Limnologische Flußstation Schlitz - The study of a rhithral ecosystem, Breitenbach

Peter Zwick

History

The Limnologische Flußstation Schlitz (LFS; Figs 1,2) owes its origin to a fortunate encounter of student enthusiasm and donor generosity. E.-J. Fittkau, J. Illies, K. Müller, W. Scheele and W. Schmitz decided to establish running water research in Germany. They chose the only major river system accessible along its entire length in post-war Germany, the Weser river with its headwaters Werra and Fulda, for study. During their work they made contact with Otto Hartmann, said von Goertz, Count of Schlitz. He donated a half timber building which he had changed into a laboratory. It was opened on 4 June 1951. Laboratory and office space was more than doubled by an extension building in 1959. An adjacent former mill donated by Count Otto Hartmann was changed to a laboratory building in 1968.

A. Thienemann mediated contact, support and, finally, incorporation of the outlying Station into the "Hydrobiologische Anstalt Plön" (now MPI for Limnology). Presently, the LFS belongs to its Department Microbial Ecology, though with independent research program and separate budget. There are six scientific and ten technical staff, plus research guests and graduate students funded by the Max-Planck-Gesellschaft, the Deutsche Forschungsgemeinschaft, and others. More than 750 scientific papers have been published to date.

Past scientific activities

Many studies of physics, chemistry, flora and fauna of the Fulda river and its tributaries were published in the early years, under the late J. Illies. The main synthetic work was a concept of longitudinal community change induced by predictable changes of abiotic factors along a stream. The terms rhithron and potamon were coined in it. It focussed on identification and description of faunal components; its recent counterpart, the River Continuum Concept, emphasizes functional change.

K. Müller's work (1958-1965) concentrated on organismic drift. Observation of larval drift led, among others, to the vision of compensatory upstream flight of adult insects, the so-called colonisation cycle.

With J. Illies's return, world expertise on Plecoptera and other groups of aquatic fauna was firmly established and expanded. It was a prerequisite for his extensive survey of the Breitenbach, a small stream near Schlitz, since 1969.

Fig. 1 The original half timber building of the Flußstation and the 1959 extension building.

Fig. 2 The Hallenmühle, a 1968 extension of the Flußstation.

The large emergence traps over the stream are widely known; a twenty year series of collections is now available. The entire survey work revealed more than 1000 metazoan species in the Breitenbach, most permanently established. The following numbers of species are known from the Breitenbach:

Turbellaria	50	Annelida	5	Megaloptera	2
Gastrotricha	6	Crustacea	24	Planipennia	2
Nematomorpha	1	Hydracarina	22	Coleoptera	71
Nematoda	141	Insecta:		Hymenoptera	3
Rotatoria	130	Odonata	1	Trichoptera	57
Mollusca	12	Ephemeroptera	18	Diptera	468
Chordata	3	Plecoptera	18	GRAND TOTAL	1085

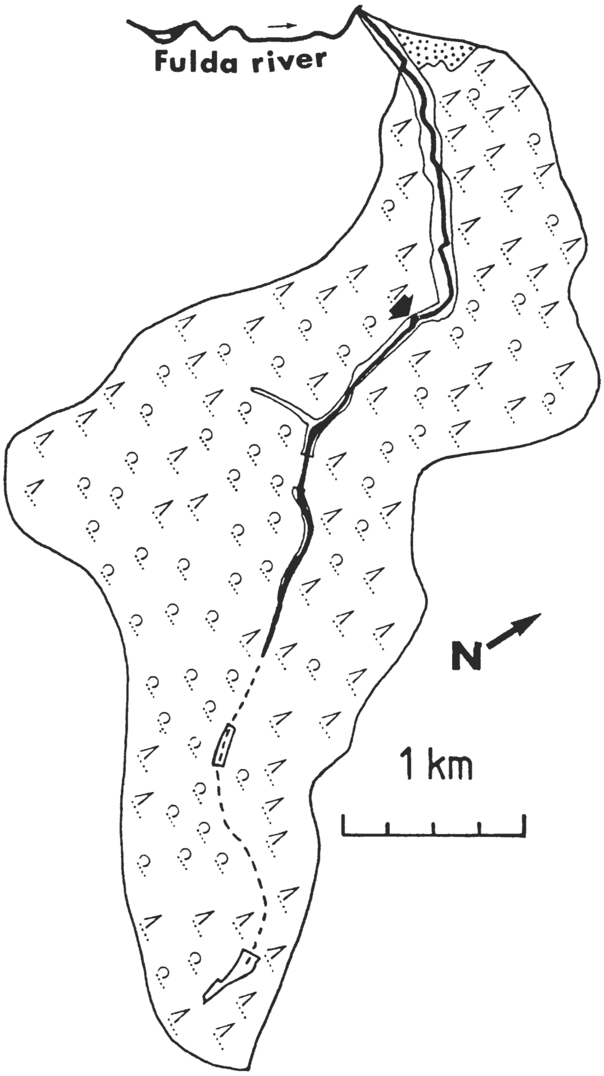


Fig. 3 The Breitenbach stream and its catchment area. The main study stretch is between the arrow marking a strong tributary spring, and the entrance of the stream into the Fulda river

Present Scientific Activities: The Breitenbach Study

The vast body of information on the fauna of the Breitenbach forms the basis of our present study of the Breitenbach ecosystem.

Habitat

The Breitenbach is a small unpolluted stream near Schlitz, Hesse. It originates 350 m a.s.l. on a sandstone plateau and enters the Fulda river at 220 m a.s.l.. It is about 5 km long, with a 9 km^2 forested catchment area. Land next to the stream itself has been cleared centuries ago; meadows are used to make hay. The lower part of the stream beyond the bend of its course is the main study stretch (Fig. 3). Mean monthly discharge and water temperature in the lower stream section in 1986 are tabulated, along with the mean concentrations of several solutes. (H.-H. Schmidt)

Mean temperature (T) (°C) and monthly discharge (D) (1000 m^3):

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T	5.0	4.0	5.5	7.0	9.2	10.3	11.2	11.4	9.4	8.6	6.9	5.6
D	3.2	1.5	6.0	8.4	2.9	1.9	0.9	0.5	0.5	0.5	0.4	0.5

pH 6.5-7.8; Conductivity (25°C) 140-190 µS/cm; Alkalinity 0.01-0.5 mval; Na^+ 10-15 mg/L; K^+ 2-5 mg/L; Mg^{++} 2-5 mg/L; Ca^{++} 20-27 mg/L; SRP 20-45 µg/L P; NO_3^- 600-1300 µg/L N; SiO_4^{---} 1500-7000 µg/L Si; SO_4^{--} 10-20 mg/L S

The poorness of the surrounding sandstone soils is reflected in the low concentration of Ca^{++} ions and in the low buffering capacity. Nevertheless, the stream is circumneutral. It offers the community a somewhat eustatic habitat, favourable to many organisms. Still, spring floods (max. discharge >1000 L/sec) and spates after heavy rains cause unpredictable disturbances of the entire system; they prevent long lasting overall equilibria. Nearly all measured parameters follow both a seasonal and diurnal periodicity in response to the photoperiod. In particular oxygen content of the water reacts very rapidly to changes in insolation. Three contrasting levels of control on the physical and chemical conditions in the stream can be recognised:

1. geological and edaphic factors;
2. seasonally and diurnally fluctuating environmental factors;
3. biologically modified chemical conditions.

While the first two levels largely determine the community that develops, the third allows us to observe and quantify the biological activity in the stream. For example, at small spatial and temporal scales, interesting evidence for an intricate interplay between chemistry of free flowing and interstitial water, and microscopic algae and their photosynthetic activity is emerging.

Producers

Because it runs largely through meadows, the Breitenbach supports extensive stands of macrophytes (see below) and, being comparatively open and unshaded, a diverse algal flora. About 150 diatom species and at least 50 species from other groups have been found to date. Estimates of algal standing crop (as chlorophyll a) on dif-

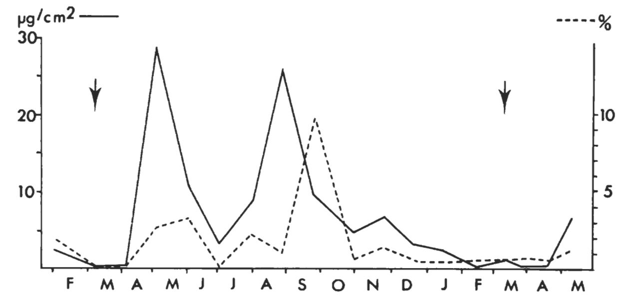


Fig. 4 Variation of chlorophyll-a levels (continuous line) and % organic content (dashed line) in soft sediments near the middle of the Breitenbach study stretch, Feb. 1987 to May 1988. Arrows show timing of major spates.

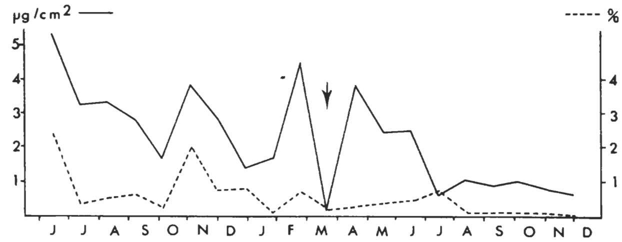


Fig. 5 As Fig. 4, but on stones, June 1987 to Sept. 1988. Dashed line represents phaeopigments.

ferent substrata are higher on soft sediments (Fig. 4), than on hard substrata (Fig. 5). On all substrata, there is a general pattern of spring and autumn algal peaks, although their extent and precise timing vary with site while spates reduce the standing crop on all substrata in the main part of the stream.

Temporal variation in species abundance, and their distribution patterns according to substratum are pronounced and complex. Some species have marked seasonal periodicity, e.g. *Surirella ovata* and *Diatoma mesodon* are spring species, while many *Nitzschia* and *Synedra* species are more abundant in the autumn; others occur throughout the year although more abundantly on certain substrata than others. Thus *Sellaphora pupula* grows better on very fine silty sediments; *Achnanthes lanceolata* and *Eunotia pectinalis* var. *minor* are characteristically epilithic or epiphytic on macrophytes; many *Pinnularia* and other *Eunotia* species are only abundant in bryophytes; *Nitzschia palea* grows particularly well in mucilage around *Batrachospermum* filaments and *Tetraspora* colonies. Longitudinal changes in the flora are also evident although the controlling factors are at present unclear: e.g. *Navicula hungarica, Nitzschia thermalis* and *N. linearis* only occur in the lower 1000 m of the stream. The filamentous green algae *Microspora* and *Vaucheria* overlap slightly in their distribution, but the former predominates upstream, the latter downstream.

Total algal production will be estimated in situ (O_2 release) and seems to be high. Grazers however can have a marked effect on algal growth; they reduce the level of the standing crop on hard substrata and in their absence algal growth can be dramatically greater: massive development of *Microspora* occurred after accidental eradication of grazers by insecticide contamination in 1986. (E. J. Cox)

Consumers

By biomass, amphipods are the most important single faunal component. Their local distribution, life cycle and reproduction have been studied extensively. An investigation into their food and feeding patterns is nearing completion; fine particulate matter appears to be unexpectedly important in the diet.

Insects are very important both by species and specimen numbers, and by biomass. Their population dynamics are continuously monitored using large emergence traps. Important changes in specimen numbers occur from year to year. This is shown in the following summary of emergence trap catches of three very abundant species, i.e., *Baetis vernus* (BV; Ephemeroptera), *Leuctra nigra* (LN; Plecoptera), *Agapetus fuscipes* (AF; Trichoptera), over 10 m^2 stream during a 12 year period:

	1974	1975	1976	1977	1978	1979
BV	5842	1135	1135	5586	4669	8005
LN	520	996	1296	2290	431	493
AF	1033	213	405	802	891	3981
	1980	1981	1982	1983	1984	1985
BV	3386	2398	5130	392	419	827
LN	789	573	236	435	805	611
AF	6901	953	6916	4832	491	4356

A multivariate statistical approach revealed several recurrent groups among mayflies, stoneflies and caddisflies following similar temporal patterns of change of abundance. Common or divergent bottom substratum preferences united groups with the highest degree of positive or negative correlation, respectively ($p < 0.01$), while no (negative or positive) correlation was observed between pairs of predator-prey species.

Emergence trap data are not readily compared to those obtained by conventional benthic sampling programs used in most other studies. A project comparing the two approaches is under way. It is designed to account also for drift displacement, the importance of which became very obvious after the accidental stream poisoning. At the same time, important compensatory upstream flights have, so far, been demonstrated for only few species in the Breitenbach: when the percentage distribution of female emergence and the percentage distribution of ovipositing females at several sites along the stream are compared (Fig. 6), distinct upstream displacement of egg-laying females becomes obvious. Some species even oviposit almost entirely upstream from their emergence sites.

Much field work, rearing, field and laboratory experimental manipulations are devoted to the study of several of the most important insect functional groups or taxa, in erosional as well as depositional habitats of the stream. This includes, e.g., study of dietary overlap between scraping caddisflies, algal-grazer interactions, growth, development and food requirements of several Trichoptera and Plecoptera, that help understand their dominance in the stream community. As an example, consumption rates (CR, mg d^{-1} specimen^{-1}; means ± 95% c.l.; n in parentheses) of several instars of the caddis fly *Chaetopteryx villosa* under a 14/10 h light/dark regime and constant laboratory temperatures are tabulated:

Instar	temperature		
	6°C	10°C	14°C
II	0.06±0.04	0.08±0.05	0.28±0.10
III	0.10±0.05	0.22±0.10	0.24±0.08
IV	0.25±0.08	0.49±0.15	0.78±0.28
V	0.60±0.18	0.98±0.26	1.01±0.29

In the case of the caddis fly *Sericostoma personatum*, the pronounced diurnal activity pattern may be decisive for its consumption rate. Larvae are hidden in streambed sediments during daylight. They are active and feed only on the surface, in the dark. In one-week experiments an abundance of *Alnus glutinosa* leaf disks was offered under different light/dark regimes. Consumption rate (CR) was strongly correlated with the length of the dark phase; the test at 11°C is shown (Fig. 7). At least in this case, activity patterns may be as significant as availability of resources, but there are more examples suggesting importance of specific animal behaviour.

Significant differences in gut content composition were noticed when six species of scraping caddisflies were studied for their feeding ecology, despite the syntopic occurrence of the animals. Differences can in several cases be well related to specific choice of microhabitats, e.g., *Micrasema longulum* in lotic mosses having the highest proportion of mosses but also of diatoms in its gut, while fine detritus is more important in the gut contents of *Silo pallipes*, a species which prefers more sheltered microhabitats, although often on the same stones as the previous species. Despite the fact that they live in close association, the importance of very fine FPOM (<5 μm) is raised in *Agapetus fuscipes, Tinodes rostocki* consumes relatively more diatoms, and cyanobacteria are significantly more important in the diets of *Drusus annulatus* and *Apatania fimbriata* than in the other species.

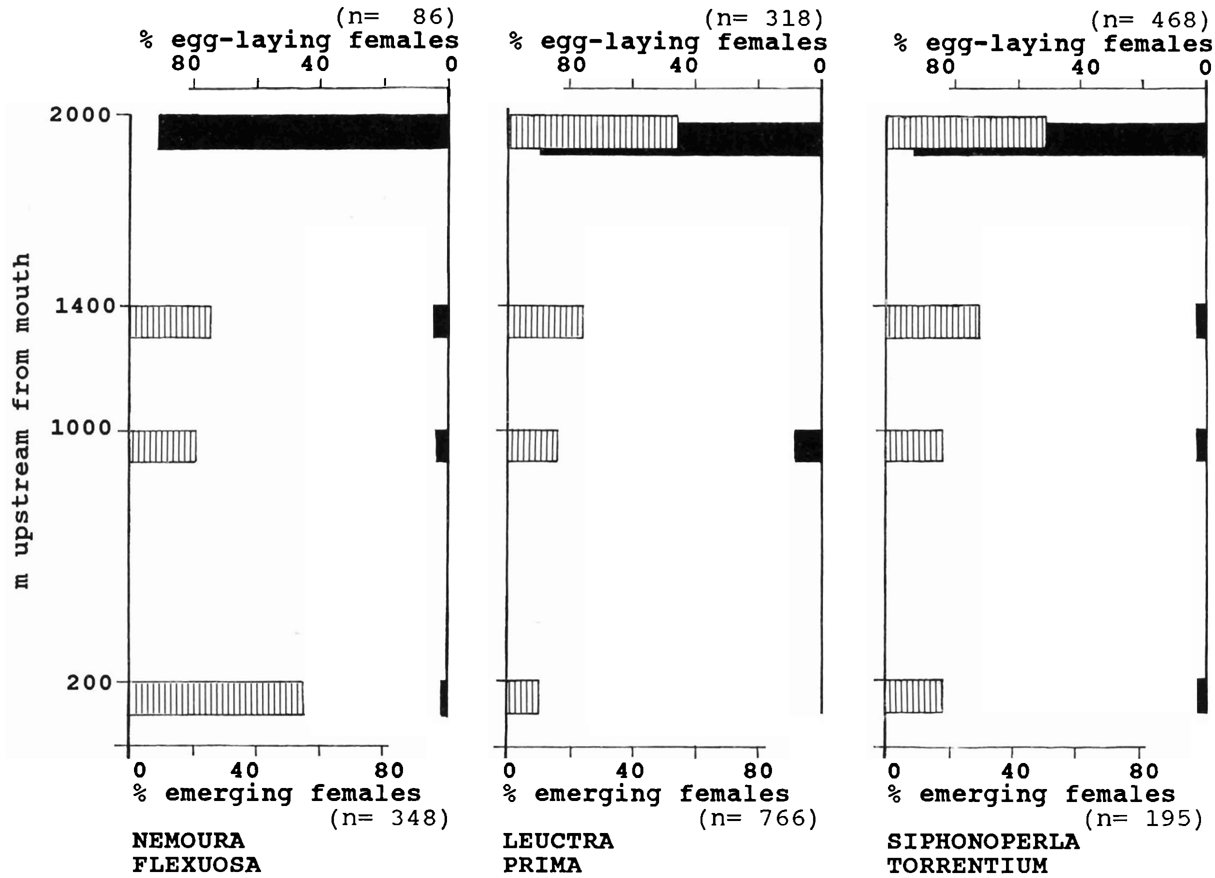


Fig. 6 Comparison of percentage distribution of emerging and of ovipositing females of three stonefly species at four sites in the study stretch of the Breitenbach.

Seasonal availability of the different food items is of course also reflected in the gut contents, with peak consumption of diatoms in spring, of cyanobacteria in summer, and of detritus (> 5µm) in October-December. On the other hand, although distribution of several of the species along the stream is not uniform but some are more abundant at upstream or downstream sites, respectively, no significant differences in food composition at different points along the stream have been noticed.

The importance of the terrestrial life phase in aquatic insects requires further study, its importance may be considerable. For instance, freshly emerged females of some Plecoptera are large-bodied but relatively lighter than males of the same species. However, females fill up and achieve a 50% increase of dry mass during one month of terrestrial feeding (Fig. 8). Further, losses during terrestrial adult life may influence population dynamics as much or even more than events during the aquatic life stages. (G. Becker, R. Wagner, P. Zwick)

Detritus supply

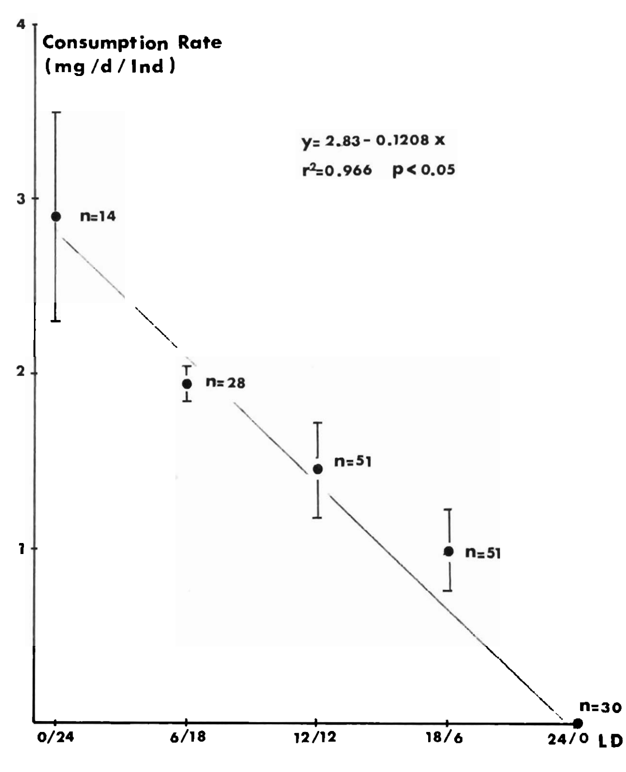
Although very abundant species contributing important fractions of total insect standing crop (*Baetis vernus, B. rhodani*) are grazers (which illustrates the relative importance of algal production in the food web in the Breitenbach) many, perhaps most, other animals feed mainly on detritus.

The input of particulate organic material (POM; g dry mass/m bank) into the Breitenbach was estimated during two years. Amount and kind of input strongly depend on vegetation on the stream banks:

Bank vegetation:	meadow	herbs and rushes	alder trees
1982/83	80.5	not measured	289.5
1983/84	130.3	47.6	560.6

Riparian vegetation partly impedes input from more distanct sources because it holds up wind blown material. The importance of the latter may be high; on a single stormy winter day without snow cover more than 500 g/m bank was blown into the stream, from distant places.

Fig. 7 Consumption rate of larval *Sericostoma personatum* at 11°C and different light/dark regimes (in hours per day).



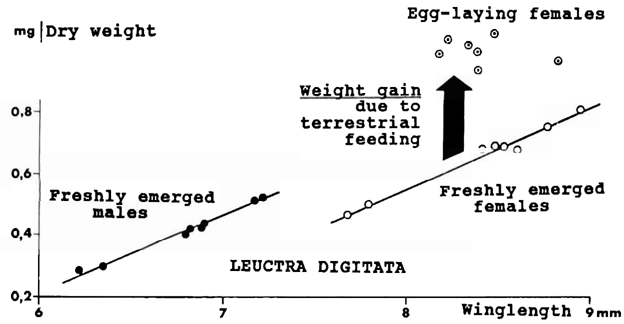


Fig. 8 Weight gain of female *Leuctra digitata* (Plecoptera) due to feeding during the terrestrial adult phase.

While input via the banks is very variable, its total amount in the 2 km study stretch of the Breitenbach is estimated to be a mean of 300 kg/a.

The amount of organic material drifting into the study stretch from upstream is important. However, in view of significant short term fluctuations with discharge, and especially in view of the importance of sudden spates, the daily mean of more than 100 kg dry mass based on monthly measurements during the period September 1985 to May 1986 cannot justifiably be converted to total transport. Also, retention times of detritus in the stream and speed of transport through the system still need to be evaluated.

A survey of the detritus pool suggests no major role for aquatic macrophytes (which are not consumed fresh), detritus is essentially allochthonus. Importance of individual components varies with time, leaves of *Alnus* and *Carpinus* disappearing more rapidly than *Fagus* and *Quercus*. Grasses, mainly from the adjacent meadows, are important most of the time. CPOM is relatively more important in coarse sediments than in fine ones; FPOM largely predominates in sandbanks. Amounts of detritus stored at or in the streambed and available to consumers are rarely below 5 and above 20 g DW/m^2 for CPOM, while FPOM fluctuates between 30-150 g DW/m^2. On the whole, supply is variable, but seems to be usually ample, except shortly after spates, when algal biomass is also reduced. FPOM is more sensitive to flushout but seems to be replaced quickly.

Bacteria

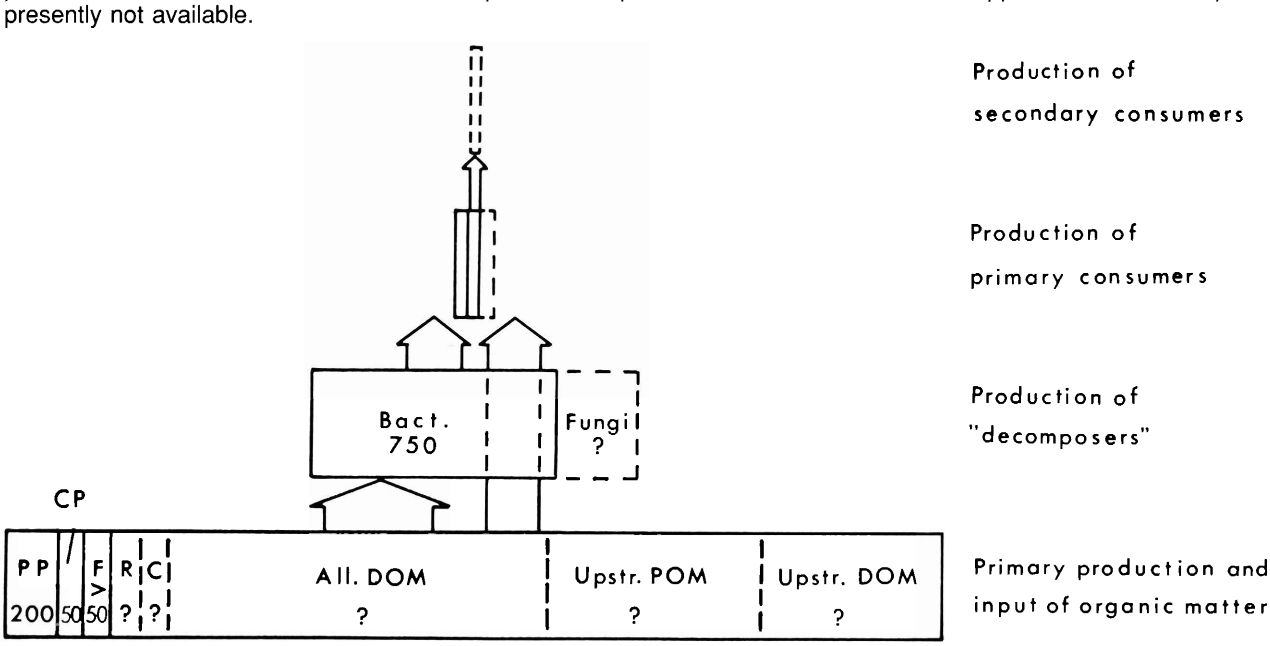
In the sandy deposits which store FPOM and thus include the largest portion of available detritus, bacterial densities and total heterotrophic bacterial activity are largest, direct counts are $0.9\text{-}11 \cdot 10^9$/mL. It appears that production of bacterial biomass in the study stretch of the Breitenbach cannot solely be accounted for by autochthonous primary production and allochthonous input of particulate organic matter in this stretch. It is presumed that input of dissolved matter (especially by groundwater entering the stream bed) and transport from the upper reach, more particulate than dissolved matter, constitute most of the remaining presently unknown carbon sources. Fig. 9 shows a hypothetical production pyramid for the middle reach of the Breitenbach.

Exoenzymatic hydrolysis, the first step of the degradation of organic macromolecules which may limit microbial substrate uptake and production is being studied extensively. Artificial substrates from which fluorescent methylumbelliferon (MUF) is set free by enzymatic reaction, in particular MUF-ß-D-glucopyranoside and MUF-phosphate are used to estimate cellulolytic activity and phosphatases, respectively, in stream water, in sandy, and in coarser sediments. Although cellulolytic activity per unit surface area was about ten times higher (five times for phosphatase) in coarse than in sandy sediments, maximum mean activity per unit volume was observed in sandy sediments where, therefore, most of the exoenzymatic activity occurs when the stream as a whole is considered.

The importance of diffuse groundwater influxes into the stream bed, especially the influence on the microbial communities, is presently another main subject of microbiological studies which closes the circle back to sediments, interstitial water and organism interactions. (J. Marxsen)

A reference and publication list is available upon request.

Fig. 9 Hypothetical production pyramid for the middle reach of the Breitenbach study stretch (g C m^{-2} a^{-1}). PP, primary production (excl. release of dissolved organic matter); CP, coarse, F, fine particulate allochthonous organic matter; estimates for compartments limited by dashed lines (R, release of DOM by primary producers; C, chemoautotrophic production; All.DOM, allochthonous DOM; Upstr.POM, Upstr.DOM, POM and DOM from upper stream sections) are presently not available.



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