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Effect of exogenous foods used in *Oreochromisniloticus* (Linné, 1758) feed on the diversity and structure of phytoplankton in Blondey fishponds (Ivory Coast; West Africa)

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Abstract

Fish farmers generally use exogenous foods to increase fish production. However, these external inputs of food are most often at the base of the increased fertilization of the fishponds. This could unbalance the native flora and fauna in these artificial hydro systems. The aim of this study is to evaluate the effect of three exogenous foods used in *Oreochromisniloticus* feed on the diversity and structure of phytoplankton stands in Blondey fish ponds. Those foods formulated solely with animal by-products were tested in juvenile and adult stages. Thus, seven fishponds whose four (E1, E2, E3, E4) at juvenile stage and three (E7, E8, E9) at adult stage were selected. Among them, E2, E3, E4, and E8 received exogenous food, while E1 and E9, stocked with no exogenous food, were used as witnesses. Phytoplankton samples were taken monthly using a plankton net from October 2016 to June 2017. A total of 111 phytoplankton taxa distributed between five phyla dominated by Chlorophyta were obtained. The taxonomic richness was high in fishponds that received exogenous food and low in those without exogenous food during the two stages (adult and juvenile). The fishponds E4 and E8 that received housefly maggot meal registered the highest taxonomic richness. The Focused Principal Component Analysis (FPCA) indicated that no physico-chemical parameter significantly influenced the most abundant phytoplankton taxa.

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Introduction

The phytoplankton stands is the main primary producer in aquatic ecosystems (Vaquer and Lautier, 1997; Behrenfeld *et al.*, 2001) and is, therefore, the basis of trophic chains in these hydrosystems (Azam and Malfatti, 2007). It supplies oxygen by photosynthetic to hydrosystems, thus contributing to their functional equilibrium (Ouattara *et al.*, 2001; Niamien-Ebrottié *et al.*, 2013). Due to its concentration on substrates immersed or suspended in the water column, this vegetable fraction of plankton is a nutritional source for many aquatic organisms such as zooplankton, insects and some fish, including feeders filter and grazers (Round *et al.*, 1990; Large *et al.*, 1993). In fish farming, phytoplankton is a very important food supplement (Bamba, 2007). According to Waidbacher *et al.* (2006), phytoplankton are part of natural foods containing 55, 60 % protein that can cover 30 % of the nitrogen requirements of Oreochromisniloticus. In addition, this plant fraction of plankton, like other native populations of fish ponds, is essential for fish production, including in systems based on the exogenous supply of high-quality food (Dabbadie, 1996).

In Ivory Coast, very few studies have been carried out on the phytoplankton stands of fish ponds (Da, 1992). To date, no study has yet taken into account the effects of exogenous feedings on farmed fish on the diversity and structure of phytoplanktonic stands in fish ponds. However, these external food inputs, beyond the increase in the production costs of farmed fish, also increase the fertilization of the breeding environments. However, the high enrichment of these structures in nutrients could lead to eutrophication synonymous with an imbalance of the presence of wild flora in these artificial hydrosystems (Sevrin-Reyssac, 1985). In addition, exogenous foods have a direct or indirect effect on water chemistry (Efole-Ewoukem, 2001). Indeed, artificial foods enrich the ponds with organic matter whose degradation by micro-organisms impoverishes the structures of fish production in dissolved oxygen, so acidifies them. This high acidity of the water could lead to the development of certain phytoplanktonic algae that are not very favorable to fish farming, such as Desmidiales and Dinoflagellata. In addition, the low levels of dissolved oxygen can cause a loss of biodiversity in living organisms.The objective of this study is to evaluate the effects of three exogenous feeds of *Oreochromisniloticus* on the diversity and structure of the phytoplankton stand in the Blondey fishponds. Specifically, this study aims to (i) characterize pond water from physicochemical parameters, (ii) determine the phytoplankton diversity and structure of these ponds and (iii) determine the relationship between abiotic parameters and the main phytoplankton taxa of these fishponds.

Material and methods

Study area and sampling sites

This study was undertaken in the piscicultural farm of Blondey located in the South Ivory Coast 25 km from Abidjan (The economic capital). This farm has 28 ponds and was used for Nile tilapia (*Oreochromisniloticus*) culture. All the ponds were fed by a man-made lake nearby. This lake was fed in the rainy season by running water from palm plantations surrounding the lake. Among the ponds, seven (E1, E2, E3, E4, E7, E8, E9) with average depth of 0.8 m were used (Fig. 1). Four of these ponds (E1, E2, E3, E4) with an area of 800 m² (20 × 40 m) were used for the juvenile stage and three ponds (E7, E8 and E9) with an area of 600 m² (20 × 30 m) in the adult stage due to the food earthworm removal as exogenous food. The fishponds E2/E7 received fishmeal as exogenous food, E3 earthworm meal and E4/E8 received housefly maggot meal (Table 1). The fishponds E1/E9 didn't receive exogenous feed.

Data collection

The phytoplanktonic stands sampling was undertaken monthly during two periods. The first period, from October 2016 to December 2016, corresponded to the juvenile stage in the selected fishponds (E1, E2, E3, E4), and the second period, from January 2017 to June 2017, corresponding to the adult stage in the selected fishpond (E7, E8, E9).

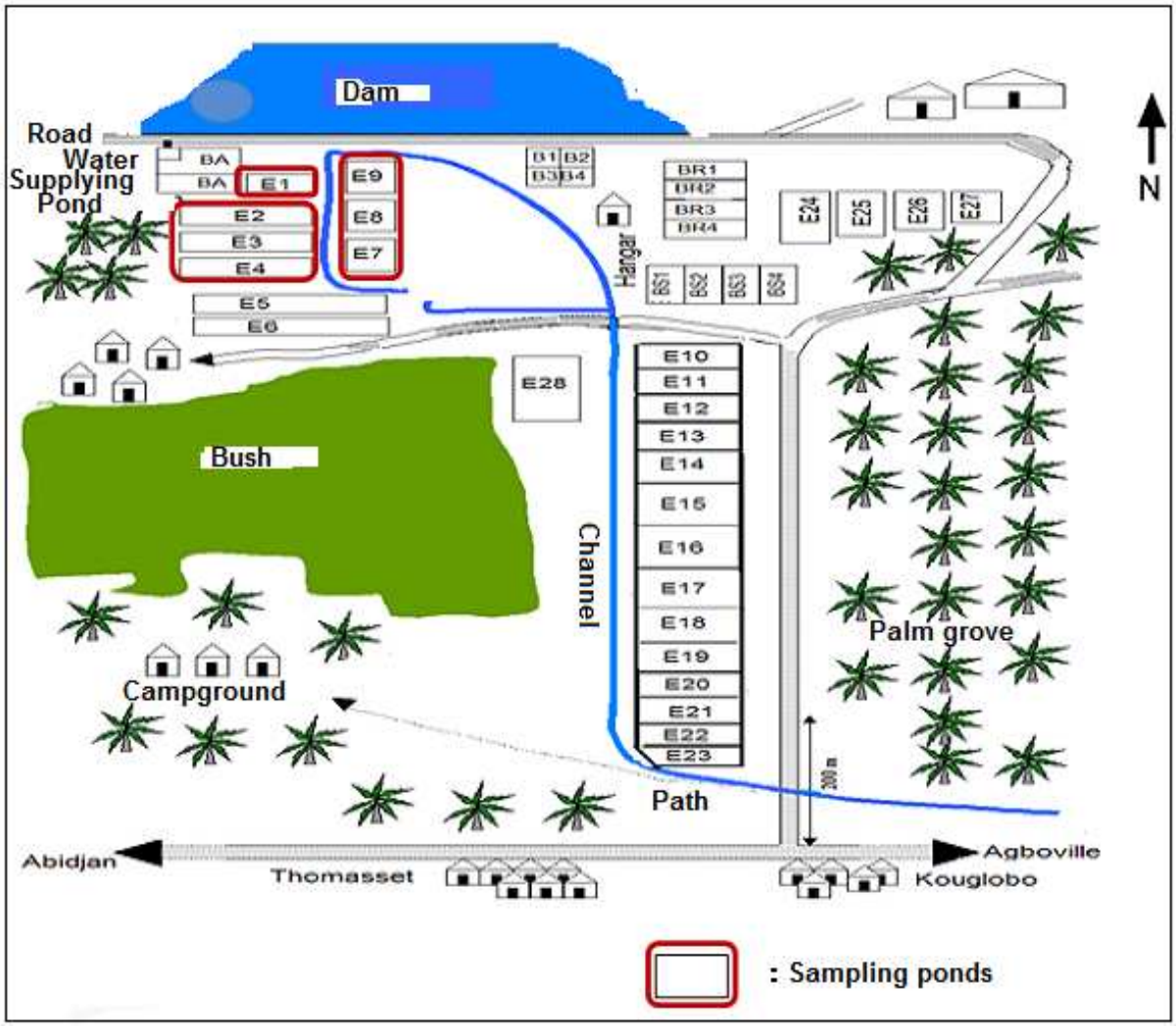

Fig. 1. Location of study area (E1, E2, E3, E4: ponds used for the juvenile stage; E7, E8, E9: ponds used for the adult stage).

At each sampling period, before phytoplankton sampling, five environmental variables (transparency, temperature, pH, dissolved oxygen, and conductivity) were measured using a multiparameter digital meter except transparency, which was determined using a 0.20 m diameter Secchi disk. For nutrients (nitrates and soluble reactive phosphorus), subsamples of 500 mL were collected and refrigerated for later analysis following the spectrometric method (AFNOR, 2005).

For the harvest of phytoplankton, 4 buckets of water with a capacity of 10 L per unit, corresponding to a total volume of 40 L, were filtered using the plankton net. The filtrate collected in the net collector was conserved in a 100 mL box and fixed at 5% formalin. For observation, a few drops of sample were placed between the slide and coverslip and observed under the light microscope Olympus BX40 brand. The observations were made first to the 10x objective for an overview and then to the 40x objective for more details. The microscope was equipped with a micrometer-eyepiece for measurements. The observed taxa were then photographed for later identification.The general works of Bourelly (1968) and Wehr and Sheath (2003) were consulted for generic determinations of organisms. Concerning the determination of Cyanobacteria species, Desikachary (1959), Komárek and Anagnostidis (1998), and Komárek and Anagnostidis (2005)were consulted. For Euglenophyta and Dinophyta, the identification of taxa required consultation with the works of Huber-Perstalozzi (1955), David *et al.* (2004), Kosmala*et al.* (2009). The works of Prescott *et al.* (1975) Komárek and Fott (1983) were used to identify

Chlorophyta taxa. The identification of Bacillariophyta required the use of works of Amossé (1970), Couté and Iltis (1985), Krammer and Lange-Bertalot (1986, 1988, 1991); Round *et al.* (1990) and Tomas (1995). The enumeration of phytoplankton species was carried out using the Malassez cell. This cell has a grid of known volume. This grid consists of boxes that each have 4 rows and 5 columns. After homogenization of the sample, the outer portions of the coverslip were moistened to adhere to the Malassez cell. After adhesion, the sample was placed on the edge of the slide using a Pasteur pipette. The liquid then filled the cell by capillarity. The slide was thus put under a microscope by making a first focus on the objective (x40). Then, the magnification (x100) was used for the focus to make visible the grid and then the number was counted for 5 boxes. For the cells positioned on the edges, only two edges were taken into account during the counting. After counting, the average of the cells was made and the cell density was calculated. The result was expressed in number of cells / mL according to El hachemi (2012) formula:

$$N = n / V * f \quad (1)$$

N: cell concentration (cell / L);
n: number of counted cells;
V: volume of a box;
f: dilution factor

About algal biomass, after each filtration, the filter was immediately packed in aluminium foil and immediately conserved in a refrigerator at a temperature of 4 ° C. In the laboratory, each filter was immersed in a test tube containing 15 mL of a 90% acetone solution and placed in a cold room at 4 ° C in the dark for 24 hours. The filters were then removed from the tube and thoroughly rinsed with acetone to prevent chlorophyll pigment loss. After centrifugation (2000 pm) for 15 minutes, the optical densities at 665 and 750 nm were measured using the spectrophotometer. Measurements at 665 and 750 nm were also made after adding two drops of 0.1 N hydrochloric acid (Lorenzen, 1967). From these values, the chlorophyll *a* content was calculated using theLorenzen equations (1967).

$$Chla = \frac{26,7 * (E_1 - E_2) * V}{l * V_g} \quad (2)$$

With :
Chl*a* expressed in µg / L;
E_1: absorbance before acidification (DO665 -DO750);
E_2: absorbance after acidification (DO665 -DO750);
V: volume of acetone;
V_g: volume of filtered water;
l: length of the optical way of the curve (cm).

Data analysis

Phytoplankton community was analysed using: taxonomic composition, rarefied taxonomic, Shannon-Weaver diversity index (H') (Quinn and Hickey, 1990),Pielou evenness index (Piélou, 1966) (E), frequency of occurrence (FO) and population density (cells.l^{-1}). Shannon-Weaver diversity index was used to assess taxa diversity of phytoplankton. Evenness was used to show the organization of the structure, regardless of species richness. Calculations were performed using the vegan package (Oksanen*et al.*, 2013) for the R 3.0.2 freeware (R Core Team, 2013). FO is the percentage of samples in which each taxon occurred. It was calculated to classify the phytoplankton according to Dajoz (2000). Phytoplankton density was obtained by counting all cells per taxon and expressing the results as numbers of cells per liter. Before performing the comparison test, the normality of data was checked by Shapiro test. Variations in environmental variables and biotic index were determined using the Mann-Whitney *U*-test. A significance level 0.05 was considered.

A Focused Principal Component Analysis (FPCA) was carried out using the "MASS" package of the software R version 3.0.2 (Thioulouse*et al.*, 1997) to express relations between the main phytoplankton taxa and environmental variables. This analysis is a variant of PCA and differs from PCA by its focus on a particular variable (Xi) (Falissard, 1999). Indeed, the FPCA makes it possible to graphically represent the correlations that exist between the variable Xi and the other variables. The graph shows not only the nature

(positive or negative) but also the significance ($p < 0.05$) of the correlations between the variable Xi and the others. In this study, the FPCA was used to determine the variables that significantly influence the abundance of Chlorophyta major taxa. Eight (8) environmental parameters were returned for the analysis.

Results

Environmental characteristics of fishponds

The variations of environmental variables among fishponds at the juvenile and adult stages are given respectively in Table 2and **3**. At the juvenile stage, water temperature varied from 26°C (E1) to 29°C (E4). The dissolved oxygen ranged between 2.4 mg/L (E2, E3) and 5.84 mg/L (E1). The fishponds E2 and E3 presented low values of pH (4.4), while fishpond E1 registered a high value (7.84). Concerning electric conductivity, it varied from 43.8 µS/cm (E1) to 61.9 µS/cm (E2). The minimal value of transparency (10 cm) was obtained in E2, E3 while the maximal value was registered in E1. The low values of nitrate (0.29 mg/L) and phosphate (0.211 mg/L) were registered in E1, while the high values (0.62 mg/L and 0.63 mg/L) of these parameters were observed respectively in E2 and E3 (Table 2). There were no significant variations in water temperature, pH and ammonia between fishponds water during this period (Mann-Whitney test, $p > 0.05$). However, dissolved oxygen and transparency were significantly higher in fishpond E1 than fishponds E2, E3, E4 while electric conductivity, nitrate and phosphate were significantly lower in fishpond E1 than fishponds E2, E3, E4 (Mann-Whitney test, $p < 0.05$).

Table 1. Characteristics of the study fishponds in the fish farm of Blondey (Ivory Coast, West Africa).

Characters	Ponds						
Geographical positions	E1	E2	E3	E4	E7	E8	E9
	5°35'25 N 4°05'26 W	5°35'25 N 4°05'23 W	5°35'26 N 4°05'23 W	5°35'26 N 4°05'23 W	5°35'25 N 4°05'26 W	5°35'26 N 4°05'24 W	5°35'25 N 4°05'27 W
Ponds area (m^2)	800	800	800	800	600	600	600
Fishmeal	no	yes	no	no	yes	no	no
Housefly maggot meal	no	no	no	yes	no	yes	no
Earthworm meal	no	no	yes	no	no	no	no

At the adult stage, water temperature oscillated between 25.6°C (E8) and 29°C (E9). The dissolved oxygen ranged between 2.3 mg/L (E7) and 6.08 mg/L (E9). Concerning pH, the values varied from 4.3 (E7) to 8.08 (E9). Electric conductivity ranged between 31.5 µS/cm (E9) and 60.15 µS/cm (E8). The minimal value of transparency (9 cm) was obtained in E7, while the maximal value (46 cm) was registered in E9. The nutrients such as nitrate and phosphate registered these minimal values (0.26 mg/L and 0.209 mg/L) in E9 and the maximum values (0.58 mg/L and 0.52 mg/L) in E7 and E8 (Table 3).

Table 2. Min, Max and Median values of the environmental variables at juvenile stage of Oreochromisniloticus in the study fishponds of Blondey (Ivory Coast, West Africa); E1 = fishponds without exogenous feed; E2 = fishponds with fishmeal; E3 = fishpond with earthworm meal; E4 = fishponds with housefly maggot meal. Different letters (a, b) on median values denote significant differences between them ($P < 0.05$; Mann-Whitney test).

Variables	Fishponds											
	E1			E2			E3			E4		
	Min	Max	Med	Min	Max	Med	Min	Max	Med	Min	Max	Med
Temperature (°C)	27.8	29	27.9^a	26	27.9	27.8^a	27.5	28.9	27.8^a	26.7	29.6	29.6^a
Dissolved oxygen (mg/L)	5.32	5.84	5.84^a	24	3.6	3.1^b	2.4	5.3	2.6^b	2.5	3.6	2.6^b
pH	7.32	7.84	7.84^a	4.4	5.6	5.1^a	4.4	7.3	4.6^a	4.5	5.6	4.6^a
Conductivity (µS/cm	43.8	46.2	46.2^a	56.3	61.9	58.6^b	45.05	57.4	56.4^b	52.6	53.5	53.5^b
transparency (cm)	32	48	35^a	10	17	10^b	10	20	10^b	11	15	11^b
Nitrate (mg/L)	0.29	0.34	0.32^a	0.49	0.62	0.59^b	0.49	0.62	0.59^b	0.49	0.62	0.59^b
Ammonium (mg/L)	0.03	0.048	0.04^a	0.045	0.056	0.055^a	0.03	0.048	0.04^a	0.035	0.055	0.046^a
Phosphate (mg/L)	0.211	0.214	0.212^a	0.317	0.417	0.417^b	0.43	0.63	0.625^b	0.396	0.496	0.49^b

The values of water temperature, pH and ammonia showed no significant variations between fishponds water (Mann-Whitney test, $p > 0.05$) during this period. However, dissolved oxygen and transparency were significantly lower in fishponds E7 and E8 than fishpond E9, while electric conductivity, nitrate and phosphate were significantly higher in fishponds E7 and E8 than fishpond E9 (Mann-Whitney test, $p < 0.05$).

Composition, distribution and occurrence

A total of 111 phytoplancton taxa were identified belonging to five phylums (Cyanobacteria, Euglenophyta, Chlorophyta, Bacillariophyta, Dinophyta). The Chlorophyta were the most diversified with 37 % of total taxonomic richness. This branch was followed by the Euglenophyta (30 %), Cyanobacteria (28 %), Dinophyta (3 %) and Bacillariophyta (2 %) (Fig. 2).At the juvenile stage, the fisponds E2, E3 and E4 registered the higher values of taxonomic richness respectively 47, 44 and 53 taxa than the fishpond E1 (26 taxa). At this stage, the total richness was 83 taxa (Table 4). Those taxa were dominated by the Chlorophyta with the highest proportion (44 %) obtained in the fishpond E1 (Fig. 3).

Table 3. Min, Max and Median values of the environmental variables at adult stage of Oreochromis niloticus in the study fishponds of Blondey (Ivory Coast, West Africa); E9 = fishponds without exogenous feed; E7 = fishponds with fishmeal; E8 = fishponds with housefly maggot meal).Different letters (a, b) on median values denote significant differences between them ($P < 0.05$; Mann-Whitney test).

Variables	Fishponds								
	E9			E7			E8		
	Min	Max	Med	Min	Max	Med	Min	Max	Med
Température (°C)	27.6	29	28.15^{a}	245	28.02	27.8^{a}	25.6	28.9	28.2^{a}
Dissolved oxygen (mgL)	4.93	6.08	6.08^{a}	23	5.1	4.15^{b}	2.8	5.5	3.55^{b}
PH	6.93	8.08	8.08^{a}	43	7.1	6.15^{a}	4.8	7.5	5.55^{a}
Conductivity (µS/cm	31.5	48.8	43.8^{a}	46.1	67.1	58.5^{b}	55.6	67.5	60.15^{b}
transparency (cm)	30	46	38^{a}	9	18	15.5^{b}	11	17	15^{b}
Nitrate (mgL)	0.26	0.38	0.335^{a}	0.38	0.58	0.45^{b}	3.38	0.58	0.45^{b}
Ammonium (ngl.)	0.031	0.058	0.0445^{a}	0.032	0.046	0.042^{a}	0.036	0.042	0.039^{a}
Phosphate (mg/L)	0.209	0.409	0.2625^{a}	0.312	0.52	0.416^{b}	0.3	0.51	0.405^{b}

At the adult stage, the highest values of taxonomic richness were observed in the fishponds E7 (59 taxa) and E8 (61 taxa) and the lowest was registered in the fishpond E9 (41 taxa). The total richness at this period was 90 taxa (Table 4). The phytoplankton community was dominated also by the Chlorophyta with the highest proportion (42 %) obtained in the fishponds E9 and E7 (Fig. 3).

Concerning the diversity, at the juvenile and adult stages, the minimal values of rarefied richness (2.39) were obtained in E1, while the maximal values (26.65) were registered in the fishponds that received housefly maggot meal (E4). Shannon-Weaver index oscillated between 0.18 and 2.75, respectively, in E1 and E4 at the juvenile stage. The low values (0.47) and the high values (0.91) of Evenness were observed respectively in the fishponds E1 and E4 at the juvenile and adult stages (Fig. 4). The rarefied richness, Shannon-Weaver index and Evenness varied significantly between the fishponds E1 and the others (Mann-Witney test, $p < 0.05$). At the adult stage, the values of rarefied richness oscillated between 2.36 (E9) and 26.62 (E8). Relatively to Shannon-Weaver index, it varied from 0.17 (E9) to 2.73 (E8). Concerning the Evenness, the values oscillated between 0.46 (E1) and 0.80 (E8). Those parameters varied significantly between the fishponds E9 and the others (Mann-Witney test, $p < 0.05$).

As concerning the biomass of phytoplankton, values oscillated between 45 µg/L (E1) and 321 µg/L (E4)

during the juvenile stage. In the adult stage, this parameter varied from 50 µg/L (E9) to 325 µg/L (E8). The biomass varied significantly between the fishponds E1/E9 and E2, E3, E4, E7, E8 (Mann-Witney test, $p < 0.05$) during the two periods (Fig. 5). Relatively to the abundance, the Chlorophyta were the most abundant. The proportions of this branch varied between 35.78 % (E3) and 55.04 % (E1) during the juvenile stage and between 34.46 % (E8) and 48.78 % (E9) during the adult stage (Fig. 6). About the frequency of occurrence (FO), *Aphanocapsagrevillei* (Cyanobacteria) was the only commonest taxa (FO ≥ 50 %) found at all the sampling fishponds. At the juvenile stage, *Lepocinclis* sp. (Euglenophyta) was very frequent (FO > 50 %) at the fishponds E1, E2, E3, E4. Conversely, the Cyanobacteria taxa *Microcystisaeruginosa*, *Planktolyngbyacontorta* and *Planktolyngbyalimnetica* were very frequent (FO > 50 %) at the fishponds E7, E8, E9 (Table 4).

Relationships between environmental variables and phytoplankton communities

Focused Principal Component Analysis (FPCA) was performed using environmental parameters with a focus on the most abundant Chlorophyta taxa. Thus, the ACPF indicates that all three taxa (*Closterium* sp., *Staurastrum* sp., *Scenedesmuscommunis*) are positively correlated to dissolved oxygen, transparency and phosphate but negatively to conductivity, nitrate and ammonium. However, dissolved oxygen influence significantly the abundance of the most abundant phytoplankton taxa (Fig.7).

Table 4. List of phytoplankton taxa at the juvenile and adult stages of Oreochromis niloticus in the study fishponds of Blondey (Ivory Coast, West Africa) (E1 and E9 = fishponds without exogenous feed; E2 and E7 = fishponds with fishmeal; E3 = fishpond with earthworm meal; E4 and E8 = fishponds with housefly maggot meal; * = rare occurrence; ** = frequent; *** = very frequent).

Taxa	Acronyms	Fishponds						
		Juvenile stage				Adult stage		
		E1	E2	E3	E4	E7	E8	E9
CYANOBACTERIA								
Cyanophyceae								
Chroococcales								
Chroococcaceae								
Chroococcus minutus (Kützing) Nägeli	Chmi			*	*		*	*
Chroococcus turgidus (Kützing) Nägeli	Chtu	*	*			**	**	
Aphanothecaceae								
Aphanothece castagnei (Kützing) Rabenhorst	Apca	*	*	*	*	*	*	*
Microcystaceae								
Microcystis aeruginosa (Kützing) Kützing-	Miae			***	**	**	***	**
Microcystis flosaquae (Wittrock) Kirchner	Mifl					*	*	*
Microcystis sp.	Misp			*		*		
Nostocales								
Aphanizomenonaceae								
Dolichospermum Crassum (lemmermann) P. Wacklin, L. Hoffmann & Komáre	Docr	*		**	*		**	*
Dolichospermum danicum (Nygard) P. Wacklin, L. Hoffmonn & J. Komàrek	Doda			*	*	*		
Synechococcales								
Leptolyngbyaceae								
Leptolyngbya perelegans(lemmermann) Anagnostidis & Komàrek	Lepe							*
*Planktolyngbya contorta (*lemmermann) Anagnostidis & Komàrek	Plco	*		**	**	**	**	**
Planktolyngbya limnetica(lemmermann) Komàrkovà-Legnerovà & Cronberg	Plli			*	*	***	***	***
Planktolyngbya sp.	Plasp							*
Merismopediaceae								
Aphanocapsa grevillei (Berkeley) Rabenhorst	Apgr	***	***	**	**	**	**	**

Table 4: (continued)

Taxa	Acronyms	Fishponds						
		Juvenile stage				Adult stage		
		E1	E2	E3	E4	E7	E8	E9
Aphanocapsa holsatica (lemmermann) G. Cronberg & Komàrek	Apho							
Aphanocapsa incerta (lemmermann) G. Cronberg & Komàrek	Apic			***	**	***	**	
Aphanocapsa sp.	Apsp				**	**	***	
Gleocapsa sp.	G1sp							
Limnococcus limneticus (lemmermann) Komàrkovà, O. Komàrek & Zap	Lili		*	***	**	**	*	*
Merismopedia glauca (Ehrenberg) Kützing	Megl		*	**			**	
Merismopedia punctata Meyen.	Mepu	**			*		*	**
Merismopedia sp.	Mesp				*	**	*	
Coelosphaeriaceae								
Coelomoron sp.	Cosp			**	***	*	**	*
Pseudanabaenaceae								
Pseudanabaena limnetica (lemmermann) Komàrek	Psli					*	*	*
Oxillatoriales								
Oscillatoriaceae								
Microseira Wollei (Faelow ex Gomont) G.B. Mcgregor & Sendall ex Kenins	Miwo				*	*		
Oscillatoria crassa (C. B. Rao) Anagnostidis	Oscr		***				**	
Oscillatoria ornata kützing ex Gomont	Osor				*			
Microcoleaceae								
Kamptonema Formosum (Bory ex Gomont) Strunecky, Komàrek & J. Smardda	Kafo				**	*		*
Gomontiellaceae								
Komvophoron sp.	Kosp						*	
EUGLENOPHYTA								
Euglonphyceae								
Euglenales								
Euglenaceae								
Euglena breviflagellum Prescott & Gojdics	Eubr							
Euglena gracilis Klebs	Eugr		*	*		*	*	**

Table 4: (continued)

Taxa	Acronyms	Fishponds						
		Juvenile stage				Adult stage		
		E1	E2	E3	E4	E7	E8	E9
Euglonphyceae								
Euglenales								
Euglenaceae								
Euglena granulata (G. A. Klebs) F. Schmitz Dangard	Euga		***	**		*	**	
Euglena pusilla Playfair	Eupu							
Euglena rostrifera Ehrenberg	Euro				***	**	*	
Euglena sp.	Eusp		*		***	*		*
Euglena spirogyroides B. Marin & Melkonian	Euspi							*
Euglena variabilis G. A. Klebs	Euva			*	*	*	*	
Euglenaformis proxima (Dangeard) M. S. Bennett & Triemer	Eupr		*		*	*		*
Euglenaria clavata (Skuja) Karbkowska & E. W. Linton	Eucl		*		*		*	
Strombomonas sp.	Stsp					*		
Trachelomonas armata (Ehrenberg) F. Stein	Tarm		**			**		
Trachelomonas armata (Ehrenberg) var.*armata* Deflandre	Trar	*		*			*	*
Trachelomonas dastuguei var. *dastuguei* f. *Africana* Couté & Iitis	Trda		*		*	*	*	
Trachelomonas planctonica Svirenko	Trpl			*	**	*	**	
Trachelomonas sp.	Trsp	*				*		
Trachelomonas volvocina (Ehrenberg) Ehrenberg	Trvo	*	*	***	*	*	*	**
Phacaceae								
lepocinclis acus (Müller) B. Marin & Melkonian	Leac		**			*	*	*
Lepocinclis ovum (Ehrenberg) lemmermann	Leov		*		**	*		
Lepocinclis salina Fritsch	Lesa		*	*				
Lepocinclis sp.	Lesp	**	***	**	**	*		**
Lepocinclis turbiniformis Deflandre	Letu							*
Phacus acuminatus Stokes var. *acuminatus* Roll	Phac			*	*	*		
Phacus lefevrei Bourrelly	Phle				**	*		
Phacus Limnophilus (lemmermann) E. W. Linton & Karnkowska-Ishikawa	Phli		***		**	**	***	*
Phacus longicauda (Ehrenberg) Dujardin	Phlo	***			**		*	

Table 4: (continued)

Taxa	Acronyms	Fishponds						
		Juvenile stage				Adult stage		
		E1	E2	E3	E4	E7	E8	E9
Phacaceae								
Phacus onyx Pochmann	Phon							
Phacus platalea Drezepolski & major De Poucques	Phpl			*	*	**	*	*
Phacus ranulus Pochmann	Phra			***			*	*
Phacus rotundus (Pochmann) Zakrys & M. Lukomska	Phro							
Phacus suecicus Lemmermann	Phsu							
Phacus swirenko Skvortzov-Unchecked	Phsw					**	*	*
Phacus tortus (Lemmermann) Skvortzov	Phto				***		**	
CHLOROPHYTA								
Chlorophyceae								
Sphaeropleales								
Hydrodictyaceae								
Goniochloris mutica (A. Braun) Fott	Temu		*	**		*	*	
Parapediastrum biradiatum var. *longicornutum* (Gutwinski) Tsarenko	Pabi	**	*				*	**
Pediastrum duplex Meyen	Pedu				**	**		
Stauridium cf. *tetras* (Ehrenberg) E. Hegewald	Stct			***	*		*	*
Stauridium tetras (Ehrenberg) E. Hegewald	Stte		**	*				
Tetraedron minimum (A. Braun) Hansgirg	Temi						*	
Tetraedron sp.	Tesp	*			*		*	*
Tetraedron tumidulum (Reinsch) Hansgirg	Tetu		**	*		**	*	
Selenastraceae								
Ankistrodesmus arcuatum Korshikov	Anac		**	*	**	*	*	*
Ankistrodesmus falcatus (Corda) Ralfs	Anfa	*	*					
Ankistrodesmus sp.	Ansp	**	*		**	**	*	
Selenastrum bibrainus Reinsch	Sebi		***	**	*		**	*
Cylindrocapsaceae								
Fusola viridis J.Snow	Fuvi							*

Table 4: (continued)

Taxa	Acronyms	Fishponds						
		Juvenile stage				Adult stage		
		E1	E2	E3	E4	E7	E8	E9
Scenedesmaceae								
Coelastrum pulchrum Schmidle	Copu	*	*		*	*	*	*
Desmodesmus abundans (Kirchner) E. H. Hegewald	Deab						**	
Desmodesmus acuminatus Lagerheim	Deac			**		*	*	
Desmodesmus armatus var. *bicaudatus* (Guglielmetti) E. H. Hegewald	Dear							
Desmodsemus sp.	Desp				*		*	
Scenedesmus arcuatus Lemmermann	Scar	*	**	*				
Scenedesmus communis E. Hegewald	Scco		*	***	*	*	*	
Scenedesmus obliquus (Turpin) M. J. Wynne	Scob		**	**		*		
Scenedesmus producto-capitatus Schmula	Spro							
Scenedesmus quadricauda var. *quadricauda* Chodat	Scqu		*					
Scenesdesmus naegelii Brébisson	Scna	**			*	*		**
Tetradesmus bernardii (G.M.Smith) M. J. Wynne	Tebe		*	*		*		*
Tetradesmus lagerheimii M. J. Wynne & Guiry	Scla						**	
Schroederiaceae								
Schroederia sp.	Scsp		*			*		
Trebouxiophyceae								
Chlorellales								
Oocystaceae								
Crucigenia fenestrata (Schmidle) Schmidle	Crfe		*		*	*	*	
Crucigeniella sp.	Crsp	*						
Zygnematophyceae								
Zygnematales								

Table 4: (continued)

Taxa	Acronyms	Fishponds						
		Juvenile stage				Adult stage		
		E1	E2	E3	E4	E7	E8	E9
Desmidales								
Closteriaceae								
Closterium sp.	Clsp	*	**		*	*	*	*
Closterium venus Kützing ex. Ralfs	Clve				***	**		
Desmidiaceae								
Staurastrum teliferum var. *gladiosum* (W. B. Turner) Coesel & Meesters	Stgl	*			*	*	*	
Euastum sp.	Easp		*	*			**	
Staurastrum brachioprominens Börgesen	Stbr							
Staurastrum forficulatum Lundell	Stfo			*	***	*	*	
Staurastrum fusiformis var. *leptodesmus* W. & G.S.West	Stfu	***						**
Staurastrum sp.	Stsp	**		*	*		**	
Staurastrum volans West & G.S.West	Stvo				**	*		
Staurodesmus convergens (Ehrenberg ex Ralfs) S. Lillieroth	Stco			*	*		*	
Staurodesmus dickei (Ralfs) S. Lillieroth	Stdi				**	*		*
Staurosdesmus sp.	Stsp							
Staurosdesmus triangularis (Lagerheim) Teiling	Sttr			***			**	
BACILLARIOPHYTA								
Bacillariophyceae								
Eunotiales								
Eunotiaceae								
Eunotia sp.	Eusp			*			*	
Naviculales								
Pinnulariaceae								
Pinnularia sp.	Pisp	*			*	*		

Table 4: (end)

Taxa	Acronyms	Fishponds						
		Juvenile stage				Adult stage		
		E1	E2	E3	E4	E7	E8	E9
DINOPHYTA								
Dinophyceae								
Peridiniales								
Peridiniaceae								
Peridinium sp.	Pesp							*
Peridinium volzii Lemmermann	Pevo			*	*	*	*	
Thoracosphaerales								
Thoracosphaeraceae								
Apocalathium aciculiferum (Lemmermann) Craveiro,Daugbjerg, Moestrup & Cala(	Apac				*		*	
TOTAL = 111		26	47	44	53	59	61	41
		83 taxa				90 taxa		

***Very frequent (FO > 50%), **frequent (25% ≤ FO ≥ 50%), *rare occurrence (FO < 25%).

Discussion

A total of 111 phytoplankton taxa were inventoried in the fishponds of Blondey. This relative wealth could be explained by the fact that they were ponds. Indeed, the stability of these hydrosystems would favor the development of planktonic species. The branchs of Chlorophyta and Euglenophyta were the most diversified with respectively 38.94% and 29.20%. This wealth was lower than that obtained (192 taxa) by Bamba (2007)on the same farm. The difference in wealth could be related to the sampling effort. Indeed, this author sampled a high number of structures with also a high frequency (every 10 days).

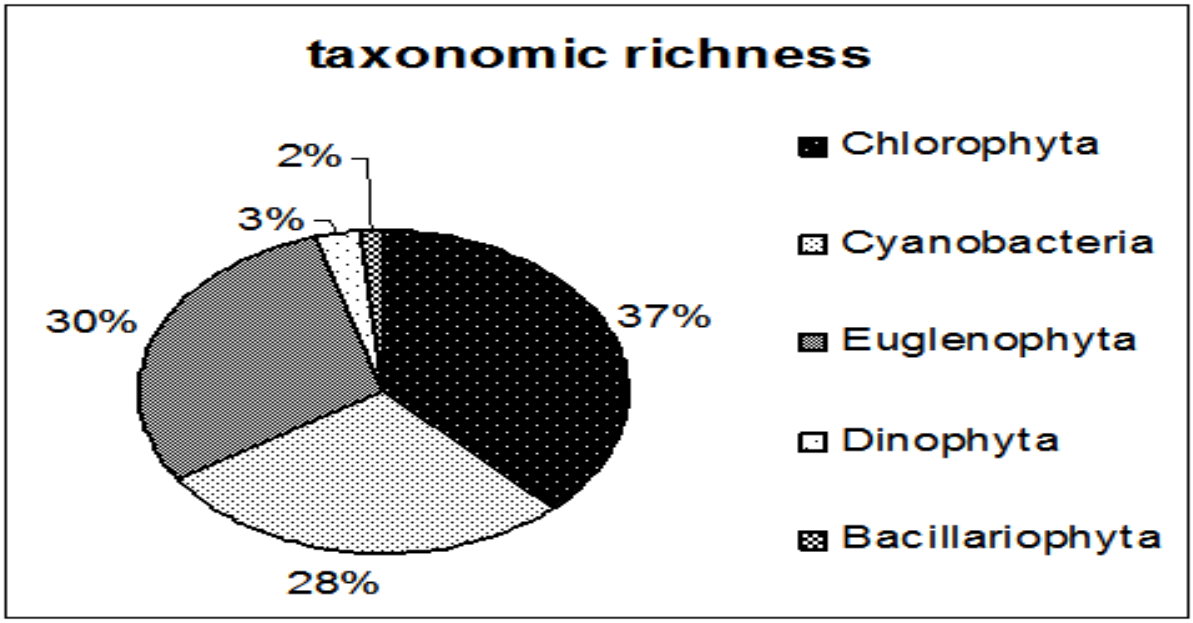

Fig. 2. Global taxonomic richness of phytoplankton in the fishponds of Blondey (Ivory Coast, West Africa).

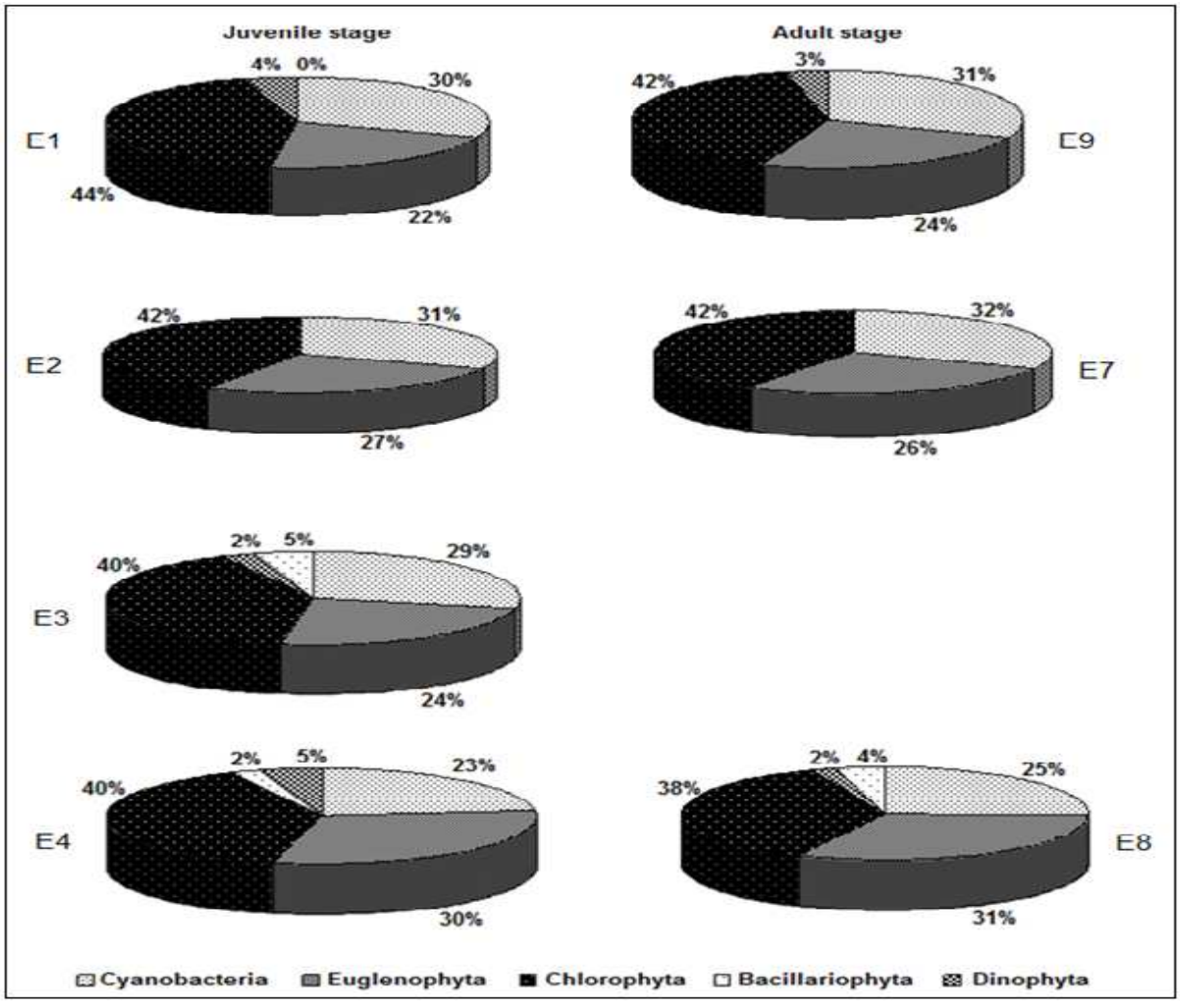

Fig. 3. Relative composition of the phytoplankton in the fishponds of Blondey (Ivory Coast, West Africa) (E1/E9 = fishponds without exogenous feed; E2/E7 = fishponds with fishmeal; E3 = fishpond with earthworm meal; E4/E8 = fishponds with housefly maggot meal) at the juvenile and adult stages of *Oreochromis niloticus*.

Overall, the fishponds that received the exogenous foods (E2, E3, E4, E7, E8) contained the highest values of taxonomic richness compared to those obtained in fishponds without exogenous foods (E1 and E9). This relatively higher richness in the fed ponds could be due to high nutrient content (nitrate and phosphate) resulting from the high mineralization activity that occurred in these ponds. Indeed, the ponds receiving the exogenous foods recorded a large amount of organic matter from the remains of exogenous food distributed. According to Shohr (2015), Baccarin and Camargo (2005), the decomposition of this organic matter provided a large amount of assimilable nutrients including phosphorus microalgae and promote their development. Of the five (5) phytoplankton phyla collected on the Blondey fishponds, the most diversified were the Chlorophyta, Euglenophyta and Cyanobacteria with respectively 37 %; 30% and 28% of the taxonomic richness.

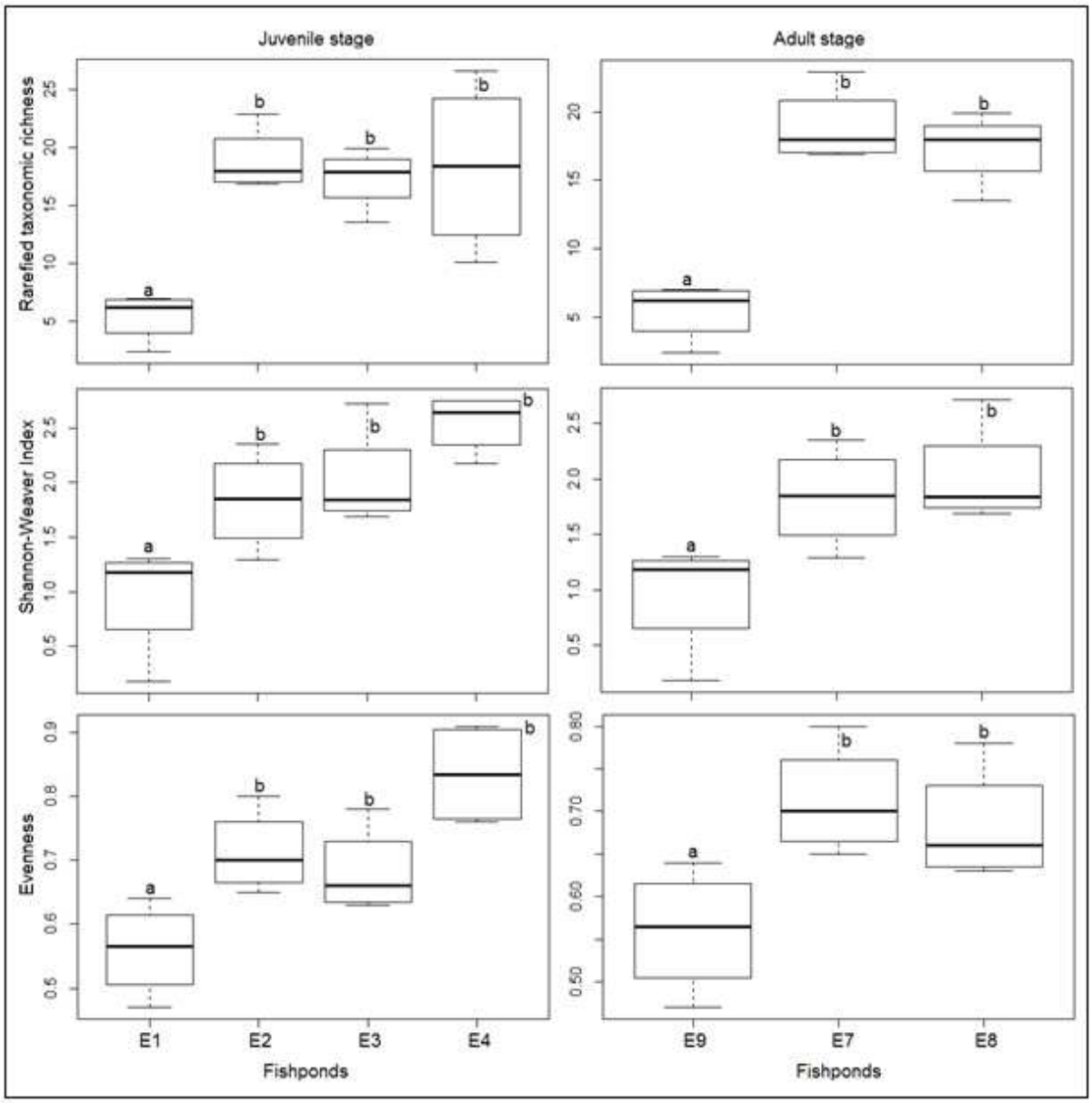

Fig. 4. Box-plots showing variations in diversity index of phytoplankton between fishponds of Blondey (Ivory Coast, West Africa) (E1/E9 = fishponds without exogenous feed; E2/E7 = fishponds with fishmeal; E3 = fishpond with earthworm meal; E4/E8 = fishponds with housefly maggot meal) at the juvenile and adult stages of *Oreochromis niloticus*, different letters on box-plots denote significant differences between them ($P < 0.05$; Mann-Whitney test).

These taxa could reflect the overall pollution status of the Blondey fishponds due to the enrichment of organic matter from the exogenous foods remains distributed and the oil palm plantation surrounding the farm (Thomas, 2003). With respect to the rearing stage, very few taxa were observed in juvenile stage compared with adult stage. This result could be justified by the length of rearing that could affect the amount of organic matter accumulated in the ponds. Juvenile stage ponds last for three months, while the adult stage taken six months. According to Schlumberger and Bouretz (2002), the amount of accumulated organic matter depends on the density of fish loading and the duration of rearing.

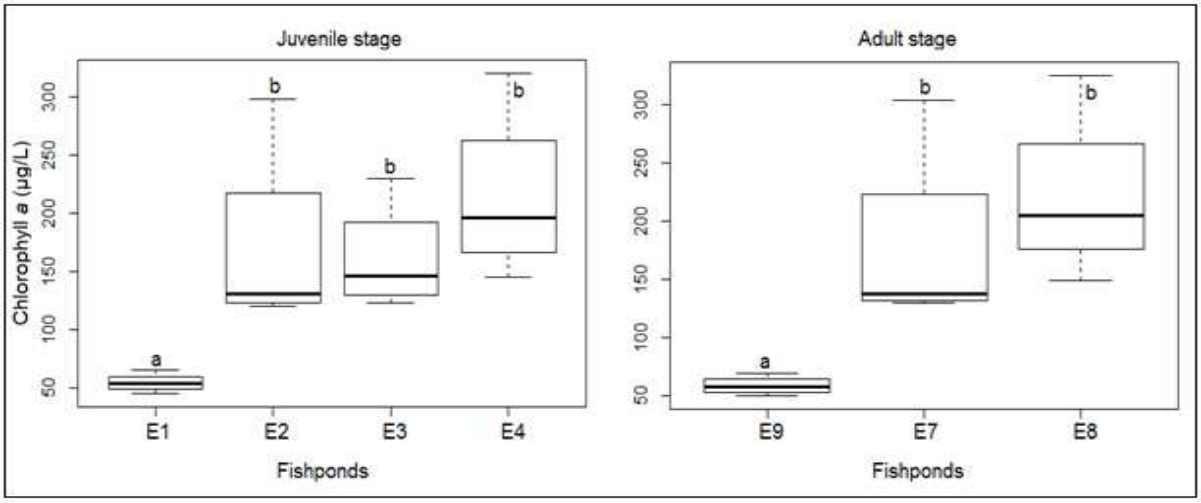

Fig. 5. Box-plots showing variations in biomass of phytoplankton between fishponds of Blondey (Ivory Coast, West Africa) (E1/E9 = fishponds without exogenous feed; E2/E7 = fishponds with fishmeal; E3 = fishpond with earthworm meal; E4/E8 = fishponds with housefly maggot meal) at the juvenile and adult stages of *Oreochromis niloticus*,different letters on box-plots denote significant differences between them ($P < 0.05$; Mann-Whitney test).

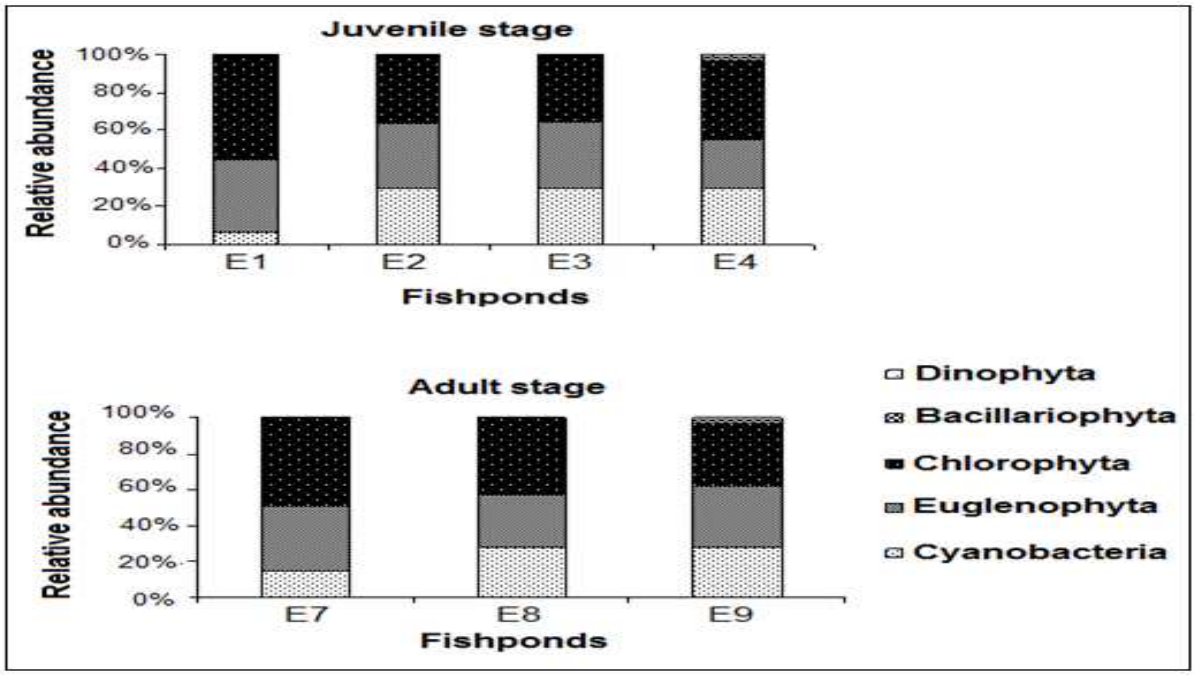

Fig. 6. Relative abundance of phytoplankton in the fishponds of Blondey (Ivory Coast, West Africa) (E1/E9 = fishponds without exogenous feed; E2/E7 = fishponds with fishmeal; E3 = fishpond with earthworm meal; E4/E8 = fishponds with housefly maggot meal) at the juvenile and adult stages of *Oreochromis niloticus*.

The values of the rarefied wealth and the Shannon-Weaver index were significantly higher in the ponds that received exogenous feed than in the ponds without exogenous feed, regardless of the rearing phase. This could translate to a more diverse phytoplankton stand with the supply of exogenous feed. The evenness value was greater than or equal to 0.6 at the level of all the food treatments. This finding could also reflect a well-organized phytoplankton population. However, these indices reveal a significant variation between the ponds receiving the exogenous foods and the control ponds. The variability of these parameters could be explained by the difference in nutrient content (nitrate and phosphate) between the two groups of stations. The results corroborated with those of Hasnaoui*et al.* (2007) obtained in nursery ponds in Morocco.

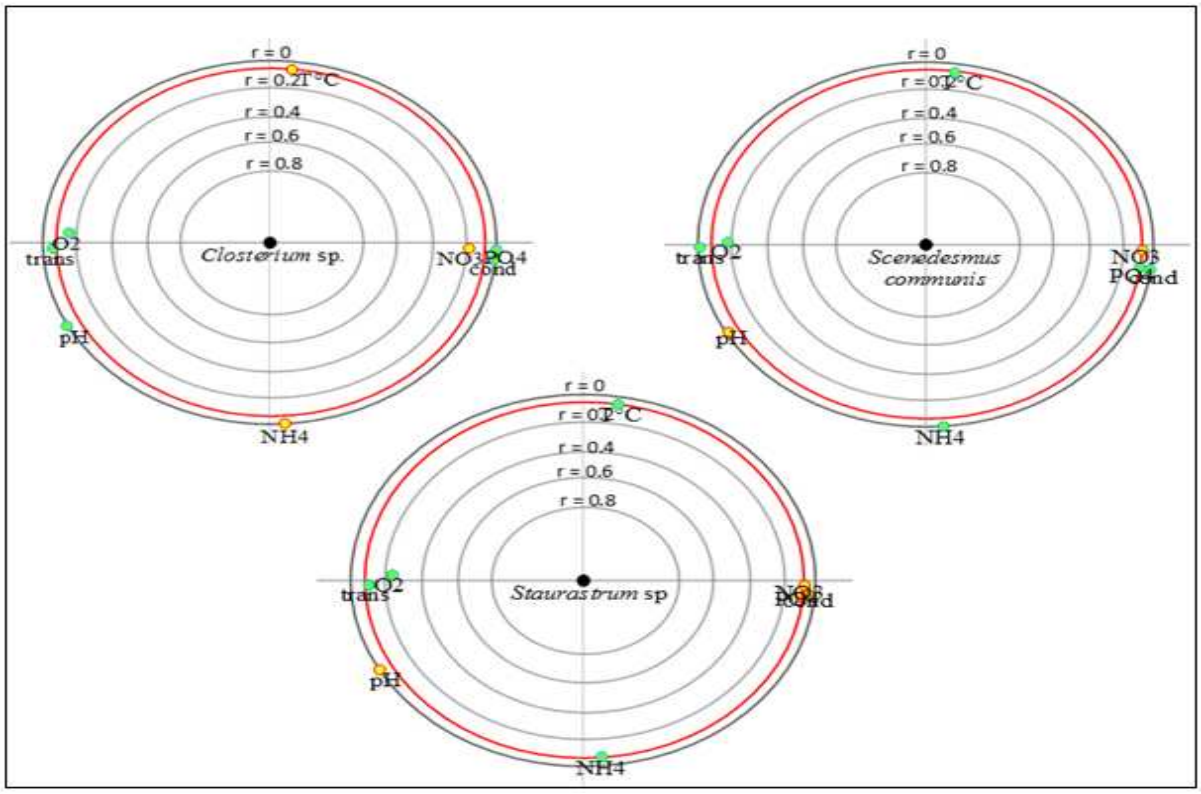

Fig. 7. Graphs illustrating the results of Focused Principal Component Analysis (FPCA) based on the three most abundant Chlorophyta taxa as dependent variables and the physico-chemical parameters representing the independent variables. The yellow dots correspond to the abiotic parameters negatively correlated to the abundance of the taxon while the green dots indicate those which are positively correlated with the abundance of the taxon. The points inside the red circle represent the parameters significantly ($P < 0.05$) correlated with the abundance of the taxon (*Closterium* sp., *Staurastrum* sp., *Scenedesmus communis*, trans = transparency, T°C = temperature, cond = conductivity, o2 = dissolved oxygen, pH = hydrogen potential, PO4 = phosphate, NH4 = ammonium, NO3 = nitrate).

At the quantitative level, phytoplankton was more abundant in adult stage than in juvenile stage, certainly because of the nutritional needs of fish, as mentioned by Hasnaoui*et al.* (2007). According to this author, diet and nutritional requirements are dependent on the stage of growth. In addition, this variation was justified by the phenomenon of grazing exerted by zooplankton and other filtering organisms as showed by Pinel-Alloul (1995). As for phytoplankton biomass, it was significantly higher in the ponds with exogenous foods than in the other ponds. Indeed, the exogenous supply of food in these ponds could increase the nutrient content and promote algal development in these areas

(Kestemont, 1996; Mélard, 2006) compared to other ponds.

Conclusion

Concerning the biotic characterization, the phytoplankton population analysis mentions 111 taxa distributed between five phylum including Bacillariophyta (02 taxa), Chlorophyta (42 taxa), Cyanobacteria (31 taxa), Dinophyta (03 taxa) and Euglenophyta (33 taxa). Fishponds that received exogenous food contained the highest values of taxonomic richness E2 (47 taxa), E3 (44 taxa), E4 (53 taxa), E7 (59), E8 (61), in contrast to the ponds that did not receive the exogenous foods E1 (26 taxa), E9 (41 taxa). During the two fish culture periods, the taxonomic richness was high in the fishponds that received exogenous foods and low in those without exogenous foods. Housefly maggot meal is the best exogenous food, which increases the diversity and structure of the phytoplankton community. The Focused Principal Component Analysis (FPCA) indicated no significant influence of physico-chemical parameters on the most abundant taxa of phytoplankton in Blondey fishponds.

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