Life cycle and growth of three species of Plecoptera in a Danish spring

TORBEN MOTH IVERSEN

Iversen, T. M.: Life cycle and growth of three species of Plecoptera in a Danish spring. Ent. Meddr, 46: 57–62. Copenhagen, Denmark 1978. ISSN 0013-8851.

In a helocrenous section of the spring Rold Kilde *Nemurella picteti* Klp. and *Leuctra hippopus* Kmp. were univoltine, and *Leuctra nigra* Ol. was semivoltine. Mean weight was estimated from log weight/log width of head capsule relationships. *N. picteti* had retarded growth during winter, *L. nigra* little or no retardation, and *L. hippopus* was unaffected by winter. The coexistence of the three species is discussed in relation to microdistribution, life cycle and growth pattern.

Torben Moth Iversen, Ferskvandsbiologisk Laboratorium, Helsingørsgade 51, DK 3400 Hillerød, Danmark.

Introduction

Plecoptera is a small systematic group with about 2000 species, but as they are important components of many running water communities, many studies have dealt with their biology and ecology (see Hynes, 1976 for references).

The Danish fauna contains 25 species (Kaiser, 1972), of which about ten species are common in the springs of Himmerland, Denmark. Aspects of their ecology have previously been dealt with by Thorup (1963, 1966, 1970) and Lindegaard, Thorup and Bahn (1975).

During a study of secondary production in a spring system with a high input of allochthonous organic matter, biological data on Plecoptera were collected. These data are reported here, as they were found to add to our present knowledge. The biomass and production of the total community will be dealt with in a separate paper.

Study area, material and methods

The investigation took place in a helocrenous section of the spring Rold Kilde, Denmark, described by Nielsen (1942), Thorup (1966) and Iversen (1973). In the study area the bottom was covered with soaked fallen beech (*Fagus sylvatica* L.) leaves with a few patches of moss and higher vegetation.

Temperature recorded on two maximum-minimum thermometers, placed respectively 5 m (Station 1) and 10 m (Station 2) from the edge of the area, showed small yearly fluctuations being greater at Station 2 than at Station 1 (Fig. 1).

Eleven quantitative samples were randomly taken monthly from September 1971 until September 1972 with a box (30 × 40 cm). The substrate within the box was removed to a depth of about five cm and preserved in 4 % formalin. After being washed in a sieve (mesh size 0.21 mm) the animals were sorted manually.

Seven taxa were found, but only three species were of quantitative importance (Table 1).

The width of the head capsules was measured, using an eyepiece micrometer at × 40 or × 80 magnification, and size-frequency diagrams were established. When total number of a species exceeded one hundred, only part of the material was analysed by taking random subsamples.

In order to avoid the weight loss due to formalin preservation a relationship was established between fresh dry weight and width of head capsule (Table 2). The animals were measured alive, killed by drying at 60°C and weighed after having reached constant weight. Mean weight was estimated by means of these relationships and the size-frequency diagrams.

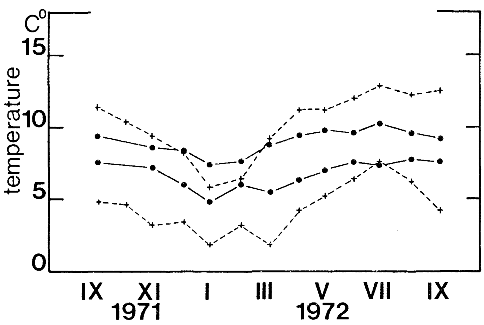

Fig. 1. Maximum-minimum temperatures recorded in the sampling area about 5 m from the edge (Station 1, complete line) and about 10 m from the edge (Station 2, dotted line).

Results

1. *Nemurella picteti* Klp.

The life cycle took one year (Fig. 2). Emergence of adults occurred mainly in May, but emergence was prolonged, and some large nymphs were still found at the beginning of August. The first small specimens of the new generation appeared at the beginning of August. Throughout its life cycle there was a wide variation in size classes. Adults have been found in Rold Kilde from April until September (Thorup, personal communication).

Growth was retarded during the winter (Fig. 5). The relatively slow increase in mean weight in the autumn may be due to hatching of eggs from late emerging adults. Thorup (1963) reported a similar pattern of growth in two Danish springs, whereas Brinck (1949) in a Swedish spring found no influence of winter. In the laboratory Khoo (1964) found no moulting during winter at 3–4°C.

In the laboratory the period between emergence and egglaying is 5–14 days (Khoo 1964), and the mean egg incubation period is 12–80 days, depending on temperature (Brittain, 1978).

Table 1. Numbers of Plecoptera collected in Rold Kilde, 1972–72.

	Numbers	%
Protonemura hrabei Raus	1	0.0
Amphinemura sp.	28	0.1
Nemurella picteti Klp.	7436	36.1
Nemoura flexuosa Aub.	67	0.3
Leuctra fusca L. (?)	5	0.0
Leuctra hippopus Kmp.	5393	26.2
Leuctra nigra Ol.	7622	37.1

These data fit well with the present interpretation of the life cycle, and confirm that *N. picteti* is univoltine in temperate regions. This has also been reported by Hynes (1941), Brinck (1949), Thorup (1963), Khoo (1964) and Lavandier & Dumas (1971). In a Norwegian mountain pool Brittain (1974, 1978) reported a two year life cycle of *N. picteti* due to strongly retarded growth during winter.

2. *Leuctra hippopus* Kmp.

The life cycle took one year (Fig. 3). Emergence of adults occurred mainly in March, but some large nymphs were still found in May. The first small specimens appeared at the end of June. Adults have been found in Rold Kilde from March until July (Thorup, personal communication).

The growth rate was very rapid, and there was no indication of retardation during winter (Fig. 5). The final mean size was reached about January–February. The same pattern of growth was reported by Hynes (1941), Brinck (1949), Thorup (1963) and Lavandier & Dumas (1971), whereas Svensson (1966), Elliott (1967) and Minshall (1969) all reported decreased growth during winter. In the laboratory Khoo (1964) found a delayed moulting rate during autumn

Table 2. The ralationship between the width of head capsule in mm (x) and the dry weight in mg (w) of three species of Plecoptera from Rold Kilde. Numbers (N), the regression equation and the standard deviation of a and b are given.

Species	N	a b	s_a	s_b
Nemurella picteti	42	$\log w = -0.0143 + 3.834 \log x$	0.023	0.223
Leuctra nigra	34	$\log w = -0.0480 + 3.233 \log x$	0.018	0.176
Leuctra hippopus	50	$\log w = -0.0822 + 3.742 \log x$	0.022	0.228

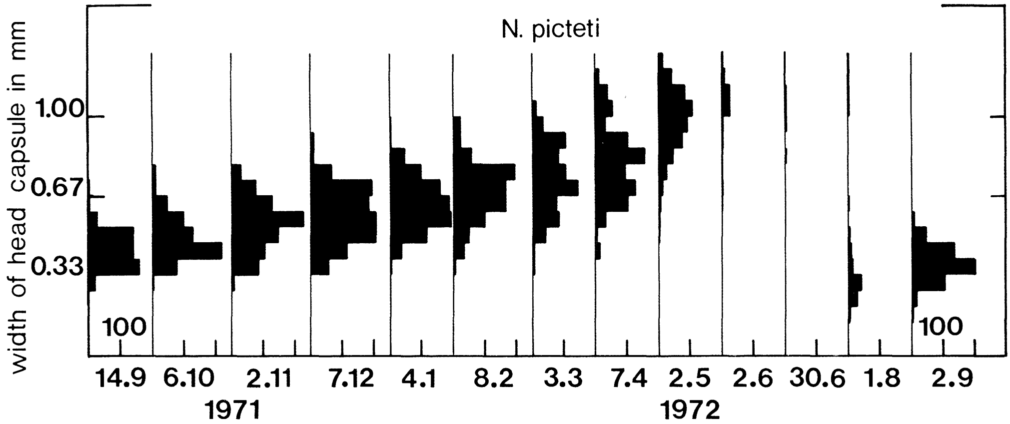

Fig. 2. Size frequency diagram of *Nemurella picteti* from Rold Kilde. The number of nymphs in each sample is indicated by the scale on the x axis.

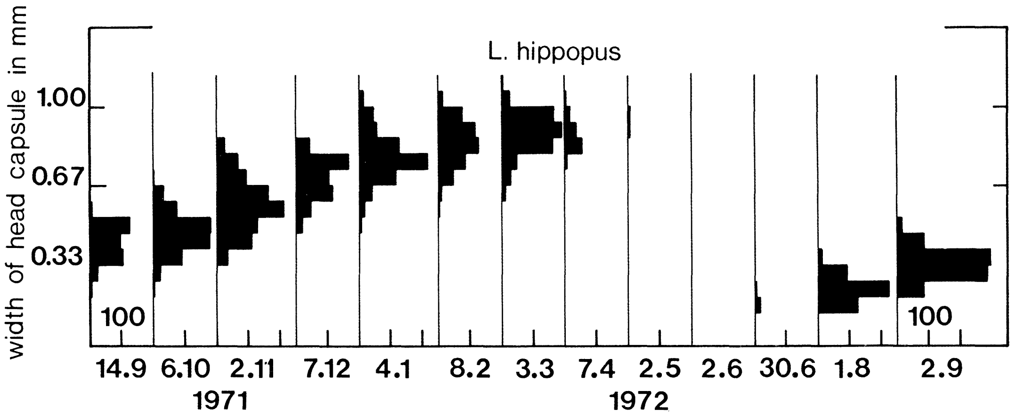

Fig. 3. Size-frequency diagram of *Leuctra hippopus* from Rold Kilde. The number of nymphs in each sample is indicated by the scale on the x axis.

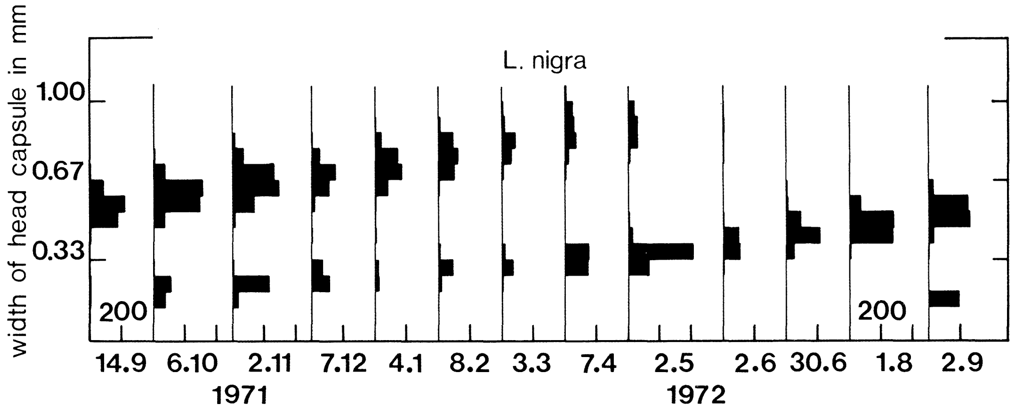

Fig. 4. Size-frequency diagram of *Leuctra nigra* from Rold Kilde. The number of nymphs in each sample is indicated by the scale on the x axis.

and winter and Lillehammer (1975) was able to shorten the life cycle significantly by rearing the nymphs at a constant temperature of 8°C.

Khoo (1964) found the period between emergence and egglaying to be 11–18 days and the incubation period to be 33–36 days at 9.5°C. Lillehammer (1975) reported an incubation period of 28–43 days at 4°C. These data fit well with the present interpretation of a one year life cycle for *L. hippopus,* which has also been reported by previous investigators.

3. *Leuctra nigra* Ol.

The life cycle of this species took two years (Fig. 4). Throughout the autumn, winter and spring the two generations could easily be separated in the size-frequency diagram. The major emergence took place in May, and the new generation appeared in the samples in September. Adults have been found in Rold Kilde from April to August (Thorup, personal communication).

The growth rate was slow compared to that of *L. hippopus,* although both generations showed little or no indication of growth retardation during winter (Fig. 5). In contrast Brinck (1949) found decreased growth in a Swedish spring.

Hynes (1941) and Brinck (1949) both stated that the life cycle of *L. nigra* took one year. Lillehammer (1976) reported an incubation time of 28 days at 4–12°C and 90 days at 4°C, and his data on nymphal growth may indicate a two year life cycle. Khoo (1964) found the period between emergence and egglaying to be 18 days, and the incubation period to be 38 days at 9.5°C. From observation of flight periods he suggested a two year life cycle, which was also indicated by his field study of nymphs. The present study confirms the suggestion by Khoo, and it may be concluded that *L. nigra* has a two year life cycle.

Discussion

Most studies of nymphal growth of Plecoptera have been performed by establishing size-frequency diagrams from measurements of total length or width of head capsule (e. g. Hynes, 1941, Brinck, 1949). As growth is geometrical, the growth of small nymphs may easily be underestimated. Therefore the present method using dry weights is recommended, although it is realised that growth in terms of weight increase is continuous and not confined to moulting. As number of instars is high, the error introduced is considered insignificant.

From laboratory studies of 14 species of Plecoptera Khoo (1964) stated, that "there is generally a retardation during winter, the extent to which the nymphs are affected is quite variable between species". This statement is confirmed by the variable growth pattern of *L. hippopus* in different geographical areas. The unfavourable

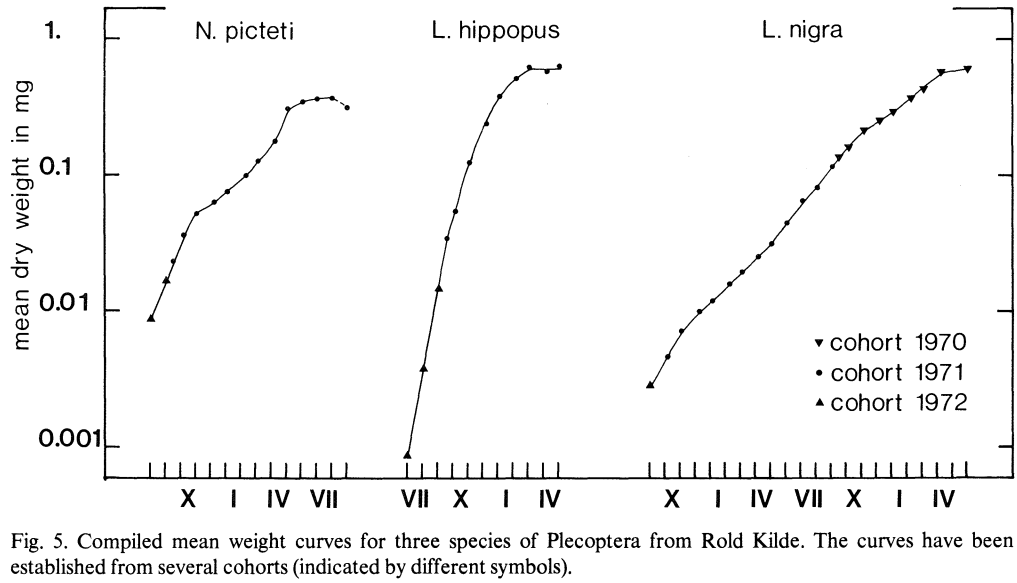

Fig. 5. Compiled mean weight curves for three species of Plecoptera from Rold Kilde. The curves have been established from several cohorts (indicated by different symbols).

effect of temperature may even prolong the life cycle of *Nemoura cinerea* Retz. and *Nemurella picteti* to two years in mountain habitats, although poor food conditions may also be involved (Brittain, 1974, 1978). A variable life cycle has also been shown for *Leuctra ferrugenea* (Walker) in Canada (Harper, 1973). Also Lillehammer (1975) has stressed the importance of temperature and food for nymphal growth.

In temperate regions the normal pattern of life cycle within the Nemouridae and Leuctridae is univoltine. Khoo (1964) suggested a two year life cycle for *Nemoura cinerea* and *Leuctra nigra*. The latter has been confirmed by the present results, whereas there is no evidence that the development of *N. cinerea* takes more than one year in Denmark (Bengtson, 1972, F. S. Hansen, personal communication). *L. nigra* appears to be the only Danish species which is not univoltine.

In the study area the three species coexisted in about the same abundance. *L. nigra* clearly differed in its life cycle, and furthermore it was only found in high numbers at the edge of the area, where the soaked beech leaves were underlain by an accumulation of fine particulate organic matter derived from the leaves.

L. hippopus and *N. picteti* were found all over the study area, and differences in their microdistribution might be concealed by the large size of the samples. Although both species were univoltine, their flight period, growth pattern as well as occurrence of maximum biomass were clearly different. It can therefore be concluded that the three species have specific roles in the spring invertebrate community.

Acknowledgements

The author thanks stud. scient. F. S. Hansen, Dr. E. W. Kaiser, Dr. Jens Thorup and Dr. John E. Brittain for valuable comments, the latter also for correcting the language.

References

Bengtson, J., 1972: Vækst og livscyklus hos *Nemoura cinerea* (Retz.) (Plecoptera). – Flora og Fauna 78: 97–101.

Brinck, P., 1949: Studies on Swedish stoneflies. – Opusc. ent., Suppl. 11: 1–250.

Brittain, J. E., 1974: Studies on the lentic Ephemeroptera and Plecoptera of Southern Norway. – Norsk ent. Tidsskr. 21: 135–154.

Brittain, J. E., 1978: Semivoltinism in a mountain population of *Nemurella picteti* (Plecoptera). – Oikos in press.

Elliott, J. M., 1967: The life histories and drifting of the Plecoptera and Ephemeroptera in a Dartmoor stream. – J. Anim. Ecol. 36: 343–362.

Harper, P. P., 1973: Life histories of Nemouridae and Leuctridae in Southern Ontario (Plecoptera). – Hydrobiologia 41: 309–356.

Hynes, H. B. N., 1941: The taxonomy and ecology of the nymphs of the British Plecoptera with notes on the adults and eggs. – Trans. R. ent. Soc. Lond. (A) 91: 459–557.

Hynes, H. B. N., 1976: Biology of Plecoptera. – Ann. Rev. ent. 21: 135–153.

Iversen, T. M., 1973: Life cycle and growth of *Sericostoma personatum* Spence (Trichoptera, Sericostomatidae) in a Danish spring. – Ent. scand. 4: 323–327.

Kaiser, E. W., 1972: Status over de danske slørvinger (Plecoptera). – In Status over den danske dyreverden 98–100. Zool. Mus., København.

Khoo, S. G., 1964: Studies on the biology of stoneflies. – 161 pp. – Unpubl. Ph. D. Thesis, Univ. Liverpool.

Lavandier, P. & Dumas, J., 1971: Cycles de développement de quelques invertébrés benthiques dans des ruisseaus des Pyrénées centrales. – Annls Limnol. 7: 157–172.

Lillehammer, A., 1975: Norwegian stoneflies IV. Laboratory studies on ecological factors influencing distribution. – Norw. J. Ent. 22: 99–108.

Lillehammer, A., 1976: Norwegian stoneflies V. Variations in morphological characters compared to differences in ecological factors. – Norw. J. Ent. 23: 161–172.

Lindegaard, C., Thorup, J. & Bahn, M., 1975: The invertebrate fauna of the moss carpet in the Danish spring Ravnkilde and its seasonal, vertical, and horizontal distribution. – Arch. Hydrobiol. 75: 109–139.

Minshall, G. W., 1969: The Plecoptera of a Headwater stream (Gaitscale Gill, English Lake District). – Arch. Hydrobiol. 65: 494–514.

Nielsen, A., 1942: Über die Entwicklung und Biologie der Trichopteren. – Arch. Hydrobiol. Suppl. 17: 255–631.

Svensson, P.-C., 1966: Growth of nymphs of stream living stoneflies (Plecoptera) in northern Sweden. – Oikos 17: 197–206.

Thorup, J., 1963: Growth and life-cycle of invertebrates from Danish springs. – Hydrobiologia 22: 55–84.

Thorup, J., 1966: Substrate type and its value as a basis for the delimination of bottom fauna communicaties in running waters. – Spec. Publs. Pymatuning Lab. Fld. Biol. 4: 59–74.

Thorup, J., 1970: The influence of a short-termed flood on a springbrook community. – Arch. Hydrobiol. 66: 447–457.

Ulfstrand, S., 1968: Life cycles of benthic insects in Lapland streams (Ephemeroptera, Plecoptera, Trichoptera, Diptera, Simuliidae). - Oikos 19: 167–190.

Sammendrag

Livscyklus og vækst hos tre arter af Plecoptera i en dansk kilde

Nærværende undersøgelse foretoges i Rold Kilde i Himmerland i 1971–72 og er et led i en undersøgelse af sekundærproduktionen og stofomsætningen i et system baseret på allochthont (tilført) organisk materiale.

Undersøgelsesområdet er dækket af nedfaldne bøgeblade, og der er en spredt bevoksning af mos og højere planter. Temperaturen varierede mellem 2,4°C og 13,6°C (Fig. 1).

Af de fundne 7 slørvingearter/slægter udgjorde *Nemurella picteti* Klp., *Leuctra hippopus* Kmp. og *Leuctra nigra* Ol. henholdsvis 36 %, 26 % og 37 % (Tabel 1).

Materialet er indsamlet ved månedlige kvantitative prøvetagninger over et år. Arternes livscyklus undersøgtes ved opstilling af størrelsesfordelingsdiagrammer baseret på måling af hovedkapselbredden. Gennemsnitsvægten beregnedes udfra størrelsesfordelingen ved hjælp af funktionen log tørvægt/log hovedkapselbredde (Tabel 2). Denne metode må anbefales fremfor at benytte størrelsesfordelingsdiagrammer. Da væksten er geometrisk, vil væksten i de tidlige stadier let blive undervurderet ved sidstnævnte metode.

Nemurella picteti var enårig (Fig. 2). Klækningen af voksne fandt sted i maj, men der var stor spredning. De første nye nymfer fandtes i august. Væksten var nedsat om vinteren (Fig. 5). Disse iagttagelser er i overensstemmelse med angivelser i litteraturen.

Leuctra hippopus var enårig (Fig. 3). Klækning af voksne fandt sted i marts, og de første nye nymfer fandtes i slutningen af juni. Væksthastigheden var høj uden retardering om vinteren (Fig. 5). Arten er enårig i hele sit udbredelsesområde, og væksten kan være nedsat, hvis temperaturen om efteråret er meget lav.

Leuctra nigra var to år om at fuldføre sin udvikling (Fig. 4). Klækning af voksne fandt sted i maj, og den nye generation viste sig i september. Væksten var relativ langsom (Fig. 5) med ringe eller ingen retardering om vinteren. Meget få undersøgelser er foretaget af denne art, og udfra laboratorieforsøg var det formodet, at den kunne være toårig.

Livscyklus hos familierne Nemouridae og Leuctridae er normalt enårig i tempererede regioner, og *L. nigra* er givetvis den eneste danske art med anderledes livscyklus. Hos alle slørvinger nedsættes væksten ved lave temperaturer, men der er stor forskel mellem arterne. Lave efterårs- og vintertemperaturer medfører forlængelse af livscyklus til to år hos f. eks. *Nemoura cinerea* og *Nemurella picteti* i det norske højfjeld. Fødebegrænsning kan muligvis være medvirkende.

L. nigra adskiller sig klart fra de to øvrige talrige arter i undersøgelsesområdet ved sin livscyklus. Desuden fandtes den kun talrigt, hvor substratet bestod af akkumulationer af fine bladrester. *L. hippopus* og *N. picteti* var begge enårige, men adskilte sig klart med hensyn til flyvetid, vækstmønster og forekomst af maksimumbiomasse. De tre arter synes derfor at have hver sin funktion i systemet.