Zeitschrift: Bulletin de la Société Fribourgeoise des Sciences Naturelles = Bulletin der Naturforschenden Gesellschaft Freiburg

Herausgeber: Société Fribourgeoise des Sciences Naturelles

Band: 77 (1988)

Heft: 1-2

Artikel: Quantitative ecological studies on "Ephemerella ignita" (PODA) (Ephemeroptera, Insecta) in a Prealpine stream

Autor: Hefti, Daniel / Tomka, Ivan

DOI: https://doi.org/10.5169/seals-308679

Quantitative Ecological Studies on *Ephemerella ignita* (PODA) (Ephemeroptera, Insecta) in a Prealpine Stream

by DANIEL HEFTI & IVAN TOMKA,
Zoological Institute, Entomological Department, University of Fribourg, Switzerland

1. Introduction

The mayfly *Ephemerella ignita* (PODA, 1761) belongs to the family Ephemerellidae (Ephemeroptera, Insecta). It is a highly polymorphic species which is widely distributed throughout Europe with the exception of Iceland (PUTHZ, 1978). This common species lives in running waters between stones and on macrophytes and, occasionally, on stony shores of lakes (MACAN, 1970). Its altitudinal distribution lies practically from sea-level to more than 1000 m. As the species generally appears at high density, *E. ignita* plays a central role in the ecosystem as a trophic resource and is involved in the regulation of the whole biotic community. That kind of organism (widely distributed geographically and occurring in abundance) can be considered as a «key» species, and its ecological study is particularly interesting for the comprehension of the whole running water ecosystem.

The present study deals with some aspects of the ecology of *E. ignita* in a prealpine calcareous stream. It presents the life cycle of the species and includes a quantitative analysis of the spatial distribution on the benthos, the growth and the production of the species.

2. Methods

2.1. Studied site

The study was carried out in a wooded section of the river «Singine» (Fribourg, CH, 589.060–170.600). The station investigated rises 1003 m above sea-level and is situated 2.3 km downstream from an alpine lake called «Lac Noir». The station belongs to the metarhithral stage (ILLIES & BOTOSANEANU, 1963). In the dominant lotic zones of

Bull. Soc. Frib. Sc. Nat. *77 (1/2),* 130–142 (1988)

the stream (0.30–1.10 m/s), the substrate is composed of gravel and stones of variable size. Both edges of the stream exhibit lentic zones covered with a thin layer of calcium carbonate, accumulated by precipitation. No macrophyte development has been recorded, but mosses and algae were present on the stones. The temperature regime as well as the geomorphological and chemical characteristics of the station are given in Fig. 1 and Table 1. From the latter, it appears that the station was exposed to anthropogenic organic sewage, but because of its high oxygen content (mainly due to the natural aeration of the system) the stream presented a good regeneration capacity. A biotic index of 9 has been attributed at proximity of the studied area (NOËL & FASEL, 1985).

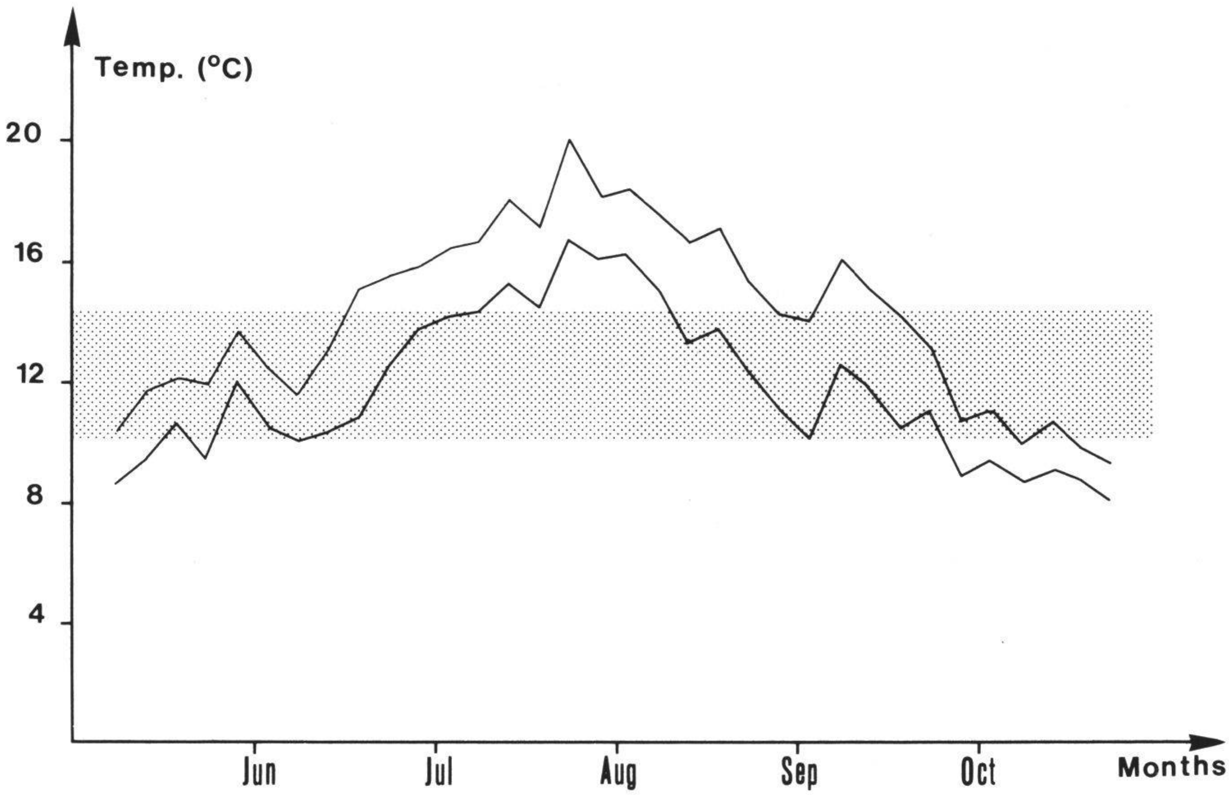

Fig. 1: Water temperature range (T_{min}-T_{max}) recorded automatically by an Elmes 12 instrument during the period of time investigated. The shaded area represents the optimum range of temperature applied in the experiment of WELTON et al. (1982).

2.2. Sampling and samples evaluation

From June to November 1988, quantitative random sampling units (n) were regularly collected in the substrate at a depth of about 7 cm with a modified surber net (mesh size: 0.7 mm; surface: 0.0625 m^2). The specimens were extracted alive in the laboratory by flotation with a 350 g/l $MgSO_4$ solution and preserved in 80% alcohol for further analysis. The experimentally gained distributions P(x) were transformed to P(log[x+1]) prior to numerical evaluation in the applied statistical tests. As the accuracy of the mean estimations is affected by the sample size (n), the relative error of the

Geomorphological characteristics :	
Mean breadth : 5.25 m	
Mean depth : 30 cm	
Mean velocity : 0.50 m/s	
Chemical characteristics :	
E.C. = 400 µS/cm ± 47.75 (n=10)	**BOD_5** = 1.40 mg/l ± 0.36 (n=10)
pH = 8.37 ± 0.14 (n=8)	**$N\text{-}NH_4$** = 56 µg/l ± 0.60 (n=6)
(O_2) = 9.68 mg/l ± 1.02 (n=7)	**$N\text{-}NO_2$** = 18 µg/l ± 13 (n=7)
(O_2) = 99.5 %	**$N\text{-}NO_3$** = 325 µg/l ± 136 (n=6)
Alc. = 2.88 mVal/l ± 0.28 (n=6)	**P** = 16 µg/l ± 15 (n=6)
T.H. = 4.44 mVal/l ±0.80 (n=6)	**DOC** = 4.5 mg/l ± 2.55 (n=2)

Table 1: Geomorphological and chemical characteristics of the station investigated: E.C. = electrical conductivity, Alc. = alcalinity, T.H. = total hardness, BOD_5 = biochemical oxygen demand for 5 days, DOC = dissolved organic carbon, with the 95% CL and the number of measurements (n).

mean (D) has been calculated for a 95% confidence limit (95% CL). The values of D are given in Table 2 for each sample. In the present study, only samples with a precision of ± 30% of the mean (equivalent to a standard error of about ± 15% of the mean) were used for the calculations of the growth rates and the production of the species.

Samples	n	Density (ind./m^2)	Biomass (mg/m^2)	D (%)	1/k (%)
24.6.88	24	304.60	42.70	± 30	2.04
6.7.88	24	312.00	74.88	± 30	1.91
25.7.88	24	520.00	145.60	± 30	1.31
6.8.88	24	377.60	151.20	± 30	1.37
17.8.88	24	333.00	139.86	± 30	0.46
5.9.88	24	18.56	8.17	± 30	6.33
22.9.88	12	5.28	-	± 40	-
29.11.88	12	1.28	-	± 40	-

Table 2: Characteristics of the samples collected: number of sampling units (n); density; biomass; index of precision (D) in term of a 95% CL of the mean for the corresponding number of sampling units, and normalized index of clumping (1/k) for each sample.

2.3. *Growth in length and in weight*

The lengths of the larvae were measured from the head to the tip of the abdomen and the geometric mean was determined for each sample. The arithmetic mean of the weight of the larvae for each sample was obtained after drying the specimens at 120°C for two hours.

3. Results

3.1. *Life cycle*

An analysis of variance (two factor-balanced factorial model) has been carried out to establish whether the observed differences in abundance between the samples collected were significant. It showed that differences between the samples collected at different times were highly significant ($F = 48.73$; $P<0.01$). On the other hand, differences between the sampling units, collected at different positions in the stream, were not significant ($F = 0.30$; $P>0.05$). This means that the variation with time recorded in the estimations of the population density was mainly due to the phenology of the species. The dynamic of the natural population investigated is shown in Fig. 2. The life cycle of *E. ignita* exhibited a univoltine pattern with a maximum peak density of the larvae at the end of July (520 individuals/m^2) and it confirmed the incorporation of the species in the type A2 of the classification of LANDA (1968). *E. ignita* is a typical summer species. The first sampled larvae appeared approximately at the end of May, but younger stages were present before (not sampled because of their small shape). Then the population grew rapidly. The emergence period started approximately at the middle of August and lasted until mid-October. The small larvae, collected at the end of November, could not complete their life cycle. The eggs overwintered in a diapause stage and the first ones hatched at the beginning of following spring.

3.2. *Spatial distribution*

The relation between the arithmetic mean ($\overline{x}$) and the variance (s^2) of the number of larvae per sampling unit followed a power law (Fig. 3):

$$s^2 = a\,\overline{x}^b$$

or

$$\log s^2 = \log a + b \log \overline{x}$$

with $a = 2.46$ and $b = 1.32 \pm 0.24$ (95% CL) ($r^2 = 0.95$; $n = 10$). Therefore the spatial distribution of the species *E. ignita* was not density-dependant. The

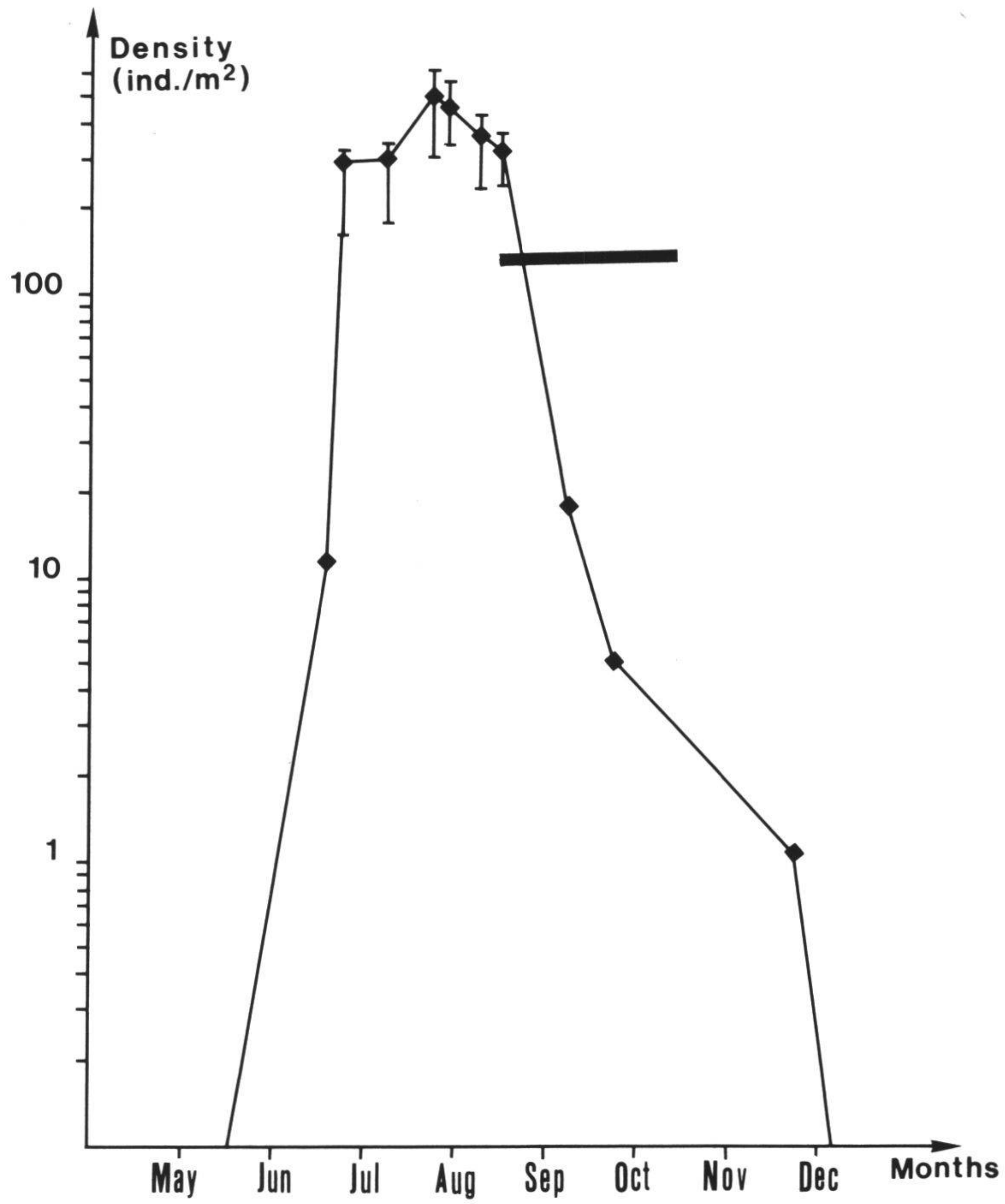

Fig. 2: Abundance (ind/m^2) of the species *E. ignita* larvae with the corresponding 95% CL. Dark area = emergence period.

population exhibited a clumped spatial distribution on the benthos during all its development. As the contagious pattern of each sample can be fitted by a negative binomial distribution ($P<0.05$), the degree of the clumping has been estimated with the parameter $1/k$ of the negative binomial model. This index ranges from 0 (for a random distribution) to $n-1/\bar{x}$ (for a maximum contagious pattern) (ELLIOTT, 1983). The relationship between the normalized clumping index ($1/k$) of each sample and the logarithm of the density was linear (Fig. 4):

$$1/k = a + b \log (\text{density})$$

with $a = 10.77$ and $b = -3.66 \pm 1.42$ (95% CL) ($r^2 = 0.93$; $n = 6$).

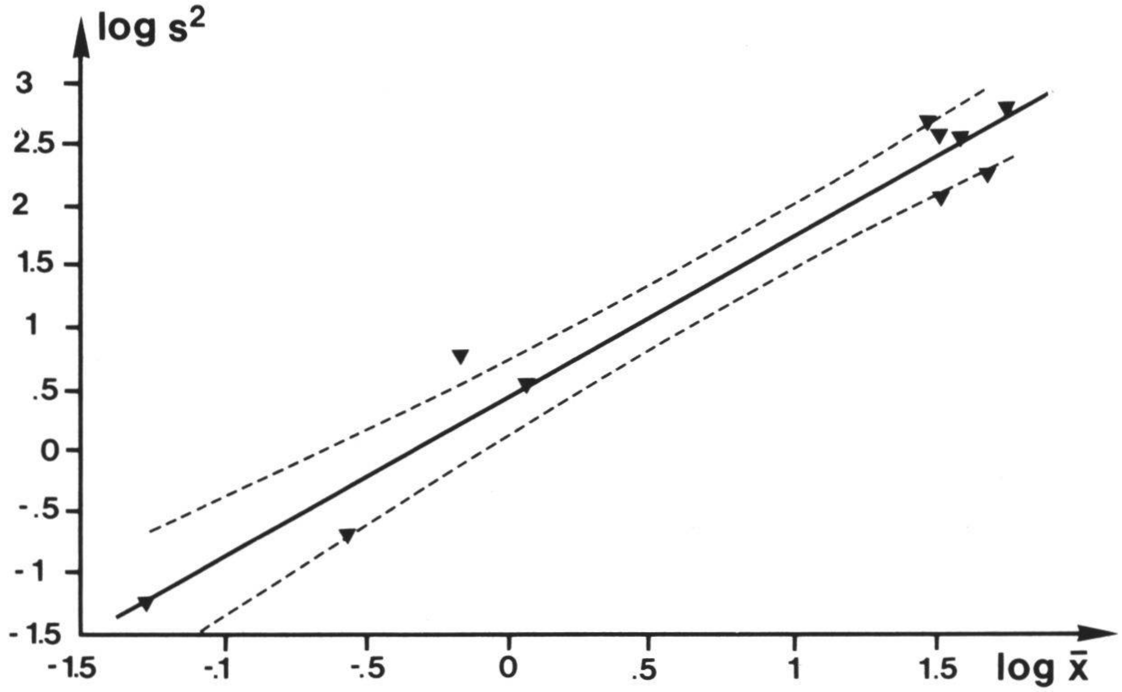

Fig. 3: Regression line of log s^2 on log $\bar{x}$ with the 95% CL. log y = log a + b log y (a = 2.46; b = 1.32; r^2 = 0.95; n = 10).

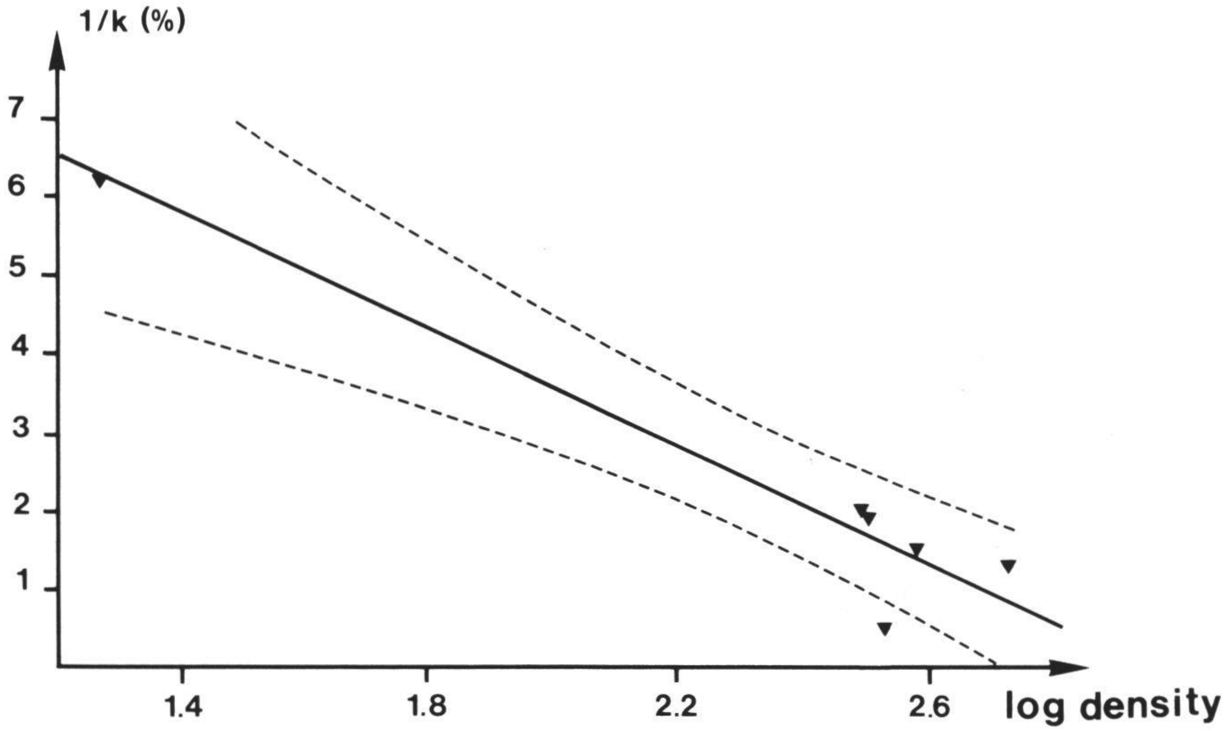

Fig. 4: Regression line of the normalized clumping index (1/k) on logarithm of the density with the 95% CL. y = a + b log x (a = 10.77; b = – 3.66; r^2 = 0.93; n = 6).

3.3. Growth in length and in weight

The experimental data (length and weight) were fitted to an exponential growth law:

$$L_t = L_o \exp([G_l/100]\ t)$$

and

$$W_t = W_o \exp([G_w/100]\ t)$$

where L_o and W_o = mean initial length and weight, L_t and W_t = mean length and weight after an interval of time t (in days). The instantaneous growth rates G_l and G_w were estimated by regression analysis (Fig. 5a and 5b) and gave respectively: $G_l = 0.67\%$ length/day and $G_w = 1.50\%$ dry weight/day for the population investigated.

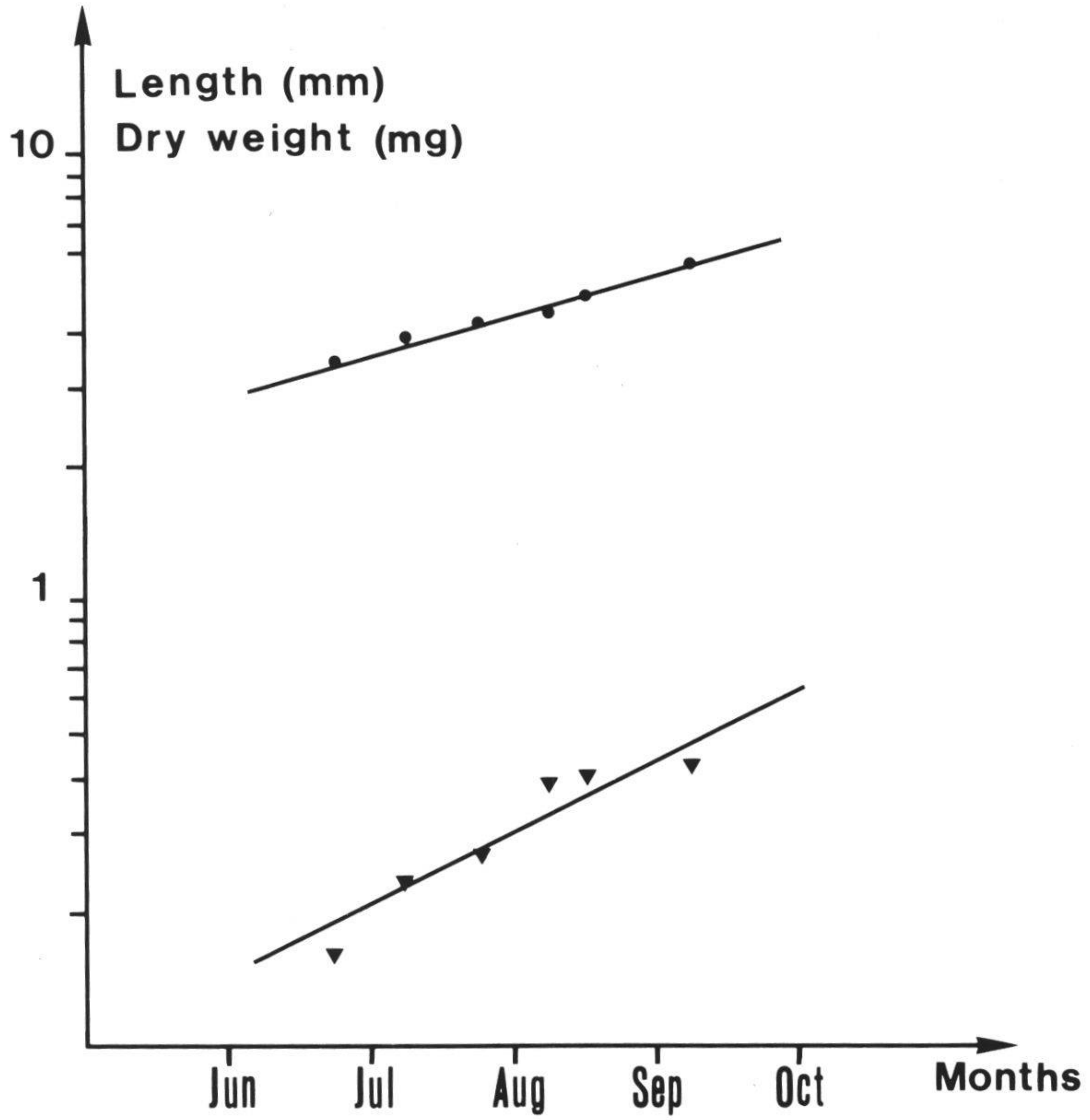

Fig. 5: Growth of *E. ignita*: a) geometric mean length of the larvae for each sample (●) and regression line: $\log_e y = 0.0067\ x + 0.061$ ($r^2 = 0.96$; n = 6). b) arithmetic mean dry weight of the larvae for each sample (▼) and regression line: $\log_e y = 0.015\ x - 4.384$ ($r^2 = 0.85$; n = 6).

3.4. Production

The estimation of the annual production for the species *E. ignita* was calculated using the formule of RICKER (1946):

$$P = \overline{B}\, G_w$$

where P = production, $\overline{B}$ = arithmetic mean population biomass (dry weight in mg) of two consecutive samples and G_w = growth rate between the two consecutive samples. The estimated annual production was equal to 870 mg/m^2. The P/$\overline{B}$ ratio was equal to 9.25 (Table 3).

T (°C)	G_l (%)	G_w (%)	$\overline{B}$ (mg/m^2)	P (mg/m^2)	P/$\overline{B}$	References
7.8-20.0	0.67	1.50	94	870	9.25	Present study
9.7-15.1	3.26	-	927-1073	3800-4400	4.10	WELTON et al. (1982)
-	-	-	96.00	635.00	6.62	BROOKER & MORRIS (1978)
-	-	-	104.00	1147	11.03	ZELINKA (1980)
-	-	-	83	584	7.00	RUSSEV & DOSHKINOVA (1985)
-	-	-	26	1230-1360	4.90	NEVEU & VIGNES (1979)

Table 3: Comparative data concerning the temperature range (T) of the period investigated, the growth rate in length (G_l), the growth rate in weight (G_w), the mean biomass ($\overline{B}$), the production (P) of the species, the P/$\overline{B}$ ratio and the references of the corresponding studies.

4. Discussion

The life cycle of *E. ignita* has been studied by various authors throughout Europe: MACAN (1957) in England, MAITLAND (1965) in Scotland, HYNES (1961) and BROOKER & MORRIS (1978) in Wales, LANDA (1968) in Central Europe, SOWA (1979) in Poland, JAZDZEWSKA (1980) in France, ROSSILLON (1986a) in Belgium. They all found a univoltine development with a rapid growth during the summer months. Nevertheless, larvae were recorded from April to September. ELLIOTT (1978) showed experimentally that the embryonic growth of *E. ignita* is mainly controlled by temperature, which affects the life cycle of the species. Under mild thermic conditions, BASS (1976) in southern England, THIBAULT (1971) and NEVEU et al. (1979) in southern France studied natural populations with a rather different flight period and with larvae present during all the year.

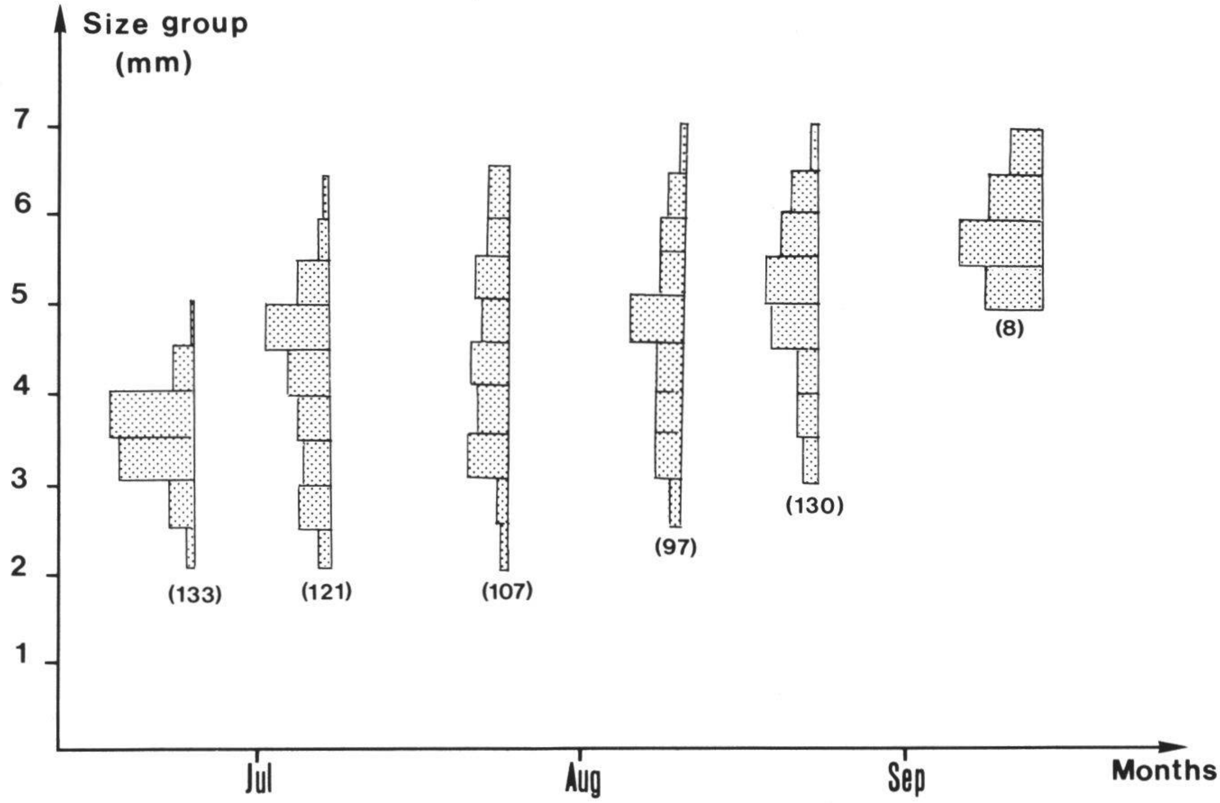

Fig. 6: Size distribution (in %) of the larvae of *E. ignita* for each sample. n = number of measured larvae.

Like in our investigations, the mentioned authors also collected some larvae during autumn months. The size distribution of the larvae collected in the present study is shown in Fig. 6. Each sample exhibited a large range of size variability. As a consequence, the population studied was not composed of a definite cohort of individuals, appearing after a short hatching period. This fact (also recorded by BASS, 1976, and JAZDZEWSKA, 1980), explained the presence of small larvae, sampled during autumn months.

The type of spatial distribution recorded for the species *E. ignita* was not related to the density of the natural population. The larvae always exhibited an aggregated pattern. Nevertheless, the degree of aggregation on the benthos presented a relationship with the population itself (Fig. 4). At low density, the aggregates were clearly recognizable (1/k high). In this situation, the larvae had enough spatial disponibility for an active and optimum positioning in the stream bed. When the population grew, the aggregates became bigger and fused together to build a more homogeneous spatial distribution (1/k low). This mechanism can reflect a certain intraspecific competition behaviour for space as the population grew. At high density, the new larvae can no longer colonize the already occupied «best» places of the biotope and must extend their niche. This adaptation was possible because *E. ignita* is mainly a clinger and a sprawler (ELLIOTT et al., 1988) which does not need specific substrate requirements (in contrast to the Heptageniidae: HEFTI et al., 1985).

Informations concerning quantitative growth rates of the species *E. ignita* are scarce. WELTON et al. (1982) studied the growth of a population in an experimental recirculating stream. The authors found a G_1 value of 3.26% length/day for monthly mean temperatures ranging from 9.7 to 15.1°C. This growth rate is significantly higher than our and it illustrates the optimum thermic and trophic conditions of chalk streams (where the study was done). The amplitudes of temperatures recorded in the present study are shown in Fig. 1. Half of the period investigated was outside the optimum thermic range applied in the experiment of WELTON et al. (1982). This fact and the absence of macrophytes on the substrate might be responsible for the relatively slow growth of the population studied.

Other estimates of the growth rates for species of the Ephemerellidae family are given below:

- in Europe: $G_l = 0.23$ to 1.37 and $G_w = 0.82$ to 3.60 for *E. major* KLAPALEK (ROSSILLON, 1986b);
- in North-America: $G_w = 1.18$ to 5.40 for *E. infrequens* MCDUNNOUGH and *E. inermis* EATON; $G_w = 2.52$ to 5.31 for *Drunella coloradensis* DODDS and *D. flavilinea* MCDUNNOUGH; $G_w = 1.00$ to 3.48 for *D. doddsi* NEEDHAM; $G_w = 0.81$ to 1.29 for *D. spinifera* NEEDHAM; $G_w = 2.41$ to 3.14 for *D. pelosa* MAYO and $G_w = 3.74$ to 5.44 for *Serratella tibialis* MCDUNNOUGH (HAWKINS, 1986).

The determinations of the biomass and of the annual production calculated in the present study were probably underestimated because the calculations did not involve the youngest larval stages (which were not sampled because of their small shape). Nevertheless, the obtained estimations are comparable with other studies (Table 3). The latter were made in different parts of Europe and were calculated after different methods. The highest values for the biomass and for the production of *E. ignita* have been recorded in the work of WELTON et al. (1981). They confirmed the optimum thermic and trophic conditions of the experiment and can probably be considered as maxima for natural populations of *E. ignita*.

5. Acknowledgments

We are grateful to Prof. G. Lampel for critical comments which helped to improve the manuscript. We further would like to thank Mrs D. Janke for her help during the preparation of the paper and Dr. F. Noël for the quantitative determination of the dissolved organic carbon. The study was supported by the Swiss National Science Foundation grant no 3.506–0.86.

6. Summary – Zusammenfassung – Résumé

Summary

The study deals with some ecological aspects of the species *Ephemerella ignita* (PODA) (Ephemeroptera, Insecta) in a prealpine calcareous stream of the Canton of Fribourg, Switzerland. The life cycle as well as a quantitative analysis of the spatial distribution, the growth and the production of the larvae of *E. ignita* are presented. The quantitative data are compared with other studies.

Zusammenfassung

Die Arbeit beschäftigt sich mit gewissen ökologischen Aspekten von *Ephemerella ignita* (PODA) (Ephemeroptera, Insecta) in einem voralpinen kalkhaltigen Bach aus dem Kanton Freiburg, Schweiz. Der Lebenszyklus sowie eine quantitative Analyse der räumlichen Verteilung, des Wachstums und der Produktion von *E. ignita*-Larven werden vorgestellt. Diese quantitativen Daten werden mit anderen Studien verglichen.

Résumé

Le travail présente quelques aspects de l'écologie d'*Ephemerella ignita* (PODA) (Ephemeroptera, Insecta) dans un cours d'eau calcaire préalpin du canton de Fribourg, Suisse. Le cycle vital ainsi qu'une étude quantitative de la distribution spatiale, de la croissance et de la production des larves d'*E. ignita* sont proposés. Les données quantitatives obtenues dans le cadre de ce travail sont comparées avec celles d'autres travaux.

7. References

BASS, J.A.B.: Studies on *Ephemerella ignita* (PODA) in a chalk stream in England. Hydrobiologia *49,* 117–121 (1976).

BROOKER, M.P., & MORRIS, D.L.: Production of two species of Ephemeroptera (*Ephemerella ignita* PODA and *Rhithrogena semicolorata* CURTIS) in the upper reaches of the R. Wye, Wales. Verh. Internat. Verein. Limnol. *20,* 2600–2604 (1978).

ELLIOTT, J.M.: Effect of temperature on the hatching time of eggs of *Ephemerella ignita* (PODA) (Ephemeroptera: Ephemerellidae). Freshwat. Biol. *8,* 51–58 (1978).

– – : Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biol. Assoc., Sci. Publ. N° *25,* third ed.(1983).

– – , HUMPESCH, U.H., & MACAN, T.T.: Larvae of the British Ephemeroptera, a key with ecological notes. Freshwater Biol. Assoc., Sci. Publ. Nº *49* (1988).

HAWKINS, P.C.: Variation in individual growth rates and population densities of ephemerellid mayflies. Ecology *67,* 1384–1395 (1986).

HEFTI, D., TOMKA, I., & ZURWERRA, A.: Recherche autoécologique sur les Heptageniidae (Ephemeroptera, Insecta). Bull. Soc. Entomol. Suisse *58,* 87–111 (1985).

HYNES, H.B.N.: The invertebrate fauna of a Welsh mountain stream. Arch. Hydrobiol. *57,* 344–388 (1961).

ILLIES, J., & BOTOSANEANU, L.: Problèmes et méthodes de la classification et de la zonation écologique des eaux courantes, considérées surtout du point de vue faunistique. Mitt. Internat. Ver. theor. angew. Limnol. *12,* 1–57 (1963).

JAZDZEWSKA, T.: Structure et fonctionnement des écosystèmes du Haut-Rhône français. 7. Le cycle vital d'*Ephemerella ignita* PODA 1761 (Ephemerellidae, Ephemeroptera) dans le Rhône lyonnais. Bull. Ecol. *11,* 33–43 (1980).

LANDA, V.: Developmental cycles of Central European Ephemeroptera and their interrelations. Acta entomol. bohemoslov. *65,* 276–285 (1968).

MACAN, T.T.: The life histories and migrations of the Ephemeroptera in a stony stream. Trans. Soc. British Entomol. *12 (5),* 129–156 (1957).

– – : A key to the nymphs of the British species of Ephemeroptera, with notes on their ecology. Freshwater Biol. Assoc., Sci. Publi. *20* (1970).

MAITLAND, P.S.: The distribution, life cycle and predators of *Ephemerella ignita* (PODA) in the River Endrick, Scotland. Oikos *16,* 48–57 (1965).

NEVEU, A., LAPCHIN, L. & VIGNES, J.C.: Le macrobenthos de la basse Nivelle, petit fleuve côtier des Pyrénées-Atlantiques. Ann. Zool. Ecol. Anim. *11,* 85–111 (1979).

NOËL, F., & FASEL, D.: Etude de l'état sanitaire des cours d'eau du canton de Fribourg. Bull. Soc. Frib. Sc. Nat. *74,* 1–332 (1985).

PUTHZ, P.: Ephemeroptera. In: Limnofauna Europaea (Ed. J. ILLIES), 256–263. Fischer: Stuttgart & New York 1978.

RICKER, W.E.: Production and utilization of fish populations. Ecological monographs *16,* 373–391 (1946).

ROSSILLON, D.: Life cycle of four Ephemeropteran species in a chalky stream. Pol. Arch. Hydrobiol. *33,* 21–31 (1986a).

– – : Life cycle, growth, mortality and production of *Ephemerella major* KLAPALEK (Ephemeroptera) in a trout stream in Belgium. Freshwater Biology *16,* 269–277 (1986b).

RUSSEV, B.K., & DOSHKINOVA, M.G.: On the development and productivity of mayfly larvae (Ephemeroptera, Insecta) in a stretch of the Iskar River. Hydrobiology *25,* 3–16 (1985).

SOWA, R.: Le développement des éphéméroptères de la rivière Dunajec aux environs de Pieniny. In: PASTERNAK, K., & SOWA, R. (Eds.): Proc. 2. Internat. Conference on Ephemeroptera, 125–131 (1979).

THIBAULT, M.: Le développement des éphéméroptères d'un ruisseau à truites des Pyrénées-Atlantiques, le Lissuraga. Ann. Limnol. *7,* 53–120 (1971).

WELTON, J.S., LADLE, M., & BASS, J.A.B.: Growth and production of five species of Ephemeroptera larvae from an experimental recirculating stream. Freshwater Biology *12,* 103–122 (1982).

ZELINKA, M.: Differences in the production of mayfly larvae in partial habitats of a barbel stream. Arch. Hydrobiol. *90,* 284–297 (1980).