Freshwater Biological Association

FBA Translation (New Series) No. 106

Title: Study of flow conditions near the substratum in an experimental channel.

Author(s) Decamps, H., Capblancq J. & Hirigoyen J.P.

Reference: Verh.int.Verein.theor.angew.Limnol. 18, 718-725

Original language: French

Date of publication of original: 1972

Translator: V.A. Wilson

Date of publication of translation: 1977

Number of pages of translation: 7 pages

FBA Translations are to be considered as "provisional". As a rule they have not been prepared by expert translators, nor have they been edited by the original authors.

They are available from The Librarian,
Freshwater Biological Association,
The Ferry House,
Far Sawrey,
AMBLESIDE
Westmorland.
England,
at the current rate for xerox copying.

FBA Transl. 106 1. Translated by V. A Wilson

Verh. int. Ver. Limnol. 18, 718-725 (1972)

Study of flow conditions near the substratum in an experimental channel

H. Decamps, J. Capblancq and J. P. Hirigoyen

Introduction

In a slow flow, on a smooth uniform substratum, a limited bed allows the existence of currents slow enough for benthic invertebrates. These conditions rarely occur naturally. In fact:

1. Important variations of pressure can be shown on substrata subjected to a current (Trivellato & Decamps 1968).

2. The bed of a watercourse is essentially irregular. On a mm scale, the unevenness of the substratum frequently pierces the limited bed. On a dm scale, the zones of still water with more or less turbulent rollers, transforms the conditions of life in the neighbourhood of the obstacles.

The investigations carried out in this work aimed, on an intermediary scale, to define the influence of irregularities in the substratum on flow near the bottom.

Methods

The substrata used were made of glass marbles of three different diameters: 3, 5 and 8 mm. These granulometries correspond to the "gravettes" (pebble sizes ?) of Cailleux's (1954) classification. The small marbles correspond to fine gravel (2-4 mm), the medium to medium gravel (4-8 mm) and the large ones to coarse gravel (8-16 mm) (Cummins 1962). The critical speeds (in cm/s) at which these elements would be affected by the current are, according to Schmitz 1961 (modified by Hynes 1971):

	Clear water	Muddy water
Fine gravel	60	80
Medium gravel	60 - 80	80 - 100
Coarse gravel	100 - 140	140 - 190

In order to remain within the limits the maximum speeds used in our experiments reached 50 cm/s.

The investigations were carried out in a transparent channel of 70 cm in length and a rectangular section 10 x 5 cm. The visualisation was made by photographing aluminium particles in intermittent light. The details of the apparatus are described in an earlier paper (Trivellato & Decamps 1971).

Figs 1 to 12 show the lines of current traced according to the course of the aluminium particles (Fig 13 for example). The diagrams in thick lines (Figs 1-12) show the speed profiles. The arrows represent speeds equal to mean speeds v_m: 5, 10, 20 and 50 cm/s.

Results

1. General evolution of flow in terms of average speeds

At v_m = 5 cm/s (Figs 1-3), the lines of current are horizontal. The thickness of the limited bed (measured at the point of inflexion of the curve of profile of the speed) reaches 3.5 to 4 mm.

At v_m = 10 cm/s (Figs 4-6) one mainly observes a deformation of the speed profile and a dimunition of the thickness of the limited bed.

At v_m = 20 cm/s (Figs 7-9) the lines of current become unstable in the area of substratum for granulometries of 5 mm and, above all of 8 mm. One passes smoothly from a turbulent regime to a regime of turbulent transition..

At v_m = 50 cm/s (Figs 10-12) the instability of the current lines exists, near the bottom, for three types of substrata. The zones of still water develop between the large diameter marbles. They coexist with an intense agition near to the tope of these marbles.

Table 1. Variation of the thickness of the limited bed in terms of mean speed on different substrata

Mean speed	Thickness of limited bed		
	marbles	marbles	marbles
(cm/s)	Ø 3 mm	Ø 5 mm	Ø 8 mm
5	3.5	3.5	4
10	3	3	2.5
20	2.5	2.5	1

2. Appearance of the turbulence near the bottom

Between 5 and 20 cm/s the thickness of the limited bed diminished with the increase of the mean speed (Table 1). For higher speeds, a turbulence appears near the bottom. The irregulaties formed by the marbles pierces the limited bed.

There is a progressive destruction of this bed, little by little replaced by a zone of turbulent transition. This change of regime appeared at first with the 8 mm marbles. One thus notes the following sequence in terms of granulometry.

1. The limited bed has practically the same thickness on the three substrata at v_m = 5 cm/s and 10 cm/s. The viscosity and not the unevennesthus determines the flow.

2. At v_m = 20 cm/s, the limited bed is clearly weaker for the marbles of 8 mm diameter which form large irregularities.

3. At v_m = 50 cm/s one observes, on the three substrata, a zone of strongly turbulent transition with exchanges of energy.

Discussion

One could not insist too much on the experimental character of these results. On the one hand, there is a certain heterogeneity of the bed in natural environments. On the other hand, fine particles often create a cement between the components of the bed of a watercourse, thus diminishing the importance of zones of still water shown in our investigations.

One important point is however dependent on these experiences. Ambühl (1959) had clearly shown the interest of the limited bed - bed of slowed water - for the benthic invertebrates of relatively weak mean speeds (< 20 cm/s) and on a smooth substratum made of plaster of Paris. Following this, in the discussions concerning the relationships between the invertebrates and the current, this idea has often been extended to other mean speeds and other substrata. Such a generalisation does not seem justified.

In fact the results obtained in this work put in doubt the protective role of the limited bed for mean speeds higher than 20-30 cm/s. At these speeds a great instability appears near the bottom. Drops of water are knocked against the upstream surfaces of the marbles, rebound and collide. They are also re-attached near the bottom, after rebounding on the horizontal subjacent drops. Thus, in the proximity of the substratum, a turbulent zone is formed for mean speeds equal to or higher than 20 cm/s.

Likewise, in natural flow with turbulent regimes existing in most cases, the irregularity of the substratum plays a determinant role. Multiple projections pierce the limited bed. A zone of turbulent transition appears between open water and the substratum. It does not assure the protection which, theoretically, a laminated film could offer to benthic invertebrates. Moreover, in the rhithron at least, some water directly knocks the substratum on the numerous obstacles at the bottom of watercourses (Trivellato & Decamps 1968).

In these conditions, for mean speeds around 30-50 cm/s, the majority of benthic invertebrates of the rapids, take refuge in the zones of still water, under stones, in crevices etc. Thus the Trichoptera larvae Rhyacophila dorsalis observed by Scott (1958), normally collected from stones, change their resting place when speeds increase to 40-50 cm/s in open water; they take refuge under stones and are only found on upper surfaces when covered with moss. As Pattee & Bournaud (1970) indicate concerning planarians, rheophily is then linked to the safety of routes chosen to the limits of the area between rapid and calm zones. When they venture into exposed places, the invertebrates become immobile, lying very close to the substratum, as do the larvae of the Ephemeroptera, Heptagenia sulphurea and the Plecoptera, Brachyptera risi observed by Madsen (1968, 1969). When they are swept into the current, these larvae often remain passive and because of the turbulence quickly make contact again with the bottom.

Finally, in relation to the benthic invertebrates, the role of the zone of transition between open water and the substratum must be considered differently according to the speed of flow in open water.

1. At weak mean speeds (v_m = 5 cm/s) a limited bed allows the fauna of the bottom to evolve in a zone of very much slowed flow. This limited bed diminishes in thickness above 5 cm/s.

2. At average mean speeds (20 cm/s v_m 50 cm/s) frequent turbulence occurs near the bottom. This can be avoided by the invertebrates thanks to the heterogeneity of the substratum, which provides shelter for them in still water. Inversely, the turbulence favours a rapid return to contact with the substratum for drifting invertebrates.

3. At higher mean speeds, with turbulence becoming intense, there is a progressive elimination of less solid forms attached to the substratum. The morphological adaptations then take the path as the aforesaid adaptations of behaviour. This latter part joins the observations made by Guidicelli (1968) in Corsica: the larvae of blepharocerids and simuliids can form 3% of the benthic population at v_m = 50-80 cm/s, 74% at v_m = 90-110 cm/s, 88% at v_m = 130-160 cm/s and 96% at v_m = 160 cm/s.

All generalisations on the role of the zone of transition between open water and the substratum must therefore be based on a precise study of different mean speeds and different substrata as well as the specific behaviour of the benthic components.

References

AMBÜHL, H., 1959: Die Bedeutung der Strömung als ökologischer Faktor. — *Schweiz. Z. Hydrol.* 21, 133—264.

CAILLEUX, A., 1954: Limites dimensionnelles et noms des fractions granulométriques. — *Bull. Soc. géol. France.* 4, 643—646.

CUMMINS, K. W., 1962: An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. — *Am. Midl. Nat.* 67, 477—504.

GIUDICELLI, J., 1968: Recherches sur le peuplement, l'écologie et la biogéographie d'un réseau hydrographique de la Corse centrale. — Thèse Sciences, Aix-Marseille, CNRS. A. O. 2478, 437 p.

HYNES, H. B. N., 1970: *The ecology of running waters.* — Liverpool University Press. 555 p.

MADSEN, B. L., 1968: A comparative ecological investigation of two related mayfly nymphs. — *Hydrobiologia* 31, 337—349.

— 1969: Reactions of *Brachyptera risi* (MORTON) (Plecoptera) nymphs to water current. — *Oikos* 20, 95—100.

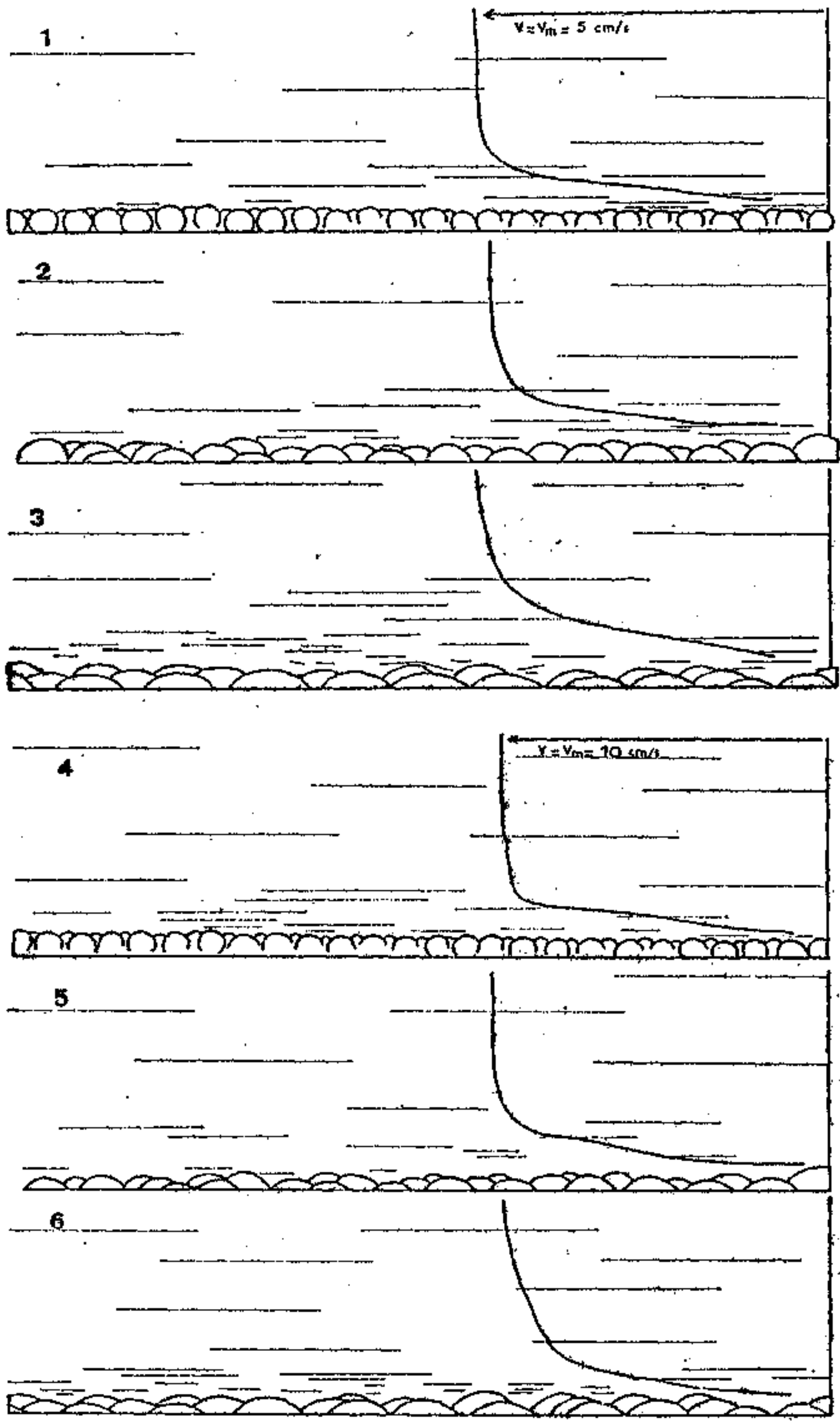
PATTEE, E. & BOURNAUD, M., 1970: Etude expérimentale de la rhéophilie chez des Planaires Triclades d'eau courante. — *Schweiz. Z. Hydrol.* 32, 181—191.

SCHMITZ, W., 1961: Fließwässerforschung — Hydrographie und Botanik. — *Verh. Internat. Verein. Limnol.* 14, 541—586.

SCOTT, D., 1958: Ecological studies on the Trichoptera of the river Dean, Cheshire. — *Arch. Hydrobiol.* 54, 340—392.

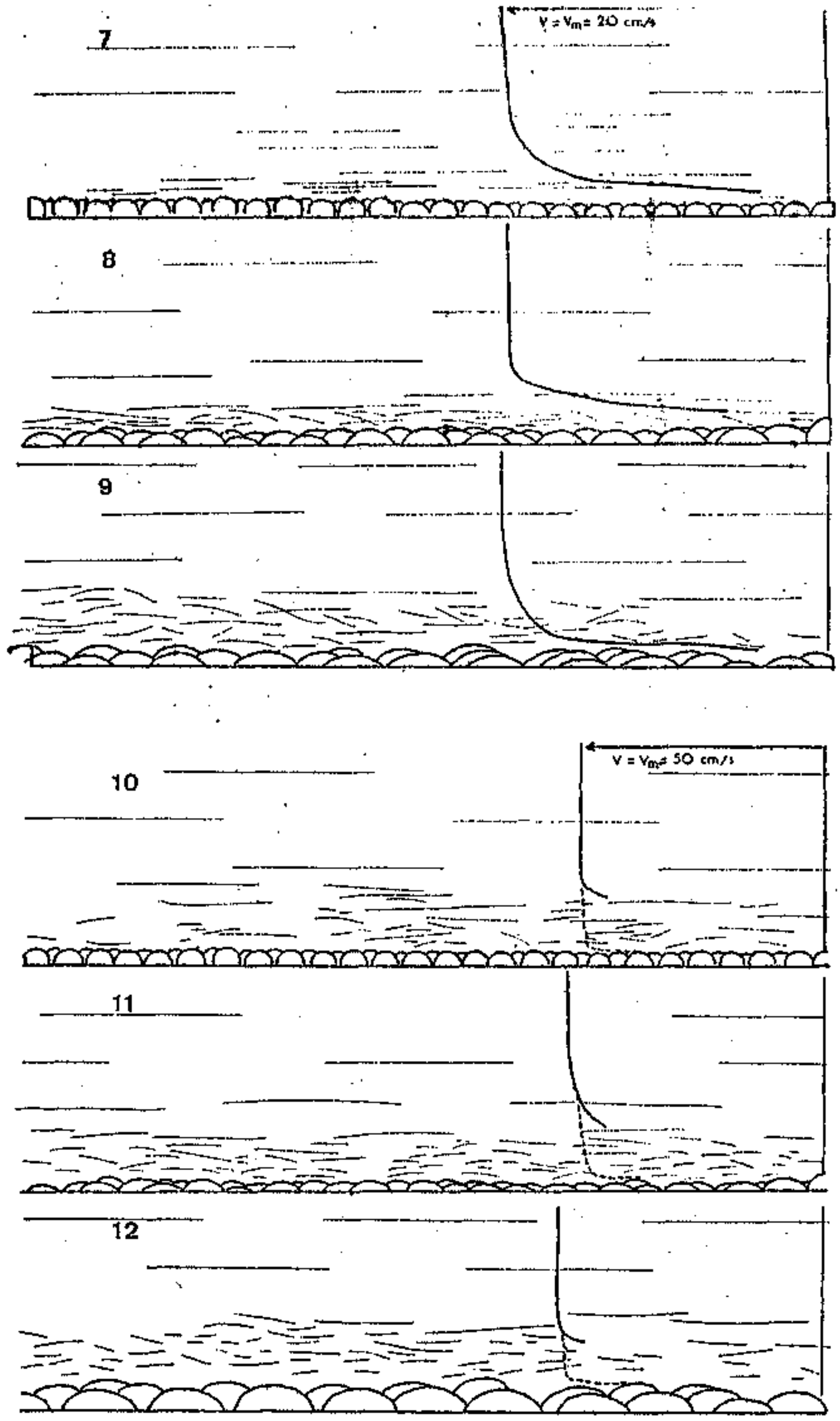
TRIVELLATO, D. & DÉCAMPS, H., 1968: Influence de quelques obstacles simples sur l'ecoulement dans un «ruisseau» expérimental. — *Ann. Limnol.* 4, 357—386.

— — 1971: Dispositif expérimental pour l'étude du comportement d'espèces benthiques en eau courante. — *Ann. Limnol.* 7, 145—155.



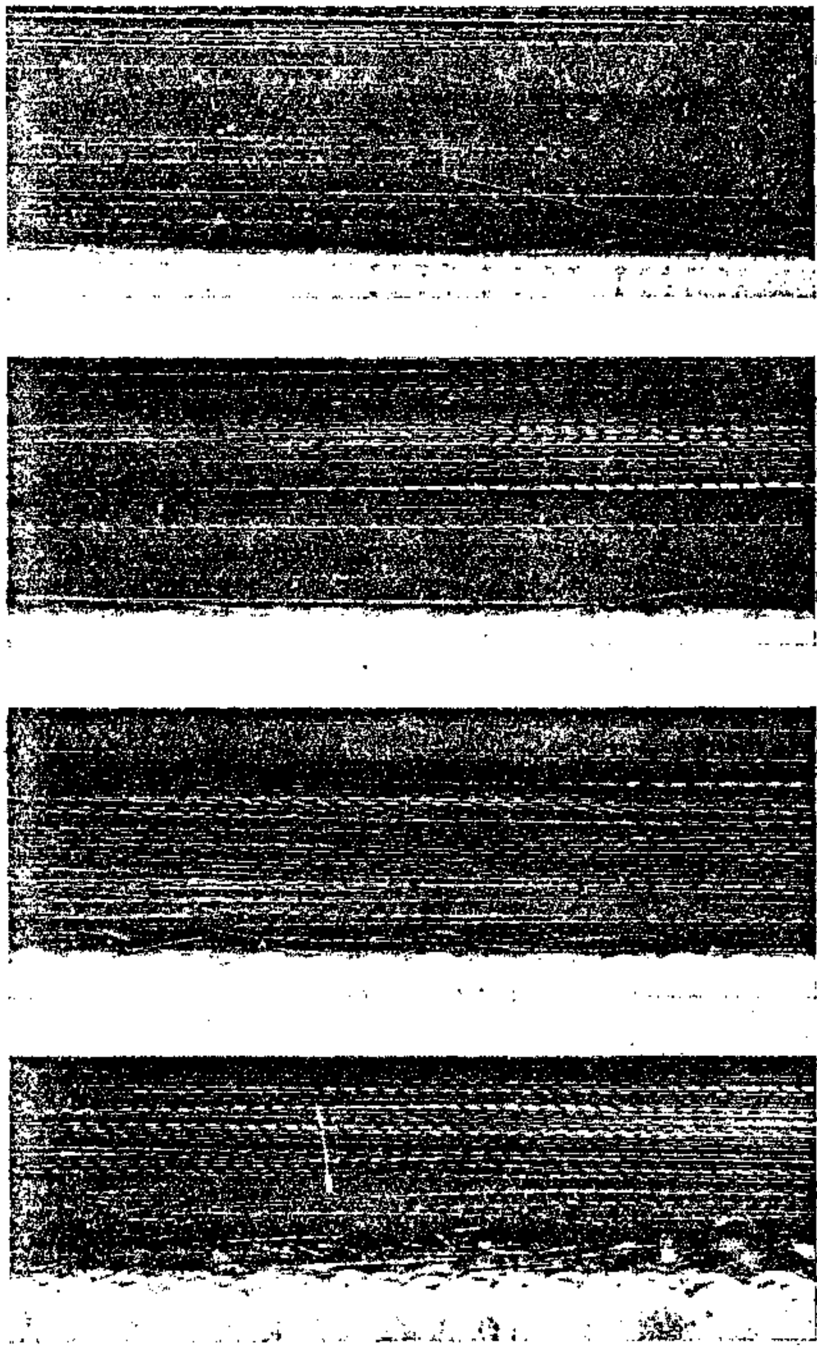
1-3 Lines of current and speed profiles for an average speed of 5 cm/s on different substrata. 1. marbles of 3 mm diameter. 2. marbles of 5 mm diameter. 3. marbles of 8 mm diameter

4-6 Lines of current and speed profiles for an average speed of 10 cm/s on different substrata. 4. marbles of 3 mm in diameter. 5. marbles of 5 mm diameter. 6. marbles of 8 mm diameter



7-9 Lines of current and speed profiles for an average speed of 20 cm/s on different substrata. 7. marbles of 3 mm in diameter. 8. marbles of 5 mm diamter 9. marbles of 8 mm diameter.

10-12 Lines of current and speed profiles for an average speed of 50 cm/s on different substrata. 10. marbles of 3 mm diamter. 11. marbles of 5 mm diameter. 12. marbles of 8 mm diameter



13 Visualisations of flow for mean speeds of 20 cm/s on four substrata (from the top: marbles of 3 mm diameter, marbles of 5 mm diameter, marbles of 8 mm diameter.

Notice

Please note that these translations were produced to assist the scientific staff of the FBA (Freshwater Biological Association) in their research. These translations were done by scientific staff with relevant language skills and not by professional translators.