BIOMASS OF EPHEMEROPTERA AND PLECOPTERA IN THREE SWISS RIVERS

Peter Landolt, Judith Thüer, and Denise Studemann

Institute of Zoology, Entomology
University of Fribourg
Pérolles, CH-1700 Fribourg, Switzerland

ABSTRACT

The fauna composition and the biomass of Ephemeroptera and Plecoptera were observed in a meandering lowland river, a prealpine stream and a regulated river. The faunal diversity in the regulated river was poor compared to the other two rivers due to the limnic character of the water, specially the suspended particles floating in the water. Growth of *Serratella ignita* depended mainly on the water temperature. The largest biomass of Ephemeroptera was observed in the lowland river, whereas that of Plecoptera was observed in the prealpine stream. The dam-regulated river produced the most biomass, composed principally of Gammaridae. Their inorganic compounds were three times higher than those of Ephemeroptera and Plecoptera.

INTRODUCTION

The biocenosis of a stream is determined by abiotic factors such as the slope (Ambühl, 1959; Statzner and Higler, 1986), the sediment (Hefti et al., 1985; Reynoldson, 1987; Maier, 1994; Palmer et al., 1995), the altitude (Margreiter-Kownacka, 1990; Ward, 1994), the temperature regime (Humpesch, 1980a, b, 1981; Ward and Stanford, 1982), the oxygen concentration (Jacob and Walther, 1981; Jacob et al., 1984), the chemical compounds in the water (e.g. Buikema et al., 1982; Smock, 1983; Townsend et al., 1983; Dewey, 1986; Winterbourn and Collier, 1987) and also by biotic interactions of the organisms, specially on the trophic level (Hawkins, 1986). The three investigated rivers, a prealpine stream, a meandering lowland river and a dam-regulated river, have different characteristics which influence the diversity of the species, the growth of the organisms and also the production of the biomass.

The aim of the present study is to show the influence of physical and chemical parameters on Ephemeroptera and Plecoptera, specially in the regulated river.

MATERIAL AND METHODS

Geographical Situation

The three rivers Nessleraa, Neirigue and Petite Sarine are located in the Canton of Fribourg (Fig. 1). The water of the Sarine river is used several times for the production of hydroelectricity. A seventy-meter high dam near Rossens forms the Lac de la Gruyère, water from a catchment area of about 640 km^2. Some 20 m^3 water per second pass through the power plant turbines 12 km downstream from the dam and the remaining water (rest water) at 1 m^3 per second is released in the river bed between the dam and the hydroelectric station and forms the Petite Sarine. One of the stations is situated near the dam (400 m downstream), whereas the second station, Hauterive, is located 12 km downstream between a waste-water cleaning plant and the power plant releasing the water into the Petite Sarine. The Nessleraa and the Neirigue have a catchment area of 30 and 57 km^2, respectively. Their normal water quantity amounts to about 0.5 m^3 per second. However, after thunder-storms in summer, the water level rises quickly up to 80 cm above the normal water level. The Neirigue, in particular, experiences extremely high water occurences with 180 cm higher water levels. The water of these two rivers joins the Sarine near Fribourg and via the Aare and the Rhine finally empties in the North Sea.

Physical Characteristics and Chemical Properties

The values of pH, temperature, conductivity and oxygen content were measured directly in the field. The amounts of nitrogen and phosphorus were determined by standard procedures in the Laboratory for Environmental Protection of the Canton of Fribourg.

The composition of sediment in the rivers were determined by analyzing a volume of 50 dm^3 at a depth of 0-30 cm from the river bottom.

Sampling of the Organisms and Their Analysis

From March 1997 to March 1998 samples were taken from four sites (Fig. 1). Sampling was carried out by a surber sampler of 41 cm side length and a mesh size of 0.7 mm. Three lentic and three lotic probes of 0.168 m^2 each were taken. The sampling was carried out up to a depth of 20 cm in the sediment. The organisms were floated in a solution of 350 g/l $MgSO_4$ in a flat basin, gathered and conserved in 80% alcohol for further investigations.

The organisms captured from April to November were determined principally by the keys of Aubert (1959), Brittain and Salveit (1996), Studemann et al. (1992), Tachet et al. (1984) and Warninger and Graf (1997).

The measurements of body length and head capsule width of *Serratella ignita* were carried out with a binocular microscope. The measured individuals (if available at least 40 specimens) were grouped by size classes of 0.35 mm.

The biomass of Ephemeroptera and Plecoptera were determined by the dry weight (organic and inorganic compounds) after drying the probes at 100°C over four days. The animals were incinerated at 900°C for one hour, and the amount of inorganic compounds was estimated from the ash. The determination of the biomass was carried out ten times from April 1997 until March 1998.

RESULTS

Physical and Chemical Characteristics

The temperature regimes in the Nessleraa and in the Neirigue are comparable as well as their oxygen contents (Table 1). The temperature in the Petite Sarine shows a different pattern

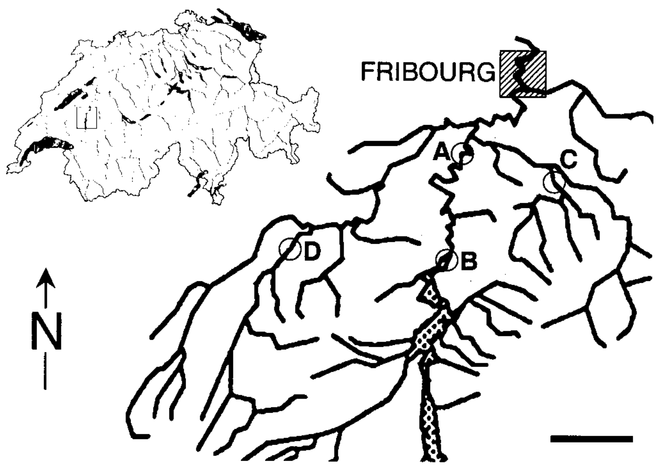

Fig. 1. General map of the main Swiss rivers and detailed map of the four investigated localities near Fribourg. A: Petite Sarine/Hauterive; B Petite Sarine/dam; C: Nessleraa and D: Neirigue. The scale represents 5 km.

Table 1. Physical and chemical characteristics (mean ± SD) of the stations investigated (*measured 5 cm above ground)

	Nessleraa	Neirigue	Petite Sarine / dam	Petite Sarine / Hauterive
Altitude [m a.s.l.]	666	652	610	577
River slope [‰]	22	11	3	3
Water current* [cm/s]	0-95	0 - 120	0 - 60	0 - 115
Conductivity [µS/cm]	464 ± 74	526 ± 51	415 ± 46	442 ± 66
O_2 content [%] in Summer	90	96	81	84
Annual mean temperature [°C]	10.2 ± 2.1	10.2 ± 2.7	8.1 ± 2.6	11.6 ± 3.0
Daily amplitude [°C]				
- Summer	12.4 - 15.1	14.0 - 17.5	10.2 - 11.7	14.0 ± 25.6
- Winter	1.8 - 4.9	2.3 - 4.3	1.3 - 3.5	-1.7 - 4.4
pH	8.0 ± 0.4	7.7 ± 0.6	8.0 ± 0.9	7.7 ± 0.5

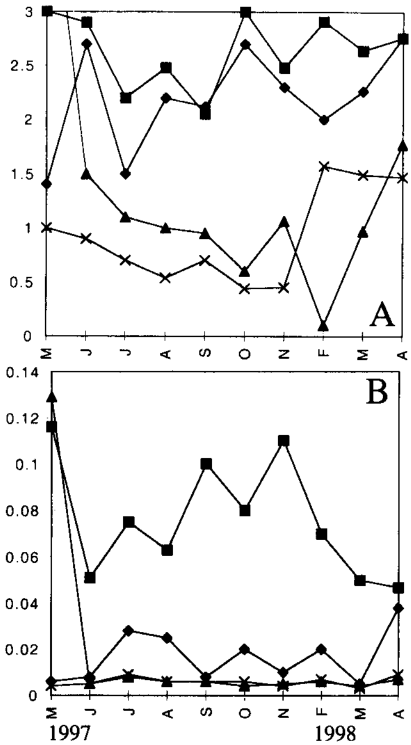

Fig. 2. Concentration of chemical compounds (mg/ml) in the three rivers. A: nitrate; B: orthophosphate; ◆ Nessleraa, ■ Neirigue, ▲ Petite Sarine/Hauterive and X Petite Sarine/dam.

between the dam and in Hauterive, 12 km downstream; the station upstream is under the influence of the 60 m deep lake water and the temperature at the dam reflects the lake temperature at 60 m depth (a low mean temperature and low temperature amplitudes within a year). At the Hauterive station, after the meandering of the river in the 200 to 500 m broad canyon, the environmental temperature influences are shown; the water temperature resembles the air temperature (low winter and high summer temperatures with high daily amplitudes).

The pH, buffered by the carbonate substrate, remained slightly alcaline and stayed stable throughout the observation period.

The mean oxygen levels in Neirigue and Nessleraa are higher than in the regulated Petite Sarine. In winter, the oxygenation levels rise about 5% in all the rivers. The conductivity amounts to about 500 µS/cm for the Neirigue and Nessleraa and nearly 430 µS/cm in the Petite Sarine (Table 1).

The amount of nitrate exceeded the Federal legal limit level of 3 mg/ml (Federal edict 1975) once in the Petite Sarine/Hauterive (12 mg/ml in April) near a waste-water cleaning plant (Fig. 2). Otherwise the amounts of the nitrate fluctuated between 0.5 mg/ml and 1 mg/ml in the regulated river. They were two times smaller than the amounts in the Nessleraa and Neirigue (Figure 2A). The amounts of nitrite were similar to those of nitrate, and the values for ammonium never exceeded the legal limits (0.1 mg/ml) (data not shown). The amounts of orthophosphate were generally low; in the Petite Sarine lower (less than 0.01 mg/ml) than in

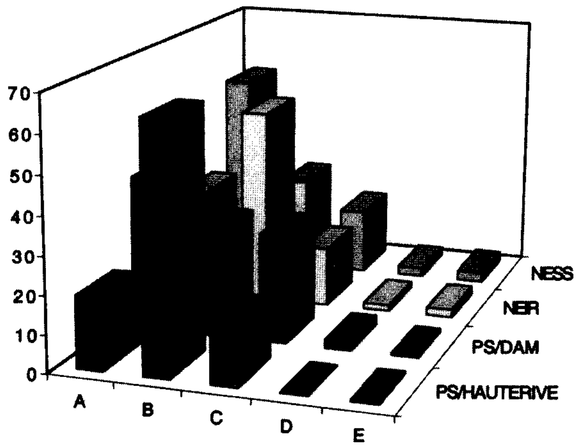

Fig. 3. Proportion (%) of different substrate classes: A: boulders (> 100 mm in diameter), B: large gravel (20-100 mm), C: fine gravel (2-20 mm), D: sand (1-2 mm) and silt (< 1 mm) at the sampling sites NESS (Nessleraa), NEIR (Neirigue), PS/DAM (Petite Sarine/dam) and PS/HAUTERIVE (Petite Sarine/Hauterive).

the two other rivers. The concentration in the Nessleraa was normally less than 0.03 mg/ml, but reached 0.13 mg/ml in May. In the Neirigue however, the mean value of orthophosphate was constantly much higher (mean value 0.08 mg/ml, Fig. 2B). The progress of the curves for the total phosphorus were comparable to those of the orthophosphate (data not shown).

The composition of sediment in the rivers is presented in Fig. 3. Boulders represented the major proportion in the Nessleraa and in the Petite Sarine near the dam, whereas large gravel was the largest fraction in the Neirigue and Petite Sarine/Hauterive. Sand (0.1 to 2.3 %) and silt (0.4% to 2.6 %) were minor constituents in the investigated rivers.

Faunal Composition

The presence of insects, crustaceans, nemathelminthes and annelides were recorded and determined from March to November 1997. *Erpobdella octoculata* and *Helobdella stagnalis* (Hirundinea) occurred all the time in high numbers in the Petite Sarine/Hauterive, whereas in the other stations these two species were found once. Crustacea (Gammaridae and Asselidae) were collected all over the year in the Petite Sarine, at Hauterive. *Gammarus pulex* lived also in huge amounts at the station near the dam. *Gammarus* represents the big mass of the macroinvertebrates of the Petite Sarine (see section biomass), these animals were present only sparsely in the Neirigue and Nessleraa.

The captured insects were representatives of Ephemeroptera and Plecoptera (Table 2), Trichoptera (species from 4 to 8 families, depending on the station), Diptera (5-7 families), Coleoptera (2-4 families) and some sparse individuals of Heteroptera (*Plea* sp. and *Corixa* sp.) and Megaloptera (*Sialis* sp.).

Table 2 gives the occurrence of the representatives from March to November 1997. The most common and abundant Ephemeroptera species was *Baetis rhodani*. *Alainites muticus*, *Baetis vernus* and *B. alpinus* were also observed. *Serratella ignita* was present in all the investigated rivers (Table 2), but the other Ephemerellidae species (*Ephemerella mucronata*) was observed only once in the Petite Sarine near the dam. A large amount of young *Ecdyonurus* larvae (especially *E. venosus*) were collected in spring, *Rhithrogena*

Table 2. Genera of Ephemeroptera en Plecoptera recorded in the stations investigated from March to November 1997 (• = presence).

Nessleraa	10.3	26.3	10.4	29.4	20.5	3.6	24.6	8.7	21.7	1.8	21.8	1.9	16.9	29.9	5.11
EPHEMEROPTERA															
Baetis	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Epeorus	•				•			•					•		•
Rhithrogena	•	•	•	•	•	•	•	•							
Ecdyonurus	•			•		•		•	•	•	•	•	•	•	•
Heptagenia				•	•										
Serratella						•	•	•	•	•	•	•	•	•	•
Caenis												•			
Paraleptophlebia	•				•							•		•	•
Habroleptoides			•									•	•	•	•
Habrophlebia							•								
Ephemera									•						
PLECOPTERA															
Brachyptera	•	•	•		•										
Protonemoura					•										
Amphinemoura				•											
Nemoura				•			•								
Leuctra	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Perlodes				•										•	•
Isoperla	•	•													
Neirigue	10.3	26.3	10.4	29.4	20.5	3.6	24.6	8.7	21.7	1.8	21.8	1.9	16.9	29.9	5.11
EPHEMEROPTERA															
Baetis	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Epeorus	•			•		•	•	•	•	•				•	•
Rhithrogena	•	•	•	•	•	•			•	•				•	•
Ecdyonurus	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Heptagenia						•	•								
Serratella						•	•	•	•	•	•	•	•	•	•
Caenis												•		•	
Paraleptophlebia	•			•	•				•						
Habroleptoides		•	•												
Habrophlebia				•	•	•	•		•	•					
PLECOPTERA															
Brachyptera	•	•	•												
Amphinemoura	•			•		•									
Nemoura	•			•		•									
Leuctra	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Isoperla	•	•		•											
Perla							•					•			
Petite Sarine / dam	10.3	26.3	10.4	29.4	20.5	3.6	24.6	8.7	21.7	1.8	21.8	1.9	16.9	29.9	5.11
EPHEMEROPTERA															
Baetis	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Epeorus	•														
Rhithrogena							•								
Ecdyonurus		•	•	•				•	•	•		•			•
Serratella							•	•	•	•	•	•		•	
Ephemerella					•										
PLECOPTERA															
Brachyptera	•	•													
Nemoura						•									
Leuctra	•														
Petite Sarine/Hauterive	10.3	26.3	10.4	29.4	20.5	3.6	24.6	8.7	21.7	1.8	21.8	1.9	16.9	29.9	5.11
EPHEMEROPTERA															
Baetis	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Epeorus	•														
Rhithrogena	•	•	•	•		•									
Ecdyonurus		•	•	•	•			•	•	•				•	•
Heptagenia			•	•	•	•									
Serratella						•	•	•	•	•	•	•		•	
Paraleptophlebia	•		•	•	•						•				
Habroleptoides			•												
PLECOPTERA															
Nemoura			•												

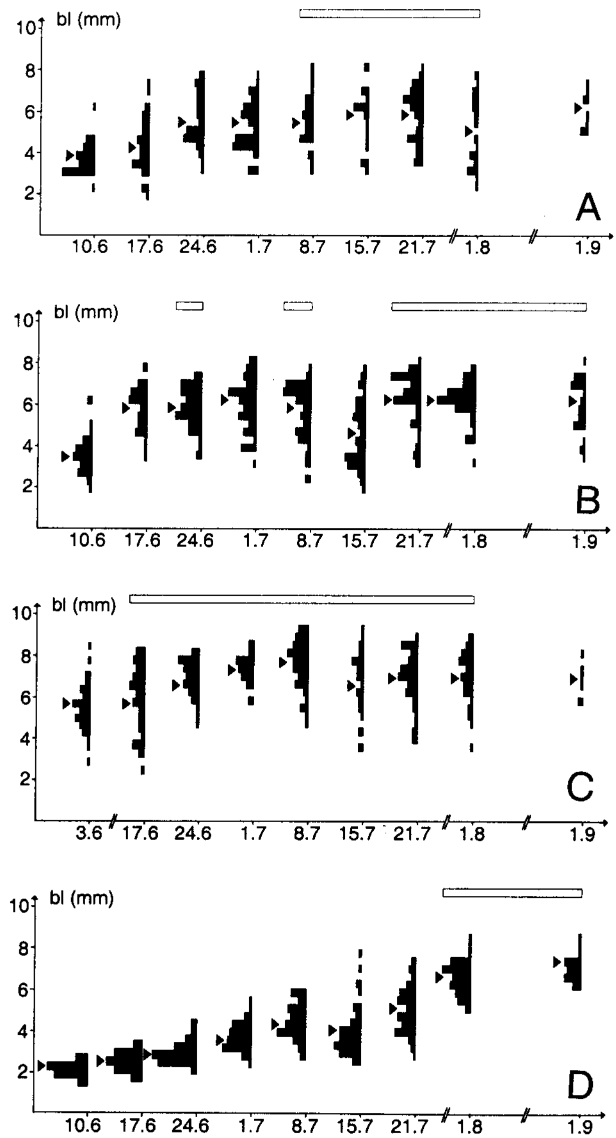

Fig. 4. Size distribution (bl=body length in mm) of *Serratella ignita* larvae for each sample from June to September 1997 at the stations A Nessleraa, B Neirigue, C Petite Sarine/Hauterive and D Petite Sarine/dam. The arrows represent the mean length of the larvae, and the white bars represent the presence of mature larvae.

semicolorata was abundant, too. The *Heptagenia* representative was the common *H. sulfurea*. Both *Epeorus* species (*E. alpicola* and *E. sylvicola*) were observed in the Nessleraa; in the other rivers only *E. sylvicola* occurred. Leptophlebiidae (*Paraleptophlebia submarginata*, *Habroleptoides confusa* and *Habrophlebia lauta*) were found occasionally.

The diversity of Plecoptera genera was relatively high in the Nessleraa and Neirigue with seven and six genera respectively. In the Petite Sarine only three genera occurred near the dam and some individuals of *Nemoura* sp. were caught in April in Hauterive.

Table 3. Dimensions of *Serratella ignita* nymphs (at least 15 specimens tested, mean ± SD).

	Nessleraa	Neirigue	Petite Sarine / dam	Petite Sarine / Hauterive
First appearance	July 8	June 24	August 1	June 17
Mean head width (hw) [mm]	1.30	1.27	1.24	1.37
Mean body length (bl) [mm]	6.31	5.96	6.32	6.72
bl/hw (male)	4.82 ± 0.55	4.63 ± 0.27	5.15 ± 0.52	4.70 ± 0.48
bl/hw (female)	4.90 ± 0.15	5.14 ± 0.50	5.20 ± 0.28	5.00 ± 0.25

Growth of *Serratella ignita*

The larval growth of *Serratella ignita* is shown in Fig. 4. The animals in the Petite Sarine near the dam presented a synchronous growth. Their growth was slower than those of the populations in the other stations. The maximal mean length was achieved only in September, the first larvae of the last instar (larvae with black coloured wing pads, also called nymphs), appeared late at the beginning of August. The station Petite Sarine/Hauterive presented the other extreme situation: the earliest appearance of nymphs were observed already in the middle of June but not later than the beginning of August. The most variable length of the larvae per sample and the maximum mean length of the larvae (7.4 mm in July) also were found in Petite Sarine/Hauterive. The maximum mean length of the animals in the Neirigue was achieved at the beginning of July (6.24 mm), whereas in the Nessleraa specimen with their maximum length were detected two weeks later (5.7 mm). The nymphs were observed in the Neirigue from June to the beginning of September, in the Nessleraa concentrated on two weeks in July.

The ratio body length to head width (bl/hw) for nymphs was always larger for females than for males due to the smaller head width of the females (Table 3).

Biomass of Ephemeroptera and Plecoptera Larvae

Figure 5 shows the biomass of Ephemeroptera per square meter in the rivers (lentic and lotic zones together). The Neirigue is the most productive river for Ephemeroptera with the biomass maxima in spring (1.64 g/m^2) . After the hatching of the spring species, the weight dropped during the summer and autumn comparable to the production of other rivers. In the winter season, an increasing number of first small and then larger individuals of Baetids and Heptagenids was observed. The maximum amounts per square meter was 0.83 g in the Nesslera, 0.28 g in the Petite Sarine/Hauterive and 0.39 g at the dam station. There was about three times less biomass of Ephemeroptera collected during the ten quantitative collection trips in the Nessleraa (2.3 g) than in the Neirigue (6.8 g). The station in the Petite Sarine near the dam was more productive (1.8 g) than in Hauterive (1.2 g). During the summer months, the main portion of the Ephemeroptera in the Petite Sarine were Baetidae. The general distribution during the year is comparable between the Nesslera and the Neirigue, but the peaks were different.

The biomass of the Plecoptera is presented in Figure 6. No prominent amounts of biomass were registered in the Petite Sarine: only three samples contained Plecoptera weighting 20 mg near the dam and none at Hauterive. The highest amount of 0.33 g/m^2 was captured March 1998 in the Nessleraa and 0.15g/m^2 in the Neirigue. The whole sampled biomass was

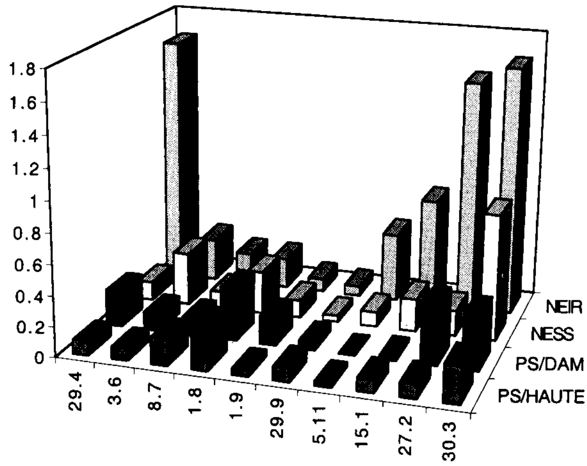

Fig. 5. Biomass of Ephemeroptera in gramme per square metre (g/m^2). Samplings were taken from April 1997 till March 1998 at the stations NEIR (Neirigue), NESS (Nessleraa), PS/DAM (Petite Sarine/dam) and PS/HAUTE (Petite Sarine/Hauterive).

0.52 g in the Neirigue and 0.71 g in the Nessleraa. In both rivers, the main proportion resulted from captures in January, February and March.

The production of invertebrate biomass in the Petite Sarine was dominated by the crustacea, mainly gammarids. Up to 19 g/m^2 dry weight was measured in August in Hauterive and 21 g/m^2 were collected near the dam. The productivity in the Neirigue and Nessleraa was much lower, due to another more diversified fauna composition. During summer and autumn, Diptera (chironomids and simulids) and Trichoptera were mainly present; the Diptera fauna reached 1.2 g/m^2 in the Neirigue and 0.2 g/m^2 in the Nessleraa, the caddisflies 4 g/m^2 in the Neirigue and near 1 g/m^2 in the Nessleraa.

For Ephemeroptera and Plecoptera, the inorganic matter, equivalent to the ash weight, reached comparable amounts of about 10% of the dry weight (Table 4). The inorganic proportion was slightly higher in January than 10 weeks later, when the larvae had matured. The proportion of ash in Trichoptera (5.3%) amounted to about half of that measured for Ephemeroptera. For gammarids, the high content of ash (31.6%) determined in the Petite Sarine in July reflected well the amounts measured in other probes (other stations and periods, data not shown). It was always about three times higher than those for Ephemeroptera and Plecoptera. The comparison between the dry weight of single specimen of gammarids with those of Ephemeroptera (e.g. Baetidae) revealed values of about five times higher the weight of gammarids (about 50 mg for a *Gammarus pulex* and about 10 mg for a *Baetis* specimen). The proportion of the organic material was calculated finally to 34 mg for a gammarid and 9 mg for a *Baetis* individual.

DISCUSSION

The permanent chemical charges of nitrogenous and phosphorous compounds, issuing principally from agricultural sources, are comparable to other Swiss rivers like the Glatt, Urnäsch, Sitter, Thur, Necker, Aare, Kander or Simme (reports from the Environmental Offices of various cantons). The values in the Petite Sarine and the Nessleraa reach the average values measured in Switzerland, whereas the Neirigue reaches the upper limit. This

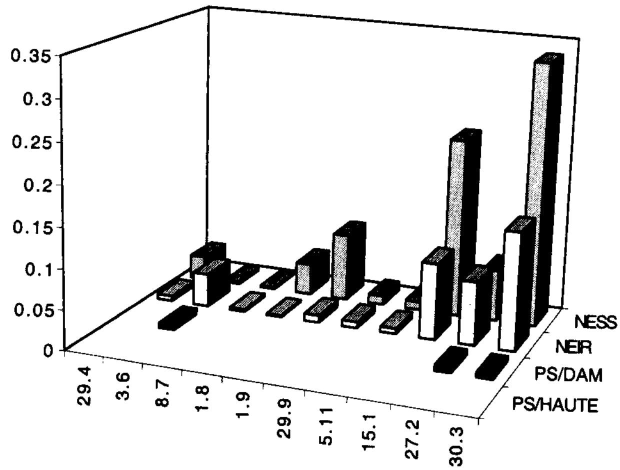

Fig. 6. Biomass of Plecoptera in g/m². Ten samplings were taken from April 1997 till March 1998 at the stations NESS (Nessleraa), NEIR (Neirigue), PS/DAM (Petite Sarine/dam) and PS/HAUTE (Petite Sarine/Hauterive).

river runs in a valley surrounded by fields highly improved by agriculture. The waste-water purification plant just upstream from the station Hauterive in the Petite Sarine has no measurable influence on the river when the new plant works well. The dilution of the released cleaned water in the river amounts to about 1:50. The exceptional high amounts of nitrate and orthophosphate on 29.4.1997 could originate from a malfunctioning of the waste-water cleaning plant or another source such as agriculture. The chemical parameters measured for this study are similar to those from Noël and Fasel (1985). After the system of Klee (1993), all four stations are classified as slightly organic charged. The constant monitoring of the rivers in the canton of Fribourg by Noël reveals a stable biotic index after the system of Verneaux and Tuffery (1967) since 1990 (Noël's personal communication), indicating the stability of the situation.

The presence of species depends more on the physical properties of the biotope, such as substrate or slope (Higler, 1987; Verdonschot, 1990), than on dissolved chemical substances. Marten and Reusch (1992) suggest that other factors, such as current velocity or substrate, modify or superpose the effects of waste water.

The water flow determines temperatures and oxygenation, as well as the composition and changing events of the sediment. The low and constant velocity in the regulated Petite Sarine differs from the characteristic of the Neirigue and Nessleraa. These rivers react with high water levels after rainfall, specially after regular thunder storms from May to September. These events change the river course in the Neirigue-bed frequently, or at least wash out primary producers like bacteria. In the Petite Sarine however, a black layer on the lower surface of the stones shows the presence of reducing anaerobic bacteria, which indicates the low amount of oxygen in this zone. This factor influences the embryonic development of deposited eggs from macroinvertebrates and fish (Dedual, 1990). The upper surface of the stones is covered by a centimeter-thick coat of stromatolite-like structures. These formations are produced by different organisms, such as coccoid bacteria, cyanophytes, eucaryotic algaes and bryophytes (Freytet and Plet, 1996). The principal composition of blocs in the Nessleraa varies only slightly, even in high water levels, but the «cleaning-effect» happens in contrast to the Petite Sarine. The comparable composition of the sediment in Neirigue and in the Petite Sarine/Hauterive on the one hand, and Nesslera and Petite Sarine/dam on the other, indicates only a modest influence of the substrate on the faunal composition in these three rivers.

Table 4. Proportion (%) of inorganic substances corresponding to the ash content in Eph (Ephemeroptera), Plec (Plecoptera), Trich (Trichoptera) and Gammarus.

	ash [%]		
	January 15	March 30	July 7
Eph: Neirigue	12.7	9.4	
Eph: Nessleraa	12.5	10.3	
Plec: Ness + Neir	12.3	10.6	
Trich: Neirigue			5.3
Gammarus: Petite Sarine / dam			31.6

The sediment composition, the water velocity and the pH values are similar at Petite Sarine/Hauterive compared to the other two rivers. The poor fauna diversity in this station results therefore from other factors. This is also true for the station near the dam.

The majority of Ephemeroptera and Plecoptera species are spring species in the rivers on this altitude. In summer *Baetis rhodani, Alainites muticus, Serratella ignita* and *Ecdyonurus venosus* have been observed. Imhof et al. (1988) showed the existence of two populations of *E. venosus* with shifted developmental times in the Petite Sarine and another river near Fribourg. The very similar genetic pattern of the populations assumes that interbreeding between spring and autumn populations happens; that means that these populations are partially bivoltine and larvae can be found throughout the year (Imhof et al., 1988).

Probably, the lower oxygen content diminishes the presence of Plecoptera in the Petite Sarine compared to the Nessleraa and the Neirigue. In the last two rivers, only *Leuctra* species were captured all year. This observation agrees with those of Gonser and Schwörbel (1985) in the Gutach-Wutach in southern Germany.

The Gammaridae have a broad spectrum of distribution but prefer to live in organic charged waters (Engelhardt, 1974). The organic material from washed lake-sediments improves their diet.

One important factor in the development of Ephemeroptera and Plecoptera is the water temperature. The two stations in the Petite Sarine differ principally in this characteristic. A time shift of development is generally observed for the captured macroinvertebrates as well as for the composition of the representatives of three Plecoptera genera in the cool water near the dam. The only single observation of Plecoptera 12 km downstream in the summer heated water can be explained by the effect of the temperature.

The growth of *Serratella ignita* clearly demonstrates the influence of temperature which was shown even in the embryonic development by Jazdzewska (1980) and the growth of larvae by various authors (e.g. Hefti and Tomka, 1990; Riano et al., 1997; Tiunova, 1997). Larvae in the Hauterive station are caught early in the season and they mature early too. The larval growth near the dam starts later, but runs more synchronously, and nymphs are formed only late in the autumn. The ratio body length/head width of male and female Serratella nymphs is clearly larger in the cool water environment than in the other stations. The growth of *S. ignita* is comparable to that of the individuals in the Sense, a prealpine Fribourg river (Hefti and Tomka, 1990).

The productivity of different individual Ephemeroptera species has been investigated by various authors (e.g. Welton et al., 1982; Zelinka, 1984, Hefti and Tomka, 1990). The present study presents the total biomass of all Ephemeroptera and Plecoptera species, respectively. In the Neirigue, their biomass is dominant in winter and spring months with a maximum of 1.6 g/m^2 in March. The amount in the Nessleraa at the same time is about half (0.8 g/m^2). The total dry weight of the captured Ephemeroptera amounts to 6.8 g in the Neirigue, 2.3 g in the Nessleraa, 1.8 g in the Petite Sarine near the dam and 1.2 g in Hauterive. The Plecoptera are more abundant in the Nessleraa (0.71 g in ten samples) than in the Neirigue (0.52 g). In the Petite Sarine, the quantitative captures were successful only three times with 0.02 g at the dam station.

Elliott et al. (1988) calculated the production of the Ephemeroptera to be 25 % of the total zoobenthos. The stoneflies do not predominate either in the Nessleraa or in the Neirigue in agreement with the findings of Teslenko (1992). Kocharina et al. (1988) estimated the annual biomass of the stonefly larvae in Far-East rivers to 12.6 % of the entire benthos biomass.

The negligible findings of Plecoptera and the only small proportion of Ephemeroptera in the Petite Sarine are presumbably due to the influence of the dam. The particles suspended in the water, issuing from the bottom of the sediments of the storage lake behind the dam, are released constantly into the Petite Sarine and they affect considerably the fauna elements. This influence, combined with the small and constant water volume over the year and the gently flowing limnic water in the broad river-bed, determine principally the poor fauna diversity with the dominant presence of the *Gammarus* which represent 81 % to 99 % of the biomass (depending on station and period). The drop in mayfly species by a dam is reported by Klonowska-Olejnik (1997) too. Usseglio-Polatera (1997) observed that dams lead to a simplified redistribution of ecological niches through the growing uniformity of the substrate and possible sources of food.

Bargos et al. (1990), Landa and Soldan (1991), Buffagni (1997) and other authors considered the mayflies as good biological indicators. The observation of long-term changes in mayfly and stonefly fauna are necessary to determine trends on a large scale (Landa et al., 1997a,b). Further investigations in collaboration with the producers of hydroelectricity will clear the impact of the interference of the particles on the faunal diversity as well as the water regime.

ACKNOWLEDGMENTS

We wish to thank the Environmental Offices of the Cantons of Appenzell, Berne, Fribourg, St.Gallen and Zürich for their river reports with chemical and biological results. M. F. Noël and D. Folly of the Environmental Office of the Canton of Fribourg are thanked for the chemical measurements of the water and their river reports. The Gravière at Tuffière carried out the granulometric measurements. Mrs. Knispel determined Plecoptera. We are indebted to M. H. Gachoud and Mrs S. Watson for their helpful technical assistance. Finally, we thank an anonymous reviewer for his valuable suggestions.

REFERENCES

Ambühl, H. 1959. Die Bedeutung der Strömung als ökologischer Faktor. Schweiz. Zeitsch. Hydrol. 21: 133-264.

Aubert, J. 1959. Plecoptera. Insecta Helvetica 1. Ed. Soc. Ent. Suisse. 1-140.

Bargos, T., J. M. Mesanza, A. Basaguren and E. Orive. 1990. Assessing river quality by means of multifactorial methods using macroinvertebrates. A comparing study of main courses of Biscay. Water Res. 24: 1-10.

Brittain, J. E. and S. J. Salveit. 1996. Plecoptera, Stoneflies. In: Nilsson, A.N.(Ed.). Aquatic Insects of North Europe. Vol. 1. pp. 55-75. Appolo Books, Stenstrup, Denmark.

Buffagni, A. 1997. Mayfly community composition and biological quality of streams, pp. 235-246. In: P. Landolt and M. Sartori (eds.). Ephemeroptera and Plecoptera: Biology-Ecology-Systematics. MTL, Fribourg.

Buikema, A. L., E. F. Benfield and B. R. Niederlehner. 1982. Effects of pollution on freshwater invertebrates. Journal WPCP 54 (6): 862-868.

Dedual, M. 1990. Biologie et problèmes de dynamique de population de nas (*Chondrostoma nasus nasus*) dans la Petite Sarine. PhD Thesis Université de Fribourg: 1-169.

Dewey, S. L. 1986. Effects of the herbicide Atrazine on aquatic insect community structure and emergence. Ecology 67 (1): 148-162.

Elliott, J. M., U. H. Humpesch and T. Macan. 1988. Larvae of the British Ephemeroptera. A key with ecological notes. Freshwater Biological Association. Sientific Publication 49: 1-145.

Engelhardt, W. 1974. Was lebt in Tümpel, Bach und Weiher. Verlag Franckh-Kosmos, Stuttgart: 1-257.

Freytet, P. and A. Plet. 1996. Modern Freshwater Microbial Carbonates: The Phormidium Stromatolites (Tufa-Travertine) of Southeastern Burgundy (Paris Basin, France). Facies 34: 219-238.

Gonser, T. and J. Schwörbel. 1985. Chemische und biologische Untersuchung des Gutach-Wutach Flusssystems zwischen Neustadt und Weizener Steg. Beih. Veröff. Naturschutz Landschaftspflege Baden-Württemberg 44: 9-112.

Hawkins, C. P. 1986. Variation in individual growth rates and population densities of Ephemerellid mayflies. Ecology 67 (5): 1384-1395.

Hefti, D. and I. Tomka. 1990. Abundance, growth and production of three mayfly species (Ephemeroptera, Insecta) from the Swiss Prealps. Arch. Hydrobiol. 120 (2): 211-228.

Hefti, D., I. Tomka and A. Zurwerra. 1985. Recherche autécologique sur les Heptageniidae (Ephemeroptera, Insecta). Bull. Soc. ent. Suisse 58: 87-111.

Higler, L. W. G. 1987. Geschiedenis van de biologische waterbeoordeling. In: Werkgroep Biologische Waterbeoordeling Leersum: 15-22.

Humpesch, U. H. 1980a. Effect of temperature on the hatching time of eggs of five *Ecdyonurus* spp. (Ephemeroptera) from Austrian streams and English streams, rivers and lakes. J. Anim. Ecol. 49: 317-333.

Humpesch, U. H. 1980b. Effect of temperature on the hatching time of parthenogenetic eggs of five *Ecdyonurus* spp. and two *Rhithrogena* spp. (Ephemeroptera) from Austrian streams and English rivers and lakes. J. Anim. Ecol. 49: 927-937.

Humpesch, U. H. 1981. Effect of temperature on larval growth of *Ecdyonurus dispar* (Ephemeroptera: Heptageniidae) from two English lakes. Freshw. Biol. 11: 441-457.

Imhof, A., I. Tomka and G. Lampel, G. 1988. Autökologische und enzymelektrophoretische Untersuchungen an zwei *Ecdyonurus venosus*-Populationen (Ephemeroptera, Heptageniidae). Bull. Soc. Frib. Sc. Nat. 77 (1/2) 55-129.

Jacob, U. and H. Walther. 1981. Aquatic insect larvae as indicators of limiting minimal contents of dissoved oxygen. Aquat. Insects 4: 219-224.

Jacob, U., H. Walther and R. Klenke, R. 1984. Aquatic insect larvae as indicators of limiting minimal contents of dissoved oxygen- Part 2. Aquat. Insects 3: 185-190.

Jazdzewska, T. 1980. Structure et fontionnement des écosystèmes du Haut-Rhône français. Bull. Ecol. 11 (1): 33-43.

Klee, O. 1993. Wasser untersuchen: einfache Analysenmethoden und Beurteilungskriterien. Ed. Quelle und Meyer, Wiesbaden: 1-245.

Klonowska-Olejnik, M. 1997. Ephemeroptera of the River Dunajec near Czorsztyn dam (Southern Poland), pp. 282-287. In: P. Landolt and M. Sartori (eds.). Ephemeroptera and Plecoptera: Biology-Ecology-Systematics. MTL, Fribourg.

Kocharina, S., M. Makarchenko, E. Markachenko, E. Nikolayeva, T. Tiunova and V. Teslenko. 1988. Bottom invertebrates in the ecosystems of the salmon streams in the South of the Far East of the USSR, pp. 86-108. In: Fauna, systematics and biology of freshwater invertebrates. FEB AS USSR, Vladivostok.

Landa, V. and T. Soldan. 1991. The possibility of mayfly faunistics to indicate environmental changes of large areas, pp. 559-565. In: J. Alba Tercedor and J. Sanchez-Ortega (eds.). Overview and Strategies of Ephemeroptera and Plecoptera, Sandhill-Crane Press.

Landa, V., S. Zahradkova, T. Soldan and J. Helesic. 1997a. The Morava and Elbe river basins, Czech Republic: a comparison of long-term changes in mayfly (Ephemeroptera) biodiversity, pp. 219-226. In: P. Landolt and M. Sartori (eds.). Ephemeroptera and Plecoptera: Biology-Ecology-Systematics. MTL, Fribourg.

Landa, V., J. Helesic, T. Soldan and S. Zahradkova. 1997b. Stoneflies (Plecoptera) of the river Vltava, Czech Republic: a century of extinction, pp. 288-295. In: P. Landolt and M. Sartori (eds.). Ephemeroptera and Plecoptera: Biology-Ecology-Systematics. MTL, Fribourg.

Maier, K. J. 1994. Effects of spates on the benthic macroinvertebrate community of a prealpine river (First results). Verh. Int. Ver. Limnol. 25: 1605-1608.

Margreiter-Kownacka, M. 1990. Einfluss der Gletscherbachfassung auf die Biozönosen der unmittelbar anschliessenden Entnahmestrecke.Österreichische Wasserwirtschaft 42 (3/4): 94-94.

Marten, M. and H. Reusch. 1992. Anmerkungen zur DIN "Saprobienindex" (38410 Teil 2) und Forderung alternativer Verfahren. In: Kohlhammer, W. Natur Landschaft, Stuttgart 67: 544-547.

Noël, F. and D. Fasel. 1985. Etude de l'état sanitaire des cours d'eau du canton de Fribourg. Bull. Soc. Frib. Sc. Nat. 74(1/2/3): 1-332.

Palmer, M. A., P. Arensburger, P. S. Botts, C. C. Hakenkamp and J. W. Reid. 1995. Disturbance and the community structure of stram invertebrates: patch-specific effects and the role of refugia. Freshw. Biol. 34: 343-356.

Reynoldson, T. B. 1987. Interactions between sediment contaminants and benthic organisms. Hydrobiologia 149: 53-66.

Riano, P., A. Basaguren and J. Pozo. 1997. Diet variations of *Ephemerella ignita* (Poda) (Ephemeroptera, Ephemerellidae) in relation to the development stage, pp. 79-82. In: P. Landolt and M. Sartori (eds.). Ephemeroptera and Plecoptera: Biology-Ecology-Systematics. MTL, Fribourg.

Smock, L. A. 1983. Relationship between metal concentrations and organism size in aquatic insects. Freshw. Biol. 13: 313-321.

Statzner, B. and B. Higler. 1986. Stream hydraulics as a major determinant of benthic invertebrate zonation patterns. Freshw. Biol. 16: 127-139.

Studemann, D., P. Landolt, M. Sartori, D. Hefti and I. Tomka. 1992. Ephemeroptera. Fauna 9, Insecta Helvetica. Ed. Soc. Ent. Suisse: 1-175.

Tachet, H., M. Bournaud and Ph. Richoux. 1984. Introduction à l'étude des macroinvertébré des eaux douces. Assoc. française Limnol. 2: 1-155.

Teslenko, V. A. 1992. Role of stonefly nymphs in the freshwater invertebrate communities in the small Kedrovaya River. Diploma thesis, Sankt-Petersburg university: 1-22

Tiunova, T. M. 1997. Growth of rheophilic mayfly larvae (Ephemeroptera), pp. 65-72. In: P. Landolt and M. Sartori (eds). Ephemeroptera and Plecoptera: Biology-Ecology-Systematics. MTL, Fribourg.

Townsend, C. R., A. G. Hildrew and J. Francis. 1983. Community structure in some southern English streams: the influence of physicochemical factors. Freshw. Biol. 13: 521-544.

Usseglio-Polatera, Ph. 1997. Long-term changes in the Ephemeroptera of the River Rhône at Lyon, France, assessed using fuzzy coding aproach, pp. 227-234. In: P. Landolt and M. Sartori (eds.). Ephemeroptera and Plecoptera: Biology-Ecology-Systematics. MTL, Fribourg.

Verdonschot, P. M. 1990. Ecological characterization of surface waters in the province of Overijssel. PhD Thesis Landbouw University Wageningen: 1-255.

Verdonschot, P. M. 1992. Typifying macrofaunal communities of larger disturbed waters in the Netherlands. Aquatic conservation: marine and frehwater ecosystems 2: 223-242.

Verneaux, J. and G. Tuffery. 1967. Une méthode zoologique pratique de détermination de la qualité biologique des eaux courantes. Ann. Sc. Univ. Besançon 3: 79-91.

Ward, J. V. and J. A. Standford. 1982. Thermal responses in the evolutionary ecology of aquatic insects. Ann. Rev. Ent. 27: 97-117.

Ward, J. V. 1994. Ecology of alpine streams. Freshw. Biol. 32: 277-294.

Warninger, J. and W. Graf. 1997. Atlas der österreichischen Köcherfliegenlarven (unter Einschluss der angrenzenden Gebiete). Facultas-Universitäts-Verlag, Wien 1: 1-286.

Welton, J. S., M. Ladle and J. A. B. Bass. 1982. Growth and production of five species of Ephemeroptera larvae from an experimental recirculation stream. Freshw. Biol. 12: 103-122.

Winterbourn, M. J. and K. J. Collier. 1987. Distribution of benthic invertebrates in acid, brown water streams in the South Island of New Zealand. Hydrobiologia 153: 277-286.

Zelinka, M. 1984. Production of several species of Mayfly larvae. Limnologica 15 (1): 21-41.