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THE NJORO RIVER-LAKE NAKURU ECOTONAL SYSTEM IN KENYA

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INTRODUCTION

Ecotones are dynamic components of landscapes and active sites for retention and transformation of nutrients (Carignan 1982, Adams & Prentki 1982, Peterjohn & Correll 1984, Ford and Naiman 1989, Bretschko & Moser 1993, Hillbricht-Ilkowska 1993) and sinks for pollutants (Salomons et al. 1987, Pinay et al. 1990), dissolved organic carbon (Hynes 1983) and particulate organic matter (Naiman and Decamps 1990).

In running water a large part of particulate organic matter is adsorbed to the sediment particles (Cummins 1974, Danielopol 1976, Bretschko 1983, Leichtfried 1985). Besides other important factors, particulate organic matter is an energy base for animals and controls at least their distribution when in low concentrations (Bretschko & Leichtfried 1988). In general, the biodiversity of an ecotone is higher than that of the two adjacent communities (Naiman et al. 1988 a, b, Naiman & Decamps 1990).

The Njoro River - Lake Nakuru ecotonal system is not only a zone of contact between lentic and lotic patches, but also between fresh water of the river and springs on the lake shore, and the alkaline water of the lake. It is also a zone of contact between polluted water of the seasonal Njoro River and clear, unpolluted water from the permanent springs. This ecotonal system, which is situated in a very disturbed watershed, provides a suitable area for comparative studies of ecological processes and mechanisms within the adjacent patches and their ecotones.

Egerton University in collaboration with the Austrian Academy of Sciences organised a workshop in September 1995 on Tropical River Ecology. The participants of the workshop were divided into five working groups, namely, Zoobenthos, Direct River Use, Fish Ecology, Riparian Vegetation and Particulate organic matter (POM) / Sediment/ Ecotone. This paper reports the findings of the POM / Sediment / Ecotone Working Group. The aim of this group was to study the longitudinal spatial distribution of organic matter, suspended matter in the surface water, sediment grain size and zoobenthos in the Njoro River / Baharini Spring - Lake Nakuru ecotonal system.

STUDY AREA AND METHODS

STUDY AREA

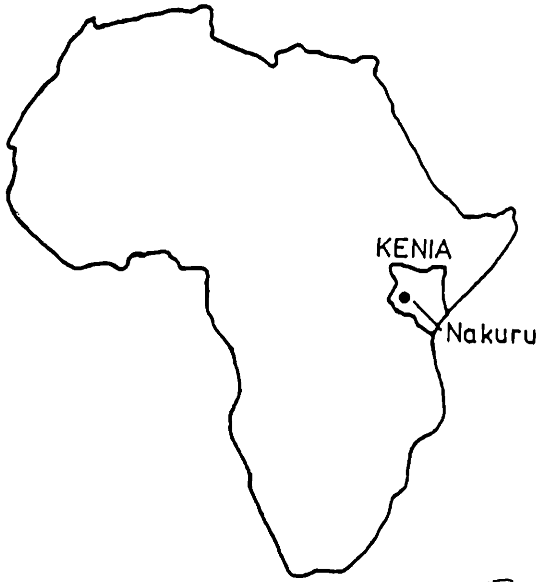
The study was carried out on the shoreline of Lake Nakuru, Kenya (0° 20' S, 36° E and 1759 m a.s.l.) in the ecotonal system of Njoro River (sites F, M, T, N1, N2, N3 & N4), Baharini Spring (sites B1, B2 & B3), and the lake (site N5, Fig. 1). The Njoro River is about 50 km long and originates from the eastern Mau Hills (site F) with the Little Shuru as its main tributary. The altitude varies from 2700 m a.s.l. at the source of the river to about 1700 m a.s.l. at the mouth (Karanja *et al.* 1986). The river is intermittent at the lowland zones near the mouth (sites N2, N3 &N4).

The Baharini Spring is a permanent spring on the shoreline of Lake Nakuru which gives rise to a 200 m, clear, clean stream that flows into the lake throughout the year (Fig. 1). It is an important source of drinking water for the animals.

Lake Nakuru is a small, shallow, hypereutrophic, alkaline-saline lake located in a closed basin without outlets in the Eastern Rift Valley of Kenya. The lake has a variable mean depth of 2.3 m, maximum depth of 2.8 m and a variable area averaging 40 km² (Burgis et al. 1987). It has very high alkalinity (150 - 400 meq/l), pH (10.5) and conductivity (6000 - 28000 µS/cm, Vareschi & Jacobs 1985). The lake is located in the Lake Nakuru National Park and is "naturally polluted" by about 700000 flamingos and many other animals in the park. The watershed area of the lake is about 1800 km² and particularly the Njoro River sub-catchment area of 200 km² includes agricultural land of the highest potential in the country with increasing use of fertilisers, herbicides, acaricide and insecticides. The total sewage effluent (both domestic and industrial) of Nakuru town (population about 1000000) goes into the lake only after minor treatment in oxidation lagoons.

SAMPLING

Samples of zoobenthic organisms were collected using the Hess sampler covering a sampling area of 2.7 dm^2 and the core tube sampler of sampling surface area of 0.59 dm^2 depending on the substrate



type. Sediment samples for grain size and organic matter analysis were collected using a small shovel. Five sampling sites were established in the Njoro River - Lake Nakuru ecotone (sites N1, N2, N3, N4 & N5) three in the Baharini Spring - Lake Nakuru ecotone (B1, B2 & B3) and three in the upper ridges of the Njoro River (sites F, M & T, Fig. 1).

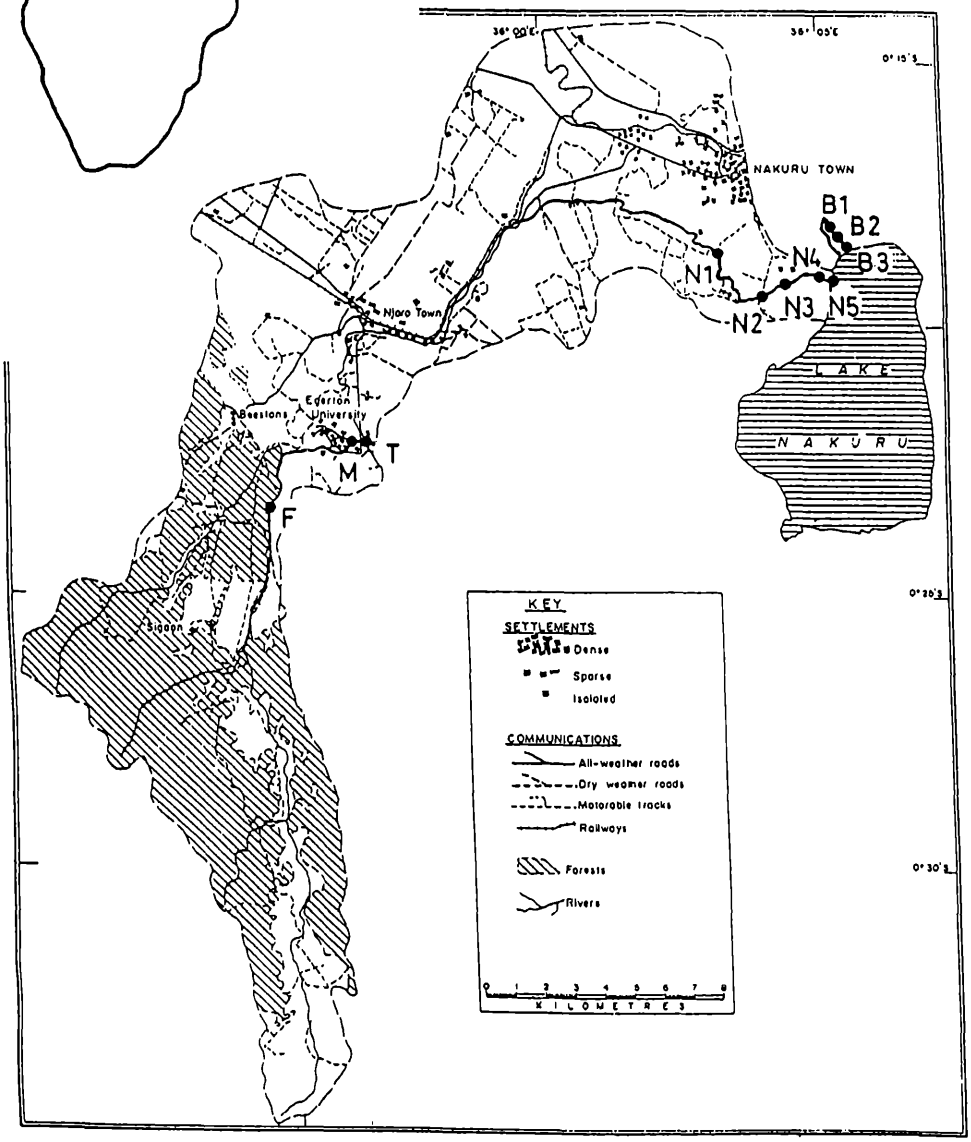


Fig. 1: The study area Njoro River (sites F, M, T, N1, N2, N3 & N4), Baharini Spring (sites B1, B2 &B3) and Lake Nakuru (site N5), Kenya

F - Forest, headwater zone of Njoro River in the Mau Hills.
M - Mary Joy, middle order zone of Njoro River near Egerton University, dense riparian vegetation.
T - Turkana, middle order zone of Njoro River near Egerton University, no riparian vegetation.
N1 - Njoro River, lowland zone before Nakuru town, little riparian vegetation.
N2 - Njoro River, lowland zone after Nakuru town at the margin of Lake Nakuru National Park, dense riparian vegetation.
N3 - Njoro River, lowland zone, open land with grass and shrubs.
N4 - Njoro River, mouth of the river with Lake Nakuru, no riparian vegetation, many animals and birds.
N5 - Lake Nakuru, saline with heavy "natural pollution" from birds, especially flamingos.
B1 - Baharini Spring, source area, dense riparian vegetation dominated by Acacia xanthoploea.
B2 - Baharini, middle zone of the stream with grass on the banks.
B3 - Baharini, stream area near Lake Nakuru at Hippo Point, no riparian vegetation.

ANALYSIS OF SAMPLES

Organic matter was determined by using a calibrated weight loss on ignition method at 500°C and by analysing total organic carbon (TOC) and total organic nitrogen (TON) using the CHN-600 LECO ANALYSER. The benthic organisms were counted and classified according to their taxa. The grain size distribution was determined by sieving sediment samples in Retsch sieving machine according to Müller (1964).

RESULTS & DISCUSSIONS

SURFACE WATER CHARACTERISTICS

Conductivity

Along the Njoro River, conductivity increases from about 100 μS/cm at the forested headwater zone (site F) to about 9000 μS/cm in the lake (site N5, Fig. 2). The conductivity in the Baharini Spring increases from 650 μS/cm at the source of the spring (site B1) to 2000 μS/cm towards the lake (site B3). The longitudinal increase in conductivity towards the lake in Njoro River (sites N3 & N4) and Baharini Spring (sites B2 & B3) is due to the high conductivity of the lake which on average range between 6000 - 28000 μS/cm.

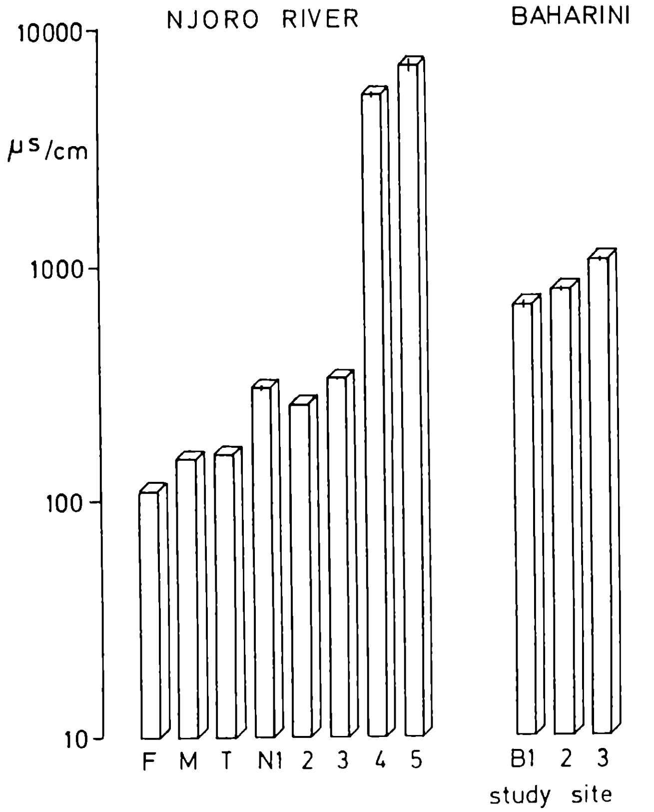


Fig. 2: Longitudinal variation in conductivity in Njoro River and Baharini Spring

Oxygen concentration in the surface water

The results indicate a general decrease in oxygen concentration in the surface water from the forested headwater zone of the river (site F) to the lake (site N5, Fig. 3). A similar trend is observed in the Baharini Spring stream where oxygen concentration decreases from the source of the spring (site B1) to mouth of the stream near the lake (site B3). The low oxygen concentration in the surface water in the lake can be attributed to the high "natural pollution" in the lake resulting from the faecal pellets of flamingos and other animals. The clear Baharini Spring water comes from the ground with low oxygen concentration which decreases towards the lake (Fig. 3).

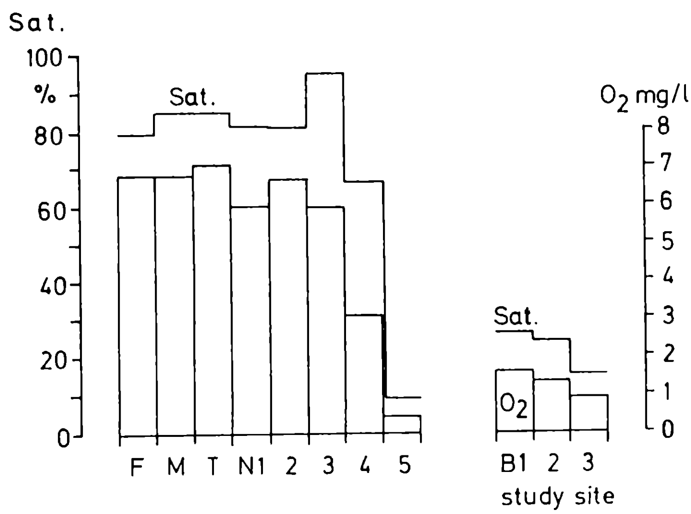


Fig. 3: Longitudinal variation in oxygen concentration in Njoro River and Baharini Spring

Suspended matter

The amount of suspended matter increases longitudinally from about 50 mg/l at the forested headwater zone (site F) to about 6000 mg/l in the lake (site N5, Fig. 4). A similar trend is observed in the Baharini Spring where suspended matter was not detectable at the source of the spring (site B1) but was 1000 mg/l near the lake (site B3, Figure 4). The high amounts of suspended matter near and in the lake (sites B3 and N5) can be explained by the high amount of fine sediments (Fig. 5c and 6) and a lot of organic pollution from many birds at these sites. The birds and other animals continuously muddle the water mixing it with the fine sediments and faecal pellets.

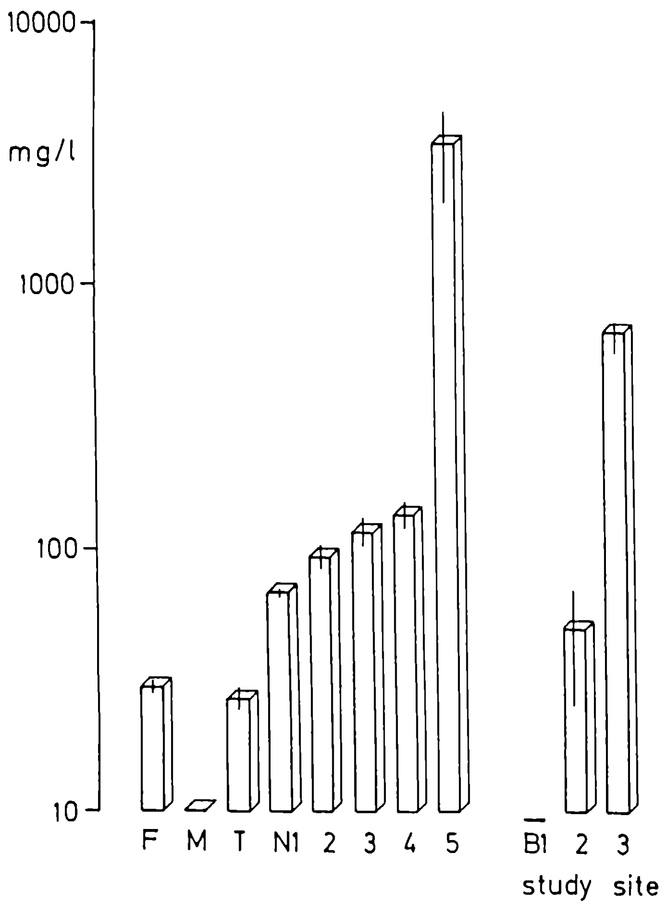


Fig. 4: Longitudinal variation in suspended matter in Njoro River and Baharini Spring

SEDIMENT CHARACTERISTICS

Grain size

Along the Njoro River, the sediment grain size < 63 µm increases from the headwater zone (site F) to the mouth of the river (site N4). The median changes from 0.65 mm to 0.05 mm (Fig. 5 a, b & c). Sediments become finer from the headwaters towards the mouth of the river. The lake itself (site N5) has more than 20 % coarse grain size > 6.3 mm in diameter, although dominant grain size < 63 µm (Fig. 5c). Therefore, the sorting coefficient (8.4) is the highest at this site.

In the Baharini Spring, the median grain size changes from 0.90 mm at the source of the spring (site B1) to 0.50 mm towards the lake (site B3, Fig. 6). Grain size class < 63 µm increases longitudinally, the sandy sediments become finer from the source of the spring towards the lake although the dominant grain size class in Baharini > 1 mm in diameter (Fig. 6).

Weight loss on ignition

The relative weight loss on ignition is high at the headwater and the middle order zones (sites F and M, Fig. 7) with dense riparian vegetation. The weight loss on ignition decreases rapidly to the lower part of the middle order zone (site T) This is followed by a general increase in weight loss from the lower middle order zone (site T) to the lake (site N5). Similarly, there is an increase from the source of Baharini Spring (site B1) towards the lake (site B3). The high relative weight loss on ignition near and in the lake (sites B3 and N5) is caused by high organic inputs from birds and other animals at these sites (Fig. 7).

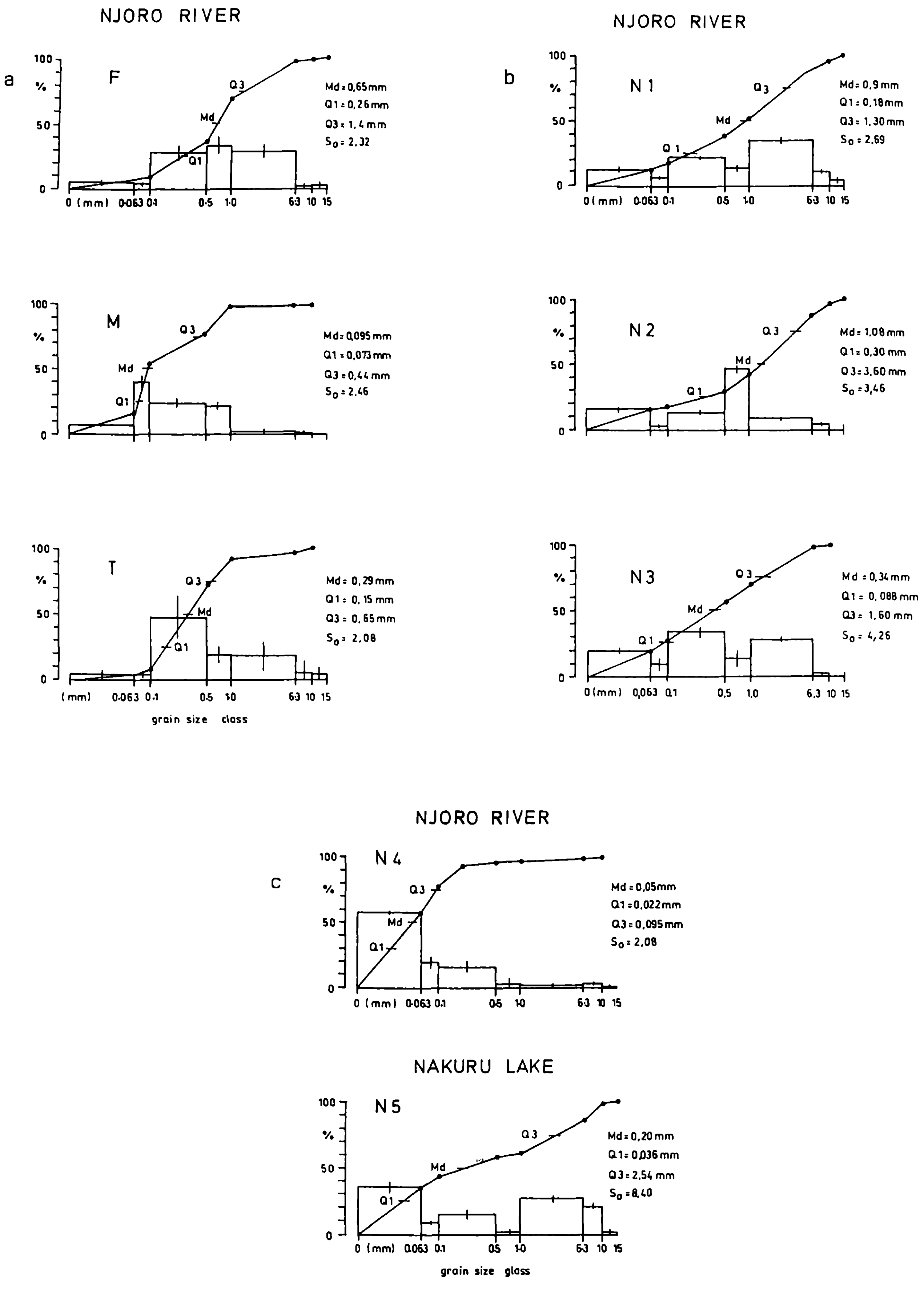


Fig. 5 a, b & c: Longitudinal distribution of sediment grain size classes in Njoro River (a - sites F, M and T; b - sites N1, N2 & N3; c - sites N4 & N5)

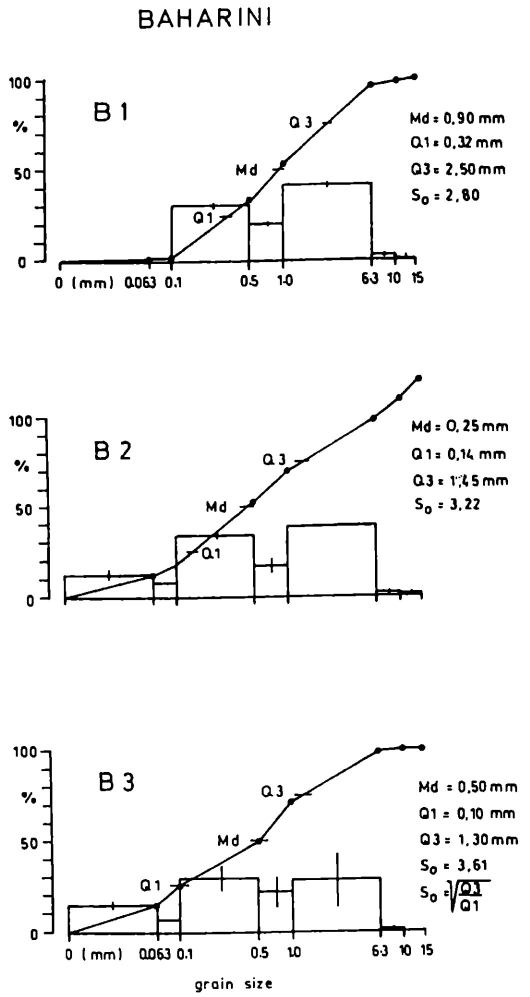


Fig. 6: Longitudinal distribution of sediment grain size classes in Baharini Spring

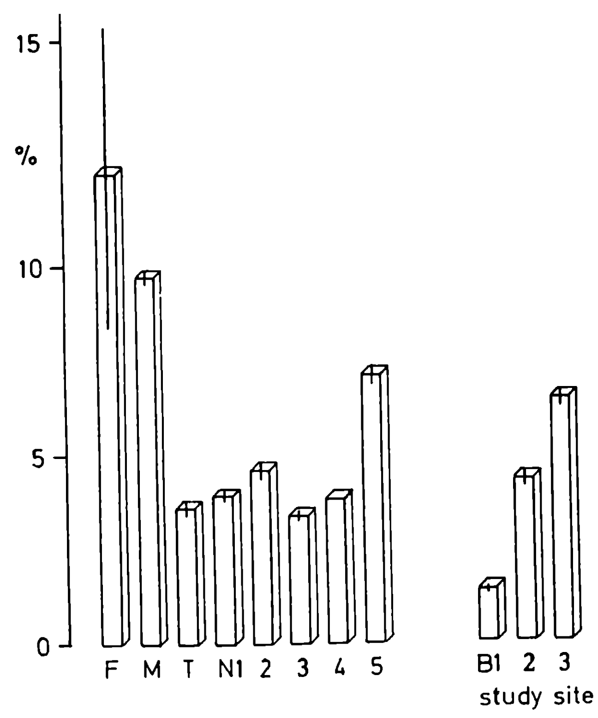


Fig. 7: Longitudinal distribution of relative weight loss on ignition in Njoro River and Baharini Spring

BIOTIC CHARACTERISTICS

Relative distribution of the major animal taxa

Due to limited taxonomic resources during the workshop, identification was only limited to higher taxa in most cases. In spite of this limitation, the results show a basic feature of the major taxa in the Njoro River ecotonal system.

In the Njoro River, only five taxonomic groups were identified The forested lowland zone (sites NI and N2) is dominated by oligochaeta while open lowland (site N3) is dominated by nematoda. The mouth of the river (site N4) has only ceratotopogonidae but there is no living benthic animal taxon observed in all the samples collected in the lake (site N5, Fig. 8, Tab. 1).

In comparison to the Njoro River, the Baharini Spring contains more benthic taxa. Crustacea and chironomidae of the Tanytarsini tribe dominated the source of the spring (site B1). The middle of the spring (sites B2) and near the lake (site B3) were dominated by hemiptera, crustacea and ceratopogonidae. In general, the number of taxa becomes smaller from the source of the spring (site B1) towards the lake (site B3). This reduction in the number of taxa correlates well with the rapid increase in conductivity from the source of the spring towards the lake (Fig. 2).

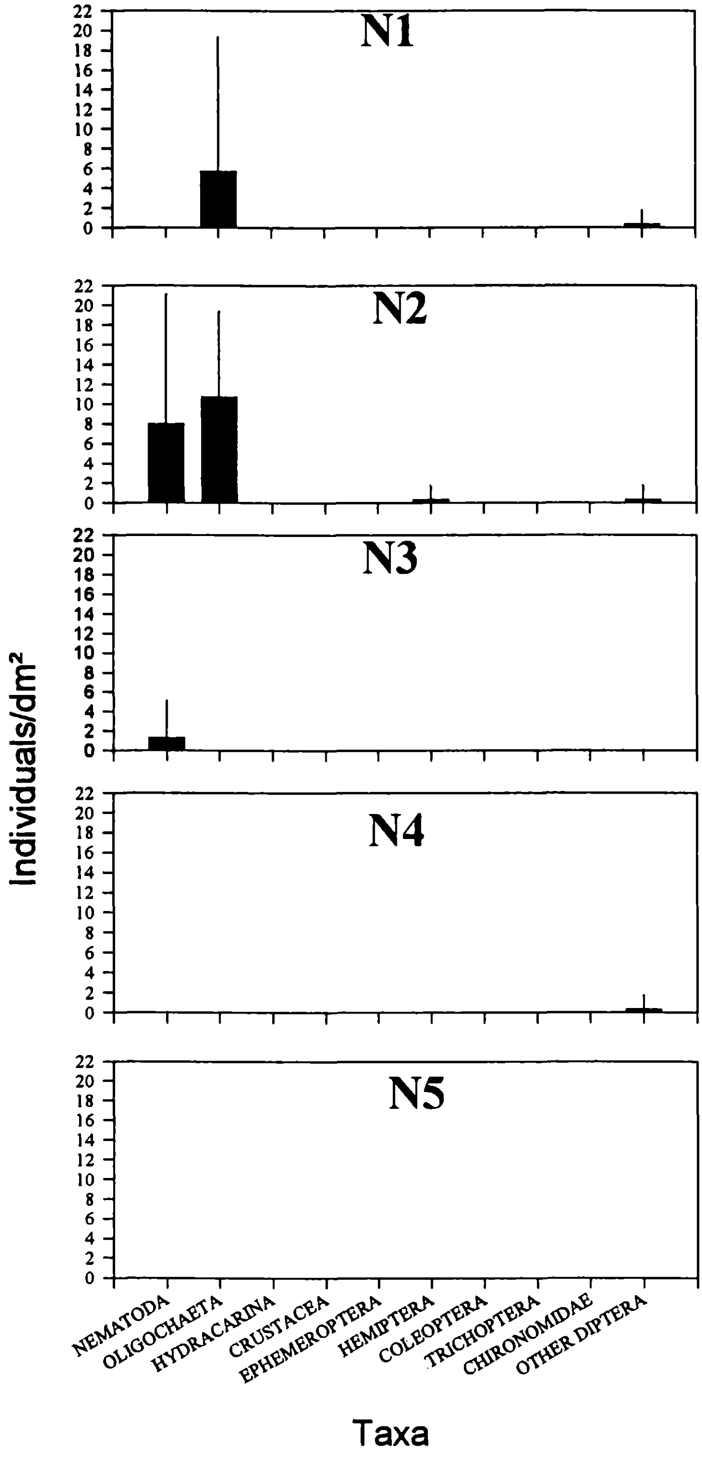


Fig. 8: Longitudinal distribution of zoobenthos in Njoro River

RELATIVE DISTRIBUTION OF ZOOBENTHOS IN THE NJORO RIVER

SITE	NI			N2			N3			N4			N5		
TAXA	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
NEMATODA	0.0	0.0	0.0	63.6	35.3	21.1	0.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
OLIGOCHAETA	100.0	100.0	92.3	31.8	64.7	73.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDRACARINA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRUSTACEA Σ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cladocera	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostracoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyclopoida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EPHEMEROPTERA Σ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HEMIPTERA	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COLEOPTERA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TRICHOPTERA Σ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydropsychidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroptilidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHIRONOMIDAE Σ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chironominae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tanypodinae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tanytarsini	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OTHER DIPTERA Σ	0.0	0.0	7.7	0.0	0.0	5.3	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Brachycera	0.0	0.0	0.0	0.0	0.0	5.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ceratopogonidae	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0
Simulidae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: a, b & c are replicates

Tab. 1: Relative distribution of zoobenthos in Njoro River.

RELATIVE DISTRIBUTION OF ZOOBENTHOS IN THE BAHARINI SPRING

SITE	B1			B2			B3		
TAXA	a	b	c	a	b	c	a	b	c
NEMATODA	0.0	0.0	0.9	0.0	0.3	0.3	0.0	0.0	0.0
OLIGOCHAETA	1.2	1.2	0.2	1.0	1.6	2.2	0.0	0.0	0.0
HYDRACARINA	4.9	3.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0
CRUSTACEA Σ	27.3	42.0	23.5	0.0	30.7	22.3	0.0	9.1	15.9
Cladocera	6.7	1.4	2.6	0.0	19.4	11.6	0.0	0.8	1.0
Ostracoda	9.1	19.9	15.9	0.0	1.8	1.7	0.0	0.0	1.0
Cyclopoida	11.5	20.7	5.1	0.0	9.5	9.1	0.0	8.3	13.9
EPHEMEROPTERA Σ	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Baetidae	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0
HEMIPTERA	1.2	10.5	0.5	92.4	58.6	66.1	100.0	56.7	35.7
COLEOPTERA	0.0	9.2	13.3	0.0	0.0	0.3	0.0	0.2	0.0
TRICHOPTERA Σ	8.5	11.5	12.4	0.0	0.0	0.0	0.0	0.0	0.0
Hydropsychidae	4.3	7.4	4.2	0.0	0.0	0.0	0.0	0.0	0.0
Hydroptilidae	4.3	4.0	8.2	0.0	0.0	0.0	0.0	0.0	0.0
CHIRONOMIDAE Σ	49.2	21.7	36.3	6.2	2.1	3.9	0.0	0.3	2.0
Chironominae	12.8	6.0	10.6	6.2	0.8	1.4	0.0	0.0	0.0
Tanypodinae	1.2	7.0	9.5	0.0	0.3	0.8	0.0	0.0	1.0
Tanytarsini	35.2	8.6	16.2	0.0	1.1	1.7	0.0	0.3	1.0
OTHER DIPTERA Σ	7.9	1.0	9.1	0.0	6.6	4.7	0.0	33.8	46.6
Ceratopogonidae	1.2	1.0	0.7	0.0	6.0	4.4	0.0	33.8	46.6
Simulidae	6.7	0.0	8.4	0.0	0.5	0.3	0.0	0.0	0.0

Note: a, b & c are replicates

Tab. 2: Distribution of zoobenthos in Njoro River.

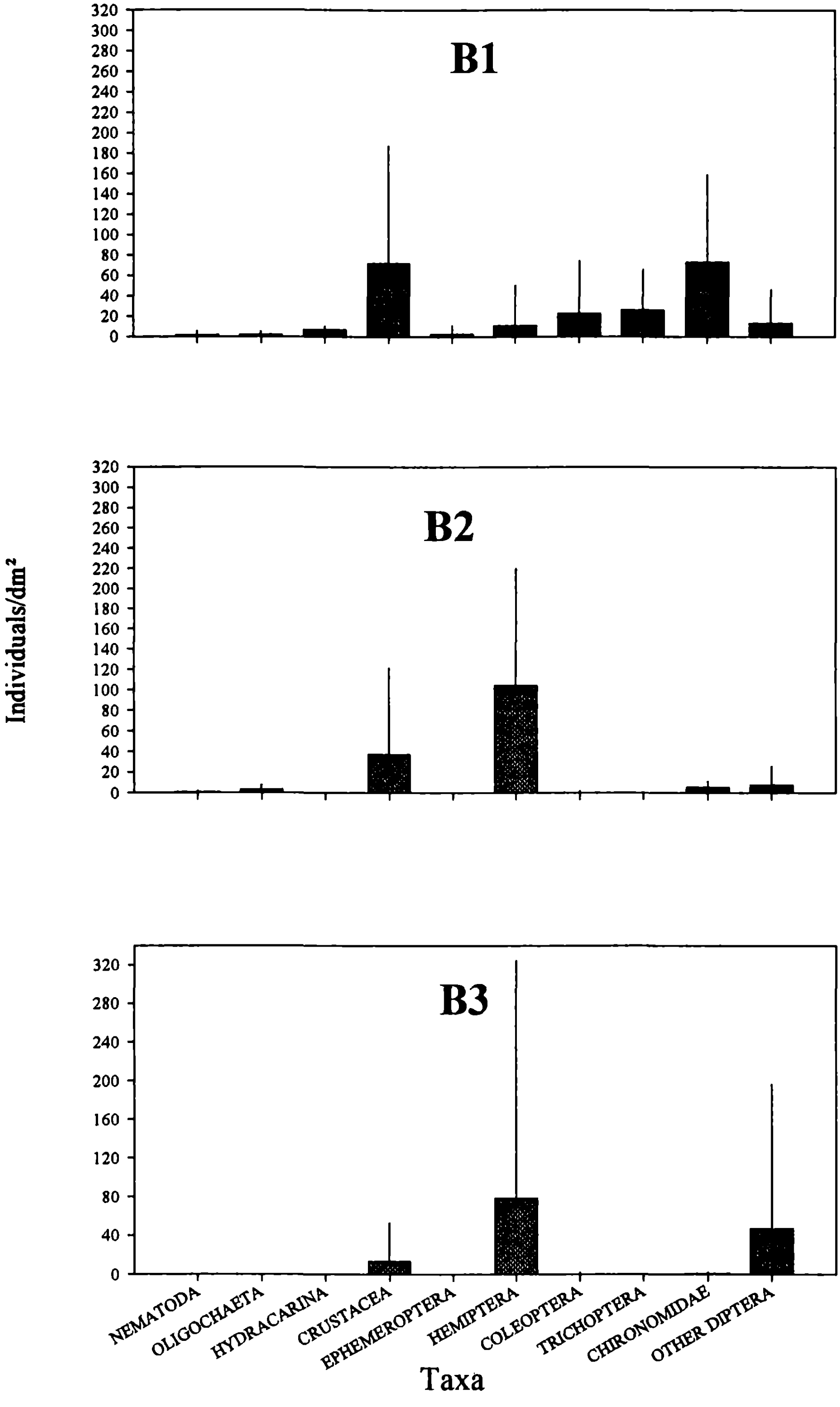


Fig. 9: Longitudinal distribution of zoobenthos in Baharini Spring

DISTRIBUTION OF ZOOBENTHOS IN THE NJORO RIVER

Individuals/dm^2

SITE	N1			N2			N3			N4			N5		
TAXA	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
NEMATODA	0	0	0	14	6	4	0	1	3	0	0	0	0	0	0
OLIGOCHAETA	3	2	12	7	11	14	0	0	0	0	0	0	0	0	0
HYDRACARINA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA Σ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cladocera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclopoida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EPHEMEROPTERA Σ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEMIPTERA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
COLEOPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TRICHOPTERA Σ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydropsychidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHIRONOMIDAE Σ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironominae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanypodinae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanytarsini	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER DIPTERA Σ	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0
Brachycera	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Simuliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE: Indivuals/dm^2 = counts * 1/1.77 for 3 large core tubes taken per sample.
a, b & c are replicates

Tab. 3: Relative distribution of zoobenthos in Baharini Spring.

DISTRIBUTION OF ZOOBENTHOS IN THE BAHARINI SPRING

Individuals/dm^2

SITE	B1				B2				B3			
TAXA	a	b	c		a	b	c		a	b	c	
NEMATODA	0	0	3	1	0	1	1	0	0	0	0	0
OLIGOCHAETA	1	3	1	2	1	3	5	3	0	0	0	0
HYDRACARINA	5	8	6	6	0	0	0	0	0	0	0	0
CRUSTACEA Σ	25	118	73	72	0	66	46	37	0	31	9	13
Cladocera	6	4	8	6	0	42	24	22	0	3	1	1
Ostracoda	8	56	49	38	0	4	3	2	0	0	1	0
Cyclopoida	11	58	16	28	0	20	19	13	0	28	8	12
EPHEMEROPTERA Σ	0	0	6	2	0	0	0	0	0	0	0	0
Baetidae	0	0	6	2	0	0	0	0	0	0	0	0
HEMIPTERA	1	29	2	11	51	126	136	104	23	193	20	79
COLEOPTERA	0	26	41	22	0	0	1	0	0	1	0	0
TRICHOPTERA Σ	8	32	38	26	0	0	0	0	0	0	0	0
Hydropsychidae	4	21	13	13	0	0	0	0	0	0	0	0
Hydroptilidae	4	11	25	14	0	0	0	0	0	0	0	0
CHIRONOMIDAE Σ	46	61	112	73	3	5	8	5	0	1	1	1
Chironominae	12	17	33	21	3	2	3	3	0	0	0	0
Tanypodinae	1	20	29	17	0	1	2	1	0	0	1	0
Tanytarsini	33	24	50	36	0	2	3	2	0	1	1	1
OTHER DIPTERA Σ	7	3	28	13	0	14	10	8	0	115	27	47
Ceratopogonidae	1	3	2	2	0	13	9	7	0	115	27	47
Simuliidae	6	0	26	11	0	1	1	1	0	0	0	0

NOTE: Individuals/dm^2 = counts * 1/1.77 for 3 large core tubes taken per sample.
a, b & c are replicates

Tab. 4: Distribution of benthos in Baharini Spring.

Abundance

The total abundance in the Njoro River varies from 0 individuals/dm^2 in the lake (site N5) to 20 individuals/dm^2 at the forested lowland zone (site N2, Fig. 8, Tab. 3). The total abundance is much higher in the Baharini Spring and varies from 421 individuals/dm^2 near the lake (site B3) to 689 individuals/dm^2 at the source of the spring (site B1, Fig. 9, Tab. 4). The lowland zone of the Njoro River had been completely dry a few days before sampling. This might be the reason for the low abundance observed in this part of the river. Baharini is a permanent spring with clean and clear water. This might be one of the reasons for the high zoobenthic abundance in the spring. The reduction in the abundance from the source of the spring (site B1) towards the lake (site B3) is again well correlated with increasing conductivity (Fig. 2, Fig. 9) as was found with the number of taxa. There is also a clear reduction in the abundance of crustacea and chironomidae from the source of the spring (site B1) towards the lake (site B3, Fig. 9). The hemiptera and other diptera, consisting mainly of ceratopogonidae, show a general increase in abundance from the source of the spring towards the lake.

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