Coastal Environmental Pollution and Fish Species Diversity in Lagos Lagoon, Nigeria

Nnamdi H. Amaeze [1], Rosemary I. Egonmwan[2], Adedamola F. Jolaoso[3] Adebayo A. Otitoloju[4]

Ecotoxicology Laboratory, Zoology Department, University of Lagos, Akoka-Yaba, Lagos, Nigeria

[1]amaezenh@gmail.com; [2]egonmwanr@yahoo.com; [3]jollydamcell2K4@yahoo.com; [4]bayotitoloju@yahoo.com

***Abstract*- The physical and chemical characteristics as well as the fish species diversity of the coastal fishing grounds of the Lagos lagoon were assessed over a twelve month period. The sampling area was divided into four Zones in line with the established salinity regimes in the area. The sources of pollution in the coast line were found to be widely varied, ranging from chemical inputs and sewage to solid waste. These have caused far reaching effects ranging from foul odour, loss of aesthetics and deterioration in the water quality to reduced fish catch. Overall fish catch was higher in areas closer to river inputs into the lagoon (Zone I and II) where the pollution input was mainly from sewage and diluted effluents. Unregulated burning of sawdust at Okobaba and oil pollution at the ports has led to depleted fish catch in Zones III and IV respectively. Chemical characteristics of the water often fell within the FEPA set limit and there was strong correlation each between chemical oxygen demand (COD), salinity and electrical conductivity of the surface water. Fish diversity significantly varied with sampling Zones ($p<0.05$) and generally areas receiving organic waste had higher fish diversity compared to those receiving chemical waste.**

***Keywords*- Waste; Coastal Pollution; Physicochemical Characteristics; Lagos Lagoon; Fish Diversity**

I. INTRODUCTION

The Lagos Lagoon is under consistent and sometimes severe pressure from diverse forms of human activities emanating from the surrounding city centres. There have been numerous investigations into the ecology and health of the Lagos Lagoon and the linear assessment of historical record points to increasing stress. Starting from the investigation of some aspects of the ecology of the lagoon [1], fisheries resources [2], plankton distribution and diversity [3], to macrobenthos [4], there has been a shift to studies centered on pollution load [5, 6], sources [7, 8, 9] and effects of pollutants in the lagoon [10,11,12] and adjourning creeks [13,14]. These studies have revealed a steady deterioration of the lagoon health by way of changing physicochemical properties, macrobenthic faunal composition, fish species and plankton diversity.

The documented sources of pollution in the lagoon are widely varied and range from industrial effluents [8, 15], domestic sewage [11], wood burning and associated atmospheric emissions and solid wastes [9] to heat from thermal plants [16]. Solid wastes such as high and low density polythene, empty cans of food/pesticide sprays, glass bottles, used needles and syringes (hospital wastes), used car tyres, worn clothes and a host of others have contributed to the high level of pollutants found virtually in all the lagoons and creeks in Lagos [7]. Most of these wastes are non-biodegradable and continuously leach heavy metals into the water body [9]. Over 2000 medium and large scale industries in Lagos metropolis and neighbouring Ogun State discharge their effluents into the lagoon [15] in an unregulated manner. One of the ecological implications of this combination of poor sewage system, industrialization and poor waste management in the Nigerian coastal waters is that pollutants enter freely into the waters unabated [17]. It has also been established that coolant water introduction from Egbin power station (the largest gas plant in Nigeria) may have affected key physiochemical properties of the water thereby causing higher surface water temperatures and transparency as well as reduced dissolve oxygen levels [17]. Waste water entering the lagoon system is also often poorly treated or untreated, containing compounds far above the national set limit [11] and these often result in far reaching alteration of ambient water quality [18].

The implications of this dwindling water quality on fish catch in the Lagos lagoon remain a question for extensive review when considered against the background of the effect of reduced fish catch on the local economy. This study therefore seeks to examine the water quality status of Lagos Lagoon along with its determinants in the coastal fishing grounds of the Lagoon so as to establish a relationship which would determine effects on fish quality and fishing activities and related future management efforts.

II. MATERIALS AND METHODS

A. Study Area

The study was carried out along the western coastline of the Lagos Lagoon (Figure 1). The lagoon complex stretches from Cotonu in the Republic of Benin and extends to the fringes of the Niger Delta in Nigeria along its 257km course (19) (Longitude 32 ^{o}3” and 3^{o}53”E and Latitude 6^{o}26” and 6^{o}37”N). The lagoon consists of estuarine water that is fed majorly in the north by Ogun River, with a host of other smaller rivers as well as tidal creeks. It discharges in the south into the South Atlantic Ocean through the Lagos Harbour. The vastness of the lagoon may easily hide the many shallow places present within the system [2]. The Lagos Lagoon is the ultimate sink of a number of industrial discharges/effluents and run-offs from the surrounding Metropolis [7, 8] and there is often high housing density along the coastline. The sampling points were selected taking into due consideration, the pollution dynamics of the Lagoon as reported by past literature [20] and areas closer to direct effluent and sewage influence.

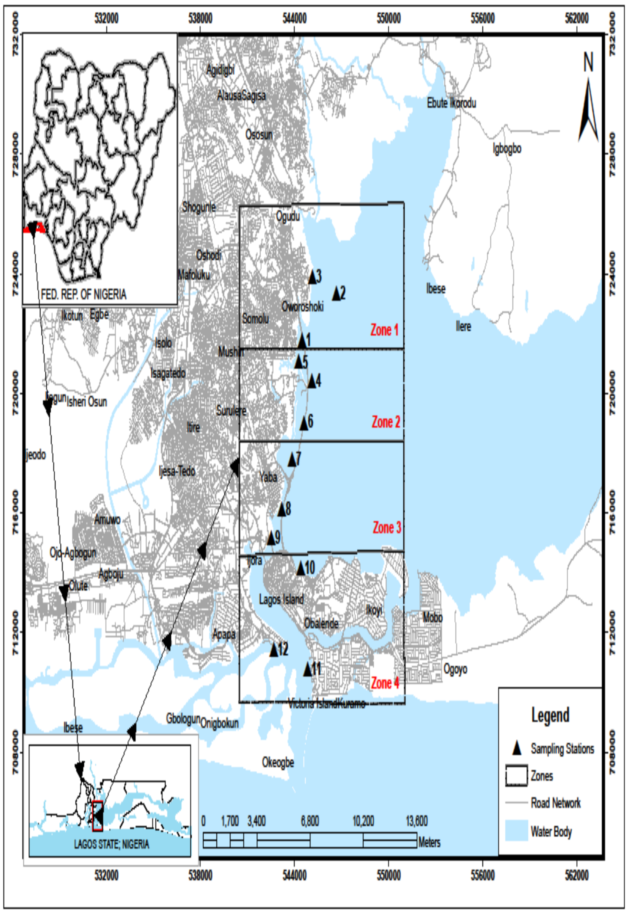

Figure 1 Map of Lagos Lagoon showing population density around sampling locations (Station selection was based on areas that are associated with high population density and high and frequent effluent/waste discharge activities)

B. *Sampling Design*

The coastal section of the Lagoon close to the sewage and effluent discharge sites were divided into four zones. The zones and sampling stations therein were selected on the basis of nearness to human activities and spread. Zone I consists of areas around Ilaje, Oworonshoki, Agboyi and Ogun River inputs. Zone II covers areas such as the University of Lagos Lagoon front to areas which receive effluents from the University Community Road/Kpako areas and areas adjourning the Third Mainland Bridge. Zone III covers areas from Makoko settlements to Okobaba Sawmill and Iddo Terminal while Zone IV comprise areas bordering Victoria Island, Ikoyi and Appapa Port jetties (Figure 1).

The parameters analyzed in the water samples included salinity, temperature, dissolved oxygen (DO), Hydrogen ion concentration (pH), Acidity, Alkalinity, Conductivity, total suspended solids (TSS), total dissolved solids (TDS), Turbidity, Chemical oxygen demand (COD), biological oxygen demand (BOD), Nitrate and phosphate concentrations. Chemical analyses for acidity, alkalinity, COD, BOD, NO_3^- and PO_4^{3-} were carried out in the Central

Within each zone, three sampling stations were randomly selected given recourse to fairness in spacing and cost of analysis, thereby making a total of 12 sampling stations. GPS coordinates and visual notes of permanent and semi-permanent structures were used in marking sampling locations. Sampling was done on a seasonal basis-rainy and dry season- reflecting the prevailing climate regime in the area. Water for physicochemical assessment and wild fishes were sampled all the year round (monthly for 12 months).

C. *Sampling Techniques*

Sampling techniques used in the study include physical observation of human activities around the coastline, chemical analysis both *in situ* and *ex situ* as well as presence of small scale fishing activities. Sampling techniques were selected on the basis of those employed by previous investigators as documented in literature and based on local adaptation where absolutely necessary.

D. *Physical Assessment*

The physical appearance of the study area was documented using photographs, physical perception of odour and observation of the different significant human activities likely to cause pollution of the water body. This process was repeated in all the sampling locations and the results documented qualitatively.

E. *Chemical Assessment*

The surface water quality was assessed *in situ* using hand held probes (Horiba multi water Sampler- Model U50) and *ex situ* Laboratory based probes (Metler Toledo - Model In lab 730) as well as galvanometric analysis. Water samples were obtained using 1 litre plastic kegs, whilst other samples were collected with simple grabs. The samples were carefully labelled, stored/cooled using ice packs in cooling boxes in which they were transported to the laboratory where they were stored at 4^{o}C before analysis within 48 hours.

The parameters analyzed in the water samples included salinity, temperature, dissolved oxygen (DO), Hydrogen ion concentration (pH), Acidity, Alkalinity, Conductivity, total suspended solids (TSS), total dissolved solids (TDS), Turbidity, Chemical oxygen demand (COD), biological oxygen demand (BOD), Nitrate and phosphate concentrations. Chemical analyses for acidity, alkalinity, COD, BOD, NO_3^- and PO_4^{3-} were carried out in the Central Research Laboratory of University of Lagos following standard procedures [21].

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F. *Fish Diversity Assessment*

Local fishermen were employed to assist in the fish sampling exercise, which was done by using subsistence techniques employed on a daily basis by the fishermen (gill and cast nets) (22). Fish sampling was done only in commercially approved area by the Lagos State Ministry of

Agriculture (Table 1), usually in Community Held fishing grounds. Fish sampling was done on a monthly basis over a twelve month period that spanned from December 2010 to November 2011.

TABLE I SELECTED FISHING LOCATIONS IN THE SAMPLING AREA

S/N	Fishing Area	Coordinates	Tenure Holding
1	Zone I	N 06^{o} 32. 709' E 003^{o} 25. 134'	Community held fishing ground where fishing is done at three days interval. Individual fishing in open waters with no coordination.
2	Zone II	N 06^{o} 31. 091' E 003^{o} 24. 126'	Community held fishing ground where fishing is done at three days interval. Individual fishing in open waters with no coordination.
3	Zone III	N 06^{o} 29. 635' E 003^{o} 23. 787'	Individual fishing in open waters with no coordination.
4	Zone IV	N 06^{o} 26. 875' E 003^{o} 18. 885'	Individual fishing in open waters with no coordination.

NB: Low fish yield around Zones III and IV makes community fishing unattractive

G. *Statistical Analysis*

The chemical characteristics of the water was estimated as mean± SE using SPSS Version 16, while correlation between parameters were calculated using Microsoft Office Excel 2007. The level of statistical significance was estimated at P<0.05 using the t-test by SPSS Version 16. Fish species diversity was assessed using a host of indices including Margalef [23], Simpson [24] and Shannon-Wiener [25].

III. RESULTS

A. *Physical Characteristics of the Surface Water*

The overall observation of the coastline points to practices which are consistent with unsustainable utilization of the water resources in the area (Plate 1). There were numerous canals, channels, gutters and pipes directly discharging municipal and domestic sewage into the lagoon. The input from these sewers includes faeces, vegetables, detergent laden waters, oil and grease, paint, wood shavings and chemicals. Generally, the nature of the pollutants varied widely depending on the prevalent activities within Zones (Table 2). Zone I is characterized by the receipt of sewage and industrial effluents while Zone II is polluted directly mostly from domestic sewage. Zone III represents a highly disturbed area characterized by receipt of municipal and domestic sewage, leachates from numerous dumpsites, direct faecal discharges, wood burnings and the nauseating foul smelling air pollutants. Zone IV on the other hand is polluted mainly from shipping activities, oil discharges from commercial vessels, leachates from ship wrecks and high density of water transportation.

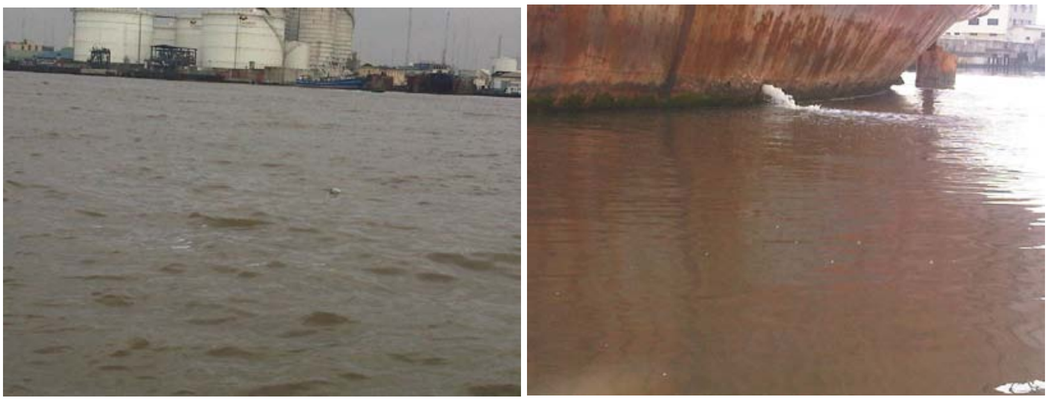

Plate 1 Sections of the Lagos lagoon, showing some of the sources of pollution

B. Chemical Characteristics of the Surface Water

The chemical properties of the water body showed variations across Zones and seasons and seasonality marked with significant differences in salinity ($p<0.05$) (Tables 3 and 4). Dissolved oxygen levels within the sampling stations were generally higher in the rainy season (4.44±0.43 to 4.73±0.52mg/l) while the hydrogen ion concentrations were higher in the dry season with values which ranged from 7.36±0.13 to 8.13±0.12 in the dry season and 7.15±0.3 to 7.37±0.32 in the rainy season. The measured pH values correlated significantly with salinity values (R= 0.7532) especially around the Apapa Port (Table 5). Physico-chemical properties of the water body were mostly within the National FEPA set limits except for TDS and DO levels, both parameters were however not significantly correlated (R= 0.2498). Measured turbidity of 13.66±3.08 to 22.92±9.21 in rainy season was consistently above the safe limit across stations (Table 4). BOD with its precursor compounds, nitrates and phosphates were higher in the dry season ($p<0.05$) than in the rainy season. Whereas COD, BOD did not differ significantly across stations and both showed strong relationship, often differing with stations irrespective of season. Chemical oxygen demand and electrical conductivity showed the greatest level of correlation with R values up to 0.7959 (Table 5). It also showed high relationship with salinity (0.7107). TDS and TSS showed a somewhat inverse relationship, with TSS values being higher in the rainy season, unlike dissolved solids which were higher in the dry season.

TABLE II DESCRIPTION OF THE PHYSICAL CONDITIONS IN THE SAMPLING LOCATIONS

Zones	Sampling Location	Description	Approximate Location
	Ilaje	Wooding residential buildings lining the coastline with direct discharge of faeces. High input of sewage and sand mining.	N 06^o 31. 778' E 003^o 24. 130'
	Oworonshoki	Wooding/Bricks residential buildings lining the coastline, solid waste dumps in several locations along the coast, and sand mining. activities.	N 06^o 31. 655' E 003^o 24. 466'
I	Agboyi/Ogudu	Solid waste dumps public toilets and residential building. Also receives effluent rich waste from Ogba/Ikeja industrial estate and Ogun river. Foul smelling air.	N 06^o 32. 940' E 003^o 24.489'
	Unilag Lagoon front	Characterised by natural fish ponds built using shrub stems, boat transport and fishing activities. **Minimal direct waste input**, littered by plastics cans, water sachets and debris	N 06^o 31. 048' E 003^o 24. 473'
II	Unilag Power station/ Off Kpako	sewage discharge from University and neighbouring communities, coolants from electricity sub-station, coastal residence and public toilets.	N 06^o 31. 388' E 003^o 24. 013'
	Unilag High/ Off 3rd mainland Bridge	Receives road-side dirt swept in by LAWMA road sweepers. **Minimal direct waste input**	N 06^o 30. 293' E 003^o 24. 194'
	Makoko	wooden residential buildings along the coast and direct toilets, fishing, boat transportation, saw mills and high boat transport density.	N 06^o 29. 635' E 003^o 23. 787'
	Okobaba	Log transportation and marketing, saw milling and wood burning, wooden residential buildings, solid waste dumps, public toilets, high boat transport density and receives road-side dirt from the third mainland bridge.	N 06^o 28. 714' E 003^o 23. 426'
III	Iddo	Public toilets, solid waste dump, direct defecation, auto mechanic workshops, sac chemical plastic washing, boat transport and an abandoned power plant. The area receives most of the untreated faeces commercially discharged into the lagoon. Faeces often seen floating on water. Area saturated by foul smelling air.	N 06^o 28. 190' E 003^o 23. 064'
	Ikoyi	Close to a road side and receives leachates from nearby solid waste dump. Characterised by boat transport activities.	N 06^o 26. 071' E 003^o 24. 332'
IV	Victorial Island	Characterised by transport activities and discharge point of gutters carrying municipal wastes.	N 06^o 26. 903' E 003^o 23. 459'
	Apapa	Oil tanker jetties, municipal waste discharge from nearby on-shore residence and Factory effluents. The water surface is covered by dirt and oil sleek.	N 06^o 29. 180' E 003^o 19.156'

TABLE III PHYSICOCHEMICAL PROPERTIES OF LAGOS LAGOON SURFACE WATER IN THE DRY SEASON

Water Characteristics	**ZONE I**	**ZONE II**	**ZONE III**	**ZONE IV**	**FEPA LIMIT**
Salinity (‰)	7.68±2.87	10.63±3.71	15.22±4.43	16.55±4.28	NS
Temp(^oC)	29.25±0.75	29.67±0.43	29.51±0.49	30.1±0.43	<40
DO(mg/L)	3.40±0.64	4.02±0.5	4.26±0.56	5.93±1.46	5.0
pH	7.38±0.13	7.36±0.13	7.47±0.13	8.13±0.12	6-9
Acidity(mg/L)	23.28±2.31	18.56±1.94	20.17±3.10	18.67±3.84	NS
Alkalinity(mg/L)	49.44±11.93	50.83± 9.40	54.17± 14.02	60.5±14.59	NS
Conductivity(mS/cm)	8.94±3.58	13.19±4.71	18.87±5.13	18.93±3.81	NS
TSS(mg/L)	12.50±6.07	11.89±3.71	9.72±1.46	8.17±1.00	30
TDS(mg/L)	3464.11±1478	1653.39±6784	3724.89±4219	9954.28±3906	2000
Turbidity(FTU)	6.73±2.08	9.55±3.86	6.02±1.57	5.63±1.47	10
COD(mg/L)	95.22±53.06	115.11±90.69	306.00±252.57	352.83±268.43	NS
BOD_5(mg/L)	5.4±0.3	4.7±0.5	5.4±0.1	5.2±0.2	50
Nitrates(mg/L)	1.2±0.1	3.6±0.3	2.6±0.1	1.2±0.5	20
Phosphates(mg/L)	1.3±0.1	2.7±0.4	2.3±0.1	2.3±0.5	5.0

TABLE IV PHYSICOCHEMICAL PROPERTIES OF LAGOS LAGOON SURFACE WATER IN THE RAINY SEASON

Water Characteristics	**ZONE I**	**ZONE II**	**ZONE III**	**ZONE IV**	**FEPA LIMIT**
Salinity (‰)	4.28±2.72	6.28±3.22	11.22±3.97	11.88±3.96	NS
Temp(^oC)	26.98±0.54	27.13±0.58	27.05±0.60	27.02±0.53	<40
D.O(mg/L)	4.58±0.31	4.63±0.34	4.73±0.52	4.44±0.43	5.0
pH	7.22±0.36	7.15±0.3	7.15±0.26	7.45±0.12	6-9
Acidity(mg/L)	22.49±2.43	16.06±3.27	13.72±1.72	15.78±1.57	NS
Alkalinity(mg/L)	122.50±8.43	103.89±5.12	109.44±9.36	115.83±11.62	NS
Conductivity(mS/cm)	14.56±9.65	17.67±11.19	28.08±13.55	33.62±14.38	NS
TSS(mg/L)	14.83±3.16	14.89±3.33	15.33±1.85	16.50±4.68	30
TDS(mg/L)	2734.8±1531.4	2190.6±1127.3	1754.1±350.5	5546.3±2209..5	2000
Turbidity(FTU)	18.25±5.69	13.66±3.08	22.92±9.21	20.96±6.66	10
COD(mg/L)	180.56±163.11	201.28±186.01	236.17±207.84	515.39±355.55	NS
BOD_5(mg/L)	3.33±0.1	2.33±0.1	3.00±0.1	3.67±0.3	50
Nitrates(mg/L)	1.03±0.3	1.15±0.1	17.17±1.2	43.76±16.4	20
Phosphates(mg/L)	0.03±0.0	0.04±0.1	0.21±0.2	0.36±0.4	5.0m

FEPA = Federal Environmental Protection Agency (Federal Ministry of Environment)

TABLE V CORRELATION COEFFICIENT (R) BETWEEN PHYSICOCHEMICAL CHARACTERISTICS OF THE LAGOS LAGOON WATER

Parameters	**Temp**	**DO**	**Ph**	**Salinity**	**Acidity**	**Alkalinity**	**Cond.**	**TSS**	**TDS**	**Turb**	**BOD**	**COD**
Temp.	1											
DO	0.36											
pH	-0.04	-0.34										
Salinity	-0.19	-0.51	0.75									
Acidity	-0.15	-0.62	0.40	0.64								
Alkalinity	-0.57	0.24	-0.09	-0.37	-0.42							
Conductivity	-0.29	-0.13	0.69	0.76	0.23	0.16						
TSS	-0.61	-0.45	-0.15	-0.13	0.42	0.33	0.80					
TDS	0.07	-0.25	0.58	0.71	0.35	-0.54	0.45	-0.32				
Turbidity	-0.33	-0.15	0.11	0.09	-0.04	0.56	0.35	0.54	-0.18			
BOD	0.90	-0.16	0.63	0.56	0.58	-0.87	-0.40	-0.80	0.44	-1.60		
COD	-0.32	-0.21	0.49	0.71	0.42	0.15	0.80	-0.08	0.16	0.24	-0.048	1

C. *Fish Species Diversity*

A total of 913 individuals belonging to 24 fish species and 19 families were observed throughout the 12 months sampling period (Table 6). The family Cichlidae recorded the highest number of species and individuals.

Zone I recorded the highest fish species (382 individuals, 16 species), followed by Zone II (287 individuals, 13 species), Zone III (189 individuals, 9 species) and Zone IV (55 individuals, 4 species). This also reflected in the species diversity indices assessment of the four Zones of the sampled Lagoon. The highest number of overall fish observed per month was the month of June (17 species and 222 individuals), this was followed by July (16 species and 115 individuals) and August (13 species and 92 individuals) while the least number of fish observed was in March (5 species and 63 individuals).

The Simpson's, Shannon-Weiner's, Magalef and Menhinick indices for species diversity at Zone I were 0.15, 0.83, 2.53 and 0.82 respectively.

TABLE VI OVERALL FISH SPECIES DIVERSITY IN THE LAGOS LAGOON (DEC 2010-NOV 2011)

Family	**Species**	**I**	**II**	**III**	**IV**	**Total**
Mugilidae	Liza falcipinnis	15	25	40	20	100
Cichlidae	sarotherodon melanotheron	128	117	18		263
	Sarotherodon galilae		5			5
	Hemichromis fasciatus	18	10			28
	Tilapia guinensis		43	20		63
	Tilapia zilli		1			1
Lutjanidae	Lutjanus agennes	5	7			12
	Lutjanus goorensis				3	3
Monodactylidae	Psettias sebae	29				29
Clupidae	Ethmalosa fimbriata	24	2			26
Carangidae	Caranx hippos	12	3			15
Cynoglossidae	Cynoglossus senegalensis	10		58		68
Osteodolossidae	Heterotis niloticus	1				1
Bagridae	Chrysichthys nigrodigitatus	53	58	33	5	149
Clariidae	Clarias gariepinus	21	10			31
Mochokidae	Synodontis nigeriata	12	3			15
Eleotridae	Batanga lebritonis	15				15
Schilbeidae	Schilbe mystus	21				21
Sciaenidae	Pseudotolithus typus			3	27	30
Pomadasydae	Pomadasys jubelini			9		9

Gobiidae	Battygobius sororator	7	3			10
Gerreidae	Gerres melanopterus			3		3
Polynemidae	Polydactylus quadrifilis			5		5
Sphyaenidae	Sphyraena barracuda	11				11
Species abundance (n)		382	287	189	55	913
Species variety (S)		16	13	9	4	
Simpson Index		0.15	0.24	0.19	0.37	
Shannon-Wiener Index (log)		3.3	2.6	2.64	1.58	
Shannon-Wiener Index (ln)		2.29	1.78	1.83	1.09	NA
Shannon-Wiener Index (Adjusted)/Equitability Index		0.83	0.69	0.83	0.79	
Margalef Richness Index:		2.53	2.12	1.53	0.73	
Menhinick Index:		0.82	0.77	0.69	0.54	

At Zone II the indices were 0.24, 0.69, 2.12 and 0.77 respectively while at Zone III it was 0.19, 0.83, 1.53 and 0.69 respectively and at Zone IV it was 0.37, 0.79, 0.73 and 0.54 respectively (Table 6). Thus indicating that Zone I had the highest species diversity while Zone **IV** had the least level.The dominant fish species obtained were Sarotherodon melanotheron,Chrysichthys nigrodigitatus and Liza falcipinnis, comprising 263, 149 and 100 individuals respectively. These dominant species (Plates 2-4) accounted for 56.1% of the overall total fish catch. They represent a largely tolerant group of fishes.

Plate 2 Liza falcipinnis Valenciennes 1836 (Sicklefin Mullet) (Yoruba-Atoko)

Plate 3 *Sarotherodon melanotheron Ruppel* 1852 *(*Black chin tilapia) (Epia-Yoruba)

Plate 4 Chrysichthys nigrodigitatus Lacepede 1803 (Silver Catfish) (Yoruba-Obokun)

IV. DISCUSSION

The emphasis on the survey of the Lagos Lagoon this time is on the unsustainability of fish life in the lagoon if the current rate of pollution is unchecked. The lagoon is still on the receiving end of indiscriminate solid waste disposal with dump sites being strategically located along some portions of the coastline (Zones I, II and III) resulting in the probable leaching of wastes into the water body. Areas around the port (Zone IV) are characterized by shipping activities and offloading of refined petroleum products into tanks within coastal depots, releasing oil and hydrocarbons into the water body. This portends future crises because of the shallowness of most sections of the lagoon. Also, there were differences in chemical characteristics of water between stations with Zone III and IV being the most polluted relative to the others. Chemical waste input was highest in Zones III and IV relative to the others as reflected in the COD values for both seasons. According to previous investigators, the volume of waste discharge is a critical factor in such water bodies as this [26, 27]. Continuous discharge of untreated human feaces into the lagoon has been associated with high abundance of pathogenic *Escherichia coli* [27], which is a major concern for a water body with high level of human interaction. It is common place to see sand miners and oyster hunters diving into the water on a daily basis and some sections such as the University of Lagos Lagoon Front (Zone II) are centers of religious practices such as baptism. Fishing is the mainstay of rural dwellers along this highly disturbed coast, with most of the fishes caught destined for sale at nearby local fish markets of Ilaje and Makoko. Several bacterial species may be pathenogenic causing gill disease in *Tilapia* fish which are transmissible to human handlers/ consumers [28].

Leachates from dumpsites are often laden with concentrated complex effluents [29] which contain diverse organic and inorganic substances such as ammonium, sulphates, chlorides and heavy metals [30]. These leachates contaminate and pollute coastal waters quite unlike on land where depending on soil permeability, they may not necessarily impact ground water quality [29]. The physico-chemical characteristics of water bodies such as rivers and streams are particularly altered depending on the constituent of the leachate [14]. Solid wastes entering the lagoon also alter the aesthetics, making the water repulsive to fishes, altering the quality and may reduce the size of available breeding grounds for various fish species. This may have far reaching effects on their reproductive success and eventually the fishes which would continue to thrive in such an area. It is now common place to see numerous used cans and water sachets floating along the shores, obstructing fishing sites and sometimes hampering boat transportation and clogging the jetties.

The general variation of water chemistry with season in the lagoon has been attributed to the influence of salinity and rainfall [31, 19, 22]. Temperature fluctuation was slightly seasonal in nature. However changes as observed in this study were not statistically significant as other studies indicated [1, 22, 32, 33]. Rainfall in the surrounding metropolis often carries floods laden with large tones of debris and waste materials. Observations from this study indicate that although suspended solids are swept into the water during the rainy season, the high level of turbulence associated with water bodies in such a season and the low surface water temperature, resulted in lower levels of solids being dissolved in the water thus increasing turbidity. Given the circadian nature of this event, fishes tend to receive minimal disturbance from this because fish catch were often higher in the rainy months. Higher fish catch in the dry season compared to the rainy season had earlier been reported in a study that covered areas with the highest salinity in this Lagoon [22]. The significant decline in fish species diversity from the least saline to most saline locations closest to the Lagos habour did not quite agree with [22] who caught up to thirty-nine fish species in areas associated with high salinity. The latter may be attributed to the scale of fishing conducted in the earlier study compared to the current one where the use of gill nets and fishing hooks were emphasized rather that cast nets.

The high influx of debris along the coast of the lagoon resulted in higher alkalinity across sampling Zones in the rainy season. The BOD and COD levels varied consistently with the observed nature of waste entering the area, with the former being high in areas receiving domestic and municipal sewage input and the latter in areas receiving effluents from port activities and where wood burning is practiced. The High level of organic nutrient elements such as phosphates (PO_4) and nitrates (NO_3^-) which are precursors of high BOD may result in ecological imbalance, leading to a subsequent loss of biodiversity [13]. The ecological stress level in the coastal Lagos Lagoon is apparently high and there is evidence that infectious diseases of fishes occur when susceptible fishes are exposed to virulent pathogens under certain environmental stress conditions [34].

There is no doubt that the coastal Lagos Lagoon is becoming more polluted because the dominant fishes include more resistant *Tilapia* species such as *S. melanotheron* and cat fishes such as *C. nigrodigitatus* which are tolerant to hypoxic and sometimes polluted water bodies. Recent studies [35, 22, 36] have all reported high numbers of Cichlids particularly *S. melanotheron*. Investigative interviews conducted among community and single holding fishermen also revealed a general consensus that the fish catch is declining both in number and variety.

V. CONCLUSION

The Lagos State Government therefore urgently needs to design a clear and focused road map to control point and non-point sources of pollutant entry into the lagoon system so as to ensure sustainable fish development and fishing industry as well as improvement of water quality to enhance its ecotourism potential. To this end, there is an urgent need for the construction of a sewage treatment plant around the area for pretreatment of municipal sewage before their discharge into the lagoon. Also alternatives to direct discharge of faeces into the lagoon via the Iddo terminal should been sought to reduce enrichment of the water body with nutrients and water borne diseases. These measures coupled with stricter enforcement of prohibition of solid waste dumping and scrutiny of effluent quality from industries would lead to reduction in the current stress levels of wild animals in the Lagoon and rejuvenation of fish populations.

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REFERENCES

[1] J.E. Webb, The Ecology of Lagos Lagoon. V. Some Physical Properties of Lagoon Deposits Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, vol. 241 (683), pp. 393-419, 1958.

[2] S.O. Fagade, C.I.O. Olaniyan, Seasonal distribution of the fish fauna of the Lagos lagoon. Bull. De IFAN Ser. A vol. 36 (1), pp. 244–252. 1974.

[3] C.I.O. Olaniyan, An Introduction to West African Animal Ecology. London & Ibadan: Heinemann. 1968.

[4] E.A. Ajao, S.O. Fagade, J.A. Oyenekan, The ecology of Aloidis trigona in Lagos Lagoon, Nigeria. Arch. Hydrobiol. vol. 121, pp. 485–496. 1991.

[5] T.V.I. Akpata, J.A. Ekundayo, Faecal pollution of the Lagos lagoon. Niger. Sci., vol.12 (1 & 2), pp. 39–49, 1978.

[6] [6] K.N. Don- Pedro, E.O. Oyewo, A.A. Otitoloju, Trend of Heavy Metal Concentrations in Lagos Lagoon Ecosystem, Nigeria. West African Journal of Ecology, vol. 5, p. 103-114, 2004

[7] E.A. Ajao, Review of the state of pollution of the Lagos Lagoon. NIOMR Tech. Paper No. 106. 19, pp. 1996.

[8] E.O Oyewo, Industrial sources and distribution of heavy metals in Lagos Lagoon and their biological effects on estuarine animals. (PhD. Thesis) University of Lagos, 1998.

[9] O.A. Nubi, E.A. Ajao, A.T. Nubi Pollution assessment of the impact of coastal activities on Lagos Lagoon, Nigeria Science World Journal, vol. 3(2), pp. 83-88. 2008.

[10] C.A. Edokpayi, A.O. Ayorinde, Physical, Chemical and Macrobenthic Invertebrate Fauna Characteristics of Swampy Water Bodies within University of Lagos, Nigeria West African Journal of Applied Ecology ISSN: 0855-4307, 2009.

[11] E.O. Longe, A.O. Ogundipe , Assessment of Wastewater Discharge Impact from a Sewage Treatment Plant on Lagoon Water, Lagos, Nigeria Research Journal of Applied Sciences, Engineering and Technology, vol. 2(3), pp. 274-282, 2010.

[12] A.A. Otitoloju, K.N. Don-Pedro, E.O. Oyewo EO, Assessment of potential ecological disruption based on heavy metal toxicity, accumulation and distribution in media of the Lagos Lagoon. Afr. J. Ecol., 45, pp. 454-463, 2007.

[13] J.K. Saliu, M.P. Ekpo, Preliminary Chemical and Biological Assessment of Ogbe Creek, Lagos, Nigeria West Africa Journal of Applied Ecology, vol. 9, pp. 15-22, 2006.

[14] N.H. Amaeze, Comparative account of the Microfauna and Planktonic Communities of Two polluted creeks associated with the Lagos Lagoon System, MSc. Thesis, University of Lagos, 2009.

[15] W.O. Odiete, Environmental Physiology of Animals and Pollution. Diversified Resources LTD, Lagos, Nigeria. P. 166, 1999.

[16] D.I. Nwankwo, L.O. Chukwu, I.C. Onyema, The hydrochemistry and biota of a thermal coolant water stressed tropical lagoon Life Science Journal., vol. 6(3), pp. 86-94. 2009.

[17] D.I. Nwankwo DI, The Microalgae: Our indispensable allies in aquatic monitoring and biodiversity sustainability. University of Lagos Press. Inaugural Lecture Series. 2004.

[18] G. Cimino, M.C. Puleio, G. Toscano, Quality assessment of freshwater and coastal seawater in the Ionian area of N.E. Sicily, Italy. Environ. Monit. Assess., vol.77 (1), pp. 61-80, 2002.

[19] M.B. Hill, J.E.Webb, The Ecology of Lagos Lagoon II. The Topography and physical features of Lagos harbour and Lagos Lagoon. Phil. Trans. R. Soc. Lond. 241 (B) pp. 317-417, 1958.

[20] K.N.Don-Pedro, E.O. Oyewo, A.A. Otitoloju, Trend of heavy metal concentrations in Lagos Lagoon Ecosystem, Nigeria. West African Journal of Applied Ecology, vol. 5, pp.103-114, 2004.

[21] APHA-AWWA-WEF, Standard Methods for the examination of water and wastewater, 21st edition, 2005.

[22] S.O. Ayoola, M.P. Kuton, Seasonal variation in fish abundance and physicochemical parameters of Lagos lagoon, NigeriaAfrican Journal of Environmental Science and Technology, vol. 3 (5), pp. 149-156, 2009.

[23] R. Margalef, Diversidad de espicces en las comunidades naturales, Publ. Inst. Biol. Apl. (Barcelona), vol. 9pp. 5–27, 1951.

[24] A.E. Ogbeib, Biostatistics: A practical approach to research and data handling. Mindex Publishing Company limited, Benin city, Nigeria. 2005.

[25] C.E. Shannon, W. Weiner W. The mathematical theory of communication. Urban University Illinois Press, 1963.

[26] E.A. Ajao, S.O. Fagade, A study of sediments and communities in Lagos Lagoon. Oil and Chemical Pollution, vol. 7, pp. 85-117, 1990.

[27] T.V.I. Akpata, Abundance, distribution and survival of *Escherichia coli* in the Lagos Lagoon. MSc. Thesis, University of Lagos, 1975.

[28] (2008) J.F. Gorge, Bacterial,Chemical Residues Impact Tilapia quality. Global Aquaculture advocate http://pdf.gaalliance.org/pdf/gaa-flick-jan08.pdf.

[29] A.O. Aderemi, A.V. Oriaku, G.A. Adewumi, A.A. Otitoloju AA, Assessment of groundwater contamination by leachate near a municipal solid waste landfill. African Journal of Environmental Science and Technology, vol. 5(11) pp. 933-940, 2011.

[30] G.F. Lee, A. Jones-Lee , Impact of Municipal and Industrial Non-Hazardous Waste Landfills on Public Health and the Environment: An Overview. Prepared for California Environmental Protection Agency's Comparative Risk Project. 2004.

[31] C.I.O Olaniyan, *The seasonal variation in plankton in Lagos harbour, Nigeria*. (PhD Thesis.) University of Lagos, Nigeria. 1957.

[32] A.R. Lenghurst, An Ecology Survey of the West African Marine Benthos. Colonial office Fisheries publication vol. 11, p. 102, 1958.

[33] C.I.O. Olaniyan , The seasonal Variations in the hydrography and total plankton of the Lagoons of Southwest Nigeria. Nig. J. Sci., vol. 3(2), pp. 101-119, 1969.

[34] S.F. Snieszko, The effects of environmental stress on outbreaks of infectious diseases of fishes Journal of Fish Biology 6, (2): 197–208, 1974.

[35] B.E. Emmanuel, I.C. Onyema, The Plankton and Fishes of a Tropical Creek in South-Western Nigeria Turkish Journal of Fisheries and Aquatic Sciences vol. 7, pp. 105-113, 2007.

[36] F.E. Ajagbe, O.A. Osibona, A.A. Otitoloju , Diversity of the edible fishes of the Lagos Lagoon, Nigeria and the public health concerns based on their Lead (Pb) content International Journal of Fisheries and Aquaculture., vol. 2(3), pp. 55-62 2012.