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DIVERSITY OF THE CHIRONOMIDAE (DIPTERA) OF RIVER NIGER RELATED TO WATER POLLUTION AT NIAMEY (NIGER)

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ABSTRACT: *This paper presents the first results on the water quality of the River Niger at Niamey based on the Chironomidae. Artificial substrata of stones covered with galvanized wire netting were used for collecting the chironomid larvae. Water samples were taken for physicochemical analysis. Twenty taxa of chironomidae were collected. Among these, Chironomus gr. plumosus represented51% and Microchironomus sp. 26% of all larvae collected. The distribution of Chironomidae throughout the river showed differences between the sampling stations. Organic pollution and nutrients loading were the main factors explaining the differences in spatial distribution. Some taxa, e.g. Chironomus gr. plumosus and Microchironomus sp. are positively correlated to those factors, while others as Tanytarsini, Nilodosis sp., Micropelopinae and Procladius sp. are negatively correlated. According to these results, Chironomidae appear an excellent tool for the assessment of the biological quality of western African rivers.*

Key words*: Chironomidae, River Niger, Niamey, water quality*

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INTRODUCTION

Chironomidae constitute the most diverse group of aquatic insects: their larvae are aquatic, but the adults terrestrial (some species have terrestrial larvae). Up to now, 4 147 species are known, of which 406 are from tropical Africa (Ferrington 2008). New species are continuously discovered; the African species especially, are poorly known (Eggermont and Verschuren 2003). Dejoux (1984) enumerates in West Africa 96 species from Togo and Benin and 31 species from Niger.

Because of their diversity and their specific sensitivity to environmental changes, chironomids are widely used in ecological investigations (Rosenberg and Resh 1993). Therefore, they are also used in monitoring water quality of lakes and rivers (Sharley et *al.* 2004; Callisto et *al.* 2002; Evrard 1996).

This study is a first attempt to use chironomid diversity in evaluating the water quality of a main African river, i.e. River Niger, with special attention to the pollution aspects of Niamey, the capital of Niger. This survey is also a contribution to the knowledge of the diversity of Chironomidae of a West African river.

MATERIAL AND METHODS

Study area

Chironomidae are sampled along the River Niger at Niamey, the capital of Niger in West Africa (218 m asl, 3°31' N and2°26'E) (Fig. 1).

The climate is arid: rainfall, temperature and evapotranspiration averages during 1995 - 2005 were respectively 517.90 mm, 29.8°C and 2 802.5 mm. River Niger

1 Tondibia (TON)

2 National Hospital of Niamey (HNN)

3 University of Niamey (UAM)

4 Big Hotel (BH)

5 Tannery (TAN)

6 MESS (ME)

7 BRANIGER (BRA)

8 ENITEX (ENI)

9 Saga (SA)

10

Figure 1: Map of the localization of the sampling stations in the River Niger near Niamey (RHNL = National Hospital of Lamordé sewage; RHNN = National Hospital of Niamey sewage; RUAM = University Abdou Moumouni sewage; RGOU = Goutiyena domestic sewage; RBH = Big Hotel domestic sewage; RMES = Mess domestic sewage; RSLA = Slaughterhouse sewage; RBRA = Brewery sewage; RENI = Nigerian Enterprise of Textile sewage).

is the unique main river of the country. Its water regime at Niamey greatly depends on the upstream rainfall seasons of its very large basin and is characterized by high waters levels from November to February, low waters from March to June, and a small ascent of waters bound at the local rain season in July - September.

Sampling methods

Ten sampling stations were selected according to the wastewater discharges of Niamey city. One station (TON) is located upstream of the discharges, eight stations in the discharge area of the city (HNN, UAM, BH, TAN, ME, SLA, BRA, ENI) and one station (SA) downstream.

Water samples were taken, to 30 cm of depth and 3 m of the banks, in the morning between 9 to 10 hours at each station in order to respect the flux of wastewater discharges. The sampling was done from March to July 2004, from January to July 2005 and from November 2005 to January 2006. Three samples were taken monthly (ten days interval) and conserved in polyethylene bottles at 4°C for laboratory analysis. The following variables were analysed: pH, conductivity, dissolved oxygen, orthophosphates, total phosphorus, nitrates, nitrites, ammonium nitrogen, chemical oxygen demand and temperature. Conductivity, pH, temperature and dissolved oxygen were measured *in situ* respectively by conductivity WTW LF 318/SET; pH WTW 330i/SET and oxygen WTW Multiline P3 pH/Oxi-SET. At the laboratory, nitrate was analyzed according to the cadmium reduction method, nitrite by diazotisation method, ammonium nitrogen by Nessler method, chemical oxygen demand by reactor digestion method, orthophosphates by phosVer 3 methods and total phosphorus by acid persulfate digestion process, using a DR/2000 spectrophotometer according to Hach manual.
Two sampling methods were used to collect Chironomidae. Chironomidae were sampled during low water (< 50 m3 s-1)
in May-June 2004 and April-May 2005 by artificial substrates made of stones in galvanized wire netting (48 cm length, 38 cm wide and 10 cm high). Four artificial substrata were used in 2004 and *eight* in 2005 once per year and per station. The artificial substrata stay 6 weeks in water.

Organisms were sorted (die) out at the laboratory through a column of sieves (5 mm, 1 mm and 0.4 mm mesh size).

All the collected specimens were preserved in formalin 10% before identification.

Specimens identification

Chironomid head capsules were cut and mounted in euparal ventral face upwards on microscopal slides (the body was mounted laterally together with the head capsule). Identifications were done with a microscope Reichert Zetopan at 100-400x magnification by referring to Eggermont and Verschuren (2004a, 2004b, and 2003), Eggermont et *al*. (2005), Eggermont (2004), Wiederholm (1983), Moller Pillot (1984) and Durand & Lévêque (1981). The majority of the specimens (63%) have been identified directly without preparation under a binocular WILD M 10 Leica.

Identification of larvae was based on ventral tubuli, and on head capsule features such as mentum, eye patches (form, position, number), mandibules, ventromental plates and antennal characteristics.

Statistical analysis

The characterization of the stations is done on a matrix of physicochemical parameters using data starting two months before chironomid sampling. This matrix is considered as representative of the mean water quality of each sampling station to which the observed chironomid community was submitted and able to react (Younes-Baraille et *al*. 2005; Ndaruga et *al*. 2004; Usseglio-Polatera and Beisel 2002).

The physicochemical data had to be normalized and standardized according to Legendre and Legendre (1998). The abundance of taxa per artificial substrata have been considered in the biological matrix. Chironomid abundance data were log (x + 1) transformed before statistical analysis in order to normalize and stabilize the variance.

The stations and species have been ordinated according to the environmental parameters by using canonical correspondence analysis (CCA, Miserendino and Pizzolon 2003; Miserendino 2001). Monte Carlo test allows selecting those environmental factors that explain significantly the distribution of taxa along the River Niger at Niamey. This method eliminates all environmental variables presenting an inflation factor superior to 10 (Ter Braak and Smilauer 1999). These factors were correlated by those variables so that they were less contributed to explain the distribution of chironomids. The option down-weighting of rares species was applied.

CANOCO for Windows for the ACC is the software used here (Ter Braak and Smilauer 1999).

The analysis of community structure is based on the taxa richness, Shannon-Weaver diversity and Shannon equitability index (Spellerberg and Fedor 2003).

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RESULTS

Structure of the communities

51% were of *Chironomus* gr. *plumosus* Linnaeus, 1758 and 26% of *Microchironomus sp*. Kieffer, 1918. The proportions of the other species vary from 0.01 to 10%.

The total number of sampled larvae varies significantly from upstream to downstream of each wastewater discharge station: i.e. 220 larvae at TON, 436 at HNN, 158 at UAM, 2 002 at BH, 98 at ME, 210 at BRA, 1 022 at ENI and 989 at SA. The number of larvae was very low at TAN and SLA, with 4 and 11 individuals respectively.

Sixteen taxa were collected, all sampling stations lumped. The highest score, i.e. 11 taxa, was recorded at UAM and the lowest, i.e. 1 taxon, was obtained at TAN and BRA (Tab. 1).

The results of the Shannon-Weaver index (Legendre and Legendre, 1979) show a difference between sampling stations (Tab. 2).

Table 1: Taxonomic list of Chironomidae sampled in different stations along River Niger near Niamey (+ = present; - = absent). Genus determination according to Wiederholm (1983) and Eggermont (2004)

Taxa\Stations	TON	HNN	UAM	BH	TAN	ME	SLA	BRA	ENI	SA
Chironominae										
Chironomini sp. 1	39	37	14	0	0	0	0	0	0	433
Chironomini sp. 2	0	2	9	44	0	2	0	0	0	0
Chironomus gr. *plumosus* Linnaeus, 1758	0	286	14	1045	4	51	9	210	981	35
Cryptochironomini sp.	0	0	0	0	0	0	0	0	0	0
Cryptochironomus sp. 1 Kruseman, 1933	0	0	23	0	0	0	0	0	0	0
Cryptochironomus sp.2 Kruseman, 1933	0	0	27	0	0	0	0	0	0	44
Dicrotendipes sp. Kieffer, 1913	0	2	5	0	0	0	0	0	0	0
Glyptotendipes sp. Kieffer, 1913	0	0	0	59	0	3	0	0	0	0
Microchironomus sp. Kieffer, 1918	80	57	14	845	0	41	0	0	41	256
Nilodosis sp.	0	0	5	0	0	0	0	0	0	0
Parachironomus sp. Lenz, 1921	0	10	0	0	0	0	0	0	0	0
Polypedilum spp. 1 Wulp	18	39	18	0	0	0	0	0	0	159
Polypedilum spp.2 Wulp	25	0	0	7	0	0	2	0	0	0
Tanytarsini spp.	16	0	0	0	0	0	0	0	0	53
Xenochironomus sp.	0	0	0	0	0	0	0	0	0	0
Tanypodinae										
Ablabesmya sp.	23	2	14	0	0	0	0	0	0	9
Cf Procladius sp.	0	0	0	0	0	-	0	0	0	0
Clinotanypus sp.	0	0	0	0	0	-	0	0	0	0
Micropelopiinae sp.	18	0	18	0	0	-	0	0	0	0
Orthocladiinae										
Orthocladiinae sp.	1	-	0	0	0	-	0	0	0	0
Number of taxa	8	8	11	5	1	5	2	1	2	7

Table 2: Characteristics of the Chironomidae fauna of the River Niger near Niamey

Stations	Substrats	Abundance	Taxonomic richness	Index of Shannon	Shannon Equitability (%)
TON	Sand + clay+ stones	220	8	2.54	91
HNN	Clay	436	8	1.65	55
UAM	Sand	158	11	3.3	95
BH	Clay	2 002	5	1.32	57
TAN	Clay + plant remnants	4	1	0	-
ME	Clay	98	5	1.32	57
SLA	Clay + stomach content	11	2	0.91	35
BRA	Clay + sand	210	1	0	-
ENI	Clay	1 022	2	0.24	24
SA	Clay+ stones	989	7	2.14	71

(AS = Artificial substrata; HN = Hand net; TON = Tondibia ; HNN = National Hospital of Niamey; UAM = University ABDOU Moumouni ; BH = Big Hotel; TAN = Tannery ; ME = Mess ; SLA = Slaughterhouse ; BRA = Brewery; ENI = Nigerian Enterprise of Textile; SA = Saga)

The Shannon-Weaver index reached a score 2 at TON, UAM and SA, was between 1 and 2 at BH, HNN and ME and inferior to 1 at SLA, ENI, BRA and TAN.

The most elevated equitability index is recorded to UAM (95%). It is from 91% at TON and 71 at SA. It was on the other hand very low to ENI (24%) and SLA (35%). HNN, BH and ME presented an intermediate equitability index ranged between 50 and 60%.

Distribution of chironomids according to environmental variables

The distribution of taxa according to the environmental parameters ($P < 0.05$) is shown in Figure 2.

The total amount of variance of the environmental factors (Fig. 2A) explained by axis 1 and 2 of the CCA was 42% (31% explained by the first axis and 11% by the second axis).

Tree significant variables (conductivity, nitrites, ammonium,) explained 47% of the variance (0.613 of total inertia) of taxa distribution.

In ordination of the environmental variables the first axis supported information relating to organic matter and nutrients. The second axis was correlated to conductivity and nitrites (Fig. 2A).

The axes 1 and 2 of the CCA for sampling stations (Fig. 2B) clearly differentiate “TON, UAM, SA” and “BRA, SLA, BH, ENI, TAN, ME, HNN”. The first axis mainly explains this difference suggested by a gradient in organic matter and nutrient concentrations (cf. mean value in Table 3).

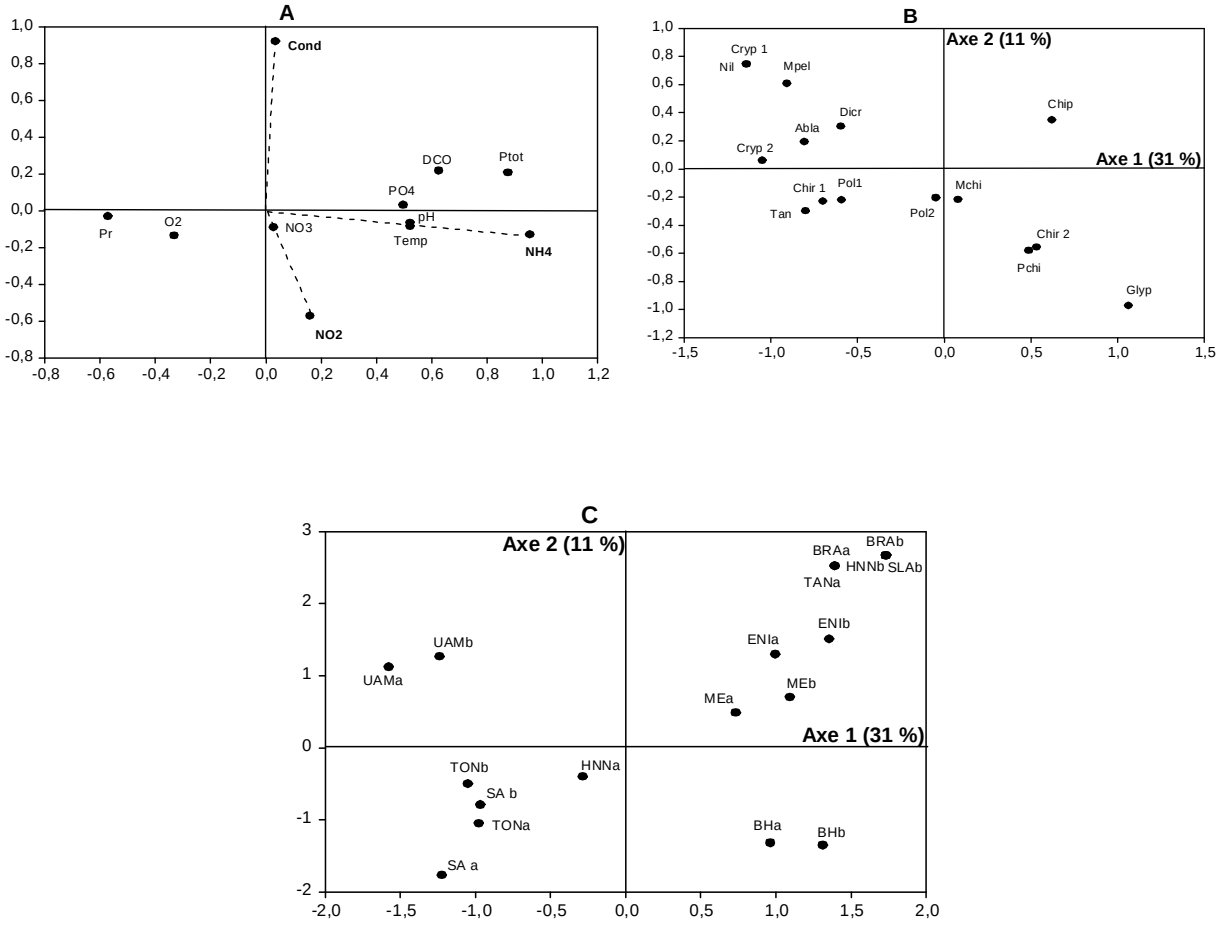

Figure 2: Ordination of environmental factors (A), taxa (B) and sampling (C) in the two first axes of the CCA (artificial substrata method, a = May-June 2004, b = April-May 2005).

Table 3: Physicochemical characteristics of water in the sampling stations of the River Niger near Niamey N = 7 (T=temperature; EC=conductivity; DCO=oxygen chemical demand; Ptot=total phosphorus; O2 =dissolve oxygen; Pr=depth; M=mean; SD=standard deviation)

Stations/Parameters	TON	HNN	UAM	BH	TAN	ME	SLA	BRA	ENI	SA
T (°C)										
M	25.5	30.1	29.7	26.4	25.9	26.2	26.4	26.2	21.6	25.9
SD	3.01	0.75	0.21	3.41	3.13	3.37	3.31	3.18	3.21	3.05
Min	20	29.6	29.6	20.5	20.5	20.5	21.2	21	21	20.9
Max	29	30.7	29.9	30.5	29.8	30.1	30.5	29.9	30.3	29.5
EC ($\mu S\ cm^{-1}$)										
M	60.6	73.5	68.7	92.7	70.2	66.6	63.8	118.2	112.8	62.9
SD	8.82	5.68	4.47	29.18	15.1	13.18	11.03	43.38	41.76	9.98
Min	46.1	69.4	65.5	47.7	48.9	46.4	46.4	48.6	46.1	46.2
Max	71.9	77.5	71.8	134.2	101.8	98.2	78	169	163.6	80.3
pH										
M	6.8	7.1	7.2	7.2	6.9	7	6.6	6.7	7.8	7
SD	0.37	0.02	0.13	0.57	0.38	0.37	0.19	0.28	0.93	0.43
Min	6.1	7.1	7.1	6.1	6.2	7.8	6.4	6.2		6.1
Max	7.3	7.2	7.3	8	7.4	7.4	7	7.2	9.5	7.5
DCO ($mg\ l^{-1}$)										
M	9	19.4	25.2	28.1	22.1	22.3	57.1	129.9	35.2	13.8
SD	3.13	7.42	11.31	13.94	11.19	11.32	61.58	96.18	31.82	5.74
Min	5	14.2	17.2	7.2	6.7	7.8	7.8	6.7	5.2	4.2
Max	16.2	24.7	33.2	52.2	49.7	52.5	248.3	363.3	129.7	22.8
NH_4 ($mg\ l^{-1}$)										
M	0.3	1.1	0.7	0.9	0.6	0.6	0.6	0.7	0.4	0.5
SD	0.43	0.78	0.9	0.64	0.43	0.42	0.37	0.51	0.43	0.53
Min	0.1	0.6	0.1	0.3	0.3	0.3	0.3	0.2	0.1	0.1
Max	1.7	1.7	1.4	2.9	2	2	1.7	2.2	1.8	2.2
NO_3 ($mg\ l^{-1}$)										
M	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
SD	0.15	0.23	0.34	0.17	0.15	0.16	0.17	0.15	0.15	0.14
Min	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1
Max	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5
NO_2 ($mg\ l^{-1}$)										
M	0.002	0.001	0.002	0.005	0.004	0.002	0.002	0.002	0.002	0.002
SD	0.001	0.001	0.001	0.002	0.002	0	0.001	0.001	0	0
Min	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.002	0.002
Max	0.003	0.002	0.002	0.007	0.011	0.003	0.003	0.003	0.003	0.003
PO_4 ($mg\ l^{-1}$)										
M	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1
SD	0.04	0.06	0.02	0.09	0.09	0.08	0.05	0.07	0.03	0.03
Min	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0
Max	0.2	0.2	0.2	0.4	0.4	0.3	0.3	0.4	0.2	0.2
Ptot ($mg\ l^{-1}$)										
M	0.2	0.3	0.3	0.4	0.2	0.2	0.6	0.5	0.4	0.2
SD	0.13	0.08	0.21	0.39	0.12	0.22	0.84	0.51	0.49	0.22
Min	0	0.2	0.1	0.1	0.1	0.1	0.1	0	0	0
Max	0.6	0.3	0.4	1.7	0.6	0.9	3.2	2.1	1.9	0.9
O_2 ($mg\ l^{-1}$)										
M	7.4	6.8	7.1	7.2	6.9	7	6.6	5.6	6.5	7
SD	0.29	0.26	0.17	1.09	0.6	0.37	0.72	0.49	0.64	0.51
Min	7.1	6.7	6.9	3.8	5.3	6.2	4.7	4.1	4.7	6.1
Max	8.2	7	7.2	8.2	7.6	7.8	7.5	6	7.4	7.9
Pr (cm)										
M	90.4	78.5	83	189	182.4	136.2	131.1	110.3	89.4	83.6
SD	37.16	21.58	22.33	63.73	74.95	56.28	47.48	50.43	49.32	42.13
Min	41.8	63.3	67.2	70.3	57.2	38.8	42.2	34	33.2	33.3
Max	174	93.8	98.8	309.6	298.8	234.4	205.5	212.7	174.1	160.5

The sampling stations TON, UAM and SA were negatively correlated to axis 1 while BRA, SLA, BH, ENI, TAN, ME and HNN were positively correlated to this axis.

A clear separation of taxa is illustrated in Fig. 2B. The first biological canonical variable was positively correlated with *Chironomus* gr. *plumosus* and *Glyptotendipes* sp. and negatively correlated with *Cryptochironomus* sp. 2, *Ablasbesmyia* sp., *Dicrotendipes* sp., *Tanytarsini* sp., *Chironomini* sp. 1 and *Polypedilum* spp. 1 (Fig. 2B).

DISCUSSION

In this study, we notified a taxonomic composition difference between stations located upstream and downstream the wastewater discharges due to a clear presence of species like *Cryptochironomus* sp., *Chironomini* sp. 1, *Polypedilum* spp.1, *Micropelopiinae* sp., *Nilodosus* sp. and *Tanytarsini* sp. in the upstream station TON, but mainly absent in the downstream station SA. Moreover, *Chironomus* genus is not present in TON, but present in SA.

Furthermore, the structure of the communities of Chironomidae shows weak similarity between sewage discharge stations. Low taxonomic diversity was observed in some stations located at the wastewater discharges, i.e. BH, TAN, SLA, BRA and ENI (Fig. 3).

Mineralization of organic compounds of wastewater linked to oxygen consumption by bacteria, especially at the bottom, could explain the lower taxonomic diversity observed in these stations and the absence of some taxa. Moreover, the sampling stations, especially those in front of Niamey, were characterized by quite different substrates (BH, TAN, ME, SLA, BRA and ENI). According to several studies (Henriques-Oliveira et *al.* 2003; Beisel et *al.* 1998), the types of substrates play an important role in the distribution of most aquatic insects, and particularly of chironomids. Unstable substrates can explain poor abundance of taxa (Olive et *al.* 1988). The sediments at the sewage stations in River Niger at Niamey appear to be very unstable, as was observed during sampling.

The dominance of *Chironomus* gr. plumosus at BH, SLA, BRA, ENI and at TAN indicated that it was the only chironomid taxon found that could be an important indicator to explain the anthropogenic impact on chironomids communities in those stations. *Chironomus* spp. is well adapted to low oxygen concentrations: their haemolymph possesses haemoglobin and the 7th and 8th abdominal segment possesses respiration tubuli. Several studies correlated the increase in the abundance of larvae of the *Chironomus* genus in aquatic ecosystem to organic enrichment and its consequence on water quality (Callisto et *al*. 2002; Marques et *al.* 1999; Petrucio and Furtado 1998). Other species are only found at the upstream unpolluted station TON, e.g. the species *Xenochironomus*

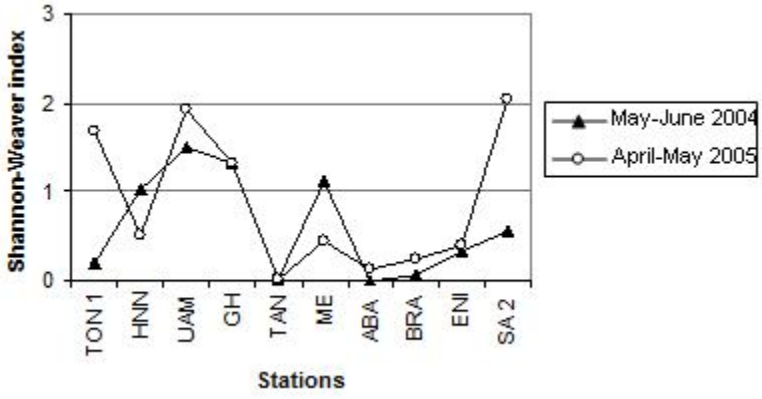

Figure 3: Diversity index

sp., *Nilodosis* sp. and *Cryptochironomus* sp. seem to be primarily related to the sandy substrate with presence of blocks of stones, a habitat with a mostly favourable oxygen condition at the water-sediment limit. In any case, 16 chironomid taxa at TON were by far the highest number found, confirming the better habitat conditions at that upstream station.

The *Tanytarsini* and Cryptochironomini sp. in this study are the only taxa present in both no sewage stations TON and SA, but completely absent in the sewage stations. *Tanytarsini* are known to be more sensitive to pollution (in lake typology, a distinction is made between eutrophic *Chironomus* lakes and oligotrophic *Tanytarsus* lakes). Perhaps their presence at SA may be interpreted as an indication of the first signs of a fast recovery of the original Niger fauna, once the sewage discharge of Niamey is over. This seems to be confirmed by the drastic drop of the dominance of the pollution indicator *Chironomus* gr. *plumosus* at SA station. The few larvae found may be emanating from drifting.

A special case is *Dicrotendipes* sp., which is negatively correlated to chemical oxygen demand, nitrites and orthophosphates. Nevertheless, this species has never been found either in TON or in SA. Maybe this species requires organic matter in combination with good oxygen conditions. In any case, it had a restricted distribution, only present in two stations, HNN and UAM. Artificial substrates which are well-exposed to the water current may be expected to have higher oxygen concentrations than in the upper sediment. The wastewater discharge of Niamey on the water quality of River Niger indicates a drastic lowering of the chironomid species diversity. Some species appear to be more or less tolerant to pollution. There are indications that the water quality rapidly recovers once the Niamey discharge is over.

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