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Ecology of the Suldalslågen river in western Norway before its regulation

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The River Suldalslågen, 22 km in length, situated in Rogaland province in western Norway, has been studied over a period of four years.

The macro-invertebrate benthos was low in abundance especially in August and September. The main biomass was contributed by large case-bearing caddis-fly larvae, such as *Potamophylax latipenis,* which are shredders. The fauna composition of the upper and lower reaches of the river differed widely. Filter feeders, such as the caddis fly *Polycentropus flavomaculatus,* occurred in large numbers below the lake outlet, while shredders were predominant in the lower reaches. Large quantities of planktonic Crustacea, washed out ot the Suldalsvatn lake, were present in the river during the summer months.

The Suldalslågen river is primarily a recruitment area for salmon and sea trout. Interestingly, the diet of the young salmonids did not show a close relationship to the available invertebrate biomass. For example, young salmon almost completely neglected the large caddis-fly larvae, while planktonic Crustacea washed out from Suldalsvatn and adult insects were taken in large numbers.

A large proportion of the food supplies of both the salmon fry and parr were thus produced outside the river system. In 1962, for example, 34 % of the food of the parr and 43 % of that of the fry was produced in other ecosystems than the river one.

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INTRODUCTION

The Norwegian watercourses are being utilised to an ever-increasing degree for hydro-electric power, involving extensive regulations. Increased knowledge of these ecosystems, their floristic and faunistic composition, their similarities and divergences are therefore necessary. Some detailed information has already been published (Lillehammer et al. 1980, Tråen 1983 and Skulberg & Lillehammer 1984), and more is presented in the present paper.

In its unregulated state, the Suldalslågen river (Fig. 1) has been studied by the author from 1960 to 1965. The benthic fauna was studied in 1961, 1962 and 1964, the zooplankton in 1962, 1964 and 1965, and the trout and salmon in 1962 and 1964. Some of the results have been published previously (Lillehammer 1964a, b, 1965a, b, 1973a, b, 1974).

The river was regulated in 1967, water flow in winter being increased and the summer flow decreased. A minor increase in water temperature occurred in the lower reaches of the river. A preliminary evaluation of the influence of the 1967 regulation has been published (Lillehammer et al. 1976, 1978 , Lillehammer & Saltveit 1979, 1984). Studies were started again in 1968 and continued from 1974 to 1980, when a second regulation of the river took place. This regulation was more drastic than the first, because the waterflow was reduced through most of the year. The level of the Suldalsvatn lake has been regulated by a dam, and water is now led directly from the lake into the power station built at a nearby fjord. In addition a supply of more acidic water, from beyond the natural catchment area of the lake, will be tapped.

STUDY AREA

The Suldalslågen river, 22 km in length, in Rogaland province in western Norway (Fig. 1) is a fifth-order watercourse, which runs out of the Suldalsvatn lake. This is a fjord-lake 29 km in extent and 375 m deep. It is situated at en altitude of 68 m above sea-level. The catchment area covers about 1000 km^2, the greater part of which is situated above the tree-line. The feeder streams lying above the tree-line are mainly of the 1st and 2nd orders, often reaching the 3rd order in the subalpine birch forest region. When

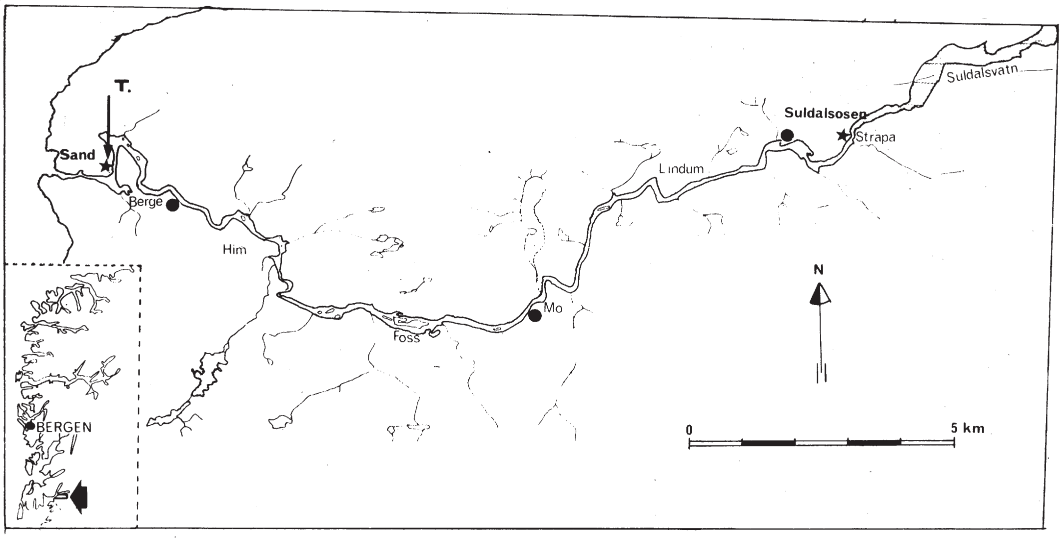


Fig. 1. Map of the course of the Suldalslågen river showing the sampling localities, ● benthos samples, ★ water temperature recordings, (T) Tjelmane bridge.

the streams enter the Suldalsvatn lake they are mainly of the 3rd or 4th order. The subalpine belt extends to about 700 m above s.l. and the boreal pine forest belt to 5—600 m above s.l. Around the lake and in the river valley stands of *Alnus, Quercus, Fraxinus* and *Ulmus* occur, while along the river and streamsides a riparian vegetation is found, mainly with stands of *Alnus*. A total of about 20 larger or smaller streams discharge directly into the Suldalslågen river from the surrounding mountains, bringing large quantities of allochthonous material into the river. The Suldalslågen river is situated in the Sub-Atlantic climatic zone of the inner fjords of Western Norway.

Water-flow

Water-flow in Suldalslågen varies widely with the seasons (Rørslett & Skulberg 1975). In 1964, the least waterflow recorded was 8 m^3 $sec.^{-1}$ in March, and the greatest 626 m^3 $sec.^{-1}$ in July. Waterflow is at a minimum in January, February and March, and reaches its maximum in June and July. The maximum flow is due to the snow-melt in the mountains. A wide difference exists in the area flooded by the river in summer and winter, of an order of approximately 3:1.

Water temperature

The temperature amplitude of the waters of the Suldalslågen river is relatively slight, being about 10°C between the warmest and coldest months. It is thus a winter-warm and summer-cold river (Fig. 2). This is apparently mainly due to the ability of the large Suldalsvatn lake to regulate and even out the annual amplitude in water temperature, especially in winter. In all winter months the water flowing from the lake enters the river at a mean temperature of over 2°C. At about 20 km below the lake outflow, the water temperature is 1°C lower during the coldest months. The low water temperature in summer is due to the great quantity of snow melt-water, which runs straight into the lake without much warming up.

Water chemistry

Analysis of water samples from the Suldalslågen river made during the period 1966—1971, showed that the river water was slightly acidic and had low conductivity. The mean pH value was 6.4 and mean conductivity 15.7 µS/cm. In general, the pH values lie between 6.2 and 6.8 and the conductivity values between 10 and 20 µS/cm, but pH values of between 5.7 and 7.7 and conductivity values between 8.0 and 156 µS/cm have been recorded at times (Gjessing & Nygård 1971).

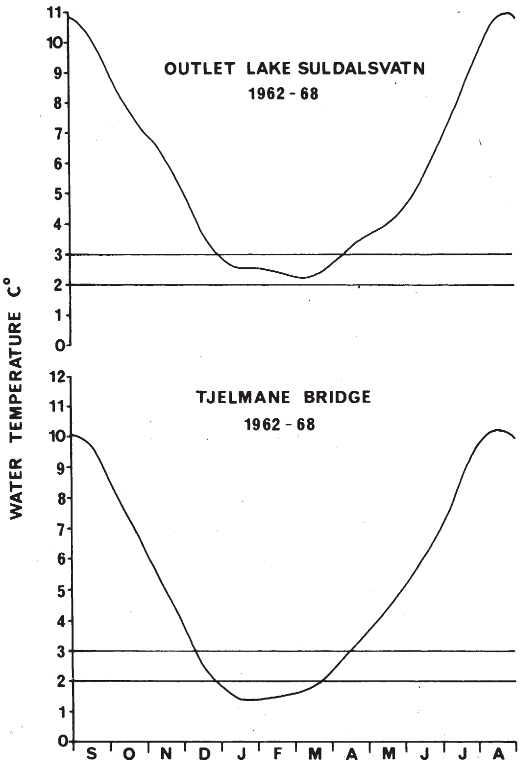


Fig. 2. The mean annual water temperatures (1962—1968) in the Suldalslågen river, based on recordings made at the outlet from the Suldalsvatn lake (Stråpa) and in the lower reaches of the river (Tjelmane bridge).

Macrophytes

The macrophytic flora of the Suldalslågen river has been studied by Rørslett & Skulberg (1975). Altogether 36 species have been recorded. Macrophytes are sparsely distributed in the river, but there is a tendency for the vegetation to be richer in shallow bays with a muddy bottom. The most common species are *Juncus bulbosus* L. and *Callitriche hamulata* Kütz, but *Subularia aquatica* L., *Ranunculus reptans* L., *Galium palustre* L., *Deschampsia caespitosa* (L.) P.B. and *Agrostis stolonifera* L. have also been recorded along the entire river course.

Sampling stations for the faunistic studies

The sampling data presented here are derived from three of the total of nine stations sampled (Lillehammer 1964). These three stations were chosen as being representative of three different stages of dependence on the fauna in the large Suldalsvatn lake, viz. Suldalsosen (Fig. 1) is situated about 2 km, Mo about 8 km, and Berge about 20 km below the lake outlet. Marked differences exist in the water temperature in winter between Suldalsosen and Berge.

MATERIAL AND METHODS

For sampling the aquatic macro-invertebrates a Surber sampler was used for the benthic forms and a net sampler (Wathers 1962) for the drifting Crustacea. The total weights of the different benthic animals were estimated by wet-weighing a number of them and then calculating the mean weight on each sampling occasion. The weights of those present in the stomach content samples were calculated from the above-mentioned mean weights by comparing the size and numbers of head capsules in stomachs with those in the benthos samples. The calculation of the % weights of the large caddis larvae which often were in a fairly digested state in the stomach content-samples from the young salmon, with this method yields a more precise value than one calculated solely on a % volume basis. The benthic animals were also sub-divided into their respective feeding-type groups, as done by Cummins & Klug (1979), based on the biomass calculations. The stomach contents of the young salmon were dealt with in the same way. The salmon, fry and parr, were sampled by electrofishing and preserved in 4% formaldehyde.

RESULTS AND DISCUSSION

Aquatic macro-invertebrates

Fauna composition

The mean biomass values (mg/m^2) for the benthos on a stony substrate at the three stations Suldalsosen, Mo and Berge in the months May—September show that Trichoptera were the dominant group, followed by Tipulidae and Plecoptera (Fig. 3).

The case-bearing and large larvae of *Potamophylax latipenis* represented the largest component of the total biomass at all 3 stations, that of the most abundant net-spinning species *Polycentropus flavomaculatus* accounted for the next largest proportion.

The large carnivorous species *Diura nanseni* was the dominant contributor of the biomass of the Plecoptera, although the three small herbi-

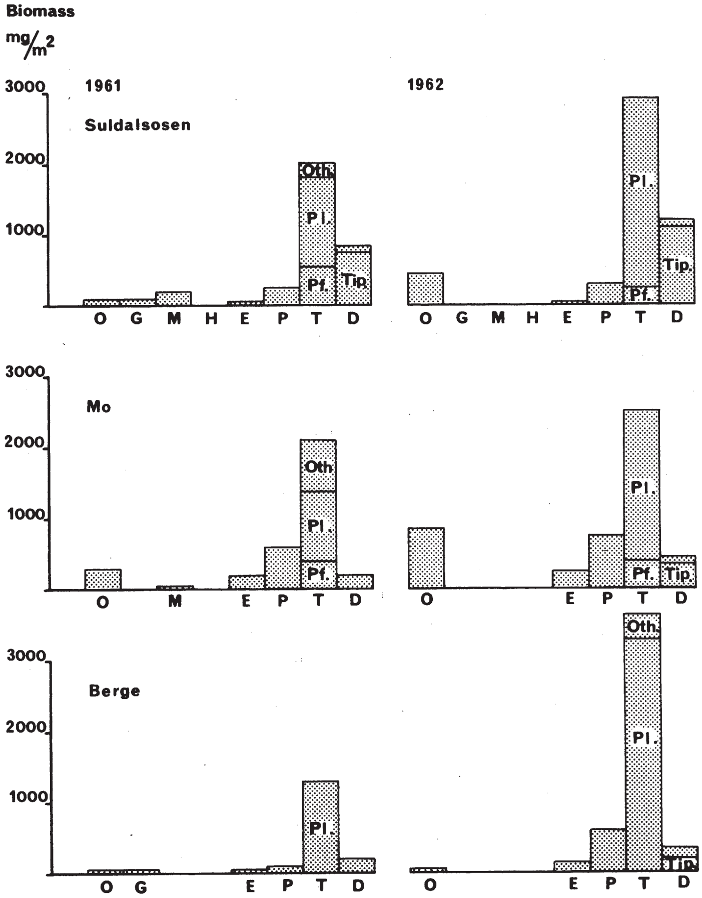


Fig. 3. Mean biomass (mg/m^2) of the different components of the benthic fauna at the three sampling stations in the Suldalslågen river. Samples were taken once a month from May to September in 1961 and 1962. O = Oligochaeta, G = Gastropoda, M = Mollusca, H = Hydracarina, E = Ephemeroptera, P = Plecoptera, T = Trichoptera, D = Diptera. P.f. = *Polycentropus flavomaculatus*, P.l. = *Potamophylax latipenis*. Oth = other Trichoptera species. Tip = Tipulidae.

vorous species *Amphinemura borealis, A. sulcicollis* and *Leuctra fusca* were numerically more abundant. The abundant Chironomids accounted for only a small proportion of the total invertebrate biomass.

Table 1. Fauna composition expressed as no. organisms m^{-2} at three different stations in River Suldalslågen, July 1961.

		Mean	Sd
Suldalsosen	N = 3		
Ephemeroptera		24.66	15.83
Plecoptera		10.30	5.83
Chironomidae		66.66	45.17
Trichoptera		166.30	25.32
Other taxa		186.14	—
Total fauna		454.06/m^2	191.60
Mo	N = 3		
Ephemeroptera		33.60	2.90
Plecoptera		58.30	38.79
Chironomidae		84.30	72.50
Trichoptera		148.00	60.00
Other taxa		104.10	—
Total fauna		428.30/m^2	144.83
Berge	N = 5		
Ephemeroptera		16.20	5.67
Plecoptera		17.00	12.90
Chironomidae		10.20	13.50
Trichoptera		24.60	29.30
Other taxa		18.80	—
Total fauna		86.80/m^2	60.00

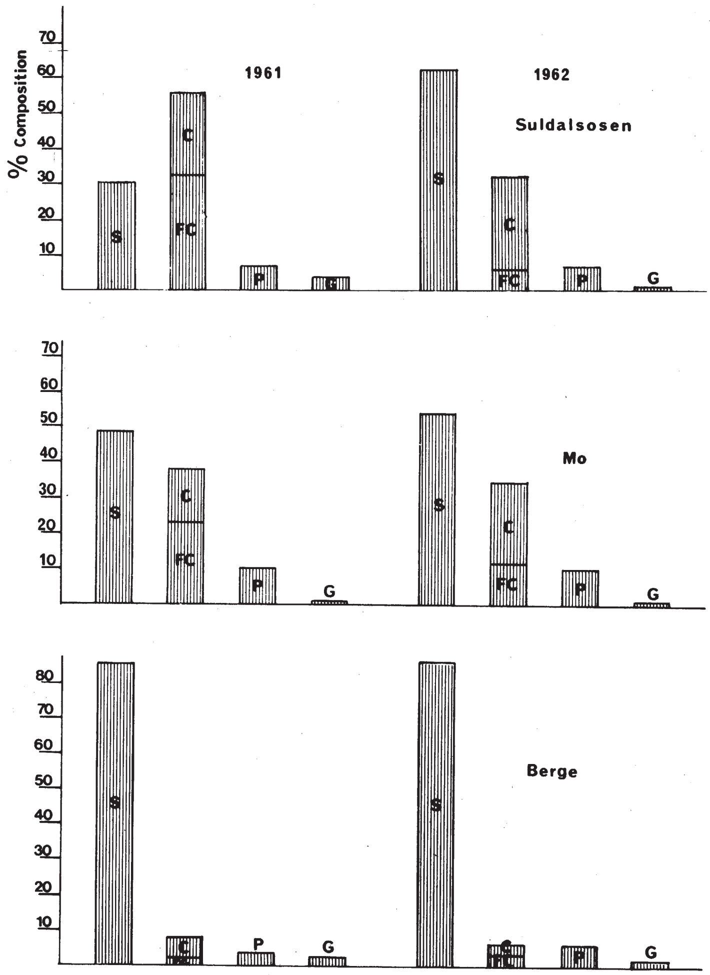


Fig. 4. The % contribution to the total biomass of the different types of benthic feeders at the three sampling stations presented in Fig. 3. S = shredders, C = Gather collectors, FC = Filter collectors, P = Predators, G = Grazers.

Significant differences were noted at times in the abundances of the different groups of the Suldalsosen station, 3 km below the lake outlet and at Berge, the lowest station, about 20 km below, e.g. in July 1961 (Table 1). Overall no significant fauna differences existed between the Suldalsosen station samples and those from Mo about 8 km below the lake outlet.

For the Trichoptera, however, significant differences were found between all three stations, mainly due to changes in the abundance of the net-spinning species *Polycentropus flavomaculatus*, which was significantly more abundant at Suldalsosen, just below the lake outlet, than at the two stations further downstream (Table 2).

The evertebrate fauna present on the stony substrate of the river-bed was predominantly insects. In the most fast-flowing reaches, they accounted for as much as 99 % (by number) of the entire benthos (Lillehammer 1966). The abundance of small-sized specimens, mainly Chironomidae and Plecoptera, was found to be much greater in shallow than in deeper water. 50 % more specimens were present in areas in which the stones of the riverbed were covered thickly with moss than where they were not moss-covered. Newly-flooded stony bottom areas were

Table 2. The composition of the net-spinning filter feeding Trichoptera *Polycentropus flavomaculatus*. No m^{-2} at three different stations. July 1961.

Locality	Mean	Sd
Suldalsosen	115.75	15.30
Mo	70.00	11.00
Berge	3.80	6.09

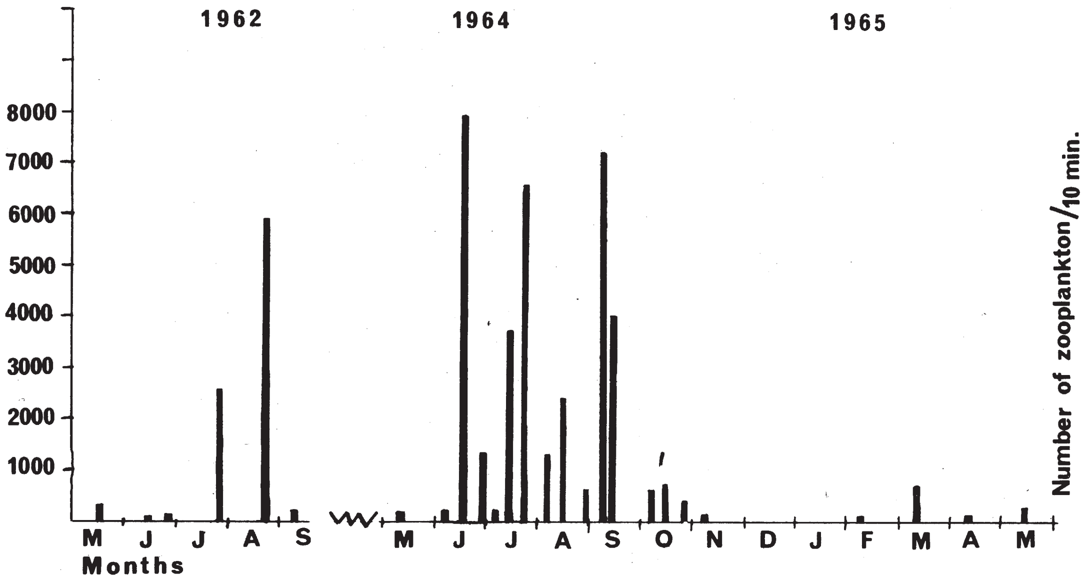
rapidly colonized by highly mobile insects nymphs, such as the Plecopteran *Diura nanseni* and the Ephemeropteran *Ephemerella aurivillii* (Lillehammer 1974).

Feeding groups

On stony substrates shredders were clearly dominant (Fig. 4), although some variation occurred. This dominance was most pronounced at Berge, in the lower reaches of the river, where the influence of the Suldalslågen lake was least and the substrate consisted mainly of stones. At the Suldalsosen station, with the same kind of substrate, an influence from the lake was seemingly visible, evidenced by a greater biomass of the filter collectors. At Mo, in the middle reaches of the river, where the substrate largely consisted of sand and gravel and the water velocity was low, the fauna group of gather collectors was almost as well represented as at Suldalsosen.

The mean benthic biomass on the stony substrate in the two study years values was 4081 mg/m^2. The group of shredders, with a mean biomass of 2776 mg/m^2, accounted for 68.3% of the total biomass, the filter collectors for 11.2%, gather collectors for 12.4%, and predators for 8.1%.

Fig. 5. Nos of planktonic Crustacea recorded at different times of the year in 10 min. filtration samples taken below the outlet of the Suldalslågen river from the Suldalsvatn lake.



Drifting zooplankton

The highest frequencies of zooplankton entering the river from the Suldalsvatn lake were recorded in June, July, August and September and the lowest frequencies during the winter months (Fig. 5). The greatest number of zooplankton was recorded at the station just below the lake outlet, but even at the one 20 km below the outflow plankton still occurred in fairly large number (Table 3).

In all three study years (1962, 1964, 1965) the most abundant group of zooplankton was the Copepoda followed by the Bosminids. Chydorids were less common.

Fish fauna

Occurrences and life cycle

Trout (*Salmo trutta* L.), salmon (*S. salar* L.), eel (*Anguilla anguilla* L.) and three-spined stickleback (*Gasterosteus aculeatus* L.) are all present in the river, while trout and char (*Salvelinus alpinus* L.) occur in lake Suldalsvatn. The river is mainly a recruitment river for sea trout and salmon, mostly young fish up to body-lengths of 10—15 cm. The fishing data obtained (Lillehammer 1964, 1973a) have shown that the salmon is the dominant species in swift-flowing water. At stations where the water velocity is lower, trout was more abundant as a rule. In two of the tributaries, trout and salmon were equally abundant. Sticklebacks have been only sparsely re-

Table 3. The numbers of planktonic Crustacea recorded in the outlet water from the Suldalsvatn lake and at Berge, 20 km downstream, on 21.8.62 (10 min. — filtration samples).

Locality	Bosminidae	Chydoridae	Copepoda	Total
Suldalsosen	1507	67	4352	5926
Berge	574	0	455	1029

corded from the main river-course, but in shallow bays they occur at times in large numbers (Lillehammer 1973a). Char, from the Suldalsvatn lake, have now and then been recorded in the river. The duration of the life-cycle of the salmon stock in the Suldalslågen river is 5 years in mean, but this may vary from 3—8 years. The residence time in the river is from 2—4 years and at sea 1—4 years (Lillehammer et al. 1976, Vasshaug 1977).

The fry which leave the safe cover of the substrate at the beginning of June are 2.5—2.9 cm in length. At the end of their first season of growth, in October, they have reached a body-length of 3—5 cm. In their second summer they reach a body-length of about 5—9 cm, and at the end of their third year they are 7—15 cm long (Lillehammer et al. 1976). They grow very fast while at sea. Vasshaug (1977) has reported mean bodyweight values of 2.0 kg, 7.2 kg, 11.2 kg and 16.4 kg after one, two, three and four years at sea, respectively. The greatest recorded bodyweight after 3 years at sea is 20 kg, and after four years at sea 23.8 kg. The biggest salmon ever caught in the Suldalslågen river weighed 34 kg.

Food

While differences in the composition of the food items in the stomachs of salmon fry were noted at different times of the year (see Fig. 6), Chironomidae were predominant in June, whereas in September zooplankton accounted for the greater part of the stomach contents.

Chironomid larvae and stonefly nymphs were the most frequent food items in the stomachs of both fry and parr salmon and of trout (Lillehammer 1973a, b).

Planktonic Crustacea are an important food for both young trout and salmon, and especially for salmon fry. Both the fry and parr of the salmon eat more zooplankton than do trout of an equivalent size (Lillehammer 1973b).

Food web

The benthic fauna consists of four different groups of feeders, which are represented to different degrees. Shredders were the main contributors to the total biomass of invertebrates in the river, in 1962 accounting for about 70% (Fig. 7). Allochthonous material therefore represents an important source of energy for the benthic fauna in the Suldalslågen river. This finding seems quite reasonable and fits in well with the results obtained from a part of Ekso river (Bæk-

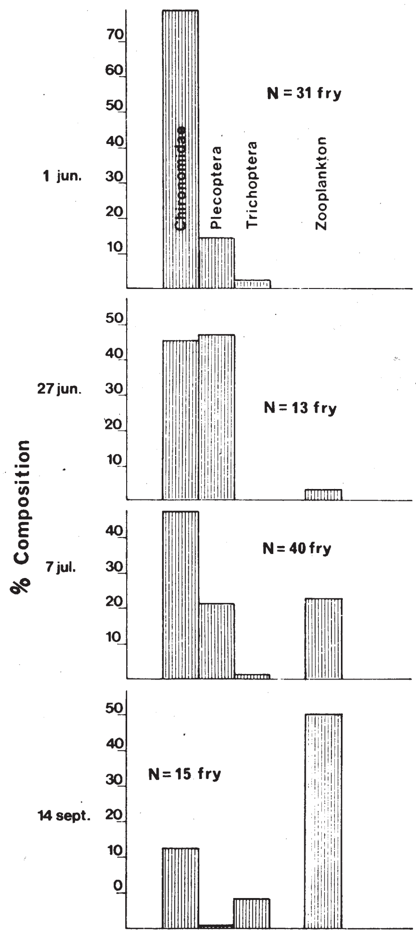


Fig. 6. The % composition by weight of the different food items found in the stomach contents of salmon fry in 1964.

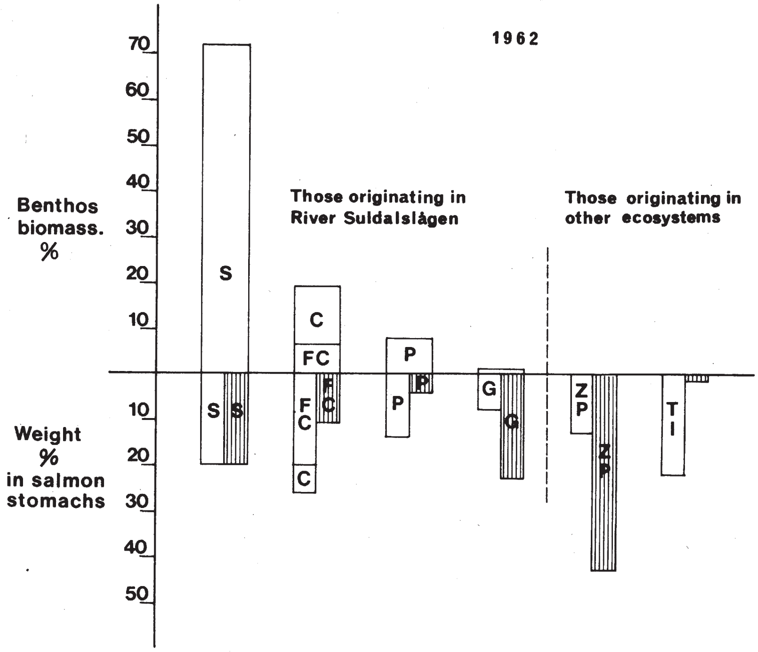


Fig. 7. The % contribution to the total mean biomass of the different types of benthic feeders in the Suldalslågen river in 1962, and the respective mean in % by weight in the stomach contents of salmon fry (hatched) and parr (open). S = Shredders, C = Gather collectors, FC = Filter collectors, P = Predators, and G = Grazers, ZP = zooplankton, TI = Terrestrial insects.

ken et al. 1979), in which allochthonous material represented 75% of the entire energy source.

The relative frequency in which different food items were taken by salmon fry and parr deviated strongly from their occurrence in the benthic biomass. Zooplankton, obtained primarily from the drift, was the most important source of food for the fry, while chironomids also were a major food item; although numerically abundant chironomids constituted only a small part of the total biomass in the benthos. Similarly, in salmon parr terrestrial insects accounted for 21.3%, filter collectors for 20.2%, and zooplankton for 12.5%. Filter collectors, grazers, and predators were thus taken to a greater extent than their representation in the benthic fauna would have led one to expect, whereas shredders were taken to a lesser degree. In the Suldalslågen river, the large shredders, which represent a major proportion of the total biomass, appear to be more important as defoliators and as producers of the smaller-sized particulate matter for other sections of the river fauna, than as food for predators such as young salmon.

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