A fish-kill in the river, Akerselva, Oslo, Norway: The use of benthos and fish to trace the source of pollution.

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In connection with a fish-kill in Akerselva, Oslo, in October 1986, studies of fish and benthos were initiated to find the source of pollution and to evaluate the consequences for the pollution status of the river.

Dead Atlantic salmon (*Salmo salar),* brown trout *(S. trutta)* and minnow *(Phoxinus phoxinus)* were reported from below the waterfall, Øvre Foss, down to the Oslofjord at Bjørvika. From Øvre Foss up to the water intake pool for the De-No-Fa/Lilleborg factory, no fish were found, while above this minnows and trout were recorded.

By following the distribution of two indicator species, *Baetis rhodani* (Ephemeroptera) and *Rhyacophila nubila* (Trichoptera), a locality was found where they suddenly disappeared from benthic samples. At this point a surface water culvert enters the river. Benthos samples taken along the underground culvert demonstrated that the pollution had originated from the De-No-Fa/Lilleborg factory. Subsequently, the factory disclosed that strongly alkaline effluent had been discharged into the culvert. Pollution indices, incorporating the whole benthos, also showed that water quality had deteriorated downstream of the discharge compared to previous surveys of the river.

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INTRODUCTION

The water quality in the river Akerselva, which runs through the centre of the city of Oslo, has improved considerably during the last ten years. It has changed from being a severely polluted river lacking fish to a moderately clean river with several fish species and a relatively diverse benthic fauna (Borgstrøm & Saltveit 1978, Brittain & Saltveit 1985). Several native fish species have colonized the previously polluted section from upstream areas, while Atlantic salmon *(Salmo salar),* brown trout *(Salmo trutta)* and rainbow trout *(Salmo gairdneri)* have been stocked. Adults of these stocked species return into the lower parts from the sea and the fjord to spawn. However, there are many factories and industrial concerns of different kinds situated along the river banks. These represent a potential threat to the river and its fauna through uncontrolled discharges.

In October 1986, large numbers of dead adult Atlantic salmon and brown trout were reported from the lowermost parts of the river. A short-term increase in specific conductivity was measured by a continuous recorder situated on the river (Hallberg, pers.comm). However, analyses of water samples taken immediately after the fish were found and analysis of the dead fish themselves provided no information on the type or the source of the pollution (Hallberg, pers. comm.). It appeared to be a short term episode in which the pollutant had been rapidly washed out of the river and could therefore no longer be traced in water samples.

Particular species of benthic macroinvertebrates are frequently used as indicators of different kinds of pollution as well as being incorporated into pollution indices (Hellawell 1986). This is because they are relatively immobile and because different species have different tolerances to a wide range of pollutants. When benthic species disappear it takes some time before they recolonize the polluted section. Thus with a knowledge of benthic species composition and their tolerance, it was our aim to trace the source of pollution using fish and benthos as indicators.

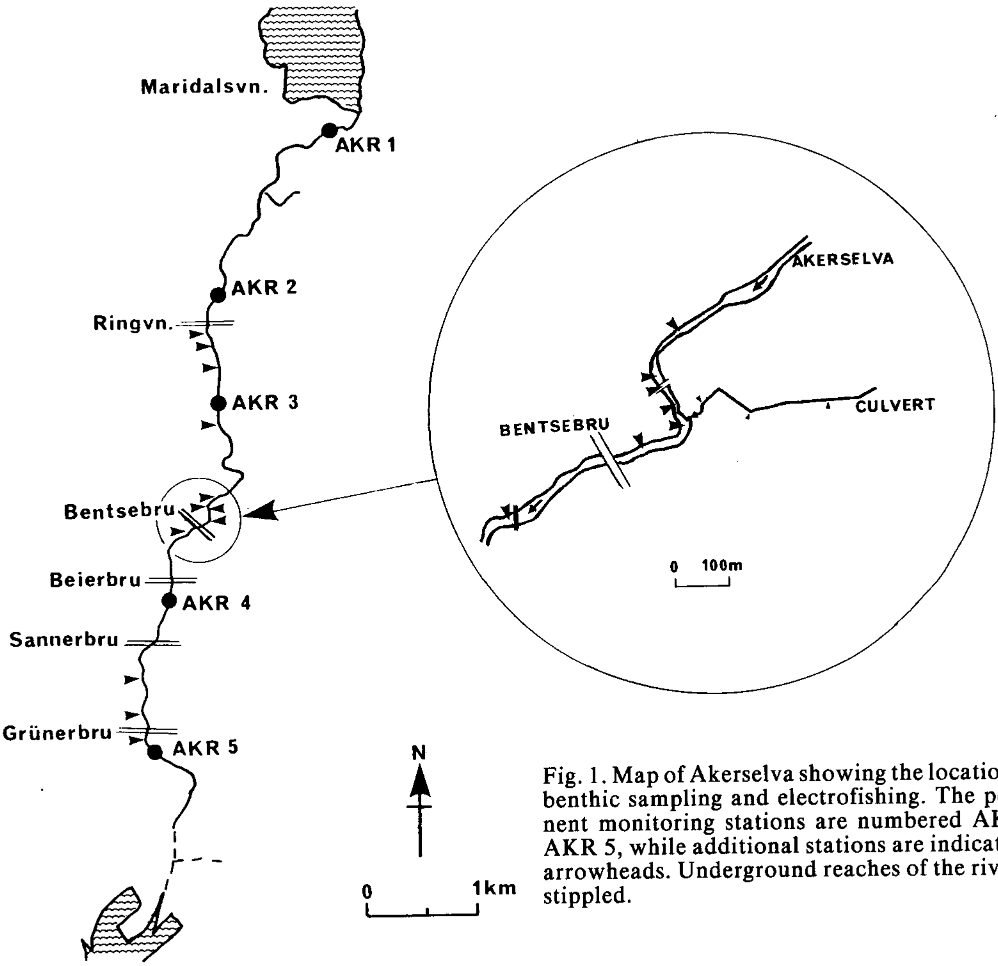

Fig. 1. Map of Akerselva showing the locations for benthic sampling and electrofishing. The permanent monitoring stations are numbered AKR 1-AKR 5, while additional stations are indicated by arrowheads. Underground reaches of the river are stippled.

AREA DESCRIPTION

The river, Akerselva, with the largest catchment in Oslo, is c. 8 km long and runs from the lake, Maridalsvatn (149 m a.s.l.), to the Oslofjord. The catchment area is 250 km^2, consisting mostly of coniferous forest above Maridalsvatn. This lake is the main drinking water reservoir for Oslo. Below the lake, the river passes through urban areas, with both old and new industries, although there are also several areas of parkland along the river banks.

The river has a large number of waterfalls, used in earlier times as a source of power for industry. The lowermost waterfall, Nedre Foss, prevents upstream migration of anadromous fish.

To trace the source of pollution, a large number of localities were investigated. These are shown in Fig. 1, together with those which are used in the permanent monitoring programme for the river (AKR 1-AKR 5). Subsequently, samples were also taken in a surface water culvert draining areas on the eastern bank about half way between Maridalsvatn and the fjord. To make possible comparisons throughout the river, all the river localities were in riffle areas with stony substrate (Figs. 5 & 6).

METHODS

A backpack electrofishing apparatus, delivering exponential pulses of 1200 V at a frequency of 86 Hz, was used to catch fish. At each locality the whole river bed was fished over a reach of 40—100 m.

Benthic animals were collected using the kick sampling method (Hynes 1961). Three, 1/2 or 1 minute, samples were taken at each locality. The mesh size of the net used in the river was 0.45 mm and the mesh size of net used in the culvert was 0.20 mm. The samples were sorted live in the laboratory and then preserved in 70% alcohol.

The general pollution status of the river, both after the fish-kill and during previous monitoring, was assessed using a modificating of the Trent Biotic Index (Woodiwiss 1964). In this modification the number of groups was reduced, with for example stone-files and mayflies counting as single groups (Borgstrøm & Saltveit 1978). Thus index values for clean water localities are somewhat lower than the original Biotic Index.

RESULTS AND DISCUSSION

Dead adult Atlantic salmon and anadromous brown trout were found below the waterfall, Nedre Foss, which prevents fish migrating further upstream (Fig. 2). Above Nedre Foss and up to Beierbrua, dead brown trout and minnows *(Phoxinus phoxinus)* were found. Live fish (minnows) were again found c. 500 m upstream of Bentsebrua and further upstream above Spigerverket (an iron foundry) live trout were also present. Normally only minnows are found from the iron foundry down to Bentsebrua. Thus, fish distributions indicated that the source of pollution was between Spigerverket and Nedre Foss, possibly in the lower part of this section.

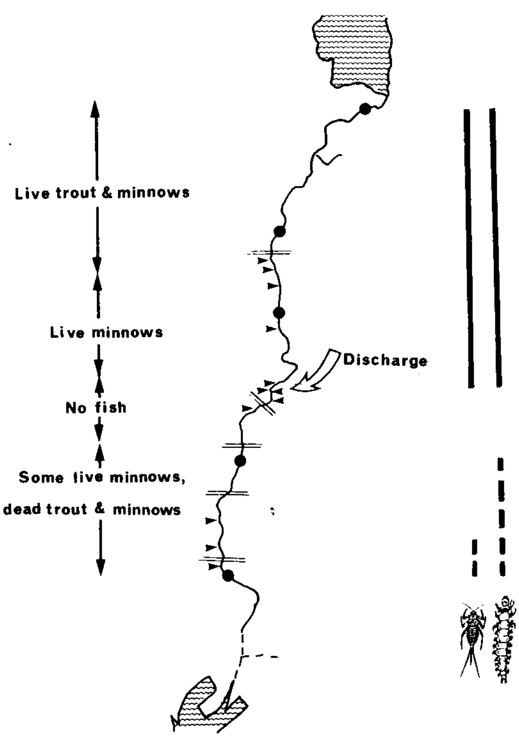

Fig. 2. Distribution of fish species and two benthic indicator species, the mayfly, *Baetis rhodani,* and the caddisfly, *Rhyacophila nubila,* along the river after the fish-kill.

To provide a more precise localization of the pollution source, two benthic organisms, the mayfly *Baetis rhodani* (Pictet) and the caddisfly *Rhyacophila nubila* (Zetterstedt), were used. From our earlier monitoring studies it was clear that these two species normally occur throughout the river.

A relatively diverse fauna was still present in the uppermost part of the river at stations AKR 1 and AKR 2. However, below Spigerverket (station AKR 3), diversity decreased and the fauna was dominated by more tolerant species. Trout are normally lacking here, but the two macroinvertebrate indicator species were still present. However, about half way down the river both species suddenly became absent from benthic samples in the space of 50 m (Fig. 2). *R. nubila* reappeared again after c. 1 km and *B. rhodani* after c. 3 km; both in very low numbers. They were obviously affected differently by the pollution. *B. rhodani,* living in the current, was more exposed, while *R. nubila,* living more among the substrate and within aquatic moss, would be less exposed to short-term pollution.

At the point where both species disappeared, a culvert enters the river. This culvert drains surface run-off both from a detergent factory (De-No-Fa/Lilleborg), and from the above-lying, largely residential area. Studies of the river fauna had clearly documented that the pollution had entered the river from this culvert. To further localize the pollution source benthic samples were taken underground at three different points within the culvert (see Fig. 3). Above the factory area the fauna in the culvert was dominated by Enchytraeidae (Oligochaeta), Psychodidae (Diptera) and Turbellaria, while no living macroinvertebrates were found in the culvert inside the factory area (Fig. 3). Thus, our results clearly demonstrated that the pollutant came from the factory.

Immediately after the fish-kill most of the

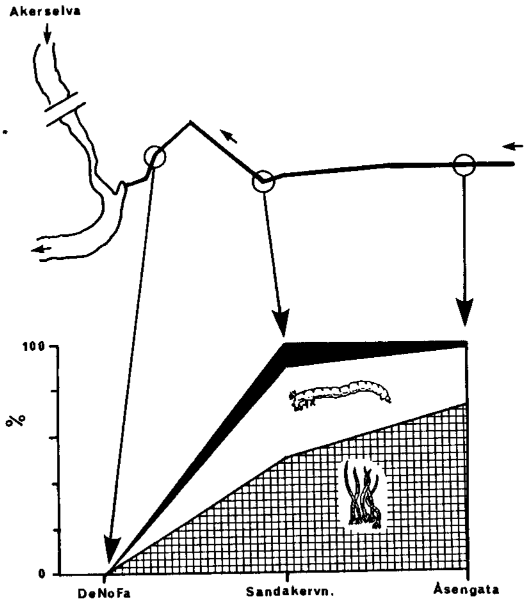

Fig. 3. Distribution of Enchytraeidae, Psychodidae (white) and Turbellaria (black) at 3 stations in the culvert which drains the De-No-Fa factory area and above-lying areas. The proportions are expressed as a percentage.

major industrial concerns along the river checked their effluent discharges. However, no unusual discharges were reported. When confronted with our biological data approximately one week later, the detergent factory, De-No-Fa/Lilleborg, rechecked their waste disposal. It transpired that a bypass around a leak in their sewerage drain had been accidentally connected back into the storm water culvert. Thus 7 tonnes of highly alkaline waste detergent had been discharged directly into the river instead of being transported to the waste treatment plant on the Oslofjord. Although the wrong connection was accidental, the discharge of highly basic waste to the city's waste treatment plant before prior neutralization was in breach of regulations.

The large amount of publicity and public awareness surrounding this pollution incident in the centre of Norway's capital city, led to a marked change in the attitude of government authorities to environmental pollution. Previously, only token fines had been imposed, bearing little relationship to the turnover of large industrial concerns. In this case, De-No-Fa-Lilleborg were subsequently fined NOK 500.000 by the State Pollution Agency (SFT). De-No-Fa/Lilleborg also funded the restocking of fish in the river and the work entailed in tracing the source of pollution.

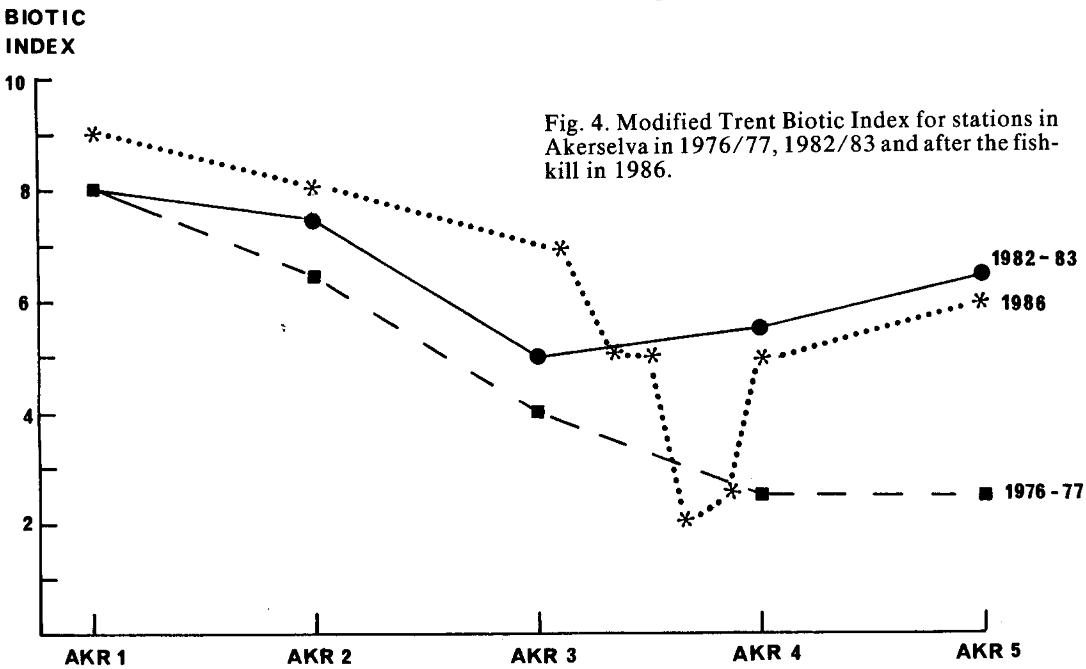

Fig. 4. Modified Trent Biotic Index for stations in Akerselva in 1976/77, 1982/83 and after the fish-kill in 1986.

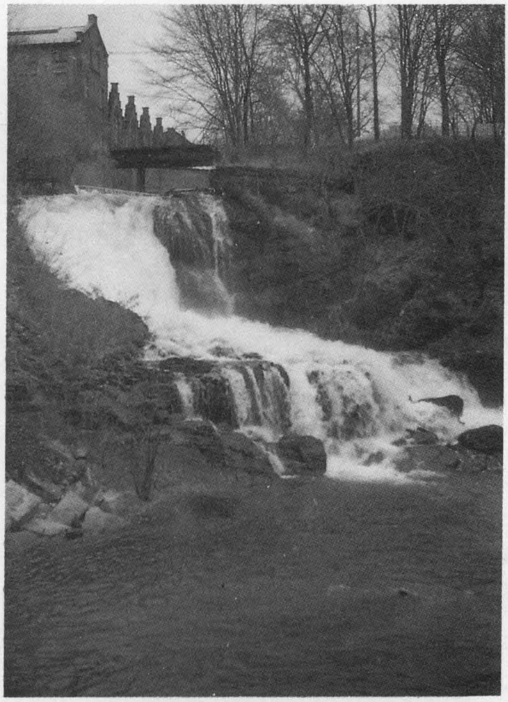

Fig. 5. The waterfall, Øvre Foss, above staion AKR 4 in Akerselva. Photo: J. E. Brittain.

Fig. 6. Electrofishing at station AKR 5 in Akerselva. Photo: S. J. Saltveit.

The macroinvertebrates and fish of the river have previously been surveyed in 1976, 1977, 1982 and 1983 (Borgstrøm & Saltveit 1978, Brittain & Saltveit 1985). A major improvement in water quality, reflected in the distribution of fish and macroinvertebrates, occurred between 1976—77 and 1982—83 as a result of advances in the treatment of urban run-off and industrial effluents (Fig. 4). Prior to the fish-kill minnows were present throughout the river. In the upper reaches (AKR 1), there was a permanent brown trout population and a diverse macroinvertebrate community containing several stonefly and mayfly species.

At Nydalen (AKR 2) the river became slightly to moderately polluted with a reduction in the stonefly fauna and absence of trout. By Bjølsen (AKR 3) conditions deteriorated considerably and only a few macroinvertebrates were recorded. These conditions continued downstream at Torshov (AKR 4), although there was an indication from the faunal composition of a slight improvement in water quality. This slow improvement continued at Nedre gate (AKR 5). The conditions in the river prior to the fish-kill are summarized in the biotic indices shown in Figure 4.

The results clearly show that benthic macroinvertebrates are not only useful for long-term surveillance of possible improvements in water quality, but can be very useful in tracing the source of short-term chronic pollutants, even several days after their release. One month later there was another fish-kill in the river, but the fauna, notably the mayfly, *Baetis rhodani,* had colonized the denuded areas sufficiently to enable detection of the pollution source yet again (Brittain & Saltveit 1987).

The presence of fish in a river, especially large angling species such as salmon and trout, was shown to be of importance in making first the public and then the relevant authorities aware of pollution incidents. Dead fish floating on the surface are immediately apparent to the general public living along the watercourse. However, fish are too mobile to be used alone in detecting the exact source of short-term pollution.

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