

Relationships between physico-chemical parameters and taxonomic structure of benthic macroinvertebrate assemblages in streams of West Cameroon

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SUPPLEMENTARY MATERIAL

Figures S1 to S8 – Tables S1 to S3

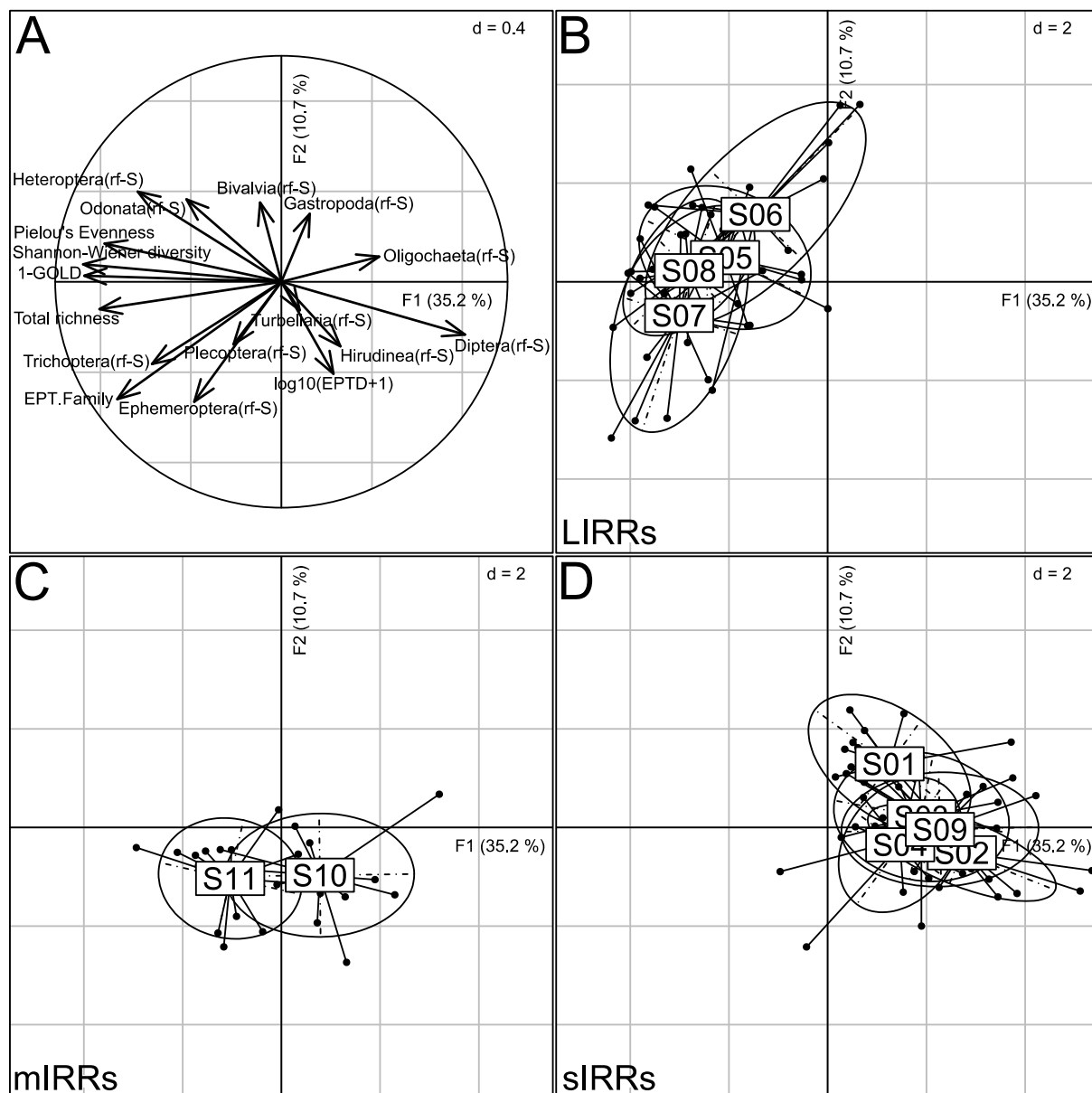


Figure S1: Ordination of sites by a "within-season" nPCA based on 17 taxonomy-based metrics. (A) Projection of taxonomic metrics on the first correlation circle (F1-F2); (B, C and D) Locations of sites (large labels) on the first factorial plane F1-F2 at the weighted average of the locations of corresponding monthly sampling events (solid points). Each event is linked by a line to the mean position of the corresponding site. Ellipses of inertia (95%) are provided by site. Sites are gathered according to anthropogenic pressure level: LIRRs = Least Impacted River Reaches; mIRRs = moderately Impacted River Reaches; sIRRs = severely Impacted River Reaches.

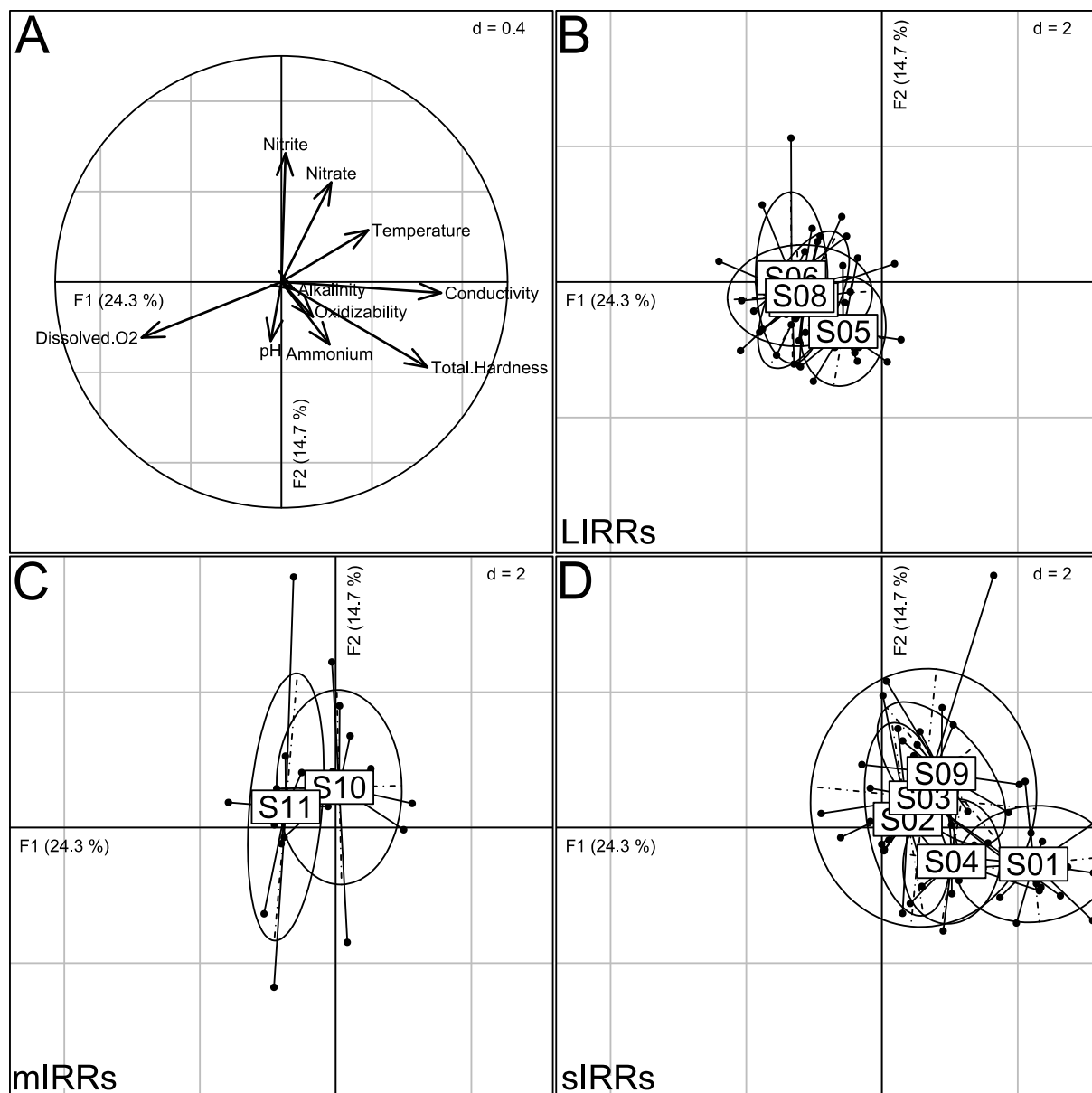


Figure S2: Ordination of sites by a «within-season» nPCA, based on 10 physico-chemical parameters. (A) Projection of physico-chemical parameters on the first correlation circle (F1-F2); (B, C and D) Locations of sites (large labels) on the first factorial plane at the weighted average of the locations of corresponding monthly sampling events (solid points). Each event is linked by a line to the mean position of the corresponding site. Ellipses of inertia (95%) are provided by site. Sites are gathered according to anthropogenic pressure level: LIRRs = Least Impacted River Reaches; mIRRs = moderately Impacted River Reaches; sIRRs = severely Impacted River Reaches.

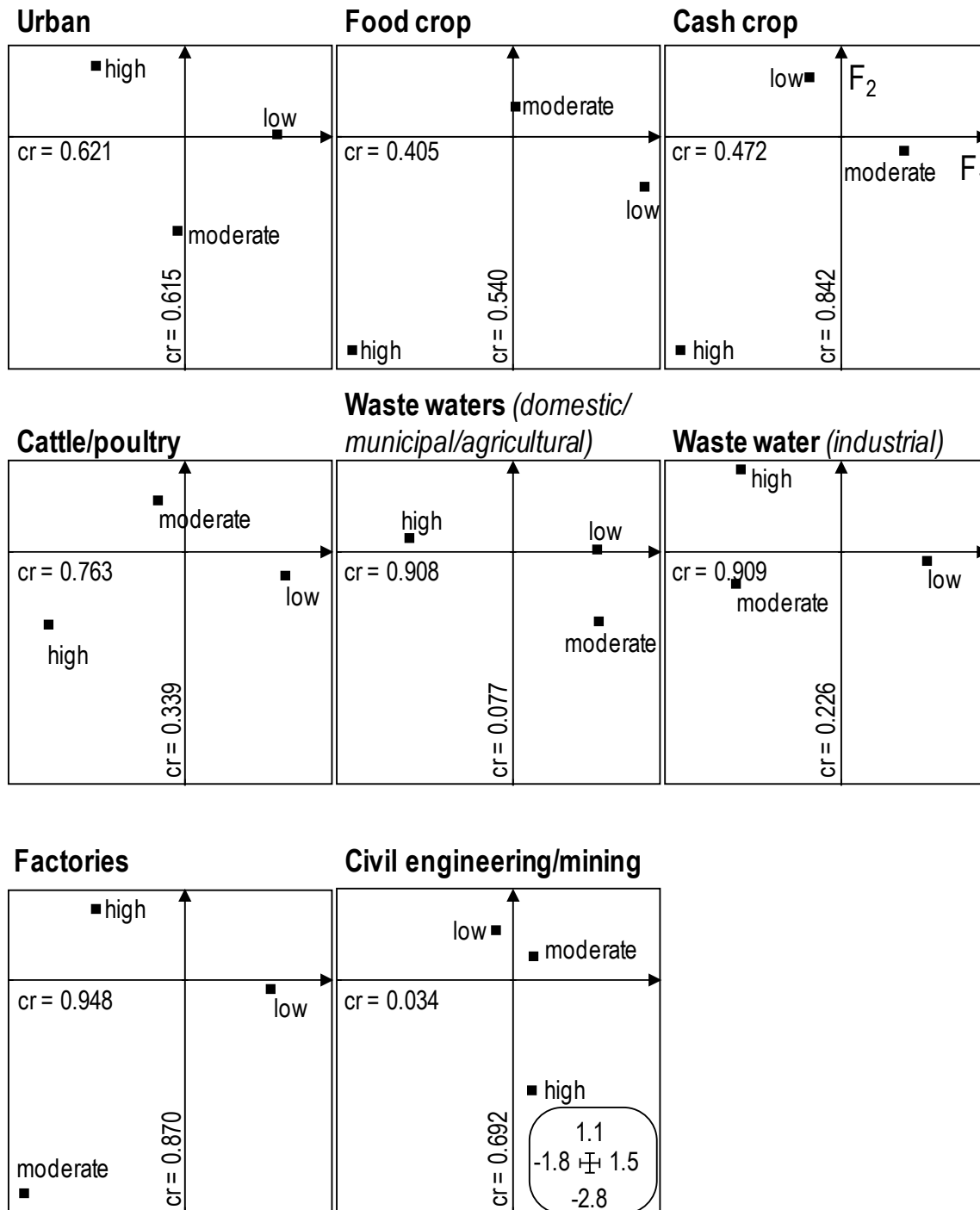


Figure S3: Ordination of impact levels (three categories: low/moderate/high) of eight pressure categories by Multiple Correspondence Analysis (MCA) based on the description of 11 study sites. cr = correlation ratio. See Table 1, Figure 2 and the text for further details.

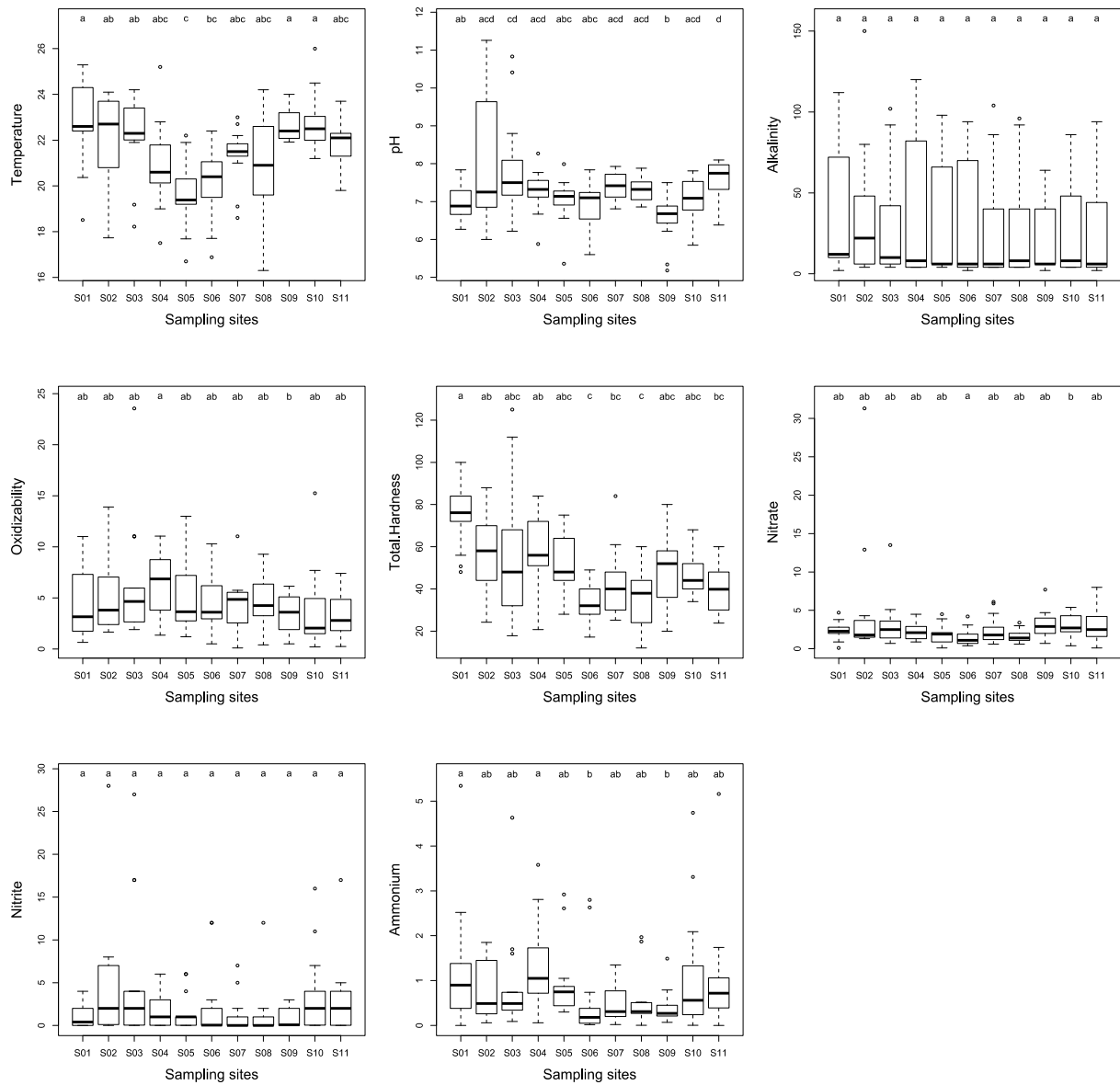


Figure S4: Box-plots (Min/Q25/Median/Q75/Max) describing the distribution of values of the remaining physico-chemical parameters exhibiting significant differences among sites, over a period of thirteen months, for 11 study sites (S01 to S11). « a », « b », « c » and « d » are distinct groups identified by post-hoc Nemenyi tests applied after identifying, for a given parameter, a significant difference among sites by a non-parametric Friedman test. Note that even if the Friedman test had identified a significant heterogeneity among sites for nitrite and alkalinity (Table 3), the Nemenyi post-hoc test has been unable to confirm such significant differences (probable beta error on post-hoc test decision). See text for further details.

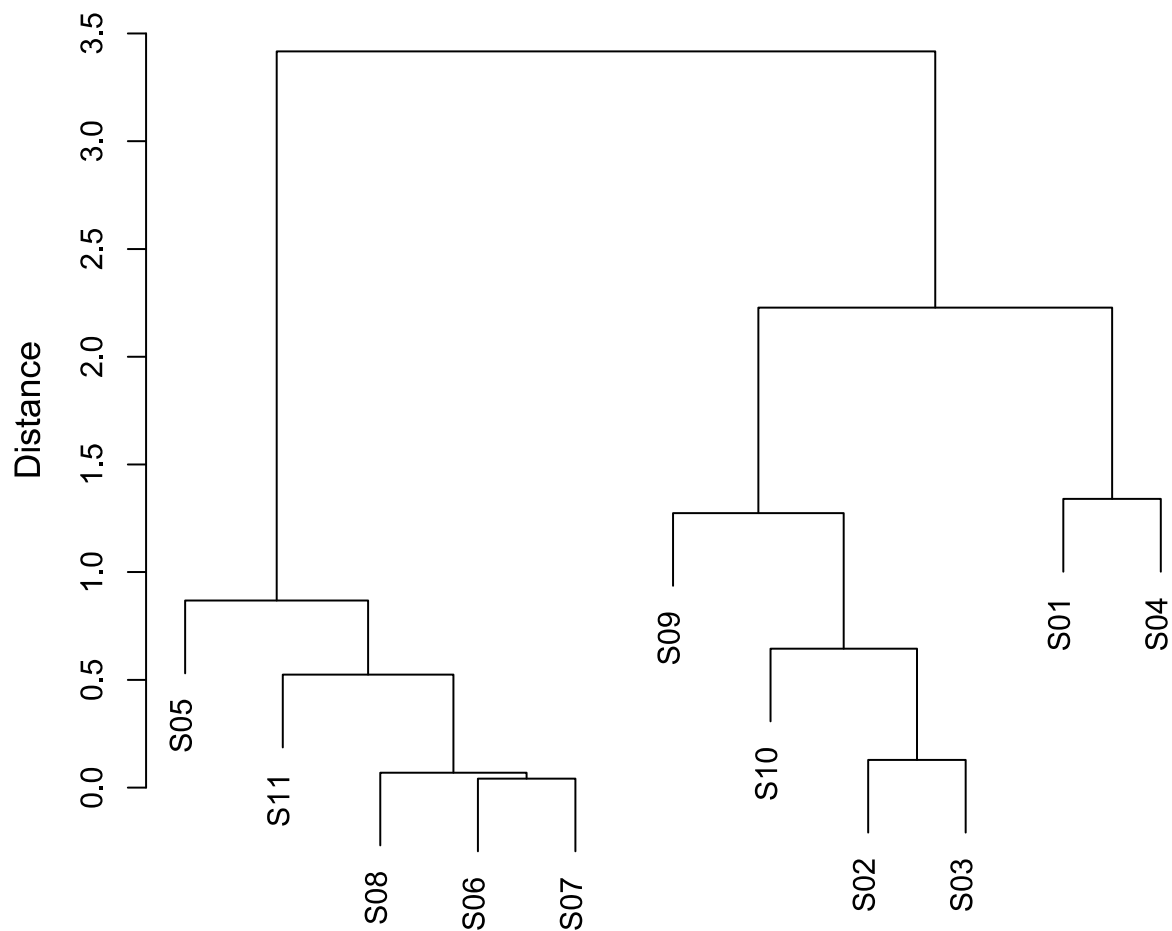


Figure S5: Dendrogram, based on the Euclidean distance (calculated between sites according to their coordinates on the first factorial plane of the nPCA) and the complete linkage method, highlighting the similarity of the 11 study sites (S01 to S11) considering their physico-chemical characteristics during the study period.

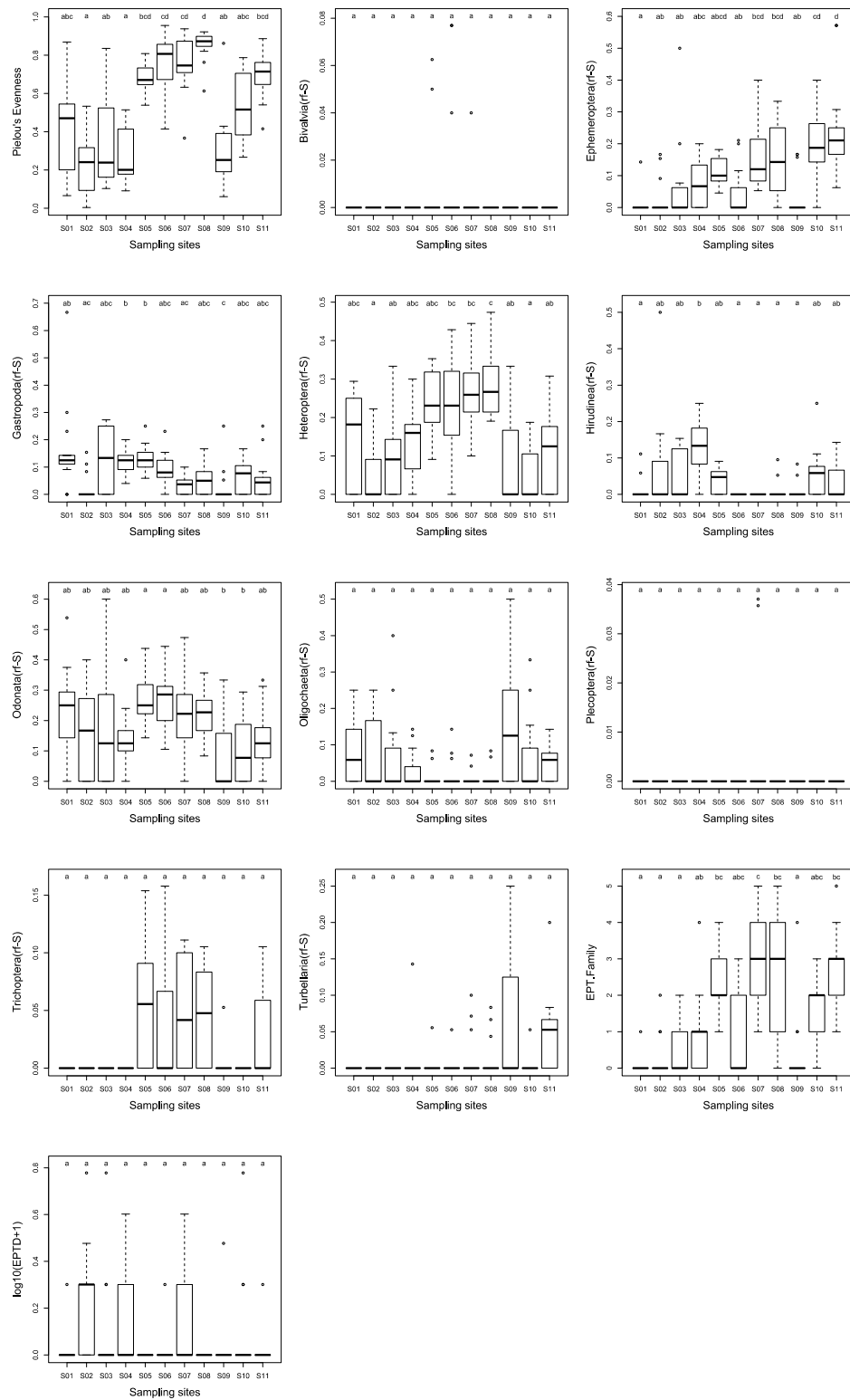


Figure S6: Box-plots (Min/Q25/Median/Q75/Max) describing the distribution of values of the remaining taxonomy-based metrics exhibiting significant differences among sites, over a period of thirteen months, for 11 study sites (S01 to S11). “a”, “b”, “c” and “d” are distinct groups identified by post-hoc Nemenyi tests applied after identifying, for a given parameter, a significant difference among sites by a non-parametric Friedman test. See text for further details.

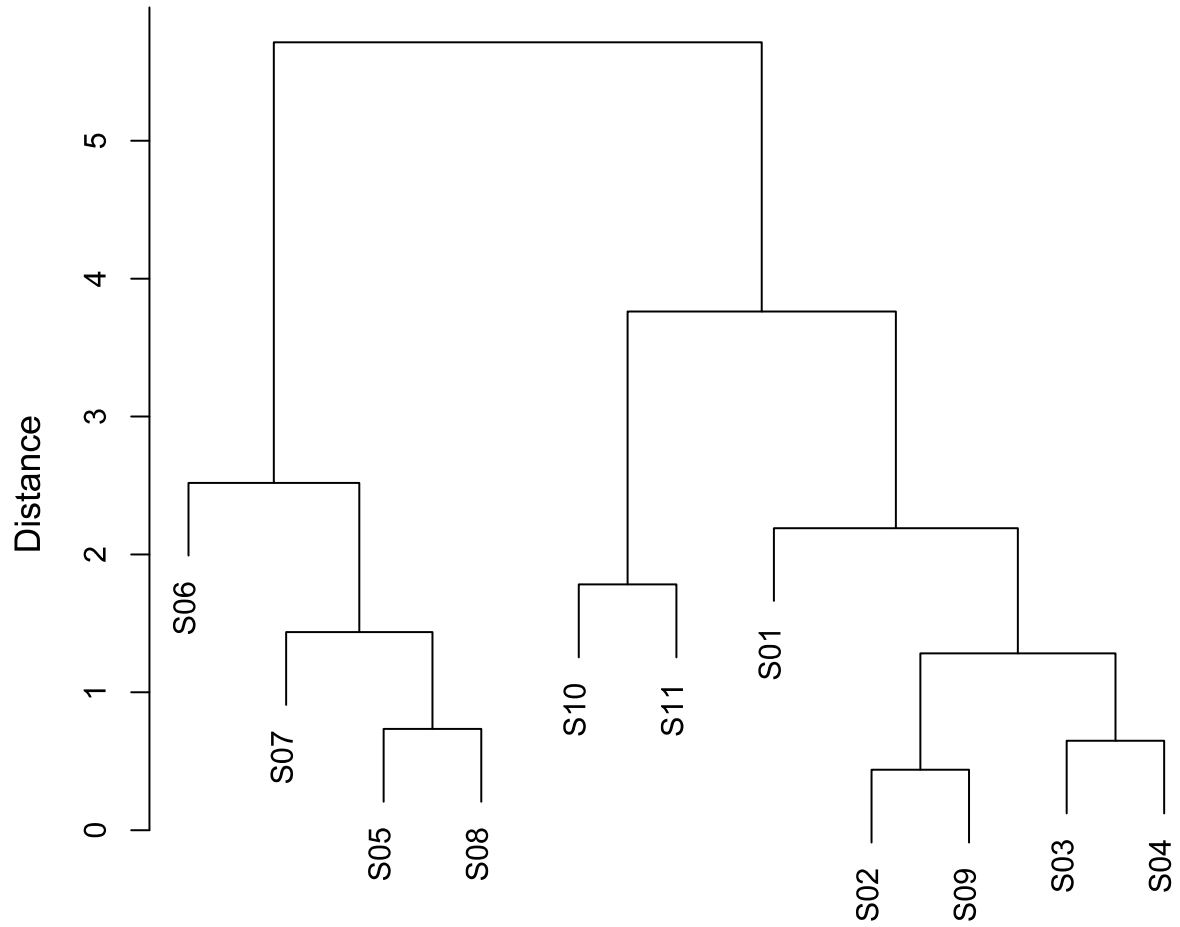


Figure S7: Dendrogram, based on the Euclidean distance (calculated between sites according to their coordinates on the first factorial plane of the nPCA) and the complete linkage method, highlighting the similarity of the 11 study sites (S01 to S11) considering the structure of their macroinvertebrate assemblage described by 17 taxonomy-based metrics.

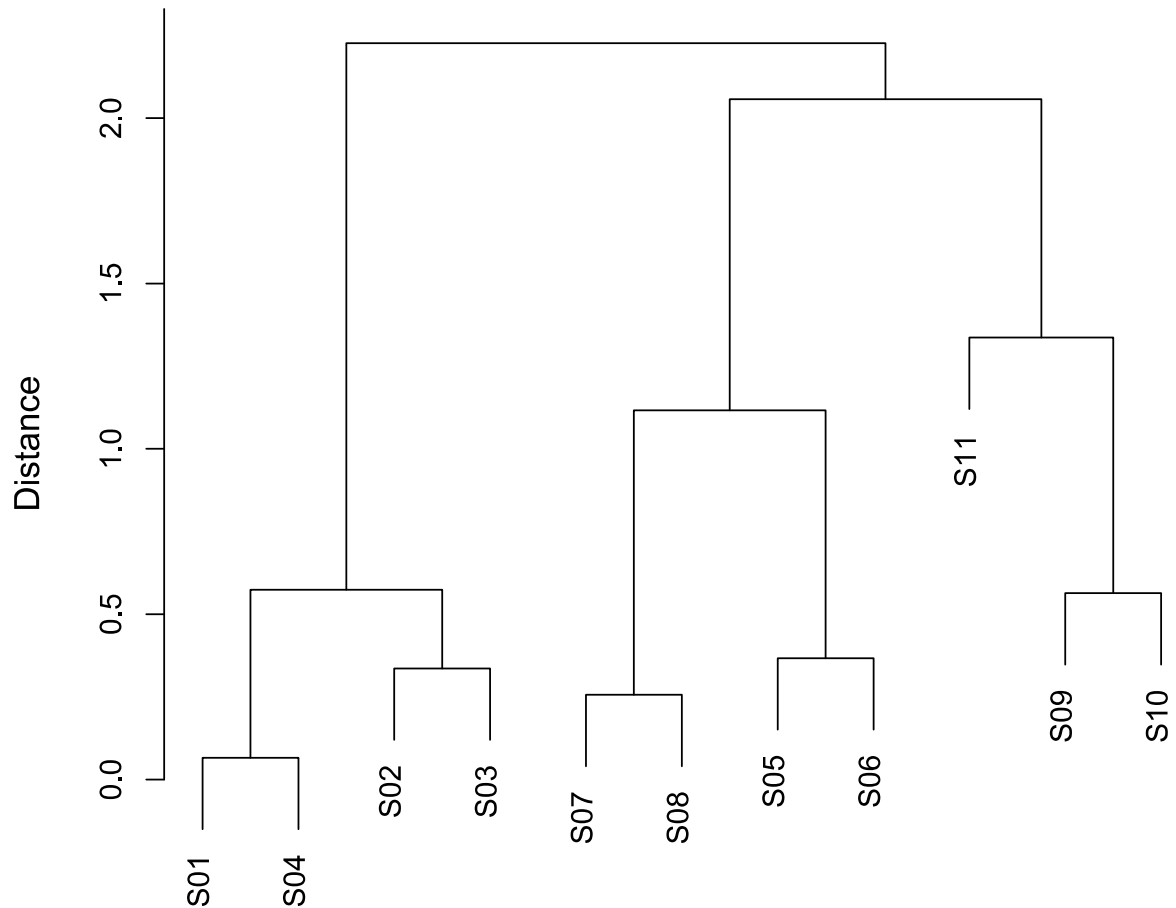


Figure S8: Dendrogram, based on the Euclidean distance and the complete linkage method applied to sampling events coordinates on the first factorial plane of the RDA, highlighting the similarity of the 11 study sites (S01 to S11) based on the structure of their macroinvertebrate assemblage described by 17 taxonomy-based metrics explained by 10 physico-chemical variables (see Figure 5S for further details).

Table S1: Semi-quantitative description of eight categories of anthropogenic pressures for 11 sampling sites (S01-S11) in three catchments of the Bafoussam region (West Cameroon). The potential intensity of each pressure category has been described using three modalities: 1 = low, 2 = moderate and 3 = high. The eight pressure categories are related to the importance of “urban” areas, “food crop”, “cash crop”, “cattle and poultry” breeding, untreated “domestic, municipal and agricultural” or “industrial” wastewater effluents, riverine “factories” and “civil engineering and mining” at reach scale. See Table 1 and Figure 1 for further details on sites.

sites	urban	food crop	cash crop	cattle and poultry	domestic, municipal, agricultural waste waters	industrial waste waters	factories, informal activities	civil engineering, mining
S01	3	2	1	3	3	3	3	1
S02	3	2	1	2	3	3	3	1
S03	3	2	2	2	3	2	3	2
S04	2	3	3	3	3	2	2	3
S05	2	2	2	2	1	1	1	1
S06	1	2	1	2	1	1	1	1
S07	1	2	2	1	1	1	1	2
S08	1	2	1	1	1	1	1	1
S09	3	2	1	2	3	2	3	1
S10	2	2	2	1	2	1	1	3
S11	1	1	2	1	1	1	1	3

Table S2: Correlations (Spearman's rho coefficient) between the 19 tested macroinvertebrate-based metrics and the environmental parameters.

N = 143. * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

Metrics	Environmental parameters															
	Temperature	pH	Conductivity	Turbidity	Suspended Matter	Dissolved O ₂	Dissolved CO ₂	Alkalinity	Oxidizability	Total Hardness	Nitrate	Nitrite	Ammonium	Ortho-phosphate	Chlorophyll a	BOD5
Total richness	-0.37***	0.10	-0.22**	-0.20*	-0.20*	0.45***	-0.12	0.16	0.11	-0.14	-0.34***	-0.18*	0.00	-0.05	0.00	-0.06
Shannon-Wiener diversity	-0.31***	0.11	-0.35***	-0.10	-0.11	0.55***	-0.05	0.12	0.06	-0.25**	-0.30***	-0.16	-0.05	-0.09	0.01	-0.02
Pielou Evenness	-0.26**	0.10	-0.37***	-0.01	-0.01	0.52***	0.02	0.08	0.05	-0.28***	-0.22**	-0.08	-0.07	-0.08	0.00	0.00
Bivalvia(rf-S)	-0.19*	-0.06	-0.05	-0.01	0.00	0.14	-0.06	0.14	0.08	-0.03	-0.25**	-0.08	0.05	-0.05	0.00	0.07
Coleoptera(rf-S)	-0.17*	-0.07	-0.16	0.05	-0.02	0.14	0.00	0.03	0.01	-0.04	0.00	0.08	-0.15	0.02	0.02	-0.02
Dictyoptera(rf-S)	0.09	-0.05	0.10	-0.04	-0.23**	-0.09	-0.07	0.27***	0.07	0.05	-0.03	0.03	0.21*	0.11	0.27***	-0.05
Diptera(rf-S)	0.35***	-0.02	0.33***	0.05	0.10	-0.46***	0.02	-0.09	-0.08	0.21*	0.30***	0.16	0.03	0.07	0.02	0.03
Ephemeroptera(rf-S)	-0.13	-0.02	-0.39***	0.10	0.05	0.37***	-0.10	-0.09	-0.05	-0.31***	0.02	-0.02	0.01	-0.02	0.01	-0.05
Gastropoda(rf-S)	-0.19*	0.04	0.15	-0.04	0.04	-0.04	-0.03	0.18*	0.09	0.17*	-0.02	-0.03	0.11	0.06	0.14	0.08
Heteroptera(rf-S)	-0.28***	-0.03	-0.14	-0.10	-0.14	0.27**	0.03	0.12	0.10	-0.12	-0.35***	-0.10	0.04	-0.09	-0.06	-0.12
Hirudinea(rf-S)	-0.01	0.07	0.30***	-0.12	-0.03	-0.19*	-0.19*	0.23**	0.17*	0.18*	0.02	0.11	0.19*	0.09	0.11	0.03
Odonata(rf-S)	-0.15	0.16	0.01	-0.30***	-0.16	0.11	-0.04	0.20*	0.09	-0.02	-0.31***	-0.06	0.05	-0.05	0.09	-0.05
Oligochaeta(rf-S)	0.19*	-0.08	0.18*	0.17*	0.04	-0.15	0.08	-0.04	-0.04	0.14	0.08	0.05	0.00	-0.08	0.01	0.05
Plecoptera(rf-S)	0.02	0.13	0.00	-0.01	-0.03	0.10	-0.11	0.14	-0.02	-0.03	-0.11	-0.08	-0.07	-0.03	-0.07	-0.05
Trichoptera(rf-S)	-0.32***	0.08	-0.27**	-0.07	-0.08	0.42***	0.01	0.08	0.08	-0.15	-0.18*	-0.15	-0.03	0.03	0.04	-0.03
Turbellaria(rf-S)	0.05	0.07	-0.04	-0.01	0.01	0.17*	0.06	0.03	-0.08	-0.14	-0.08	0.03	-0.17*	-0.12	-0.21*	0.10
1-GOLD	-0.35***	0.04	-0.40***	-0.10	-0.13	0.48***	-0.03	0.06	0.08	-0.31***	-0.29***	-0.13	-0.06	-0.08	-0.08	-0.08
EPT Family S	-0.26**	0.05	-0.37***	0.00	-0.07	0.49***	-0.12	0.02	0.04	-0.27**	-0.15	-0.08	0.01	-0.03	0.02	-0.06
log10(EPTD+1)	-0.10	0.08	0.18*	0.09	-0.08	-0.18*	-0.09	0.01	0.02	0.21*	0.05	0.05	-0.09	-0.04	0.05	-0.07

Table S3: Proposed reference values and ecological quality class boundaries for the ten metrics exhibiting significantly different ranges of values between LIRRs and IRRs in wadeable rivers of the Bafoussam Region. Ecological class boundaries have been defined following Mondy et al. (2012; [90]). As recommended by the WFD, ecological quality class boundaries (i.e. delimiting ‘high’, ‘good’, ‘moderate’, ‘poor’ and ‘bad’ classes) have been defined based on the distribution of each metric values from the LIRR data set. For each metric decreasing with increasing anthropogenic pressures (i.e. all the metrics except Diptera(rf-S) and Oligochaeta(rf-S); cf. Figure 8), the 95th, 75th and 25th percentiles of the metric value distribution in the LIRRs were calculated. These values have been considered as the reference value, the ‘high–good’ boundary and the ‘good–moderate’ boundary, respectively. For the two metrics increasing with increasing anthropogenic pressures (i.e. Diptera(rf-S) and Oligochaeta(rf-S)), the 5th, 25th and 75th percentiles of the metric value distribution in the LIRRs were considered as the reference value, the ‘high–good’ boundary and the ‘good–moderate’ boundary, respectively. For defining the ‘moderate–poor’ and the ‘poor–bad’ boundaries, we divided the metric scoring range between the minimal possible value (decreasing metric) or the maximal possible value (increasing metric) and the ‘good–moderate’ boundary in three equal classes.

Metrics	Reference value	Ecological class boundaries			
		High/Good	Good/Moderate	Moderate/Poor	Poor/Bad
Total richness	26.45	21.25	13.75	9.83	5.92
Shannon-Wiener diversity	2.776	2.540	1.790	1.194	0.598
Pielou's Evenness	0.923	0.859	0.669	0.447	0.225
Ephemeroptera(rf-S)	0.260	0.169	0.053	0.035	0.018
Heteroptera(rf-S)	0.422	0.319	0.200	0.133	0.067
Odonata(rf-S)	0.428	0.308	0.165	0.110	0.055
1-GOLD	0.975	0.900	0.772	0.515	0.257
EPT.Family richness	5	3	1	0.67	0.33
Diptera(rf-S)	0	0.028	0.091	0.394	0.697
Oligochaeta(rf-S)	0	0	0	0.333	0.667