18. Mayflies (Ins.: Ephemeroptera) in coastal areas of the Gulf of Bothnia

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1. Introduction

Mayflies (Ephemeroptera) can be regarded as one of the most typical insect groups in freshwater biotopes. From European lakes, rivers and streams 217 species have been described (Puhtz 1978). Only a few investigations mention the occurrence of representatives of this insect group in brackish waters. Firstly, Stammer (1928) found larvae of *Cloeon dipterum* L. in the estuary of the river Ryck, near Rostock, in the southern part of the Baltic Sea. Segerstråle found 'mayflies' in brown-grey mud of the Pellinge area, near Tvärminne, in the coastal part of the Gulf of Finland. Salinity at this site was around 6‰. It is certain that these mayfly nymphs belonged to the species *Caenis horaria*. L. Saaristo (1966) and Lingdell & Müller (1979b) have found this species in several oligohaline localities in coastal areas of the Gulf of Bothnia.

Extensive investigations which we have carried out since 1977 in coastal areas of the Gulf of Bothnia provide a survey of the distribution of the ephemeroptereans in the oligohaline environment.

2. The investigation areas and methods

Both parts of the Gulf of Bothnia, the Bothnian Sea and the Bothnian Bay are to a high degree influenced by rivers and streams. With the exception of the Ulvö depth, the whole Gulf of Bothnia can be called an oligohaline brackish water. Salinity decreases from south to north and even somewhat from east to west.

The investigation of the occurrence, distribution and abundance of mayfly species in coastal areas of the Gulf of Bothnia began in 1977 in the mouth part of the river Ängerån (Fig. 1) with regular sampling of drifting mayfly nymphs and flying adults. In the following years 1978 to June 1980 the occurrence of

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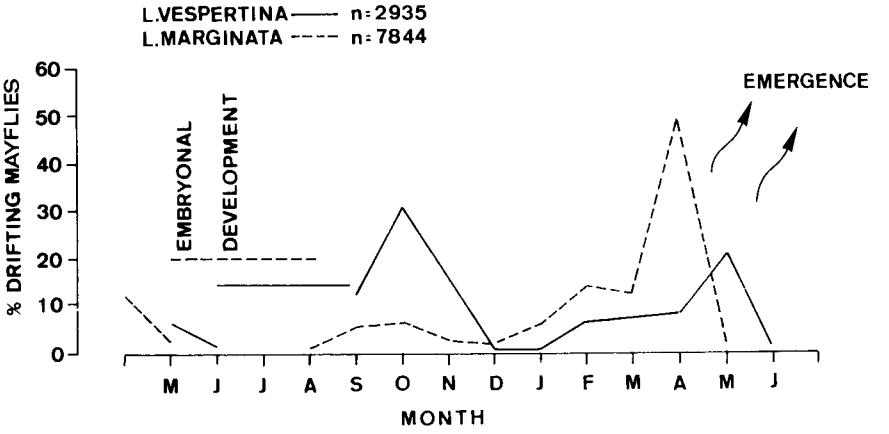

Fig. 1. The drift of *Leptophlebia marginata* and *L. vespertina* at the mouth aprt of the river Ängerån.

mayflies in the Ängerån estuary and adjacent coastal areas as well as in the sea-shores of the islands of the Norrby archipelago has been investigated with help of bottom samples, colonization boxes and a diversity of different traps. The traps used were: Light-traps, window-traps, Malaise-traps, yellow dishes and sweep netting catches. In 1979, comparative studies on the distribution of mayfly adults around the whole Gulf of Bothnia were started. Table 1 gives the location position of the sampling sites and their mean salinity.

Table 1. The position of the investigated localities in the Gulf of Bothnia (1979).

Locality	Position	Mean salinity ‰
Storön	65°44'N, 23°06'E	2–3
Holmön	63°44'N, 20°50'E	3–4
Norrby	63°35'N, 19°50'E	4–5
Vallgrund	63°20'N, 21°10'E	4–5
Forsmark	60°32'N, 18°23'E	5–5.5

This mayfly inventory around the Gulf of Bothnia was made by light-traps, the lamps used were General-Electric Type F15 T8 BL. The insects were caught in plastic vessels filled with ethylene glycol. The traps were emptied either once a week at Vallgrund and Forsmark or at 14 day intervals at the other localities. All material is deposited in the collections of P. E. Lingdell, Enskede, Sweden.

3. Results

3.1 The mayfly fauna in the mouth of the river Ängerån

This investigation is based on drift samples in the mouth part during an annual period. 24h samples were taken continuously from May 19 to November 20, 1978, 69 random samples from under the ice were collected from December 1978 to April 1979 and after ice-break 21 samples in May-June 1979. Table 2 shows the number of samples per month and the captured mayfly nymphs in them.

98% of the 10 974 captured mayfly nymphs were represented by the two *Leptophlebia* species, *L. marginata* and *L. vespertina*. From the abundance of these two species in the drift their life-cycle may be explained: In May and June (Fig. 1) they disappear from the drift because they emerge. *L. marginata* two-three weeks earlier than *L. vespertina*. From the middle of August small nymphs of *L. marginata* and from September those from *L. vespertina* occurred in the drift. The increase of *Leptophlebia* in the drift in September

Table 2. The monthly average of drifting mayfly nymphs at the mouth part of the river Ängerån.

	No. of samples	*Leptophlebia marginata*	*Leptophlebia vespertina*	*Heptagenia fuscogrisea*	*Siphlonurus alternatus*	*Siphlonurus lacustris*	*Baetis rhodani*	*Baetis subalpinus*	*Cloeon simile*	Total number of Ephemeroptera
May	12	33	93	5	–	–	–	–	–	131
June	30	–	21	4	–	–	–	–	–	25
July	31	–	–	–	4	–	2	7	–	13
August	31	40	–	4	–	–	1	15	–	60
September	30	895	505	17	–	–	–	1	1	1 419
October	31	1028	1218	10	–	–	–	–	1	2 257
November	20	406	395	7	–	–	–	–	–	808
December	12	74	11	51	–	–	–	–	–	136
January	13	419	14	1	–	–	–	–	–	434
February	7	522	65	5	–	–	–	–	–	592
March	12	789	128	3	–	–	–	–	–	920
April	13	3457	140	13	–	–	–	–	–	3 610
May	13	180	337	29	–	11	–	–	–	557
June	8	1	8	3	–	–	–	–	–	12
Total	263	7844	2934	152	4	11	3	23	2	10 974

and October is connected with rapid growth and several of molting (Lingdell & Müller 1979c). Drift during the winter months is low, but slightly increasing from February to a maximum in April respectively May, a short time before emergence. The developing stages of *Leptophlebia* nymphs are combined with a change of biotope. The nymphs mainly leave the river by drifting into the estuary when this is ice-covered and has become a freshwater biotope (cf. Müller-Haeckel & Sjöberg, Chap. 6). The restriction of life space in the river as a consequence of low water discharge and sporadic bottom freezing from January to April is compensated for *Leptophlebia* nymphs by large freshwater areas in the estuary. Besides the *Leptophlebia* species some other Ephemeroptera species showed the same behaviour in the drift. *Heptagenia fuscogrisea* and *Baetis subalpinus* also occurred regularly with low numbers in the drift.

3.2 The distribution of mayfly species in the estuary of the river Ängerån

After three years investigations using different methods, a zonation in the distribution of mayflies in the estuary can be shown (Fig. 2). While the nymphs of *Leptophlebia* occupy the estuary up to the island Skepparhällan, *Baetis subalpinus, Cloeon simile* and *Heptagenia fuscogrisea* stay in the rich vegetation of the river-near part of the estuary. *Baetis fuscatus* prefers the stony region around the Getholmen peninsula. *Caenis horaria* was found in the outermost part of the estuary where salinities vary between 3 and 4.5‰. Obviously, *B. subalpinus* and *Cloeon simile* mainly stay their whole life in the river-near part of the estuary as only a few of their nymphs have been found within the Ängerån.

3.3 The periods of emergence and flight in mayfly species in the Ängerån and its estuary

The flight periods of the different mayfly species have been determined in four-year investigations with different capture methods (Table 3). *Baetis subalpinus* had two generations a year in the Ängerån area (Lingdell & Müller 1980).

3.4 The distribution of mayflies in coastal areas of the Gulf of Bothnia

The Ängerån estuary belongs to the Norrby archipelago, a group of islands of the Swedish province of Västerbotten, which extends about 10 kms off the coastal area of the Bothnian Sea. Mayflies at the islands have been captured

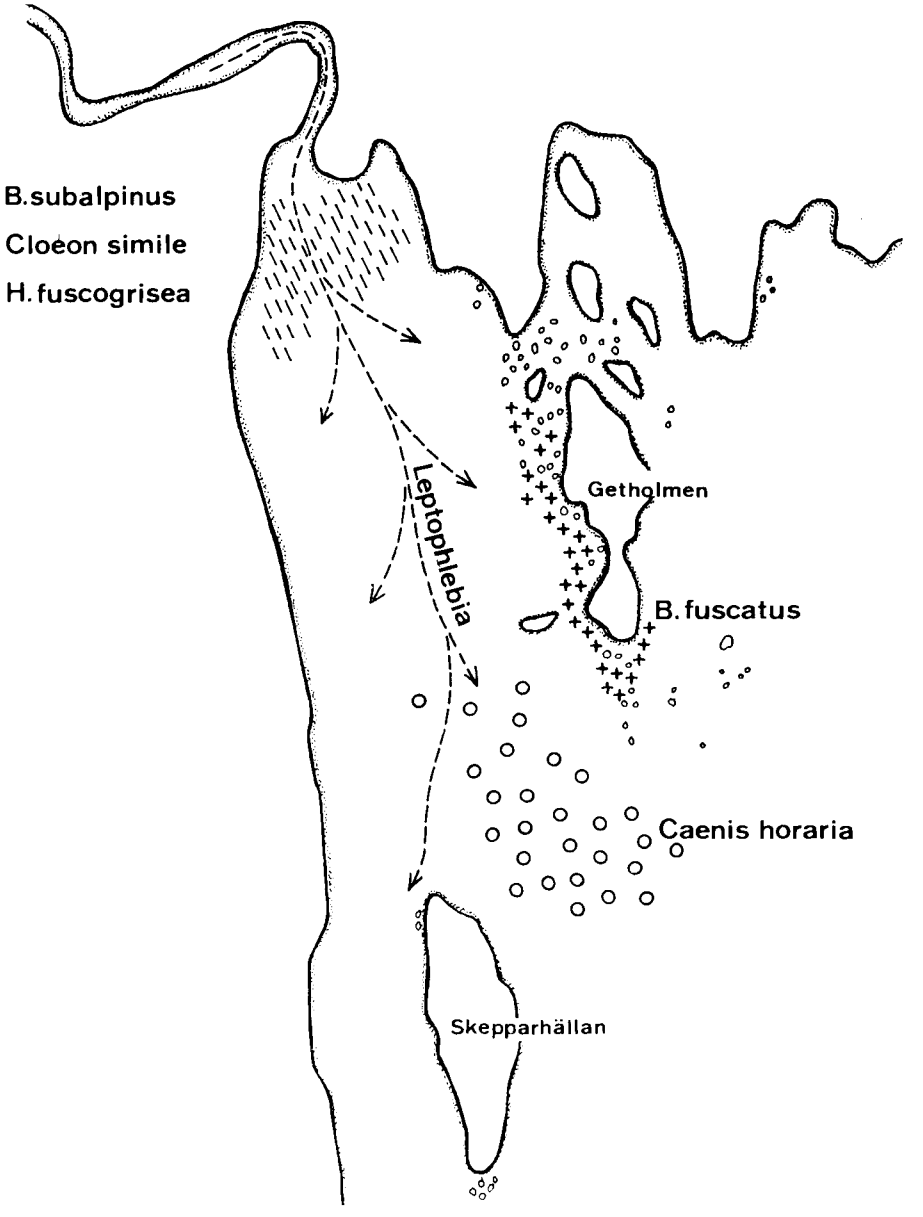

Fig. 2. The distribution of mayfly nymphs in the estuary of the river Ängerån.

Table 3. Flight periods of mayflies in the mouth part and the estuary of the river Ängerån.

Species	May	June	July	August	September
Leptophlebia marginata L.	---===	----			
Leptophlebia vespertina L.	---===	----			
Heptagenia fuscogrisea Retz.	---===	---===	----		
Baetis rhodani Pict.	---===	---===	---===	---===	----
B. subalpinus Bgtss.	---===	---===	---===	---===	----
Cloeon simile Eth.		---===	---===	---===	---===
Baetis fuscatus L.		---===	---===	---===	---===
Caenis horaria L.		---===	---===	---===	---===

by yellow-dishes and by net catches. The richest mayfly fauna has been found in the river-near area of the estuary (Fig. 3). But the samples from the outer part of the archipelago show that *Baetis fuscatus* and *Caenis horaria* are so well-adapted to brackish water that they can live during their whole life cycle in it.

The mayfly distribution around the Gulf of Bothnia is shown in Fig. 4 and Table 4 shows the captured material at the several sites.

Table 4. Mayflies (Ephemeroptera) caught in brackish water biotopes in coastal areas of the Gulf of Bothnia (excluding the Ängerån area).

Species	1	2	3	4	5	6	7	8
Leptophlebia marginata L.	1	–	–	–	–	–	–	–
Heptagenia sulphurea Retz.	1	–	–	–	–	–	–	–
Heptagenia joernensis Bgtss.	1	–	–	–	–	–	–	–
Metretopus borealis Eth.	2	–	–	–	–	–	–	–
Cloeon simile L.	–	–	–	–	–	–	–	1
Baetis fuscatus L.	14	72	31	12	28	8	2	–
Caenis horaria L.	–	88	44	18	14	12	16	57

1 = Storön; 2 = Holmö island; 3 = Vallgrund; 4 = Norrbyskär island (c.f. Fig. 3); 5 = Perskär island (c.f. Fig. 3); 6 = Gråskär island (c.f. Fig. 3); 7 = Snöan island (c.f. Fig. 3); 8 = Forsmark.

In the region of lowest salinity at Storön (2.0-2.5‰) the greatest diversity was observed. The sampling around Oulu has been made by Kuusela (pers. comm.) that form Turku by Saaristo (1966). It can be concluded that in the oligohaline Gulf of Bothnia the number of mayfly species decreases from north to south. *Caenis horaria* occurred at all localities with the exception of Storön which has the lowest salinity. *Baetis fuscatus* tolerates the salinity degrees of the Gulf of Bothnia but is dependent on stony coastal areas.

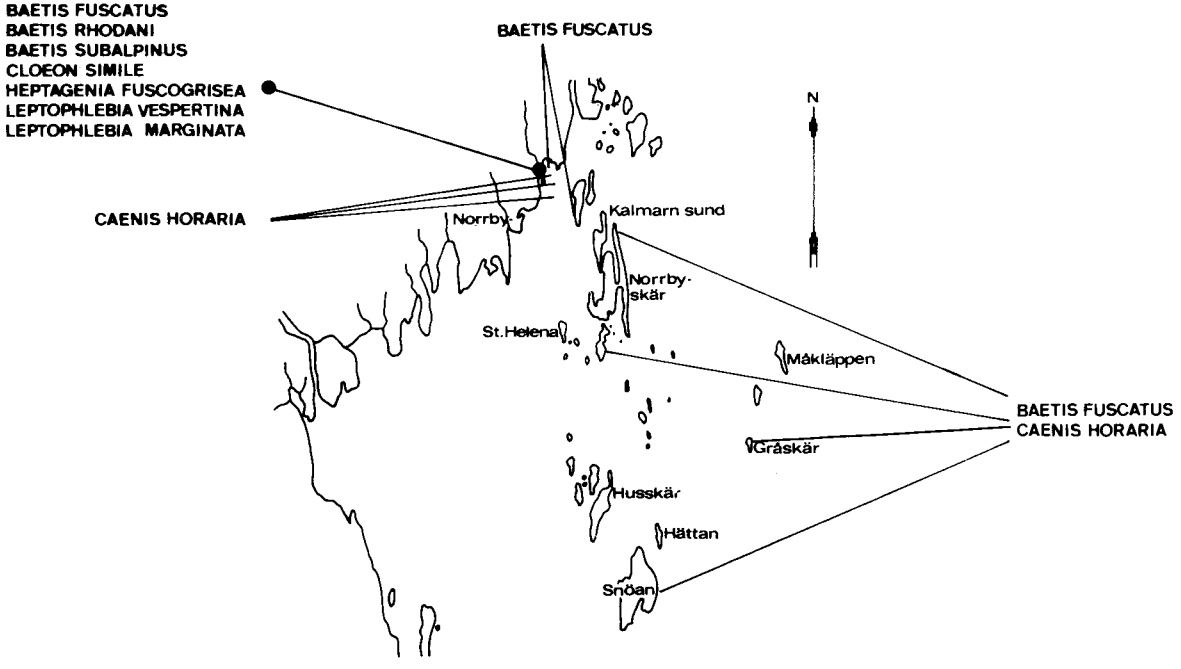

Fig. 3. The occurrence of adult mayflies in the Norrby archipelago.

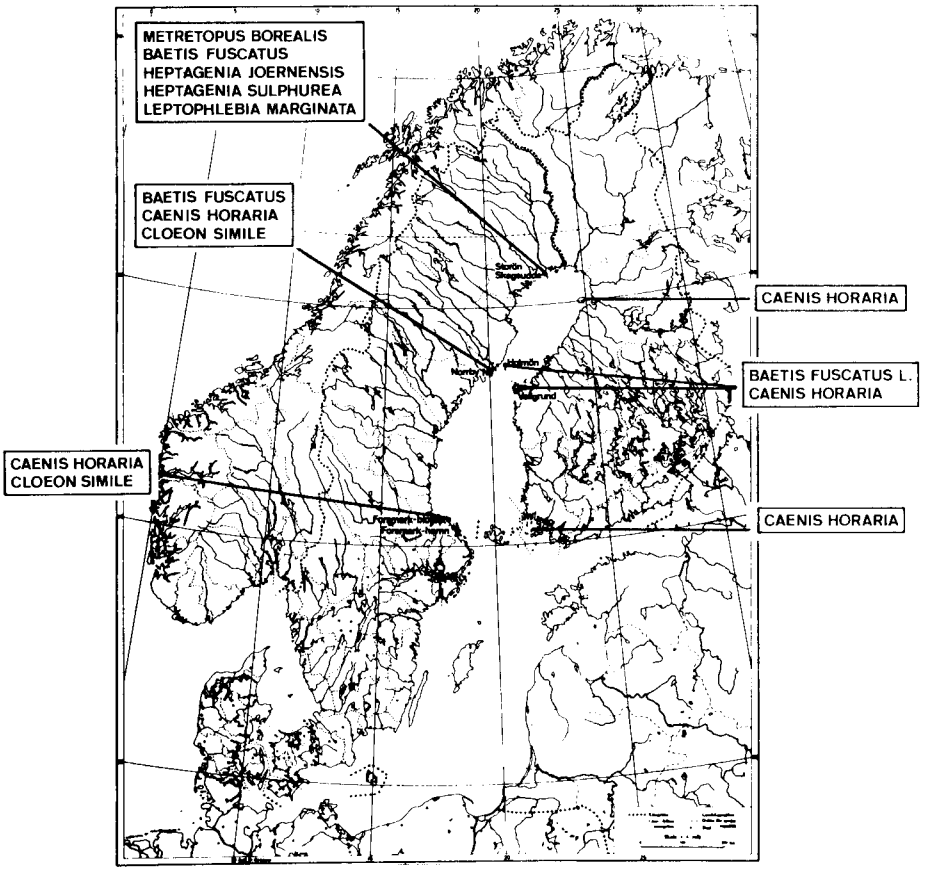

Fig. 4. The occurrence of mayflies in several coastal parts of the Gulf of Bothnia.

3.5 Survival mechanisms of mayfly species living in both fresh and brackish water

In our first investigation (Lingdell Müller 1979c) we could demonstrate by means of window-traps that the mayfly nymphs which drift and migrate to the estuary fly back to the coastal stream for oviposition. This phenomenon has been checked by a Malaise-trap of bilateral type which has been built up across the mouth part of the river Ängerån. The number of mayflies in the 'upstream' and the 'downstream' part of the Malaise-trap showed that there is a tendency for the mayflies that have drifted and grown up in the estuary to fly upstream to continue their life cycle in the river (Table 5).

Table 5. Flight direction of several mayfly species by means of a bilateral Malaise-trap in the mouth part of the river Ängerån (after investigations of 1979).

Species	Upstream directed flight		Downstream directed flight	
	Number	%	Number	%
Leptophlebia marginata	29	69.1	13	30.9
Leptophlebia vespertina	337	92.8	26	7.2
Heptagenia fuscogrisea	98	98.0	2	2.0
Baetis subalpinus	516	99.8	1	0.2

4. Discussion

The Gulf of Bothnia is an exceptional brackish water with transitional salinity degrees from the north (1-2‰) to the south (about 6‰). The distribution of mayflies demonstrates these conditions with different groups of species:

1. Mayfly species which only can live in estuaries, because they spend their life partly in freshwater partly in brackish water biotopes.
2. Species which regularly and permanently live in estuaries, but near the river mouth.
3. Mayfly species which have entirely adapted to brackish water.

The species best adapted to salinity, *Caenis horaria* and *Baetis fuscatus*, have an interesting distribution in Sweden. One of us (Lingdell, unpubl.) has investigated *C. horaria* at 39 localities in Sweden. He found the species in high mountain lakes and streams in the Abisko area, along the chain of mountains of the Swedish-Norwegian border, in the lake Vänern and in the river Kävlingeån. *C. horaria* was found on the islands of Gotland and Öland and in the Stockholm archipelago. Jensen (1974) described the occurrence of *C. horaria* from a dystrophic small lake woodland north of the Arctic circle. The species *Baetis fuscatus* is known from mountain rivers and streams (Müller-Liebenau 1969). Lingdell (unpubl.) found this species at 22 other localities in inland waters of the provinces Uppland, Kopparberg, Stockholm and Östergötland and even in the river Kävlingeån in the southern part of the country. At seven coastal localities the species was observed.

Komnick et al. (1972) and Wichard et al. (1975) have shown that mayfly nymphs of the genus *Caenis* are able by means of chloride cells to regulate osmotic pressure in brackish water biotopes. The distribution of these two mayfly species let us ask the question whether individuals from the fresh and from the brackish water biotopes still genetically are equal. The mayfly species which are mostly restricted to the river-near part of the estuary, *Cloeon simile* and *Baetis subalpinus*, are somewhat different in their behav-

iour. While it could be observed that *Cloeon* had oviposited in the estuary, *Baetis subalpinus* showed even upstream directed flight and oviposition in the lower reaches of the Ängerån.

Extensive insect investigations in the Norrby archipelago have shown that some of the mayfly species living in the coastal areas come there from the coastal river or streams, having a colonization cycle between freshwater and brackish water biotopes, but others live permanently in the brackish water despite that these species are known as extreme freshwater biotopes in high mountain regions (cf. Müller, Chapt. 24).

Acknowledgements

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