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The relationship of plankton abundance to Physico-chemical parameters in a segment of lower IMO river estuary

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Abstract
The relationship of plankton abundance to physico-chemical parameters of Lower Imo River Estuary were studied for a period of 12 months, (January - December, 2021). Physico-chemical parameters and planktons samples were collected in three stations along the course of lower Imo River and were analysed according to standard methods following the procedures outlined by APHA (2012). 7 families and 53 species of phytoplankton were identified while 5 families and 21 species of zooplankton were also recorded. There was an increasing trend in the level of concentrations of physico-chemical parameters but were within the approved limits of standard bodies. Canonical Correspondence Analysis (CCA) was used to establish the relationship of planktons to physico-chemical parameters. Its relationship revealed that the planktons interaction between physico-chemical parameters affect their abundance and also show strong correlation of some physico-chemical parameters, which suggest that these parameters are interconnected and rolled out some common data information on plankton species. Evidence from findings of the present study revealed that the physico-chemical parameters has a crucial role to play in the abundance and subsequent distribution of plankton within water biosystem and as such regular monitoring of aquatic biosystem is highly recommended in order to forestall any changes that may lead to disruption in the system.

Keywords: Planktons, diversity, abundance, relationship, lower IMO river estuary

1. Introduction
The aquatic environment productivity is determined by the presence of planktons, due to their role as the major primary producers. The ultimate function of planktons in the aquatic ecosystem has been reported by various authors (Akpan, 2006, Emmanuel and Onyema, 2007, Onyema, 2007) [19, 8, 33]. The basis to assess biological integrity of the aquatic habitat had been reported by Davis *et al.*, 2009 [18], to include; species distribution, its abundance, its diversity and its composition. The presence of Plankton has been reported by various scientists to reflect water quality status and changes, therefore enhancing planktons to play the role of bio-assesor in the aquatic ecosystem, which finger to the health status of the system (Onyema *et al.*, 2003 Akpan, 2006 and Akpan and Akpan, 1994) [35, 7, 8].
Plankton community in a dynamics ecosystem plays a key position in the physico-chemical characteristics of aquatic habitat, as they are a baseline of the food chain in the system, (Adeyinka and Imoobe, 2009) [3]. Their key role in the trophic level makes them susceptible to minimal change in the environment and therefore used as a good bio-indicator of water quality (Wetsel, 1983) [40].
The dynamics and assemblage structure of the phytoplankton of the aquatic ecosystem are factored by the physico-chemical parameters (Kumar *et al.*, 2018) [27]. Various changes and disturbances in physico-chemical parameters of aquatic ecological systems could lead to a pertinent impact on the population dynamics of phytoplankton species (Sharma *et al.*, 2020) [36]. Cyclical differences of these parameters could prompt an imperative role in the composition of aquatic biota, its distribution and periodicity, (Sharma *et al.*, 2020). The plankton diversity and physico-chemical parameters often interconnect and usually influenced by some anthropogenic factors of point sources that enter the aquatic ecosystem (Chang, 2005, Akpan, 2006, Esenowo *et al.*, 2017, Sharma, *et al.*, 2020 and Ariyadeji *et al.*, 2004) [15, 8, 13, 21, 36]. The physico-chemical parameters and its plankton diversity is well researched in Lower Imo River Estuary (Akpan, 2006, Akoma and Osundu, 2008 and Akoma, 2008) [8, 5, 6]; however, for proper management of the estuary, the determination of the relationship between plankton diversity and physico-chemical parameters is necessary.

The main objective of this research study was to determine plankton abundance and its relationship to physico-chemical parameters in a segment of lower Imo River Estuary.

2. Materials and Methods

2.1 Study Area

This study was carried out in a segment of Lower Imo River Estuary located in Niger Delta Region, Nigeria (Fig.1). It situated between latitude $6^0 50'$ and $7^0 40'$E and longitude $4^0 25'$ and $6^0 25'$N of the South Eastern coastline. The mean annual rainfall recorded here was about 350mm with a mean annual temperature of 33^0C and a relative humidity of 75% (Udo, 1995) [39].

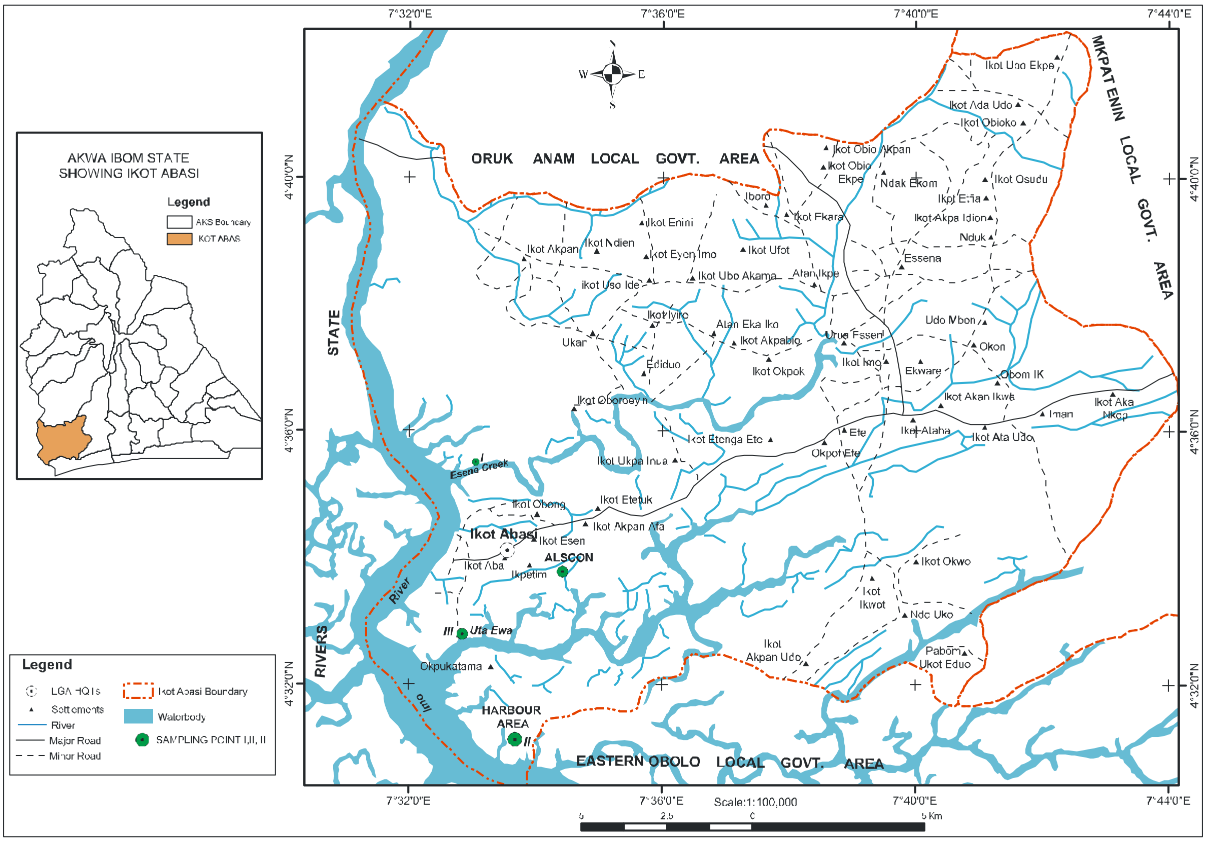

Fig 1: Map of the study area showing sampling locations

2.2 Sample Collection/Analysis

Samples were collected monthly (January - December, 2021) in three stations (Esene Creek) (SI), Harbour Area (SII) and Uta Ewa Creek (SIII). At each sampling day, the process of sample collection was done between 08:00am and 12:00 noon. Total Dissolved Solids (TDS), Hydrogen ion concentration (pH), Temperature and Electrical Conductivity (Ec) were measured insitu. Electrical conductivity and Total Dissolved Solids were measured with an extract meter model Extik EC400; Temperature was measured with a digital thermometer (INDEX model ID1090) while pH was measured with a denver model 15. Other parameters were collected and analyzed by using standard methods as prescribed by APHA (2012) [12]. The plankton samples were collected in 250ml bottles using plankton net of mesh size, 55mm.

The collection of water samples were in plastic bottles and fixed insitu with 4% of formaldehyde. They were transported to the laboratory for identification and analysis. The identification of composite taxa of plankton was carried out with the aid of keys description and illustration given by Nwankwo (2004) [32], Jeje and Fernando (1986), Needham and Needham (1962) [31], Jeje and Fernando (1991) [26] and Needham and Needham (1978) [30].

2.3 Data Analysis

In the analysis of Data, Microsoft Excel (2007) package was used, while the usage of version 3 of PAST software Design was employed in the Analysis of Variance and Canonical Correspondence Analysis (CCA) to determine the relationship of physico-chemical parameters to plankton abundance (Ter Braak and Verdonschot, 1995) [38].

3. Result

3.1 Physico-Chemical Parameters

The range, mean ($\bar{X}$) and standard deviation (SD) of the physico-chemical parameters of the various stations of a segment of Lower Imo River Estuary measured during the study are shown in Table 1, while Table 2 shows the analysis of variance of the physico-chemical parameters at various stations of the study area.

Table 1: The range, mean and standard deviation of Physico-chemical Parameters of various stations of the segment of Lower Imo River Estuary during the period of study (January- December, 2021)

Parameters	SI Range	$\bar{x} \pm$ SD	SII Range	$\bar{x} \pm$ SD	SIII Range	$\bar{x} \pm$ SD
Ec/cm	10.10-15.1	13.25 ± 3.58	12.14-19.24	17.83 ± 4.96	18.31-24.12	22.44 ± 843.13
Na (mg/l)	0.0001-0.390	0.16 ± 0.13	0.08-0.92	0.39 ± 0.23	4.21-8.00	6.34 ±1.25
K (mg/l)	0.01-1.00	0.59 ± 0.32	0.17-14.13	1.49 ± 2.76	4.82- 6.22	39.59 ±15.29
SO_4 (mg/l)	0.001-0.300	0.04 ± 0.59	0.02-0.82	0.16 ±0.22	0.07 - 6.03	2.86 ± 1.46
Cl (mg/l)	17.18-70.25	29.79 ±13.09	20.10-90.18	38.99 ± 17.63	550.40 -1984.0	1412.0 ±515.04
PO_4 (mg/l)	0.00-0.16	0.02 ± 0.04	0.01-0.72	0.09 ± 0.19	0.11-0.82	0.14 ± 0.19
TA (mg/l)	12.20-30.20	18.82 ± 5.08	13.22-41.22	25.99 ± 8.07	20.12-88.21	55.33 ± 20.50
TH (mg/l)	12.39-17.20	14.25 ± 1.59	14.18-21.52	16.447 ±1.86	16.16-42.18	23.82 ±7.02
Mg (mg/l)	5.03-22.33	13.27 ±4.65	12.01-37.01	23.74 ± 6.08	25.39-58.31	37.32 ± 9.35
A (mg/l)	9.82-18.95	15.88 ± 2.53	10.22-21.51	18.60 ± 2.43	18.55-30.12	23.33 ± 2.72
DO (mg/l)	2.89-5.33	3.94 ± 0.44	3.72-5.82	4.49 ± 0.49	5.11-7.12	5.79 ± 0.54
TDS (mg/l)	2.98-100.22	21.59 ± 28.62	3.02-702.12	90.49 ± 1509.79	15.69-821.01	1114.00 ± 467.48
BOD (mg/l)	1.59-2.19	1.96 ± 0.19	2.02 -3.14	2.28 ± 0.33	2.16-4.32	3.19 ±0.48
TSS (mg/l)	0.002-0.373	0.09 ± 0.14	0.004-0.422	0.12 ±0.16	0.23-0.63	0.45 ± 0.12
Ca (mg/l)	2.32-50.22	26.06 ±10.43	27.32-65.12	48.72 ±11.15	50.31-90.12	69.36 ±12.39
pH	4.73-6.51	5.62 ± 0.46	5.23-6.82	6.03 ± 0.49	6.02-8.33	7.03 ± 0.74
Temp (^{0}C)	21.90-28.20	26.80 ± 1.08	28.20-27.31	26.15 ± 0.55	24.22 -26.73	25.40 ± 0.66

Table 2: The Analysis of variance of physico-chemical parameters at various stations of the segment of Lower Imo River Estuary on monthly basis during the period of study (January- December, 2021)

Months	Temp	pH	Ec	Na	K	SO_4	PO_4	TA	Cl	TH	Mg	DO	A	TDS	BOD	TSS	CA
January	26.4^{ab}	6.3^{ab}	960.0^{b}	2.5^{bc}	17.9^{ab}	1.0^{bcca}	0.1^{bc}	37.5^{ed}	653.1^{a}	16.6^{ed}	25.5^{c}	4.6^{cd}	20.1^{al}	257.8^{ed}	2.5^{bcd}	0.8^{c}	53.9^{a}
February	26.1^{ab}	6.3^{ab}	729.4^{c}	1.6^{af}	7.2^{e}	0.4^{f}	0.0^{f}	15.8^{f}	2400.9^{f}	14.9^{g}	$^{17.4}g$	5.1^{ab}	18.8^{al}	193.9^{e}	2.6^{abc}	0.4^{a}	36.8^{d}
March	26.8^{a}	5.7^{c}	192.1^{d}	1.8^{f}	8.5^{ed}	0.6^{ef}	0.1^{b}	18.2^{ef}	251.9^{f}	15.3^{gf}	18.3^{fg}	4.5^{d}	256.7^{ed}	256.7^{ed}	2.5^{bad}	0.1^{f}	42.1^{ad}
April	25.7^{i}	5.8^{c}	220.1^{d}	1.9_{e}	9.9^{ed}	0.6^{ef}	0.0^{c}	19.4^{e}	218.5^{f}	16.2^{ef}	20.3^{ef}	4.7^{bcd}	19.7^{ale}	276.5^{ed}	2.3^{al}	0.1^{ef}	40.3^{ad}
May	25.9^{ab}	5.9^{c}	732.1^{a}	1.6^{gf}	10.7^{adc}	0.5^{ef}	0.0^{c}	36.5^{d}	594.2^{a}	16.7^{ed}	22.3_{DE}	4.4^{d}	20.3^{bc}	334.1^{ade}	2.7^{ab}	0.4^{a}	53.1^{ab}
June	26.1^{ab}	5.9^{c}	703.9^{c}	2.4^{d}	16.2^{bac}	0.9^{edc}	0.0^{c}	36.0^{d}	637.2^{ab}	16.7^{ed}	20.9^{c}	4.6^{de}	20.8^{b}	651.0^{a}	2.5^{bad}	0.2^{c}	53.1^{a}
July	26.1^{ab}	6.3^{b}	953.5^{a}	2.4^{d}	17.3^{ab}	1.3^{bece}	0.1^{bc}	35.6^{d}	5585.1^{d}	21.2_{b}	30.1^{b}	4.5^{cd}	$^{19.1}al$	515.1^{abc}	2.4^{ale}	0.2^{c}	56.7^{a}
August	25.9^{ab}	6.4^{ab}	968.6^{ab}	2.6^{bc}	16.7^{abc}	0.7^{edt}	0.0^{c}	40.5^{b}	316.8^{c}	17.4^{c}	29.5^{b}	4.9^{abc}	20.4^{bc}	423.8^{bcd}	2.1^{c}	0.2^{c}	37.9^{a}
September	26.1^{ab}	6.5^{ab}	932.9^{b}	2.7^{b}	21.9^{a}	1.4^{abc}	0.1^{bc}	46.3^{a}	655.0^{a}	21.5^{b}	24.8^{c}	4.7^{bcd}	22.8^{a}	516.4^{abc}	2.9^{a}	0.2^{ed}	45.6^{bc}
October	26.4^{ab}	6.4^{ab}	720.6^{c}	2.8^{a}	8.7^{ed}	1.4^{abc}	0.1^{bc}	40.5^{ba}	532.6^{i}	25.3^{a}	23.6^{ed}	4.6^{cd}	15.6^{g}	392.5^{ed}	2.5^{bcd}	0.3^{b}	51.3^{ab}
November	25.9^{b}	6.5^{ab}	922.4^{b}	2.5^{ed}	17.4^{ab}	1.6^{ab}	0.4^{a}	37.3^{d}	638.6^{a}	19.2^{c}	34.1^{a}	5.3_{a}	17.2^{f}	593.9^{ab}	2.5^{bbad}	0.2^{ale}	51.9^{ab}
December	25.9^{ab}	6.6^{a}	1052.9^{a}	2.5^{ad}	14.0^{bcd}	1.7^{a}	0.1^{bc}	37.2^{d}	599.8^{bc}	16.9^{ed}	30.4^{b}	4.7^{bcd}	18.3^{ed}	494.1^{abc}	2.3^{al}	0.1^{def}	53.7^{ab}
LSD	0.93	0.34	34.72	0.14	0.06	0.57	0.11	2.75	37.93	1.14	2.34	0.39	1.50	192.02	0.26	0.1	7.68
P	0.5	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0026	0.0001	0.0002	0.0001	0.0001	0.0001

*Means with the same letter are not significantly different (P = 0.05)

* Means with different letter are significantly different (P = 0.05)

3.2 Plankton Composition and Abundance

A checklist for the phytoplankton is shown in Table 3 and that of zooplankton shown in Table 4, fifty-three species of phytoplankton and twenty-one species of zooplankton were identified and recorded. The phytoplankton composition was dominated by green algae (chlorophyceae) with the highest species richness (23 species). It also shows a higher group abundance (x = 380 cell count per litre for station I, 744 cell count per litre for station II and 3197 cell count per litre for station III. This was followed by diatoms (bacillariophyceae) with a group abundance of 200 cell count per litre for station III while the least group abundance was recorded for xanthophyceae (x = 39 cell count per litre for station 1 and 62 cell count per litre for station II).

The zooplanktonic composition was dominated by Copepoda with highest species richness (6 species). It also showed a higher group abundance of 89 cell count per litre for station I and 233 cell counts per litre for station III. There was a noticeable increase in the abundance of most planktonic groups downstream. Bacillariophyceae dominated in all stations, while xanthophyceae was recorded with lowest abundance of 38 cell counts per litre in station I. All the planktonic species were recorded in all the sampling stations. The zooplanktonic composition followed the same spatial trend as the phytoplankton with more abundance downstream than in the upstream, except protozoa which had a higher abundance of 55 cell counts per litre in station II, but 51 cell counts per litre in station III.

The analysis of variance for total cell counts of plankton in a segment of Lower Imo River on monthly basis, indicated variation in monthly composition, but however showed a significant relationship in all months, except March, April and December for phytoplankton's (Table 5). For Zooplankton, the non-significant relationship was indicated for February, March and May (Table 6). On the station basis, species richness declined from stations III to 1 (Table 7 and 8). The analysis of variance of total cell counts per litre indicated no significant measure between the wet and dry season (Tables 9 and 10).

Table 3: Composition and Relative abundance of Phytoplankton in a Segment Lower Imo River Estuary during the period of study (January - December, 2021)

Bacillariophyceae	Chlorophyceae	Cyanophyceae	Euglenophyceae	Dinophyceae	Xantophyceae	Chryaiphyceae
Cyclotella striata	*Microspora villeana*	*Anabeana affinis*	*Euglena acus*	*Ceratum hirudinella*	*Trimbonema vivid*	*Tanacetum vulgare*
Cyclotella comta	*Coniochaeta nitellarum*	*Anabeana arnoldii*	*Euglena viridis*	*Peridinium depressum*	*Dicranotropis divergens*	*Centrium hirudinea*
Cyclotella operculata	*Mesotoenium species*	*Anabeana spiroides*	*Euglena gracilis*	*Cymidium rhomboides*		*Peridium cintum*
Cyclotella meneghiniana	*Closterium longissima*	*Raphidiopsis curvata*	*Trachelomonas africana*			*Dinobryon sertularia*
Navicula species	*Tetraedon* species	*Trachelomonas hispida*	*Trimbonema vivid*			
Coscinodiscus radiatus	*Euastrum elegans*	*Gloeotrichia echinulata*				
Coscinodiscus lacustris	*Pediastrum duplex*	*Lyngbya major*				
Melosira moniliformes	*Crucigema* species	*Dinobyron soule*				
Melosira varians	*Staurastrum grande*					
Melosira undulata						
Melosira pusila	*Pediastrum simplex*					
Asterionella formosa	*Coscinodiscus kutzingi*					
	Cosmarium granatum					
	Clodophoora glomerata					
	Caenorhabditis elegans					
	Cooelatrium micromium					
	Coelatrum recticulatum					
	Clostridium lunala					
	Netrium digitus					
	Bulbochaete species					

Table 4: Composition and Relative abundance of Zooplankton in a Segment Lower Imo River Estuary during the period of study (January - December, 2021)

Copepod	Cladocera	Juvenile	Rotifera	Protozoa
Palacalamus paris	*Alonella excisa*	Shrimp larvae	*Brachionus calcyciflorus*	*Arcella mitrata*
Centropages hamastus	*Alona diaphnia*	Fish larvae	*Keratella* species	*Amoeba* species
Penducalamus elongatus	*Moina dubia*	Fish egg	*Platyias patulus*	*Dinabryon* species
Megacyclops viridis			*Lacane lunula*	*Rhabdonella* species
Oncaea venusta			*Philodina* species	
Canthocalanus species				

Table 5: Analysis of variance for total cell count of Phytoplankton in a Segment of Lower Imo River Estuary on monthly basis

Months	Total cell count/l
January	257.0^{ab}
February	221.3^{ab}
March	202.0^{b}
April	444.0^{a}
May	369.0^{ab}
June	392.0^{ab}
July	344.0^{ab}
August	339.7^{ab}
September	356.7^{ab}
October	359.7^{ab}
November	344.3^{ab}
December	187.0^{b}
LSD	223.28
P	0.05

*Means with the same letter are not significantly different

Table 6: Analysis of variance for total cell count of Zooplankton in a Segment of Lower Imo River Estuary on monthly basis

Months	Total cell count/l
January	37.33^{bcde}
February	23.33^{e}
March	25.00^{e}
April	49.33^{abcd}
May	58.33^{a}
June	55.67^{abc}
July	49.33^{abbcd}
August	57.33^{ab}
September	49.67^{abcd}
October	35.00^{cde}
November	30.00^{de}
December	29.67^{de}
LSD	20.912
P	0.05

*Means with the same letter are not significantly different

Table 7: Analysis of variance for total cell count of Phytoplankton in a Segment of Lower Imo River Estuary on station basis

Station	Cell count
1	85.19^{b}
2	159.19^{b}
3	709.08^{a}
LSD	111.64
P	0.05

*Means with the same letter are not significantly different

Table 8: Analysis of variance for total cell count of Zooplankton in a Segment of Lower Imo River Estuary on station basis

Station	Cell count
1	31.167^{b}
2	41.500^{b}
3	52.33^{a}
LSD	10.456
P	0.05

*Means with the same letter are not significantly different

Table 9: Analysis of variance for total cell count of Phytoplankton in a Segment of Lower Imo River Estuary on seasonal basis

Season	Cell count
Wet	2967^{a}
Dry	849^{a}
LSD	6438.9
P	0.05

*Means with the same letter are not significantly different

Table 10: Analysis of variance for total cell count of Zooplankton in a Segment of Lower Imo River Estuary on station basis

Season	Cell count
Wet	384.67^{a}
Dry	115.33^{b}
LSD	178.12
P	0.05

*Means with the same letter are not significantly different

3.3 The Relationship of Physico-chemical Parameters to Plankton

The connectivity between Zooplankton abundance and Physico-chemical variables, showed that the CCA yielded four set of significant variables (P = 0.0100), with fourth CCA axis explaining 58.7% of the environmental correlation cumulative percentage variance of species-environment relation (Table 11). For Zooplanktons, pH, Ec, Na, K, SO_4, TA, TH, Mg, DO, A, TDS, TSS and Ca showed a positive correlation in the first canonical axis, while a positive correlation was recorded for temperature in the second canonical axis. A higher negative correlation was also recorded for temperature in the third canonical axis. For the connectivity between phytoplankton abundance and physico-chemical variables, the CCA yielded four set of significant canonical variables (P = .2250), with the first three canonical axis explaining 51.9% of the environmental correlation cumulative percentage variance of species-environment relation (Table 12). Temperature showed positive correlations in the first canonical variable, while the rest showed a higher negative correlations, except PO_4-P. The second canonical variable indicated positive correlation for temperature, the rest correlated negatively, the third canonical variable showed negative correlations in all variables.

Table 11: The CCA biplot scores of Zooplanton abundance and Physico-chemical variables

Variables	Axis I	Axis II	Axis III	Axis IV
Temp (^{0}C)	-.3488	.2126	-.4589	-.2239
pH	.4582	-.2629	.3252	.3332
Ec	.5068	-.1267	.2046	.5902
Na	.6408	-.1549	.1488	.5524
K	.5087	-.2578	.2139	.5848
SO_4	.6120	-.1571	.1636	.4433
PO_4	.2684	-.2088	.3815	.1266
TA	.6282	-.2142	.0653	.3527
Cl	.6324	.0813	.1985	.5397
TH	.8425	-.2405	.1470	.2317
Mg	.6131	-.2405	.1470	.2317
DO	.6785	-.2391	.2391	.3217
A	.4782	-.3532	.1762	.4033
TDS	.5502	-.1466	.3593	.5013
BOD	.0751	-.1705	.3220	.3618
TSS	.6127	.1120	.1820	.4034
Ca	.6276	-.2575	.2691	.3397
Eigen values	.125	.084	.065	.060
Species environmental canonical correlation	.915	.926	.920	.864
Environmental correlation cumulative %	21.9	36.8	48.2	58.7
Variance of species-environment relation				
Sum of all eigen values	.570			
Test of significance of all canonical axis:	.0100			

Table 12: The CCA biplot scores of phytoplanktons abundance and physico-chemical variables

Variables	Axis I	Axis II	Axis III	Axis IV
Temp (^{0}C)	.5435	.2423	-.0175	-.0227
pH	-.5198	-.2423	-.0738	.2058
Ec	-.7228	-.3088	-0.536	.1384
Na	-.8951	-.2122	-.1184	.1299
K	-.7834	-.1848	-.0604	.0763
SO_4	-.7756	-.3315	-.1265	.1283
PO_4 - P	-.1398	-.2914	-.0504	.1143
TA	-.7114	-.4625	-.1064	.1848
Cl	-.8299	-.2773	-.0132	.1419
TH	-.6125	-.4876	-.1173	.2180
Mg	-.6026	-.3105	-.0933	-.0064
DO	-.7502	-.2886	-.1825	.0650
A	-.7980	-.1377	-.0314	-.0697
TDS	-.8213	-.1992	-.1927	.0017
BOD	-.7701	-.2914	-.0840	.1031
TSS	-.7542	-.1589	-.1152	.1787
Ca	-.8072	-.2947	-.0693	-.1251
Eigen values	.060	.028	.023	.019
Species environmental canonical correlation	.967	.949	.786	.825
Environmental correlation cumulative %	28.0	41.1	51.9	60.6
Variance of species-environment relation				
Sum of all eigen values	.214			
Test of significance of all canonical axis:	.2250			

4. Discussion

The study of the physico-chemical and biological aspect of an aquatic system is very pertinent, (Akpan, 2013; Akpan and Etim, 2015; Abdul *et al.*, 2016; Jannat *et al.*,2019; Esenowo *et al.*, 2017) [9, 10, 1, 21, 25,], as this will enable the detection of any significant change in the system (Akpan, 2012). Aquatic environmental monitoring in combination with the use of biotic and abiotic factors usually provides reliable assessment of any significant input in such system. According to the study revealed by Adeyinka and Imoobe (2009) [3], zooplankton species kind, abundance and distribution in any aquatic environment usually give information on the conditions of physico-chemical nature of that environment, thus the interaction between different environmental variables can either be beneficiary or non-beneficiary to such biological component (Abdul *et al.*, 2016 and Ju *et al.*, 2021) [1]. Meanwhile, some zooplankton have been noted as biological indicators of the aquatic environment. Lo *et al.*, 2019, Ismail and MohAdnan, 2016 [29, 24], opined that some species are indicators of organic pollution due to high organic matter deposit. The planktonic dynamics in aquatic ecosystem may be due to organic matter (Ake-Castilo and Vazquez *et al.*, 2008) [4]. The limitation of nutrients is also a common factor in other studies (Abrantes *et al.*, 2006) [2].

The phytoplanktonic flora of the system was on the whole sparse, 53 species, this was less than values recorded in other waters of the zone (Chindah and Braide (2004) [16], Chindah and Keremiah (2001) [17] and Esenowo *et al.*, (2017) [21]. Majority of the genera were the green algae and diatoms, this confirm with the reports of Onyema (2008) [34], which recorded diatoms are the most prominent member of the phytoplankton in seas, rivers and lakes. The abundance of algae can be attributed to favourable pH of the water body (Akoma, 2008 and Esenowo *et al.*, 2017) [5, 21]. The differences in the community structure is mainly due to the importance posed by green algae, diatom, cyanophyceae, eugleonoplyceae and chrysophyceae being the least, could be due to inefficiency to compete for nutrients (Akoma, 2008, Akoma and Osundu, 2008) [5, 6]. With a dominance of fresh water Chlorophyceae phytoplankton and a salinity tolerant brackish water Bacillariophyceae, the water body could be said to be a tropical mesotrophic system, this agrees with the work of Akoma (2008) [5] in the estuary.

The general trend of low abundance of zooplankton density could be due to surface run-off, predation by other aquatic species and low nutrients availability (Essien-Ibok and Ekpo, 2015) [22]. The general trend of increase abundance of plankton at wet season as compared to dry season, could be attributed to availability of abundance nutrients from allochthonous and authochthonous sources (Essien-Ibok and Ekpo, 2015 and Adeyinka and Imoobe, 2009, Ju *et al.* 2019) [22, 3].

The plankton abundance ordination by canonical correspondence analysis (CCA) revealed that the abundance patterns were related to the physico-chemical parameters of the estuary, this agrees to the work of some authors (Esenowo *et al.*, 2017 and Abdul *et al.*, 2016) [1, 3, 21], Sharma *et al.*, (2020) [36]. The studied physico-chemical parameters explained the basic variations in the plankton community. The CCA biplot showed a either a strong positive or negative correlation among each physico-chemical parameters, which opined that these parameters were interconnected and exhibit some common information of species data, this agrees with the study carried out by Yang *et al.*, 2005 [41]. The CCA biplot of this study showed that temperature was inversely proportional to other parameters, in most of the canonical axis, this indicate the important of temperature in the development of plankton in an aquatic system. This also emphasize light as an important factor for growth of plankton, in which through photosynthesis, light energy is used to transform inorganic molecules to organic matter (Chalindah *et al.* (2008), Striebel *et al.* (2016), Coles and Jones (2000), Cross *et al.* (2015)). This investigation did not reflect any problems from phytoplankton bloom, and such indicates that the estuary is a dynamic system.

5. Conclusion

The physico-chemical parameters of a segment of lower a Imo River Estuary showed a basic relationship with plankton abundance, this suggest that the parameters are crucial to the distribution of the plankton structure in water system and as such, should be co-ordinated to be in line with several approved standards of water bodies devoid of pollution.

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5.2 Authors' Contribution

All authors have contributed significantly to the success of the study. They read, corrected and approved the final manuscript.

5.3 Conflict of Interest

The authors hereby declare no conflict of interest in this study.

5.4 Consent for Publication

The authors declare that the work has consent for publication.

5.5 Funding Support

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