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Physicochemical Conditions and Trophic State of Two Fish Ponds in Edo State

Ekikhalo Catherine Osimen[1], Glory Omontese Ogbagha[2], Cyril Oziegbe Onogbosele[3]

Department of Zoology, Ambrose Alli University, Ekpoma, Edo State, Nigeria

Abstract: ***Several commercial fish farms are sited in Owan West, Edo State, Nigeria, because of the existence of numerous rivers. These farms are managed with little knowledge of water quality and aquatic productivity. A study of two earthen ponds (Pond 1 and 2) in Uhonmora, Owan West, was carried out from March to June 2015, to determine their physicochemical conditions and trophic state. Water samples were collected monthly from the ponds and analyzed using standard methods. Chlorophyll a was extracted with 10% acetone. Trophic state was determined using the Carlson's trophic state index (CTSI) model. Data were statistically analyzed with GraphPad Prism Software. The range of the physicochemical parameters measured was within acceptable limits for pond fish culture. However, Pond 1 mean values were significantly higher ($p < 0.05$) than Pond 2 for water level, dissolved oxygen, total dissolved solids, conductivity, total hardness and calcium. Pond 2 mean Chlorophyll a (3.30±0.81 µg/l) was significantly higher than Pond 1 (2.30±0.24 µg/l). CTSI values varied between 37.87 and 39.58 (oligotrophic) for Pond 1 and 39.18 to 44.19 (oligomesotrophic) for Pond 2. Oligotrophic state of Pond 1 despite its higher nutrient level may be attributed to the effect of duckweed infestation and poor management.***

Keywords: Carlson's index, oligomesotrophic, Owan West

1. Introduction

A water body is a sensitive ecosystem influenced by climate and land use within the catchment, physical and chemical properties and its biological activities. Water quality is important in drinking water supply, irrigation, fish production, recreation and other purposes [1]. Physicochemical conditions of water quality and large deviations from the natural state of such conditions could have adverse impact on a water body. Water quality is important for every living organism. Ponds are important sources of water in some localities. They also provide habitat for invertebrates, fishes and aquatic birds [2].

A fish pond is a controlled aquatic environment stocked with fish for culture, recreational or ornamental purposes.Whereas rivers are influenced by a wide range of human activities, a major activity that leads to the availability of nutrients in ponds is fertilization and runoffs from farmlands which stimulate algal growth necessary for fish yield. However, this could lead to eutrophication. Potential impacts of eutrophication include oxygen depletion in water bodies, phytoplankton blooms, and recreational use limitations [3],[4].

Primary production is a critical part of the carbon cycle. Trophic state of a water body describes its potential for primary production, and ranges between oligotrophic and hypereutrophic state [5]. A scale of 1-100 is used to indicate the relative trophic state of a water body [6].Water bodies with values ranging from 25-40 are said to be oligotrophic; 40-55, mesotrophic; 55-65, eutrophic and 65-80, hypereutrophic [7]. Trophic state index has been used over the years as a criterion for definingwater quality.In different parts of the world including Nigeria, studies on trophic state indices of water bodies have been used in determination and evaluation of the biological conditions of water bodies [8],[9],[10],[11].

Chlorophyll *a* is a green pigment that allows plants to convert sunlight into organic compounds during photosynthesis, and its abundance is a good indicator of the amount of algae in ponds, lakes, rivers and streams [12]. In water bodies, its levels can be an effective measure of trophic state, potential indicator of maximum photosynthetic rate and a measure of primary production and water quality [13],[14]. The advantages of the use of chlorophyll *a* over other methods include sensitivity, ease of collection, low cost of analysis and detectability [15].

Owanin Edo state, Nigeria, is renowned for production in agriculture because of the existence of numerous large rivers and wetlands. All year round availability of water encourages the establishment of fish farms in the area. However, these fish farms are managed with little or no knowledge of water quality and aquatic productivity which leads to high cost of production per kilogramme of fish. Earthen and concrete ponds are the primary media for fish culture here.Limited information is available on physicochemical conditions and trophic state indices of fish ponds in Edo State [16], andno publishedinformation is available in Owan.The aim of this study was to determine the physicochemical conditions and trophic stateof fish ponds in Owan in order to provide information on pond water quality and productivity for proper fish pond management.

2. Materials and Methods

Study area

The study was conducted in two fish farms at Uhonmoratown, Owan West, Edo State. Uhonmora is located at longitude 6°52'N and latitude 5°57'E, and 87m above sea level. The area exhibits twodistinct tropical seasons, the wet (April - October) and dry (November - March). Air temperature during the study varied between 28.7°C and 33°C.The study spanned between March and June 2015. Two major fish farms (FOLAD Farms and

UyiosaifoFadama III Fish Farms) were selected. One pond in each farm was used for the study.

FOLAD farms, an integrated farm (piggery and fish) have ten concrete and three earthen ponds where they practice intensive monoculture of the African catfish (*Clariasgariepinus*). The main source of water is by abstractionfor the concrete pond and diversion/flooding from the nearby Ovbioku River. However, the earthen ponds were abandoned due to duckweed (*Lemna* species) infestation, presence of predatory indigenous fish species, predation by water fowls and poor management due to lack of funds. The earthen Pond 1 studiedhas a stockingcapacity of 10,000 fingerlings(Farm Manager personal communication). It is sited about 100m from the river. The surrounding was overgrown by weed and shrubs suchas *Pennisetumpurpureum* and *Chromolaenaodonata.*

UyiosaifoFadama III Fish Farm has six earthen ponds of equal size, stocked with *C.gariepinus*at a density of 2000 fingerlings in each pond. The source of water is from nearbyOwan River. Water is pumped twice a week into the ponds by means of a pumping machine from upstream while the wastewater is pumped back into the downstream section of the river. Good management practice in the farm includes use of nets to prevent predatory birds, dyke with grasses to prevent flooding and invasive speciesfrom the river and removal of sediment after harvest. A fallow pond, Pond 2in the farm was used for the study.

Sampling

Collection of water samples was carried out monthly from March to June 2015, between 0800 - 1100hours from each pond using labeled plastic bottles and 250ml glass bottles in triplicate. In the field, the bottles were rinsed with the pond water before collection. *In-situ* measurement of some parameters[water level, air and water temperature, pH, total dissolved solids (TDS), and conductivity] was carried out in the field. Water samples were taken to the laboratory for determination of other parameters[alkalinity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chloride, free CO2, total hardness, phosphate, calcium, magnesium, and chlorophyll].

Measurement of physicochemical parameters

The physicochemical parameters were measured using portable meters in the field and titration in the laboratory following standard methods and procedures [17],[18]. Temperature was measured using mercury-in-glassthermometer; water level, using a pole and a tape while pH, TDS and conductivitywere measured with portable meters (HANNA Instrument Model H196107, Model E-150-9001 and HM digital tester, AP-2), respectively.In the laboratory, total alkalinity, chloride, free CO_2, DO, BOD, total hardness, calcium and magnesium were determined by titration. Phosphate was determined using a spectrophotometer (Jenway, UK) at a wave length of 470nm.

Determination of trophic state

Trophic state of the ponds was determined by single parameter index using chlorophyll *a* according to Carlson's model.

Chlorophyll *a* determination

Chlorophyll *a*, a characteristic algal pigment constitutes approximately 1% to 2% (dry weight) of planktonic algal biomass which makes ita convenient indicator of algal biomass [12]. Chlorophyll *a*was determined using the acetone trichromatic method.Water samples were collected using one liter plastic bottles from each pond and wrapped immediately with black nylon bags to prevent photochemical breakdown of the chlorophyll. Samples were transported in iced box to prevent deterioration.In the laboratory, 50ml of sample was filtered through a 5µm membrane filter and vacuum was applied until the sample was dry. 0.2ml of $MgCO_3$(magnesium carbonate) suspension was added during the final phase of the filtration to prevent phytophytinization. The filter was folded into quarters and placed in a centrifuge tube. 10 ml of aqueous acetone was added, covered and placed in a dark box for extraction for 24 h. The clear extract was transferred to a 1.0 cm cell, using the multi-wavelength mode on the 6715 UV/visible spectrophotometer. The absorbance was measured at 630, 645, and 665 nm for chlorophyll *a, b* and *c*, respectively.

Parsons and Strickland's[19]equationwas used to extrapolate chlorophyll *a* as follows:

Chl*a* (µg/l) = $(11.6D_{665}-1.31D_{645}-0.14D_{630})vl^{-1}v^{-1}$

Where V, volume of acetone used (ml)

l, path length of cuvette (cm)

V^{-1}, volume of water filtered for extraction (l).

The values were then substituted in Carlson's equation (TSI –C = 9.81 In (Chl*a*) + 30.6)

Statistical analysis

Statistical analysis was done using the GraphPad Prism Software (version 5.0) for calculating mean, standard deviation (SD) and students't-test for comparing means.

3. Results

A summary of the results of the physicochemical parameters is presented in Table 1.

Water temperature

Narrow fluctuation was recorded in the water temperature of both ponds which varied between28.1 and 32.6°C (Table 1). Generally, the temperature of Pond 1 was lower than Pond 2 (Figure 1) with significantdifference in mean values ($p<0.05$).

Water level

Slight variation in water level was recorded in Pond 1 while fairly constant level was observed in Pond2 during the study (Figure 2). Mean value of Pond 1 was significantly higher than that of Pond 2.

TDS

The TDS ranged between 126-193 mg/lfor Pond 1 and 18-56 mg/l for Pond 2 with significant difference in mean values ($p<0.05$) (Table 1). Monthly variation showed increasing trend with increase in rainfall and a reverse order for Pond 2 (Figure 3).

pH
Narrow variation in pHof the two ponds was recorded which fluctuated between slightly acidic (pH 6.4) to slightly alkaline condition (pH 8.1) (Figure 4).

Conductivity
Conductivityincreased with rainfall (280-408 µS/cm) for Pond 1 and decreased (109-41 µS/cm) for Pond 2, similar to TDS (Figure 5).The mean level was statistically significant ($p<0.05$).

Free CO_2
Irregular fluctuation was recorded in free $CO_2$for both ponds. The values were generally higher in Pond 1 except in the month of April (Figure 6). Mean levels were, however, not significant ($p>0.05$).

Total hardness
Pond 1 was characterized by hard water condition (156 -262 mg/l) while soft water condition (16-58 mg/l) was recorded for pond 2 (Table 1). Mean levels showed significant difference ($p<0.05$). Total hardness increased with rainfall, particularly in Pond 1 (Figure 7).

Chloride
Chloride in bothponds ranged between 5-34mg/l, with no significant difference in mean levels ($p>0.05$)Chloride increased steadily with rainfall with highest values recorded in June in both ponds (Figure 8).

DO
Pond 1 had higher DO levels than Pond 2 with significantly higher mean values ($p>0.05$). Monthly variation showed decrease in DO with rainfall (Figure 9).

BOD
BOD was very low for both ponds (0.3-0.5mg/l) from May-June 2015 (Figure 10) with no significant difference in mean levels ($p<0.05$).

Total alkalinity
Pond 2 had higher variation in total alkalinity with significantly higher mean value ($p>0.05$) (Figure 11).

Phosphate
Phosphate level was low for both ponds. Itrangedbetween 0.04-0.23 mg/l with no significant difference in mean values($p>0.05$) (Figure 12).

Magnesium
Magnesium levels were generally high, which increased with rainfall with Pond 2 having wider fluctuations (Figure 13). Mean levels did not show significant difference between ponds ($p>0.05$).

Calcium
Calcium values were low.Itranged from 0.64-5.6mg/l, with wider variation and higher values in Pond 1 (Figure 14). Difference in mean levels was significant ($p< 0.05$).

Table 1: Physicochemical conditions of two fish ponds

Parameters	*Pond 1*			*Pond 2*			t value
	Mean±SD	Min.	Max.	Mean±SD	Min.	Max.	
Water temperature (^{o}C)	29.17±1.02	28.10	30.20	32.30±0.24	31.90	32.60	9.90*
Water level (m)	0'25±1.25	0.23	0.26	0.07±0.05	0.07	0.08	25.40*
TDS (mg/l)	167.12±30.70	126.00	193.00	34.50±15.96	18.00	56.00	7.11*
pH	6.92±0.17	6.70	7.10	7.17±0.74	6.40	8.10	0.90
Conductivity (µS/cm)	361.25±58.8	280.00	408.00	73.75±29.90	41.00	109.00	8.30*
Free CO_2 (mg/l)	9.00±5.71	4.00	17.00	5.50±5.06	2.00	13.00	0.79
Total hardness (mg/l)	214.50±46.77	156.00	262.00	35.37±22.52	16.00	58.00	6.75*
Chloride (mg/l)	27.00±8.28	15.00	34.00	15.25±12.39	5.00	33.00	0.47
DO (mg/l)	4.58±1.09	3.50	6.10	6.38±1.96	4.80	9.10	5.23*
BOD(mg/l)	0.43±0.09	0.30	0.50	0.35±0.06	0.30	0.40	1.00
Total alkalinity (mg$CaCO_{3}$/l)	32.37±6.07	25.00	38.50	84.75±23.59	70.00	120.00	5.46*
Phosphate (mg/l)	0.15±0.05	0.13	0.23	0.08±0.06	0.04	0.17	1.24
Magnesium (mg/l)	49.86±2.59	36.72	60.55	18.69±0.79	3.39	55.76	1.48
Calcium (mg/l)	4.10±1.40	2.24	5.60	0.76±0.24	0.64	0.84	4.23*

* Significant $p< 0.05$; SD, standard deviation; t, students' t test

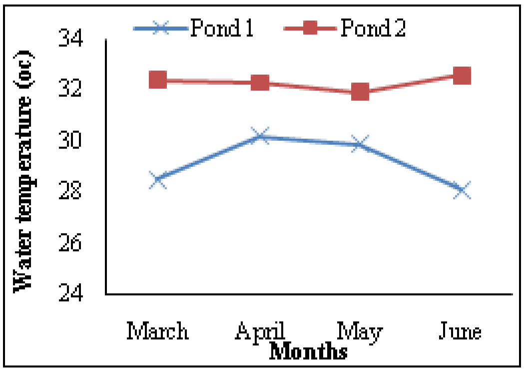

Figure 1: Monthly fluctuation of pond water temperature

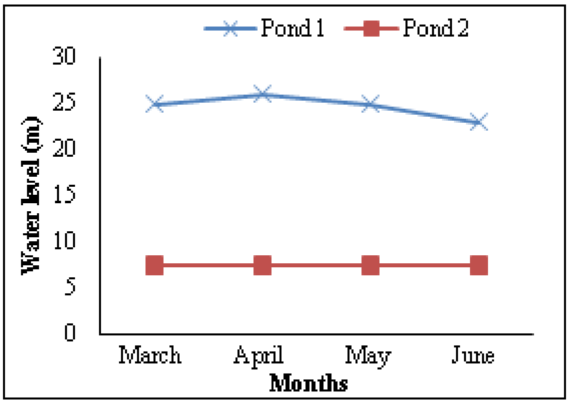

Figure 2: Monthly fluctuation of pond water level

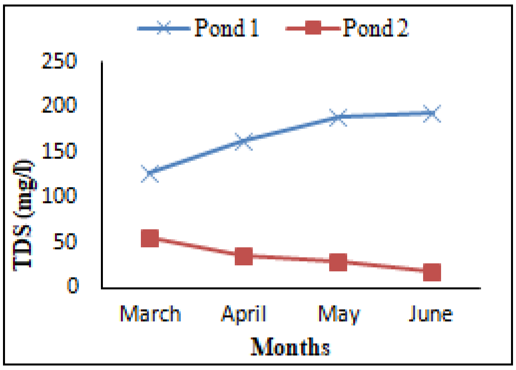

Figure 3: Monthly fluctuation of pond TDS

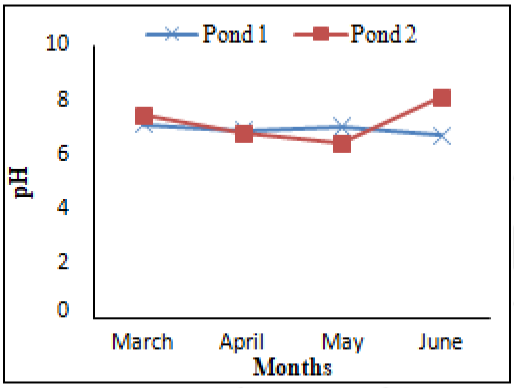

Figure 4: Monthly fluctuation of pond pH

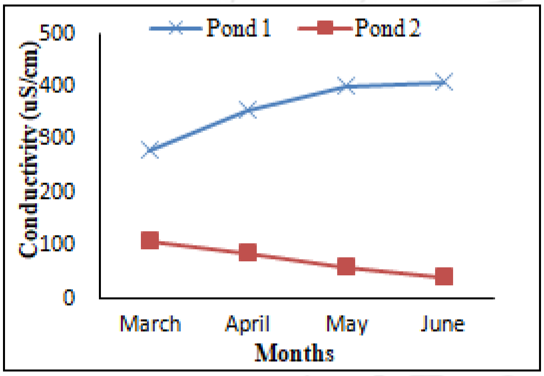

Figure 5: Monthly fluctuation of pond conductivity

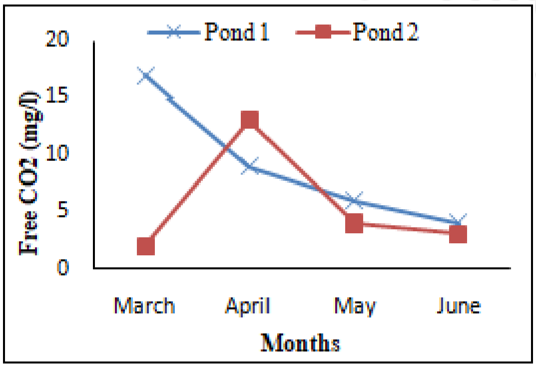

Figure 6: Monthly fluctuation of free CO_2 of pond

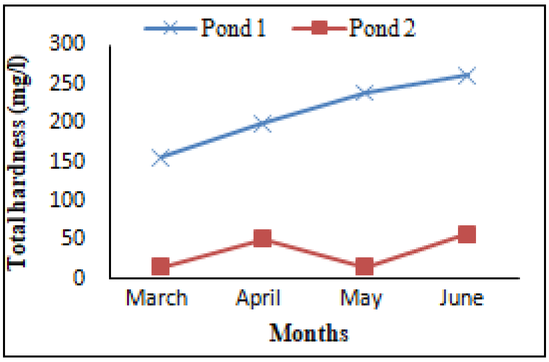

Figure 7: Monthly fluctuation of pond total hardness

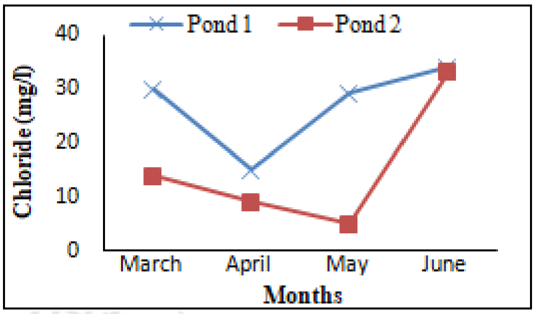

Figure 8: Monthly fluctuation of pond chloride

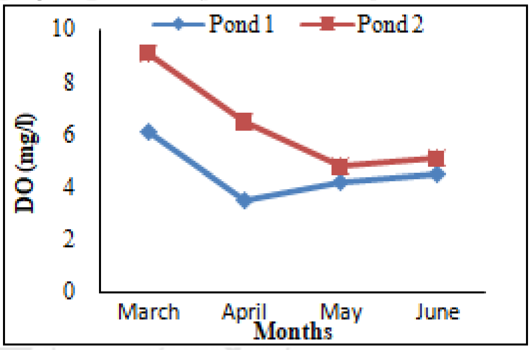

Figure 9: Monthly fluctuation of pond DO

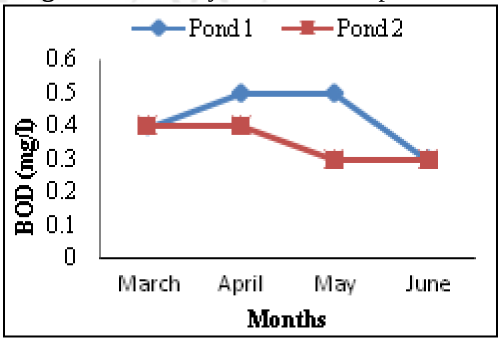

Figure 10: Monthly fluctuation of pond BOD

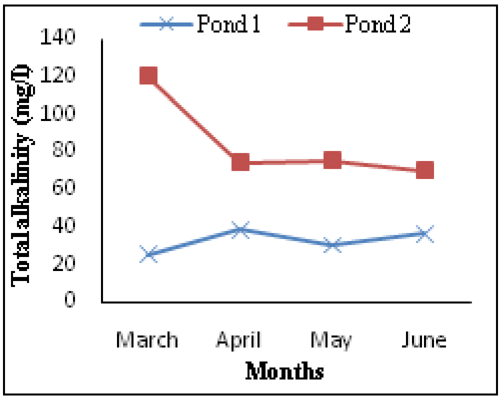

Figure 11: Monthly fluctuation of pond total alkalinity

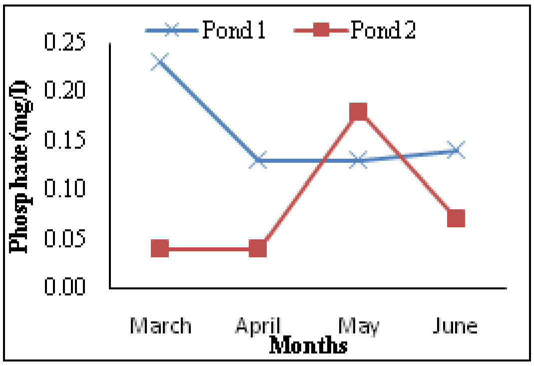

Figure 12: Monthly fluctuation of pond phosphate

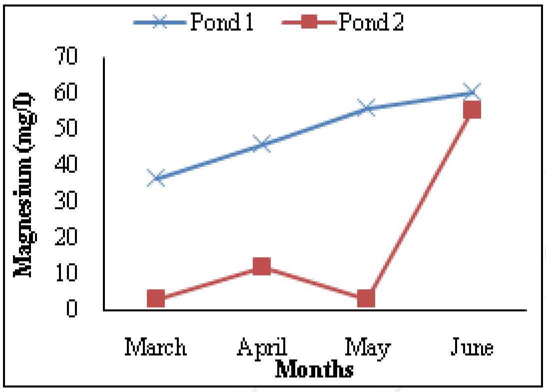

Figure 13: Monthly fluctuation of pond magnesium

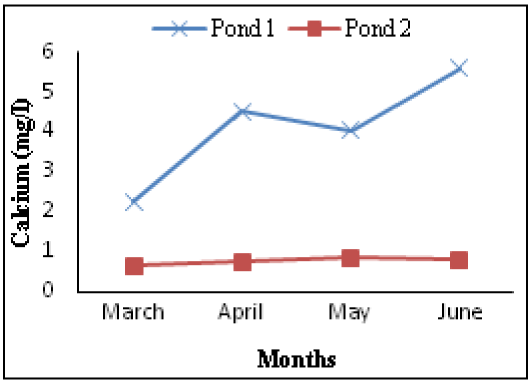

Figure 14: Monthly fluctuation of pond calcium

Chlorophyll *a*

Chlorophyll *a* levels ranged between 2.2 and 4.0µg/lwith higher levels in Pond 2 in early rainy months (Figure 15). Chlorophyll *b* levels ranged between 0.2-1.2 µg/l while chlorophyll *c* concentration in both ponds was between 0.4-1.9µg/l (Table 2).

Carlson's trophic state index (CTSI)

CTSI during the study varied between 37.89 and 44.19 (Table 2). Maximum CTSI value (44.19) in Pond 2 occurred in April, indicating mesotrophic state which reduced to minimum in June, indicating slightly oligotrophic state. In Pond 1, CTSI ranged from 37.87-39.58, indicating oligotrophic state throughout the study (Figure 16).

Table 2: Summary of productivity variables of two ponds in Owan

	Pond 1			*Pond 2*			*t value*
Parameters	Mean±SD	Min.	Max.	Mean±SD	Min.	Max.	
Chlorophyll *a* (µg/l)	2.30±0.24	2.20	2.70	3.30±0.81	2.50	4.00	2.44*
Chlorophyll *b* (µg/l)	1.06±0.11	1.00	1.20	0.50±0.30	0.20	1.10	2.43*
Chlorophyll *c* (µg/l)	0.96±0.81	0.40	1.90	0.96±0.47	0.60	1.50	0.26
CTSI Range		37.87	39.58		39.18	44.15	

*Statistically significant (p< 0.05); CTSI, Carlson trophic state index; SD, standard deviation; t, students' t test

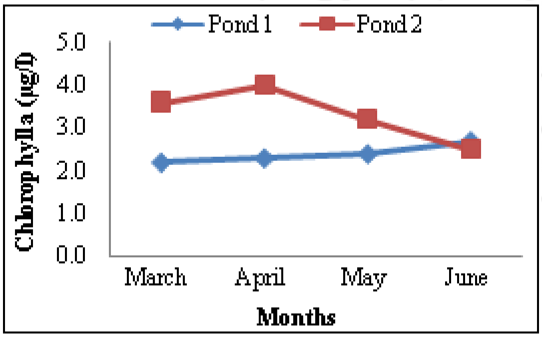

Figure 15: Monthly fluctuation of chlorophyll *a* in ponds

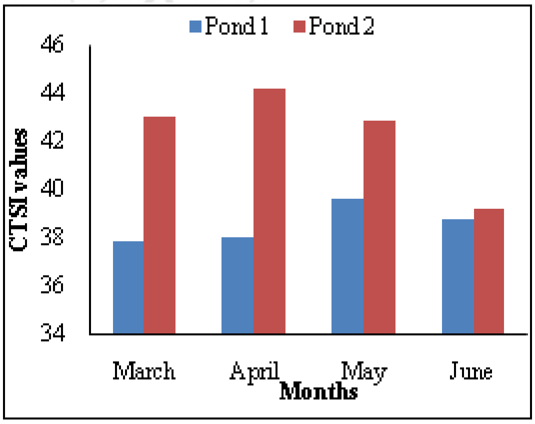

Figure 16: Monthly fluctuation of pond trophic state

4. Discussion

Physicochemical characteristics of ponds

The physicochemical characteristics showed variations, some were minimal, others maximal depending on the water quality. The variations observed between the ponds could be attributed to microhabitat difference and management strategy.For instance, biweekly water replacement in Pond 2 guaranteed better aeration hence higher DO level.The range of water quality with particular reference to temperature, TDS, pH, conductivity, alkalinity, DO and BOD were within permissible limits for fish growth and survival [16],[20]. The ranges of water temperature and pH in this study are similar to those reported by [16] and[21] for fish ponds in Edo and Bayelsa, respectively.

TDS and conductivity were higher in Pond 1. This could be attributed to lack of use of the pond which allowed nutrients to accumulate in the pond. TDS reduces solubility of gases like oxygen, utility for drinking purpose and also enhances eutrophication of the aquatic ecosystem [22]. The range of TDS and conductivity values in both ponds were within the limits suitable for aquaculture

Though carbon dioxide is readily soluble in water, very little free CO_2 was measured in the ponds. Pond 1 had the higher free CO_2 concentration probably due to the presence of more macrophytes. In addition, decomposition of organic matter and the respiration of aquatic plants and animals probably contributed to the free CO_2in the pond.Oxygen content of a water body is important for direct need of many organisms. It is one of the most significant parameters affecting the productivity of aquatic systems [23].The DO levels in this study were suitable for fish survival.

Alkalinity is a measure of the capacity of water to neutralize or buffer acids using carbonate, bicarbonate ions, and in rare cases by hydroxide, thus protecting the organisms from major fluctuations in pH. The recommended alkaline level for catfish,*Clariasgariepinus* is ≥ 20mg/l [24] while the recommended alkaline level in freshwater system is 5-500mg/l [25].The alkalinity levels in this study were within the recommended range which may account for the pH stability in the ponds.

Phosphate is one of the critical limiting nutrients needed by plants and fish. It is required by algae in small quantities. A water body may be considered eutrophic if total phosphate value ranged between 20-30 mg/l [26]. The highest concentration of phosphate was measuredin Pond 2, indicating mesotrophic state of the pond.

The total hardness measured in both ponds indicated hard water (Pond 1) and soft water (Pond 2).Hardness is important to aquaculture for good growth, and thedesirable range for fish is 75-200 mg/l $CaCO_3$ [25].Calcium and magnesium are the most common sources of water hardness. Higher magnesium recorded is at variance with some studies in Nigerian waters [27],[28].

Trophic state

During the study, the CTSI ranged from 37.8-44.19, indicating oligotrophic (low productivity) to mesotrophic state (moderate productivity) of the ponds. Oligotrophic state of Pond 1 throughout the studywas unexpected considering the higher nutrient levels. Abundance of duckweed and other macrophytes covering the pond was probably responsible for its low algal content, and therefore, its low productivity. Weed covering prevents sunlight penetration in ponds, inhibiting photosynthetic activity and decreasing chlorophyll concentration and hence phytoplankton abundance [29]. The direct effect of this is low production in natural fish food (phytoplankton and zooplankton), thus resulting in overall low fish productivity.

The mesotrophic statein three of the four months of study indicated moderate productivity in Pond 2. Fish production is optimal in productive water bodies [30]. Phytoplankton abundance in this pond was higher as indicated by the green colouration of the water, making it suitable for fish farming.Phytoplankton in ponds stimulates the growth of zooplankton which is a source of food for fish. The oligotrophic state of the pond in the month of June was due to dilution by rainfall and reduced solar radiation. Rainfall is one of the factors limiting available nutrient in water bodies [14]. High water level period coincided witholigotrophic statusin SelingueReservoir, Mali [31].

5. Conclusion

A study of the physicochemical conditions and trophic state of fish ponds in Owan West in Edo State,indicated that the water quality was within limits suitable for aquaculture. The productivity measured by the trophic state varied between oligotrophic (low productivity) and oligomesotrophic state (moderate productivity). The oligotrophic state of one of the ponds was due to poor pond management and duckweed infestation. Relatively better pond management accounted for the oligomesotrophic state of the second pond. This study is useful in the provision of information that could guide proper management of fish ponds in relation to water quality, nutrient level, trophic state and pond fish production.

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