EMERGENCE OF *EPHEMEROPTERA* FROM ØVRE HEIMDALSVATN, A NORWEGIAN SUBALPINE LAKE

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Introduction

Øvre Heimdalsvatn is situated at 1090 m a. s. l. in the eastern part of the Jotunheim Mountains of southern Norway (61°26′ N, 8°52′ E). It lies in the upper part of the subalpine zone, has a surface area of 0.78 km², a length of 3 km and a maximum depth of 13 m. The lake is ice covered from the end of October until the beginning of June. Øvre Heimdalsvatn and its catchment area have been the subject of wide-ranging studies in connection with the Norwegian contribution to the freshwater section of the International Biological Programme. Some of the material has been published (e. g. BRETTUM, 1972, GRÖTERUD, 1972, LARSSON & TANGEN, 1975) but the major part is still in preparation (VIK — in preparation).

Methods

Maximum and minimum air temperatures were taken daily between 0800 and 0900 hrs at the eastern end of the lake. Lake temperatures at 0.5 m were taken at stations L–2 and L–3 (BRETTUM, 1972) which are situated over the deepest parts of the lake. Irradiance, that is the total radiation energy received per unit of lake surface per unit time, was measured by a star pyrometer connected to a Schenk point recorder. Wind speed was measured by an automatic wind meter connected to the same recorder.

Emergence traps of the box type (DAVIES, 1950) were set up in the lake during the ice free periods of 1971 and 1972. During 1971, 2 traps were located in the lake itself and 1 in the outflow stream, while during 1972 all 3 traps were set up in the lake. The traps were emptied daily, usually around 0900 hrs. Further details, including the precise location of the traps, are given in BRITTAIN & LILLEHAMMER (in preparation).

Results and discussion

Ephemeroptera emerged from Ø. Heimdalsvatn between late June and the end of August (Fig. 1). Emergence commenced when water temperatures at 0.5 m in the central parts of the lake reached 7–8 °C. MACAN & MAUDSLEY (1966) suggested, on the basis of 6 years' records, a temperature limit for emergence in *Leptophlebia marginata* of 10–11°C. However, temperatures in the shallow waters of Ø. Heimdalsvatn were probably somewhat higher, at least during daytime, on account of the close relationship between shallow water and air temperatures. Emergence terminated when the temperature fell below 10°C.

The species recorded in the emergence traps, their numbers and percentage composition, are given in Table I. *Leptophlebia vespertina* (L.) was the most abundant species, while *Leptophlebia marginata* (L.), *Siphlonurus lacustris* EATON and *Baetis macani* KIMMINS were also common. The remaining species, *Siphlonurus aestivalis* EATON, *Baetis rhodani* (PICTET) and *Ameletus inopinatus* EATON were only taken in small numbers. The 7 species showed a succession in their emergence periods as the season progressed (Fig. 2), reaching their peak emergence, expressed as 50% emergence, at different times. In 1971 temperatures were significantly lower during late June and much of July (BRITTAIN — in preparation). Although this resulted in delayed emergence in most species, the species succession was maintained. This species succession, present not only in the *Ephemeroptera* but in other aquatic insects in Ø. Heimdalsvatn (LILLEHAMMER, 1975, BRITTAIN & LILLEHAMMER — in preparation), is of importance for predatory organisms such as the brown trout and the birds around the lake (LIEN — in preparation).

HARPER & MAGNIN (1971) in a study of Ephemeropteran emergence in a Canadian stream postulated 2 types of emergence, synchronized and dispersed, which were more or less constant for

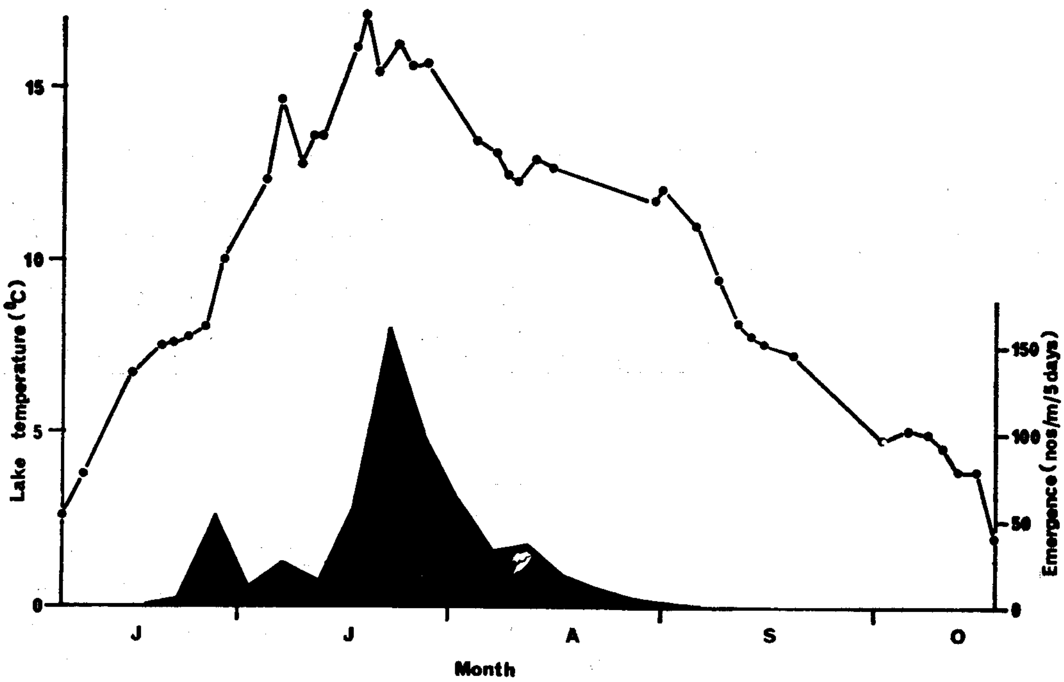

Fig. 1. Emergence of *Ephemeroptera* (shaded) from Ø. Heimdalsvatn, expressed as numbers /m shoreline/ 5 days, during the ice free period of 1972 in relation to lake temperatures at 0.5 m over the lake's deepest parts (●—●)

Table I

Numbers of Ephemeroptera taken in emergence traps by Øvre Heimdalsvatn during 1971 & 1972

Species	No.	%
Leptophlebia vespertina	1646	53.6
Siphlonurus lacustris	464	15.1
Baetis macani	442	14.4
Leptophlebia marginata	439	14.3
Siphlonurus aestivalis	40	1.3
Baetis rhodani	29	0.9
Ameletus inopinatus	11	0.4
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a particular species. In contrast emergence pattern in Ø. Heimdalsvatn varied both with abundance and with species. Species uncommon in a particular year or at a particular locality generally had a more synchronous emergence. This can be illustrated by *S. lacustris*, in which emergence became less synchronized and more dispersed as abundance increased (Table II & Fig. 3). Similar variation has been shown in the *Plecoptera* of Ø. Heimdalsvatn (LILLEHAMMER, 1975).

Nevertheless, when present in higher numbers the 4 major species, *L. vespertina, L. marginata, S. lacustris* and *B. macani* showed more characteristic patterns of cumulative emergence (Fig. 4).

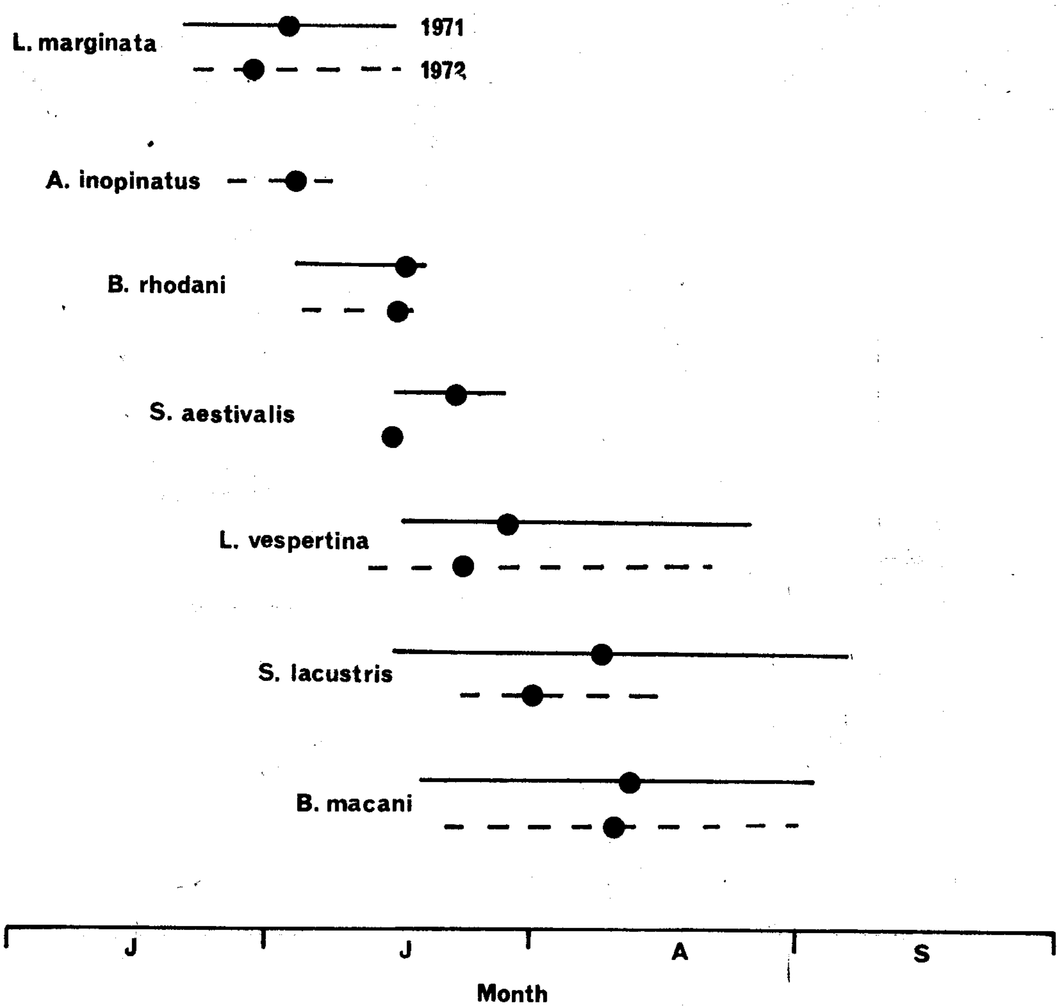

Fig. 2. Succession in the emergence of Ephemeropteran species from Ø. Heimdalsvatn during 1971 and 1972. Peak emergence of each species, taken as the date on which 50% had emerged, is indicated by a shaded circle. *Ameletus inopinatus* was not recorded in 1971

Table II

Values for 50% (E_{50}) and 100% (E_{100}) emergence in S. lacustris from Ø. Heimdalsvatn in relation to the numbers taken in the different traps

Trap	No. emerged	E_{50} (Days)	E_{100} (Days)
A	22	6	15
1	23	6	18
B	25	11	18
C	35	10	23
2	183	22	56
3	198	26	54

There was a gradual change from *L. marginata*, which had the most synchronous emergence pattern, via *L. vespertina* and *B. macani*, to *S. lacustris* which was the most dispersed. These species have respectively 1, 46, 100 and 77% of their growth between ice break and emergence (BRITTAIN, in preparation). *Leptophlebia marginata* which emerges soon after ice break has accomplished the major part of its growth during the preceding autumn and winter and it is probably just a case of sufficiently high water temperatures and perhaps a final instar change before emergence can commence. Thus emergence is more synchronous. *Leptophlebia vespertina* has significant growth between ice break and emergence, producing a population with nymphs at different stages of maturity and therefore a less synchronous emergence. *Baetis macani* and *S. lacustris* are both "summer species" (LANDA, 1968), that is most of their growth takes place between ice break and emergence. Of the two *S. lacustris* has the more dispersed emergence. According to previous laboratory and field studies

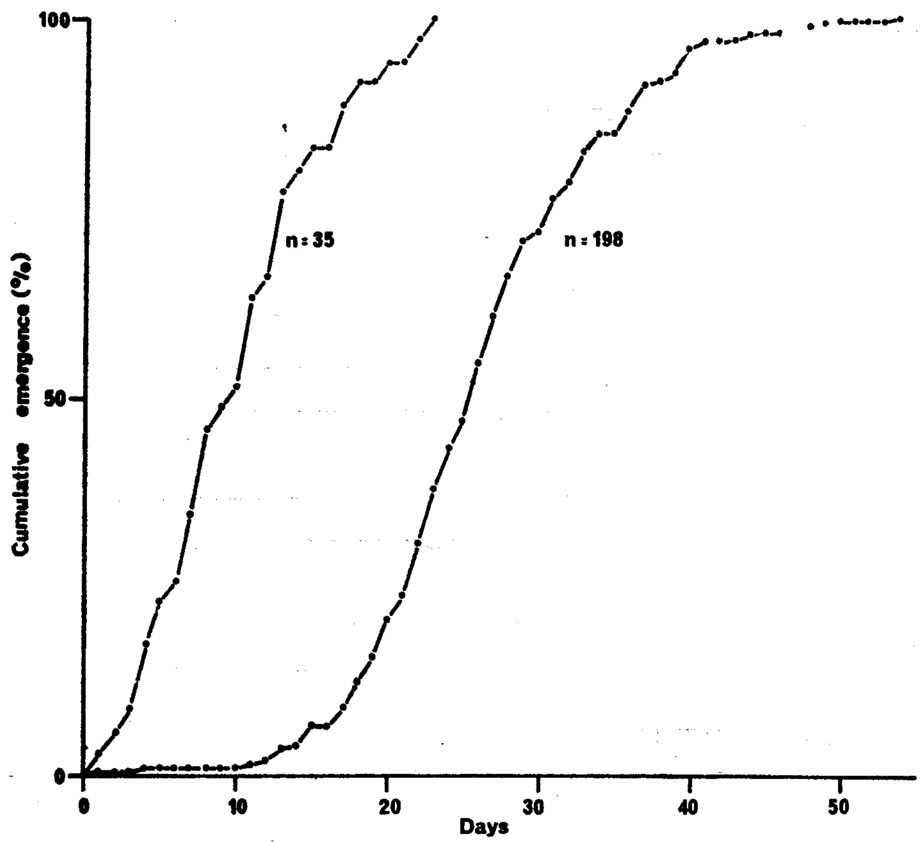

Fig. 3. Cumulative emergence of *S. lacustris* from Ø. Heimdalsvatn in trap C (n = 35) and trap F. 3 (n = 198)

(DEGRANGE, 1960, HYNES, 1961) and data from Ø. Heimdalsvatn (BRITTAIN, in preparation) part of the population overwinter in the egg stage and part as small nymphs. This produces a heterogeneous nymphal population with a dispersed emergence pattern. Egg hatching in *B. macani* is more synchronized and is probably associated with the rise in temperature after ice break (BRITTAIN, 1975).

Emergence pattern also varies with locality. If the emergence patterns of *L. vespertina* in Ø. Heimdalsvatn and a Swedish lowland tarn (KJELLBERG, 1972) are compared (Fig. 5), it is evident that emergence is more synchronous in the Swedish locality, assuming that Kjellberg's data, based on a single season, are representative for that locality.

There was little difference between the emergence patterns of the sexes, although in *L. vespertina*, *L. marginata*, *A. inopinatus* and *B. rhodani* males tended to emerge before females (Fig. 6). There was less difference in *S. lacustris* and in *B. macani* females generally emerged first.

The daily variation in numbers of *L. marginata* and *L. vespertina* emerging from Ø. Heimdalsvatn is shown in Figs 7 and 8. An attempt was made to relate this variation to certain environmental

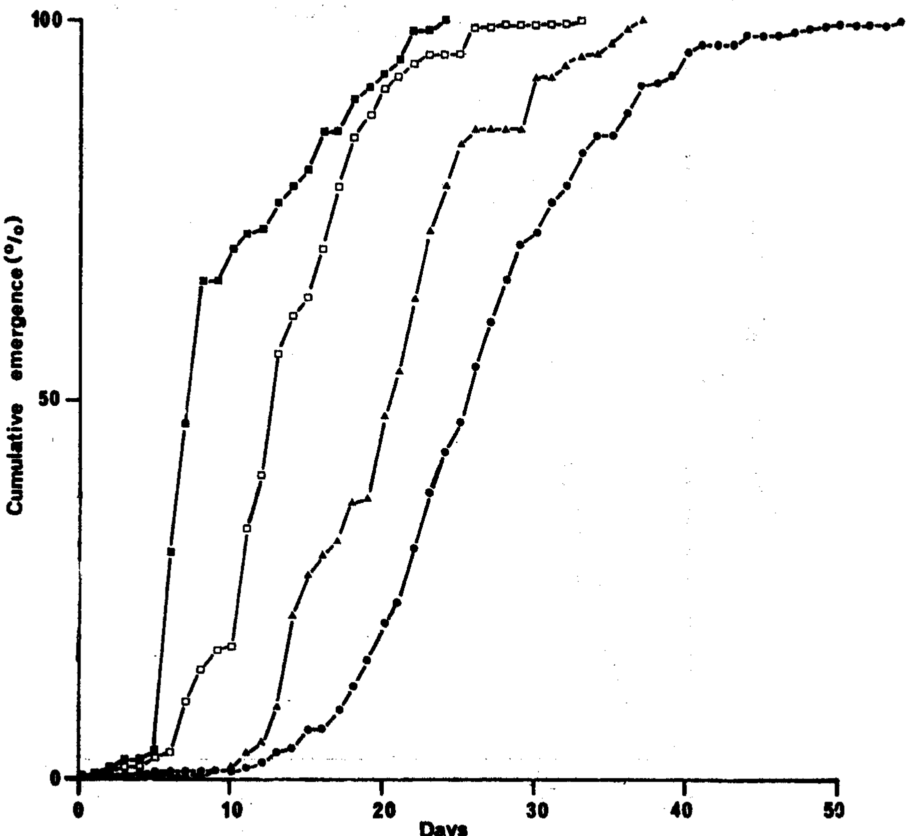

Fig. 4. Cumulative emergence of *L. marginata* (■—■, n = 157). *L. vespertina* (□—□. n = 178); *B. macani* (▲—▲, n = 167) and *S. lacustris* (●—●, n = 198). Data for the first 3 species are from trap A, while the *S. lacustris* data are from trap F. 3

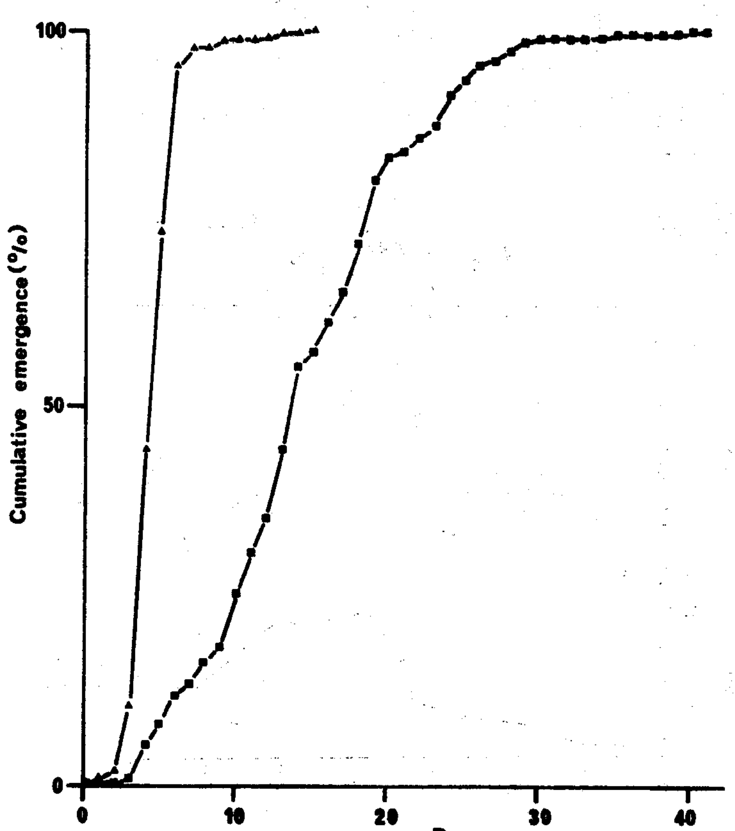

Fig. 5. Cumulative emergence of *L. vespertina* from Ø. Heimdalsvatn during 1971 (■—■, 3 traps, n = 641) and from a Swedish tarn (▲—▲, 3 traps, n = 670). The Swedish data are modified from Kjellberg (1972)

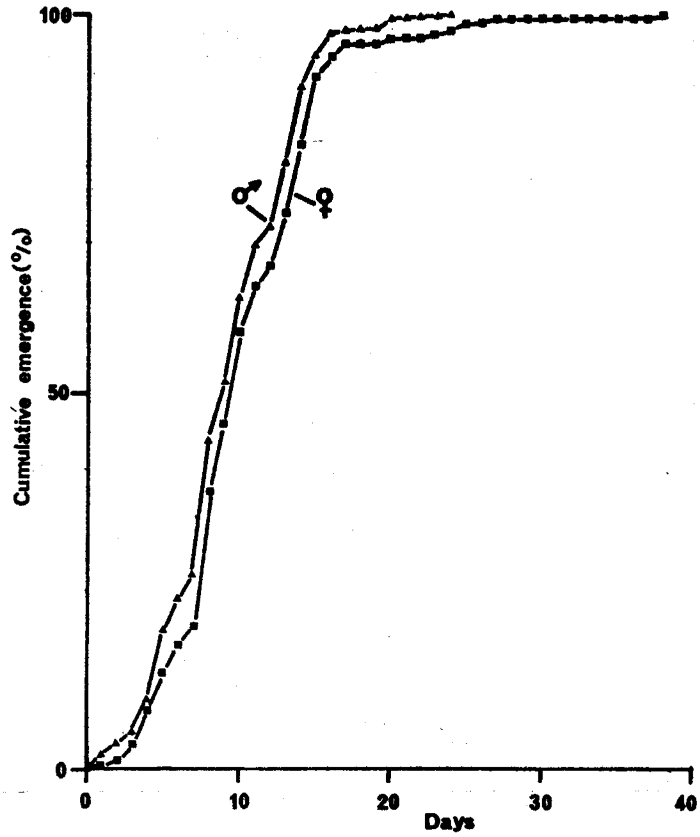

Fig. 6. Cumulative emergence from Ø. Heimdalsvatn of males (n = 311) and females (n = 242) of *L. vespertina* in trap C

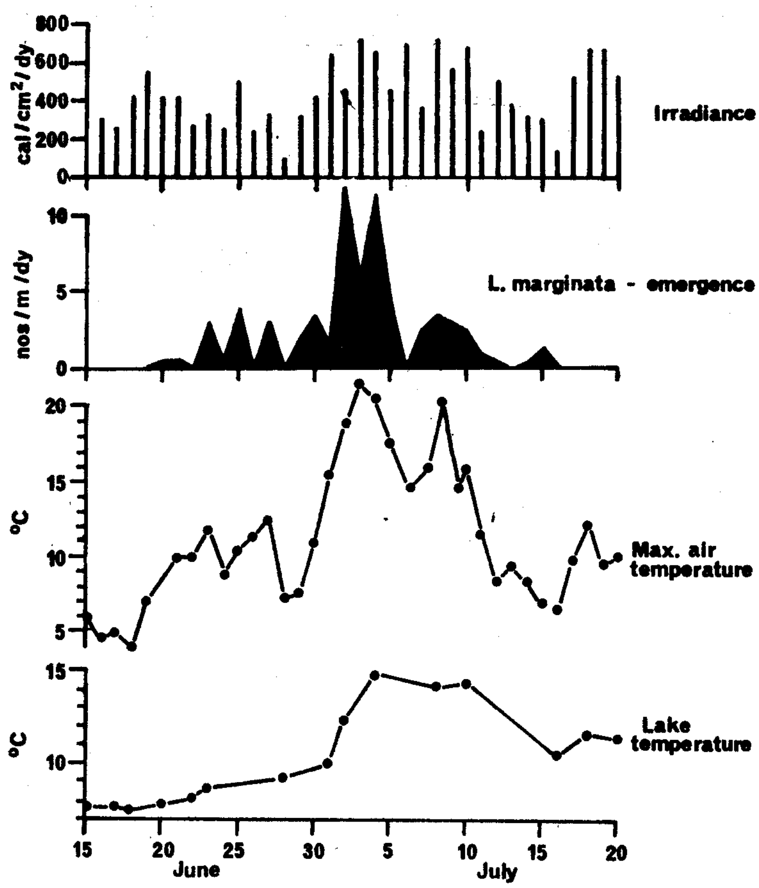

Fig. 7. Relationship between daily emergence of *L. marginata* from Ø. Heimdalsvatn during 1971, expressed as numbers/m shoreline, and lake temperature at 0.5 m taken over the lake's deepest parts, daily maximum air temperature and daily irradiance

parameters — air and lake temperature, irradiance, wind speed, precipitation and humidity. These parameters are clearly interrelated, so it is difficult to separate their individual effects. However, maximum air temperature and irradiance showed the best correlation with the daily variation in emergence, and only high winds or heavy precipitation had a major effect on emergence. The relationship between humidity and emergence was, if anything, negative, perhaps because values under 60% were rare and high values were associated with heavy precipitation. It is known that temperature is a major factor regulating the onset of emergence in *Ephemeroptera* (MORGAN, 1964,

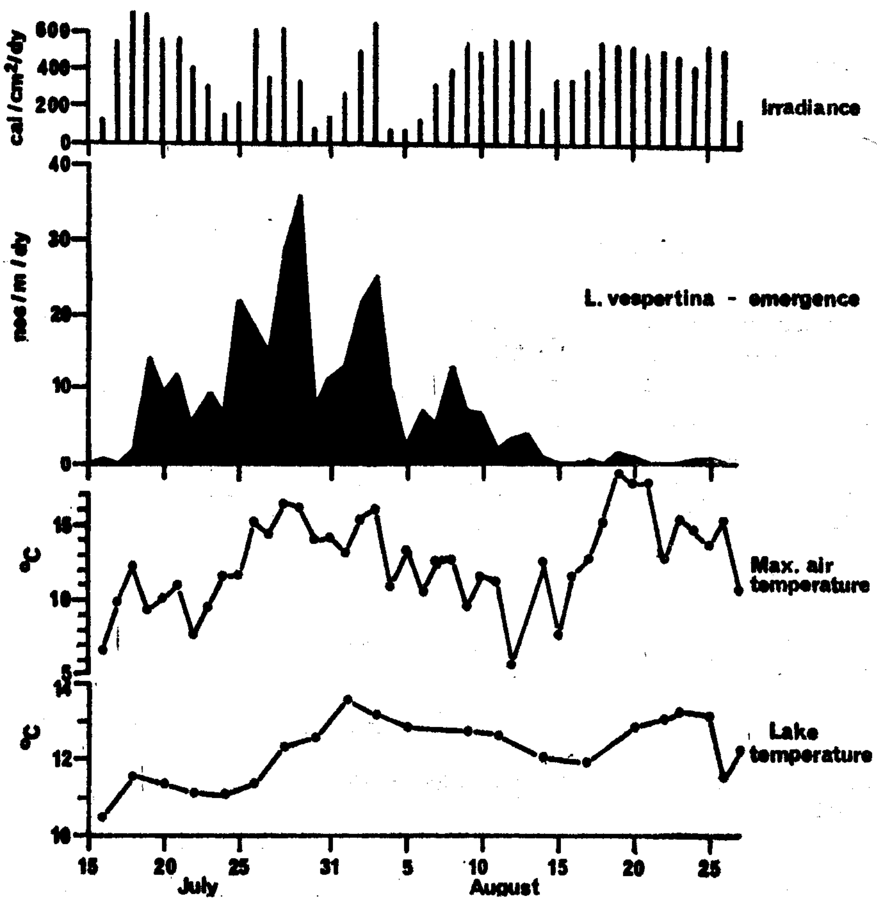

Fig. 8. Relationship between daily emergence of *L. vespertina* from Ø. Heimdalsvatn during 1971, expressed as numbers/m shoreline and lake temperature at 0.5 m taken over the lake's deepest parts, daily maximum air temperature and daily irradiance

MACAN & MAUDSLEY, 1966, NEBEKER, 1971, BRITTAIN, in press). It is therefore not surprising that in Ø. Heimdalsvatn temperature plays a role both in the onset of emergence and in the daily variation once emergence has commenced. The relationship between irradiance and emergence may be either direct or indirect via water temperature. FLANNAGAN & LAWLER (1972) found that *Caenis forcipata* emerged on sunny days but not on cloudy ones, although no water temperature data are given. Laboratory studies could provide a solution to this problem.

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SUMMARY

Emergence of Ephemeroptera from Øvre Heimdalsvatn, a norwegian subalpine lake

Ephemeroptera emerged between late June and the end of August. *Leptophlebia vespertina, L. marginata, Siphlonurus lacustris, Baetis macani, B. rhodani, S. aestivalis* and *Ameletus inopinatus* were recorded, the last three only in small numbers.

Despite different temperature conditions in 1971 and 1972, a succession of species throughout the season was maintained in both years. Emergence pattern varied with both species and abundance. Daily fluctuations emergence resulted mainly from variations in temperature and irradiance.

Discussion

M. D. HUBBARD: Could the differences in emergence pattern be due to sampling error at low densities?

J. BRITTAIN: This is unlikely and the slopes of the main parts of the curves are usually different.

Dr. U. HUMPESCH: Have you found small nymphs of *Siphlonurus aestivalis* during the winter?

J. BRITTAIN: I have not, as yet, sampled during the period of ice cover.

Dr. J. FONTAINE: Could you explain why daily variation in emergence was better correlated with air than lake temperatures?

J. BRITTAIN: Lake temperatures were taken at 0.5 m over the lake's deepest parts and therefore air temperatures are probably a better indication of shallow water temperatures.

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