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# REGULATED RIVERS

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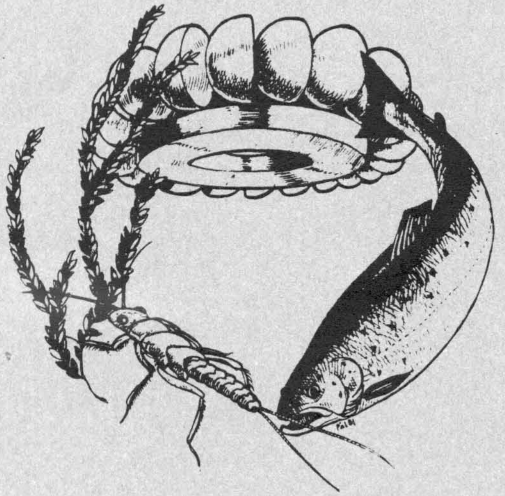

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# THE IMPACT OF A WATER TRANSFER SCHEME ON THE BENTHIC MACROINVERTEBRATES OF A NORWEGIAN RIVER

JOHN E. BRITTAIN, ALBERT LILLEHAMMER AND RUNE BILDENG

In connection with hydro-electric power generation water is transferred from the River Glomma over to the River Rena in eastern Norway. Benthic macroinvertebrates were sampled above and below the transfer site on the River Glomma. Trichoptera, Ephemeroptera and Plecoptera constituted over 90% of the macroinvertebrate numbers at both stations, but densities of all three orders were considerably lower below the transfer site. On account of the greater percentage reduction in water flow during the winter, the effects on the benthos were most obvious at this time. Most noticeable was the elimination of the winter growing Capniidae (Plecoptera) and the severe reduction in the winter generation of *Baetis rhodani* (Ephemeroptera). In contrast densities of filter-feeding Trichoptera increased and *Diura nanseni* became an even more dominant member of the plecopteran community. After the reduction in benthic densities during the winter, recovery was relatively rapid, and by August benthic densities were similar above and below the transfer site.

## Introduction

Until recently most regulation schemes have involved the regulation of a single catchment independently of neighbouring catchments. Therefore most of our data on the effects of regulation are from this type of regulation. However, in the eastern part of southern Norway water is transferred from the River Glomma over to a power station in the neighbouring drainage. For this purpose the Glomma is dammed at Barkal (Høyegga dam) and the water transferred through a tunnel to the Rena catchment. Such a transfer of water can clearly have far-reaching faunal effects in the recipient drainage. However, our aim in this particular study was to investigate the effects of water transfer on the macroinvertebrates of the River Glomma itself downstream of the transfer as part of an ongoing programme for the whole Glomma watercourse (Borgstrøm et al. 1976, Skulberg and Lillehammer - in press). The effects on the downstream benthos in this type of regulation are likely to be similar to schemes in which water is piped down to the power station intake leaving the river section with reduced water flows.

## Study area

The Glomma is the largest river in Scandinavia based on discharge.

Its catchment area is almost 42 000 $km^2$ (Skulberg & Lillehammer - in press) and its total length is about 600 km. Discharge is low during winter and high in May, June and July due to snowmelt in the catchment (Fig. 1).

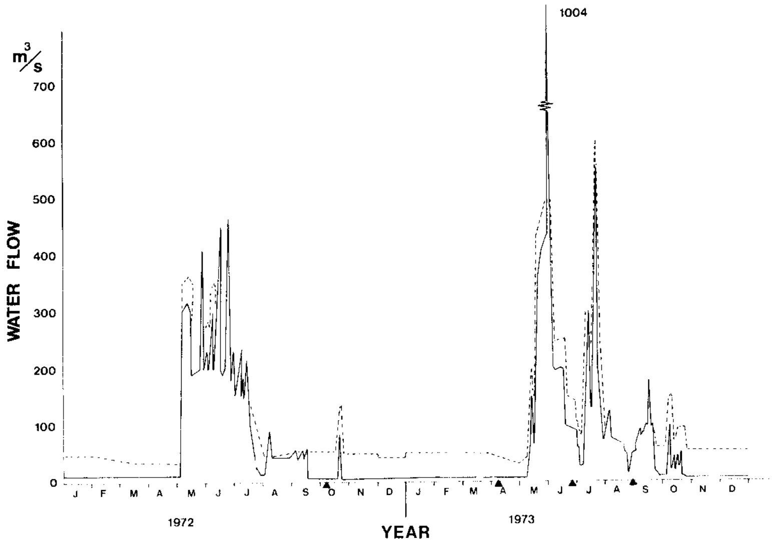


Figure 1 - Water flow rates in the River Glomma: dashed line - water transferred to the neighbouring catchment; solid line - water flow below the Høyegga transfer dam. Sampling dates are indicated by triangles along the time axis.

The river is used for hydro-electric power production at several localities. The present study has been carried out at Bellingmo and Hanestad, about 200 km north of Oslo, in connection with the Høyegga dam. Bellingmo (475 m a.s.l.) is situated 2 km above the dam at which water is transferred to the neighbouring valley, Rendalen, via a 28 km long tunnel. Hanestad (380 m a.s.l.) is situated 25 km below the dam and experiences 25-50% of pre-impoundment flows during winter and part of the summer (Fig. 1). During the summer water temperatures may reach 15-16°C at Høyegga, while from November until April or May the river is ice-covered (Fig. 2). The substratum at both sites is stable and is composed of stones about 10 cm in diameter or larger. The current is in the region of 05.-1.0 m/sec. The river is 100-125 m wide at normal water flows and the maximum depth is usually 0.5-1.25 m. Water chemistry is similar at both sites. Mean values at Bellingmo and Hanestad, respectively, for the period July-October 1977 were: pH - 7.3 and 7.4; sp. conductivity (20°C) - 51.5 and 45.0 uS/cm;

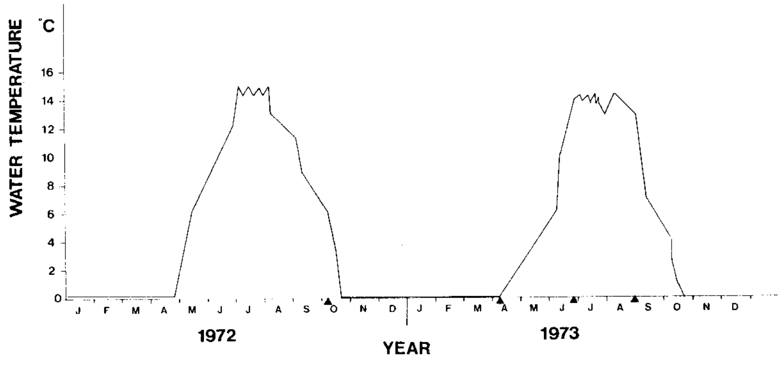


Figure 2 - The water temperature regime at Høyegga dam on the River Glomma. Sampling dates are indicated by triangles along the time axis.

total P - 7 and 6 ugP/l; calcium - 8.5 and 7.6 mgCa/l (Skulberg & Kotaie 1978). There is a rich epiphytic algal growth in the river, especially Chlorophyceae, Zygnema sp. and Ulothrix zonata being among the most common species (Skulberg & Kotaie 1978).

## Methods

Benthic macroinvertebrates were sampled using the 'kick method' (Hynes 1961). Four parallel, 2 minute kick samples were taken at each locality using a net with a square opening 30 x 30 cm and netting mesh size of 450 u. Sampling was carried out on four occasions: 11 October 1972, 9-12 April 1973, 26-27 June 1973 and 30-31 August 1973.

The net contents were preserved in 4% formalin in the field and subsequently sorted in the laboratory and transferred to 70% alcohol. All Ephemeroptera, Plecoptera and net-spinning Trichoptera were identified to species when possible. Knowledge of Norwegian case-building Trichoptera is incomplete, so only limited identification was possible. The nomenclature used is according to the following authorities: Trichoptera - Svensson and Tjeder (1975); Ephemeroptera - Dahlby (1973); Plecoptera - Lillehammer (1974).

95% confidence limits were estimated after logarithmic transformation. Samples from the two localities were compared statistically using the Mann-Whitney U-test.

Water temperatures, taken daily at the intake to Høyegga dam, were obtained from "Glomma og Laagens Brukseierforening", the association responsible for the regulation scheme. Water flow and water transfer data were obtained from the same source.

## Results

The dominant macroinvertebrate taxa both above and below the transfer dam were Trichoptera, Ephemeroptera, Plecoptera and Chironomidae. At Bellingmo, above the dam, the first three taxa consituted 95% of total macroinvertebrate numbers, while the equivalent value at Hanestad, below the dam, was 85%.

The abundance of Trichoptera, Ephemeroptera and Plecoptera showed a different seasonal pattern, with the lowest densities generally occurring at Bellingmo during the summer in contrast to the obvious minimum densities at Hanestad during April (Fig. 3). Apart

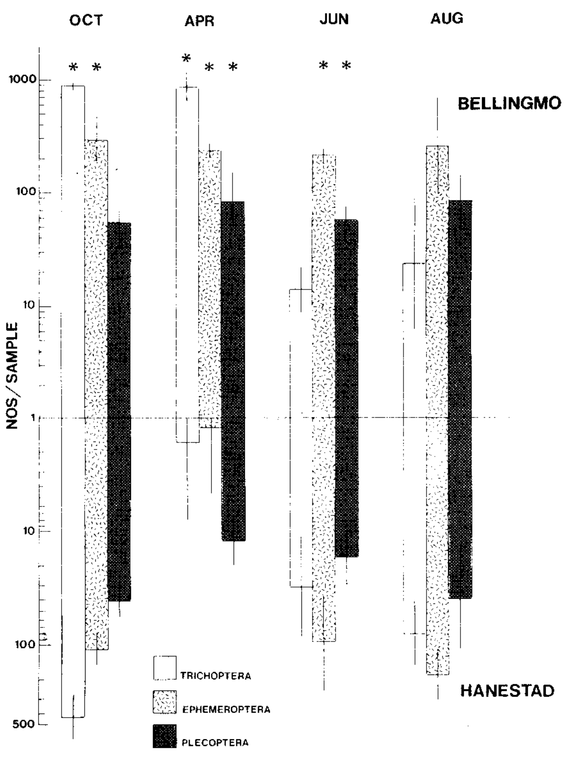


Figure 3 - Mean numbers/sample (± 95% C.L.) for Trichoptera, Ephemeroptera and Plecoptera taken in benthic samples above (Bellingmo) and below (Hanestad) the water transfer. Significant differences (P 0.05) between stations are indicated by an asterisk.

from August, significant differences were found between the two stations. There were significantly more Ephemeroptera in October, April and June, significantly more Trichoptera in October and April and significantly more Plecoptera in April and June at Bellingmo.

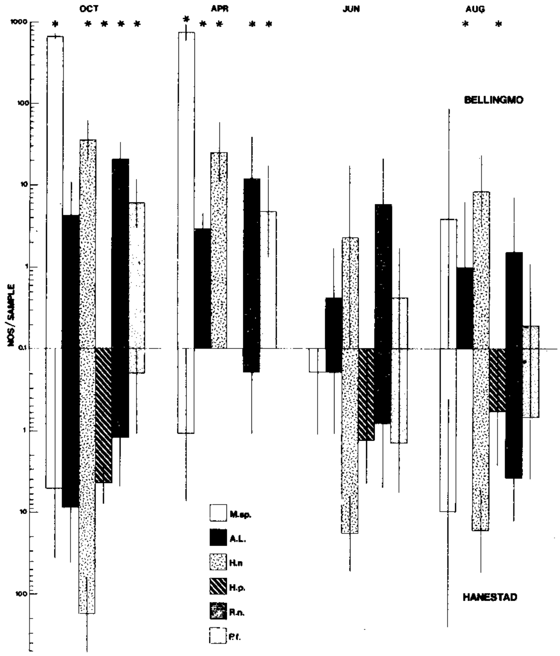


Figure 4 - Mean numbers/sample ($\pm$ 95% C.L.) for trichopterans taken in benthic samples above (Bellingmo) and below (Hanestad) the water transfer. Species are: M sp. - Micrasema sp., A.l. - Arctopsyche ladogenesis, H.n. - Hydropsyche nevae, H.p. - Hydropsyche pellucidula, R.n. - Rhyacophila nubila and P.f. - Polycentropus flavomaculatus. Significant differences (P 0.05) between stations indicated by an asterisk.

At the species level differences were even more marked. Among the Trichoptera the differences were especially apparent during October and April (Fig. 4). Apart from Hydropsyche pellucidula, which was restricted to Hanestad (Table 1), all species showed significantly higher numbers at Bellingmo at one or more times during the year. Within the Ephemeroptera the greatest differences between the two stations occurred during April when virtually no ephemeropterans were taken at Hanestad (Fig. 5). Baetis rhodani had in fact significantly lower numbers at Hanestad on three of the four sampling occasions (October, April and June). Even Ephemerella aurivillii, which had significantly higher numbers at Hanestad during

Table 1 - Total numbers of each species (n) and their respective percentage (%) of the total Ephemeroptera, Plecoptera and Trichoptera in benthic samples taken at Bellingmo and Hanestad on the River Glomma, during April, June, August and October.

| | BELLINGMO | | HANESTAD | |
|---|---|---|---|---|
| | n | % | n | % |
| EPHEMEROPTERA | | | | |
| Baetis rhodani | 2641 | 63.6 | 490 | 29.7 |
| Ephemerella aurivillii | 695 | 16.7 | 593 | 35.9 |
| Heptagenia dalecarlica | 692 | 16.7 | 494 | 29.9 |
| Ephemerella mucronata | 124 | 3.0 | 62 | 3.8 |
| Ameletus inopinatus | 2 | 0.1 | 7 | 0.4 |
| Parameletus sp. | - | - | 5 | 0.3 |
| Centroptilum luteolum | - | - | 1 | 0.1 |
| PLECOPTERA | | | | |
| Diura nanseni | 617 | 58.4 | 308 | 80.8 |
| Isoperla obscura | 122 | 11.6 | 46 | 12.1 |
| Capnia atra | 108 | 10.2 | - | - |
| Xanthoperla apicalis | 68 | 6.4 | 11 | 2.9 |
| Amphinemura borealis | 57 | 5.4 | 8 | 2.1 |
| Capnia spp. | 49 | 4.6 | - | - |
| Taeniopteryx nebulosa | 14 | 1.3 | 4 | 1.0 |
| Leuctra hippopus | 9 | 0.9 | - | - |
| Capnia pygmaea | 6 | 0.6 | - | - |
| Amphinemura sulcicollis | 3 | 0.3 | - | - |
| Amphinemura spp. | 3 | 0.3 | - | - |
| Leuctra spp. | - | - | 4 | 1.0 |
| TRICHOPTERA | | | | |
| Micrasema sp. | 5725 | 79.9 | 159 | 6.8 |
| Other case-building spp. | 856 | 11.9 | 1074 | 45.6 |
| Hydropsyche nevae | 315 | 4.4 | 999 | 42.5 |
| Rhyacophila nubila | 181 | 2.5 | 31 | 1.3 |
| Polycentropus flavomaculatus | 52 | 0.7 | 12 | 0.5 |
| Arctopsyche ladogensis | 39 | 0.5 | 51 | 2.2 |
| Hydropsyche pellucidula | - | - | 27 | 1.2 |

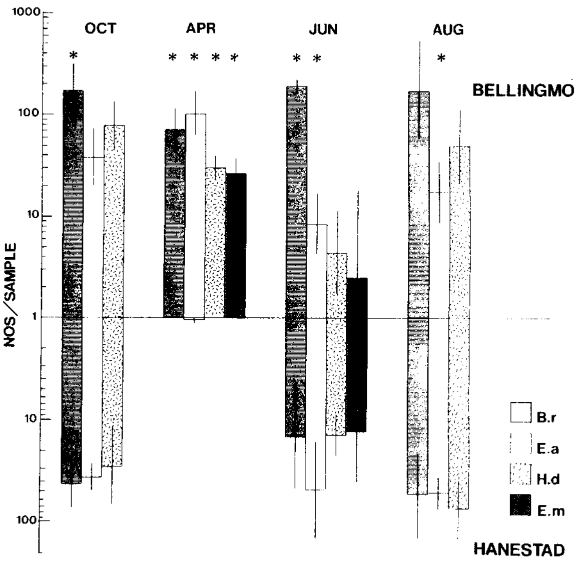


Figure 5 - Mean numbers/sample (± 95% C.L.) for ephemeropterans taken in benthic samples above (Bellingmo) and below (Hanestad) the water transfer. Species are: B.r. - Baetis rhodani, E.a. - Ephemerella aurivillii, H.d. - Heptagenia dalecarlia and E.m. - Ephemerella mucronata. Significant differences (P 0.05) between stations are indicated by an asterisk.

June, was barely recorded there during April. There were also significant differences at the species level among the Plecoptera (Fig. 6). These were most marked during October, April and August.

The major species of Ephemeroptera and Trichoptera were the same at both stations (Table 1), although there were differences in their relative importance. The greater abundance of the mayfly Baetis rhodani and the caddisfly Micrasema at Bellingmo and the greater abundance of Hydropsyche species at Hanestad were most obvious (Table 1). Among the Plecoptera, the complete absence of Capniidae at Hanestad was most striking, despite the fact that Capnia atra was one of the major species at Bellingmo. However, although reduced in number, Diura nanseni retained and in fact increased its numerical dominance of the stonefly fauna.

Among the minor taxa there were few differences, except a reduction in Tipulidae and an increase in Oligochaeta at Hanestad.

## Discussion

There are clearly major faunal differences above and below the water

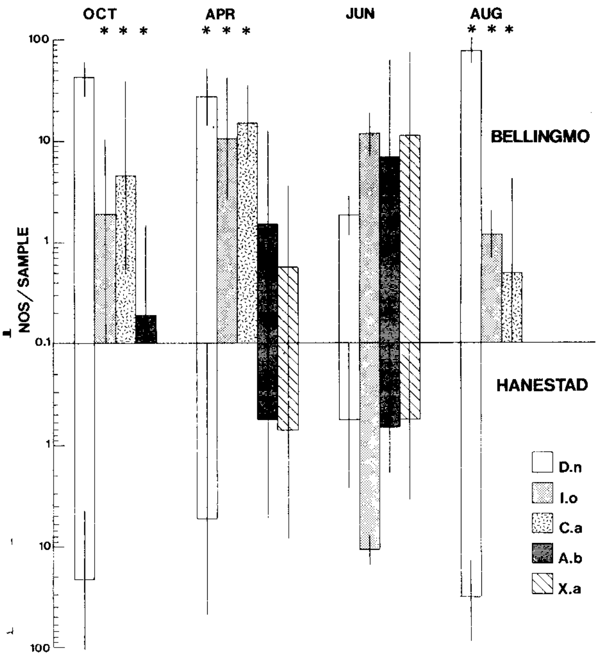


Figure 6 - Mean numbers/sample (± 95% C.L.) for plecopterans taken in benthic samples above (Bellingmo) and below (Hanestad) the water transfer. Species are: D.n. - Diura nanseni, I.o. - Isoperla obscura, C.a. - Capnia atra, A.b. - Amphinemura borealis and X.a. - Xanthoperla apicalis. Significant differences (P 0.05) between stations are indicated by an asterisk.

transfer dam on the River Glomma. However, samples taken during the summer months, especially during June and July, would show few differences between the two stations. It is during the winter months that the major effects of the water transfer can be seen. From May until September water flow rates in the river are high on account of snow melt and precipitation falling as rain. Therefore removal of water at Høyegga has little influence on the flow rate at Hanestad. However, during the autumn the natural water flow in the river decreases and from October onwards about 80% of the water is removed and transferred over to the neighbouring drainage. In practice this leaves only a minimum flow rate of 10 $m^3$ sec $^{-1}$ throughout the winter. As well as reducing the area available for benthic production, such a severe reduction in water flow markedly increases the danger of anchor ice (Ward 1976).

The stoneflies, Capnia atra and C. pygmaea are common along much of the River Glomma (unpubl. data) and their absence from what appears to be a suitable habitat is striking. Another species adversely affected by the water transfer scheme is the mayfly *Baetis rhodani*. In the River Glomma this species is bivoltine, with both a winter and a summer generation. At Hanestad there were significantly lower numbers of the winter generation of *B. rhodani*, while the numbers of the summer generation, reflected by the August samples, were similar at the two stations. The sampling site at Hanestad is 25 km downstream of the transfer dam. Owing to this distance and the epilimnial release from the dam, water temperatures are unlikely to be greatly different from the fast-flowing section of the river above the dam. This opinion is substantiated by recent continuous recording of temperature at Hanestad (Bildeng 1982). Therefore, it appears that the low winter flow rates are responsible for the elimination of the early emerging Capniidae and the severe reduction in the winter generation of *B. rhodani*. In a regulation scheme in northern Sweden these same genera were among those adversely affected by the building of a dam (Henricson and Müller 1979). Thus species which have a major part of their growth during winter appear to be especially susceptible to watercourse regulation. Reduced current speed on account of low winter flows may provide a stimulus for drift in *Baetis* which may take them into unsuitable habitats where they perish (Henricson and Müller 1979). Freezing and ice scouring will be more prevalent at low rates of flow, especially as the river profile is U-shaped. This often leaves small pools isolated from the main channel when flow rates fall.

In contrast to the above species, the stonefly *Diura nanseni*, which occurs in the egg stage during the first winter and is nearly fully-grown at the beginning of the second winter, is less influenced by regulation. In fact, it increases its dominance of the stonefly fauna below the dam.

As reported in a number of other studies (Lillehammer and Saltveit 1979, Ward and Stanford 1979), the numbers and relative importance of net-spinning Trichoptera increased at the site downstream of the transfer dam. Although the sampling station was 25 km below the dam, increased seston transport would still appear to be of importance.

The reduction in population densities during late winter, together with the low rates of flow in the river, permits colonization by species that are more typical of the slower reaches of the River Glomma. These include the mayflies, *Parameletus* sp. and

*Centroptilum luteolum*, and a number of case-building caddisflies. Nevertheless, recovery of faunal densities is rapid, and even by June many of the species are back to their "normal" densities. The spring spate, by producing an increase in drift among the aquatic insects due to increased water flow and turbidity (Townsend and Hildrew 1976, Ciborowski et al. 1977), undoubtedly contributes to recolonization, especially from small tributary streams which are not affected by the regulation scheme.

Aerial movements by adult insects are likely to be important in the build up of populations during the autumn. Another possible source of new individuals is the hyporheic zone (Coleman and Hynes 1970). The final possible source of colonizing individuals is from downstream populations, but this is unlikely to be important owing to reduction in their own populations. Initially at least downstream drift would appear to be the major source of colonizing animals. Drift was also the major source in the colonization of a natural stream, although aerial sources were also important (Williams and Hynes 1976).

In conclusion, therefore, it is clear that the water transfer scheme, by drastically reducing winter flow rates, leads to a major reduction in macroinvertebrate densities. Owing to the absence of major tributaries in the river stretch below the transfer dam, the effect is still marked over 20 km below the dam. However, recovery of many species takes place within 2-3 months and by the autumn the faunal composition is more similar above and below the transfer dam, although some species, such as the capniiids, remain permanently absent.

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