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Environmental variables structuring *Labeo* species (Pisces, Cyprinidae) in Malebo Pool, Congo River

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ABSTRACT

This study examined the effect of ten environmental variables on the distribution of five species of the Cyprinid fish (*Labeo lineatus, L. nasus, L. macrostomus, L. sorex and L. weeksii*) in Malebo Pool, Congo River. A total of 3468 individuals of *Labeo* spp. were collected in 7 sites. Three species namely *Labeo lineatus, L. weeksii* and *L. sorex* represented 94% of the total number of *Labeo* caught in 7 sites. A significant correlation between species distribution and environmental variables was found using the Canonical Correspondence Analysis. Water depth and current speed, dissolved oxygen concentration and substrate types were the main environmental variables influencing the distribution of *Labeo* species in Malebo Pool and these species are accordingly divided in two groups. Three species: *Labeo sorex, L. nasus* and *L. macrostomus* prefer deep, rocky sites with fast current and high dissolved oxygen concentration. These species are thus considered as rheophilic. Two species: *Labeo lineatus* and *L. weeksii* are considered limnophilic as they are usually found in shallow sites with slow current and lower dissolved oxygen concentration. In this last group, *L. weeksii* was found in sandy sites while *L. lineatus* preferred mud.

Key Words: Malebo Pool-Congo River - *Labeo* spp- Environmental variables- substrate types

INTRODUCTION

Habitat structure, defined as the physical arrangement of objects in aquatic environment, is an important characteristic for the fishes. Several authors have emphasized the importance of the difference in biotic and abiotic characteristics of streams (Culp and Davies, 1982; Orendt, 2003). Several factors including abiotic parameters of water or human can also influence abundance and distribution of fish along the river, and habitat used by each species reflects the interactions of many of these characteristics (Suthers and Gee, 1986; Chapman and Liem, 1995; Moyle and Light, 1996; Alcarez et al., 2005). Fish species respond in a different way to factors within communities in space and time, and microhabitats variation determines which species coexist (Brown, 2000; Feyrer and Healet, 2003, Kouamélan et al., 2003; Zhang et al., 2011). However, many studies suggested that strategies of resource use must be developed by closely related species to allow coexistence and to avoid competitive exclusion (Yamaoka and Takamura, 1983; Mbomba, 1986; Hori et al., 1997). It is thus interesting to study and elucidate microhabitat partitioning by these closely related cyprinid species exploiting similar resources in Malebo Pool. Unfortunately, the ecology of many African cyprinid fishes remains poorly known especially in Congo River where studies are mainly limited to the systematic aspects (Poll, 1957; Tshibwabwa and Teugels, 1995). Malebo Pool (formerly Stanley Pool) is located between Kinshasa (Democratic Republic of Congo) and Brazzaville (Republic of Congo). It is a lake-like expansion of Congo River at its lower region where the waters slow down considerably (Burgis and Symoens, 1987). This area is characterized by various microhabitats mainly a deep water zone with rocky bottom in the upstream, a rather shallow water with sandy bottom at the middle, and a rocky bottom area with shallow and rapidly flowing water in down stream. Two hundred and eighty two (282) fish species have been identified including 17 species of the genus *Labeo* (Cyprinidae) (Tshibwabwa, 1997). Based on their lip forms, these *Labeo* species are divided into two groups: The first one includes the *Labeo* species with papillose lips and the second includes the *Labeo* species with folded lips (Tshibwabwa, 1997). These species show no clear competitive interactions for food while feeding mainly on the periphyton.

The main objective of this study was to investigate the influence of ten environmental variables on the spatial distribution patterns of 5 *Labeo* species from Malebo Pool (Congo river): *Labeo lineatus,* Boulenger 1898); *Labeo weeksii* Boulenger 1909; *Labeo nasus* Boulenger 1899; *Labeo macrostomus* Boulenger 1898 and *Labeo sorex* Nichols and Griscom 1917. It helps us to understand the major environmental factors which determine the distribution of these species in this ecoregion.

MATERIALS AND METHODS

Study sites

Our sampling campaign was performed in the Malebo Pool, Congo River. This study was conducted in 7 sites (Fig. 1): Two sites are located in Ngamanzo (upstream part of Malebo Pool) (4° 10’ 33.9” S; 15° 31’ 20.9” E), 3 sites are located in Kinkole: Mipongo island (4° 10’ 29.6” S; 15° 27’ 29.8” E), Japon island (4° 18’ 26.9”S; 15° 30’ 33.7” E) and Molondo island (4° 17’ 4,2” S; 15° 27’ 29.8” E). Two sites are located in Kinsuka (end of Malebo Pool): Kinsuka 1 (4° 19’ S and 18° 15’ E) and Kinsuka 2 (4° 18’ S and 15° 16’ E).

Fish sampling

Fish were collected each month between January and December 2005 using gillnets (10 to 100 mm mesh with 1.8 m depth and 25 m long for each gillnet), seine net and catnet. Fishing was performed overnight (5 PM to 7 AM). All *Labeo* species were identified and counted (Tshibwabwa and Teugels, 1995; Stiasny et al., 2007; Ibala, 2010).

Environment variables measurement

Environmental variables were measured in each site. The following parameters were recorded: the temperature was measured to the nearest 0.1 °C using an alcohol thermometer, water samples were collected for laboratory analysis of NO_3^- and PO_4^{3-} using a spectrometer Hach DR 2400. Conductivity (µS/cm), pH and turbidity (NTU) were measured in the field using the pH, conductimeter and turbidity meter of Hanna Combo instruments (model Ec N° HI 98129). Water depth (m) was measured with a Kutech depth-meter. Transparency was measured with a Secchi disck scaled in (cm) and dissolved oxygen (mg/l) was measured with an oxymeter (WTW oxi 330 i). Except for water depth, the other variables were measured at 5 cm depth at every sampling station and when gill nets were released.

The surface area of a given substrate type was measured as percent of total area covered by that substrate on the bottom surface for each microhabitat. The following substrates were identified as: mud, sand, rock and boulder.

Statistical analysis

Canonical correspondence analysis (CCA) was used to investigate the influence of environmental variables upon *Labeo* species (Legendre and Legendre, 1984). CCA is a multivariate direct ordination technique that extracts synthetic environmental gradients that maximize niche separation in fish communities. Analyses were conducted with the Canoco 4.0 program (Ter Braak and Smilaurer, 2003). Fish data have been transformed using $\log_{10}(x+1)$ and the environmental variables have been standardized prior to the analysis (Underwood, 1997).

RESULTS

A total number of 3468 individuals of *Labeo* spp. were sampled: *Labeo lineatus, L. weeksii*, and *L. sorex* represent 94% of the total number (1446; 950 and 874 individuals respectively). As shown in Fig.2, in every site, *L. macrostomus* (122 specimens) and *L. nasus* (76 specimens) were less abundant.

It has also been found that, *L. lineatus* and *L. weeksii* are distributed in most sites while *L. sorex, L. nasus* and *L. macrostomus* are usually found to Ngamanzo and Kinsuka (Table 1).

Environmental variables

Ten environmental variables were measured in the 7 study sites. Mean values for each site are presented in Table 2.

Substrate description

The 7 sites differ in terms of substrate composition (Fig. 3). The upstream sites of Ngamanzo 1 and the downstream sites of Kinsuka (1 and 2) are mainly composed of rocks and boulders, while Ngamanzo 2 is essentially made of sand and rocks. The bottom of the three sites studied in Kinkole (Mipongo, Japon and Molondo) is mainly composed of sand.

Species-environment relationships

The canonical analysis of correspondence (CCA) was applied to the tables ‘species-sites’ and ‘environmental variables-sites’ (5 *Labeo* species, 10 environmental variables and 7 sites).

The ordination of the correlations by the CCA indicates that axis 1 (eigenvalue (λ_1 = 0.64; 0.63, 0.15 and 0.02) is characterized by water current speed, depth of water and dissolved oxygen concentration. The eigenvalues associated to the Monte Carlo test allowed to select three statistically significant variables ($p < 0.05$).

Among the 10 variables studied, the PO_4^{3-} concentration had a very low variability and was automatically suppressed during the analysis. Depth and speed current are the main variables positively correlated to axis 1 of CCA. Water temperature, pH and NO_3^- are positively correlated to axis 2 while oxygen, water transparency and conductivity are negatively correlated to this axis (Fig.4).

Two groups of sites can be distinguished from these physico-chemical variables. Our results show that water current and dissolved oxygen concentration are different. Thus sample from Kinsuka 2 are characterized by lower temperature and higher dissolved oxygen concentration than samples from Ng1. The second group (including the 5 remaining sites: Ng1, Mi, Ja, Mo and Ki1) is negatively correlated to depth and speed. Observations from Ng2 and Ki1 reveal higher temperatures and lower oxygen concentrations and transparency than the 3 sites of Kinkole (Mi, Ja and Mo).

The species distribution also reveals 2 groups (fig. 5). The first group includes 3 *Labeo* species (*L. sorex, L. nasus* and *L. macrostomus*) and is positively correlated to the first group of sites (Ng1 and Kins2). The second one includes the species *L. lineatus* and *L. weeksii* and is correlated to the second group of sites (Ng1, Mi, Ja, Mo and Ki1).

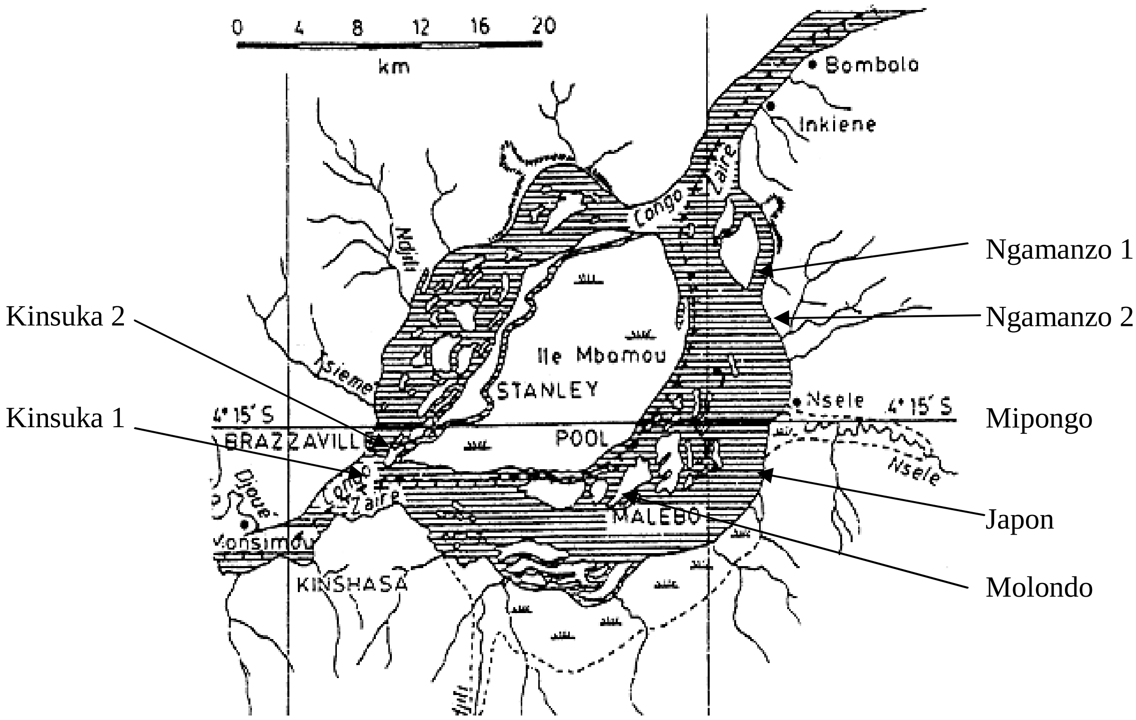

Figure 1: Map of Malebo Pool showing sampling sites (modified from Burgis & Symoens (1987)).

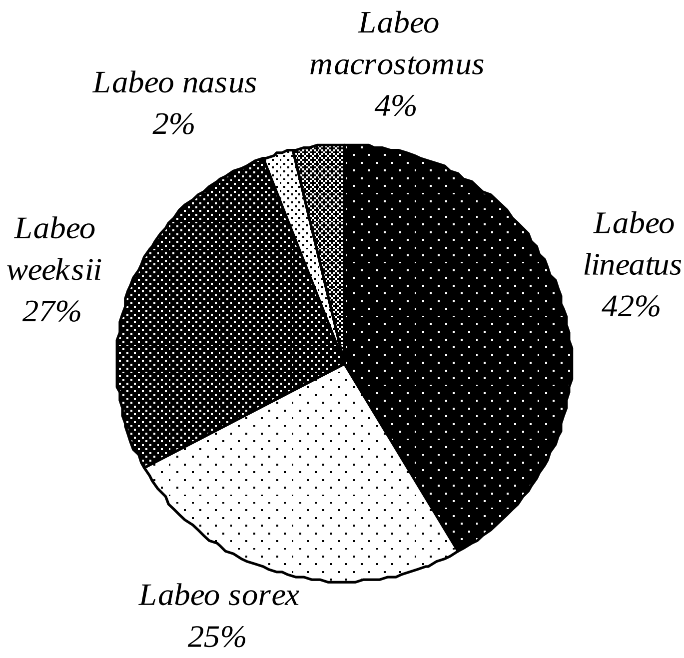

Figure 2: Relative abundance of *Labeo* species sampled in 7 sites of Malebo Pool from January to December 2005.

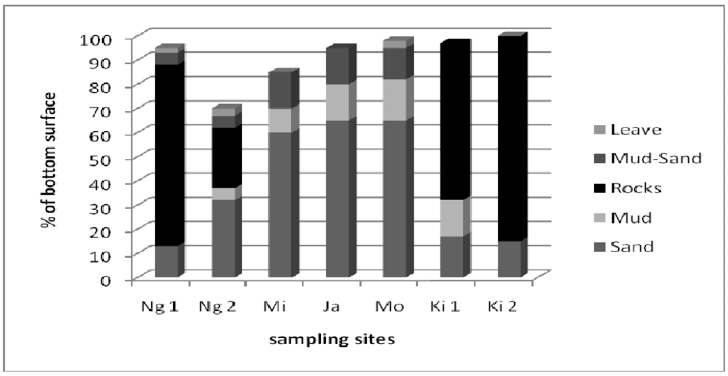

Figure 3: Substrate composition of sampling sites in Malebo Pool.
Ng1=Ngamanzo 1; Ng2=Ngamanzo 2; Mi=Mipongo; Ja=Japon; Mo=Molondo; Ki1=Kinsuka 1, Ki2=Kinsuka 2.

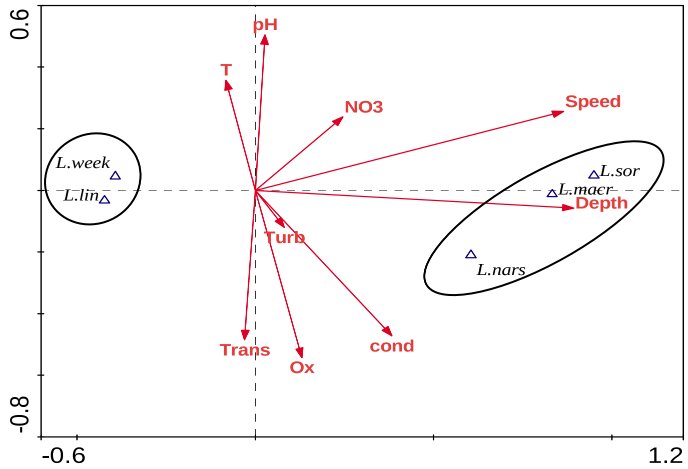

Figure 4: Ordination diagram of 5 *Labeo* species and 10 environmental variables at the first two axes produced by the Canonical Correspondence Analysis.
L.lin=*L. lineatus*, L.week=*L. weeksii*, L.sor=*L. sorex*, L.macr=*L. macrostomus*, L.nars=*L. narsus*.

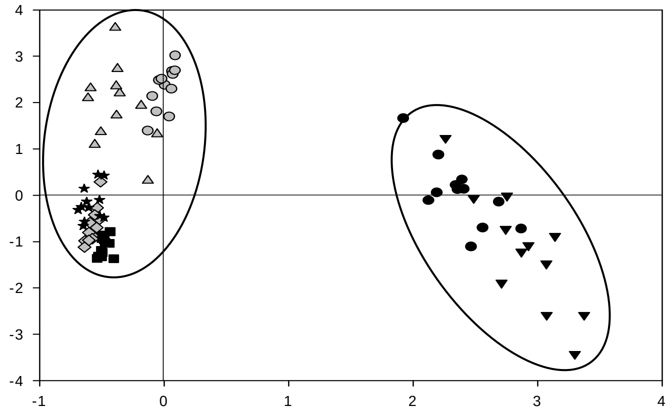

Figure 5: Ordination diagram of the sampling units at the two first axes produced by the Canonical Correspondence Analysis.
Sites symbols: ● Ng1; ○ Ng2; ■ Mi; ◇ Ja; ★ Mo; △ Ki1; ▼ Ki2.

Table 1: Distribution of 5 *Labeo* species sampled in Malebo Pool, Congo River.

Species	Total number of individuals per sampling site						
	Ng1	**Ng2**	**Mi**	**Ja**	**Mo**	**Ki1**	**Ki2**
Labeo lineatus	3	26	407	575	370	65	0
Labeo sorex	505	0	1	0	0	5	363
Labeo weeksii	0	24	335	201	243	142	5
Labeo nasus	0	0	0	0	0	6	70
Labeo macrostomus	15	0	0	0	0	5	102

Sites: Ng1=Ngamanzo 1, Ng2=Ngamanzo 2, Mi=Mipongo, Ja=Japon, Mo=Molondo, Ki1=Kinsuka 1, Ki2=Kinsuka 2.

Table 2: Mean values of environmental variables measured in 7 sites in Malebo Pool, Congo River.

Variables	Sampling sites						
	Ng1	**Ng2**	**Mi**	**Ja**	**Mo**	**Ki1**	**Ki2**
Temperature (°C)	27.92	28.68	28.04	28.64	29.10	28.89	28.68
pH	6.20	6.44	5.89	6.02	6.20	6.39	6.12
Turbidity (TDS)	13.46	13.17	13.43	13.13	12.48	14.42	13.63
Conductivity (µS/cm)	30.97	30.08	28.02	26.55	26.32	28.58	30.67
Transparency (Secchi-depth) (cm)	47.83	42.17	50.92	50.83	52.04	42.17	50.08
NO_3^- (mg/l)	0.27	0.42	0.06	0.04	0.24	0.06	0.26
PO_4^{3-} (mg/l)	0.28	0.27	0.29	0.22	0.22	0.21	0.20
Dissolved oxygen (mg/l)	6.58	6.53	6.57	5.99	6.70	5.70	7.10
Depth (m)	14.33	1.60	2.60	2.04	1.78	2.62	8.02
Current velocity (m/s)	0.41	0.22	0.10	0.13	0.10	0.29	0.47

Ng1=Ngamanzo 1; Ng2=Ngamanzo 2; Mi=Mipongo; Ja =Japon; Mo=Molondo; Ki1=Kinsuka 1, Ki2=Kinsuka 2.

DISCUSSION

Our objective was to understand the distribution and microhabitat preferences of 5 *Labeo* species of the Malebo Pool (Congo River). This study has distinguished two kinds of sites in relation to the bottom structure of the substrates found in Malebo Pool. According to CCA analysis (Fig 4), depth and current speed of water including dissolved oxygen concentration were the main variables that influenced *Labeo* species distribution and determined habitat partition. Among the 7 species studied, *Labeo sorex, L. macrostomus* and *L. nasus* are abundant where water current is high and the substrate being rocky. These species are known as rheophilic and preferred well oxygenated waters as confirmed in this studied where dissolved oxygen in the microhabitats were high. In the same sites, especially at the rapids of Kinsuka Robert and Steward (1976); Ferreira et al. (2001); Alcarez et al. (2005); Lévêque and Paugy (2006) also found the same results

In the second group which included *Labeo lineatus* and *L. Weeksii*, their microhabitat was characterized by shallow and substrata that were mainly composed of sand (*L. weeksii*) or mud (*L. lineatus*). From this aspect, water depth, dissolved oxygen concentration and water current speed are important environmental parameters associated to the first axis of CCA (Fig. 5) they are negatively correlated to abundance of *L. lineatus* and *L. weeksii*, indicating that these species preferred shallow zones where substrata were composed of sand and mud.

The correlation between *Labeo sorex*, *L. nasus* and *L. macrostomus* suggests that these species preferred deep areas with fast current and rocky substrate. Also, Brown (2000); Vadas and Orth (2000); Bond and Lake (2003) emphasized that depth could be an important significant variable because it acted in concert with factor such as sediment.

Conclusion

The *Labeo* species studied show a clear distribution pattern along the environmental variables gradient in Malebo Pool (Congo River). *Labeo lineatus* and *Labeo weeksii* cluster in the same sites. These sites are lentic and shallow. Substrate is made up either of sand (*Labeo weeksii*) or of mud (*Labeo lineatus*). Adult specimens of *Labeo lineatus* were found in deep water but with substrate made up of sand and mud. The remaining species; *Labeo macrostomus, Labeo nasus* and *Labeo sorex*, are rheophilic. They are concentrated in the lotic sites where current was fast and bottom substrate was composed of rocks and boulders. The water transparency was relatively high as well as dissolved oxygen concentration. This study suggests linear relationships between the *Labeo spp*'s distribution and the environmental variable conditions in Malebo Pool, Congo River.

With regard to their morphological adaptation, we are interested in analyzing in near future the influence of those environmental factors upon this type of distribution among the *Labeo spp.* and especially in relation to their food habit.

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