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# Life Cycles and Emergence of Ephemeroptera and Plecoptera from Myrkdalsvatn, an Oligotrophic Lake in Western Norway

by

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Comparative data are presented on nymphal growth and adult emergence for *Nemoura avicularis*, *N. cinerea (Plecoptera)*, *Siphlonurus aestivalis*, *S. lacustris* and *Leptophlebia vespertina (Ephemeroptera)* from lake Myrkdalsvatn, western Norway. These species are all univoltine in Myrkdalsvatn. However, they show different nymphal growth patterns and emergence periods. The timing of emergence in Plecoptera was largely determined by water temperature, and in the Ephemeroptera by changes in both water temperature and cloud cover.

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## INTRODUCTION

During the course of an ecological investigation of the benthic fauna in lake Myrkdalsvatn, a part of the Voss river system in western Norway, the life cycles and emergence of the most abundant Ephemeroptera and Plecoptera were examined. There are no previous data on the life cycles and emergence of Ephemeroptera and Plecoptera from lentic habitats in this part of Scandinavia. This study enables comparison with the extensive data from the subalpine Norwegian lake, Øvre Heimdalsvatn, (e.g. Brittain & Lillehammer, 1978; Brittain, 1979) which has a much shorter ice free period, but is not subject to the large fluctuations in water level associated with periods of heavy rainfall which characterize Myrkdalsvatn.

The effect of temperature on growth and emergence in Ephemeroptera and Plecoptera has received much attention (see Brittain, 1982; Ward & Stanford, 1982). Irradiance, photoperiod, water level fluctuations, wind and humidity have also been mentioned as regulating emergence. Many of these environmental factors interact and it is often difficult to assess their individual effects.

## HABITAT DESCRIPTION

The lake Myrkdalsvatn (60°49′N, 6°28′E, UTM ref. 626447) is situated 25 km north of Voss at 230 m a.s.l., and forms part of the Voss river system of Western Norway (Fig. 1). The lake has a surface area of 1.66 $km^2$ and a maximum depth of 107 m. Myrkdalsvatn is oligotrophic ($k_{18}$: 7-20 μs $cm^{-1}$, $Ca^{++}$: 0.7-1.1 mg $l^{-1}$, pH: 5.9-6.4), dimictic and typified by its rapid flow-through rate. The lake is surrounded by mountains whose slopes reach down to the lake, especially along the north-eastern side. The littoral zone is narrow and due to rapid, usually short-term, fluctuations in water level it is stony with few aquatic macrophytes. A major part of the organic matter in the lake is of terrestrial origin. Surface water temperatures reach a maximum of about 23°C during July and from late November until mid-May the lake is ice-covered.

## MATERIAL AND METHODS

The upper stony littoral of Myrkdalsvatn was sampled at monthly intervals during the ice-free periods of 1977 and 1978. Benthos samples were taken at 15 stations (Fig. 1), with a hand net (mesh size 300 μm) using the kick method and by picking up stones from the lake bottom (Hynes, 1961; Macan & Maudsley, 1968; Brittain & Lillehammer, 1978). The net contents were sorted in a field laboratory and preserved in 3% formalin. Nymphs of Ephemeroptera and Plecoptera were measured from the front of the head to the base of the cerci to the nearest 0.5 mm. Emergence along one meter of shoreline was recorded daily using box-type emergence traps of 1 $m^3$ (Brittain & Lillehammer, 1978). Four traps were in operation during 1977 and a control trap was also set up at one of these sites during 1978 (Fig. 1). All emerging adults were preserved in 70% ethanol and subsequently identified to species, sexed and counted. Water level, air temperature and water temperature at a depth of 50 cm were measured daily in the vicinity of the emergence traps. Weather conditions, notably the degree of cloud cover, were also noted.

## RESULTS

The following plecopteran species were recorded from Myrkdalsvatn: *Siphonoperla burmeisteri* (Pictet), *Brachyptera risi* (Morton), *Amphinemura sulcicollis* (Stephens), *Nemoura avicularis* Morton, *N. cinerea* (Retzius), *Nemurella picetii* Klapálek, *Protonemura meyeri* (Pictet), *Capnia pygmaea* (Zet-

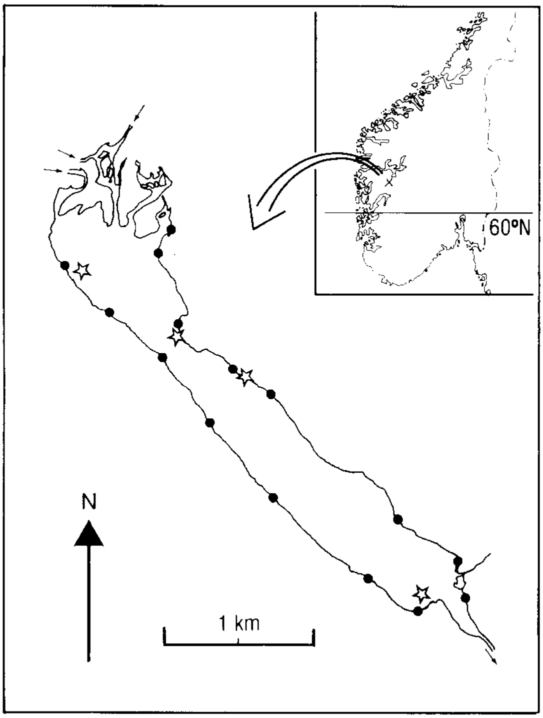



Fig. 1. Lake Myrkdalsvatn, western Norway, with the location of the sampling stations (dots) and emergence traps (stars).

terstedt), *Leuctra fusca* (Linnaeus), and *L. nigra* (Olivier). *N. avicularis* was the most abundant and constituted 67% of the Plecoptera taken in the benthic samples and 87% of those in the emergence traps. *N. cinerea* was also common in benthic samples, but most other species of Plecoptera were uncommon and only recorded rarely from the emergence traps.

*N. avicularis* and *N. cinerea* were both univoltine in Myrkdalsvatn. The two species showed differences in life cycle timing (Fig. 2). Nymphs of both species first appeared in collections during August, but the nymphs of *N. avicularis* were larger on account of their earlier hatching. Growth of both species continued throughout the winter and the nymphs of *N. avicularis* were almost fully grown by ice-break.

The emergence of *N. avicularis* started soon after ice-break in the middle of May, while *N. cinerea* emerged in late June (Fig. 2). In 1977 the main emergence period of *N. avicularis* was at the end of May and the beginning of June. The last emerging adults were taken on 20 June (Fig. 3). Although the number of *N. avicularis* trapped in 1978 may be underestimated due to difficulties in using emergence traps during the spring spate this year, the main emergence period was clearly earlier than in 1977 (Fig. 4).

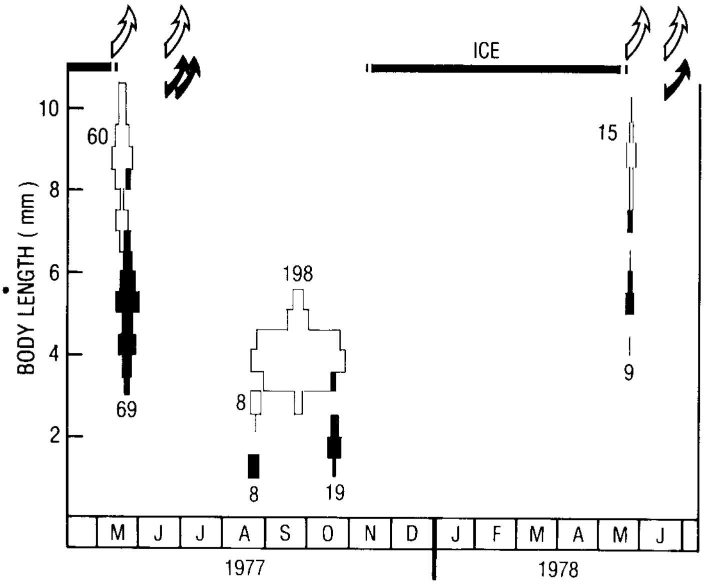


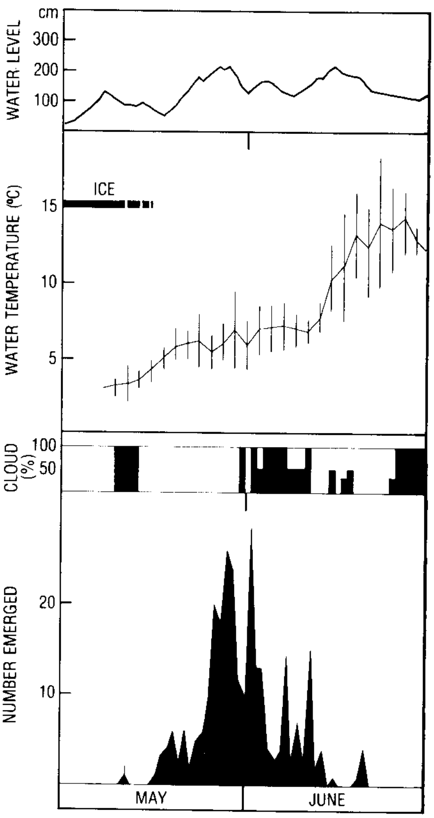

Fig. 2. Nymphal size distribution of *N. cinerea* (shaded) and *N. avicularis* in Myrkdalsvatn during the ice free periods in 1977 and 1978. Arrows indicate emergence periods. The number of nymphs measured is also given.

After the emergence of *N. avicularis* in 1977, several minor species were recorded from the middle of June to the middle of July (Fig. 5). *P. meyeri* was the most common of these and constituted 4.2% of the total plecopteran specimens trapped in the ice-free period. During a period of one month in the middle of the summer no Plecoptera were recorded in the emergence traps until *L. fusca* started emerging on 19 August. This species emerged sporadically for 2½ months until 7 November.

The ephemeropteran species *Leptophlebia vespertina* (Linnaeus), *Siphlonurus lacustris* (Eaton), *S. aestivalis* (Eaton) and *Baetis rhodani* (Pictet) were recorded from Myrkdalsvatn. *L. vespertina* was numerically the dominant species and constituted 72% and 95% of the total Ephemeroptera in benthic samples and emergence traps respectively. *S. lacustris* was also common but *S. aestivalis* was only taken in small numbers. *B. rhodani* was only recorded in the emergence traps.

*S. lacustris*, *S. aestivalis* and *L. vespertina* were univoltine in Myrkdalsvatn. *S. lacustris* and *S. aestivalis* showed a similar differentiation in life cycle timing to the two *Nemoura* species (Fig. 6).

*Siphlonurus* nymphs already appeared in collections during late August and early September (Fig. 6). It was not possible to separate the two species at this stage. However, both species were probably present as the largest *S. lacustris* in



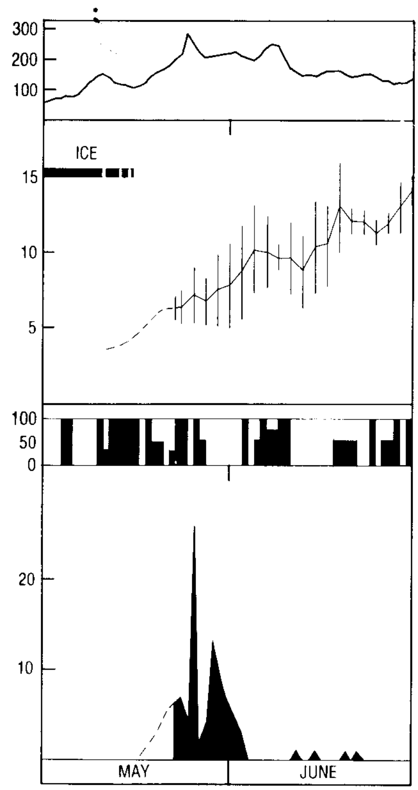




Fig. 3. (left) Relationship between daily emergence of *N. avicularis* from Myrkdalsvatn during 1977, daily maximum and minimum water temperature in the exposed zone, ice cover, daily water level fluctuations and daily cloudiness.

Fig. 4. (right) Relationship between daily emergence of *N. avicularis* from Myrkdalsvatn during 1978, daily maximum and minimum water temperature in the exposed zone, ice cover, daily water level fluctuations and daily cloudiness.

May were smaller than the largest *Siphlonurus* nymphs taken during October. After ice-break both species were clearly separated in size and both species grew rapidly prior to emergence.

The emergence of *S. aestivalis* lasted for only a few days during the first half of July (Fig. 7). *S. lacustris* emerged over a long period from 10 July to 14 October, with most emerging during August. A comparison of the emergence pattern of *S. lacustris* in 1977 with the water temperature, water level and cloudiness is given in Fig. 8.

*L. vespertina* nymphs first appeared in collections during September. Although growth continued throughout the winter the nymphs grew most rapidly during the autumn and between ice-break and emergence (Fig. 9). The emer-

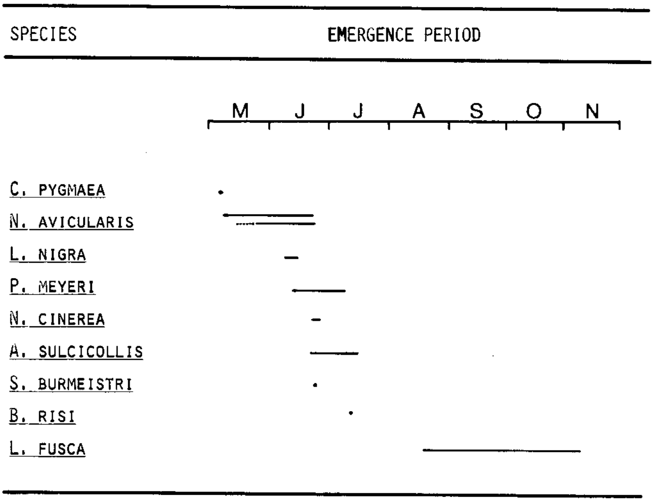



Fig. 5. Emergence periods of Plecoptera from Myrkdalsvatn during 1977 (also 1978 for *N. avicularis*).

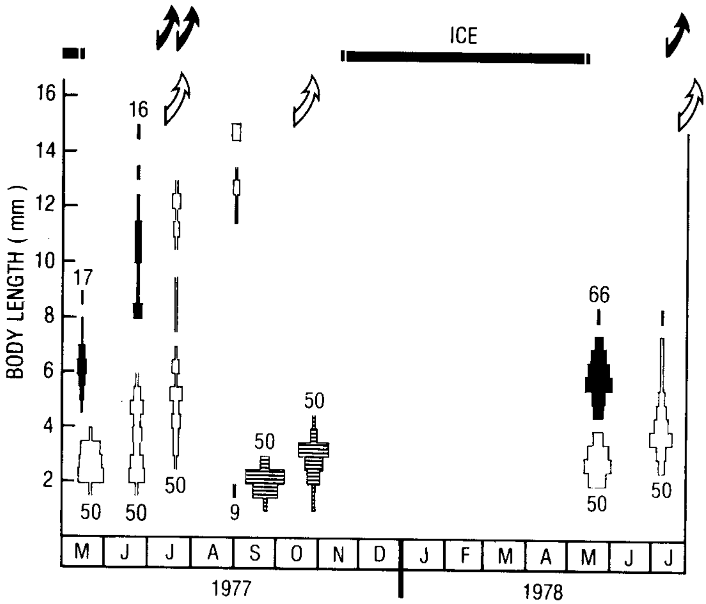



Fig. 6. Nymphal size distribution of *S. aestivalis* (shaded) and *S. lacustris* in Myrkdalsvatn during the ice free period in 1977 and 1978. Arrows indicate emergence periods. The number of nymphs measured is also given.

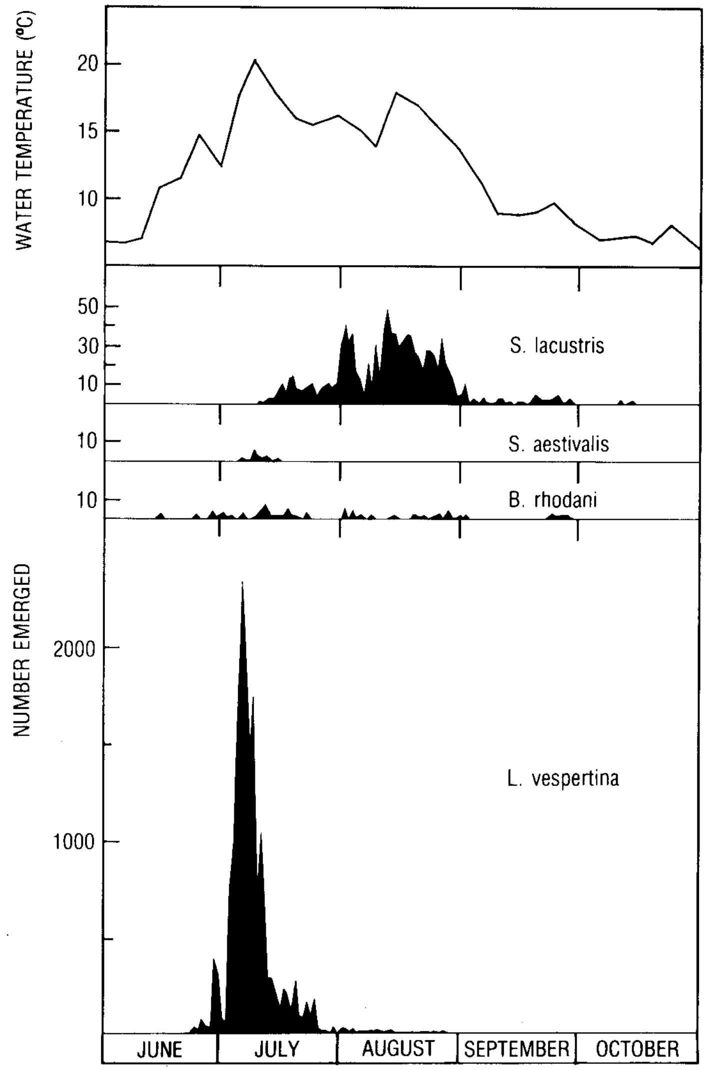



Fig. 7. Relationship between daily emergence of *L. vespertina, B. rhodani, S. aestivalis* and *S. lacustris* from Myrkdalsvatn in 1977 and water temperature in the exposed zone. Note the various scales for different species.

gence of *L. vespertina* in 1977 commenced in June reaching a peak at the beginning of July and continued with relatively low numbers from the end of July to late August (Fig. 7). Emergence of *L. vespertina* in 1977 and 1978 in relation to water, temperature level and cloud cover is given in Figs. 10 and 11. In 1977 the emergence pattern of *L. vespertina* at trap 1 was characterised by

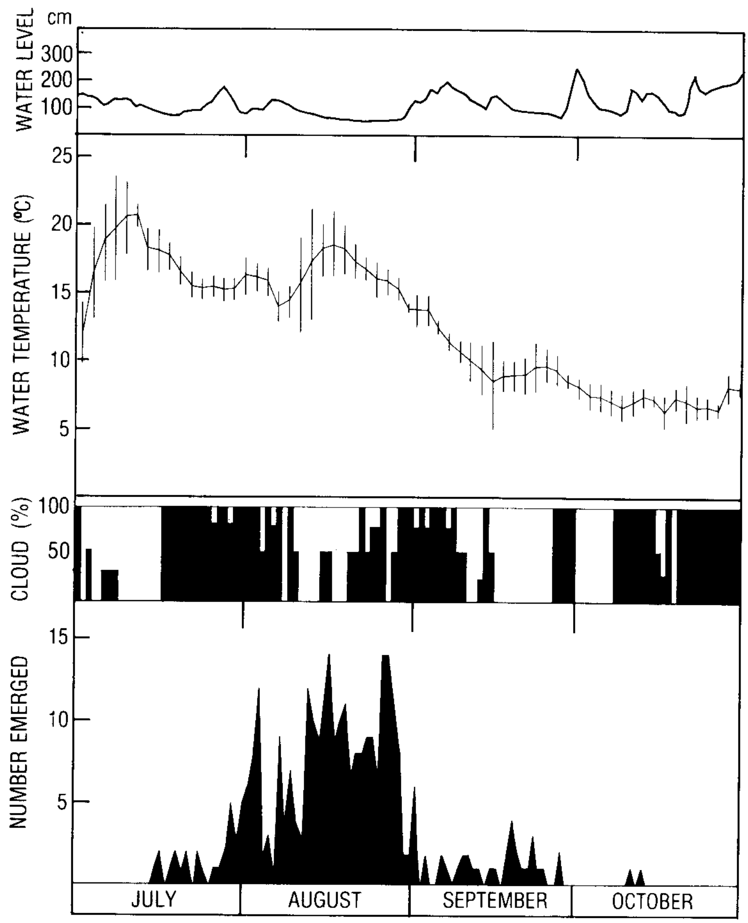



Fig. 8. Relationship between daily emergence of *S. lacustris* from Myrkdalsvatn during 1977, daily maximum and minimum water temperature in the exposed zone, daily water level fluctuations and daily cloudiness.

one peak in July, while the emergence in 1978 showed two peaks, one during the first half of July and one in late July and early August.

*B. rhodani* emerged sporadically for a long period during spring, summer and autumn until late September (Fig. 7). All specimens trapped were spent females.

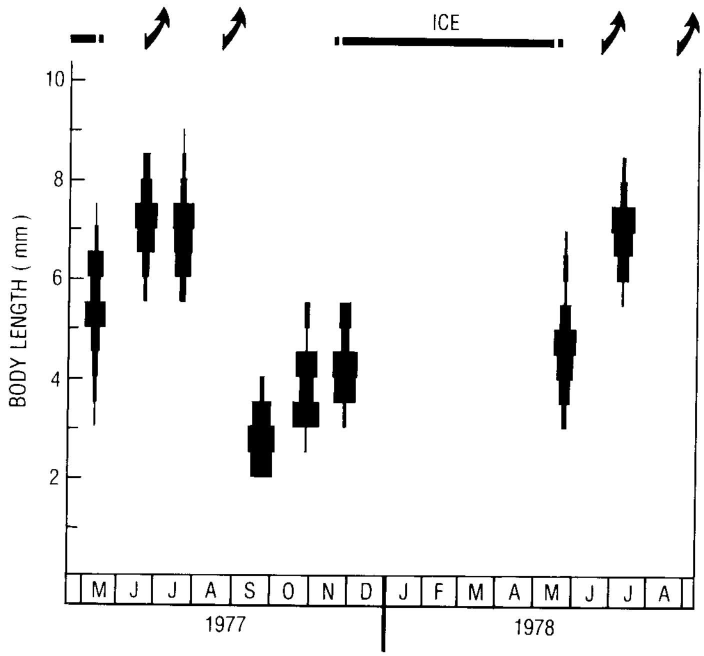



Fig. 9. Nymphal size distribution of *L. vespertina* in Myrkdalsvatn during the ice free periods in 1977 and 1978. Arrows indicate the emergence period. Fifty nymphs were measured on each occasion.

## DISCUSSION

*Nemoura avicularis, N. cinerea* (Plecoptera) *Leptophlebia vespertina, Siphlonurus aestivalis* and *S. lacustris* (Ephemeroptera) are all univoltine in Myrkdalsvatn. The sporadic records of adult *B. rhodani* throughout the whole ice-free period may, however, indicate a complex life cycle with overlapping cohorts (Baekken, 1981). The trapping of *B. rhodani*, a typical lotic species (Müller-Liebenau, 1969), in the lake may be due to nymphs being washed in from nearby streams, where the species was very common, or entering while ovipositing, which the sex ratio indicates. A similar phenomenon was reported from Norway by Brittain (1978). Many of the plecopteran species recorded only rarely in the emergence traps are more typical of lotic habitats (Andersen et al., 1978) and probably originate from nearby rivers and streams.

*Nemoura avicularis* was the most abundant plecopteran species in Myrkdalsvatn. Although widely distributed in Scandinavia (Brinck, 1949; Lillehammer, 1974) this species has not been recorded in western Norway prior to this study (Sættem, 1981). Nymphs were fully grown by ice break in spring

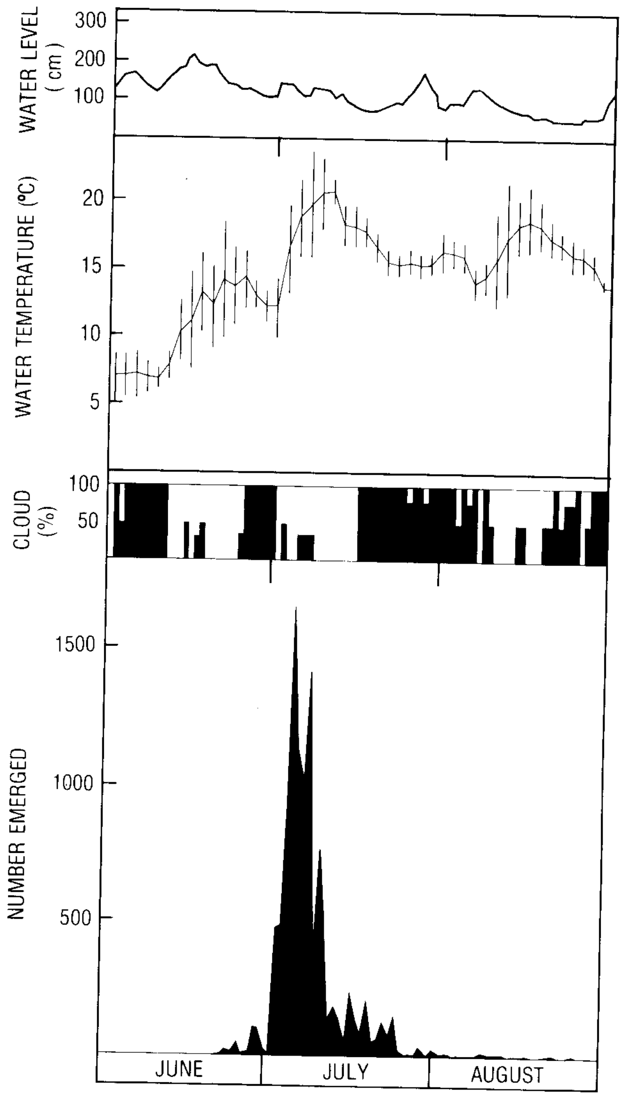



Fig. 10. Relationship between daily emergence of *L. vespertina* at trap 1 from Myrkdalsvatn during 1977, daily maximum and minimum water temperature in the exposed zone, daily water level fluctuations and daily cloudiness.

after substantial growth during winter, although the highest growth rates occurred during late summer and autumn. The growth of *N. cinerea* was similar, but the nymphs grew more slowly in the autumn and were always smaller than *N. avicularis* at a given time. This difference in life cycle is the

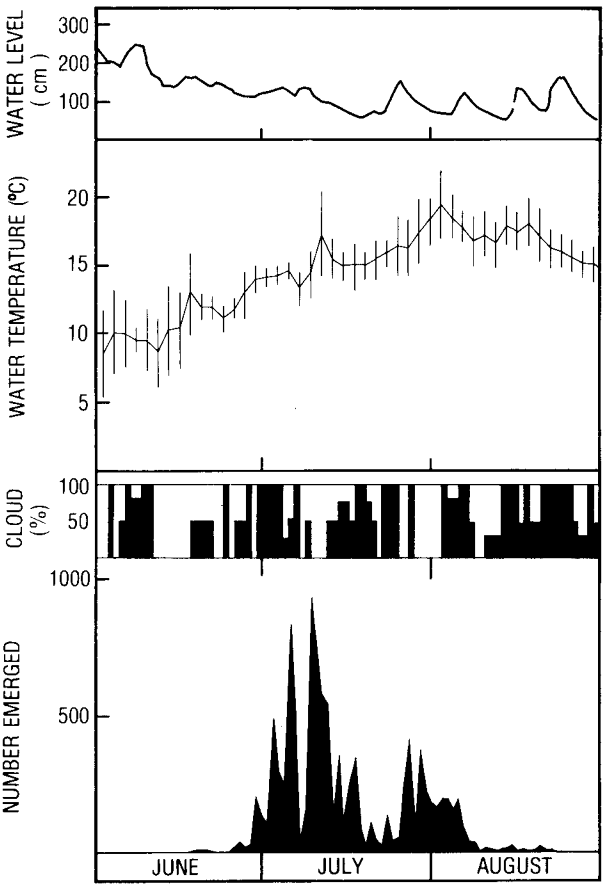



Fig. 11. Relationship between daily emergence of *L. vespertina* at trap 1 from Myrkdalsvatn during 1978, daily maximum and minimum water temperature in the exposed zone, daily water level fluctuations and daily cloudiness.

result of earlier emergence and oviposition in *N. avicularis* giving them a longer nymphal summer growth period than *N. cinerea* (Brittain, 1983).

Water temperature and cloudiness appear to be the major factors governing the emergence of *N. avicularis*. On clear days in late May and early June when daily mean water temperature reached about 7°C, *N. avicularis* emergence peaked. The earlier emergence period of *N. avicularis* in Myrkdalsvatn in 1978 therefore reflects the higher water temperatures prevailing during May 1978. High water levels seemed to have little influence on emergence in *N. avicularis*.

The relationship between emergence pattern and fluctuations in water temperature and cloudiness are even more readily apparent in ephemeropteran emergence from Myrkdalsvatn. In both 1977 and 1978 the emergence of *L. vespertina* did not commence until the minimum water temperature reached 10°C in spite of daily maximum temperatures of 17-18°C. Subsequent emergence was characterised by peaks corresponding to sunny weather and maxima in water temperature. Temperature as a major factor regulating the onset and subsequent pattern of emergence in Ephemeroptera is well known (Brittain, 1982). However, the relationship between irradiation and emergence may be either direct or indirect via water temperature (Morgan & Waddel, 1961; Morgan, 1964; Macan & Maudsley, 1966; Flannagan & Lawler, 1972; Brittain, 1979). Differences in cloudiness cause changes in irradiation, and emergence of both *L. vespertina* and *S. lacustris* in Myrkdalsvatn indicate that irradiation influences emergence directly. For example, during the cloudy weather at the beginning of July 1977, the emergence of *L. vespertina* was depressed in spite of apparently favourable temperature conditions with both high and rising temperatures. In addition, as water temperatures were falling during late August the number of emerging *S. lacustris* suddenly rose on sunny days.

The different nymphal growth patterns of *L. vespertina*, *S. aestivalis* and *S. lacustris*, with 25%, 40% and 60% of their respective total growth between ice break and emergence, explains their succession in emergence. A similar succession occurred in Øvre Heimdalsvatn, a Norwegian subalpine lake (Brittain, 1978). However, the same species emerged earlier in Myrkdalsvatn than Øvre Heimdalsvatn on account of the earlier break up of ice and subsequent rise in temperature. A change in temperature regime also occurs with latitude as well as altitude and the emergence of *L. vespertina* is later in Myrkdalsvatn than in Britain (Macan, 1970; Brittain, 1972), south-eastern Norway (Brittain, 1974) and southern Sweden (Kjellberg, 1972). A similar change in emergence timing occurs in the North American *Leptophlebia cupida* (Clifford et al., 1979).

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