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# Effect of Water Quality and Bottom Soil Properties on the Diversity and Abundance of Macrobenthic Fauna in Some Tropical Grow-out Earthen Fish Ponds

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## ABSTRACT

Macrobenthic communities can be used in the assessment of environmental quality of earthen fish ponds. This study was conducted to investigate the effect of water quality and bottom soil properties on the diversity and abundance of macrobenthic fauna in some tropical grow-out earthen fish ponds. The aim was to enhance the proper management of soil and water qualities in relation to various groups of benthic organisms found in ponds. Physico-chemical parameters, bottom soil properties and benthic community assemblages were studied in three selected commercial fish farms in Calabar, Cross River State, Nigeria. Results revealed that macrobenthic assemblages were influenced by both the physico-chemical parameters and bottom soil properties in each of the farms. The macrobenthic faunal patterns in earthen fish ponds under investigation showed to be influenced by changes in abiotic parameters. This was caused by seasonality and fish production. Oligochaetes were generally dominant 31(50.82); 21(27.27); 22(31.88) in Aqua Vista farm, UNICAL farm and Akai Efa farm, respectively. From the biotic indicators that show a differential response to organic input in fish earthen ponds, the abundance of *Aulophorus* spp. (41.99%; 14.29%) in Aqua Vista and UNICAL farms, respectively as well as the diversity (Shannon-Wiener and Margalef species richness), seem to be the best indicators to be used in monitoring studies in similar systems. In general, Farms with optimum physicochemical parameters, high sand and low clay content had the highest assemblages of macrobenthic organisms. Farm managers should pay particular attention to the physico-chemical parameters and soil properties as they are determinant factors of macrobenthic assemblage within the fish ponds. These will enhance high productivity of the grow-out fish ponds since they form the major bulk of fish food.

**Key words:** Aquatic ecosystem, food chain, sediment, runoffs, productivity

## INTRODUCTION

When trying to understand river health, aquatic biologists often look not at fish but rather at fish food: Benthic Macroinvertebrates (BMI) which are effective integrators of physical, chemical and biological processes (Othman *et al.*, 2002). Due to various species of BMI found in different consumer levels in marine food webs, they are used to ascertain the health of river ecosystem.

Consequently, BMI serve as food resources for the myriads of vertebrates including fish (Varadharajan *et al.*, 2010). In pond ecosystem, water quality and soil properties play a significant role in the life of benthic organisms (Tabatabaie *et al.*, 2009). Water exhibits both physical and chemical properties and the suitability of water for the survival and growth of fish is governed by a myriad of water quality variables (Boyd, 1982). According to Udo (2007), the quality of water used in a pond is affected by the chemical properties of the soils on which it runs. In the course of constructing fish ponds the upper horizons of the terrestrial soil is usually excavated, thereby exposing the subsoil to water when ponds are filled. The main requirement is that, soil for pond consists of a mixture of particles from, within or outside the pond and the accumulation of sediments which have a direct contact with water can either enhance or hinder the growth of benthic organism (El-Marakby *et al.*, 2006). Benthic organisms can be used to monitor the type of soil or the quality of water used in ponds. Macrobenthos comprises many different groups of aquatic animals with a large number of species possessing a wide range of responses to stressors such as sediments, toxicants and organic pollutants (Maryland Department of Natural Resources, 1999). Benthic organisms offer themselves as a live food or dead food for culture organisms in their trophic relationship. They out do artificial feed since they have higher protein content, fats, cellulose, lignin, starch waxes and oils which are lacking in supplemental feeds. The abundance and growth of benthic organisms depends on the pond preparation management and chemical used (Abu Hena *et al.*, 2004). In intensive fish culture, use of fertilizers, fish feeds or both usually increase production; the use of high stocking/feeding rates may lead to severe water quality problems (Green *et al.*, 1989). The effects of inorganic fertilizer are also reflected in benthic production and abundance (Zorriasatein *et al.*, 2009). According to Boyd (1995), soft sediment accumulation makes ponds shallow, encourages anaerobic conditions at the sediment-water interface and interferes with harvest. This being the case, it is pertinent to study the relationship between the pond bottom soil properties and their influence on the macrobenthic assemblage. The objective of this study therefore, was to assess different water quality parameters and bottom soil properties and their effects on macrobenthic faunas in some tropical earthen fish ponds.

## MATERIALS AND METHODS

**Study area:** Three study sites were selected. These were: UNICAL, Aqua Vista and Akai Efa fish farms.

**UNICAL farm:** This is located in the vicinity of the University of Calabar staff quarters at approximately 04.56°, 020'N and 08.20°, 456'E in Cross River State, Nigeria. The climate of the area is governed by its latitude and to a large extent by the two dominant winds, the Southwest monsoon and northeast trade winds common in most parts of West Africa. The area is also characterized by distinct wet and dry seasons (Akpan *et al.*, 2002; Asuquo *et al.*, 2004).

**Aqua Vista fish farm:** This is located along Anantigha Beach at approximately 4°60 N and 8°5 E in Calabar South Local Government Area, Cross River state, Nigeria. It has a very large catchment area which traverses through fresh water swamp to mangrove swamp forest forming a tributary of the Cross River system itself (Moses, 1987).

**Akai Efa fish farm:** This is located along MCC road in Calabar Municipality, Cross River State, Nigeria at approximately 4°59 N and 8°19 E.

**Vegetation of the study areas:** They are part of tropical rainforest areas in West Africa and consists mainly of wood trees and other trees like palm trees and fruit trees (Asuquo, 1998; Akpan *et al.*, 2002).

**Climate:** The study area is characterized by a long wet (April-October) and a shorter dry season (November to March). Mean annual rainfall is about 2000 mm (Akpan and Offem, 1993). Short period of drought occurs in the wet season around August/September which is called the August drought. There is usually a cold, dry and dusty period between December and January referred to as the harmattan season. Temperatures generally range from 22°C in the wet to 35°C in the dry season. Relative humidity is generally above 60% at all seasons with close to 90% during the wet season (Akpan, 1993; Akpan and Offem, 1993; Asuquo, 1998).

**Geology:** The soil here, is composed of coastal plains sand; belonging to tertiary deposits and forms in an island south of Ikot Ekpo, between the alluvial deposits of the Calabar River and the Great Kwa River. These coastal plain sand is most preferable for the development of Calabar. The alluvial deposits usually are on low lying, swampy areas unsuitable for construction work. Also, the dominant soils are light brown, grey and white sand with clay, grey shales, carboneous shales, feldsper fragments and pest bands, alternating from 80' downward (Asuquo, 1998).

**Human activities:** These include farming, hunting, fishing, boat building and sand mining (Holzlohner *et al.*, 2002).

**Sampling:** Samples were collected fortnightly for 3 months between November 2010 and January 2011.

**Sampling for water parameters:** Sampling for water parameters was done *in situ* at the different sites thrice a month for pH, temperature and transparency while some integrated samples were taken in Winkelr's bottle to the laboratory for the analysis of dissolved oxygen. The pH was measured using a pH meter. A mercury in glass thermometer was lowered into water up to 2 cm below the water surface, allowed to stabilize for 2 min and temperature readings were taken in degree Celsius (°C). A weighted Sechi disc was lowered into each pond until it just disappeared and pulled up until it appeared again. The two readings were recorded and an average value calculated for transparency.

**Collection of soil samples:** A total of 3 soil samples were collected from Aqua Vista, Akai Efa and UNICAL farms on each sampling date using an augar sampler (Abu Hena *et al.*, 2004). Soil samples were collected between 0-25 cm depths, stored in a well labeled polythene bag and transported to the laboratory for necessary analysis.

**Macrobenthos collection:** This was done using a shovel and augar sampling method; after sieving the soil samples macrobenthoses were handpicked based on Anderson *et al.* (1982), stored in a sample bottle and preserved in 4% buffered formalin prior to identification.

**Laboratory studies:** Winkler's titrimetry was used to estimate each level of $DO_2$ in mg $L^{-1}$ for each pond. Soil samples were dried at room temperature and ground; sieved through 200 Nm mesh screen. Organic matter was determined using Walkey-Black wet oxidation method. Particle size distribution was determined by Bougorcos hydrometer method using sodium hexametaphate as dispersant (Udo and Ogunwale, 1986). Macrobenthoses were identified by use of identification guide and standard texts based on the morphological structures of the organisms to the nearest possible taxa (Ingram *et al*., 1997).

**Determination of numerical abundance of macrobenthic species:** To achieve this, the total number of species was recorded for each week of sampling and was computed following Ewa-Oboho (1993).

**Determination of Relative abundance of macrobenthic species:** This was done according to Amar *et al*. (2007).

**Determination of species richness of the macrobenthic organisms:** This was done using Shannon-Wiener and Margalefs index (d) following Ogbeibu (2005).

**Determination of species dominance (D):** This is the best known index for the determination of the commonest species in studies involving community ecology and was done according to Ogbeibu (2005) using Simpsons index (D). The dominance index gave the probability that two individual drawn at random from the total population of the macrobenthic organism belong to the same species.

**Determination of species diversity:** This was done according to Shokat *et al*. (2010) using Shannon-Wiener and Margelef's index (d).

**Computation of results:** Numerical abundance, relative abundance, richness, dominance and diversity of the species in the ponds were, respectively calculated and the results arranged in a tabular form based on Ewa-Oboho (1993).

## RESULTS

**Physico-chemical parameters:** The pH mean values were 5.67 in Akai Efa farm, 5.57 in Aqua Vista farm and 6.20 in UNICAL farm. Mean water temperature values were observed to vary slightly in the study ponds but with very close ranges to each other with a value of 29.2°C in Akai Efa farm, 30.0°C in Aqua Vista farm and 29.8°C in UNICAL farm. Mean dissolved oxygen concentration was low in all the farms with 2.1 mg $L^{-1}$ in Akai Efa farm, 1.7 mg $L^{-1}$ in Aqua Vista and 2.2 mg $L^{-1}$ in UNICAL farm. Air temperature had the same value of 30°C in all the farms studied but transparency was observed to vary slightly in all the farms with a mean value of 17.5 cm in Akai Efa farm, 23.0 cm in Aqua Vista farm and 12.0 cm in UNICAL farm (Fig. 1).

**Soil characteristics:** These were observed to vary in each of the farms. In Akai Efa farm organic matter was 11.82%, while in Aqua Vista a value of 4.74% was obtained and in the UNICAL farm, a value of 10.46% was obtained. Clay content was very low in the UNICAL farm with a value of 2.0%, while in Aqua Vista a clay content of 26.0% was obtained and in Akai Efa it was 8.0%. Sand content was 74.6% in Akai Efa farm, 64.6% in Aqua Vista and 88.6% in the UNICAL farm. Silt content had the same value of 9.4% in Aqua Vista and the UNICAL farm but with a value of 17.4% in Akai Efa farm (Fig. 2).

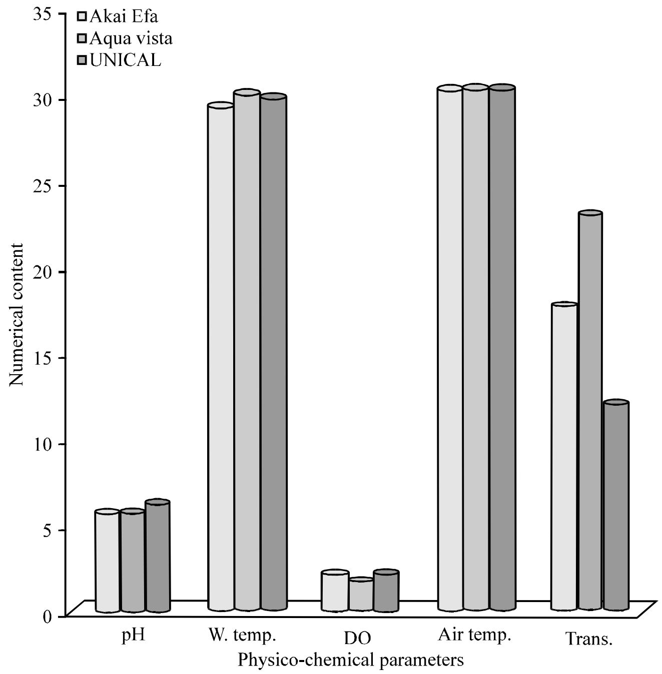


Fig. 1: Variation in physico-chemical parameters in different farms studied

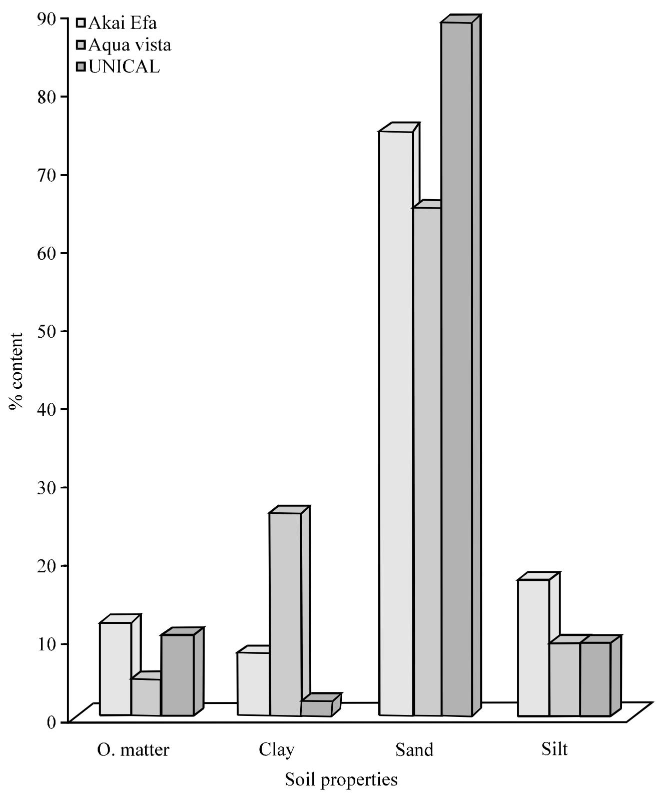


Fig. 2: Variation in soil characteristics in different farms studied

**Species composition of benthic organisms:** Altogether twelve macrobenthic species were identified during the study period. However, the distribution of the benthic species was observed

Table 1: Benthic organisms identified from the different fish farms during the study period

| | Fish farm | | | | | |
|---|---|---|---|---|---|---|
| | Aqua Vista farm | | UNICAL farms | | Akai Efa Farm | |
| Benthic organisms | No. identified | Relative abundance | No. identified | Relative abundance | No. identified | Relative abundance |
| *Tubifex* sp. | 7 | 11.48 | 3 | 3.90 | - | - |
| *Lumbriculus* sp. | 9 | 14.75 | 5 | 6.49 | 3 | 4.35 |
| *Branchiurea* sp. | - | - | 6 | 7.79 | 4 | 5.79 |
| *Dro* sp. | - | - | 4 | 5.19 | 9 | 13.04 |
| *Aulophorus* sp. | 13 | 21.31 | 3 | 3.90 | - | - |
| *Chaetogaster* sp. | 2 | 3.28 | - | - | 6 | 8.70 |
| *Chirononus* sp. | 5 | 8.19 | 9 | 11.69 | 3 | 4.35 |
| *Culicodes* sp. | - | - | 3 | 3.90 | 5 | 7.25 |
| *Dragon fly nymphs* | 6 | 9.84 | 12 | 15.58 | 15 | 21.74 |
| *Mayfly nymphs* | 9 | 14.75 | 17 | 22.08 | 21 | 30.43 |
| *Dytiscus* sp. | 3 | 4.92 | 6 | 7.79 | - | - |
| *Gyrinus* sp. | 7 | 11.48 | 9 | 11.69 | 3 | 4.35 |
| Total | 61 | 100.00 | 77 | 100.00 | 69 | 100.00 |

to vary in each of the farms (Table 1). A total of 61 individuals of the benthic organisms were recorded in Aqua vista farm, 77 in UNICAL farm and 69 in Akai Efa farm. The macrobenthic organisms identified in Aqua vista farm were: *Tubifex, Lumbriculus, Autophorus, Chaetogater, Chironomus,* Dragon fly nymphs, Mayfly nymphs, *Dytiscus* and *Gyrinus*. In the UNICAL farm, the following benthic organisms were recorded: *Tubifex, Lumbriculus, Branchiura, Dro, Autophorus, Chironomus, Culicodes,* Dragon fly nymphs, Mayfly nymphs and *Gyrinus,* while in Akai Efa farm, *Lumbriculus, Branchuirea,* Dro, *Chaetogarfer, Chironomus, Culicodes,* Dragonfly nymphs and *Gyrinus*. On the whole, Aqua vista farm had 9 macrobenthic species, UNICAL farm 11 and Akai Efa farm 9. The richest farm in terms of macrobenthic species composition was UNICAL.

**Numerical and relative abundance of benthic organisms:** Five groups made up the entire macrobenthic communities in all the farms (Table 2). There were 31 (50.82%) Oligochaetes in Aqua vista farm, 21 (27.27%) in UNICAL farm and 22 (31.88%) in Akai Efa farm; 5 (8.20%) Diptera, in Aqua vista farm, 12 (15.58%) in UNICAL farm and 8 (11.59%) in Akai Efa farm; 6 (9.84%) Odonata, in Aqua vista, 12 (15.58%) in UNICAL farm and 15 (21.74%) in Akai Efa farm. In the Order Ephemeroptera; 9 (14.75%) individuals were present in Aqua Vista, 17 (22.10%) in UNICAL farm and 21 (30.43%) in Akai Efa farm while in the Order Coleoptera, 10 (16.39%) individuals were recorded in Aqua Vista, 15 (19.48%) in UNICAL farm and 3 (4.35%) in Akai Efa farm.

## DISCUSSION

All factors occurring in the pond, whether physical, chemical or biological, influence the pond ecosystem. The physico-chemical parameters in each of the fish farms showed normal ranges. According to Boyd (1998), the optimum pH range for the reduction of algae production is 7.0 to 8.0. In this study, the minimum and maximum pH recorded in all farms were 5.57 to 6.20 in Aqua vista and UNICAL farms respectively. However, pH of ponds water depends on a number of factors (Nyam, 1988). First, pH levels of pond water are known to change depending on the aquatic life

Table 2: Major Macrobenthics orders identified during the study period

| | Fish farm | | | | | |
|---|---|---|---|---|---|---|
| | Aqua vista farm | | UNICAL farm | | Akai Efa Farm | |
| Macrobenthic organisms | No. identified | Relative abundance | No. identified | Relative abundance | No. identified | Relative abundance |
| **Oligochaeta** | | | | | | |
| *Tubifex* sp. | 7 | 22.58 | 3 | 14.29 | - | - |
| *Lumbriculus* sp. | 9 | 29.03 | 5 | 23.80 | 3 | 13.64 |
| *Branchiura* sp. | - | - | 6 | 23.57 | 4 | 18.18 |
| *Dro* sp. | - | - | 4 | 19.05 | 9 | 40.91 |
| *Aulophorus* sp. | 13 | 41.94 | 3 | 14.29 | - | - |
| *Chaetogaster* sp. | 2 | 6.45 | - | - | 6 | 27.27 |
| **Total** | 31 | 100.00 | 21 | 100.00 | 22 | 100.00 |
| **Dipterea** | | | | | | |
| *Chironomus* sp. | 5 | 100.00 | 9 | 75.00 | 3 | 37.50 |
| *Culicodes* sp. | - | - | 3 | 25.00 | 5 | 62.50 |
| **Total** | 5 | 100.00 | 12 | 100.00 | 8 | 100.00 |
| **Odonata** | | | | | | |
| *Dragon fly nymphs* | 6 | 100.00 | 12 | 100.00 | 15 | 100.00 |
| **Total** | 6 | 100.00 | 12 | 100.00 | 15 | 100.00 |
| **Ephemeroptera** | | | | | | |
| *Mayfly nymphs* | 9 | 100.00 | 17 | 100.00 | 21 | 100.00 |
| **Total** | 9 | 100.00 | 17 | 100.00 | 21 | 100.00 |
| **Coleoptera** | | | | | | |
| *Dytiscus* sp. | 3 | 30.00 | 6 | 40.00 | - | - |
| *Gyrinus* sp. | 7 | 70.00 | 9 | 60.00 | 3 | 100.00 |
| **Total** | 10 | 100.00 | 15 | 100.00 | 3 | 100.00 |

within the pond. In the UNICAL farm, a pH value of 6.20 was recorded. This value was however close to the required pH level in earthen ponds. The varied and reduced values in pH in these farms may not be unconnected with phytoplankton (algae) level in them. Low phytoplankton level was observed in Akai Efa and Aqua Vista farm hence the decreased pH recorded in them. Water temperature observed fall within acceptable range of between 24°C and 34.0°C for the tropics (Udo, 2007). Ideally, increased temperature causes an increase in the metabolic activity of organism while reducing the DO, content in the system (Boyd, 1998; Macan, 1978; Udo, 1991). Little wonder Aqua vista farm with water temperature of 30.0°C had the lowest dissolved oxygen of 1.7 mg $L^{-1}$ as against the other ponds. In tropical earthen ponds a minimum dissolved oxygen of 2.0 mg $L^{-1}$ has been reported to sustain aquatic life (Udo, 2007) though, the optimum range of 5.0-15.0 mg $L^{-1}$ was reported by Boyd (1998). In this study Aqua Vista farm had the least DO (mg $L^{-1}$) concentration of 1.7 mg $L^{-1}$ while Akai Efa farm and the UNICAL farm had a little above the minimum value of DO (mg $L^{-1}$) during the study period. The low DO (mg $L^{-1}$) in this farm might be attributed to high temperature recorded in the pond. Tave (1999), Boyd (1998) and Udo (2007), reported that high temperatures are responsible for reduced DO in water bodies including fish ponds. Transparency of water bodies indicates the extent to which sunlight can penetrate in order to cause photosynthesis. The presence of large amount of suspended matter or high plankton load is known to decrease the amount of light energy entering the water (Seah *et al.*, 2011). The UNICAL farm was the most turbid followed by Akai Efa farm each with a transparency value of 12.0 cm and 17.5 cm, respectively while a value of 23.0 cm was recorded at Aqua Vista farm. These values were quite below the acceptable values of 2.0-7.5 cm (Boyd, 1998; Nandlal and Pickering, 2004). This was unconnected with catchment area of the farm.

The composition of the soil bottom in relation to organic matter, clay, sand and silt content in the three farms was observed to vary. Clay content was low in the UNICAL farm with a value of 2.0%, sand content was rather high with a value of 88.6%. This was followed by Akai Efa farm with a value of 74.6% and organic matter with a value of 11.82% in Akai Efa farm and 10.46% in the UNICAL farm. The least organic matter content was recorded at the Aqua Vista farm with a value of 4.74%. The nature of pond bottom is known to influence the type of benthic organisms inhabiting them and hence, the macrobenthic assemblages (Goldman and Horne, 1983). Most macrobenthic organisms inhabit pond bottom with rich organic matter which they filter their food. Any aquatic habitat with high percentage of sand has been reported to have high nutrient seepage capacity (Udo, 2007). Nutrients on the bottom surface seeps to the inner layers of the sediment (Ingram *et al.*, 1997). When this happens the benthic organisms burrow into the sediment to derive the nutrients there in (Boyd, 1990). Ingram *et al.* (1997) reported high benthic assemblages in pond bottom with high sand content in Birmingham ponds and attributed it to nutrient seepage into the under sediment layers, a result which agrees with that of the present study. UNICAL farm with the highest sand content has high macrobenthic fauna than either Akai Efa or Aqua Vista farms. Goldman and Horne (1983) also observed high benthic assemblages in earthen ponds with sandy bottom in Canada.

The distribution of the macrobenthos in the study ponds was observed to be influenced by the physico-chemical parameters. More macrobenthos was recorded in the UNICAL farm with the highest individuals followed by Akai Efa farm. Aqua Vista recorded the lowest number of benthos with the lowest number of individuals. These variations in macrobenthic assemblages may be attributed to variations in the water temperature which invariably influences the amount of DO. In Aqua Vista, water temperature was 30.0°C with a corresponding reduction in dissolved oxygen of 1.7 mg $L^{-1}$ which caused a reduced number of benthic organisms. As it has been established, temperature causes an increase in the metabolic activity of organism. Hence, with increased temperature, organisms tend to be erratic in behaviour, seeking a more comfortable zone in the sediment and go into hiding or preventing them to be caught during sampling (Needham and Needham, 1974). The results of the present study is again in agreement with those of Unanam and Akpan (2006) who reported that the macrobenthic community in earthen ponds of AKSCOA fish farm in Oruk Anam Local government, Akwa Ibom State, Nigeria became structurally reduced with increase in temperature which invariably influence the activity of the benthos, causing them to go into hiding. Hence, they usually observed reduction in the number of most of the benthos which cannot withstand high temperature. Carvalho *et al.* (2010) also observed that a shift from optimal physicochemical parameters in fresh water bodies in earthen fish ponds of the Ria Formosa lagoon resulted in a reduction in the community structure of the macrobenthos, a result which agrees with that of the present study although the polychaetes were generally dominant as against the oligochaetes observed in this study.

The ecological parameters, such as species dominance and species diversity of the benthic organisms were observed to vary. However, there was no difference in species dominance of the benthos in all the study ponds indicating that all the earthen ponds experienced similar structural formation as is known in tropical earthen ponds (Udo, 2007). In terms of species diversity, it was observed that the benthic assemblages showed differential structural variation. Unanam and Akpan (2006) observed similar structural variation in the macrobenthic community in earthen ponds of AKSCOA fish farm in Oruk Anam, Akwa Ibom State, Nigeria and related it to the varying degrees of responses of the macrobenthos to the variation in the physico-chemical parameters in the pond water and nature of the bottom sediment. Voshell (2002) observed that macroinvertebrates in Maryland streams became reduced in population structure with a shift from optimal values of the physico-chemical parameters and denatured pond bottom when studying the behavioural patterns of the macroinvertebrates in the stream. The general pattern of macrobenthic community in water bodies is influenced by the prevailing physico-chemical parameter in the system, hence the usually observed variations in the community structures in a particular environment (Melntire and Boyd, 1980). This, in its general perspective causes the different species of organisms inhabiting different habitats to respond according to the prevailing ecological settings in the habitat (Odum, 1971; Azizul *et al.*, 2006). Similar observations were made during the period of this study.

## CONCLUSION

Macrobenthic communities are important to pond ecosystem in that they form food source for most of the fresh water organism especially cultured fishes. Physico-chemical parameters, bottom soil properties and benthic community assemblages were observed to vary in each of the fish farms. Each of the benthic assemblages was influenced by both the physico-chemical parameters and bottom soil properties in each of the farm. Farms with high sand content had the highest number of macrobenthic organisms while those with high organic matter, clay and silt had the lowest abundance. The varied distribution in number and relative abundance were related to both the physico-chemical parameters and bottom soil properties. The present study therefore confirms that runoff from the pond catchment area directly affects the species diversity and indirectly affects aquaculture potentials.

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