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ASPECTS OF HYDROBIOLOGY OF LAKE ONA IN SOUTHERN NIGERIA 2: PHYSICAL AND CHEMICAL HYDROLOGY

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Studies of the physical and chemical conditions of the water of Lake Ona, Asaba, Southern Nigeria were conducted fortnightly between August 2001 and July 2003. The physical parameters of the water were determined on site, while the chemical parameters were determined in the laboratory using standard methods for water analysis. Water temperature had a range of 22.5-29.0 ^{0}C, water level 1.03-6.32 m, pH 6.28-7.69, dissolved oxygen 2.40-12.80 mg/l, conductivity 19.50-69.00µS/cm, total alkalinity 12.50-45.0 mg/l, nitrate-nitrogen 0.03-0.64 mg/l, phosphate-phosphorus 0.11-5.51 mg/l, calcium 1.20-9.89 mg/l, magnesium 0.49-3.89 mg/l, total dissolved solids 10.18-36.50 mg/l, and transparency 9.00-82.00 cm. With the exception of water temperature, water level, total alkalinity, calcium ion, dissolved oxygen, conductivity, phosphate as well as transparency which showed significant inter-season variations ($P<0.05$), the other water parameters did not correlate significantly with season ($P>0.05$). Out of the twelve parameters studied, only conductivity and total alkalinity showed significant inter-station variation ($P<0.05$).

INTRODUCTION

Beadle (1981) stated that there are eight great lakes in tropical Africa, which range in size from 2,003 to 75,000 km^2. In addition to these great lakes there are other innumerable smaller natural and man-made lakes like the Ona and Kainji in Nigeria, and the Volta in Ghana. These lakes together with rivers and streams constitute the inland water systems of Africa. The hydrology of the inland water of Nigeria has been much documented, with discussion being approached from several viewpoints vis-à-vis the geochemistry, floral and faunal composition and community structure (Olatunde, 1977; Egborge, 1977; Ogbeibu and Victor, 1995).

Like other freshwater bodies in Nigeria, Lake Ona has been undergoing steady exploitation over the years for its fish resources with no scientific work carried out on it. This paper, the second in a series of the ecological study of this lake, provides baseline information on such aspects of the physical and chemical hydrology of the lake as water temperature, water level, pH, dissolved oxygen, conductivity, total alkalinity, nitrate, phosphate, calcium and magnesium ions, total dissolved solids as well as transparency.

MATERIALS AND METHODS

Study Area

Lake Ona is a tropical freshwater lake, west of the Niger River, having its source from the Utto spring (Figure 1). It is located around Isoko Camp, which is eight kilometers from Asaba, Nigeria, lying on latitude 6^o 43´ E and longitude 6^o 1´ N of the equator. In the wet season, the lake appears as a common sheet of water but it is compartmentalized into three distinct sections of Ona-ododo, Ogbu and Obabala, with Ogbu and Ona-ododo being the largest and smallest compartments respectively.

Topography and Vegetation

Lake Ona is situated in the Asaba–Ogwashi rock formation and has a gentle slope from its banks that permits inflow of surface runoff and organic matter derived from the surrounding vegetation. This load contributes to the allochthonous input of the lake. The substratum is made up of a deep layer of clay and an admixture of silt and decomposing organic matter. The lake is devoid of thick tree canopy but it is dominated by floating aquatic macrophytes viz *Salvinia nymphellula* Desv., *Nymphaea lotus* Linn., present mostly in the back waters found floating on the water surface are *Azolla pinneta*, R.Br. Var. Africana (Desv) and *Pistia straitiotes*. Fringing the shoreline, is a dense population of *Panicum subalbidium*, Kunth. *Paspalum scrobiculatum*, Linn. And *Diplazioum sammati,* Kahn

Study Stations

Five sites were chosen and designated I, II, III, IV and V as shown in Figure 1c. Stations I, III and V were located respectively in the Ona-ododo, Ogbu and Obabala compartments. Station II is the link between Stations I and III, while the link between Stations III and V is Station IV.

The morphometric features of the lake are presented in Table I. The lake has a length of 2,250 m, an area of 516,197 m^2 and a volume of 4,413,804 m^3

Sampling and Study of the Physico-Chemical Parameters

Water samples were collected between 07.30 hr-10.30 hr on sampling days at fortnightly

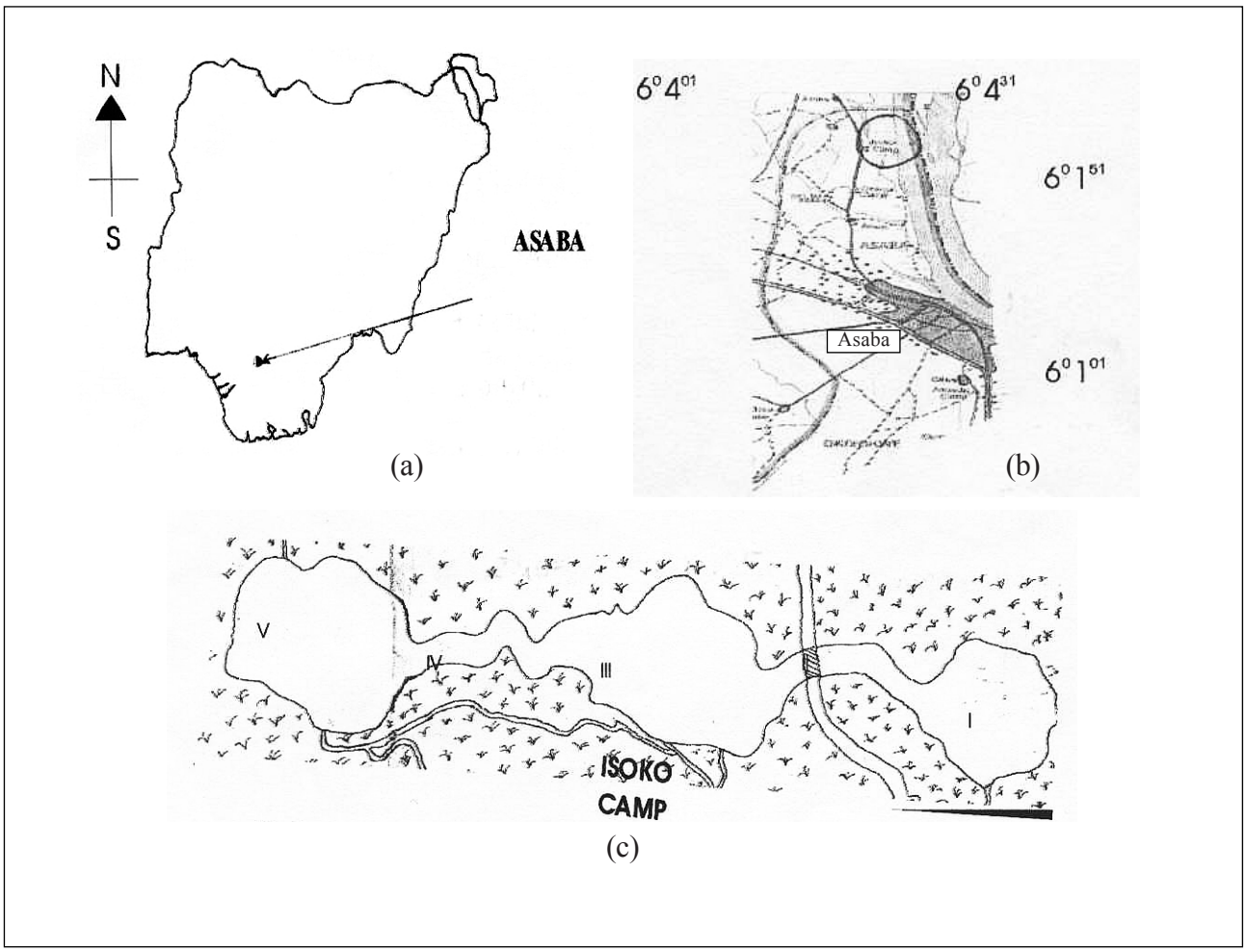

Figure 1a, 1b and 1c. Map of Nigeria showing Asaba, Study Area, and Stations on Lake Ona.

intervals between August 2001 and July 2003 from the five stations. The physical and chemical water parameters for all five stations of the lake were measured in-situ. Temporal changes in water level were measured to the nearest centimeter using a simple graduated weighted line. Subsurface water temperature was measured using a mercury-in-glass thermometer (0-110 ^{o}C) graduated at 0.1 ^{0}C intervals. The water pH and conductivity were measured using the Griffin battery-operated pH and conductivity meters respectively.

Transparency was measured to the nearest centimeter using a 20 cm diameter Secchi disc attached to a meter pole graduated at 1.0 cm intervals. Dissolved oxygen concentration was determined by the Winkler's method as described by APHA (1998) and Miroslav et al. (1999). Total dissolved solids, total alkalinity, nitrate, phosphate, calcium and magnesium were assessed using standard methods as described by APHA (1998), EPA (1996) and Miroslav et al. (1999).

Besides the basic parametric measurements of central tendency and dispersion, data were analyzed for inter-season and inter-station variability in water quality parameters using the Kruskal Wallis non-parametric tests ZAR (1984). The inter-relationship among the parameters was determined using the Spearman rank correlation coefficient. Data were further subjected to analysis of variance by General Linear Models (GLM) of SAS (1998) and means were separated by the DUNCAN multiple range test. Meteorological weather data for the study area extracted from the Federal Ministry of Aviation meteorological station in Delta State University, Asaba Campus, were used to delineate the sampling period into dry and wet seasons.

Table 1. Summary of the morphometric features of the study stations.

Features	Station I	Station II	Station III	Station IV	Station V	Total
Volume (m^3)	176,396.17	111,380.13	2,105,824.00	59,648.28	1,960,555.54	4,413,804
Water level (Max.in m)	5.73	5.57	6.32	5.23	5.98	
Length (Max.in m)	117.28	265.91	980.00	131.85	694.97	2,250.01
Width (Max.in m)	173.65	75.20	340.00	86.50	471.75	
Shoreline (Max.in m)	428.20	664.78	2,254.00	350.21	2,333.43	6,030.62

Mean Width of the lake = 229 m

Area of lake = 516,197 m^2 (0.5162 km^2)

RESULTS

The meteorological conditions of the study area is presented graphically in Figure 2.

There was no drastic change in the air temperature recorded during the study period. The highest temperature recorded was 31ºC in February 2003 while the lowest was 26.5ºC recorded August 2002. Except for the month of December 2002 when no rain was recorded, rainfall was evenly distributed throughout the study period with the highest value 48.1 mm, recorded in May 2003. Like rainfall, December 2002 had the lowest relative humidity of 20% while the most humid month was August 2002 with a value of 89%.

Physical and chemical conditions

The range of physical and chemical parameters is presented in Table 2. Inter-station comparison of the means of all water parameters studied in the lake are presented in Table 3, and seasonal variation is presented in Table 4.

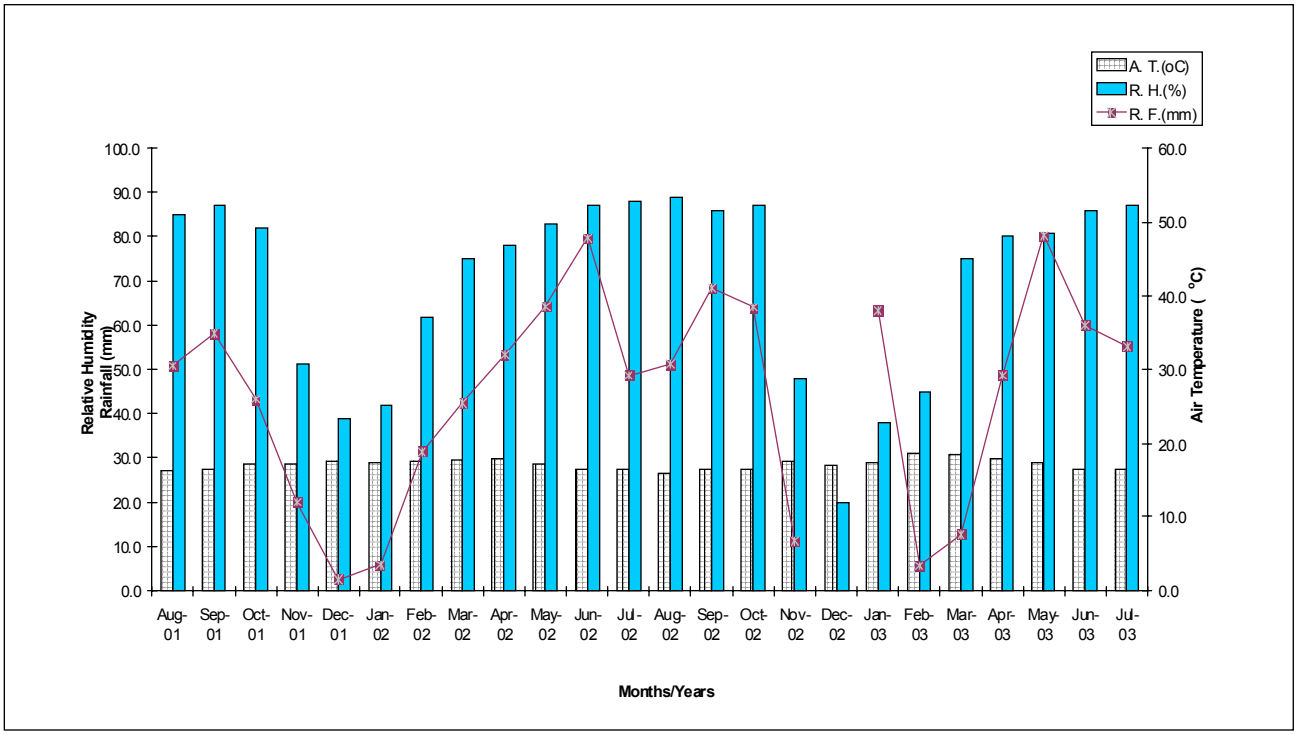

Figure 2. Mean monthly climate for the study area.

Table 2. Range of values of the physical and chemical water parameters of Lake Ona.

Parameters	Station I	Station II	Station III	Station IV	Station V
Water temp (^{0}C)	23.50 – 28.00	22.50 – 29.00	23.00 – 29.00	23.00 – 28.80	22.60 – 28.50
Water level (m)	1.03 – 5.73	0.33 – 5.57	1.86 – 6.32	0.85 – 5.23	0.94 – 5.98
pH	6.28 – 7.69	6.17 – 7.71	6.08 – 7.66	6.04 – 7.67	6.13 – 7.69
Dissolved Oxygen (mg/l)	2.40 – 12.80	2.80 – 8.40	2.00 – 11.40	2.80 – 12.00	2.40 – 10.20
Conductivity (µS/cm)	19.50 – 69.00	31.00 – 65.00	38.00 – 85.00	39.5 – 89.00	27.00 – 87.56
Total alkalinity (mg/l)	12.50 – 45.00	12.50 – 45.00	10.00 – 35.00	11.30 – 42.50	10.00 – 41.30
Nitrate –N (mg/l)	0.03 – 0.64	0.02 – 1.18	0.03 –0.89	0.06 – 0.69	0.06 – 0.91
Phos – P (mg/l)	0.11 – 5.51	0.11 – 8.17	0.15 – 2.14	0.12 – 2.84	0.15 – 1.75
Calcium (mg/l)	1.20 – 9.89	0.80 – 9.08	0.08 – 9.35	0.08 – 8.81	0.80 – 9.62
Magnesium (mg/l)	0.49 – 3.89	0.73 – 3.40	0.97 – 3.89	0.49 – 3.40	0.73 – 3.89
TDS (mg/l)	10.18 – 36.50	15.00 – 39.00	21.70 – 43.00	19.50 – 46.00	20.05 – 45.10
Transparency (cm)	9.00 – 82.00	10.00 – 68.50	11.50 – 75.50	15.50 – 73.00	17.00 – 82.00

Water Temperature

The water temperature closely followed the ambient air temperature, with a range of 22.5-29.0 ^{o}C. The highest temperature of 29 ^{o}C was recorded at Stations II and III. The highest mean and minimum mean temperature of 26.6 ^{o}C and 26.32 ^{o}C were recorded at Stations IV and II respectively. Dry season water temperatures were significantly higher than those of the wet season ($p<0.05$).

Water Level

The highest value of water level was obtained in the rainy season and the lowest was recorded in the dry season. It had a range of 0.33 to 6.32 m (Table 2). The maximum and minimum mean water levels recorded were 3.27 m and 1.54 m at Stations III and II respectively. Water level differed significantly ($p<0.05$) among stations.

pH

The highest and lowest values of pH were recorded at Stations II and IV respectively. The highest mean of 6.98 was obtained at Station I while the least mean value of 6.82 was obtained at Station IV. The pH of the lake did not show seasonality ($p>0.05$).

Dissolved Oxygen

The dissolved oxygen range was 2.0-12.80 mg/l as recorded at Stations II and I respectively. Maximum and minimum means were obtained at Stations V and II. There were no inter-station variations ($p>0.05$) (Table 3), but the dry season concentrations were significantly higher than the wet season values ($p<0.05$).

Conductivity

The highest conductivity recorded was 89.0 µS/cm at Station IV while Station I had the least value of 19.50 µS/cm. The maximum and minimum mean values obtained were respectively 54.53

Table 3. Summary of analysis of variance for inter-station water parameters.

Parameters	Station I	Station II	Station III	Station IV	Station V
Water temp (^{0}C)	26.4083 ± 0.304	26.3167 ± 0.316	26.5917 ± 0.316	26.6042 ± 0.344	26.5417 ± 0.325
Water level (m)	2.2179 ± 0.309	1.5413 ± 0.311	3.2742 ± 0.304	2.0000 ± 0.302	2.5812 ± 0.310 NS
pH	6.9808 ± 0.104	6.8738 ± 0.110	6.9179 ± 0.116	6.8212 ± 0.0.116	6.8271 ± 0.095 NS
Dissolved Oxygen (mg/l).	5.1321 ± 412	4.8333 ± 0.249	5.4458 ± 0.445	5.4875 ± 0.466	7.0804 ± 0.389 NS
Conductivity (µS/cm)	47.2875 ± 2.613 ^{a}	49.2083 ± 1.757 ^{ab}	51.2833 ± 2.036 ^{ab}	54.4333 ± 2.593^{b}	52.7500 ± 2.505 ^{ab}
Total alkalinity (mg/l)	31.9000 ± 1.655^{b}	29.8250 ± 1.437^{ab}	437^{ab} 28.3458 ± 1.329^{ab}	25.9458 ± 1.802^{a}	26.8583 ± 2.025 ^{ab}
Nitrate –N (mg/l)	0.3271± 0.044	0.4229 ± 0.060	0.3396 ± 0.048	0.3546 ± 0.046	0.3825 ± 0.054
Phos – P (mg/l)	1.1358 ± 0.247	1.2483 ± 0.325	0.7388 ± 0.102	0.9650 ± 0.145	0.8458 ± 0.106 NS
Calcium (mg/l)	4.7588 ± 0.445	4.2863 ± 470	4.6800 ± 0.456	4.2233 ± 0.486	4.3225 ± 0.514 NS
Magnesium (mg/l)	2.0758 ± 0.166	2.1171± 0.131	2.0463± 0.169	1.7396 ± 175	2.0183 ± 0.190 NS
TDS (mg/l)	24.8263 ± 1.148	26.2975 ± 0.187	27.8542 ± 1.100	28.6250 ±1.405	26.9333 ± 1.271
Transparency (cm)	40.4875 ± 3.262 38.9583 ± 3.395	38.9583 ± 3.395	41.6542 ± 3.750	40.0292 ± 3.318	40.333 ± 3.636 NS

µS/cm and 49.29 µS/cm. Conductivity showed distinct seasonality with higher values recorded in the dry season (compared with the wet season ($p<0.05$).

Total Alkalinity

The range of total alkalinity recorded was 10.0-45.0 mg/l. Highest concentration was recorded at Station I while the least was obtained at Stations III and V. The maximum and minimum means were 31.9 mg/l and 25.95 mg/l recorded at Stations I and IV respectively. Dry season mean values were significantly higher than those of the wet season ($p<0.05$).

Nitrate-Nitrogen

Station II had the highest and least values of 1.18 mg/l and 0.02 mg/l recorded in the study. Station II had the highest mean of 0.42 mg/l while the least mean of 0.33 mg/l was obtained at Station I. This parameter did not show seasonality, as the seasonal mean values recorded were not significantly different ($p>0.05$).

Phosphate-Phosphorus

The range for this parameter was 0.11-8.17 mg/l. The highest and least values were obtained at Stations I and II respectively. The highest mean of 1.25 mg/l was obtained at Station II while the lowest mean of 0.74 mg/l was recorded for Station III. Dry season concentrations were significantly higher than those of the wet season ($p<0.05$).

Table 4. Dry and wet season mean, maximum and minimum values of water parameters.

Parameters	Wet Season	Dry Season
Water temperature (^{0}C)	25.77 ± 0.409^b (22.50 – 27.60)	27.05 ± 0.392^a (24.00 – 29.00)
Water level (m)	2.89 ± 0.487^a (1.10 – 6.32)	1.54 ± 0.281^b (1.03 – 4.50)
pH	6.80 ± 0.126^a (6.28 – 7.69)	7.16 ± 0.153^a (6.35 – 7.71)
Dissolved O_2 (mg/l)	4.37 ± 0.244^b (2.40 – 5.60)	5.90 ± 0.737^a (3.00 – 12.80
Conductivity (µS/cm)	46.43 ± 4.694^b (19.50 – 89.00)	48.14 ± 2.525^a (34.50 – 61.00)
Total alkalinity (mg/l)	30.04 ± 2.752^b (10.00 – 41.30)	33.76 ± 1.772^a (20.00 – 45.00)
Nitrate –N (mg/l)	0.44 ± 0.052^a (0.10 – 1.18)	0.22 ± 0.056^a (0.03 – 0.64)
Phosphate – P (mg/l)	0.92 ± 0.433^b (0.11 – 5.51)	1.35 ± 0.231^a (0.12 – 8.17)
Calcium (mg/l)	3.31 ± 0.422^b (1.20 – 6.82)	6.21 ± 0.519^a (3.21 – 9.89)
Magnesium (mg/l)	1.73 ± 0.232^a (0.49 – 3.17)	2.43 ± 0.186^a (1.71 – 3.89)
Total dissolved solids(mg/l)	24.38 ± 2.073^a (10.18 – 36.50)	25.28 ± 1.083^a (19.00 – 46.00)
Transparency (cm)	32.58 ± 4.117^b (9.00 – 61.00)	48.40 ± 4.019^a (33.50 – 82.00)

Calcium ion

The maximum and minimum concentrations of calcium ion recorded were 9.89 mg/l and 0.08 mg/l at Stations I and IV respectively. The maximum and minimum mean values of 4.76 and 4.2 mg/l followed the same pattern. There was distinct seasonality, with the dry season concentrations higher than the wet season values ($p<0.05$).

Magnesium ion

The range of concentration obtained for magnesium ion was 3.40-3.89 mg/l. The highest values were recorded at Stations I, III and V while the minimum concentration was recorded at Stations II and IV. The highest and least mean concentrations were recorded at Stations II and IV respectively. There was no seasonality between the wet and dry season parameters ($p>0.05$).

Total Dissolved Solids

The range of total dissolved solids was 10.18-46.0 mg/l. The highest concentration was obtained at Station IV while the least value was recorded at Station I. Station III had the highest mean, while the least value was obtained at Station II. The wet and dry season concentrations of this parameter were not significantly different ($p>0.05$).

Transparency

Transparency range was 9.00-82.0 cm. The upper limit was recorded at Stations I and IV while the least limit was recorded at Station I. Station III had the highest mean while the least value was obtained at Station II. There was distinct seasonality with the dry season values higher than those of the wet season ($p<0.05$).

Apart from water temperature, water level, dissolved oxygen, total alkalinity, phosphate, calcium and transparency which showed significant inter-season variation ($P<0.05$), all other water parameters studied did not show significant inter-season variation ($P>0.05$).

DISCUSSION

In the present study, temporal variations in temperature were observed to be similar in all the study stations of Lake Ona, with higher values recorded in the dry season than in the wet months

of the year. The observed mean temperature of 26.6 ^{o}C with a range of 22.5-29.0 ^{o}C, is well within the desired temperatures for fish production. Temperature has a profound effect on chemical and biological processes in water, and fishes are known to grow best in temperatures between 23.0-32.0 ^{o}C (Boyd and Lichktoppler, 1979).

Lake Ona is shallow with a maximum-recorded depth of 6.32 m and a mean depth of 3.27 m. The observed shallow nature and the fact that it is not bordered by heavy tree canopies, make it susceptible to wind and wave actions. In consequence, mixing of the lake waters encourages high productivity that enhances its ability to support a rich fish fauna.

The highest pH recorded for the lake (7.71) is well within the preferred pH range (6.5-9.0) for optimum growth and reproduction of fish. It was equally observed that seasons of the year have no effect ($P>0.05$) on this parameter. This lack of seasonality may be due to the fact that most of the H^{+} ions are derived in-situ, hence the minimal influences of precipitation and inputs from surface runoff during the rains. A similar observation was made in the study of water bodies in the Okomu forest reserve (Ogbeibu and Victor, 1995).

Apart from a few occasions when the dissolved oxygen concentrations rose to 12.0 mg/l, the dry season mean dissolved oxygen concentration was 5.90 mg/l while the wet season mean was 4.37 mg/l. These values are quite adequate for fish production (Anyanwu, 1988). The higher mean dissolved oxygen concentration recorded in the dry season, did not agree with the findings of Egborge (1971), Ogbeibu and Victor (1995), that dissolved oxygen is generally higher in the wet season in the tropics.

A possible explanation for the lower concentration of dissolved oxygen in the wet season is that inflows from runoff bring in decomposing organic matter whose breakdown requires oxygen. Although the dissolved oxygen concentration recorded is lower than the standard values, quoted at equivalent temperatures viz 8.38 mg/l at 23.0 ^{o}C and 7.64 mg/l at 29 ^{o}C (Boyd and Lichktoppler, 1979), the dissolved oxygen concentration in the lake could be higher as measurements were made in the morning and concentrations are known to be low in the morning.

Lake Ona was found to have high conductivity of 89.0 µS/cm, which confirms its freshness as the value is less than 100 µS/cm. Conductivity of a water body is an index of its total ionic content and is an index of its freshness (Ogbeibu and Egborge, 1995). It was observed that seasons affect conductivity ($P<0.05$), 89.0 µS/cm for wet season and 61.0 µS/cm for dry season. This is in agreement with the work of King and Nkanta (1991) who reported higher wet season conductivity in the Mfangmfang pond compared to the dry season. This trend may be due to the influx of allochthonous organic and inorganic materials from the surrounding catchment area during the flood.

It was observed that total alkalinity in the lake exhibited a seasonal regime, being higher in the dry season than in the wet season. This is in agreement with the findings of Adebisi (1981). This trend could be due to evaporation and concentration of the bases in water in the dry season. The availability of CO_2 for phytoplankton growth is related to alkalinity, and waters with total alkalinities of 20-150 mg/l are said to contain suitable quantities of CO_2 to permit plankton production for fish production. Thus the lake, in having a mean alkalinity value within this range irrespective of season, is good for fish production.

Nitrate-nitrogen and phosphate-phosphorus showed seasonal variability. Only small concentrations of these nutrients i.e. nitrate (0.01 mg/l) and phosphate (0.1 mg/l) in water are

sufficient to stimulate growth of phytoplankton. Wet season mean concentration of nitrate was significantly higher than that of the dry season. This is consistent with the findings of Ogbeibu and Egborge (1995). The wet season enrichment values may be due to input of allochthonous nitrate-containing substances by surface runoff. Unlike the nitrates, dry season mean concentration of phosphate was higher than in the wet season. This is in agreement with Etiene et al. (1997). This situation is attributed to the high rate of decomposition of organic matter and mineralization of mineral salts in the dry season. The high concentrations of these nutrients in the lake are indicative of organic pollution but the level is not sufficient to be a limiting factor to primary production.

Season was found to affect concentration of ions in Lake Ona, with dry season values being higher than those obtained in the rainy season. This may be attributed mainly to the reduction in water volume caused by evaporation and the consequent increase in concentration of the ions. Results of the study show the lake water to be slightly hard, having a high alkalinity value of pH 6.80-7.16. In all the stations, Ca^{2+} correlated significantly with water level ($P<0.05$). Mg^{2+} and total alkalinity as well as Mg^{2+} and Ca^{2+} correlated significantly ($P<0.05$) in all the stations. The presence of high concentrations of these ions (Ca^{2+} and Mg^{2+}) in the lake, corroborate the assertion of the water being hard due to the presence of their trioxocarbonate salts.

Seasonality was observed in the concentration of total dissolved solids in the lake. Dry season values were generally higher with a maximum mean value of 25.28 mg/l, compared to that of the wet season with a maximum mean of 24.28 mg/l. The low value recorded in the wet season may be due to dilution from rain and runoff. Results from the study show total dissolved solids to correlate significantly ($P<0.05$) with conductivity at all stations except Station V, and the lake has a morpho-edaphic index of above 5 which, if well exploited, can be highly productive (Ryder, 1965).

Transparency values in the lake showed some seasonality at ($P<0.05$) and were high at all the stations. The low wet season values could be due to the effect of the lake receiving runoff carrying along with it heavy loads of silt, clay particles and decomposing organic matter. Some of these particles remain suspended in water with attendant clouding, restriction of light penetration, and invariably limiting phytoplankton growth. In the dry season, most of these suspended particles have settled to the bottom, hence transparency is higher.

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