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# Water quality and productivity of the traditional aquaculture system (whedos) in Oueme delta (Benin)

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## ABSTRACT

In regard to improve the fish yield of the whedos (traditional fish ponds) by stocking and rearing during the draw-down period, we assessed their water quality comparatively to those of the Oueme River on which they depend. Variables such as pH, $K_{25}$, $NO_2^-$ and cladocerans density were similar in both systems while temperature, dissolved oxygen, transparency and microalgal biomass were significantly lower ($P<0.05$) in the whedos than the river channel. Using multivariate analyses, it was demonstrated that the variability of water quality in the whedos depends not only on their size but also on their width and water height. Moreover, many fish species were observed in the whedos (*Clarias*, *Ctenopoma*, *Parachanna*, *Protopterus*, *Polypterus*, *Malapterurus*, *Xenomystus* and *Brienomyrus*) and all display adaptations for survival in low dissolved oxygen conditions. The macrophytes were also abundant in the whedos and very diversified (24 species). In summary, the observations carried out in the whedos during this study show that the quality of their water limits consequently the possibilities to stock many fish species. However, potentiality of improving the fish yield of the whedos by stocking and rearing air breathing fish species during the draw-down period is currently debated.


**Keywords :** Whedo, fisheries management, water quality, plankton, fish stocking.

## INTRODUCTION

In the South Benin wetlands, a traditional practice of fish rearing in trenches dug in the floodplains and locally called “whedos” are common. This practice is especially developed in the Oueme river valley (South-east Benin) which, each year, knows in its plain a flood that lasts approximately six months (from July to December). At the draw-down period, when the floodplains are dry, intensive fishing activities proceed in more than 1000 whedos of various sizes (Imorou Toko, 2007). In spite of their importance in the local fish production, no data of whedo water quality are available. However, considering the


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capital role played by the whedo exploitation in the improvement of fish production, and therefore, in the enhancement of fishermen livelihood conditions and economic incomes, the need to get a better knowledge of the physicochemical and biological quality of the water in these holes is obvious. Furthermore, the assessment of water quality in these whedos as well as the analyses of its planktons (microalgal biomass and zooplankton), constitute an essential precondition to their management and development in regard to increase their fish output. The outputs were high from 1955 to 1958, averaging 2.12 t/ha/year, but were reduced between 1968 to 1970 at 1.57 t/ha/year and further declined to 0.8 t/ha/year in 2003 (Welcomme et al., 2004). This marked decline in yield could correspond to a reduction in the populations of fish in the Oueme due to very heavy fishing. Therefore, stocking whedos with some fish species after traditional exploitation (*i.e.* from February to June), is a necessary alternative to enhance their yields.

Indeed, stocking of closed floodplain pool similar to the whedos, has been previously reported in different countries. It is a highly practical way to increase yields of marketable fish and one that can be also integrated with other agricultural practices as the agro-cultural systems of Mexico (Micha et al., 1992) and Rwanda (Barbier et al., 1985). Moreover, in Hungary, stocked relic floodplain water bodies gave yields similar to traditional aquaculture in ponds (Pinter, 1983). In Bangladesh, Ahmed (1998) reported that stocking small floodplain lakes may increase yield by about eight times. Large wetlands stocked with carp species in India also give better yields than the natural production without stocking, increasing from 300 to 2000 kg/ha/year (Sugunan et Sinha, 2001). In the tropics, stocking small water bodies in Burkina Faso with 20 kg (800 fingerlings) of Nile tilapia (*Oreochromis niloticus*) per hectare increased yield from 23 to 269 kg/ha (de Graaf et Waltermath, 2003).

In order to improve their yield by fish stocking during the dry season, fisheries management and water quality of the whedos were examined during this study.

## MATERIALS AND METHODS

The management study was based on literature review, personal investigations and field data supplied by fishery workers. The ecological study was carried out from 1999 to 2011, each year during the dry season period (from March to June) in twelve whedos previously exploited and located in the Oueme valley at Gangban village (06°39′N - 02°27′E.), 108 km northeast from Cotonou (Figure 1). The physical characteristics of these whedos are shown in Table 1.

### Geographical characteristics of the study zone

The Oueme valley covers an area of approximately 100,000 ha and in some zones as much as 13% of the areas are exploited as whedos (Welcomme, 1975). The climate of this valley is subequatorial, called "Guinean" and characterized by four seasons: (i) a short rainy season, from October to November; (ii) a long dry season, from December to March; (iii) a long rainy season, from April to July, and (iv) a short dry season, from August to September. The average temperature is about 27 °C (with a diurnal thermal difference fluctuating between 3 and 4 °C). The maximum ambient temperature is observed in March (29.5 °C) and the minimal in August (26 °C). From 1996 to 2011, annual rainfall averaged 1300 mm. Rains are irregular in time and space. Although the maximum rainfall is observed in May-June (165-250 mm), the water level in the Oueme River is not generally sufficient to flood the plains. The relative humidity is high, and almost constant. The minimum moisture is recorded in February (75%) and the maximum in July (84%). The periods of sunshine amount to approximately 1700 hours/year, and the wind is relatively variable in intensity.

The relief of the Oueme floodplain presents low lying plateaus slightly inclined towards the main river channel, and a swampy coastal zone (around Porto-Novo, Sô-Ava and Cotonou; Figure 1). The pedology of the valley indicates high proportion of clay. The grounds are impermeable, compact, and seasonally inundated. Two major pedological formations are thus distinguished: (i) the levee that is muddy-argillaceous or muddy-sandy, in the immediate surroundings of the river, and (ii) the flat, nether zone which is located between the levee and the plateau delimiting the plain, and receives the water of the river during the flooded period (approximately 1.5 to 2 m height). The whedos and many villages of the Oueme delta, which are susceptible to be flooded six months a year, are constructed in this zone where the grounds are flat, rich in alluvia and clay.

**Physicochemical measurement**

Physicochemical parameters of water were monitored fortnightly between 10.00 and 11.00 h in the twelve whedos already exploited and in the main Oueme River channel (approximately 200-800 m from the whedos) as reference. Temperature (T), dissolved oxygen (DO), pH and conductivity ($K_{25}$) were recorded directly by portable digital water quality analysers (WTW Oxy 197, WTW pH330 and WTW LF340 for T and DO, pH and K respectively) at approximately 10 cm depth and transparency (Transp.) by Secchi disk. Nitrite ($NO_2^-$) and ammonium ($NH_4^+$) were determined by HACH water analysis kit (NitriVer® 3 Nitrite reagent for nitrite and spectrophotometric method using Nessler reagent for ammonium) in water samples collected from each whedo and stored in plastic bottles (1.5 l) until analysis the same day at the laboratory.

The daily variations of T, DO, pH and $K_{25}$ were also measured fortnightly from 07.00 to 19.00 h in these whedos according to the same methods.

**Determination of microalgal biomass**

The water samples (1.5 l) were collected fortnightly in the 12 whedos and in the main river channel, stored in plastic bottles and transported to the laboratory where they were immediately analysed for chlorophyll a (Chl. a) determination. For this purpose, the samples were prefiltered using a 200-µm mesh filter to remove coarse material, then filtered through a Whatman GF/C filter, with 0.45-µm porosity and 90 mm diameter, using a Millipore vacuum pump (KNF Neuberger, type N 022 AT. 18) at a pressure of 25 kPa. The filtered residue was put in a test tube, 5 ml of the solvent (acetone-methanol mixture 5:1) was added, and then stored during 24 h at 4 °C. The optical density of each extract was measured at 665 nm, before and after acidification (HCl 0.1N) (Lorenzen, 1967) using a spectrophotometer (WPA, S104). The chlorophyll a concentration in each extract was determined by difference according to Marker, Nusch et al. (1980) and Pechar (1987), using equation (1) where Db : optical density of extract before acidification; Da : optical density of extract after acidification; v : volume of total extract (ml); V : volume of water sample filtered (l); d : diameter of the optical cell used (cm).

$$Chl.a\,(\mu g\, l^{-1}) = \frac{v}{V \times d} \times (Db - Da) \times 2.439 \times 11.89 \qquad (1)$$

A rough microalgal biomass was computed from the chlorophyll a values. Assuming that chlorophyll a constitutes, on the average, 1.5% of the dry weight of organic matter (ash-free weight) of algae, the algal biomass can be estimated by multiplying the chlorophyll a content by a factor of 67 (APHA, 1992; Raschke, 1993).

**Zooplankton monitoring**

Quantitative estimates of zooplankton density (copepods and cladocerans) in the whedos and the main river channel were also made fortnightly. Samples were collected by scooping the first 10 cm of water with a fine-meshed plankton net (55 µm), so that approximately 20 l were filtered. The concentrated samples (more or less 100 ml) were preserved immediately with 4% buffered formalin in plastic bottles (250 ml). Microcrustacea (cladocerans and copepods) were counted with a binocular at 10X to 40X magnification by using a sub-sampling (3 x 10 ml) technique (APHA, 1992). The following equation (2) was used to compute their density:

$$No\,.\,l^{-1} = \frac{n \times V_1}{V_2 \times V_3} \quad (2)$$

where

n : number (No.) of organism counted; $V_1$ : volume of the concentrated sample (ml); $V_2$ : volume of sub-sample (ml); $V_3$ : volume of the water filtered (l).

**Other organisms of the whedos**

Before starting these investigations, the experimental fishing was carried out in the selected whedos at the end of January. Fishing in the whedos is an operation which can last several days. Before fishing, the daily part of whedo to be exploited was delimited with a net or a barrier achieved locally with bamboo sticks. In this compartment, the floating vegetation was removed and the fish were then captured by two to four fishermen using a trailing net. After 4 to 6 turns with this net, various equipments namely current basket, conical basket, cylindrical drum trap or funnel trap were then used to catch the fish that escaped the net. The diversity of the catch was determined using the West African Fishes Determination guides (Daget and Durand, 1981; Lévêque et al., 1990) and specimens were preserved in glass bottles with 4% buffered formalin. In each whedo, fish were counted by species and the abundance (Equation 3) of each species and their occurrence (Equation 4) were calculated as follow:

$$\text{Abundance (\%)} = \frac{\text{No.} \times \text{species}^{-1}}{\text{Total No.} \times \text{whedo}^{-1}} \times 100 \quad (3)$$

$$Occurence = \frac{No.\ of\ whedos\ where\ the\ species\ is\ observed}{Total\ No.\ of\ whedos} \quad (4)$$

The aquatic vegetation diversity was determined in each whedo before their exploitation. They were collected in the surface of the whedos and preserved fresh before identification at the laboratory with the assistance of botanists of the National Herbarium (University of Abomey-Calavi, Benin).

**Statistical analysis**

The inter-variation (whedo-river and between whedos) of the water quality parameters were tested using one-way analysis of variance (ANOVA). Significant results were further tested using LSD test to observe differences among months. An ordination of the whedos based on physicochemical parameters was obtained by carrying out a principal component analysis (PCA). Subsequently, a cluster ordination was applied in order to assess the inter-whedos variations. The stepwise multiple regression analysis was also used to identify physicochemical variables predictors of microalgal biomass, copepod and cladoceran densities. Before any statistical test, variance normality was examined by Hartley or Skewness test, and data (N) log-transformed according to Legendre et Legendre (1998) as follows: $\log_{10}$ (N + 1) for transparency, microalgal biomass, copepods and cladocerans abundance or $\log_{10}$ ((N + 0.001) x 1000) for $NO_2^-$ and $NH_4^+$. Before multivariate analysis, all variables were standardized (centred and reduced) to reduce co-linearity (Legendre et Legendre, 1998). The level for statistical significance was set at 0.05, 0.01 or 0.001.

All statistical analyses and graphical outputs were performed with R and ADE-4 softwares (Ihaka et Gentlemen, 1996; Thioulouse et al., 1997) and Statistica, version 4.0.

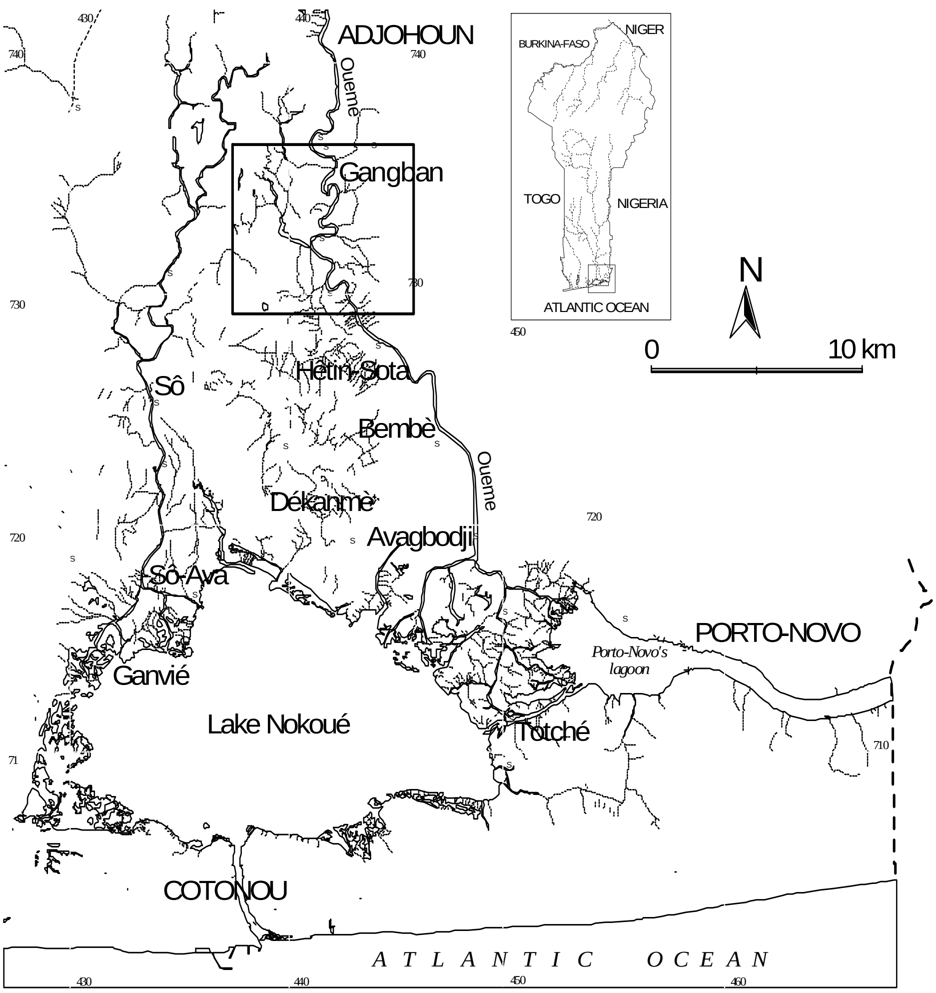


**Figure 1:** Map of the Oueme Valley showing the study area.

**Table 1:** Measurement of 12 whedos investigated during this study.

| No. | Length (m) | Width (m) | Water level[a] (m) | Area (m²) | Class[b] |
|---|---|---|---|---|---|
| 1 | 162.5 | 4.0 | 0.5 - 0.4 | 650 | M |
| 2 | 184.0 | 3.0 | 0.8 - 0.6 | 552 | M |
| 3 | 154.0 | 3.3 | 0.8 - 0.6 | 516 | M |
| 4 | 59.0 | 4.3 | 0.6 - 0.4 | 254 | S |
| 5 | 100.0 | 3.7 | 1.0 - 0.8 | 375 | S |
| 6 | 88.0 | 6.0 | 1.0 - 0.7 | 528 | M |
| 7 | 193.0 | 4.3 | 1.0 - 0.8 | 830 | L |
| 8 | 218.0 | 5.1 | 1.0 - 0.8 | 1112 | L |
| 9 | 121.0 | 6.0 | 1.1 - 0.9 | 726 | L |
| 10 | 162.5 | 4.1 | 1.0 - 0.7 | 666 | M |
| 11 | 173.3 | 2.1 | 0.7 - 0.6 | 364 | S |
| 12 | 84.0 | 2.7 | 0.5 - 0.3 | 227 | S |
| Mean | 141.6±50.0 | 4.1±1.2 | 0.8 – 0.6 | 567±253 | - |

[a]maximal - minimal values; Mean are value ± standard deviation; [b]S: small whedos (<375 m²), M: medium whedos (375-700 m²) and L: large whedos (>700 m²).

## RESULTS

### Fisheries management in the whedos

Various equipments, often specific, are used for maintenance and fishing in the whedos. Fishing in the whedos is an operation which can last several days. Before fishing, the daily part of the whedo to be exploited is delimited with a net or a barrier achieved locally with bamboo sticks. In this compartment, the floating vegetation is removed by the workers disposed on the dams and using a long pole. This vegetation and the fertile deposit of the bottom removed are leaved on the dikes, and thus used as fertilizer to improve vegetables production. The fish present in this compartment are then captured using a trailing net whose edges are especially replaced by wood. About 90% of the fishermen exploit their whedos once a year, generally between January and March (Imorou Toko, 2007).

Annual yield of the whedos has been estimated by various authors, either by experimental fishing or by stocking (Imorou Toko, 2007).

### Water quality characteristics

A comparison of water quality measurements from both the whedos and Oueme River channel is shown in Table 2. The values of ten water quality parameters were considered for comparison purposes. Parameters such as pH, $K_{25}$, $NO_2^-$ and cladoceran density were very similar in both systems while others, especially DO, transparency and microalgal biomass significantly differed between the whedos and the Oueme River (Table 2).

During the sampling period, DO, pH, $NO_2^-$, $NH_4^+$ and cladoceran density displayed a significant ($P<0.05$) monthly variation (Figure 2; Table 3). Some parameters, namely pH, $NO_2^-$ and microalgal biomass, decreased from March to June while DO and $NH_4^+$ increased.

Figure 3 shows the daily fluctuation in some physicochemical parameters in the whedos from March to June. Water temperature and DO vary significantly during the day while pH and $K_{25}$ were rather steady.

### Variability of the whedos according to physicochemical characteristics

A principal component analysis (PCA) was performed in order to assess the variability of the whedos based on their physicochemical characteristics (Figures 4A and 4B). On the other hand, the physicochemical variables variations in the whedos were appraised according to the month and the size of the whedos (Figures 4C and 4D).

The first two components accounted for 47.1% of total inertia. This analysis separated on the F1 axis factors such as T, pH, $K_{25}$, transparency and $NH_4^+$ with 27.4% of explained variance while $NO_2^-$ and DO were correlated to the F2 axis with 19.7% of explained variance (Table 4; Figures 4A). The PCA performed on the physicochemical dataset classified the 12 whedos studied into three groups (Figure 4B): the first group (whedos 3, 4 and 9) and group 2 (whedos 5, 8 and 10) are differentiated by their $NH_4^+$ concentration while group 3 is composed of whedos having high conductivity (whedos 1, 2, 6, 7 and 8).

The projection of the DO and $NO_2^-$ on the factorial plan of the PCA showed that their concentration in whedo increased from March to June while $NH_4^+$ concentration were higher in April and May than in March or June. pH was lower in April and May than in March and June (Figure 4C). On the other hand, no significant variations of the physicochemical parameters were observed according to the whedos size (Figure 4D). However, DO and $NO_2^-$ concentrations tended to be lower in small whedos than in medium and large ones.

The cluster ordination based on water quality parameters (physicochemical and plankton), water height and whedo size shows an obvious classification of the whedos (Figure 5). Two groups can be distinguished according to their size. The first group (I) is composed of the small size whedos (area < 364 m²: whedos 4, 11 and 12) and the second of the whedos which are larger than 364 m². Afterwards, the whedos of the second group can be subdivided into two subsets (II and II') according to their width and height of water (Figure 5).

Using the stepwise multiple regression, the physicochemical variables which best predict the densities of microalgae, cladocerans and copepods in the whedos are identified (Table 5). According to this analysis, only density of cladocerans best reflected the change of multiple physicochemical variables (temperature, transparency and $NO_2^-$) in the whedos while microalgal biomass and copepod density are significantly correlated to $NH_4^+$ and $NO_2^-$, respectively (Tables 5 and 6).

**Fish and macrophytes**

The list of fish and floating plants harvested from the whedos and their frequencies is given in Tables 7 and 8. Ten fish species gathered in eight families were observed in the whedos. *Clarias spp* were more abundant (68%) and always encountered in the whedos while *Brienomyrus niger* and *Parachanna africana* were very scarce. The macrophytes were also abundant in the whedos and diversified (24 species). Species like *Pistia stratiotes*, *Ipomea aquatica*, *Phyllanthus niruri* and *Salvinia sp* were always observed in the whedos.

**Table 2:** Comparison of physicochemical and biological variables in the whedos and river channel.

| Variables | River channel | Whedo | P |
|---|---|---|---|
| Temperature (°C) | 30.7±0.6 | 29.3±0.2 | 0.0050$^{**}$ |
| Dissolved oxygen (mg/l) | 6.7±0.9 | 2.3±0.5 | 0.0002$^{***}$ |
| pH | 6.7±0.1 | 6.5±0.2 | 0.1980 |
| Conductivity $K_{25}$ (µS/cm) | 105.4±2.8 | 100.6±6.3 | 0.2147 |
| Transparency (cm) | 108.5±6.9 | 19.0±1.9 | <.0001$^{***}$ |
| $NO_2^-$ (mg/l) | 0.005±0.0 | 0.054±0.04 | 0.0737 |
| $NH_4^+$ (mg/l) | 0.003±0.0 | 0.013±0.005 | <.0126$^{*}$ |
| Algal biomass (µgC/l) | 76.4±13.2 | 0.27±0.03 | <.0001$^{***}$ |
| Cladoceran density (n/ml) | 2.9±0.5 | 5.0±2.1 | 0.1016 |
| Copepod density (n/ml) | 19.1±0.8 | 72.9±13.1 | 0.0002$^{***}$ |

*P<0.05; **P<0.01; ***P<0.001.

**Table 3:** Monthly variation of plankton in the whedos.

| Variables | March | April | May | June | P-level |
|---|---|---|---|---|---|
| Algal biomass (µgC/l) | 0.277±0.15 | 0.283±0.16 | 0.225±0.10 | 0.295±0.14 | 0.638 |
| Cladoceran density (n/ml) | 7.6±7.4$^{a}$ | 5.6±6.1$^{ab}$ | 4.0±5.0$^{ab}$ | 2.8±4.0$^{b}$ | 0.037$^{*}$ |
| Copepod density (n/ml) | 85.4±82.4 | 79.7±76.0 | 71.3±74.1 | 55.2±56.9 | 0.795 |

Values in the same row bearing different letters are significantly different; *P<0.05.

**Table 4:** Correlation coefficients between PCA scores (F1 and F2) and physicochemical variables.

| **Variables** | **F1 (27.4%)** | **F2 (19.7%)** |
|---|---|---|
| Temperature (°C) | -0.53* | 0.17 |
| Dissolved oxygen (mg/l) | 0.27 | 0.59* |
| pH | 0.62* | -0.28 |
| Conductivity $K_{25}$ (µS/cm) | 0.51* | 0.43 |
| Transparency (cm) | -0.43 | 0.04 |
| $NO_2^-$ (mg/l) | -0.01 | 0.85* |
| $NH_4^+$ (mg/l) | -0.85* | 0.09 |

*P<0.05.

**Table 5:** Correlation matrix of the stepwise multiple regression showing the potentially physicochemical variables predicting the densities of microalgae, cladocerans and copepods.

| **Variables** | **Microalgae** | **Cladocerans** | **Copepods** |
|---|---|---|---|
| Temperature (°C) | nc | 0.0146* | 0.8413 |
| Dissolved oxygen (mg/l) | nc | nc | nc |
| pH | nc | nc | 0.2762 |
| Conductivity $K_{25}$ (µS/cm) | 0.0935 | nc | 0.7070 |
| Transparency (cm) | nc | 0.0157* | nc |
| $NO_2^-$ (mg/l) | nc | 0.0146* | 0.0397* |
| $NH_4^+$ (mg/l) | 0.0136* | nc | nc |

nc: not correlated; *P<0.05.

**Table 6:** Summary of the stepwise multiple regression analysis between plankton density and physicochemical factors.

| | **Multiple R** | **Multiple R²** | **Adjusted R²** | **F-value** | ***P*** |
|---|---|---|---|---|---|
| Microalgae | 0.492 | 0.242 | 0.208 | 7.18 | <0.00196*** |
| Cladocerans | 0.598 | 0.358 | 0.314 | 8.17 | <0.00020*** |
| Copepods | 0.467 | 0.218 | 0.146 | 3.0 | <0.02852* |

*P<0.05; ***P<0.001.

**Table 7:** Diversity and abundance of fish in the whedos (1999 – 2011).

| Family | Species | Total number observed[$] | Relative abundance (%) | Occurrence |
|---|---|---|---|---|
| Mormyridae | *Brienomyrus niger* | 57 | 2.2±2.8 | 0.5 |
| Clariidae | *Clarias gariepinus* | 1103 | 35.7±5.6 | 1.0 |
| | *Clarias ebriensis* | 1040 | 32.3±4.7 | 1.0 |
| Anabantidae | *Ctenopoma kingsleyae* | 227 | 6.4±2.7 | 1.0 |
| Malapteruridae | *Malapterurus electricus* | 132 | 4.1±2.2 | 1.0 |
| Polypteridae | *Polypterus senegalus* | 264 | 7.9±3.3 | 0.9 |
| Channidae | *Parachanna obscura* | 157 | 4.0±2.6 | 0.8 |
| | *Parachanna africana* | 13 | 0.4±0.6 | 0.3 |
| Protopteridae | *Protopterus annectens* | 196 | 4.7±3.4 | 0.8 |
| Notopteridae | *Xenomystus nigri* | 63 | 2.0±1.6 | 0.7 |

[$]In the twelve whedos.

**Table 8:** Aquatic vegetation observed in the whedos (1999 – 2011).

| Family | Species | Number of whedos | Occurrence |
|---|---|---|---|
| Amaranthaceae | *Alternanthera sessilis* | 10 | 0.8 |
| Acanthaceae | *Asystasia gangetica* | 9 | 0.8 |
| Araceae | *Pistia stratiotes* | 12 | 1.0 |
| Asteraceae | *Ethulia conyzoides* | 8 | 0.7 |
| | *Eclipta prostata* | 7 | 0.6 |
| Azollaceae | *Azolla pinnata var. imbricata* | 7 | 0.6 |
| Capparidaceae | *Cleome rutidosperma* | 8 | 0.7 |
| Commelinaceae | *Commelina erecta* | 10 | 0.8 |
| Convolvulaceae | *Ipomoea aquatica* | 12 | 1.0 |
| Cyperaceae | *Cyperus haspan* | 10 | 0.8 |
| | *Cyperus alopecuroides* | 11 | 0.9 |
| Euphorbiaceae | *Phyllanthus niruri* | 12 | 1.0 |
| Fabaceae | *Aeschynomene indica* | 8 | 0.7 |
| Nympheaceae | *Nymphaea lotus* | 6 | 0.5 |
| Onagraceae | *Ludwigia abyssinica* | 7 | 0.6 |
| | *Ludwigia stenorraphe* | 8 | 0.7 |
| Poaceae | *Eleusine indica* | 8 | 0.7 |
| | *Oryza longistaminata* | 7 | 0.6 |
| | *Sacciolepis Africana* | 5 | 0.4 |
| | *Scirpus cubensis* | 9 | 0.8 |
| | *Echinochloa pyramidalis* | 11 | 0.9 |
| Pontederiaceae | *Eichhornia natans* | 6 | 0.5 |
| Rubiaceae | *Pentodon pentandrus* | 10 | 0.8 |
| Salviniaceae | *Salvinia nymphellula* | 12 | 1.0 |

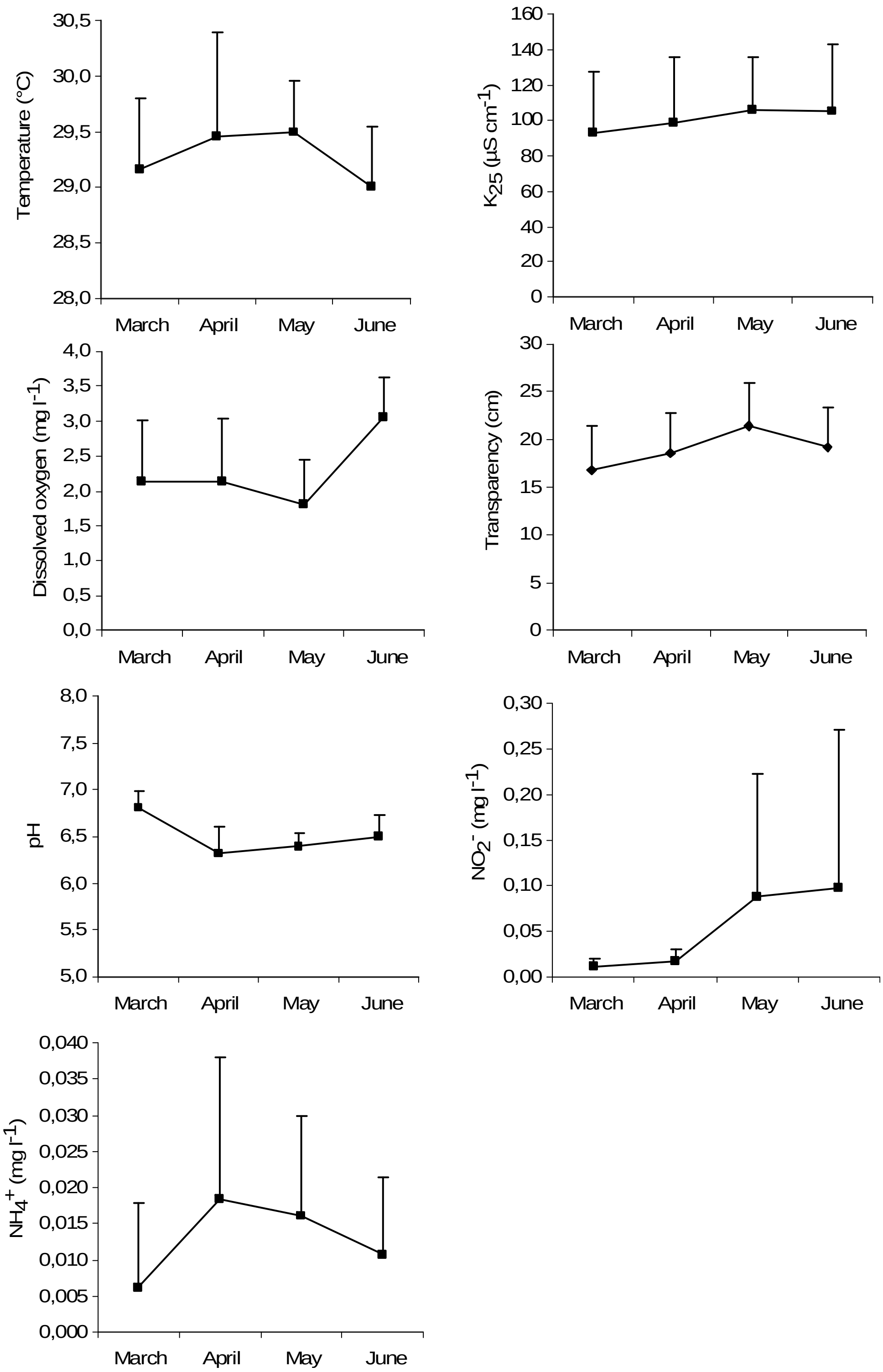


**Figure 2:** Monthly variation of physicochemical variables in the whedos.

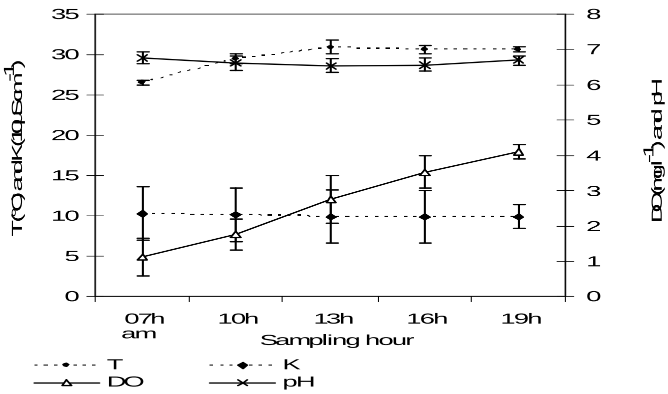


**Figure 3:** Daily profile of temperature (T), dissolved oxygen (DO), pH and conductivity ($K_{25}$) in the whedos during the dry season (n = 12).

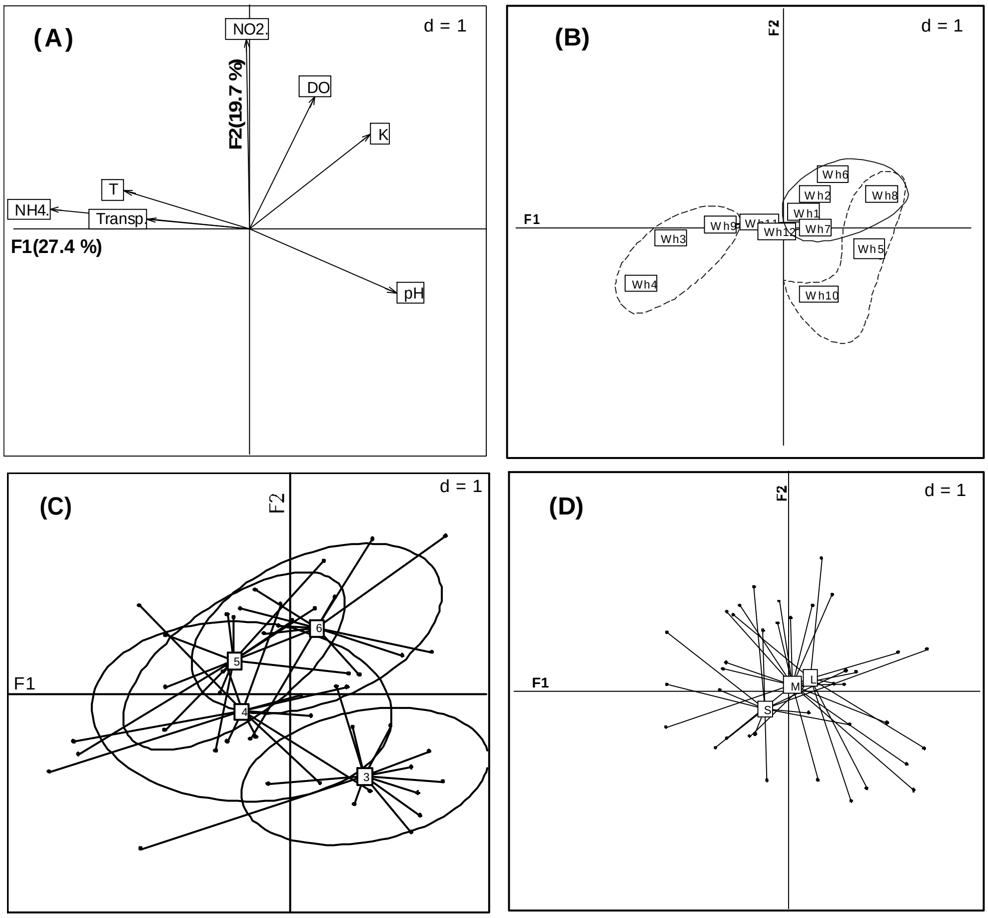


**Figure 4:** PCA analysis based on the physicochemical variables (A): according to the whedos (B), the monthly (3: march; 4: april; 5: may; 6: june) variability (C) and size (S: small, M: medium, L: large) of the whedos (D).

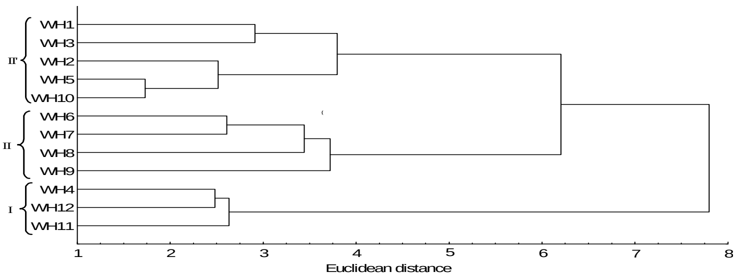


**Figure 5:** Cluster ordination (Ward's method) of whedos based on physicochemical factors, plankton, water height and whedo size.

## DISCUSSION

Before assessing data it is noteworthy to reiterate that the whedos are located on the floodplain of the Oueme River from which they depend. However, water physicochemical variables such as temperature, DO, transparency, and microalgal biomass were in most cases significantly lower in the whedos than those recorded in the main river channel. The shade generated by the surrounding vegetation and the height of the banks probably protects the whedos against warming. Lowered DO levels can be induced in the whedos by the low photosynthetic activity of aquatic plants (Holden and Green, 1960; Welcomme, 1975), partially due to the low transparency of water (Egborge, 1974). Likewise, the dry season is an intense activity for aquatic vegetation in the whedos and it is possible that the utilization of minerals by growing plants is so rapid that few ions enter the aqueous component for algal development (Welcomme, 1975). High production of zooplankton organisms was also noticed in the pools of the floodplain during the dry season comparatively to the main river channel (FAO/UN, 1970).

As expected, DO concentration in the whedos was lower in the morning (07.00 h) than in the afternoon (16.00-19.00 h) due to the photosynthetic activity of phytoplankton and aquatic macrophytes. This result indicates the significant effect of the algae and other aquatic plants on the daily DO concentration profile in the whedos and this appears also true for their monthly variation albeit the microalgal biomass did not vary significantly from March to June. It also results in an improvement of the nitrification process which induces an increase in the $NO_2^-$ concentration in the whedos from March to June.

The multivariate approach used in this study to appraise the inter-variation of the whedos brings important information in regard to their use for fish production. Ultimately, we can retain that the variability of water physicochemical quality between the whedos depends not only on their area but also on their width and depth. These observations are primordial insofar as they will permit to improve the construction of the whedos and in the other hand will be determining in the choice of the whedos that could be used for fish rearing. Moreover, the organisms (microalgae, cladocerans, copepods and fish) in whedos were found to be strongly correlated with the physicochemical variables. Overall, the low DO concentration plays an essential role in the occurrence of fish species in the whedos. Indeed, many species commonly encountered in the whedos display adaptations for survival in low dissolved oxygen conditions (Welcomme, 1975; Imorou Toko et al., 2011; Hauber et al., 2011). Species of *Clarias*, *Ctenopoma*, *Parachanna*, *Protopterus* have accessory breathing organs which permit aerial respiration. The others (*Polypterus*, *Malapterurus*, *Xenomystus* and *Brienomyrus*) are also well adapted to swamp life and are quite abundant in de-oxygenated small or medium pools (Welcomme, 1975; Welcomme et al., 2004). Furthermore, it is well established that species sensitive to deoxygenated conditions, such as *Alestes sp*, *Schilbe mystus*, *Barbus spp*, *Sarotherodon sp* or *Tilapia spp*, leave the plain earlier at the draw-down period than other species (Daget, 1957; Williams, 1971; Trewavas, 1973). More resistant genus like *Clarias* leaves the floodplain later, explaining why they are more abundant in the whedos.

It arises that fish diversity in the whedos represents about 15% of the species and 41% of the families commonly encountered in the main river channel in Oueme Valley (Lalèyè et al., 2004; Imorou Toko, 2007). Species like *B. niger* and *P. africana* were scarce and generally found in the whedos exploited earlier while Clariidae species were abundant and represent about 68% of the fish captured in whedos. Furthermore, despite *Heterotis niloticus* is mentioned among the species encountered in the whedos (Welcomme, 1975), we had never met it during our studies. Indeed, although this species is well adapted to swamp life, his abundance in deoxygenated small pools is too weak probably due to the fact that it does not support containment. Moreover, albeit *Heterobranchus longifilis* is present in the Oueme River, this species ecologically close to *Clarias*, had never been caught in the whedos assuming that vundu is possibly more sensitive to the draw-down flow.

All the macrophytes observed in the whedos were already found in several wetlands and whedos in South Benin (unpublished data). Some of them as *Lemna*, *Azolla* and *Salvinia* are known to be well consumed by many fish species.

In the Oueme Valley, about 90% of the fishermen exploit their whedos between January and March (Imorou Toko, 2007). After that period, the whedos are abandoned until next water draw-down period on the floodplain, *i.e.* next December. Stocking fish in the whedos during this period of abandonment (*e.g.* from February to June) could be an alternative to improve their yield. Indeed, stocking programmes to enhance yields of floodplain pools, small dams and reservoirs have been done in several countries (Bangladesh, India, Kenya, Thailand, Indonesia, Philippines, Burkina-Faso, etc.). According to Welcomme et al. (2004), properly managed, these programmes can be highly productive and beneficial to human communities, particularly in developing countries where stocking wetland systems are undertaken to address problems of food insecurity or declining capture fisheries. For example in Burkina-Faso, stocking small dams with 20 kg of Nile tilapia fingerlings per hectare increased yield from 23 to 269 kg/ha (de Graaf and Waltermath, 2003). Similar increases (from 300 to 2000 kg/ ha) were also observed in India (Sugunan and Sinha, 2001).

Furthermore, fish stocking in whedos supposed that these species are well adapted to livelihood conditions (*i.e.* water physicochemical quality) in these systems. Good candidates for this purpose are probably endogenous species encountered in the whedos. However, as reported by several authors (Barnabé, 1989) the choice of species for aquaculture depends on many factors as (i) their adaptation to rearing conditions (water quality, handling, exogenous feeding, etc.); (ii) the availability of juveniles from rivers and lakes or from hatcheries, and (iii) the easy flow of the fishing products. Considering all these conditions, African catfish (*Clarias gariepinus*) and vundu (*Heterobranchus longifilis*) are good candidates as these species are well consumed in the Oueme Valley and the production of their fingerling is well developed (Imorou Toko et Fiogbe, 2007). Nevertheless, their high environment tolerance and wide food spectrum (Munro, 1967; Haylor, 1989; Viveen et al., 1985; Legendre, 1992; Luquet et al., 1993) are the mains reasons why these catfishes are the excellent candidates for stocking than any other species in whedos (Imorou Toko et al., 2007).

In summary, the observations carried out in the whedos during this study show that the quality (physicochemical and biological) of their water limits consequently the possibilities to stock many fish species during the dry season (at the draw-down period). However, stocking whedos with African catfish or vundu which are well adapted to these ecosystems and already used in several fish farming in Benin appears as a necessary alternative to enhance their output.

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