Jber.Biol.Stn Lunz 14: 102 - 110 (1993)

Hydraulic measurements and distances travelled by drifting invertebrates in a calcareous mountain brook (Ritrodat-Lunz)

Johann WARINGER

Keywords: hydraulic parameters, drifting distances, macroinvertebrates, FPOM

Abstract: For the determination of distances travelled by drifting invertebrates, benthic animals were introduced into the water column by disturbing the gravel sediment along cross sections of the brook at increasing distances (1 to 21 meters) upstream from three drift nets (Fig.1). During the experimental period, discharge was very low (0.2 $m^{3s^{-1}}$); Froude numbers ranged from 0-0.57, the shear stress from 0 to 620 dyn cm^{-2}; the boundary Reynolds number ranged from 0 to 4384, and the thickness of the viscous sublayer varied between 0.08 and 0.14 mm (Fig.2). The mean distances for 50 % of animals travelled ranged from 20.9 m in *Nemouridae* to 6.5 m in *Chironomidae.* The mean distances of pooled invertebrates was 5.5 m and of fine particulate organic matter (FPOM; <1 mm particle size) 4.0 m (Table 2, Figs.3, 4).

Introduction:

Data of distances travelled by drifting invertebrates provide useful information for the interpretation of drift density - bottom density relationships. Drift distance can be measured in two ways: ELLIOTT (1971) used a blocking technique by placing a net across the whole cross section of the stream and by introducing a known number of invertebrates at increasing distances from the net. A different method was used by McLAY (1970) who introduced benthic animals into the stream by disturbing the substrate at increasing distances upstream from a drift sampler.

Generally, drift distances of benthic invertebrates vary between 1 and 10 m (ELLIOTT et al., 1988). McLAY (1970) observed a maximum distance of 46.7 m, but 60 % of the animals were derived from within 10 m upstream and more than 40 % from within 6 m.

The aim of the present study was to provide preliminary results of the drift distances of benthic invertebrates in the Ritrodat research area during an extended period of low discharge. The data should be useful for estimating the maximum distance of disturbances along profiles in further studies.

Material and methods:

In order to obtain information on the actual geometry of the stream channel and on hydraulic parameters, water depth, mean current speed, Froude number, shear stress, boundary Reynolds number and thickness of the viscous sublayer was measured on July

26–27, 1990, at intervals of 1 m over stream cross sections 0–8. Mean current speed was obtained by exposing a propeller-meter (Ott C2; diameter of propeller = 30 mm) at 0.6 of the depth measured from the water surface downward; water depth could be read from the scale on the propeller-meter's shaft. Data on complex hydraulic parameters were obtained by the standard hemisphere method described by STATZNER & MÜLLER (1989). Due to the low discharge, only three drift nets at the northern half of the brook sampling immediately above the substrate could be used (a detailed description of the drift nets is given by WARINGER, 1991). Using the method given by McLAY (1970), the undisturbed drift was measured for one hour. Immediately afterwards the sediment was disturbed by stamping across the stream bed and kicking the gravel at the sediment surface, starting with profile 5 (= 1 m upstream from the nets) and stopping with profile 1 (= 21 m upstream from the nets); this artificial drift was also sampled for one hour. Short sampling periods were necessary to nullify the effects of diel drift periodicity (WARINGER, 1991). In order to consider different stream widths, the difference "artificial drift" – "undisturbed drift" was divided by the width of the disturbed profile. Data of the three drift nets were pooled, and drift distances are given for 50 % of the artificial drift.

Results:

Hydraulic measurements

During the two days of the study, water depth was invariably 11 cm; this value is close to the yearly minimum for 1990 (= 6 cm; yearly mean 1990 = 22.3 cm; BRETSCHKO, 1991). The discharge during the study period was 0.2 m^3s^{-1}. The main current was close to the northern bank (Fig. 1) with the southern main fork of the brook being nearly stagnant downstream of profile 3. Between profiles 2 and 0, a central gravel bank divided the brook in two forks: the main current was observed within the northern, shallow part of the brook with the southern fork being deeper and slowly flowing. Between profiles 2 and 3, the flow in this southern part changed its direction northwards, created a riffle area and opened into the main current which had a mean water velocity of 40 to 50 cm s^{-1} between profiles 7 and 8 (Fig. 1).

For the estimation of hydraulic stress of benthic invertebrates four parameters were chosen:

- The Froude number (F) evaluates the ratio of inertial to gravitational forces and thus streaming (F<1) or shooting flow (F>1; STATZNER, GORE & RESH, 1988, DINGMAN, 1984); the hydraulic stress increases with increasing F and varied between 0 and 0.57 in the study area.

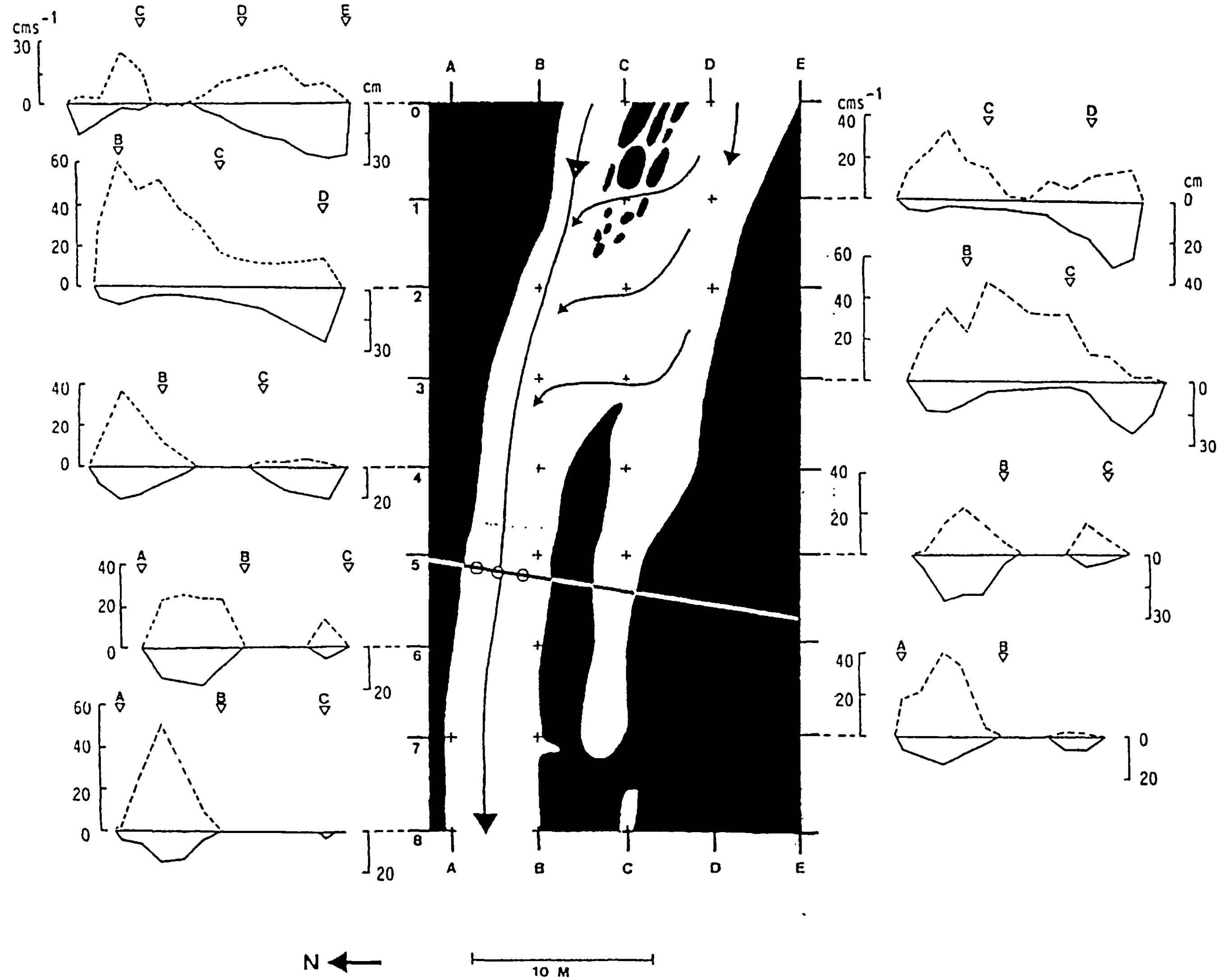

Figure 1: Map of Ritrodat research area between profiles 0 and 8. Banks are shown for a water depth of 11 cm, and arrows indicate the direction of the current. Reference points of the grid are marked by small crosses, and the position of the three drift nets attached to the instrument bridge are indicated by open circles. For each profile, the water depth (cm) and the mean water velocity (cm s^{-1}) is given at intervals of 1 m.

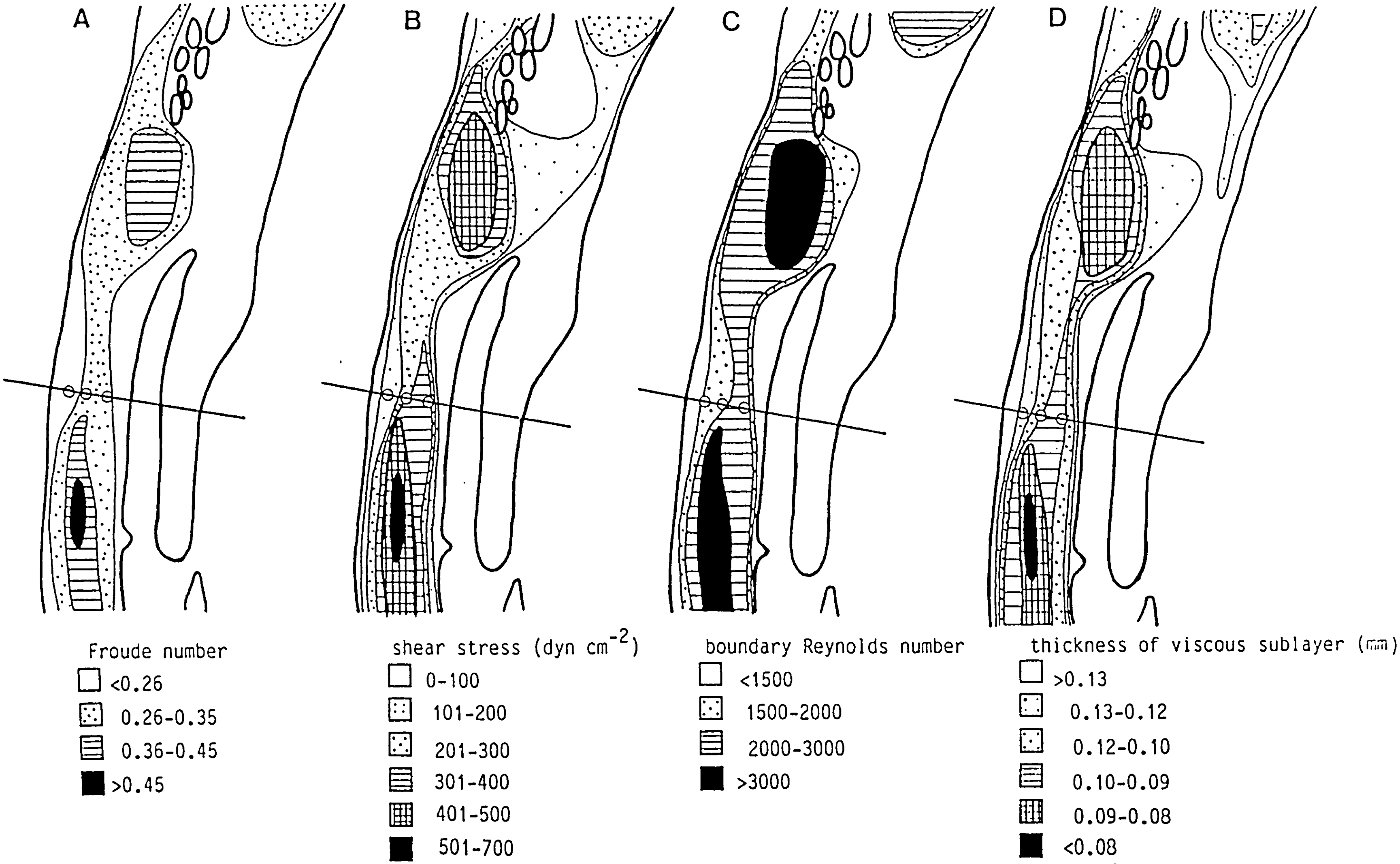

Figure 2: Hydraulic parameters between profiles 0 and 8, acting at a water depth of 11 cm; showing the Froude number (A), the shear stress (B; dyn cm^{-2}), the boundary Reynolds number (C) and the thickness of the laminar sublayer (D; mm). The data are based on measurements using the standard hemisphere method (STATZNER & MÜLLER, 1989).

- The shear stress is the force acting on the stream bottom as a result of the shear velocity. Shear stress is responsible for the erosion of sediment particles and benthic organisms and ranged from 0 to 620 dyn cm^{-2}. For example, a shear stress of 55 dyn cm^{-2} is necessary for the drift entry of fifth instar larvae of the caddis *Allogamus auricollis* (WARINGER, 1989).
- The thickness of the viscous sublayer and the boundary Reynolds number can be considered as approximate indicators of the turbulance conditions close to the bottom (STATZNER, GORE & RESH, 1988). The thickness of the viscous sublayer was 0.08 - 0.14 mm, indicating that only a small organism can be fully embedded within this layer. The more it emerges from the viscous sublayer, the higher is its hydraulic stress.

In addition, a high boundary reynolds number indicates a high amount of turbulance and a high lift force - pressure force ratio.

A map of the hydraulic conditions acting at the study area is shown in Fig. 2. Hydraulic stress was highest in the riffle area between profiles 6 and 7. It was lowest around the gravel bank at profile 1 and within the southern fork of the brook.

Distances travelled by drifting invertebrates

The most abundant taxa collected by the drift nets were young larvae of *Ephemeroptera* (36.2 %; mostly *Baetidae*), tiny larvae of *Hydracarina* (32.0 %), *Diptera* (15.7 %, mostly *Chironomidae*) and early instars of *Plecoptera* (9.7 %; mostly *Nemouridae*; Table 1). In *Plecoptera* (Fig. 3d), *Leptophlebiidae* (Fig. 4a), *Nemouridae* (Fig. 4b) and FPOM (Fig. 4d), the most distant disturbance (=21 m upstream) still yielded a small proportion of artificial drift; for these taxa, therefore, additional experiments at greater distances from the nets are necessary in further studies. In the remaining taxa, no effect of artificial drift could be detected at the most distant disturbance.

Distances travelled by drifting invertebrates were greatest in *Nemouridae* (20.9 m for 50 % of the artificial drift; Table 2). In *Ephemeroptera* (pooled data), the mean drift distance was 6.7 m, with *Baetidae* drifting 8.5 m, *Heptageniidae* 8.0 m and *Leptophlebiidae* drifting 6.9 m (Table 2). ELLIOTT (1971) reported, that, on stony substrate, *Heptageniidae* drifted 1.6 - 17.5 m and *Baetidae* 1.0 - 5.6 m.

Drifting distances of the remaining taxa ranged from 5.5 to 10.5 m, and FPOM-particles drifted 4.0 m (Fig. 4d).

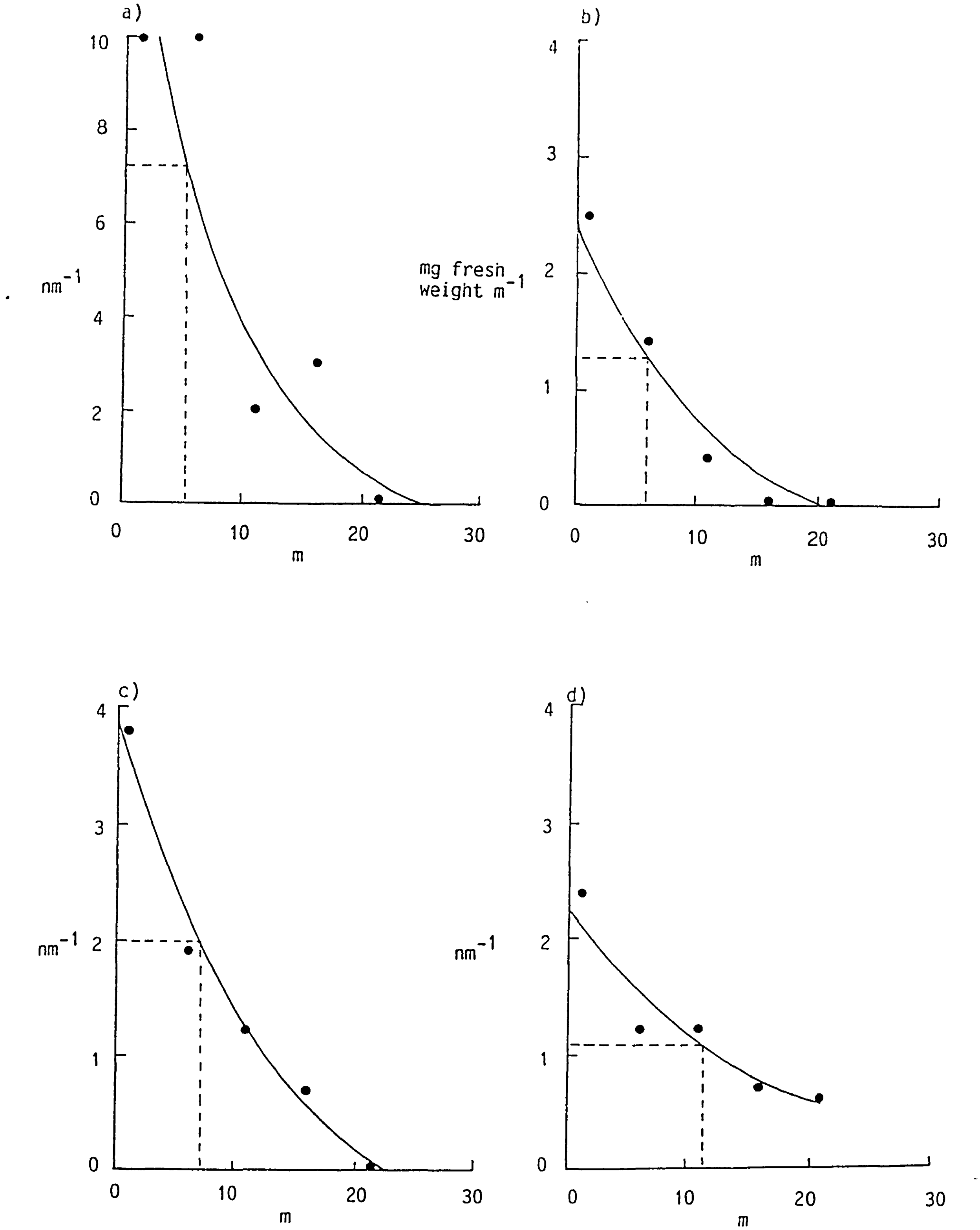

Figure 3: Distances travelled by drifting invertebrates in the Ritrodat research area; showing the regression lines based on the equations given in Table 2 and calculated mean distances for 50 % of the artificial drift (dotted lines). a = pooled data for all taxa (n); b = pooled data for all taxa (mg fresh weight); c = *Ephemeroptera* (n); d = *Plecoptera* (n).

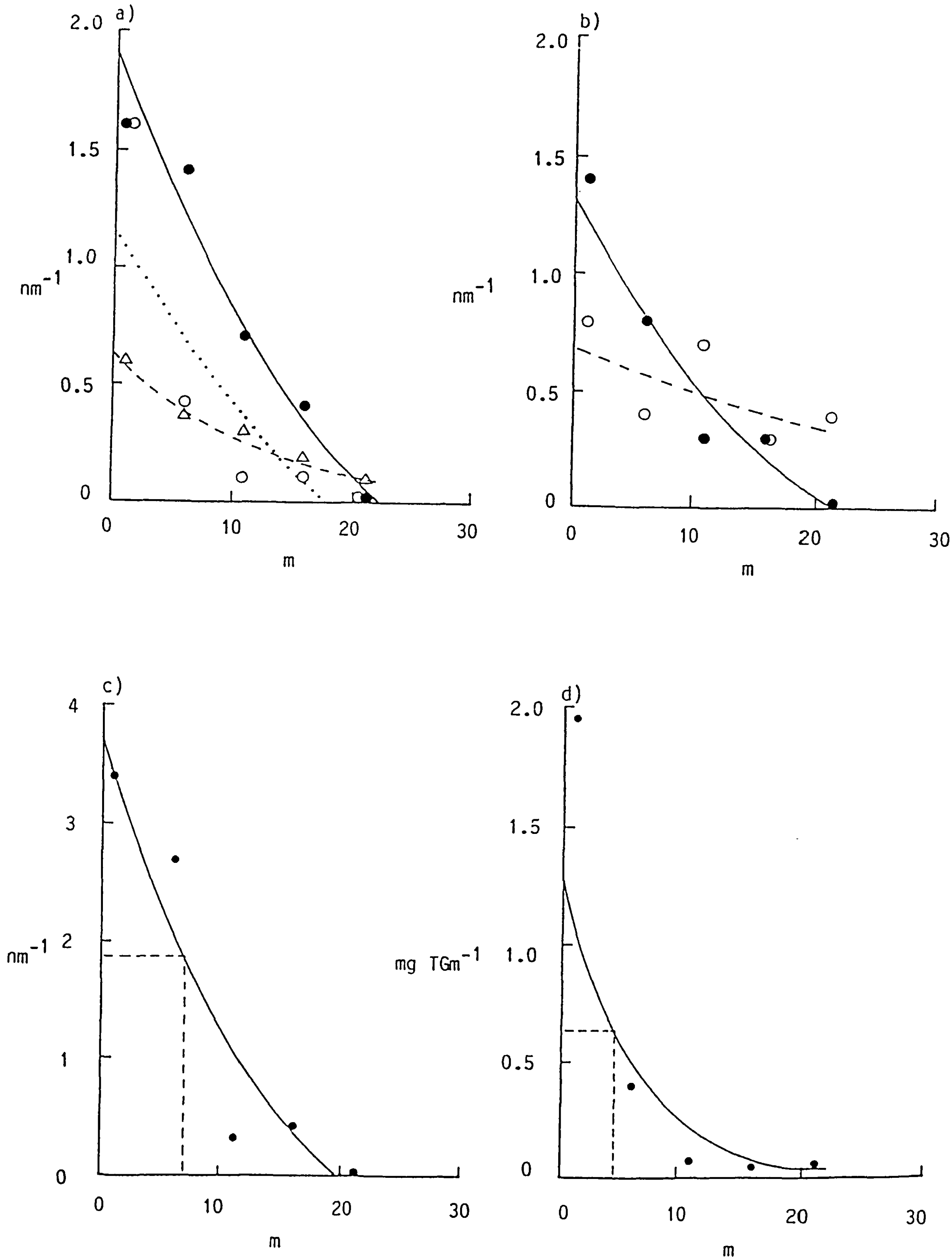

Figure 4: Legend as in Figure 3

a = -- *Baetidae*, ··o·· *Heptageniidae*, -▲- *Leptophlebiidae;*
b = -- *Leuctridae*, -o- *Nemouridae;*
c = *Chironomidae*;
d = fine particulate organic matter (FPOM; mg dry weight).

Taxon		n	%
Oligochaeta		1	0.1
Hydracarina		290	32.0
Copepoda		16	1.8
Ostracoda		1	0.1
Collembola		2	0.2
Ephemeroptera:	*Baetidae*	293	32.3
	Heptageniidae	20	2.2
	Leptophlebiidae	13	1.4
	Ephemerellidae	3	0.3
Plecoptera:	*Nemouridae*	56	6.2
	Leuctridae	25	2.8
	Perlodidae	6	0.7
Rhynchota		1	0.1
Psocoptera		1	0.1
Thysanoptera		1	0.1
Megaloptera		2	0.2
Coleoptera:	*Elmidae*	11	1.2
	Dytiscidae	1	0.1
Hymenoptera		1	0.1
Lepidoptera		1	0.1
Trichoptera:	*Rhyacophilidae*	4	0.4
	Philopotamidae	4	0.4
	Limnephilidae	9	1.0
Diptera:	*Simuliidae*	15	1.7
	Chironomidae	127	14.0
S		**904**	**100.0**

Table 1: Total numbers (n) and percentage (%) of organisms caugth by three drift nets in the Ritrodat research area.

Component of drift	Regression equation	r^2	Drift distance (m)
all Taxa (n m^{-1})	(ln y)-1 = 2.73-0.12x	0.84	5.5
all Taxa (mg fresh weight m^{-1})	(ln y)-1 = 1.24-0.07x	0.93	6.0
Ephemeroptera, pooled (n m^{-1})	(ln y)-1 = 1.60-0.07x	0.98	6.7
Baetidae (n m^{-1})	(ln y)-1 = 1.08-0.05x	0.97	8.5
Heptageniidae (n m^{-1})	(ln y)-1 = 0.77-0.04x	0.77	8.0
Leptophlebiidae (n m^{-1})	ln y = -0.37-0.09x	0.97	6.9
Plecoptera, pooled (n m^{-1})	ln y = 0.80-0.07x	0.92	10.5
Nemouridae (n m^{-1})	ln y = -0.36-0.03x	0.41	20.9
Leuctridae (n m^{-1})	(ln y)-1 = 0.85-0.04x	0.94	8.3
Chironomidae (n m^{-1})	(ln y)-1 = 1.54-0.08x	0.86	6.5
FPOM (mg dry weight m^{-1})	ln y = 2.53-0.17x	0.80	4.0

Table 2: Relationships between artificial drift (number of individuals, fresh or dry weight per metre of disturbed cross section) and distances from the drift nets (m); showing the most abundant taxa and drifting FPOM, the regression equations, the coefficient of determination (r^2) and drift distances for 50 % of the artificial drift, based on the regression equation shown.

References:

BRETSCHKO, G. 1991: Pegel und Oberflächenwassertemperatur im Ritrodat-Areal 1990.- Jber.Biol.Stn Lunz 13: 35-36.

DINGMAN, S.L. 1984: Fluvial Hydrology.- Freeman and Company, New York, 383 pp.

ELLIOTT, J.M. 1971: The distances travelled by drifting invertebrates in a Lake Distict stream.- Oecologia 6: 350-379.

ELLIOTT; J.M.,HUMPESCH U.H. & MACAN, T.T. 1988: Larvae of the British Ephemeroptera.- FBA Scientific Publication No. 49, 145 pp.

McLAY, C. 1970: A theory concerning the distance travelled by animals entering the drift of a stream.- J. Fisheries Res. Board Canada 27: 359-370.

STATZNER, B,. GORE, J.A. & RESH, V.H. 1988: Hydraulic stream ecology: observed patterns and potential applications.- J.N.Am.Benthol.Soc. 7: 307-360.

STATZNER; B. & MÜLLER, R. 1989: Standard hemispheres as indicators of flow characteristics in lotic benthos research.- Freshwater Biology 21: 445-460.

WARINGER, J.A. 1989: Resistance of a cased caddis larva to accidental entry into the drift: the contribution of active and passive elements.- Freshw Biol. 21, 411-420.

WARINGER, J.A. 1991: The drifting of invertebrates and particulate organic matter in an Austrian mountain brook.- Submitted to Freshwater Biology.