upward to the surface ( $n_3$ ) are caught by the net. If we assume that the rate of movement of an animal in the stream to the surface and back ( $V_1$ ) is constant and that consumption by predators can be neglected, then

$$n_3 = (n_1 - n_4)/2, \quad (5)$$

where  $n_4$  is the number of organisms in passive drift caught by the lower net in time  $\tau$ .

Knowing  $V_1$ , we determine how much time ( $t$ ) is required for an animal to swim to the surface from a distance equal to the height of the net ( $L$ ):

$$t = L/V_1. \quad (6)$$

After measuring stream velocity ( $V_2$ ) in the near-bottom layer, we determine what distance ( $L_1$ ) an animal moves with the current in time  $t$ :

$$L_1 = V_2 \cdot t. \quad (7)$$

Since the width of the net is  $l$ ,  $n_3$  will represent the migratory activity of organisms in time  $\tau$  on a bottom area of  $l \times L_1$  m<sup>2</sup>. Thus we can easily calculate the migratory activity ( $M$ ) in time  $\tau$  for a bottom area of  $l$  m<sup>2</sup>. Obviously the value of  $M$  calculated for individual 24-hour periods shows the minimum possible population density of organisms in the substrate ( $N_{\min}$ ). We note that calculating the latter value becomes particularly important in the case of rivers in which direct measurement of  $M$  is difficult or impossible.

It follows from Eq. (1) that we must calculate  $N_d$  in order to find  $L$ . For this purpose we assume that the amount of drift from the lower net to the upper increases gradually and that the height of the net is  $l$ . Then

$$N_d = (n_1 \cdot h/2l) + (n_2 \cdot h/2l) = h(n_1 + n_2)/2l, \quad (8)$$

where  $N_d$  is the total number of passive and active migrants transported in time  $\tau$  through a cross section of the stream with width  $l$  and depth  $h$ . The magnitude of the drift in time  $\tau$  for active migrants ( $N'_d$ ) will be

$$N'_d = (n_1 - n_4) \cdot \frac{h}{2l} + (n_2 - n_5) \cdot \frac{h}{2l} = h(n_1 - n_4 + n_2 - n_5)/2l, \quad (9)$$

where  $n_5$  is the number of passive drift organisms caught by the upper net in time  $\tau$ . Using Eq. (1), we calculate the average drift distance for active migrants:

$$L' = N'_d l / M_1. \quad (10)$$

If we assume that the migratory activity of passively transported invertebrates is close to zero, then the average drift distance ( $L$ ) for all of the types of individuals noted in transport will be:

$$L = N_d l / M_1. \quad (11)$$

As a calculation example the data of Levanidov and Levanidova [2] obtained from the Amur River near Khabarovsk in June-September 1958 are used. They present the catch results for the larvae of caddisfly, mayfly and stone fly with two nets with an opening measuring 0.5 m<sup>2</sup> emplaced for 15 minutes at different times of day at the surface and at a depth of 10 m. We calculate  $M$ ,  $L$  and  $T$  for mayfly larvae.

The average rate of movement ( $V_1$ ) of various species of nymphs of Amur mayflies which we determined in aquaria was about 0.05 m/sec. For convenience in the rest of the calculation we assume that the height of the net used to catch the migrants is 0.5 m and the breadth 1.0 m. From Eq. (6) we find the time ( $t$ ) required for a larva to swim to the surface through a distance equal to the height of the net:

$$t = 0.5 \text{ m} : 0.05 \text{ m/sec} = 10 \text{ sec.}$$

The average surface velocity in the Khabarov section from June to September is about 2-2.5 m/sec, while at a depth of 10 m it is 0.8-1.0 m/sec. We assume that at a depth of 10 m the bottom velocity ( $V_2$ ) is 0.9 m/sec. Then in 10 seconds the water mass will travel 9 meters. If the width of the net is 1 m, then the lower net caught organisms rising to the surface from 9 m<sup>2</sup> of bottom area. From data obtained previously [3], in 15 minutes the average catch in the lower net is 3.3

individuals at night and 1.6 in the day. The individuals involved in the daytime transport were probably those making up only the passive drift, which is constant throughout the day [7]. Accordingly, the night catch in the lower net of individuals swimming actively to the surface ( $n_3$ ) is

$$n_3 = (3,3 \text{ individ.} - 1,6 \text{ individ.}) : 2 = 0,85 \text{ individ.}$$

and hence

$$M_1 = 0,85 \text{ individ.} : 9 \text{ m}^2 = 0,09 \text{ individ./m}^2$$

where  $M$  is the number of organisms entering the water from  $1 \text{ m}^2$  of bottom area in 15 minutes. If active drift continues for 8-9 hours, then  $M$  for the day is about  $3 \text{ individuals/m}^3$ , which is equivalent to  $N_{\text{min}}$ .

From Eq. (8) we find the total drift of organisms ( $N_{d1}$ ) in 15 minutes through cross section 10 m deep and 1 m wide. Since during this time the average catch in the upper net ( $n_2$ ) was 6.2 individuals, and since we assume that the height of the net was 0.5 m,

$$N_{d1} = (3,3 \text{ individ.} + 6,2 \text{ individ.}) \times 10 = 95 \text{ individ.}$$

so that

$$L = 95 \text{ individ.} \times 1 \text{ m} : 0,09 \text{ individ./m}^2 = 1060 \text{ m.}$$

The depth-averaged current speed ( $V$ ) at the section studied was about 1.1-1.5 m/sec. We assume that  $V = 1.3 \text{ m/sec.}$  so that

$$T = 1060 \text{ m} : 1,3 \text{ m/sec} = 800 \text{ sec.}$$

Since the larvae rise to the surface of the stream in 3 minutes and descend to the bottom in the same amount of time, floating on the water surface continues for 8 minutes. During this time the water mass travels about 1,000 m, and thus the catch in the upper net (6.2 individuals) is equivalent to the number of individuals derived from a bottom area of  $1000 \text{ m}^2$ . If  $M_1 = 0.09 \text{ individuals/m}^2$ , the number of mayflies migrating from  $1000 \text{ m}^2$  of bottom in 15 minutes is 90. It is easy to determine that only 7% of this quantity in the surface water mass to a depth of 0.5 m will be floating.

The value of  $L$  which we calculated for caddisfly and stone fly larvae are for the same value of  $V_1$  as for the mayfly was about 0.05 km. But this quantity is clearly too low, since for these groups of invertebrates the average nightly catch ( $n_1$ ) includes the catch at the time when the bottom water mass is an area of active swimming. For example, the maximum density of transport for stone flies at twilight was found in the bottom layer [2].

We note that because of an absence of data, we did not use the filtration coefficients of the nets used to catch the invertebrates in our calculations. But large-mesh No. 14 gauze installed in the nets gave good water filtration [2], so that we may neglect these quantities.

It is evident from the foregoing that the new method of calculating the migratory activity and drift distance of hydrobionts enables us to find these characteristics for large and deep streams. Since the daily migratory activity of benthos calculated by this proposed method represents the minimum possible population density of these forms in the bottom material, calculating this value becomes particularly important for rivers where direct measurement of the population density of bottom invertebrates is either extremely difficult or impossible.

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