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Temporal dynamics of *Chaoborus* larvae (Diptera : Chaoboridae) in the tropical ecosystem (lake Ayamé I ; Côte d'Ivoire).

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Abstract

Chaoborus larvae are voracious predators of zooplankton able to change their specific composition and size structure. Thus they appear as competitors of fish. They also represent food for planktophage fish. The temporal dynamics of *Chaoborus* larvae was studied (from january to october 1997) in the fishery of Bakro (5°33'N and 3°15'W) situated in lake Ayamé I (Côte d'Ivoire). Two peaks of density were observed : the most pronouced in March (end of the major dry season) with 747 ind./m^2, and another, less pronouced in June (end of the major rainy season), with 280 ind./m^2. Differences between densities may well be explained by the advent of the rainy season which leads to a decline in trophic resources (zooplankton) and exposes *Chaoborus* larvae to predation by fish.

***Key-words* :** Chaoborus larvae, Dynamics, lake Ayamé I, Côte d'Ivoire,West Africa.

Résumé

Dynamique temporelle des larves de Chaoborus *(Diptera : Chaoboridae) dans le lac tropical Ayamé I (Afrique de l'ouest ; Côte d'Ivoire).*

Les larves de Chaoborus *sont des compétiteurs (consommateurs voraces de zooplancton) et des aliments des poissons planctophages. La dynamique temporelle de ces larves a été étudiée dans la pêcherie de Bakro (5°33'N et 3°15'W) située dans le lac Ayamé I (Côte d'Ivoire), de janvier à octobre 1997. Deux pics de densités des larves de* Chaoborus *ont été mis en évidence : le premier, plus important, est observé en mars (fin de la grande saison sèche) avec 747 ind./m^2 et le second, de moindre importance, est noté en juin (fin de la grande saison de pluies), avec 280 ind./m^2. Cette inégale importance de densité s'expliquerait par la saison des pluies dont l'arrivée entraîne la baisse des ressources trophiques disponibles (mortalité du zooplancton dues aux averses) et expose les larves de* Chaoborus *à la prédation des poissons ; celles-ci migrant sur des distances plus grandes, due à la montée du niveau de l'eau.*

Mots-clés *:* *Afrique de l'Ouest, Côte d'Ivoire, larves de* Chaoborus*, Dynamique temporelle, lac Ayamé I.*

1. Introduction

Insects of the *Chaoborus* genus undergo three phases of development in their biological cycle : two aquatic phases (larval and nymphal phases). The larval phase lasts 7 to 12 days and the nymphal phase, from 2 to 4 days. The third phase, which takes place in the air and corresponds to the imago phase, lasting less than 10 days (Sweetman & Smol, 2006). The larval phase presents four stages. Larvae at stages I and II have a pelagic life while those at stages III and IV live in the pelagic zone at night and in the benthic zone in daytime. This can be interpreted as a mechanism to avoid fish predation (Liljendahl-Nurminen *et al*., 2008).

Chaoborus are at the heart of trophic networks, being preys for pelagic and benthic young and adult fish (Dawidowicz *et al*., 1990; Lampert, 1993; McQueen *et al*., 1999). Furthermore, in several lakes, *Chaoborus* larvae represent the top level of invertebrate predators in the food chain in the pelagic zone (McQueen *et al*., 1999; Riessen, 1999). These larvae are gluttonous predators of zooplankton, able to change their specific composition and size structure (Arcifa, 2000; Pekcam-Hekim *et al*., 2006; Castilho-Noll & Arcifa, 2007). The first two stages feed on rotifers and copepods nauplii, whereas the third and fourth stages eat cladocerans and copepods (Moore *et al*., 1994; Riessen, 1999). Therefore, Chaoborus appear as competitors of planktophage fish (Persson *et al*., 1992).

In Côte d'Ivoire, few studies concern larvae of Chaoborus : inventory (Dejoux *et al.*, 1981) and predation on zooplancton (Aka-Koffi, 2003; Pagano *et al.*, 2003). The aim of this study of *Chaoborus* larvae in lake Ayamé I is :

- to describe the temporal variation in *Chaoborus* larvae densities (stages III and IV) in Bakro fishery,
- to analyze this temporal variation in relation to both the biotic environment (phytoplankton biomasses) and the abiotic environment (physicochemical parameters).

2. Material and methods

2.1. Study site

Lake Ayamé I is situated in South-Eastern Côte d'Ivoire (Figure 1). It is the result of a hydroelectric dam constructed on the river Bia in 1959. This lake covers a total area of 190 km^2 with an average length of 80 km, an average width of 27 km and an average depth of 15 m (at the foot of the dam).

The climate includes four seasons : a major dry season (from December to March), a major rainy season (from April to July), a minor dry season (August and September) and a minor rainy season (October and November). The lake's level is directly influenced by the rainfall. Water level decreases regularly from November to March (during the major dry season), and increases with the coming of the rains, reaching its highest level in July (Ouattara *et al.*, 2001).

2.2. Sampling of *Chaoborus* larvae

Bakro (5°33'N and 3°15'W), the sampling station, is the biggest Bozo fishermen's camp in one of the major fishing zones of the lake.

Sampling of *Chaoborus* larvae spanned a period of ten months (from January to October 1997). Monthly samples were collected between 8:30 and 12 noon, at 4 points of increasing depth radiating from the shore outwards for 100 m. The first point presents mainly a sandy substratum (88.7 % of sand against 12.1 % of fine fraction composed of clay and silt), the second point (59.1 % against 39.7 %), the third point (57.5 % against 31.1 %) and the fourth point (9.6 % against 79.2 %) contain a relatively large fine fraction. At each point, 10 samples were taken and pooled with an Ekman grab sampler (MOD 55 HYDRO-BIOS type) for a total surface of 0,225 m^2, every month. Samples were sieved (mesh 1 mm) and fixed with formalin 5 %. In the laboratory, *Chaoborus* larvae were sorted and counted with a magnifying glass **(**magnification x 2.5-4).

2.3. Physico-chemical parameters and phytoplanktonic biomasses

The following parameters were measured *in situ*, on the surface : conductivity (Conductivity meter LF95), transparency (Secchi disc), total hardness, nitrates (NO_3^-), nitrites (NO_2^-), ammonium (NH_4^+) and phosphates (PO_4^{3-}) (spectrometer HACH model DR 2000 and kits AQUAMERCK), temperature, dissolved oxygen (Oxygen meter OXI 96) and pH (pH-meter WTW). Rainfall data for this region were provided by SODEXAM (the Aviation and Meteorology Development Company).

Phytoplankton biovolumes were estimated from measurements taken on different taxa cells (n = 30). Each cell was linked to one or several geometrical forms. Then, cellular volumes were calculated using geometrical formulas. Phytoplankton biomass was obtained by conversion of biovolumes into biomass. Data obtained in $\mu m^3.L^{-1}$ were directly converted into biomass ($1 \mu m^3 = 10^{-9}$mg), while seaweeds were attributed a density roughly identical to that of the water (Iltis, 1982). Formulas were used to calculate the cellular volume of certain forms (Wetzel & Likens, 2000). Plasma volume of Diatoms and Peridiniens was determined according to Sicko-Goad *et al.* (1977).

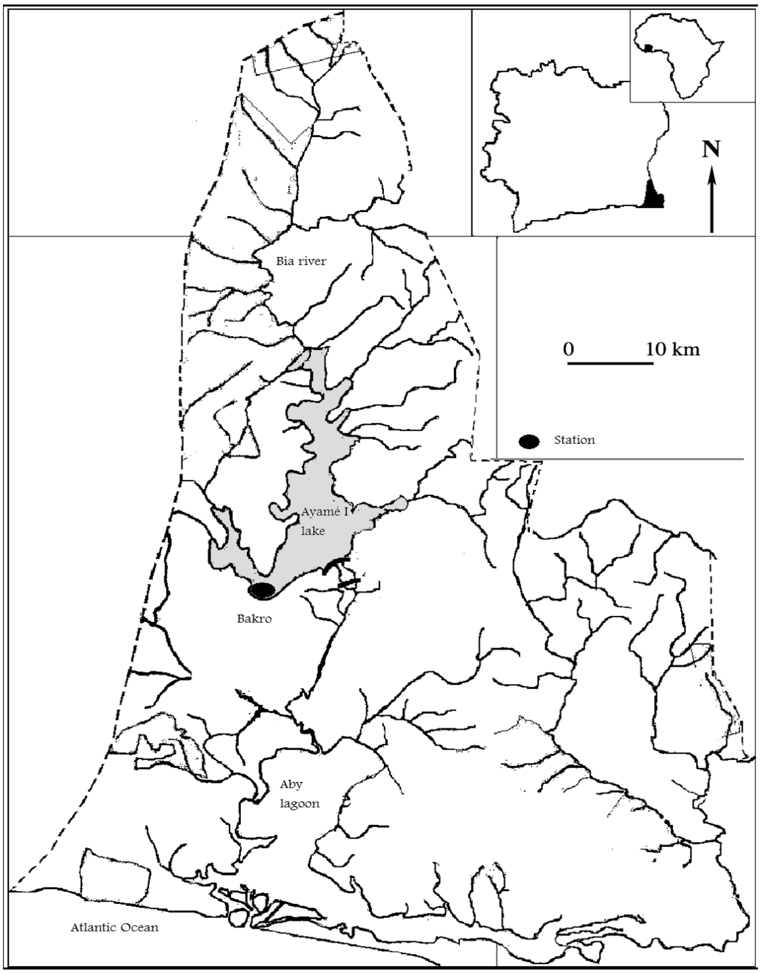

Figure 1 : Situation of Bakro station in lake Ayamé I.

2.4. Statistical treatment

Chaoborus densities obtained at the different sampling points were compared using Anova I (STATISTICA 4.5). We used a logarithmic transformation on the densities to reduce distances [log (x + 1)]. The post hoc analysis of comparison Tukey HSD test allowed levels of difference to be detected.

To understand the temporal variation of *Chaoborus* larvae, a Principal Components Analysis (ADE-4 program; Thioulouse *et al.*, 1996) was realized. Ten abiotic variables (conductivity, transparency, total hardness, nitrates, nitrites, ammonium, phosphates, temperature, dissolved oxygen, pH) and 2 biotic variables (phytoplankton biomasses and *Chaoborus* larvae densities) were used. We used a Matrix of ten lines (month of sampling) and 12 columns (abiotic and biotic variables).

3-Results

3.1. Temporal distribution of *Chaoborus* larvae

A total of 1016 *Chaoborus* larvae were collected. Anova I (Table) showed no significant difference in densities between the third and the fourth points, where the majority of the *Chaoborus* larvae were collected (97.1 %). Data from both points were thus pooled for the study of temporal variation. This variation was compared with the data on rainfall and phytoplankton biomasses. Two peaks of density appear (Figure 2a) : the highest in March (747 ind./m^2), therefore in dry season and a lesser one in June (280 ind./m^2), therefore in rainy season.

The rainfall we observed (Figure 2a) follows the classic seasonal pattern described for Côte d'Ivoire South region, except for September (minor dry season) with precipitations comparable to those of a rainy season. For phytoplankton (Figure 2b), apart from January and February, peaks are observed in April, June and October. However, biomass values obtained in March, May, and from July to September remain relatively high.

Table : Results of Anova I comparing the densities of *Chaoborus* larvae in differents sampling points of Bakro station.

	Bakro2	Bakro3	Bakro4
Bakro2	1		
Bakro3	0,015*	1	
Bakro4	0,1106	0,6347	1

** = test significant.*

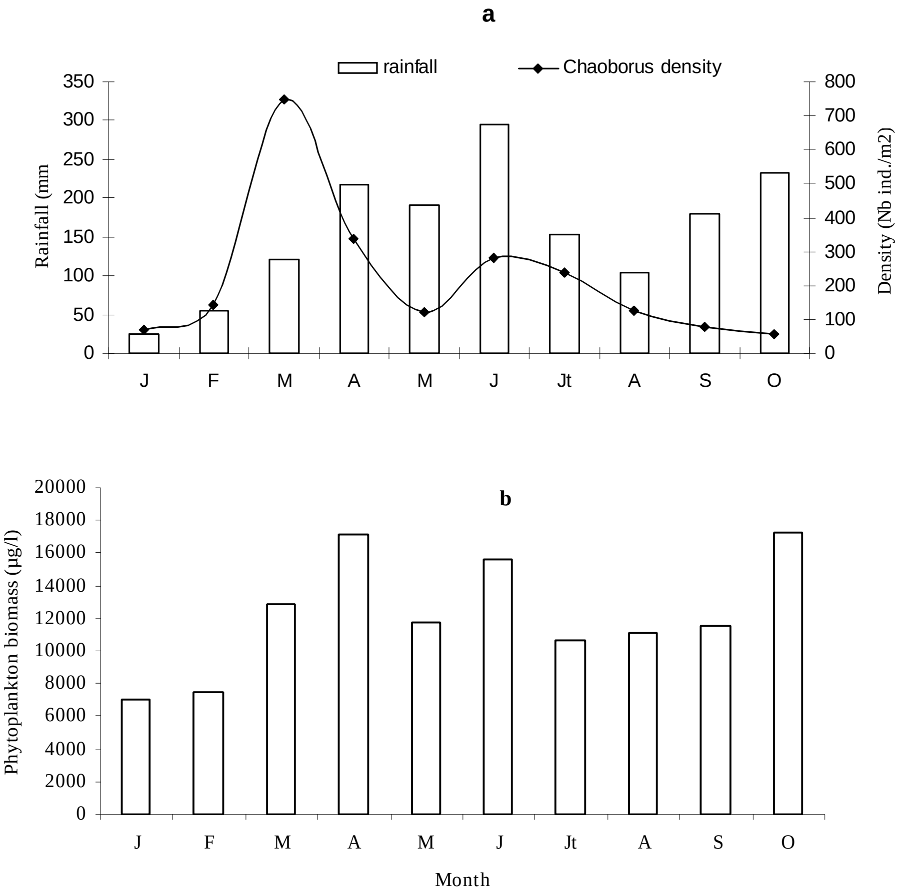

Figure 2 : (a) Seasonal variations in rainfall and *Chaoborus* larvae density and (b) phytoplankton biomass at Bakro station (lake Ayamé I, Côte d'Ivoire).

3.2. Relation between biotic parameters, abiotic variables and *Chaoborus* larvae

The first (F1) and the second axes (F2) (Figure 3) represent respectively 34 % and 22 % of the total variance, over a total of 56 %. Axis I indicates that February, March and April are characterised by the highest values for conductivity and temperature. June and October stand out as months with strong phytoplankton productivity, as shown by a good correlation with high values of dissolved oxygen and phosphate. In contrast, August and September record the lowest rates of dissolved oxygen. On the whole, values for January, May and July are more moderate than those recorded during other months.

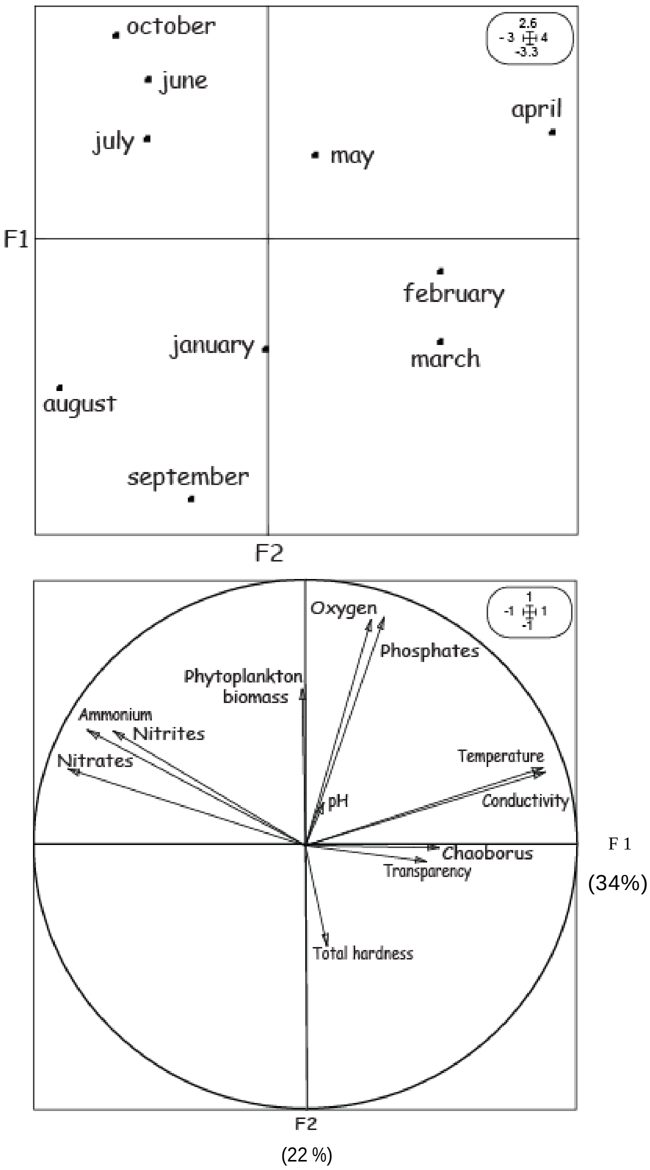

Figure 3 : Principal component analysis (ADE-4 software) using 10 sampling months and 12 biotic and abiotic variables (10 physico-chemical parameters, phytoplanckton biomass and *Chaoborus* larvae density) at Bakro station.

4-Discussion

Both peaks of density obtained during the study would indicate two generations or the succession of different species of *Chaoborus*. The same trend was observed by Kagalou *et al.* (2006) in lake Pamvotis (Greece) where two peaks of *Chaoborus flavicans* density were found during warm months (May and July). In present study, the first cohort seens to benefit from favourable trophic and hydrological conditions. Indeed, the peak in March is probably due to the abundance of zooplankton, which increased because of the strong phytoplankton biomasses. In fact, the weakest phytoplankton biomasses were registered in January and February, possibly due to extensive grazing by zooplankton. Favourable hydrological conditions are the result of the lake level decreasing from January (87 m) to March (85 m), a decline of 2 m (Ouattara *et al.*, 2001). This decline reduces distances covered during vertical migrations. Such zooplancton abundance during dry season has already been reported in the La Fé reservoir in Colombia (Roldán & Ruíz, 2001).

On the other hand, for the second *Chaoborus* larvae cohort, conditions are different, with the lake level increasing from 85 m (in May) to 88.5 m (in July) due to the advent of the rainy season, 3.5 m more than in March, when the first peak is recorded. So the second cohort of larvae has to cross greater distances during vertical migrations. Thus, they are exposed to a higher risk of predation, which could affects their density. Therefore the low number of zooplankton is probably due to the rainfall. There is a negative correlation between thunderstorm intensity and zooplankton density (Roldán & Ruíz, 2001), probably due to the fact that zooplankton seem to remain in the suface zone (Cherbi *et al.*, 2008). Thus, rains may lead to a decrease in zooplankton density, reducing *Chaoborus* trophic resources. Considering that there is good phytoplankton production from June to October (rainy season), this hypothesis appears more plausible. Moreover, the impact would be greater on young zooplankton. Indeed, a vertical stratification linked to age exists, for example, for the copepod *Termocyclops inversus*. Nauplii of this species are found between 0.4 and 0.8 m deep, copepodites between 0.4 and 1.2 m and adults between 1.1 m and 2.1 m deep (Bezerra-Neto & Pinto-Coelho, 2007). Nauplii which are know to be the food of *Chaoborus* larvae at stages I and II, are the zooplankton most likely affected by thunderstorms. Finally, predation by fish (Yan *et al.*, 1985; Wissel *et al.*, 2003; Kouamelan *et al.*, 2006) and decline in trophic ressources linked to major rainfalls may be responsible for the low density of *Chaoborus* obtained in June, and their progressive decline until October.

The high values for conductivity and temperature obtained in March and April (Figure 3) may be due to the major dry season, which has direct impact on temperature and water level. The increase in temperature at this season stimulates organic matter degradation, which releases ions, while the decreasing water level generates a greater concentration of ions. The strong phytoplankton production which characterizes June, may be the result of strong rains during this month, which may have a negative effect on herbivorous zooplankton. These explanations are also valid for October (rainy month).

Densities obtained in our study are low compared to the data of Kagalou *et al.* (2006) in lake Pamvotis (Greece) who record peaks of 3555 ind./m^2 and 1580 ind./m^2. They are also very low compared to those for ponds without fish in Japan (18 600 ind./m^2) (Xie *et al.*, 1998). They approach those for lake Mikri Prespa in Greece (2150 ind./m^2) (Petridis & Sinis, 1995). These low densities could be the result of weak phytoplankton production, in turn explained by the weak values for nitrates (0.1 - 0.45 mg.L^{-1}), phosphates (0.49 - 1.45 mg.L^{-1}) and transparency (54 - 142 cm) registered in the lake.

5. Conclusion

This study has highlighted two periods of *Chaoborus* larvae abundance in lake Ayamé I. The first peak, the most pronounced, is registred during the dry season in March, under favourable trophic (high abundance of zooplankton) and hydrological (decline of lake level) conditions. The second and less pronounced peak is obtained in the rainy season, in June. This rainy season seems to create unfavourable conditions for *Chaoborus* larvae by affecting zooplankton, thus generating a decline in their trophic ressources, especially at stages I and II. The increase in water level exposes *Chaoborus* larvae to fish predation during their vertical migrations (stages II and IV), by increasing the distances they need to cover. Densities obtained in lake Ayamé I are low compared to those obtained in other lentic aquatic ecosystems.

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