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Ecology of the regulated river Storelva in western Norway 50 years after regulation[1)]

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The river Storelva, situated in Sauda, Rogaland in western Norway has been regulated for hydroelectric power since 1914 and about 80% of the water-flow is transferred through tunnels to the various power stations and then to the fjord.

The river held a uniform benthic invertebrate fauna which was dominated numerically by chironomids and a few other groups, viz. the trichopteran *Polycentropus flavomaculatus* and the stoneflies *Amphinemura sulcicollis* and *Leuctra fusca.*

The feeding groups collectors, both filterers and gatherers, and predators were strongly represented in this regulated river. The population of salmon was negligible and only low numbers of trout occurred. The young trout mainly fed on the chironomid larvae.

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INTRODUCTION

The river Storelva has been utilised for hydroelectric power since 1914. This involved extensive regulation of the water flow. About 80% of the river water is transferred through a tunnel to a power station near the fjord at Sauda. This long-term regulation has influenced both the invertebrate fauna and the population of trout and salmon in the river. The main aim of the present paper, therefore, is to provide information about the effects of the initial regulation of waterflow at the time by which the fauna composition was considered to have become stabilised.

The fauna in Storelva was studied by the author in 1961 and 1962, some 50 years after its regulation. Some preliminary results of that study have already been published by Lillehammer & Saltveit (1979).

Previous studies on regulated rivers (Bækken et al. 1984, Brittain et al. 1984, Heggberget 1984, Lillehammer & Saltveit 1984) have dealt with the effect of relatively new regulations where further changes in the faunistic composition of the river can be expected in the future.

Study area

River Storelva has a catchment area of 348 km^2 and is now regulated by several dams (Fig. 1). From the lowest one, Storlidammen, at an altitude of 253 m above s.l. the river runs for 20 km before it enters the sea in Saudafjorden, at the end of Boknafjorden in the north of Rogaland province (59°40'N, 6°20'E).

The Storelva is situated in the sub-Atlantic climatic zone of the inner fjords of western Norway. The mean annual precipitation is high (2.047 mm, meteorological station Sauda).

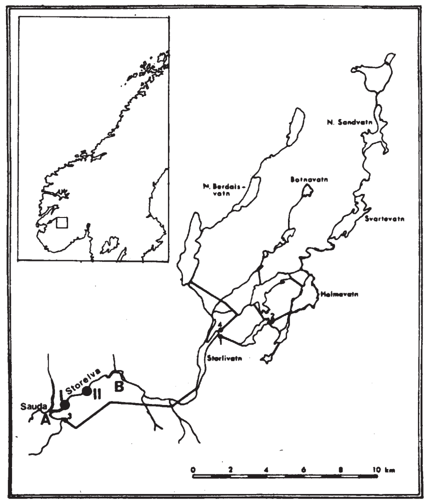

Fig. 1. Map showing the course of the regulated river Storelva in the Sauda district in the North of Rogaland province in south-western Norway. — = tunnels for water transfer, number 1—4 = power stations. A—B indicates the area in which salmon and sea trout occur. I and II are the sampling stations.

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The river is now mainly fed by the small tributary streams which enter it below the Storlidammen in the lower part of the catchment area. This means that after regulation the waterflow in summer is mainly influenced by the local precipitation and not by the snow-melt in the high mountains, as it was before regulation. This has resulted in a low water-flow in summer and a much altered water temperature regime resembling that of the small tributary streams, i.e. strongly influenced by the prevailing air temperature. The water conductivity was low, 21.9 µS/cm in August 1974, the total hardness was 3.3 mgCaO/l and the pH value was 6.3. However, the recorded acidity values may vary considerably, from 5.0 in January to 6.4 in July of the same year (Mørkgjerd & Gunnerød 1975). In 1961 and 1962 the highest recorded pH value was 6.1 (Lillehammer 1964).

The substratum mainly consisted of large stones firmly embedded in a substrate of smaller stones and gravel. About 50% of the stones were covered by Bryophytes, principally *Fontinalis dalecarlica* B.S.G. and *Marsupella emarginata* (Ehrb.) Dum.. A covering of benthic algae (diatoms) was also commonly present on the stones. The fairly dense riparian vegetation consists mainly of *Alnus* and *Betula*.

MATERIAL AND METHODS

The type of substrate mentioned above made it difficult to use a net sampler. Instead frames and boards of a type used by Moon (1935) and Josefsen (1953), and tested by Lillehammer (1964) were selected for this study. This method was also discussed by Økland (1962). However, the values are often higher than those obtained by a Surber sampler. Sampling was carried out at two stations in the lower part of the river, Klekkeriet (I) and Austarheim (II) (Fig. 1). Biomass for each species was estimated by weighing subsamples at each sampling occasion. Weights in the stomach content samples were calculated from the above-mentioned mean weights by comparing the size and numbers of head capsules in the stomachs with those found in the benthos samples. The benthic macroinvertebrates were also subdivided into their respective feeding groups (Cummins & Klug 1979). The trout fry and parr were sampled by electro-fishing and preserved in 4% formaldehyde.

Few young trout were caught, although great efforts were made to catch them. Only in May and August 1962 were sufficient numbers caught. The data for a total of 24 trout have been used for feeding analyses.

RESULTS

Invertebrate abundance and biomass

In both 1961 and 1962 the benthic macro-invertebrate fauna on stony substrates in the Storelva was in abundance predominantly made up of Chironomidae larvae (Table 1). Orthocladiinae were most common but specimens belonging to Tanypodinae and Chironominae were also fairly numerous at times. Orthocladiina were predominant in all months except May. Due to their small size, the chironomids at all times accounted for only a small part of the biomass.

The biomass was dominated by Trichoptera species in both years (Table 2). The largest diffe-

Table 1. The occurrence of benthic macroinvertebrates (No/m^2) on stony substrate in Storelva 1961 and 1962.

	1961				1962			
	May	June	July	Aug.	May	June	July	Aug.
Samples (N)	3	5	10	5	7	6	5	5
Oligochaeta	9	3	13	18	10	6	4	12
Hydracarina	0	20	5	3	3	25	40	28
Ephemeroptera	49	6	0	0	0	1	0	0
Plecoptera	166	129	18	26	44	74	58	101
Trichoptera	135	100	82	63	26	43	63	59
Diptera								
Chironomidae	347	161	454	154	169	169	116	50
Tipulidae	7	2	1	0	1	0	0	1
Simuliidae	10	4	11	11	0	22	56	51
Other Diptera	0	10	10	0	1	1	2	4
Total	723	435	593	275	273	341	339	306

Table 2. The biomass (mg/m^2) of benthic macroinvertebrates on stony substrate in Storelva in 1961 and 1962.

	1961				1962			
	May	June	July	Aug.	May	June	July	Aug.
Samples	3	5	10	5	7	6	5	5
Oligochaeta	180	30	260	200	50	30	40	80
Hydracarina	0	5	1	1	1	6	10	7
Ephemeroptera	525	12	0	0	0	2	0	0
Plecoptera	890	230	172	152	420	118	217	243
Trichoptera	789	560	1732	1091	386	1548	714	1049
Diptera								
Chironomidae	346	150	455	143	160	169	116	50
Tipulidae	630	200	100	0	20	0	0	10
Simuliidae	20	8	24	50	0	22	160	210
Other Diptera	0	30	30	0	10	10	20	40
Total	3380	1225	2774	1637	1047	1905	1277	1689

Table 3. The biomass (mg/m^2) of Trichoptera larvae on stony substrate in Storelva in 1961 and 1962.

	1961				1962			
	May	June	July	Aug.	May	June	July	Aug.
Samples	3	5	10	5	7	6	5	5
Rhyacophila nubila	0	60	0	180	0	30	0	210
Polycentropus flavomaculatus	495	230	600	340	99	234	570	308
Plectrocnemia conspersa	0	0	0	60	40	60	0	30
Potamophylax latipennis	110	200	520	0	0	800	130	180
Limnephilus spp	100	10	600	500	200	400	0	320
Lepidostoma hirtum	14	0	0	0	42	20	10	0
Oxyethira frici	70	60	12	11	5	4	4	1
Total	789	560	1732	1091	386	1548	714	1049

rences from 1961 to 1962 were seen among Ephemeroptera, and the dipteran Chironomidae, Tipulidae and Simuliidae. The group Trichoptera was dominated by the same species in both years, i.e. the case-bearing *Potamophylax latipennis* and *Limnephilus* sp. and the net-spinning filter feeder *Polycentropus flavomaculatus* (Table 3).

In both years the most abundant species of Trichoptera was *Polycentropus flavomaculatus,* except in May and June 1961 when *Oxyethira frici* was the most abundant species (Fig. 2).

The Plecoptera biomass was in May of both years dominated by the large carnivorous species, *Diura nanseni* (Table 4). In June the herbivore *Amphinemura sulcicollis* made up for the larger part. In July and August the next generation of small *D. nanseni* nymphs contributed a large biomass, although the herbivorous *Leuctra fusca* was strongly represented and made up for a large part of the biomass in August.

Numerically the Plecoptera fauna was dominated by *Amphinemura sulcicollis* in May and June. In July and August *Leuctra fusca* was the most common species (Fig. 3).

Feeding groups

In both 1961 and 1962 the collector and shredder groups were the major ones (Fig. 4), while there were seasonal differences in the composition of the feeding groups recorded in the two years.

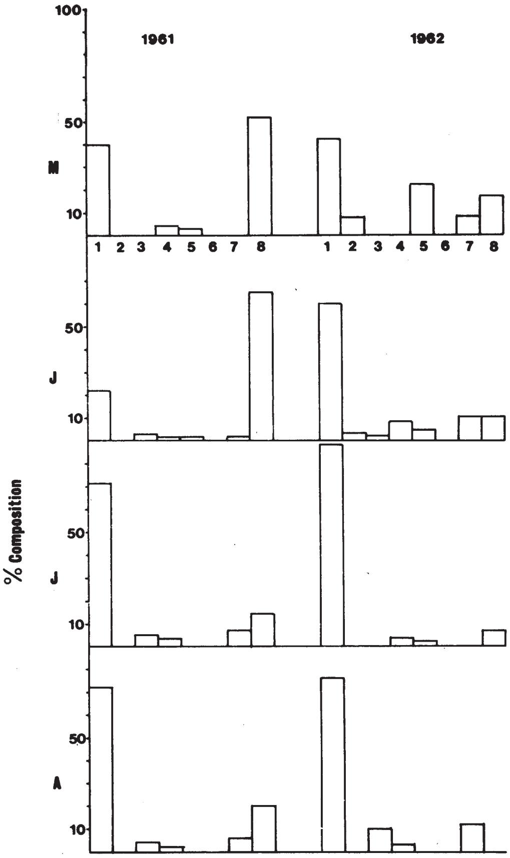

Fig. 2.
The % representation (absolute numbers) of Trichopteran species in the samples. 1 = *Polycentropus flavomaculatus*, 2 = *Plectrocnemia conspersa*, 3 = *Rhyacophila nubila*, 4 = *Potamophylax latipennis*, 5 = *Lepidostoma hirtum*, 6 = *Apatania stigmatella*, 7 = *Limnephilus spp.*, 8 = *Oxyethira frici*.

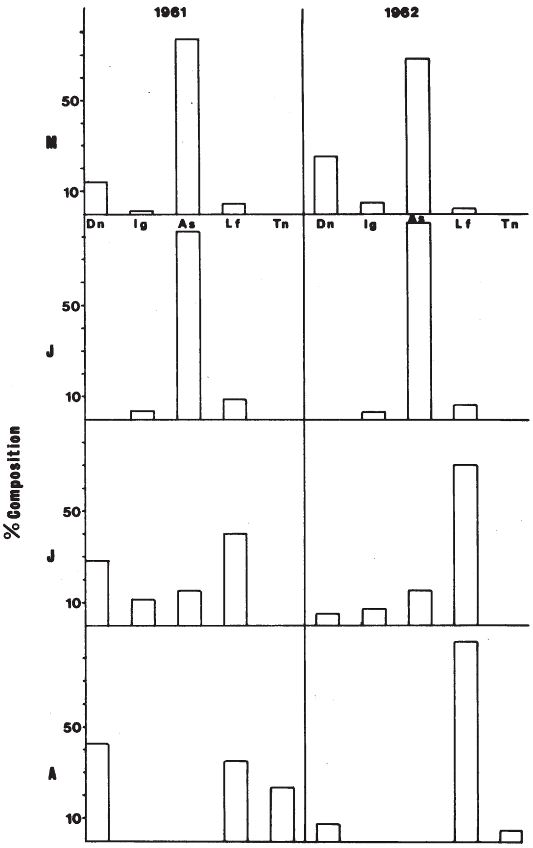

Fig. 3.
The % representation (absolute numbers) of the predominant Plecopteran species in the samples. *Diura nanseni* (D.n.), *Isoperla grammatica* (I.g.), *Amphinemura sulcicollis* (A.s.), *Leuctra fusca* (L.f.) and *Taeniopteryx nebulosa* (T.n.).

Table 4. The biomass (mg/m^2) of Plecoptera nymphs on stony substrate in Storelva in 1961 and 1962.

	1961				1962			
	May	June	July	Aug.	May	June	July	Aug.
Samples	3	5	10	5	7	6	5	5
Diura nanseni	710	0	100	64	322	0	96	27
Isoperla grammatica	37	24	22	0	60	38	23	0
Amphinemura sulcicollis	143	200	30	0	34	74	20	0
Leuctra fusca	0	6	20	58	4	6	78	206
Taeniopteryx nebulosa	0	0	0	30	0	0	0	10
Total	890	230	172	152	420	118	217	243

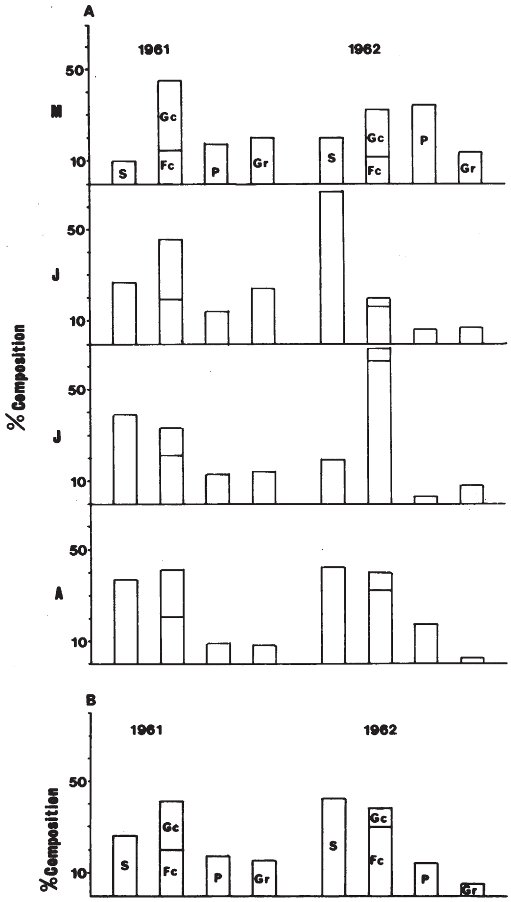

Fig. 4.
The % representation by biomass of different feeding groups during the months May—August (A), and during the entire summer (1961 and 1962) (B), based on the biomass values given in table 2. S = shredders, Fc = filter-collectors, Gc = gather-collectors, P = predators, Gr = grazers.

In 1961 the predominance of the collectors was greatest in May and June, and grazers also were common at the same time. In July and August the role of the shredder groups increased. In 1962 the degree of variation was larger. In May the predatory groups formed a greater proportion of the total biomass, while in June the shredders were completely dominant and in July the filter collectors; in August shredders again increased.

Feeding habits of the trout

The food of the trout (*Salmo trutta* L.) (Body size 5.2—9.5 cm) was primarily chironomids, both in absolute number and in biomass, both in May, and again in August (Table 5). The most abundant stonefly species in the benthos, *A. sulcicollis* and *Leuctra fusca,* were taken relatively frequently by the trout, while the most abundant Trichoptera, *P. flavomaculatus,* only was taken occasionally. *Rhyacophila nubila,* Oligochaeta, Hydracarina, planktonic Crustacea and the Ephemeroptera *Baetis* sp. were only occasionally present in the trout stomachs.

DISCUSSION

The river Storelva, regulated early this century is situated in the same faunistic area as the river Suldalslågen (Lillehammer 1984). In its unregulated condition the river was fed by the snow melt in the high mountains during the summer months and had a waterflow regime and a yearly temperature curve much like the unregulated river Suldalslågen. The fauna of river Storelva was therefore expected to contain much of the same species, although the waterflow is reduced by 80% and the summer temperature is expected to have increased. Most of the same species also occurred although there were some differences in dominance. The Plecoptera species *Amphinemura borealis* and *A. sulcicollis* occur in both rivers, but while *A. borealis* dominates in Suldalslågen, the opposite dominance occurs in Storelva. Two other common species have the same position in both rivers, *D. nanseni* and *L. fusca,* both species are little influenced by regulation effects.

The Trichoptera fauna is dominated by two species also occurring in large numbers in the

Table 5. The stomach food content analyses of young trout caught in May (N = 13) and August (N = 11) 1962. Only the most abundant taxa are represented in the table.

	Chironomidae		Plecoptera		Simuliidae		Terr. insects	
	May	Aug.	May	Aug.	May	Aug.	May	Aug.
No. %	94	93	5	3	0	1.5	0.9	0.7
Frequency	84	100	61.6	90.9	0	36	17.3	9
Biomass %	78.6	85	13.8	5.1	0	4.6	6.7	0.8

unregulated Suldalslågen, *Polycentropus flavomaculatus* and *Potamophylax latipennis*. The third abundant species *Oxyethira frici* is much more abundant in Storelva than in Suldalslågen.

All the above-mentioned species are common over a large part of Norway. They are species that can tolerate wide variations in environmental factors, both natural (Lillehammer 1974, 1978b, Lillehammer & Brittain 1978) and artificial such as the effect of hydro-electric regulation (Josefsen 1953, Henriksen & Müller 1979, Langeland & Haukebø 1979, Lillehammer & Saltveit 1979, 1984, Brooker & Morris 1980).

Shredders were much more weakly represented in Storelva than in the formerly unregulated River Suldalslågen (Lillehammer 1984), but more strongly so than after its regulation (Lillehammer & Saltveit 1984). Grazers were more strongly represented in Storelva than in Suldalslågen. This may be connected with the fact that the substratum of the former is more stable and that the stones to a greater degree are covered by moss and algae. Predators, such as the predatory Plecoptera species and the subfamily Tanypodinae of the Chironomidae have a relatively strong position in Storelva. The Trichoptera filter feeder species *P. flavomaculatus* also takes animals for food (Badcock 1949, Tachet 1965, Eikeland 1983). The strong position of predators can be seen as a direct result of the river regulation. The same result has been noted in other regulated rivers, such as Suldalslågen (Lillehammer & Saltveit 1984) and the Glomma (Brittain et al. 1984).

The water of Storelva which is markedly more acidic than that of Suldalslågen, has only a negligible population of young salmon and small trout, which feed almost entirely on chironomid larvae.

The small size of the trout and salmon populations in the Storelva may be a result of a shortage of food, although the abundance of benthic macroinvertebrates is not much lower than in Suldalslågen (Lillehammer & Saltveit 1979). However, the Storelva fauna is more dominated by only a few species such as *Leuctra fusca, Amphinemura sulcicollis* and *Polycentropus flavomaculatus*. The reduced water flow may also have had direct influence on the populations of young salmonids due to the unfavourable hydrographic conditions produced during both winter and summer. However, a reduced water-flow does not necessarily lead to a reduction in the populations of salmon and trout. In the river Skjomen, Heggberget (1984) reported that marked reduction in the water-flow had had no negative effect on the population of young salmon in this river.

It is probable that the periods of acid water that sometimes occur in the Storelva (Mørkgjerd & Gunnerød 1975) in combination with the strongly reduced water-flow have a negative effect on fish production, especially on that of the salmon.

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