Impact of dam construction on the diversity of benthic macroinvertebrates community in a periurban stream in Cameroon

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Received: 07 October 2012
Revised: 15 November 2012
Accepted: 23 November 2012

Key words: Benthic macroinvertebrates, physicochemical variables, dam construction, Mefou stream, Cameroon.

Abstract
In the aim of evaluating the impact of a dam construction on the biodiversity of aquatic organisms, physicochemical variables coupled to benthic macroinvertebrates communities were analysed at the upstream and downstream of the Mefou stream dam from September 2009 to March 2010. Physicochemical results revealed a slightly acidic and well oxygenated water of the Mefou stream, being appropriated for the development of benthic macroinvertebrates organisms. Significant differences were observed for temperature and oxygen between the stations (P < 0.05). Of the 1801 individuals collected (4 phyla, 6 classes, 13 orders, and 47 families), Arthropods (99.25%) dominated, while Annelids, Nemathelminths and Mollusca were less represented (2 %). The Correspondence Canonic analysis (CCA) distinguished two sections on the stream: a superior section at the upstream of the dam which is characterised by much oxygenation and abundance of Atyidea (excellent bioindicators of good quality water) (r = 0.04; P < 0,05); an inferior section at the downstream of the dam, dominated by rheophil organisms (odonates). The relative abundance of odonates correlated with the values of water flow rates of each station (r = 0.94 ; P < 0.01). The presence of polluo-tolerant organisms (Chironomidae and Haplotoxidae) at station 3 could reflect anthropic action at the downstream of the dam. Shannon and Weaver (H = 4.1±0.5 bits) and Pielou index (J = 0.8 ± 0.1bits) revealed favourable conditions for the coexistence of benthic macroinvertebrates. This results could provide viable information used in evaluating the water quality of lotic systems subjected to dam construction in Cameroon.

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Introduction
Since the works made to understand the functioning of natural lotic systems (Vannote et al., 1980; Statzner & Higler, 1985; Wasson, 1989), other hydrosystemic factors (climate, geology, streams, and human perturbations: pollution, dams, sand removals, river deviations, water feedings and river border deforestation) also influence the distribution of aquatic organisms. Also, the longitudinal structure of lotic ecosystem organisms could highly be explained by the differences of hydrological regimes between the upstream and downstream of streams (Zorn et al., 2002; Pyron and Lauer, 2004).

Fig. 1. Location of sampling stations on the Mefou stream.

Retention dams are natural infrastructures which modify liquid and solids flux, maters and organisms flux, and the thermal regimes of streams on which they are implanted. These modification can modify the functioning of streams, according to the intensity of the barrier effect subjected to different habitats necessary to accomplish aquatic organisms vital cycles. They are also link to the nature and size of the structure (height and configuration of the dam retention) and their position on the hydrographic basin. Following the modification of habitat caused by the construction of such structures, the ecosystem undergoes some transformation and the biodiversity of species present is often modified (Woolsey et al., 2005). This progressively lead to the multiplication of lotic habitats, a reduction of species number and diversity. For the case of a dam built to reconstitute the flow rate at the downstream, the functioning of the dam (variations at different levels) and its evolution influence the physicochemical and ecological quality of the water mass at downstream (Woolsey et al., 2005).

Benthic macroinvertebrates are among the organisms which are used to evaluate water quality of streams. They give a good indication of the global health status of aquatic ecosystems (Williams & Smith, 1996; Clarke et al., 2002, WFD, 2003), related to their biodiversity and structure (Allan & Johnson, 1997; Woodcock & Huryn, 2007). In Cameroon, hydrobiological studies carried out on streams having constructed dams are rare or even non-existing. The present study aim at completing this lapse by providing an analytical approach on the distribution of benthic macroinvertebrates at the upstream and downstream of the Mefou stream dam. It aims specifically to: (1) Carry out a qualitative and quantitative identification of the benthic macroinvertebrates fauna, (2) Analyse the spatial variation of physicochemical and biological variables, (3) Determine the physicochemical variables which could influence the distribution of benthic macroinvertebrates.

The results obtained from this study shall highlight on the impact that the construction of dams could have on the biodiversity of aquatic organisms and will provide viable information which could be used to evaluate the water quality of lotic systems subjected to such structures in Cameroon.

Materials and methods
Description of the sampling sites
The Centre-South forestry region of Cameroon is located between 3°30’ - 3°58’ of latitude Nord and 11°20’ - 11°40’ of longitude East. The average altitude attends 750 m, the relief is globally accidental, and the zone extends on many high hills of 25 m to 50 m below the plateau (Mulder, 2009).

This region is exposed to equatorial climate of a specific type, known as “the Yaounde Climate”, which is characterised by moderate precipitations (1576 mm/year) with an average temperature of 23.5°C (Suchel, 1987; Mulder, 2009; Zebazé...
Togouet, 2011), and four unequal seasons which vary from one year to another: a long dry season (Mid November to mid March), a small rainy season (Mid March to end of June), a short dry season (July to Mid August) and a long rainy season (Mid August to mid November) were elucidated. The vegetation is of a secondary dense forest type and the river basin is dense with different streams flowing towards the Nyong and Sanaga rivers.

The Mefou stream which irrigates part of Yaounde town, is one of the principal right tributary of the Nyong river. It takes its source at 1225 m altitude on the bank of Odou mountain from where its flows in NNW-SSE direction (Fig. 1). Samples were collected twice a month in the morning (8 to 10 a.m.) from September 2009 to March 2010, during 12 campaigns. Four sampling stations were chosen for this study following their accessibility and position with respect to the dam. They were: stations Mefou 1 (S 1), Mefou 2 (S 2), and Mefou 3 (S 3).

The station Mefou 1 (03°54'23'' N and 11°23'41.4'' E) is located at about 4.5 km from the source with an altitude of 764 m. The water speed is 2.2 m/s for a water flows rate of 2.5 m$^3$/s. The minor bed is 3.6 m width and the substrate is constituted of organic mud essentially derived from dead leafs. Anthropic action is limited to local forest exploitation.

The station Mefou 2 (3°54'23''N and 11° 24'18''E ), is found in the midstream above the dam and located at about 4 km from the source with an altitude of 754 m. The water bed is muddy and 4.2 m width with a speed and water flow rate of 3 m/s and 2.7 m$^3$/s respectively. Some local farms are under exploitation along this station.

The station Mefou 3 (3° 52' 21,3''N and 11°26'13,8''E) is located at the downstream at 1.5 km below the dam, and at about 9.5 km from station 2 with an altitude of 711 m. The water bed measures 6.6 m width and is constituted of organic mud. The water speed is 4.2 m/s for a flow rate of 3.2 m$^3$/s. Laundry activities are done around this station.

**Physicochemical parameters**

Physicochemical parameters of water were measured at different sampling points according to Rodier (1996) and APHA (1998). Temperature (°C), pH (CU), conductivity (µS/cm) and dissolved oxygen (% saturation) were measured in situ. In the laboratory, phosphates, nitrites, nitrates and ammonium values were determined by colorimetry using HACH DR/2800 spectrophotometer while HACH DR/2000 spectrophotometer was used for suspended solids, turbidity and colour and the results expressed in mg/L. Oxydability was measured by volumetry while CO$_2$ previously fixed in situ was titrated in the laboratory and the results expressed in mg/L.

**Sampling of benthic macroinvertebrates**

Macroinvertebrates were collected using a 30 x 30 cm kick-net with a 250 µm mesh size. Care was taking to include all possible habitats over representative sections of the stream (10 m samples), according to multi-habitat sampling procedure proposed by Barbour et al. (1999). In the laboratory, the organisms were washed with water, handpicked from samples and preserved in 70% alcohol for subsequent counting and identification up to the family level using a stereoscopic microscope Wild M 5. The identification keys of Durand and Levêque (1991), Tachet et al. (2006) and Moisan (2006, 2010) were used.

**Statistical treatment**

The parametric and non parametric analysis of variance tests (One way ANOVA and Kruskal-Wallis) were used to compare physical and chemical parameters values between stations. The Spearman correlation coefficient was used to determine the link between different variables. The level of statistical significance was maintained at 95 % ($P < 0.05$).

Biological variables were analysed using diversity index of Shannon and Weaver and equitability index of Piérou. The Correspondence Canonic analysis (CCA) was used to show the affinities between physicochemical and biological variables. The R logistic was used in all cases.
Results and discussion

Physicochemical results

Temperature values varied significantly (P < 0.05) from upstream to downstream with values reaching 27°C at station 3 below the dam. A slight variation of turbidity and colour was observed at the different stations during the study period with high values recorded at the upstream (Table 1). The pH was stable along the stream with a mean value of 6.6 ± 0.3 UC. The mean values of conductivity varied less from one station to another while suspended solids were more important at station 2 (6±3.4 mg/l). Low values of dissolved CO₂ and organic matter were observed during all the study period with the exception of station 3, where high values were recorded (8 ± 3,8 mg/l and 10,1 ± 7,2 mg/l respectively). Dissolved oxygen values were significantly higher (P < 0.05) at the upstream compared to downstream (74.1 ± 0.6 % and 80.9 ± 0.8 % respectively at stations 1 and 2; Table 2). Nitrates, nitrites, ammonium and phosphates values remained low during the study period, varying less from one station to another.

Table 1. Physicochemical variables recorded in the Mefou stream during the study period.

<table>
<thead>
<tr>
<th>Stations</th>
<th>Temperature (°C)</th>
<th>Turbidity (NTU)</th>
<th>Colour (Pt-Co)</th>
<th>pH (UC)</th>
<th>Conductivity (µS/cm)</th>
<th>CO₂ (mg/l)</th>
<th>DO (%)</th>
<th>Oxydability (mg/l)</th>
<th>NO₂⁻ (mg/l)</th>
<th>NO₃⁻ (mg/l)</th>
<th>NH₄⁺ (mg/l)</th>
<th>Phosphates Suspended solids (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>21.6±1.3</td>
<td>12±4</td>
<td>60.3 ± 22.3</td>
<td>6.5±0.5</td>
<td>32.8±5.7</td>
<td>74.1±4.6</td>
<td>6.5±5</td>
<td>8±5</td>
<td>0.3±0.2</td>
<td>0.3±0.2</td>
<td>0.3±0.2</td>
<td>5.2±2.6</td>
</tr>
<tr>
<td>S2</td>
<td>22.4±1.4</td>
<td>14.1±5.7</td>
<td>77.2±3.8</td>
<td>6.9±0.1</td>
<td>31.7±5.3</td>
<td>80.9±3.8</td>
<td>7.3±3.8</td>
<td>12±17</td>
<td>0.2±0.3</td>
<td>0.3±0.2</td>
<td>0.3±0.2</td>
<td>6±3.8</td>
</tr>
<tr>
<td>S3</td>
<td>25.6±1.3</td>
<td>14.4±2.8</td>
<td>81.4±19.2</td>
<td>6.6±0.2</td>
<td>34.7±7.8</td>
<td>8±3.8</td>
<td>47±0.7</td>
<td>10.1±7</td>
<td>8±11</td>
<td>0.3±0.2</td>
<td>0.3±0.2</td>
<td>4.9±2.4</td>
</tr>
</tbody>
</table>

Table 2. Variation of the abundance of some groups of benthic macroinvertebrates in the Mefou stream during the study period.

<table>
<thead>
<tr>
<th>Stations</th>
<th>Odonates</th>
<th>Haplotaxidae</th>
<th>Chironomidae</th>
<th>EPT</th>
<th>EPT/Chironomidae density ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>68</td>
<td>0</td>
<td>3</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>S₂</td>
<td>126</td>
<td>0</td>
<td>6</td>
<td>17</td>
<td>2.8</td>
</tr>
<tr>
<td>S₃</td>
<td>563</td>
<td>48</td>
<td>77</td>
<td>7</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>252.33 ± 270.6</td>
<td>16 ± 27.7</td>
<td>29 ± 42</td>
<td>13 ± 5.3</td>
<td>2.6 ± 2.4</td>
</tr>
</tbody>
</table>

Relative abundance of benthic macroinvertebrates

During this study, a total of 12 campaigns were realised for 1801 organisms collected. The number of macroinvertebrates collected during the study period was 21 % and 19% at stations 1 and 2 respectively, with a pronounced increase at station 3 (60 %) for a mean value of 600 ± 383 organisms. Most of these organisms belonged to the phyla of Arthropoda (98 %) while the phyla Mollusca, Annelida and Nemathelmintha represented 2 %. These organisms were distributed under 6 classes, 13 orders and 47 families. The class of insecta dominated (75.0 %) with 8 orders and 35 families, followed by the class of oligochaeta (11.0 %) with 1 order and 5 families. The class of crustacean (7 %) counted 1 order and 3 families. The remaining 3 classes (Gastropoda, Bivalva and Gordiaca) represented 7.0 % of the total relative abundance. Of the 13 orders identified, 10 (Odonata: 39%; Hemiptera: 25 %; Coleoptera: 11%; Ephemeroptera: 6.0 %; Diptera: 5.0 %; Decapoda: 5.0 %; Trichoptera: 4.0 % and Blattoptera: 3.0 %) were present in all stations through out the study period. The remaining 5 orders (Plecoptera, Haplotaxida, Basomatophora, Gordioida and Unionida) appeared sporadically, representing 2.0 % of the total abundance (Fig. 2). The relative abundance of Odonata correlated highly with the values of the water flow rates of each station (r = 0.94; P < 0.01).
The evolution of taxonomic richness and abundance was similar along the stream. The taxonomic richness increased from the upstream (33 and 35 families at stations 1 and 2 respectively) to the downstream (39 families at station 3) of the dam. The taxonomic abundance increased from 383 and 375 individuals (station 1 and 2 respectively) to 1043 individuals (station 3) (Fig. 3).

Among all benthic macroinvertebrates sampled, odonates predominated (54% at station 3) with their values being relatively low at stations 1 (17.75%) and station 2 (33.60%) situated before the dam. This was followed by Chironomidae and Haplotaxidae families which developed preferentially at the downstream (station 3) despite their low values of relative abundance (7.38% and 4.60% respectively). The Ephemeroptera, Plecoptera and Trichoptera group (EPT) were more abundant at the upstream with a relative abundance of 3.91% (station 1) and 4.53% (station 2) compared to station 3 (0.67%). Similar observation was noted for EPT/Chironomidae density ratio with high values at station 1 (5) and station 2 (2.8) compared to station 3 (0.1) situated at the downstream of the dam (Table 2). This ratio varied significantly between the different stations of the stream (P < 0.05).

The Shannon and Weaver index ($H'$) were high at stations 1 (4.1 bits/ind.) and station 2 (4.6 bits/ind.) compared to station 3 below the dam (3.6 bits/ind.). The Pielou equitability index ($J$) followed the same variation trend with 0.8 and 0.9 bits above the dam at stations S1 and S2 respectively, and a relative low value obtained at station S3 (0.7 bits) (Fig. 4).
The results of Canonic Correspondence analysis (CCA) showed that some physicochemical variables determine the distribution of benthic macroinvertebrates. On the first axis of correspondence, oxygen, temperature and colour influenced the distribution of Atyidae, Gordiidae, Calopterygidae and Dytiscidae at stations 1 and 2. Also, the Spearman correlation confirmed the link between the abundance of Atyidae and the rate of dissolved oxygen at the upstream of the dam (Station S1: \( r = 0.04; \ P < 0.05 \)). At the second axis of correspondence, Gomphidae and Tubificidae showed at station 3 affinity with phosphates, nitrates and suspended solids, which are mineral and organic pollution indicators (Fig. 5).

**Discussion**

The significant variation of temperature between the upstream and downstream of the dam with relatively high values at station 3 observed during the study period could imply that the dam influences directly the water quality at the downstream. Souchon & Nicolas (2011) showed that the temperature of water liberated by the dam is always high, if the water volume is important with much surface being exposed to solar rays. The increase of temperature at the downstream could also be due to light thickness of water that could favour the penetration of solar rays that lead to the heating of water. The flow rate increase due to the important quantity of water liberated by the dam \((50\text{m}^3/\text{s})\) could explain the high values of turbidity and colour of water at station 3 situated below the dam. The pH values which were almost acidic are similar to that obtained in the Abiergue and Ake streams of the same ecological region (Foto Menbohan et al., 2006). These values reflect the acid nature of the soil of Yaounde (Temgoua et al., 2003).

The significant high values of dissolved oxygen recorded at stations 1 and 2 indicates high oxygenation of water at the upstream of the dam, indicating that the downstream is semi-anthropized. Thus, Foto Menbohan et al. (2010) identified referential stations in a similar study carried out in Nga stream, a periurban stream in Yaounde which is found in the Mefou river basin. Also, low concentrations of nitrogen constituents and phosphates are lower to those obtained by Diomande et al. (2009) in a non polluted river in Ivory Coast, confirming the less anthropized status of the Mefou stream.

The predominance of arthropods in the Mefou stream (98%) is similar to the observations of Foto Menbohan et al. (2010) in the Nga stream. However, the taxonomic richness is more important than that obtained by these authors in an anthropized stream of Yaounde town (Foto Menbohan et al., 2011). More also, the relatively low values of taxonomic richness obtained at the upstream of the dam (33 families at station 1) could be attributed to a deficit of organic debris essentially made of dead leaves in this zone.

The taxonomic richness and abundance increase at the downstream of the dam could be a result of secondary tributaries inputs constituted of much organic debris, which lead to an increase of food resources of some benthic organisms (Pelletier, 2002). The increase of flow rate at the downstream could also lead to an increase of derived benthic organisms (Pelletier, 2002). The unique apparition of Haplotaxidae at the upstream (station S1) may indicate the pollution-tolerant potentialities of this organisms. The high EPT index at the upstream of the dam may reflect the non polluted quality of water in these sections (Pelletier, 2002). Our observations are contrary to that of Gup (1994) who declared a decrease of this index at the upstream of dams. High water flow rates generated by water fall of the dam could favour positively the high abundance of odonates observed at the downstream (station 3) of the dam (Poff & Allan, 1995). Also, high abundance of Chironomidae observed at the downstream of the dam (77 organisms) compared to upstream (3 and 4 organisms at stations S1 and S2 respectively) may probably be due to an increase of periphyton biomass in this station, on which they feed according to their filter-collector food regime (Voelz & Ward, 1991).
Studies conducted in a periurban stream by Foto Menbohan et al. (2010) showed an increase of diversity index from upstream to downstream reflecting normal functioning of less anthropised lotic ecosystem, being in line with the Vannote et al. (1980) theory of Continuum Fluvial concept. However, the relative decrease of biological diversity at the downstream of the dam may reflect the modification of the biocenose structure due to the dam. These results are similar to those obtained on ciliates community in Gidra stream (Tirjakova, 2003). According to Ward & Stanford (1983), hydraulic structures often interrupt longitudinal distribution of organisms that could lead to diversity decrease at the downstream of the dam. Also, Poff and Zimmerman (2010) showed that macroinvertebrates response to multiple pertubated hydrological regime, with their abundance or diversity either increasing or decreasing. Previous studies have equally showed the catastrophic effect of dams construction on fundamental ecological process such as, suppression of some macroinvertebrates habitats and homogenisation of biocenoses (Ramade, 2005; Decamps, 2011).

The affinity of Atyidae with dissolved oxygen (r = 0.4; P < 0.05) as earlier revealed by Pelletier (2002), is in line with the results obtained by Foto Menbohan et al. (2010) in the Nga stream, who declared that these organisms could be excellent bioindicators of good water quality. The second axis of CCA correspondence showed that physicochemical variables (phosphates, nitrates, ammonium, conductivity, turbidity and suspended solids) which are organic and mineral indicators of pollution, influence the distribution of Gomphidae and Tubificidae at the downstream of the dam (station 3). The abundance of odonates, especially Gomphidae (rheophil organisms) at the downstream could reflect the relatively high water temperature at this section of the dam (Souchon & Nicolas, 2011; Foto Menbohan et al., 2011). The association of Tubificidae with indicators organisms of pollution at station 3, could be a sign of a start of the river basin anthropisation at the downstream of the dam. Tachet et al. (2006) classified Tubificidae as saproihal and polluo-tolerant organisms, colonising high rates organic of matter waters (Durand et Lévêque, 1980).

Conclusion
This work has permitted to study the diversity of benthic macroinvertebrates of a periurban stream (Mefou) in Cameroon, characterised by 47 families belonging to 13 orders, 6 classes for a total of 1801 organisms collected. The spatial variation of physicochemical variables showed low acidity and mineralization with high oxygenation of water, indicating that less anthropic action is executed in the Mefou hydrographic basin. The taxonomic richness coupled to the taxonomic diversity index revealed favourable medium conditions for the coexistence of many macroinvertebrates taxa. However, the discontinuity observed at station 3 may probably be due to the impact of the dam on the longitudinal distribution of macroinvertebrates by instability of flow rate caused by it. Water turbulence caused by the dam could also favour the multiplication of rheophil odonates at the downstream of the dam.

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