Longitudinal zonation of the benthic invertebrate fauna in the river Glomma, Eastern Norway

ALBERT LILLEHAMMER AND JOHN E. BRITTAIN

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Zonation studies of the benthic invertebrate fauna of stony substrates were made along a longitudinal gradient (600 km) in the Glomma river which drains 13% of Norway's land area (41767 km^2). Wide differences in the faunal composition were found between the upper, middle and lower reaches of the river. Plecoptera were most abundant in the upper and Chironomidae and Trichoptera in the lower reaches. Ephemeroptera were abundant throughout the river. The faunal composition showed a dominance of shredders in the upper, grazers in the middle and collectors in the lower reaches. Some local effects of human influence were observed, but no general changes from the natural faunal composition and zonation seem to have taken place. The benthic data are in general agreement with the predictions of the River Continuum Concept (Vannote et al. 1980).

Albert Lillehammer & John E. Brittain, Zoological Museum, University of Oslo, Sarsgt. 1, N-0562 Oslo 5.

INTRODUCTION

Studies of the longitudinal zonation of the benthic invertebrate fauna along a river from source to mouth yield information about the ranges and dominance relationships of individual species. When these results are compared with changes in environmental factors, such as water temperature, transport of organic matter, substrate composition and instream primary production, an indication of the habitat range of each species is gained.

Few attempts have been made to study the zonation in the benthic fauna of Fennoscandian rivers and to compare the results with those of studies made elsewhere, especially recent conceptual studies in North America (Vannote et al. 1980). Such a study of the major benthic invertebrate groups and the dominant species in a major Norwegian river system is reported in the present paper.

A number of ecological studies have previously been carried out in the Glomma river. Basic information about the chemical/physical factors and primary production, together with a summary of information concerning the aquatic invertebrates and the fish fauna have already been published by Skulberg & Lillehammer (1984). Studies of the fish fauna have been made by Halvorsen (1968), Hansen (1978) and Pethon (1978, 1980), while studies of the benthic invertebrate fauna in the lower reaches of the Glomma and some of its tributary streams have been published by Lillehammer (1965) and Raastad (1974). In the middle reaches, Brittain et al. (1984) studied the effect of the Barkal dam on the invertebrate fauna.

GENERAL DESCRIPTION OF THE RIVER

The Glomma is the largest watercourse in Scandinavia with respect to discharge, the catchment area of 41767 km^2 comprising 13% of Norway's total land area. From its headwaters in the sub-alpine region at about 800 m a.s.l. to its mouth, is a distance of 598 km. Most of the catchment is situated in the boreal forest zone. All the eleven sampling stations are situated within the boreo-montane subzone and the boreo-nemoral vegetation zone (Sjörs 1963). The highest sampling station was south of Røros (62° 30'N, 10° 70'E) at an altitude of 620 m and the lowest (60° 10'N, 11° 20'E) at Rånåsfoss, 120 m a.s.l.

The sampling stations (Fig. 1) were chosen to yield a picture of the benthic fauna on stony substrates in fast flowing stretches, at different altitudes. All eleven stations were

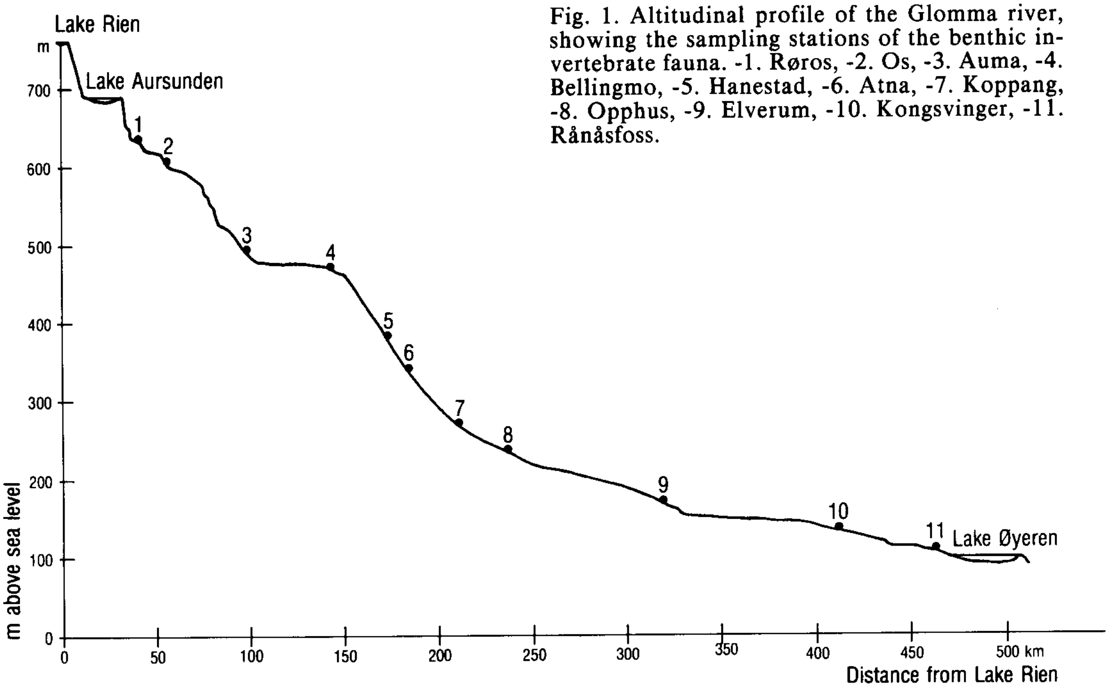


Fig. 1. Altitudinal profile of the Glomma river, showing the sampling stations of the benthic invertebrate fauna. -1. Røros, -2. Os, -3. Auma, -4. Bellingmo, -5. Hanestad, -6. Atna, -7. Koppang, -8. Opphus, -9. Elverum, -10. Kongsvinger, -11. Rånåsfoss.

chosen to obtain similar substrate composition. However, stations 1—9 were situated on glaciofluvial sediments, while stations 10 and 11 were situated within the area of postglacial marine deposition.

Spot recordings have shown that the water temperature conditions change markedly downstream, but no comparable long-term recordings of water temperature have been made.

Sewage from farms and villages is discharged along certain stretches of the river. In the upper reaches the influence of agriculture is especially noticeable between stations 2 and 4. The river environs below station 4 down to 7 are largely forest, but from below station 7 to the mouth human influence rapidly increases.

According to measurements made in April 1967 (Skulberg & Lillehammer 1984) typical changes in the chemical components downstream are: total nitrogen (μg l^{-1} N) increases from 65 to 330, total phosphorus (μg l^{-1} P) from 5 to 83, dissolved oxygen demand (μg l^{-1} 0_2) from 1.4 to 5.0, while the pH remains fairly stable at 6.8—6.9.

Attached algae are abundant on stony substrates and more than two hundred species, mainly green algae and diatoms, have been recorded (Skulberg & Lillehammer 1984).

At several localities the river has been regulated by the building of dams for hydroelectric power production.

MATERIAL AND METHODS

The benthic invertebrate fauna was sampled in October 1972 and again in April, June and August 1973, using the kick method (Frost et al. 1971, Brittain 1978), for one or two minute intervals. Four samples were taken at each station on each occasion. The material was fixed in 4% formaldehyde and stored in 80% alcohol.

RESULTS

The benthic macroinvertebrate fauna on stony substrates consisted mainly of aquatic insects, other groups comprising only a small proportion of the fauna.

Chironomids dominated in absolute numbers, but Trichoptera, Plecoptera and Ephemeroptera individually accounted for a much greater proportion of the total biomass

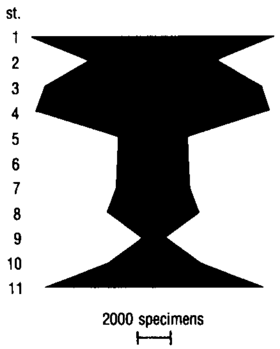


Fig. 2. The total numbers of specimens recorded at the eleven stations.

than the Chironomida because of their larger body mass. The wet body weight of chironomids were on average only about 1 mg, while those of Trichoptera were 10—20 mg, and those of Plecoptera and Ephemeroptera about 2—4 mg.

The total number of macroinvertebrates was highest at stations 1, 3, 4 and 11, and lowest at station 9 (Fig. 2). The greatest differences between stations in absolute numbers were found in April, and the least variation in August (Fig. 3). In general the numbers of Chironomidae and Trichoptera varied most widely (Fig. 4). The highest numbers of Chironomidae were recorded at stations 1, 3 and 11, Plecoptera at stations 1, 2 and 3, Trichoptera at stations 3 and 4 and Ephemeroptera at stations 4 and 6.

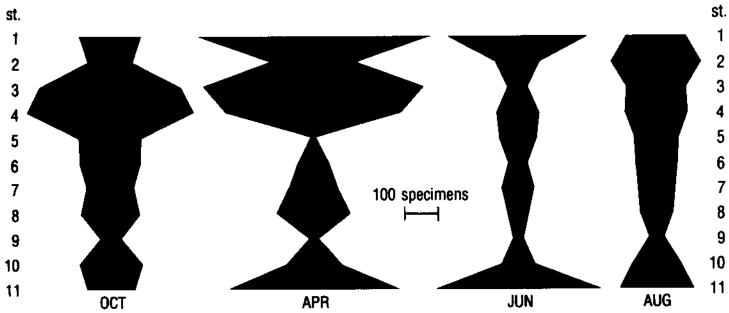


Fig. 3. The total numbers of specimens recorded in October 1972 and in April, June and August 1973.

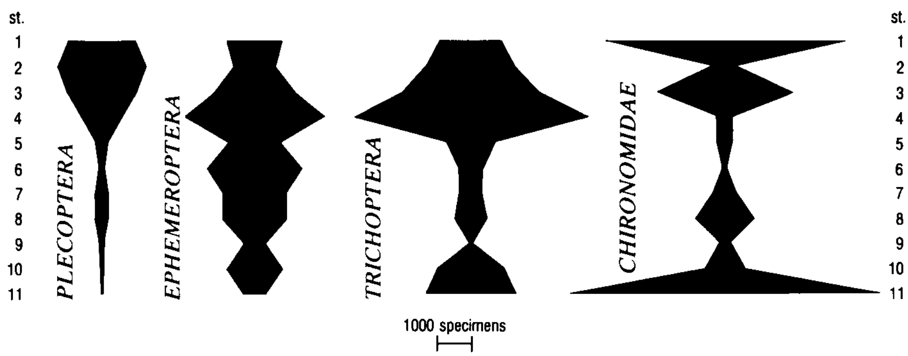


Fig. 4. The total numbers of Plecoptera, Ephemeroptera, Trichoptera and Chironomidae recorded at the eleven stations.

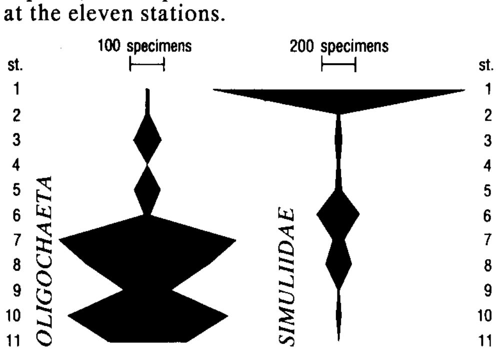


Fig. 5. The total number of Oligochaeta and Simuliidae recorded at the eleven stations.

The Simuliidae were most numerous at station 1 (Fig. 5) and Oligochaeta from station 7 downwards. Only small numbers of other groups were recorded (Fig. 6), for instance Mollusca mainly at stations 10 and 11 and *Asellus aquaticus* restricted to the same stations.

The seasonal variation in the numbers of the main groups differed greatly (Figs. 7, 8 and 9). Ephemeroptera were most numerous at stations 3 to 8 in April and at stations 1, 2 and 4 in June.

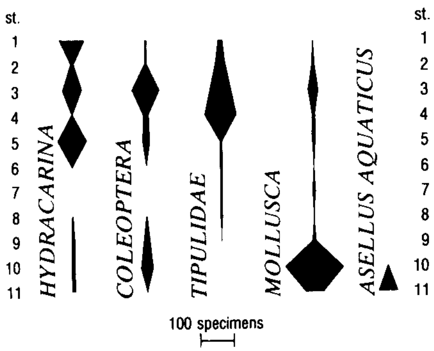


Fig. 6. The total number of minor groups recorded at the eleven stations.

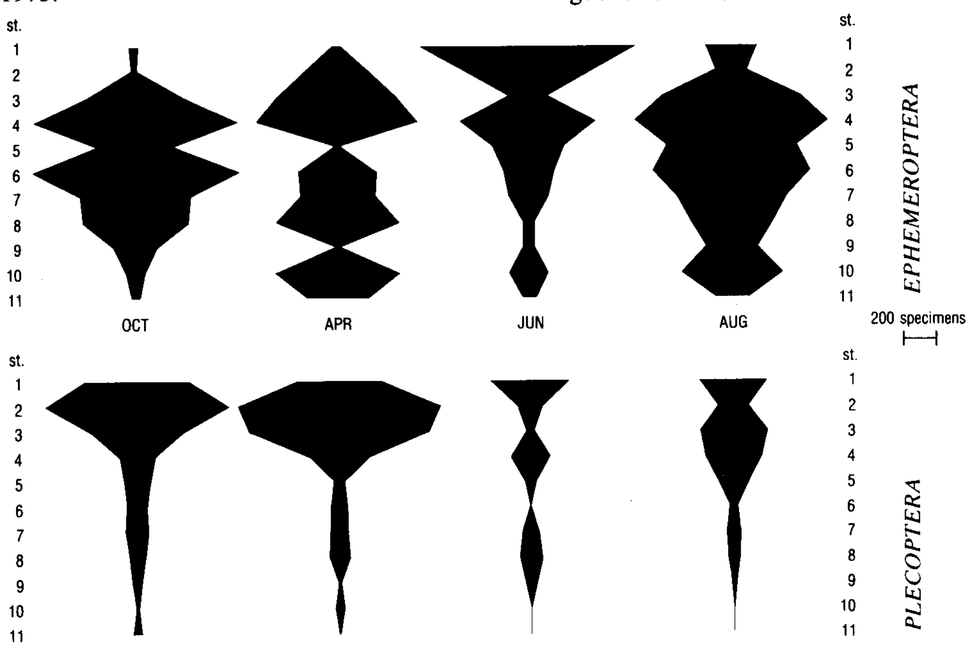
The mayflies *Baetis rhodani* and *Ephemerella aurivillii* were both present in large numbers at all the stations sampled. The overall variation in total ephemeropteran numbers was mainly due to these two species.

The highest numbers of Plecoptera were recorded at stations 1, 2 and 3 in October and again in April the following year (Fig. 7). Two species were particularly abundant, the herbivores *Capnia atra* and *C. pygmaea,* both of which emerge in late April and are present as eggs and small nymphs during the summer. Their main period of nymphal growth is during the autumn. The carnivorous stonefly *Diura nanseni* was also numerous at some stations, especially in the upper reaches of the river. During June and August, however, it was only sparsely represented at all stations. In the lower part of the river, *D. nanseni* was replaces by *Isogenus nubecula.* The carnivore, *Xanthoperla apicalis,* was numerous at stations 4 to 7.

The highest numbers of Trichoptera were recorded at stations 3 and 4 in October and April, and in August at station 2 (Fig. 8). In October they were also numerous at stations 5, 10 and 11. Trichoptera were recorded in low numbers at all stations in June. At stations 2, 3 and 4 the predominant species was the case-building grazer *Micrasema* spp., while at stations 10 and 11 filter-feeding species of *Hydropsyche,* mainly *H. nevae,* accounted for the greatest part of the Trichoptera fauna. The filter-feeding caddisflies, *Arctopsyche ladogensis* and *Polycentropus flavomaculatus,* and the carnivorous *Rhyacophila nubila* were also quite numerous at most stations.

Chironomidae were numerous at stations 1 and 11, occurring in greatest numbers in April and June, but only in low numbers in August and October.

Fig. 7. The total numbers of specimens of Ephemeroptera and Plecoptera recorded at the eleven stations in October 1972, and April, June and August 1973.



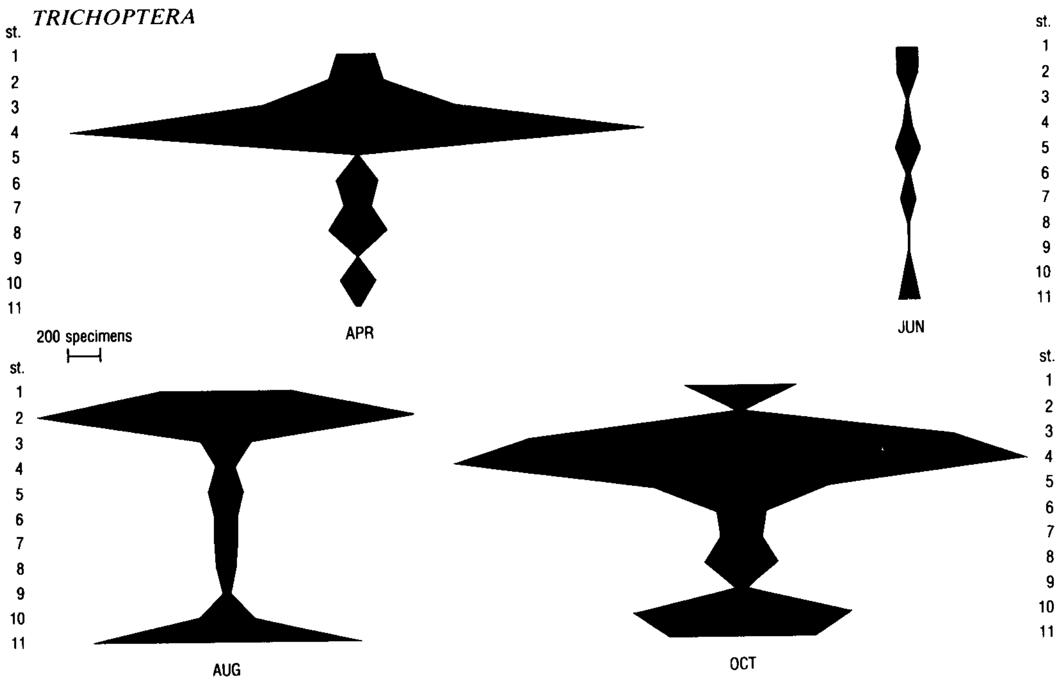
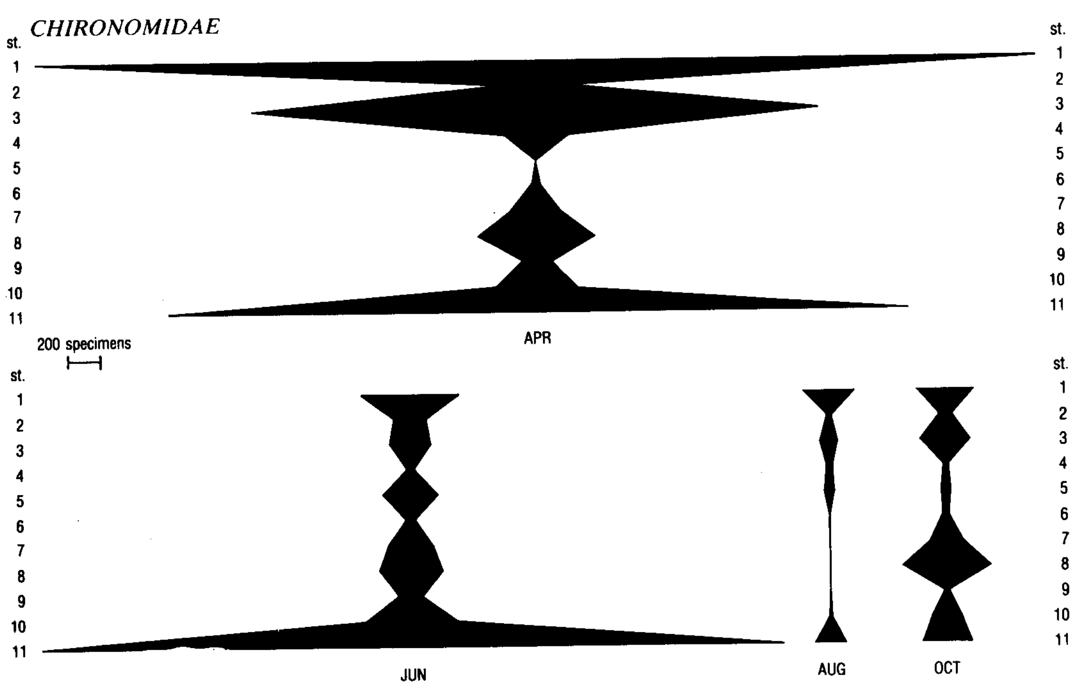


Fig. 8. The total number of Trichoptera recorded at the eleven stations in April, June and August 1973 and October 1972.

Fig. 9. The total number of Chironomidae recorded at the stations in April, June and August 1973 and October 1972.



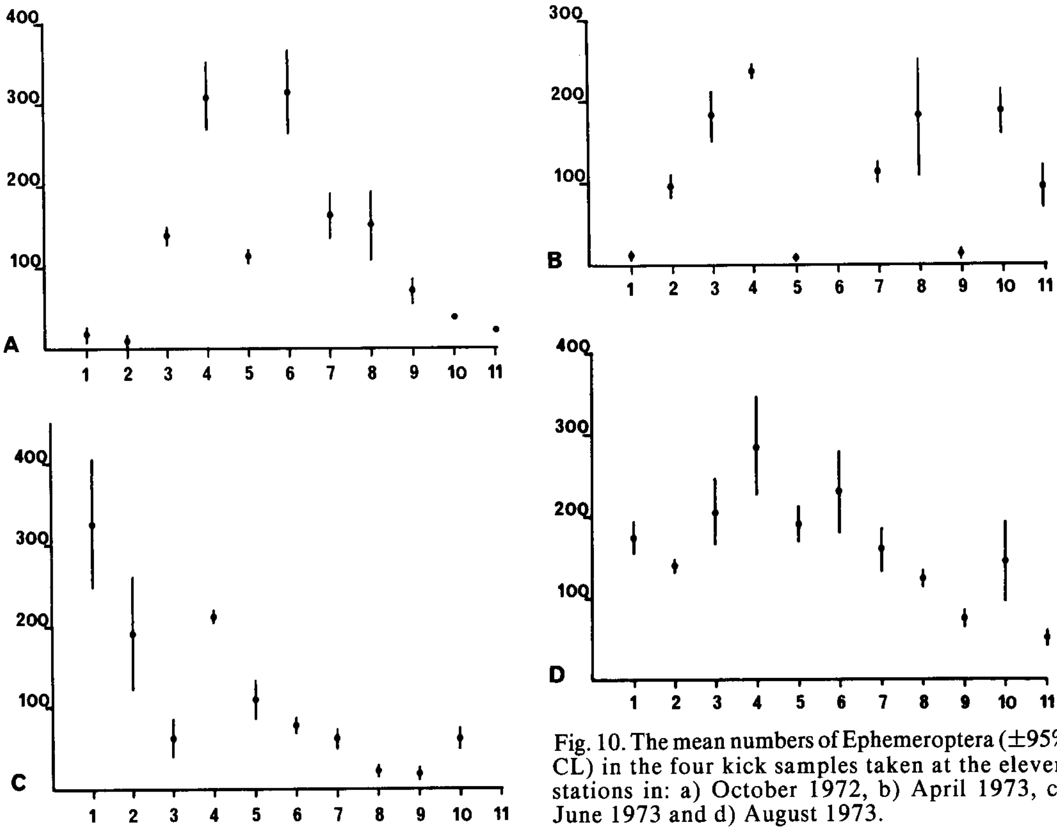


Fig. 10. The mean numbers of Ephemeroptera (±95% CL) in the four kick samples taken at the eleven stations in: a) October 1972, b) April 1973, c) June 1973 and d) August 1973.

Considerable significant differences in the abundance of the individual benthic groups were recorded along the different stretches of the river (Figs. 10—12). The greatest variation in the abundance of Plecoptera along the course of the river occurred in October and April, among Trichoptera in April, October and August. Less variation was seen in ephemeropteran abundance.

In April significant differences in the abundance of Plecoptera were observed between the upper (stations 1—4), middle (5—7) and lower (8—11) reaches of the river. In October and April a large significant difference in the abundance of Trichoptera was found between stations 3 and 4 and all the remaining stations. Their abundance in August at station 11 was significantly higher than values at any of the stations in the middle and lower reaches of the river.

Ephemeroptera were most abundant both in August and October at stations 4 and 6, while in April this was true of stations 3, 4, 8 and 10, and in June at stations 1—2.

Thus, the three groups were generally most abundant in the upper and to some extent the middle reaches of the river. The dam built at Barkal above station 5 (Hanestad) had a negative influence on the abundance of Trichoptera and Ephemeroptera in April, but not in the other months.

DISCUSSION

The Glomma is a long river, and differences in the composition of the benthic invertebrate fauna between the lower, middle and upper reaches were to be expected.

The abundance of Plecoptera at the stations in the upper reaches was also as expected, since this is the stretch of the river with the lowest water temperatures, and human influence is only slight. The same type of distribution of Plecoptera was found in an altitudinal zonation study in a Rocky Mountain stream (Ward 1986). Plecoptera are in general cool water species and typical of headwaters (Hynes 1976). River regulation

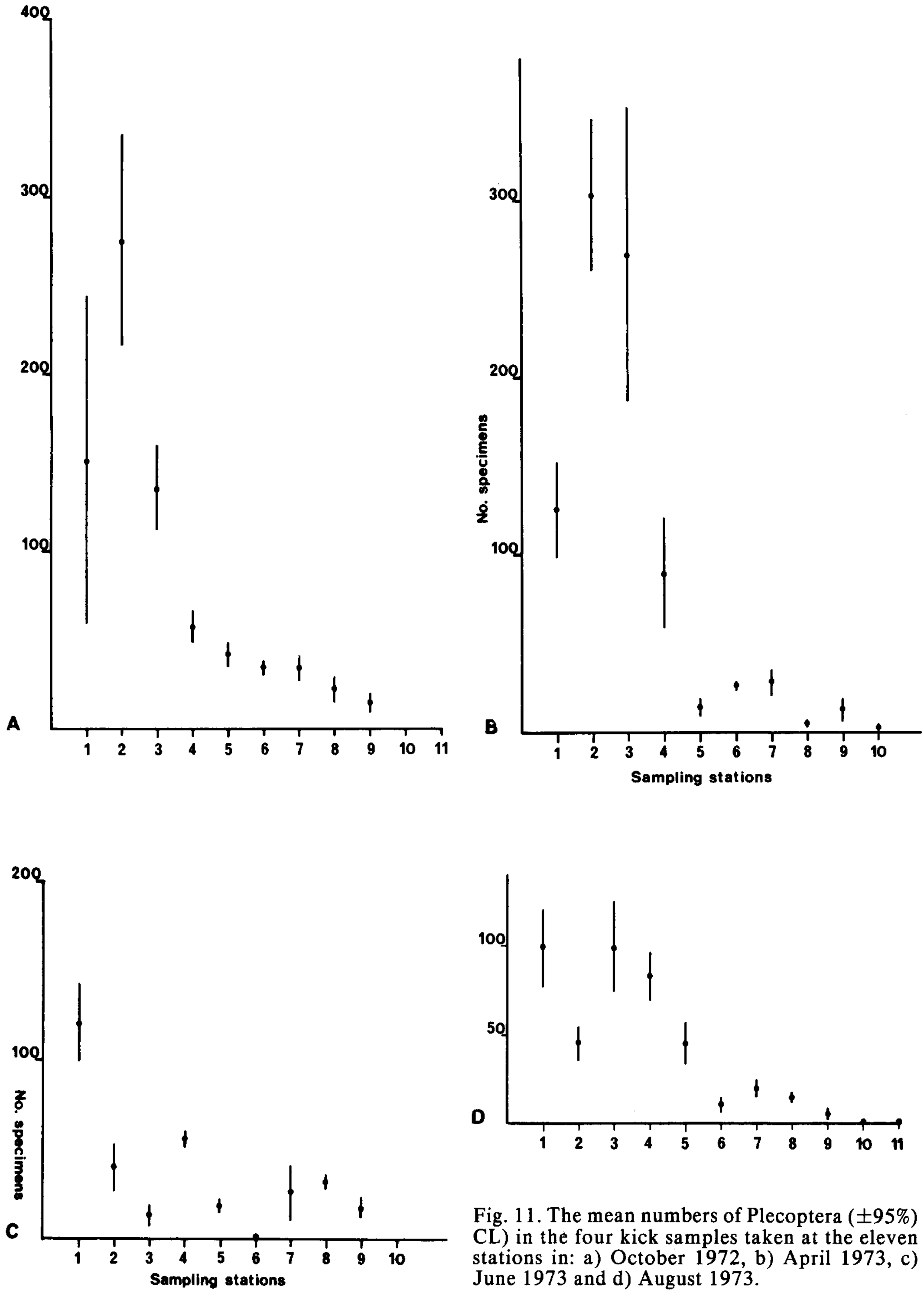


Fig. 11. The mean numbers of Plecoptera (±95% CL) in the four kick samples taken at the eleven stations in: a) October 1972, b) April 1973, c) June 1973 and d) August 1973.

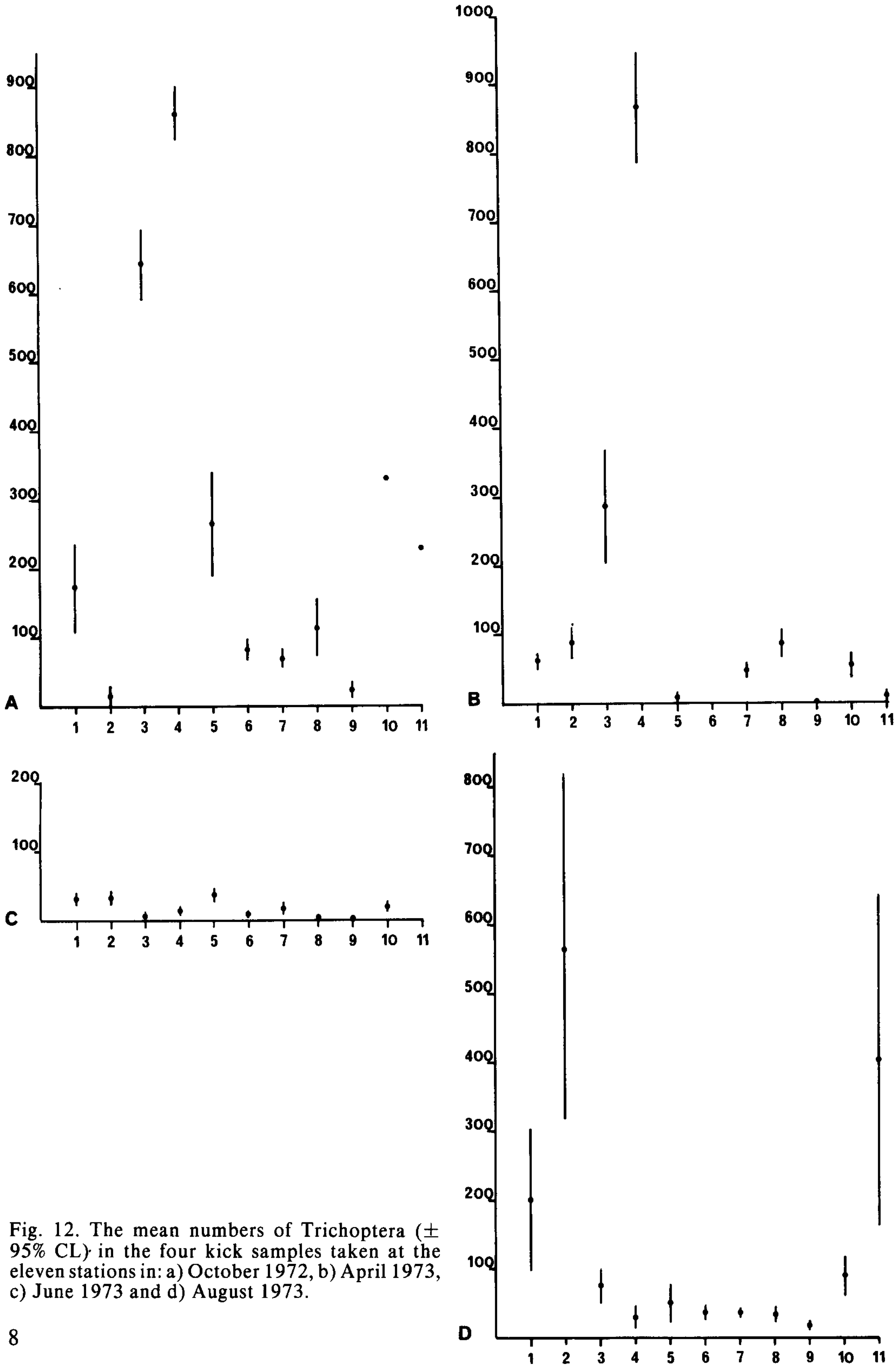


Fig. 12. The mean numbers of Trichoptera (± 95% CL) in the four kick samples taken at the eleven stations in: a) October 1972, b) April 1973, c) June 1973 and d) August 1973.

for hydro-electric power below these stretches may have influenced the stonefly fauna. Brittain et al. (1984) recorded an effect in the river Glomma below the dam at Barkal, and the same has been found in the Suldalslågen river (Lillehammer & Saltveit 1984). A reduction in the plecopteran fauna below dams is well known in other parts of the world (Saltveit, Brittain & Lillehammer 1987). The pattern of distribution of Plecoptera in the Glomma may therefore be a reflection of the conditions in the upper reaches and the increasing degree of pollution and regulation downstream.

Increased abundance of grazing benthic invertebrate species, such as the Trichoptera *Micrasema* spp. at stations 3 and 4, may be a result of increased algal growth caused by enrichment from two nearby small towns along the river, Tynset and Alvdal. The lake-like stretch above the dam at Rånåsfoss explains the increase in abundance of filter-feeding species of the caddisfly genus *Hydropsyche* at station 11 in August.

The increasing pollution downstream is not reflected in the species composition of the hydropsychid fauna. *Hydropsyche augustipennis,* which usually takes over when pollution increases (Wiberg-Larsen 1980), only occurs in low numbers in the Glomma. Compared to many rivers in Central Europe, the river Glomma must therefore still be considered relatively moderately polluted at the investigated localities.

The changes in the different fauna elements downstream of the hydro-electric dams can be explained as an effect comparable to that of natural lakes, i.e. an increase in the abundance of filter-feeders and a decrease in plecopteran species, such as was found in the comparative inlet/outlet studies of the lake in the Norwegian subalpine lake Øvre Heimdalen (Lillehammer & Brittain 1978).

The faunal zonation recorded in the Glomma, with a clear predominance of herbivorous Plecoptera in the upper reaches in October and April, fits well with the River Continuum Concept-RCC (Vannote et al. 1980), which predicts that shredders should be dominant in the upper reaches and grazers most abundant in the middle reaches. However, as mentioned earlier this may be a result of human influence caused by sewage from Tynset and Alvdal.

In the lower part of the river the predicted dominance of the gatherer-collector chironomids and of the filterer-collector *Hydropsyche* spp. was clearly visible.

Longitudinally the predatory invertebrate components changed little in relative dominance, such as also described in the RCC (Vannote et al. 1980), but different species replaced each other. The plecopteran *Diura nanseni,* which dominated the upper reaches was replaced by *Isogenus nubecula* and the trichopteran *Rhyacophila nubila* in the lower reaches.

Culp & Davis (1982) found that the longitudinal zonation of macroinvertebrates in a South Saskatchewan river system was related to the terrestrial ecosystems through which it flowed. The longitudinal trends in functional feeding groups in general followed the predictions of the RCC. Other authors have found the concept less applicable. Winterborn et al. (1981) showed that river ecosystems that lack coarse organic matter such as New Zealand rivers, do not follow this system in the representation of feeding groups, and Brönmark et al. (1984) stated that stream size is an important factor determining stream community structure. However, Minshall et al. (1985) concluded that although variations occur, it appears that most lotic ecosystems can generally be accommodated within the current conceptual framework of the RCC. Statzner and Higler (1985) confirm this, but also advocate modifications of its theoretical background.

Our benthic data from the River Glomma, which show only small differences from the theoretical RCC, endorse its validity for large rivers in our region.

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