Algal homogeneity in water and sediment of mid- Ethiope River, Nigeria: a response to severe ecological disturbances.

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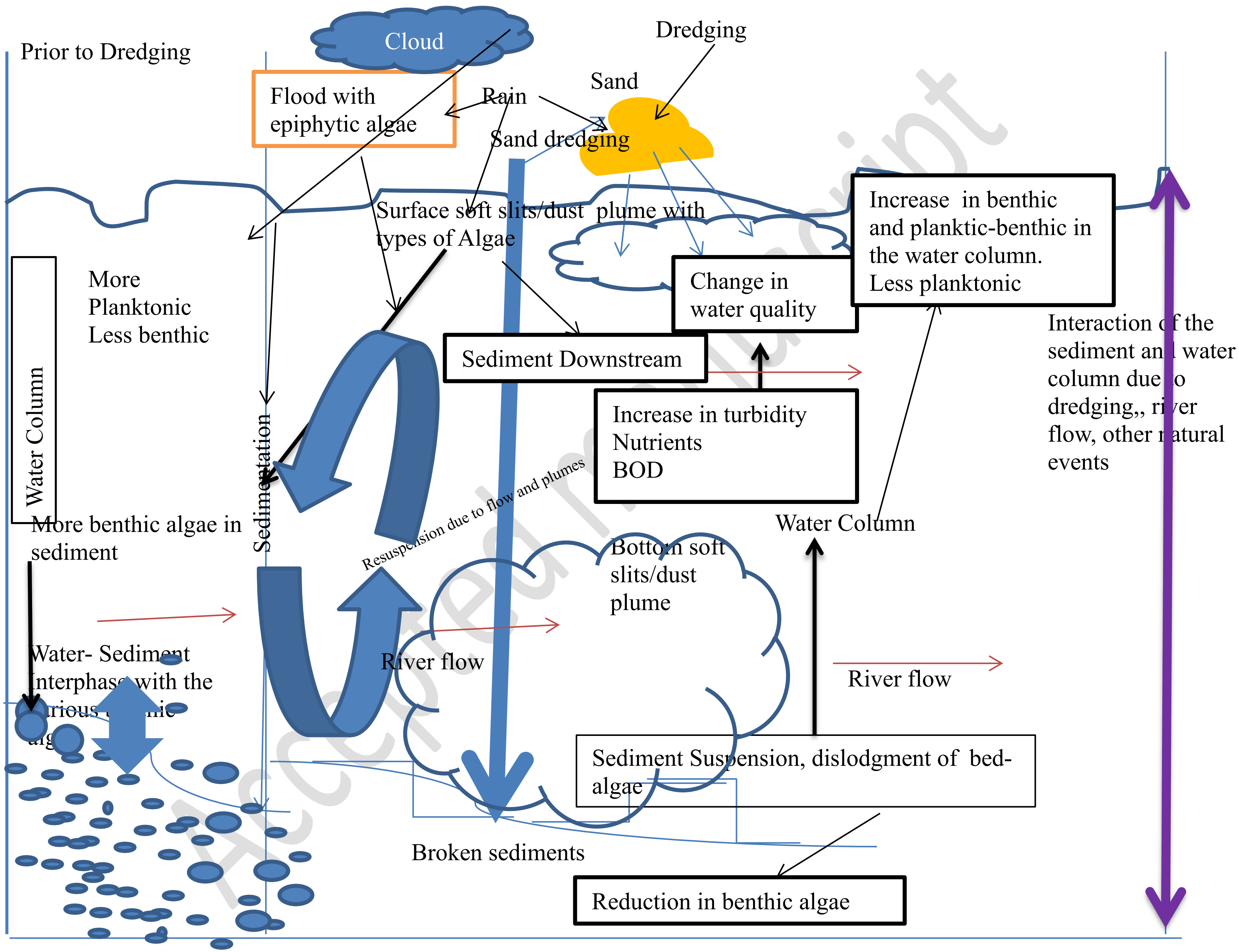
Graphical Abstract



Abstract

Different aquatic ecological zones exhibit different gradients present heterogeneous algal composition. The algal community in the water column and sediment with certain environmental factors were screened monthly for twelve months with standard methods, to ascertain disparate in algal distinction. Air and water temperature, conductivity, water depth, dissolved oxygen and nutrients were the primary factors that influenced the algal abundances and diversities. 90% of the algal communities were benthic (33 species) and planktic-benthic (21) with 10% truly planktonic (6) species. Comparatively, the water-column benthic and planktic-benthic surpasses the benthic species associated with the sediment. The PCA on the habitat- type abundance revealed that 99.5% benthic algae in the water column are responsible for the total algal- abundance variance. Species richness and Shannon diversity indices were low, which ANCOVA and Levene tests demonstrated significantly equal and homogeneity of algae respectively between the studied zones. The linear relationships between the algae in the water and sediment zones were non-significant ($p>0.05$). The Euclidean algorithm confirmed algal community similarity in the water column and sediment. Species diversity limits, a high proportion of benthic algae in the planktonic, and significant homogenous algae in water and sediment. Signatures sediment destruction, breaking and dislodgement and uplifting of associated bottom algae, and the constant mixing of the water column and sediment due to sand dredging in the study area. Machines and human-dredging has exacerbated the abundance of benthic algae in the water column.

Keywords: Dredging, diversity indices, Microflora, Univariate analyses, Water - River bed, Water variables.

1. **Introduction**

The middle reaches of River Ethiope in Niger Delta, serve as a means of livelihood for the Ethiope East communities living in its watershed for decades. These communities are highly interested in sand mining and dredging as a primary profession not undermining their trailing problems and other magnetized negative impact anthropogenic activities (Morhit and Mouhir, 2014). The reliance of the communities in and around on this water resource for sand-dredging jobs for sustenance has been on the rise, particularly with the advent of sand dredging machines for small-scale industries (Renuka et al., 2013).

Sand mining in Nigeria is un-regulated in Nigeria despite the stunning policies in place. Sand mining has plagued River Ethiope for decades via the production of very coarse sand of 0.5-1.00mm needed for quality construction (Iloba, 2012). These mechanical events result in water quality degradation, species loss and the destruction aquatic habitats. The employment of these environmental-stressor dredgers curates the river bed, impacts on the sediment, algal communities and the water quality via eroding, undercutting and the collapse of river beds and banks (Mugaga and Nabaasa, 2016) notwithstanding its benefits (Grygoruk et al., 2015). Other morphological impacts associated with sand mining include an increase in the river channel, the reconfiguration of the imagery events developed over the years and compromising the prime condition of the aquatic systems (Erftemeijer et al., 2012).

Algae are heterogeneous autotrophs, distributed heterogeneously in space and time via the creation of distinct habitats; a product of the interactions between the river flow with the sediment (Stancheva and Sheath, 2016). The water column and sediment algal distribution studies in rivers hypothesized their spatial and temporal distribution in the created distinct habitats (Pla-Rabe's and Catalan 2018). Therefore, algae distribution in water bodies is naturally temporal and spatial in a relatively calm environment (Hamid et al., 2020).

However, the established algal distribution in rivers may be mediated by disturbances such as dredging. Algal distribution, diversity and richness are therefore tools for detecting disturbance impacts in any aquatic ecosystem; since they have lifestyles associated habitats and are also highly sensitive to habitat-ecological stressors (Wan Maznah, 2010; El-karim 2015). Thus, algal species richness, composition, and abundance speak of river system's productivity and trophic dynamics (Jyothi et al., 2016), health (Omar, 2010; Desianti et al., 2017) and specific niche quality and characteristics of the ecological habitat (Estepp and Reavie, 2015), regardless of whether pelagic or benthic (Kim et al., 2018) and not underestimated (Colwell, 2012).

Evident from works of literature, algal studies in water and sediments of rivers had received considerable attention in the developed world than the underdeveloped nations, particularly in Nigeria (Adeyemo et al., 2008; Wu et al., 2009; Wakoma et al., 2016; Tyovenda et al., 2018). There are no water-sediment algal studies in Ethiope River outside a few studies on heavy metals (Asonye et al., 2007; Kaizer, and Osakwe 2010), fish (Ikomi et al., 2005; Iloba and Eferakeya 2019) and macrobenthic invertebrates (Iloba, 2012; Iloba et al., 2019). The limited research and the global use of information on the algal composition, species richness and diversity in the water column and sediments of rivers for development have generated interest and the investigation of this essential economic, natural resource (Desianti et al., 2017). Applications of such information by the developed world in the conservation and management of rivers under intense anthropogenic activities are worth emulation (Apitz, 2012; Ouillon, 2018).

The habitat specificity of algae is first hand in the assessment of dredging impact on algae species composition, and abundance and distribution via the absence or presence of habitat-indicator species, since algae distribution in rivers are not homogenous despite its lotic nature (El-Karm, 2015). Thus the impact of dredging on algae in the sediment and the water column in mid-Ethiope River was assessed by investigating their composition, abundance and their heterogeneity using different diversity indices. Furthermore, the associations between the algae in both zones with the environmental variables were also evaluated. On this subject, water and sediments samples were collected and scrutinized for algae to evaluate the hypothesized variability in sediment and water column algae due to habitat heterogeneity. Information from this study will establish the River's health as well as guide better water management policies.

2. Materials and Methods

2.1 Study Area

The steep topography gradient and the morphometry of River Ethiope make the River the final recipient of the terrain-flood and fast-flowing Lowland River. In addition to natural attributes, the River at the middle experiences several impacts from small-scaled industrial and traditional sand dredging as well as other anthropogenic activities along its course. The River lies within the Niger Delta basin in Delta state, the southern part of Nigeria, with Benin River as its major tributary (Figure 1). The River is a transparent oligoionic freshwater system. Its entire length between is latitude 6^{o}31 and 6 ^{o} 30 N and longitude 500 - 600 E. The River is tidally influenced partially from Sapele to Aghalokpe, and sometimes it gets at Igun. Its width and depth range from less than 10 m to 90 m and 1m to 20 m, respectively (Iloba, 2017). The river flow is perennial with the highest level and discharges during the flood (July - November).

2.2 Water and Algae Sampling Collection

Water and sediment samples from three sampling stations of 2km apart longitudinally, in the middle reach of the Ethiope River (Figure 1). Firstly, composite water samples from the subsurface, above sediments were collected using a 2-litre Hydro bios sampler and analyzed for dissolved oxygen, temperature, pH, conductivity, alkalinity, nitrate, sulphate and phosphate using APHA (1989). The water and air temperature were determined directly in the field using mercury in glass thermometer (0 – 100 ^{0}C). The use of a calibrated pole measured depth. A pH meter (model 7065) was used to determine the pH.

Alkalinity analyzed by titration method. Dissolved oxygen concentration was by Winkler's method, while Biochemical Oxygen Demand was determined after five days by Winkler's method too. Nitrates were determined using the diazotization method. The auto-analyzer II was used to determine the phosphate. Next, composite water column algae samples collected by straining 200L of water with 25 µm-mesh plankton net, preserved with 4% formaldehyde.

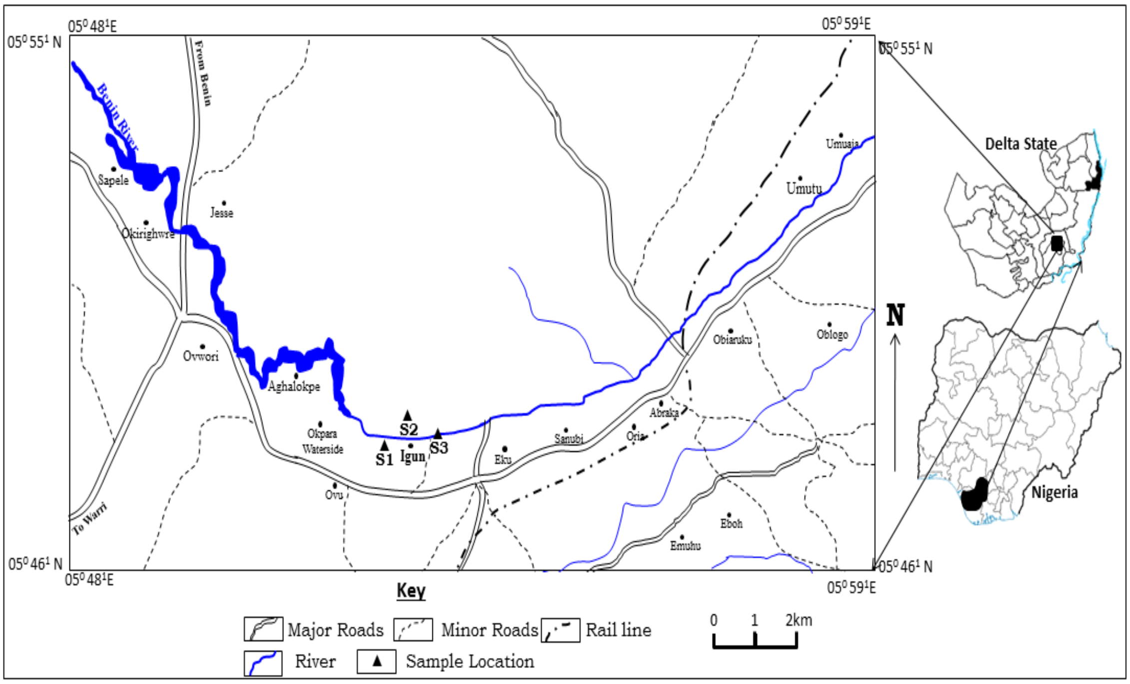


Fig 1: Sampling locations at the middle reaches of Ethiope River at Igun**.**

Sediment samples were collected by pressing a bucket grab into the sediment to a depth of 5cm transferred into a plastic basin. The temperature and pH of the retrieved sediment samples were taken and subsequently preserved with 5 % formaldehyde and then taken to the laboratory. In the laboratory, sediment algae were collected by modified floatation method in a plastic basin with distilled water and sieved through 25 µm mesh-plankton net. The algal samples were viewed at 40x magnification using an Olympus binocular microscope. Taxonomic denominations and identifications were made by consulting AHPA (1989), Withford and Schumacher, (1973; Wehr and Sheath, (2003) and Wehr et al., 2015

2.3 Statistical Analysis

To test statistically significant differences between monthly physicochemical parameters of the water column and sediment, one way ANOVA performed. One way ANCOVA was used to establish linear regression slopes and their equalities for water and sediment algae for all studied zone. Levene's test was performed to appraise the sameness of algae in the water column and sediment algae tested at 0.05 confidence limits as the impact of dredging. Linear correlation analysis and principal component analysis was performed to buttress similarities between relative abundances of algae in water and sediment among the studied stations. Euclidean distance elucidated the similarities in habitat-type in the three studied stations. Pearson linear correlation applied on log x+1 transformed abundances, and environmental variables, correct non-uniformity in metric scale and taxa variability are to detect the most influential parameters on algal abundances among studied stations. Species diversity and individual richness were used to predict the stability (expected trend) of algae in both water habitats using Hammer et al., 2001; Colwell et al., 2012).

3. Results

The overview of the outcome of water quality variables given in Table 1, identified variations within the different zones of study, however, no significant variations were found between the different zones except in nitrate ($p<0.05$) (Table 1).

A total of sixty (60) species of phytoplankton were detected in the water and sediment samples during this study, of which 46.67 % was Bacillariophyta (28 species), 31.67% Chlorophyta (19 species), 20 % Cyanophyta (12 species) and 1.67 % Euglenophyta (1 species) (Table 2). 90% of the algal communities were benthic (33 species) and planktic-benthic (21) with 10% truly planktonic (6) species. Total sediment algal density varied from 189 ind ml^{-1} to 200 ind ml^{-1} lower than water column algal species which varied from 200 ind ml^{-1} to 248 ind ml^{-1}. The algal composition in the water column and the sediment were dominated by *Fragilaria javanica, Navicula tenelloides, Synedra acus and Tabellaria fenestrate (*Bacillariophyceae*)* as shown in Table 2 and Figure 2A. In this study, 66.67% of the algal community had species primarily with 1-5cells/ml except for few species. A few species such as *Fragilaria javanica* (6-70cells/ml), *Navicula tenelloides* (1-45 cells/ml), *Synedra acus* (1-25cells/ml) dominating the group Bacillariophyta, and *Pleurotaenium sp*, *Scenedesmus incrassatulus*, *Spirogyra insignis* had 6-25cells/ml each, dominating for the Chlorophytes (Table 2). *Merismopedia elegans* dominates the group Cyanophyta while others (1-5cells/ml) but one; *Microcystis aureginous,* were widely distributed in the water columns and sediments.

Table 1: The summary of mean, coefficient of variation (C.V %) in parenthesis, range, F and P values for the sediments and pelagic zone stations (August to December 2011 and 2012) Mean±SE

	Station 1		Station 2		Station 3		F	p
Stations	ST1SD	ST1W	ST2SD	ST2W	ST3SD	ST3W		
Air temperature (^oC)	21.7(1.67)	22.0(2.0)	22.8(0.31)	23(1.82)	24.0(1.6)	24.6(1.63)	1.30	0.87
Range	17.4 – 26.0	15.0-25.0	19.0 – 26.7	18-27.0	20.2 – 27.8	20.0-30.0		
Water temp	25.0(1.77)	27.8(1.39)	28.8(2.29)	30.2(2.24)	29.8(1.76)	31.4(0.98)	1.91	0.69
Range	20.5-29.6	25.0-32.0	23.0-34.7	25.2-38.0	25.3-34.4	30.0-35.0		
Depth (m)	8.6(0.30)	7.5	8.3(0.31)	7.0()	9.2(0.34)	8.0(0.29)	1.19	0.91
Range	7.8 - 9.4	6.8-8.4	7.5 – 9.05	6.5-8.1	8.0-10.0	7.0-9.0		
Conductiv	30.8	66.8(2.6	23.9()	62.2(2.6	27.4()	61.2(3.3	1.33	0.85

ity		3)		5)		1)		
Range (µS/cm)	3.22 – 58	60.0-74.0	5.76 - 47.8	53-69.0	9.7 - 39.8	50.0-69.0		
pH	3.7(0.16)	3.7(0.17)	3.8(0.16)	3.8(0.17)	4.0(0.10)	4.04(0.07)	1.5	0.8

		STN 1	STN 2	STN 3	RA	H	E

Range	3.3 – 4.2	3.2-4.2	3.4 – 4.2	3.2-4.2	3.7 – 4.2	3.8-4.2		
Dissolved Oxygen	6.18(0.55)	6.3(0.64)	4.8(0.52)	4.8(0.64)	5.7(0.72)	5.74(0.88)	1.16	0.92
Range	4.8-7.6	4.0-7.5	3.5- 6.17	2.5-6.2	3.8-7.5	3.1-8.5		
Biochemical Oxygen Demand	5.4(0.40)	5.6(0.44)	5.0(0.46)	5.1(0.55)	4.8(0.4)	4.8(0.48)	1.78	0.72
Range	4.3-6.5	4.7-6.8	3.8-6.2	3.5-6.5	3.8-5.8	3.2-6.0		
Phosphate	0.33(0.06)	0.24(0.03)	0.40(0.06)	0.32(0.04)	0.35(0.35)	0.30(0.03)	1.54	0.79
Range	0.15-0.48	0.16-0.32	0.3–0.60	0.19-0.42	0.20-0.45	0.22-0.40		
Nitrate	1.5(0.07)	0.23(0.02)	0.3(0.04)	0.30(0.03)	1.70(0.07)	0.30(0.03)	356.25	0.005*
	1.30-1.70	0.18-0.30	0.20-0.40	0.24-0.38	1.30-1.70	0.18-0.38		

Table 2: Species Checklist, distribution, abundance, diversity indices and ecological habitats (in parenthesis BOLD) of the algae community in the water-columns and sediments of mid-Ethiope River.

	Bacillariophyceae	Acronym	ST1SD	ST1W	ST2SD	ST2W	ST2SD	ST3W			
1	Achnantes minutissima v affinis **(B)**	AMVA	-	++	-	++	-	+	1.82	1.39	0.67
2	Aulacoseira granulate(**P-B)**	AUGR	+	+	+	+	+	+	1.5	1.75	0.96
3	*Asterionella formosa***(P)**	ASFO	+	+	+	+	+	+	0.55	1.75	0.96
4	*Asterionella sp***(P)**	ASSP	+	+	+	+	+	+	1.26	1.74	0.95
5	*Cyclotella comta*(**P-B)**	CYCO	+	++	+	++	+	++	2.84	1.55	0.73
6	*Cymbella gracilis***(B)**	CYGR	+	+	+	+	+	+	0.79	1.74	0.96
7	*Diatom enlongatum*(**P-B)**	DIEN	++	+	++	+	++	+	3.71	1.68	0.89
8	*Diatoma hyemale*(**P-B)**	DIHY	-	+	-	+	-	+	0.47	1.67	0.89
9	*Diatoma vulgare*(**P-B)**	DIVU	+	+	+	+	+	+	0.71	1.77	0.93
10.	*Eunotia monodon***(B)**	EUMO	+	-	+	-	+	-	0.87	1.39	0.80
11	*Eunotia sudetica***(B)**	EUSU	++	-	++	+	++	+	2.61	1.69	0.90
12	*Eunotia serra***(B)**	EUSE	+	+	+	+	+	+	1.19	1.69	0.90
13	*Fragilaria javanica***(B)**	FRJA	++	+++++	++	-	++	++++	11.14*	1.32	0.62
14	*Mastogloia smithi***(B)**	MASM	+	+	+	+	+	+	0.87	1.78	0.98
15	*Melosira granulata***(B)**	MEGR	+	+	+	+	+	+	0.71	1.75	0.96
16	*Luticola mutica***(B)**	LUMU	+	+	+	+	+	+	0.79	1.77	0.98
17	*Navicula. viridula***(B)**	NAVI	+	+	+	+	+	+	0.63	1.74	0.95
18	*Navicula tenelloides***(B)**	NATE	**++++**	++	+++	++	+++	++	6.79	1.75	0.96
19	*Peronia intermedium***(B)**	PEIN	+	+	+	+	+	+	0.95	1.76	0.97
20	*Pleurosigma obtusatum***(B)**	PLOB	-	+	+	+	-	+	0.47	1.72	0.93
21	*Quadrigula*	QUCL	+	-	+	-	+	-	0.32	1.52	0.92

	closteriodes(**B**)										
22	*Rhopalodia gibba*(**B**)	RHGI	+	+	+	+	+	+	0.55	1.75	0.96
23	*Stauroneis phoenicentron*(**B**)	STPH	-	-	+	-	+	-	0.16	1.55	0.94
24	*Surirella sp*(**B**)	SUSP	-	++	-	++	-	+	1.58	1.37	0.65
25	*Synedra acus*(**P-B)**	SYAC	+++	+	+++	++	+++	+	6.32	1.58	0.81
26	*Synedra ulna*	SYUL	+	-	+	+	+	-	0.71	1.37	0.79
27	*Tabellaria fenestrata*(**P-B)**	TAFE	++	+	++	+	++	+	3.08	1.60	0.83
28	*Tabellaria flocculosa*(**B) ***minina*(**P-B)**	TAFL	++	+	+	+	+	+	1.5	1.70	0.91
	***Chloro*phyceae**										
29	*Closterium acerosum*(**P-B)**	CLAC	-	+	-	++	-	+	0.87	1.32	0.62
30	*Closterium incurvum*(**P-B)**	CLIN	+	+	+	++	+	+	1.58	1.49	0.74
31	*Closterium sigmoideum*(**P-B)**	CLSI	+	+	++	+	+	+	1.74	1.75	0.96
32	*Closterium granatum*(**P-B)**	CLGR	+	-	+	-	-	-	0.16	1.73	0.94
33	*Chlorella Sp*(**P-B)**	CHSP	+	-	+	-	+	-	0.32	1.70	0.91
34	*Desmidium asymeticum*(**P-B)**	DEAS	+	++	+	++	-	+	1.74	1.55	0.78
35	*Gonatozygon knahani*(**B)**	GOKN	+	+	+	+	+	+	1.26	1.77	0.98
36	*Mougeotia parvula*(**B)**	MOPA	-	-	-	++	-	++	1.66	1.15	0.53
37	*Mougeotia sp*(**B)**	MOSP	-	-	-	-	-	++	1.01	1.00	0.45
38	*Mougeotiosis sp*(**B)**	MOUG	-	-	-	-	-	++	0.71	0.85	0.39
39	*Oedogonium grande*(**B)**	OEGR	+	+	+	+	+	+	1.66	1.77	0.98
40	*Pleurotaenium sp*(**P-B)**	PLSP	-	+++	-	++	-	-	2.45	1.10	0.50
41	*Scenedesmus ecornis v. polymorphus*(**P)**	SEVP	+	+	+	+	+	+	0.63	1.74	0.95
42	*Scenedesmus incrassatulus*(**P)**	SCIN	+++	-	+++	-	+++	-	4.19	1.30	0.61
43	*Spirogyra africana*(**B)**	SPAF	+	+	+	+	+	+	1.11	1.78	0.99

44	*Spirogyra insignis*(**B)**	SPIN	-	++	-	+++	-	++	2.92	1.33	0.63
45	*Spirogyra sp*(**B)**	SPSP	-	++	++	-	++	-	3.00	1.34	0.64
46	*Ulothrix tenuissima*(**B)**	ULTE	+	+	+	+	+	+	1.34	1.78	0.99
47	*Zygogorium ericetorum*(**B)**	ZYER	-	+	+	+	+	+	0.71	1.71	0.93
	Cyanophyceae										
48	*Aphanizomenon sp*(**P)**	APSP	+	-	+	-	+	-	0.79	1.52	0.76
49	*Merisimopedia elegans*(**P-B)**	MEEL	++	++	++	++	++	++	3.32	1.79	1.00
50	*Microcystis aureginous*(**P-B)**	MIAU	++	-	++	-	++	-	1.74	1.42	0.69
51	*Microcystis viridis*	MIVI	+	+	+	+	+	+	1.19	1.75	0.96
52	*Oscillatoria brevis*(**P-B)**	OSBR	+	+	+	+	+	+	1.34	1.74	0.95
53	*Oscillatoria proboscidea*(**P-B)**	OSPR	+	+	+	+	+	+	1.26	1.76	0.97
54	*Phormidium ambiguum*(**B)**	PHAM	+	+	+	+	+	+	0.79	1.78	0.98
55	*Phormidium ingricum*(**B)**	PHIN	+	+	+	+	+	+	1.19	1.71	0.92
56	*Phormidium mucicola*(**B)**	PHMU	+	+	+	+	+	+	1.34	1.78	0.98
57	*Phormidium tenius*(**B)**	PHTE	+	+	+	+	+	+	1.34	1.75	0.96
58	*Schizothrix sp*(**B)**	SCSP	+	+	+	+	+	+	0.71	1.77	0.98
59	*Spirulina major*(**P-B)**	SPMA	+	-	+	-	+	-	0.32	1.70	0.91
	Euglenophyceae										
60	*Euglena oxyuris*(**P)**	EUOX	+	-	+	-	+	-	0.71	1.06	0.96
	Taxa		47	46	51	47	47	45			
	Individuals		189	248	193	210	200	200			
Diversity Indices	Dominance		0.05	0.01	0.05	0.04	0.05	0.05			
	Shannon		3.33	3.07	3.43	3.57	3.04	3.36			
	Evenness		0.59	0.47	0.60	0.76	0.61	0.61			

Note: (-):0cell/ml; +:1-5cells/ml; ++: 6-15cells/ml; +++: 16-25; ++++:26-45cells/ml; 46-69 :+++++:> 70cells/ml; H: Habitat: (B: Benthic; P: Planktonic; P-B: Planktonic-Benthic) RA: relative abundance; H: Shannon index; E: Evenness.

Microcystis aureginous/ viridis registered only at the bottom (sediment). The generated linear model generated between water and sediment algae compositions (Figure 2B) revealed no marked distinction between the algae community structure of the water column and sediment. The co-variance test for equal means for the three significant taxa; Bacillariophyta, Chlorophyta and Cyanophyta, in water, sediment and water-sediment algae revealed no statistically different taxa ($F=3.111$; $p=0.09$). Levene's test for homogeneity of variances for means ($p=0.1214$) and median ($p=0.1243$) equally detected no significant difference. The correction matrix map for the three significant taxa; Baccilariophyta, Chlorophyta and Cyanophyta in water, sediment and water-sediment are in Figure 2C. The environmental variables influence the major taxa are shown in Table.

The species-diversity indices limits at the species level were low (Table 2). Shannon indices and evenness varied from between 0.85 to 1.79 and from 0.39 to 1.0 for *Merisimopedia elegans* (Cyanophyceae) and *Mougeotiosis* sp (Chlorophyceae) respectively. Aggregately, the community diversity indices at the different stations and zones revealed very high Shannon indices of $H>3.0$, with the correlation coefficient amongst the algae abundances of the studied stations very high($r >0.90$). The least correlation coefficient was 0.9769 for between station 1 sediment (ST1SD) and Station3 water column (ST3W) while the maximal correlation coefficient was 0.99915 between Station 2 sediment (ST2SD) and Station3 sediment (ST3SD). Shannon diversity t-test detected highly statistical differences between algae composition in station 1 bottom(ST1-B) and Station 2 bottom(ST2-B) (t:-4.5165; df:429.41, p: 8.1354E-06; Station 1 bottom (ST1-B) (2.7124) and Station 3 bottom(ST3-B) (3.1523) t:-

4.5165, t: 8.1354E-06 and non-statistical differences between Station 2 bottom (ST2-B) and Station 3 bottom (ST3-B), t:1.2617, df: 443.98, p: 0.20778.

The principal components analysis clustered the identified species at the central axis, shown in Figure 3A. The first and the second axes revealed that 82% of the algal composition influence algal variability among the studied stations in the mid-Ethiope River. The position of the studied zones separated the sediments of the three stations, stations 1and 2 water column and station 3 as three different zones. Figure 3C identified the high strong positive association between benthic algae with the water column. The total number of individuals/species influenced the sediments algae positively while the P and P-B influenced one another positively along the negative axis.

The first axis isolating water column and benthic algae accounted for 99.5% of the total algae variance, separated from the water-sediment and the total algal and planktonic-benthic and benthic. The PCA further confirmed by the Euclidean similarity and distance indices (Table 3A). Although, some similarities (small distances) surprisingly were not correlated (Table 3A). Analyzing the algal community upon habitat/life forms preference, benthic and planktonic-benthic species dominated all stations and zones of mid-Ethiope River, and real planktonic species were very few Table 1 and Figure 3B. The affinity between the betwixt the physicochemical parameters and the algae abundances are in Table 3B.

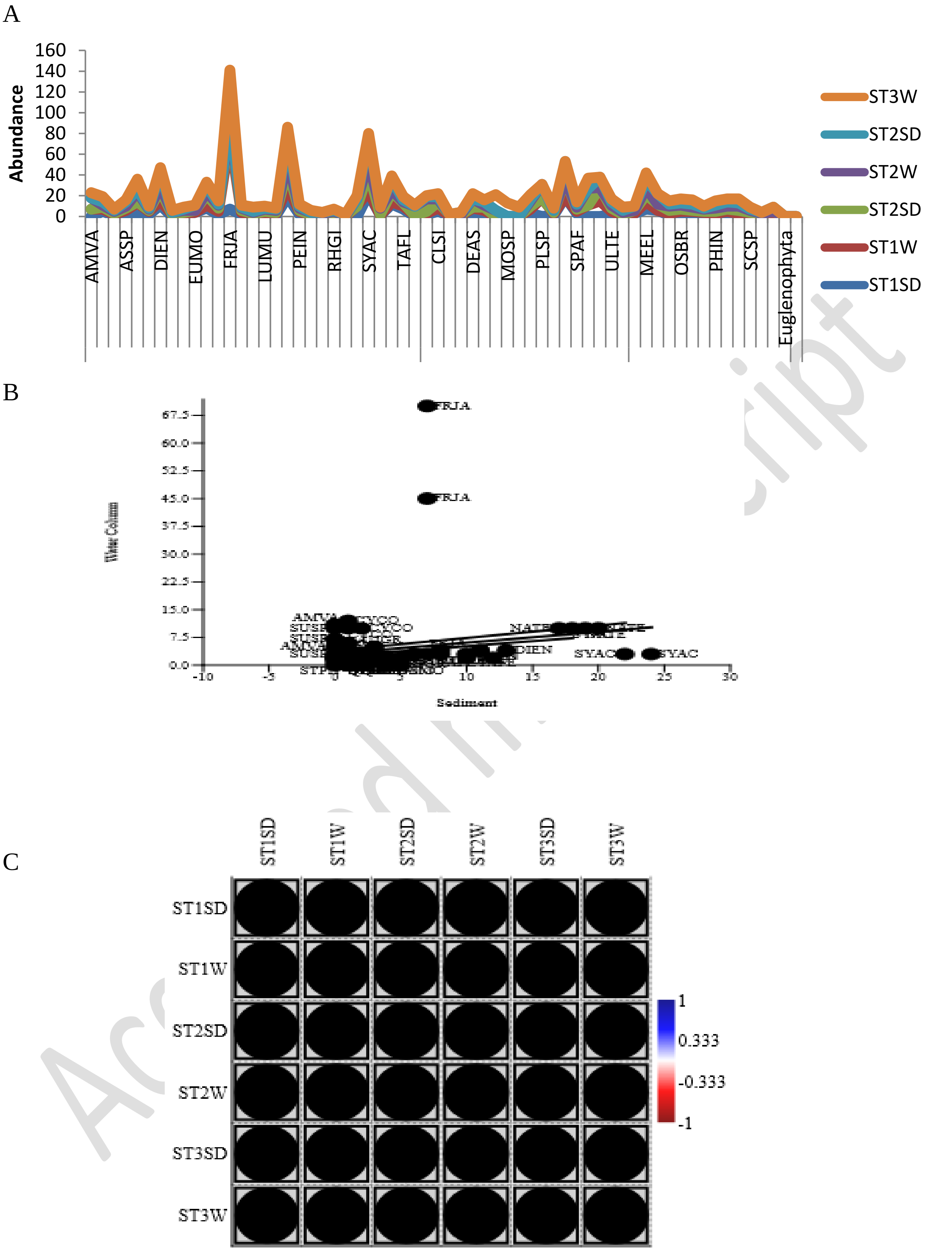


Figure 2: Taxa distribution(A), linear relationship (B) and the correlation matrix map(C) between water, sediment, water-sediment algae at the various stations (Acronyms in Table 2)

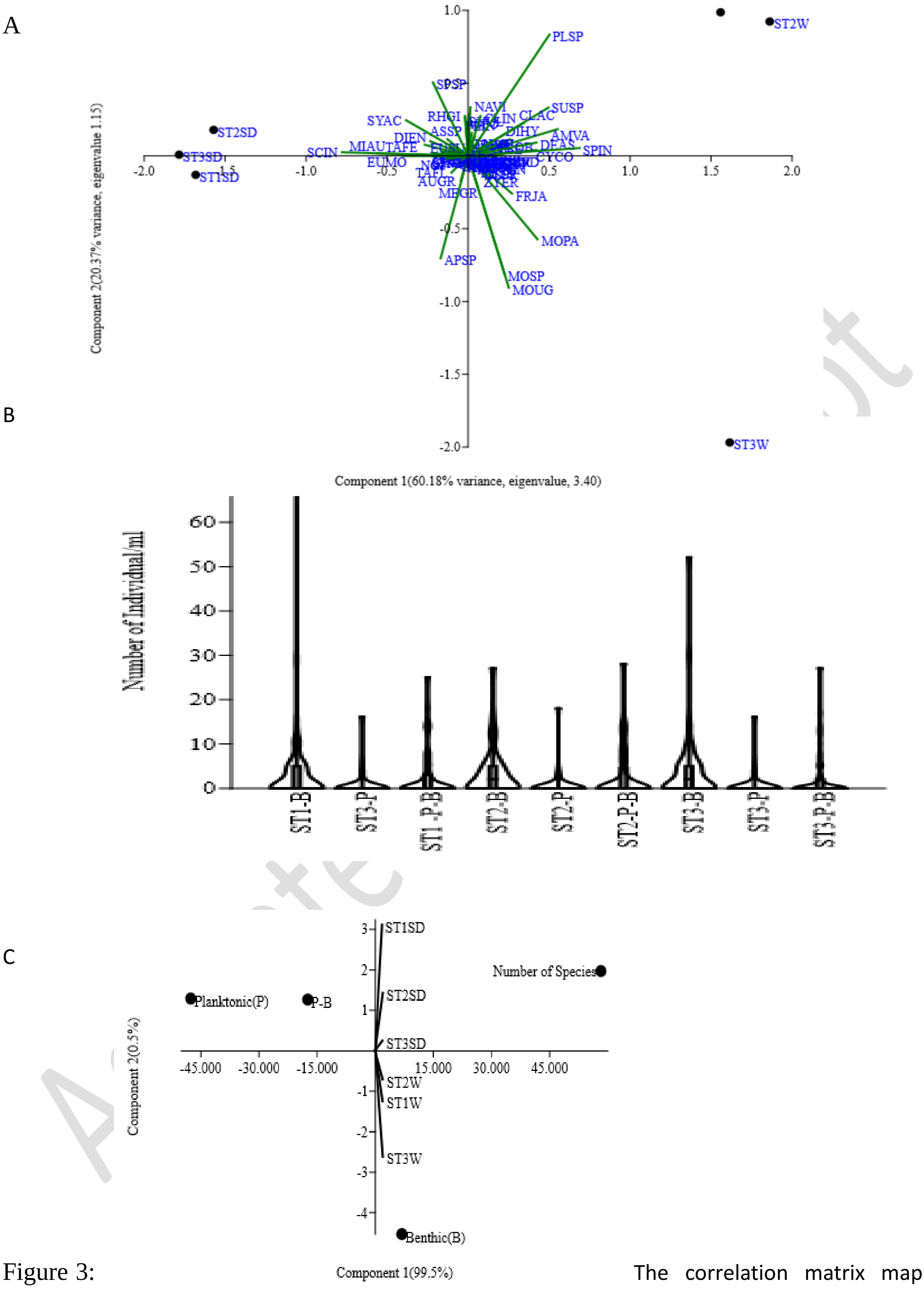


Figure 3: The correlation matrix map(A), abundance for Benthic (B), planktonic (P), Planktonic-Benthic (P-B) algae(B) and position of studied sites, ha in Stations 1(ST1), 2(ST2) and 3(ST3)

4. Discussion

In the present study, water temperature, air temperature, conductivity, water depth, dissolved oxygen and nutrients ($p<0.05$) factors influenced algae abundance and diversities in middle River Ethiope (Table 3B). Thus, biological events in aquatic ecosystems are influenced by these environmental variables. Hou et al., (2018), reported that changes in the physicochemical variables modify algal abundance, composition and diversities in rivers.

The geomorphic and inherent fundamentals are primers in structuring and controlling aquatic communities (Wu et al., 2009; Onyema and Popoola, 2013; Wang et al., 2016; Hou et al., 2018). Ethiope river’s sediment acidic nature (3.7 to 4.2) and high BOD (4.5 to 6.8mg/l) values inferred zones of higher oxygen consumption than in the water column. However, the BOD at both zones was more significant than 3, which inference the impact of released nutrients and bottom-associated vegetation decomposition from the sediment, thereby impairing the river water quality (Pan et al., 2013; Wang et al., 2016). This is also evident in the nutrient-enriched River's sediments noted in this study. Which may be attributable to nutrients released from the sediment during the dredging possesses (Hamid et al., 2020). Rich nutrient sediments are crucial in the abundance of the blue-greens in any aquatic ecosystem but not evident in the present study (Adeyemo et al., 2008). This may be attributed to insufficient light due to its absorption by solids, sand slits in the water column, which is evident from the reduced transparency in this section of the river (Iloba, 2012). The negative association between the Cyanophytes and BOD ($r=-0.8241$; $p=0.04$), and Chlorophytes versus nitrate ($r=-0.8273$; $p=0.04$) (Table 3B) was contrary to natural expectations, signature other underlying determining factors in the study area. However, differential responses of algal community to nutrients or organic enrichment have been noted in other water and sediment studies (Desianti et al., 2017). The positive correlation of dissolved oxygen on Bacillariophyta ($r = -\ 0.8137$, $p = 0.0478$) indicates its positive influence on the proliferation of Bacillariophyta in this system. The relatively high amount of dissolved oxygen is due to exchange between the air-water interphase (Hamid et al., 2020).

Table 3: Similarity and distance indices and correlation coefficients in parenthesis between benthic, planktonic, planktonic-benthic algae associations in water column and sediments zones (A) and Pearson correlation and p values of environmental variables and major taxa(B) in mid-Ethiope River

A	**ST1-B**	**ST1- P**	**ST1 -P-B**	**ST2-B**	**ST2-P**	**ST2-P-B**	**ST3-B**	**ST3-P**	**ST3-P-B**
ST1-B	0	92.5 (0.50)	104.0(0.14)	68.7(0.00)	91.4(0.51)	102.7(0.12)	36.0(0.0)	91.1(0.50)	99.4(0.16)
ST1- P	92.5(-0.09)	0	50.0(0.52)	51.8(0.24)	2.7(0.0)	52.3(0.36)	73.3(0.36)	3.9(0.0)	46.9(0.45)
ST1 -P-B	104.0(-0.20)	50.0(-0.09)	0	65.7(0.02)	50.9(0.50)	18.0(0.0)	86.4(0.04)	50.2(0.49)	20.4(0.0)
ST2-B	68.7(0.62*)	51.8(-0.16)	65.7(-0.33)	0	50.7(0.25)	67.0(0.0)	47.0(0.0)	50.2(0.25)	62.0(0.03)
ST2-P	91.4(-0.09)	2.7(0.99*)	50.9(-0.09)	50.7(-0.15)	0	52.5(0.36)	72.3(0.38)	4.5(0.0)	47.4(0.43)
ST2-P-B	102.7(-0.21)	52.3(-0.12)	18.0(0.91*)	67.0(-0.35)	52.5(-0.12)	0	85.9(0.03)	52.0(0.35)	22.2(0.0)
ST3-B	36.0(0.92*)	73.3(-0.12)	86.4(-0.28)	50.0(0.68*)	72.3(-0.12)	85.9(-0.28)	0	72.0(0.37)	82.1(0.06)
ST3-P	91.1(-0.09)	3.9(0.99*)	50.2(0.09)	50.2(-0.16)	4.5(0.97*)	52.0(-0.13)	72.0(-0.12)	0	46.9(0.43)
ST3-P-B	99.4(-0.19)	46.9(-0.10)	20.4(0.88*)	62.0(-0.30)	47.4(-0.10)	22.2(0.86*)	82.1(-0.24)	46.9(-0.10)	0

B	**Air-T**	**Water-T**	**Depth**	**Conductivity**	**D O**	**BOD**	**PO4**	**NO4**
Bacillariophyta	-0.84(0.04)				0.81(0.05)		-0.79(0.059)	
Chlorophyta			-0.91(0.01)	0.88(0.02)				-0.83(0.04)

Cyanophyta						-0.82(0.04)		
Conductivity			-0.82(0.05)				-0.84(0.04)	
NO3			0.81(0.04)					
BOD		-0.83(0.04)						

. This association is attributable to the dominance of Bacillariophyceae in this study and exertion of the River's flow on algal assemblages and habitat destruction by dredge through dislodgement and nutrients enhancement as demonstrated in this study (Berge et al., 2010). The predominance of diatoms in this river is contrary to the noted dominance of Chlorophytes in rivers. This may be due to out-competition of the chlorophytes by the benthic. Benthic algae are essential indicators of human disturbances (Gokce, 2016). Abonyi et al., (2014) opined that the algae biomasses in the middle reaches of large rivers are exceptionally high in line with the river continuum concept (RCC) (Vannote et al., 1980). A high number of species and abundance is partially valid for mid- River Ethiope with only 60 species, which is incomparable with the over 150 species upstream the studied stations (Iloba, 2012). The number of algae species in the present study does not validate the river continuum concept, as demonstrated by the Euclidean similarity distances. The closet clustering found between the same habitat-types and their non-significant between across the three stations revealed habitat similarity and possibly no downstream habitat-gradient in the study area (Vannote et al., 1980). Thus, the high correlation found between the three stations' benthic, planktic-benthic and planktonic, respectively (Table 3).

The study revealed that the water column benthic and planktic-benthic surpasses the benthic species associated with the sediments. This observation may attributable to the fracture, breakdown, and extraction of sand from the riverbed or sediment during sand mining. The mechanical processes involved in sand excavation dislodge and upload benthic algae-associated slits, particulate organic loads, solids and substrate into the water column (Adeyemo et al., 2008; Anderson, 2014; Mabidi et al., 2017). These suspensions harbour benthic and planktic-benthic species which remain suspended via the continuous surface and benthic plumes by multiple dredges produced over a long period continually, and the river flow overwhelming the ephemeral nature of plumes (Jones et al., 2015). This breakdown facilitated the loss of algae chronicles expected in the ideal or undisturbed water column and sediment prior to dredging. Thus, machine and human-dredging has exacerbated the abundance of benthic algae in the water column.

The high number of benthic and planktonic-benthic habitat-indicator algae in the water column, therefore, suggests the prevalence of suitable niches for their existence in the water column of the studied River, which is enhanced by light penetration. Autecological analysis of such benthic algae-heavy water column suggests numerous benthic associated habitats to which benthic-associated algae are attached and planktonic-benthic are entangled (Wu et al., 2009; Wehr et al., 2015). Secondly, the persistence of associated benthic-algae across or through the studied stations may be associated with the water column mixing and downstream movement of algal associated sediments (Wu et al., 2009). Again, the persistence and dominance of benthic and planktonic-benthic could be due to their resilience to a vast array of disturbances indicated by the dominant species; *Fragilaria javanica* (Murnaghan et al., 2015; Breuer et al., 2017). The interactive processes between the attached algae and stable, liquid compounds (Moreira-Gonzalez et al., 2020) and also the dredging impact exceed the community resilience (Erftemeijer et al., 2012).

Algal uniformity among the studied stations testifies of algal response to anthropogenic activities in this River (Table 3). The interconnectedness of the different taxa in the two aquatic zones is also evident from their non-significant linear model (Figures 2A and 2B). Such an extent of uniformity in the algal composition of the two river zones is not far-fetched from the various dredging activities on the River. The Anthropocene activities are thus responsible for the low species diversities (Table 2), thereby impacting negatively on the species and number of algae in the present study (Mabidi et al., 2017). Several researchers have reported similar dredging impacts on algae composition and abundances in river systems (Erftemeijer et al., 2012; Grygoruk et al., 2015; Iloba et al., 2018). Dredging activities in this river make it impossible to predict the synergistic consequences of other plausible natural stressors responsible for algal uniformity among the studied stations. These may include planktic-benthic algae importation during flood and the continuous algal mixing via flow and water currents (Erftemeijer et al., 2012).

Algae are not isopycnic (having the same density) with the medium resulting in the instability of the composition, abundance and diversity of the species in the water and sediments (Vinogradov et al., 2018). The dominant appearances of epiphytic algal species in the planktonic zones could be responsible for the non-significant difference between the algal composition of the water column and sediment at the various stations ($p<0.05$).

The overt low species diversities demonstrated in the present study expressed an impaired stressful, disturbed, and an unstable water body for the algal species (Omar, 2010; Ahmed et al., 2015). The low number and the disproportionate distribution of algae species demonstrated significantly equal and homogenous by the ANCOVA and Levene tests respectively in the studied zones due to the interaction between the surface and the bottom water by intense anthropogenic disturbance is not by chance. The regression plot is indicative of a strong relationship between the water column and sediment algae which was further confirmed by the non-violation of equal co-variance of algae in the studied zones ($p>0.05$). The algal homogeneity is therefore not random, but due to dredging impact. Researchers have demonstrated that the impact of human-disturbance in rivers more significant than the interactions between algae and water (Ishaq and Khan, 2013; X-Gao et al., 2018). Contrary to species diversity, the relatively zonal biological diversities (Shannon (H) > 3) at the different stations portray stable ecological zones (Jyothi et al., 2016). Researchers have reported a reduction in species diversity and richness through habitat destruction, disruption in water and sedimentary environment (X-Gao et al., 2018). The algal composition and abundance in the studied area are unknown to assess the magnitude of damage and alteration of the River's habitat and local biota for comparison but is already threatened evidenced from the low biological indices (Iloba et al., 2019 and Hamid et al., 2020). The non-significant and significant differences demonstrated by the Shannon diversity t-test predict niche overlap among the studied sites. However, species diversity indices are an unparalleled tool to the taxon to taxon analyses, which evidenced stressed condition for the algal species. These findings are in agreement with Iloba (2017) in microfauna evaluation of Ethiope River, opined that diversity could be high in a stressful environment.

5. Conclusion

This research evaluated the algal composition and abundance distinctiveness in the water column, and sediment of the middle reaches of the Ethiope River and observed no heterogeinity. The study identified 60 species of algae belonging to four taxa; Bacillariophya, Chlorophyta, Cyanophyta and Euglenophyta in decreasing order. The study has substantiated that algal community in the water column was higher than those of the sediment due to upload, and release of algae into the water column in response to the dredging activities; however, the algal communities of both zones were dominantly attached algae (tychoplankton and euplankton). Furthermore, the algal communities at the different zones demonstrated no distinction among the study sites when subjected under different statistical evaluations ($p>0.05$), thus, revealed no habitat heterogeneity. Thus the destruction of the natural river bed of this River through sand mining and dredging has created a river with significant slits or organic loads. The study envisioned ecological disaster in future if sand mining is not put under control. The boundary disappearance between sediments and water column also indicts the sand dredging activities in the study area. Sand dredging and its associated plumes mixed and impact uniformity between the algal community structure of the water column and sediment. Thus the water column and sediment algal communities in the study are similar. The low species richness and low Shannon diversity indices revealed a disturbed and unstable river indicting observed human interferences; dredging. The algal communities in the water-sediment of the middle reaches of Ethiope River have been severely altered and homogenized from bottom to top. This situation calls for a functional regulatory body to constrain on the dredging activities in the area, to abate habitat destruction, and avoid socioeconomic disaster. Law enactment will also monitor these activities or put a hold on sand dredging, to allow time for sediment recovery before engaging in regulatory and guided dredging.

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