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Original Research Paper

Spatial-temporal dynamics of population structure for macro invertebrates families in a continuum dam - effluent - river in irrigated system. Volta Basin (Burkina Faso)

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A monthly sampling of benthic macro invertebrates was carried out at the hydro-agricultural dam of Boura in the Volta watershed basin (Burkina) during the period of February through July 2012 in order to describe the structuring of insect succession along with changes occurring in habitats of this irrigated dam farming system. The samples of insects were collected from 6 stations located inside the littoral (Station I), the sublittoral (Station II), the sewage channel or effluent (Stations III, IV, V) and the Mouhoun River (Station VI). The sampling method employed is a conventional method by the European Union named " Directive Cadre sur l'Eau (DCE) " recommended for the survey of benthic macro invertebrates. The survey reveals a community composed majorly of insects (more than 75%) variously distributed. On one hand at the shoreline and the coastal- adjoining zone in the dam, 23 families of macro invertebrates were identified; mostly belonging to the shoreline except for 10 families identified as endemic to the adjoining zone of the coastline. These two zones of the dam shelter the same malacological fauna consisting of the Unionidae, Lymneidae, Ampullariidae, Planorbidae, Valvatidae and Bulinidae families. The survey reveals otherwise that the differences between the Shannon biological diversity indices for these two zones were more pronounced during the month of July, the rainy period in the basin. On the other hand, concerning the dam-effluent-river continuum, a total of 35 families are sampled: 27 from dam water and stations near the irrigated zones; and 32 from the station of the sewage channel far from the irrigated zone and the river. The identification of individuals belonging to the family of the Baetidae and the Ephemerellidae (order of Ephemeroptera) in the river water highlights a subsequent reconstruction of the biodiversity in the river as the presence of both families is an indicator of fertile water. Further analysis on the spatial and temporal distribution involved 17 families out of the 35 sampled not common to all habitats. This lead to the conclusion that changes in natural habitats dictate the clustering patterns of macro invertebrates populations during the year long.

Key words: Macro invertebrates, succession, continuum, irrigation, dams, effluent, river, Volta basin, Burkina Faso

INTRODUCTION

In Sub-Saharan Africa, the construction of dams for hydro agricultural purpose on the river beds has resulted in habitat fragmentation and ecological changes in natural environments. This is the case in Burkina Faso where

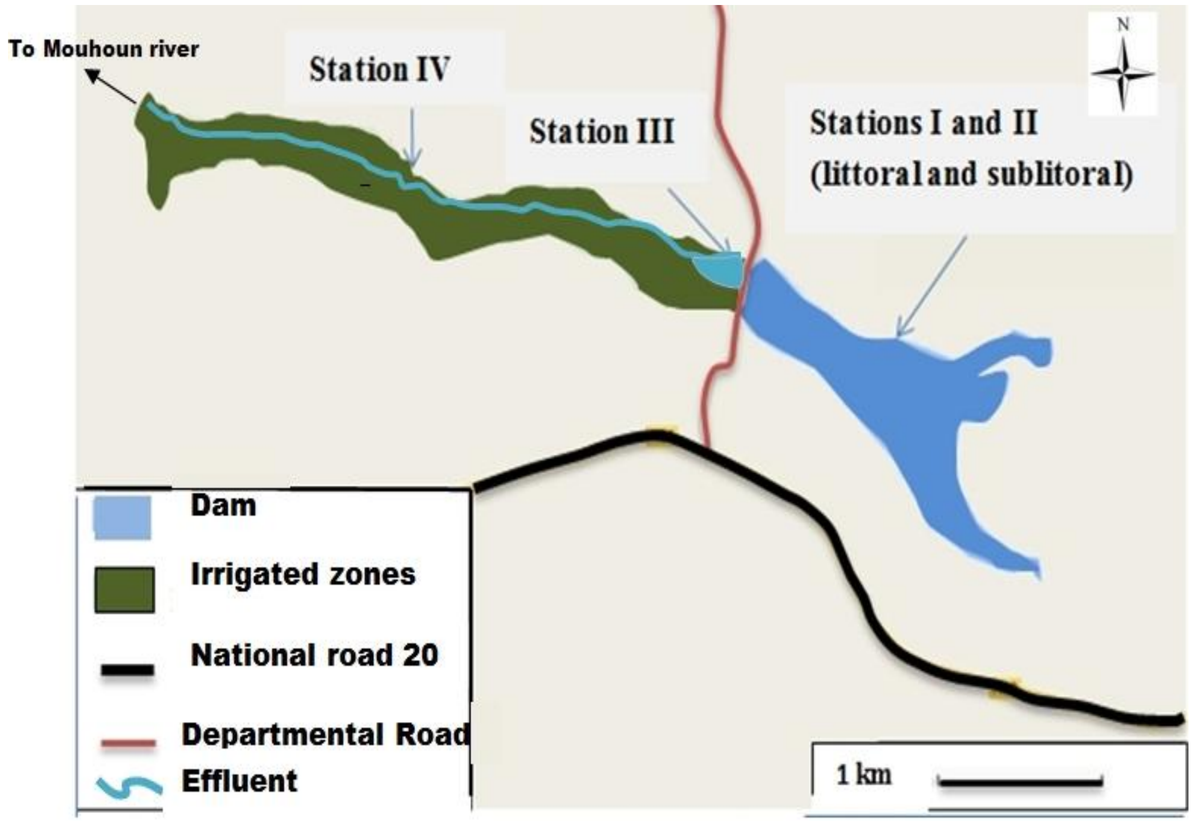

Figure 1: Location of the different sampling stations in the continuum

nearly 1,700 dams and reservoirs were built (Cecchi et al., 2009). These ecosystem changes are steady realities that brought Venot and Cecchi (2011) to consider them as “socio- ecosystems”. Leigh et al. (2010) and Sass et al. (2010) indicate that agricultural intensification is a major cause of degradation of aquatic ecosystems in Sub-Saharan Africa. The evaluation of the impact of various anthropogenic pressures on natural resources is now been focused on in the analysis of changes in structure of organisms constituting biodiversity thus the differential sensitivity of macro invertebrates polluo - defined by Marzin et al. (2012) remains the tool of choice in evaluating the biological quality of such ecosystems.

Previous works on the assessment of the quality of water bodies and benthic macro invertebrates in Burkina Faso include those of Dejoux (1977) at the Bam Lake, Guenda (1996) at the Mouhoun River and Kabré et al. (2002) at the Comoé Reservoir. However, the relative dependence between the sampling of macro invertebrate taxa in agricultural habitats and their spatial-temporal structuring was not clarified by these studies. The present study in the hydro- agricultural dam of Boura in the Volta Basin is therefore aimed to pinpoint the interdependence between the distribution of benthic macro invertebrates and changes occurring in the continuum dam - effluent – river system.

METHODOLOGY

Characteristics of the sampling area

The Volta Basin is the largest watershed in Burkina Faso lying in the Central and Western parts of the country covering an area of 178,000 km^2. It consists of three sub-basins among which belongs the sub-basin Mouhoun with a main river the Mouhoun River. Our study area started in Boura hydro agricultural Dam (11° 02’N, 2° 30’W) built on a tributary of the Mouhoun River (Figure 1). This dam water was built to support the activities of populations in 22 villages with about 40,000 inhabitants. Indeed, historically the dam was settled-in in 1950 by the villagers and was rebuilt in 1983 by the National Office of Dams and Irrigation (ONBI) with a maximum capacity of 4.2 million m^3. This water body has been used to supply an integrated irrigation (rice and corn) system of 62 ha to yield and to produce a cash crop seasonally from 30 ha (vegetables and corn) located upstream of the weir. Excess water from the dam overflows downstream in the effluent that primarily drains into the Mouhoun River and secondly collects the sewage-water from the irrigated system, thus we call it sewage channel. Aquatic plants mainly present in the dam or reservoir and the effluent are *Azzola*, *Ceratophyllum*, the lilies, and grasses of the genus *Oryza*.

Collection of macro invertebrates

A monthly sampling was conducted from February to July 2012 at the dam and the effluent from irrigated areas downstream of the dam. The stations of investigation are as follows (Figure 1):

- Station I: shores (or littoral) of lake dam (less than a meter from the shoreline);
- Station II: near shore (or sublittoral) Lake Dam (more than a meter from the shoreline)
- Station III: beginning of the effluent to 50 m downstream of the spillway of the dam;
- Station IV: the full effluent section crossing the irrigation area, 2 km downstream of the weir;
- Station V: the effluent far away section, at 14 km downstream of the weir (intermediate zone between the irrigated plain and the Mouhoun River);
- Station VI: Mouhoun River 36 km away from the dam weir.

The collection period of aquatic macro invertebrates at different stations is marked by a steady drawdown of the water' width as a result of an intensification of irrigation in the dry season (November to May). Effectively the farming complex of various cultures downstream of the reservoir is irrigated by valves that drain water through a piping system. We considered the significance of the vegetation cover at the sampling sites and took 12 benthic samples as recommended by the European Framework Directive on Water (AFNOR, 2009); the 12 samples were distributed within the clear and weedy water areas. Aquatic insect species on surfaces were also captured. At each station, macro invertebrates were collected using a Surber net type with a mesh size of 25 cm in diameter and a kick net, 30 cm diameter in mesh size.

The Surber that was used to collect benthic species is based on a dragged length of 1 m and the scanning surface corresponds to 3 m^2 per sampling. After capture, the macro invertebrate species were sorted and stored in alcohol at 90°C temperature. The rest of the benthos containing macro invertebrates not visible to the bare eye were preserved in jars with alcohol at 90°C for further sorting in the laboratory.

The kick net was used to collect species restricted to the root hairs of macrophytes: for 30 seconds, the thread is passed under the plants. The content of the compound included fillet parts of plants and sludge with macro invertebrates which were rinsed with water. The macro invertebrates were removed and stored in 90°C alcohol while the remainder was kept in jars with alcohol at the same temperature for further sorting in the laboratory. This net was also used to capture surface insect species.

Identification of macro invertebrates

The insects were identified by using the identification keys of Levêque and Durand (1981), Merritt and Cummins (1984) and Tachet et al. (2000). The molluscs were identified using the key of Moisan (2010) and the publication of Brown (1980). Annelids were identified with the key provided by Lafont (1983). Taxonomic level reached in our study is the family. Indeed it provides a global level taxonomic discrimination sites in studies for bioindication type (AFNOR , 2004 AFNOR , 2009; Moisan and Pelletier, 2008).

Statistical analyses

The Shannon index of biodiversity (Shannon and Weaver, 1949) is given by the formula;

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

$p_i = Ni / N$

where Ni: number of individuals of a given i from 1 to S (total number of taxa) taxon; N: total number of individuals; H' is minimal (= 0) if all individuals in the population belonging to a single taxon. H' is also minimal if, in a stand each species is represented by a single individual, except a taxon that is represented by all other individuals stand. The maximum index is 5 when all individuals are distributed in an equitable manner to all taxa.

Generally this index is calculated by considering the species as a taxonomic level. Moisan and Pelletier (2008), believes that the structure of benthic macro invertebrate communities of course, gathering the metric variables and indices such as the Shannon diversity index, can be defined using the families as the taxonomic level. This taxonomic level has indeed allowed Zouggaghe and Moali (2009) to show that polluted areas have low indices relative to unpolluted areas in Algerian waters. With reference to the work of these authors, we have chosen the family as a taxonomic level for the calculation of the index of diversity.

In terms of statistical analysis the PAST software (Hammer et al., 2001) was used to perform a clustering of hierarchical classification. The Euclidean distance is used as the distance of assemblage and the Shannon diversity indices were calculated using the PAST software. The Fisher least significant difference of $\alpha = 0.05$ (LSDF) was used to compare the diversity indices on one hand within the same station and between stations on the other hand. The difference is significant when LSDF is less than the absolute value of the difference between two means.

The similarity analysis between the stations was performed by calculating the similarity coefficient (Cs) according to Sørensen (1948) thus:

$$Cs = \frac{2C}{a + b} * 100$$

where Cs: Sorensen similarity coefficient; a: number of taxon in medium A; b: number of taxa in medium B; c: number of taxon common to A and B

The referred values for Cs are:

85% similarity indicates no disturbance (similar)

70 to 84% similarity indicates light disturbance (almost similar)

50 to 69% similarity indicates moderate disturbance (moderately similar)

50% similarity indicates acute disturbance (totally or acute difference)

RESULTS

Discrimination of macro invertebrates sampling stations

The survey resulted in the harvest of 27,177 individuals, 8644 individuals at the shores of the dam and 1272 at the sublittoral, respectively at Stations I and II (Table 1). In the downstream of the dam weir in the effluent of the Mouhoun River (Table 2a), 5618 specimens were collected at Station III, 5572 at Station IV, 3051 at Station V and 3020 individuals at Station VI (Table 2b). These macro invertebrates consist of insects, crustaceans, worms and molluscs grouped into 35 families, including one family each of Amphipod and Cladocera; both of which are unidentified crustaceans due to their small size and fragility during conservation. Stations I, II, III and IV with 27 families are theoretically considered to be impacted by agricultural activities and Stations V and VI which are far from the irrigated areas consists of 32 families. Insects are the most dominant with 89.23% at the shore areas (Station I) and 65.64% at the sublittoral (Station II), 85.81, 86.49 and 75.22%, respectively at stations III, IV and V in the effluent; and finally 89.11% at the river station VI.

The hierarchical classification of stations based on the similarity of macro invertebrate families (Figure 2) is used to group the sampling stations thus:

Group 1: the shore area resort of Lake dam (station I)

Group 2: stations in irrigated areas (stations II and III)

Group 3: stations after the irrigated areas (stations IV and V)

Group 4: sublittoral Lake Dam (station VI)

Structural variability of macro invertebrate

Inside the reservoir

Among the families present at the sublittoral, 13 are aquatic insects (Hydrophilidae, Dytiscidae, Noteridae, Belostomatidae, Nepidae, Chironomidae), worms (Hirudinea) and molluscs (Bulinidae, Unionidae, Lymneidae Ampullariidae, Planorbidae and Valvatidae). These 13 families listed have also been identified from the samples taken from the shore area which already yielded 10 endemic aquatic insect families (Carabidae, Notonectidae, Naucoridae, Gerridae, Herbridae, Hydrometridae, Gomphidae, Libellulidae, Coenogrionidae and Syrphidae). The fact is that all the molluscs families colonized the shore area and the sublittoral as well. Table 3 gives a comparison between the Shannon indices from the littoral and sublittoral areas. Furthermore, the Sørensen similarity index (Table 4)) is 72.22 % which indicates a difference between Stations I and II in terms of their diversity. Indeed these differences are highlighted by Fisher's test (LSDF) with α = 5 % (Table 3). The use of this value (LSDF 0.05) reveals a difference between the months of July and other months at the shore areas and a difference between the months of March and other months at the sublittoral area. Comparing the straight linear regression indices by month for the two stations (Figure 3) during the period from February to July, it depicts an increase in the index values at the shore areas (Station I) whereas a decreased state is observed at the sublittoral zone (Station II).

Along the continuum reservoir - effluent – river

Overall 35 macro invertebrate families were sampled through the continuum (Tables 1 and 2); among these families 18 are depicted as common to the reservoir-effluent-river, the parts of the continuum in other words. Families belonging to different orders are: Coleoptera (Hydrophilidae, Dytiscidae, Noteridae), Heteroptera (Belostomatidae, Nepidae, Gerridae, Herbridae, Hydrometridae), Odonata (Gomphidae, Libellulidae, Coenagrionidae), Diptera (Chironomidae), the worms (Hirudinea) the molluscs (Unionidae, Lymneidae, Ampullariidae, Planorbidae, Valvatidae).

Sørensen index values calculated for the similarity of the different stations are roughly over 80% (Table 4); while Table 5a show part of the differences between the Shannon index of diversity monthly values at each station and other differences between the monthly values for the stations for a chosen month. In addition, a comparison between the mean values of the three ecological zones of the continuum (dam, river and effluent) indicates a significant difference between the dam and the other two (river and effluent) during the period of February, April and May (Table 5b). At the dam (station I and II) and the effluent (station III and IV, theoretically impacted areas) Shannon diversity indices in July differ from those of other months.

This survey also yielded 17 families not common to the various stations (along with the 18 families that are common) and this helps to magnify the contrast or the discrimination between ecological zones of the continuum. Therefore we have chosen to demonstrate the spatial distribution pattern of this particular population (Figure 4). On the transect from the reservoir (Stations I and II), and at the first two stations of the effluent (stations III and IV)

Table 1.Number of individuals per family of macroinvertebrates sampled at two observation stations in the Boura dam waters during the period of February through July 2012.

Macroinvertebrates	Station I (littoral of the dam)						Station II (sublittoral of the dam)					
	Feb	Mar	Apr	May	Jun	Jul	Feb	Mar	Apr	May	Jun	Jul
Coleoptera												
Hydrophilidae	986	418	845	704	356	0	0	17	47	88	8	0
Dytiscidae	358	313	263	188	208	59	0	20	0	16	21	0
Gyrinidae	0	0	0	0	0	0	0	0	0	0	0	0
Carabidae	3	11	0	2	0	0	0	0	0	0	0	0
Noteridae	419	687	398	244	104	69	85	90	157	73	46	0
Chrysomelidae	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0
Heteroptera												
Notonectidae	16	25	12	18	22	15	0	0	0	0	0	0
Naucoridae	7	23	0	6	0	9	0	0	0	0	0	0
Belostomatidae	23	27	20	6	9	13	0	8	11	15	7	5
Nepidae	38	17	29	15	31	6	0	6	3	1	3	1
Gerridae	0	23	0	0	13	19	0	0	0	0	0	0
Herbridae	22	0	6	18	21	0	0	0	0	0	0	0
Hydrometridae	12	6	22	3	9	8	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera												
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0
Ephemerellidae	0	0	0	0	0	0	0	0	0	0	0	0
Odonata												
Gomphidae	15	3	17	11	4	10	0	0	0	0	0	0
Libellulidae	13	8	22	10	19	6	0	0	0	0	0	0
Coenagrionidae	10	1	6	2	7	6	0	0	0	0	0	0
Diptera												
Chironomidae	46	112	98	31	26	6	12	49	22	17	7	0
Syrphidae	2	5	13	0	0	0	0	0	0	0	0	0
Crustacera												
Potamidae	0	0	0	0	0	0	0	0	0	0	0	0
Amphipodes	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
Worms												
Hirudinae	3	14	3	4	20	11	4	0	0	0	6	9
Lumbricidae	0	0	0	0	0	0	0	0	0	0	0	0
Naididae	0	0	0	0	0	0	0	0	0	0	0	0
Molluscs												
Bulinidae	114	56	51	29	14	5	29	73	83	18	0	1
Unionidae	4	7	15	3	12	6	0	3	0	10	5	0
Pleuroceridae	0	0	0	0	0	0	0	0	0	0	0	0
Lymneidae	140	84	20	20	3	8	44	52	12	3	0	8
Ampullariidae	10	58	44	8	2	8	27	6	6	0	0	0
Planorbidae	21	41	14	2	11	26	0	22	6	3	0	0
Valvatidae	15	6	11	5	0	3	3	4	0	0	0	0

one can depict a permanent presence of Naucoridae and Bulinidae; these stations are close to agricultural activities and have a total of 27 macro invertebrates families.

Two families of Coleoptera (Chrysomelidae and Elmidae), frequently described at all stations of the effluent and of the river are absent at the reservoir (Figure 4). At Stations III and IV, one can observe an endemic presence of Lumbricidae and Veliidae. The Veliidae is also seen in the river continuum. The Potamidae, Naididae and Pleuroceridae are only found at the intermediate Station V (not exploited by farmers). This intermediate zone and the river are considered as non- impacted stations by agricultural activities; both zones comprise a total of 32 families (Figure 4).

The Gyrinidae family finally begin to appear starting from the last station of the effluent (Station V) to the Mouhoun River (station VI). This River Station VI is characterized by the presence of Baetidae, Ephemerellidae, Amphipoda and

Table 2a. Number of macroinvertebrates per family sampled at different stations located on downstream during the period of February through July 2012 in the Volta basin.

Macroinvertebrates	Station III						Station IV					
	Feb	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**
Coleoptera												
Hydrophilidae	512	311	355	356	511	17	47	469	188	608	600	0
Dytiscidae	274	279	183	120	109	28	320	250	148	221	108	0
Gyrinidae	0	0	0	0	0	0	0	0	8	0	0	13
Carabidae	21	0	0	0	3	0	0	0	16	3	0	0
Noteridae	131	232	109	121	44	18	166	314	130	104	49	18
Chrysomelidae	13	6	41	12	12	0	0	14	25	0	0	0
Elmidae	0	14	2	3	13	0	11	15	12	0	13	24
Heteroptera												
Notonectidae	0	0	0	0	0	0	0	0	0	0	0	0
Naucoridae	3	0	0	8	0	0	2	4	0	10	5	26
Belostomatidae	18	31	11	41	23	25	18	28	13	12	20	34
Nepidae	21	39	10	22	43	3	29	28	36	9	7	10
Gerridae	14	0	23	13	11	7	31	20	6	14	39	22
Herbridae	37	12	41	10	0	0	18	24	2	11	0	0
Hydrometridae	9	0	3	9	2	0	9	2	6	11	0	1
Veliidae	44	7	17	0	11	0	33	7	0	12	0	0
Ephemeroptera												
Baetidae	0	0	0	0	0	0	0	0	0	0	0	0
Ephemerellidae	0	0	0	0	0	0	0	0	0	0	0	0
Odonatera												
Gomphidae	9	6	18	17	1	4	3	5	8	10	9	17
Libellulidae	16	22	6	13	6	23	14	9	22	13	5	11
Coenagrionidae	2	8	13	9	7	10	9	11	3	5	2	1
Diptera												
Chironomidae	41	18	77	10	36	0	58	20	16	44	9	0
Syrphidae	6	11	8	6	0	0	23	11	11	17	0	0
Crustacera												
Potamidae	0	0	0	0	0	0	0	0	0	0	0	0
Amphipodes	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
Worms												
Hirudinae	8	0	11	9	16	31	16	18	7	12	31	21
Lumbricidae	0	5	14	4	4	0	41	18	22	31	15	8
Naididae	0	0	0	0	0	0	0	0	0	0	0	0
Molluscs												
Bulinidae	55	18	5	52	0	0	16	0	91	26	12	0
Unionidae	40	33	28	30	18	13	23	39	15	13	25	11
Pleuroceridae	0	0	0	0	0	0	0	0	0	0	0	0
Lymneidae	55	34	25	22	12	22	32	14	15	13	0	0
Ampullariidae	11	18	7	2	0	23	10	9	15	11	0	0
Planorbidae	27	11	15	6	0	11	0	14	6	0	3	0
Valvatidae	23	14	20	19	10	16	34	23	13	8	14	8

Cladocera, all absent from other stations. Finally Figure 4 shows that all other stations are distinguished by the presence of Carabidae and Syrphidae while both families are missing in the Mouhoun River Station VI.

DISCUSSION

Aquatic ecosystems in Burkina Faso are subjected to anthropogenic pressures through agricultural activities (GIRE, 2001). Concerning the areas of irrigation, Davis et al., (2011) reported the adverse effects of pesticides on macro invertebrates' communities. At the Boura Dam, our survey on macro invertebrates at different stations located in the effluent midsection crossing the irrigated zone revealed 27 families of macro invertebrates. This result matches the findings of Diomandé et al. (2009) and Foto et al. (2011) who each got 28 families, respectively, in Ivory Coast and Cameroon in the areas impacted by agricultural activities and urban discharges. In contrast, at the level of

Table 2b. Number of macroinvertebrates per family sampled at different stations located on downstream during the period of February through July 2012 in the Volta basin.

Macroinvertebrates	Station V (effluent station)						Station VI (Mouhoun river)					
	Feb	Mar	Apr	May	Jun	Jul	Feb	Mar	Apr	May	Jun	Jul
Coleoptera												
Hydrophilidae	0	165	182	149	0	13	299	0	234	54	13	7
Dytiscidae	0	183	193	224	85	15	232	230	159	127	42	0
Gyrinidae	0	0	4	0	17	0	9	0	7	0	3	0
Carabidae	0	3	0	11	0	0	0	0	0	0	0	0
Noteridae	0	35	25	22	25	0	3	0	23	0	3	0
Chrysomelidae	12	25	7	17	4	0	26	3	15	18	0	0
Elmidae	27	3	9	0	0	3	44	12	15	11	0	18
Heteroptera												
Notonectidae	0	0	33	10	7	0	0	0	0	0	0	0
Naucoridae	0	0	0	0	0	0	0	0	0	0	0	0
Belostomatidae	0	15	21	19	46	21	9	23	19	11	23	41
Nepidae	2	73	32	54	19	6	6	7	15	0	0	0
Gerridae	0	39	7	12	41	37	36	49	61	40	21	32
Herbridae	0	9	26	13	0	0	4	7	2	18	0	0
Hydrometridae	0	7	12	3	0	0	9	1	6	2	0	0
Veliidae	2	0	11	0	5	10	12	1	14	11	41	32
Ephemeroptera												
Baetidae	0	0	0	0	0	0	1	0	3	0	2	0
Ephemerellidae	0	0	0	0	0	0	2	0	1	0	0	4
Odonatera												
Gomphidae	0	15	3	2	14	0	22	19	3	6	7	18
Libellulidae	0	21	17	9	8	4	36	38	16	25	17	23
Coenagrionidae	0	6	11	5	4	2	14	21	24	10	3	11
Diptera												
Chironomidae	0	11	36	15	26	12	65	19	82	21	11	7
Syrphidae	0	8	3	13	0	0	0	0	0	0	0	0
Crustacera												
Potamidae	0	0	9	3	0	5	0	0	0	0	0	0
Amphipodes	0	0	0	0	0	0	0	0	14	0	0	0
Cladocera	0	0	0	0	0	0	7	0	5	0	0	0
Worms												
Hirudinae	0	0	7	3	21	38	0	0	1	6	0	0
Lumbricidae	0	0	0	0	0	0	0	0	0	0	0	0
Naididae	0	17	26	32	11	0	0	0	0	0	0	0
Molluscs												
Bulinidae	0	0	0	0	0	0	0	0	0	0	0	0
Unionidae	35	18	39	15	29	10	54	32	54	27	22	16
Pleuroceridae	63	21	2	107	21	0	0	0	0	0	0	0
Lymneidae	0	25	20	13	0	0	15	5	0	0	0	0
Ampullariidae	0	7	16	11	0	0	6	2	3	0	0	0
Planorbidae	0	21	39	24	0	0	3	13	11	9	0	0
Valvatidae	5	11	12	8	6	6	9	8	7	0	0	0

non- impacted areas (intermediate zone and river) 32 families were described. These results do not tally with that of Foto et al. (2010) who obtained 59 families at the Nga River in Cameroun.

The observed difference between the stations of the reservoir (Figure 2) was confirmed by the regression analyses (Figure 3) thus indicating a stronger colonization of coastal or littoral areas by macro invertebrates than in the sublittoral zone. Yet the sublittoral is often presented as an area housing the sensitive taxa in eubiotics systems (Mazzela et al., 2009); otherwise it is an area where the natural diversity of invertebrates in general is at its highest level (Wiederholm, 1980). Kouamé et al. (2011) reported a concentration of macro invertebrates of a dam rich in aquatic macrophytes in the Lake Taabo in Ivory Coast (overall, 43 taxa of macro invertebrates were identified. Ten of them were exclusively associated with water hyacinth while five were only associated with littoral macrophytes). Along with this report, at the Boura Dam, the use of banks for agricultural activities has led to the

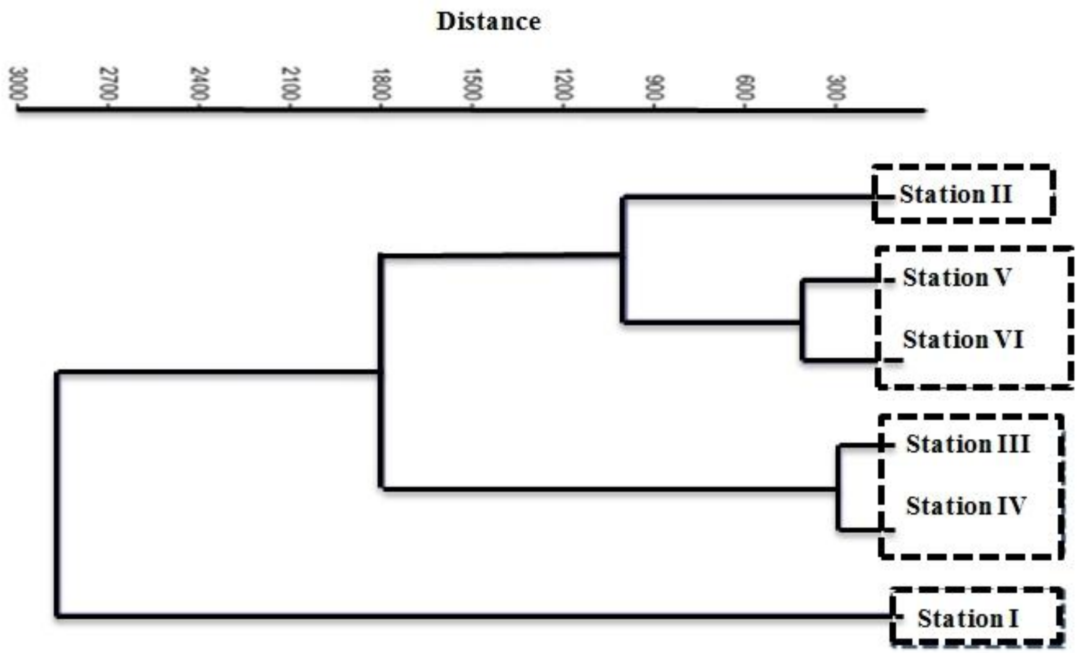

Figure 2: Hierarchical Classification of different stations based on similarity of macroinvertebrates families assemblages

Table 3. Comparison of the monthly change in the Shannon diversity index along a transect from the coast to the nearshore in the dam of Boura; the Least Significant Difference Fisher (LSDF with α = 5 %) was used.

Month	**Littoral (Station I)**	**Sublittoral (Station II)**
February	1.804	1.546
March	1.988	2.037
April	1.792	1.554
May	1.577	1.718
June	1.951	1.664
July	2.501	1.326
Average	1.935	1.640
$LSDF_{0.05}$	0.289	0.289

Table 4. Sørensen Index of similarity between different locations in a continuum from the lake dam to the river

	Dam (stations I and II)	**Irrigated zones(stations III and IV)**	**Effluent station (station V)**	**Mouhoun river (station VI)**
Dam (station I and II)	100%	92%	82.35%	85.71%
Irrigated zones (stations III and IV)	92%	100%	98.18%	81.48%
Effluent station (station V)	82.35%	98.18%	100%	86.79%
Mouhoun river (station VI)	85.71%	81.48%	86.79%	100%

concentration of aquatic plants in the littoral thus justifying the concentration of macro invertebrates at this level.

The regression (Figure 3) lines for monthly indices of Shannon diversity indicate that the end of the dry season depicts an increasing number in diversity of macro invertebrate families at the coast while it decreases at the sublittoral level. The least significant difference of Fisher springs a difference between the diversity indices of the two stations in July, which corresponds to the full rainy season at the Volta Basin. Despite this dissimilarity, we found that the littoral and sublittoral both had the same mollusc populations. Indeed, in his study of the distribution

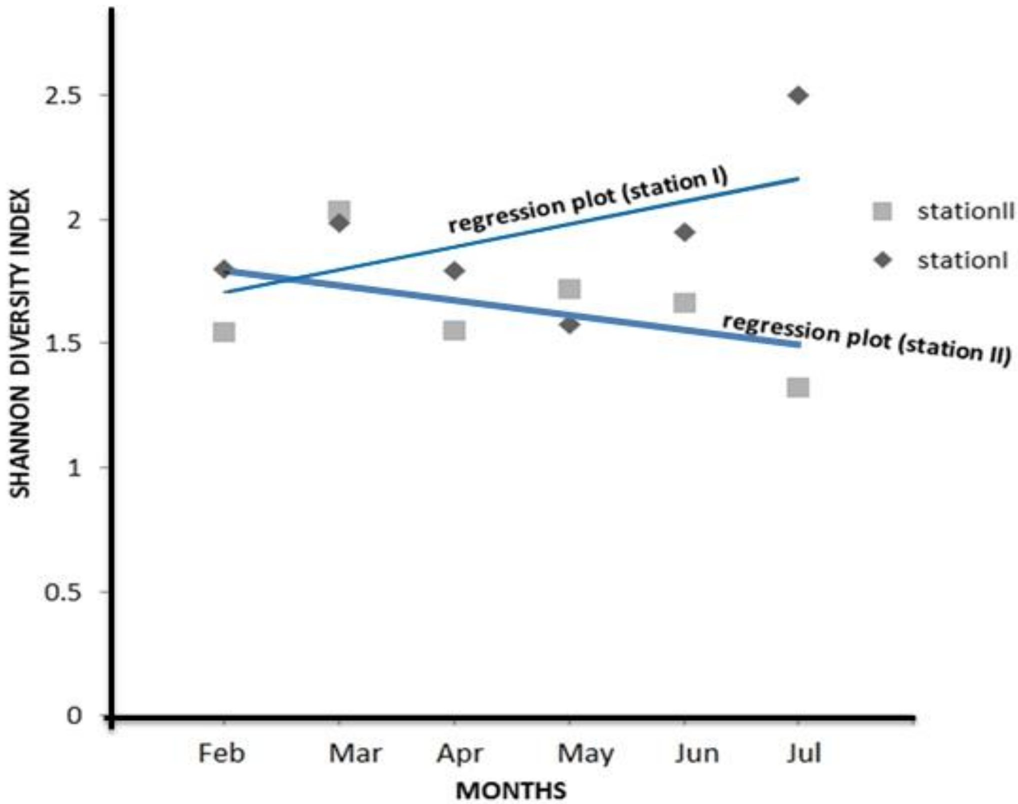

Figure 3: Comparison of linear regression diversity indices of Shannon obtained at coastal and nearshore in the dam Boura February to July 2012.

	Station I and II (Dam)	Station III (Irrigated zones)	Station IV (Irrigated zones)	Station V (Effluent station)	Station VI (Mouhoun river)
Gyrinidae			1	1	1
Carabidae	1	1	1	1	
Chrysomelidae		1	1	1	1
Elmidae		1	1	1	1
Notonectidae	1			1	
Naucoridae	1	1	1		
Veliidae		1	1		1
Baetidae					1
Ephemerellidae					1
Syrphidae	1	1	1	1	
Potamidae				1	
Amphipod					1
Cladocera					1
Lumbricidae		1	1		
Naididae				1	
Bulinidae	1	1	1		
Pleuroceridae				1	

1 : Present

Figure 4: Spatial distribution macroinvertebrates non-common to all habitat and sampled in 6 stations located on the continuum dam-effluent-river in the Volta basin, Burkina Faso.

Table 5a. Comparison of the monthly change in the Shannon diversity index along the continuum reservoir - effluent - river; the comparison uses the Least Significant Difference Fisher (LSDF with α = 0.05).

	Dam (station I and II)	Irrigated zone (station III and IV)	Effluent station (station V)	Mouhoun river (station VI)
February	1.9	2.438	1.456	2.204
March	2.092	2.117	2.479	1.994
April	1.876	2.484	2.602	2.347
May	1.648	2.072	2.426	2.293
June	1.989	1.679	2.559	2.231
July	2.551	2.830	2.317	2.14
Mean value	2.009	2.270	2.306	2.201
$LSDF_{0.05}$	0.340	0.340	0.340	0.340

Table 5b. Summary of differences between the monthly index values of Shannon diversity between stations (station I to VI, Table 5) observation along the continuum reservoir - effluent – river. (NB: bold absolute values are greater than $LSDF_{0.05}$).

Month		Dam	Irrigated zone	Effluent stations	River
July	Dam	0			
	Irrigated zone	0.279	0		
	Effluent station	-0.234	**-0.513**	0	
	River	**-0.411**	**-0.69**	-0.177	0
June	Dam	0			
	Irrigated zone	-0.31	0		
	Effluent station	**0.57**	**0.88**	0	
	River	0.242	**0.552**	-0.328	0
May	Dam	0			
	Irrigated zone	**0.424**	0		
	Effluent station	**0.778**	**0.354**	0	
	River	**0.645**	0.221	-0.133	0
April	Dam	0			
	Irrigated zone	**0.608**	0		
	Effluent station	**0.726**	0.118	0	
	River	**0.471**	-0.137	-0.255	0
March	Dam	0			
	Irrigated zone	0.025	0		
	Effluent station	**0.387**	**0.362**	0	
	River	-0.098	-0.123	**-0.485**	0
February	Dam	0			
	Irrigated zone	**0.538**	0		
	Effluent station	**-0.444**	**-0.982**	0	
	River	**0.304**	-0.234	**0.748**	0

of mollusks Mouthon (1993) reported that molluscs had the ability to colonize both littoral and sublittoral zones in a lake. A proliferation of Bulinidae was observed at the Boura dam during this study; a proliferation that was confirmed earlier by Poda et al. (2006) in small dams in Burkina.

Concerning the continuum reservoir - effluent – river system, we observed that 18 of the 35 families of macro invertebrates were common to all stations while 17 other species were not common to all ecosystems/habitats. Figure 2 summarizes this continuum. These results indicate that changes in the habitat determine the structure of macro invertebrate communities. Significant differences were observed when the differences between the monthly indices were compared; especially the differences between the index level of the reservoir and the other stations (Table 5b) during the months of February April and May. Indeed, at this habitat (dam), we found that the average monthly diversity index is at its lowest in the continuum during these months. In addition, the observed difference between the cropping areas (impacted area) and non-impacted zone during the month of July (month of heavy rainfall) indicates a significant increase of diversity in these riverine areas that are not impacted during the rainy seasons. Along with our findings, Foto *et al*. (2010) had also found an abundance of taxa in streams during these seasons. Indeed at the effluent, the Sørensen similarity index of 98.18% (Table 4) between the stations at the irrigated and the intermediate zones indicate that these stations on the effluent are very similar in terms of aquatic macro invertebrates. These stations share, in addition to the 18 families, five other families represented in Figure 4. The observed clustering between the intermediate stations and the station at the river level confirms the resilience capacity of this river system for a possible recovery (i.e. recolonization of biodiversity) during the watercourse. Indeed, our statement of possible recovery is supported on one hand by Cissé (1997) who noticed a decrease in the concentration of chemical products in a river as one moves away from the farming zones; and on the other hand the identification in the samples taken from the river of individual macroinvertebrate families of Baetidae and Ephemerellidae (both are Ephemeroptera). The order Ephemeroptera is described by Moisan and Pelletier (2008) as an indicator of good water quality.

Agricultural activities have great effects undoubtedly on the aquatic ecosystems (Sass et al., 2010; Leight and al., 2010). This study has described the spatial and temporal variabilities of the macroinvertebrate populations in the continuum and it depicted that a differential polluo-sensitivity of these organisms exists therein. Therefore such results highlight the merits of our approach as it is fundamental in performing the indicators of biological quality of the aquatic ecosystem. Yet, the enhancement of the irrigated zone requires the use of different types of pesticides with different molecules by peasant farmers. Therefore, further studies on the sensitivity of macroinvertebrates to potential pollutants should be considered.

Conclusion

The spatial-temporal distribution of macro invertebrate populations is driven by changes occurring in the habitat all year long in the dam-effluent-river continuum at the Volta Basin. In the continuum reservoir - effluent – river system, we observed that 18 of the 35 families of macro invertebrates are common to all stations. These results indicate that changes in the habitat determine the structure of macro invertebrate communities; the use of 17 families not common to all habitats generates a spatial distribution of individuals that gives a better understanding of the clustering patterns of the populations as an indicator of timely changes in habitat quality. This study reveals a community composed mainly of insects (over 75%) variably distributed. The study also reveals that the difference between the Shannon index of diversity between these two areas increases during the month of July, the rainy season in the basin. The identified individuals belonging to the family of Baetidae and Ephemerellidae (Ephemeroptera) at the river suggests a possible recovery of the river fauna; because this order of insects is considered sensitive to disturbance due to water quality losses.

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