Physicochemical Variables and Zooplankton Populations of the Upper Bonny Estuary in Relation to Jetty Operations

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Abstract

Marine logistics operations at are a potential source of water pollution. We examined the effect of operations at Jetties in the upper Bonny Estuary on surface water quality and the zooplankton communities. Four jetty sites and a Control were chosen and sampled in the wet (September 2018) and dry season (December 2018). The sampling sites were: Stn 1- NNPC Refinery petroleum products loading jetty; Stn 2 – Okrika passenger Jetty; Stn 2- Kalio George-Ama axis (presumed Control with no jetty activity); Stn 4 – Abuloma passenger jetty and logistics bases for some companies; Stn 5- Marine Base passenger jetty. Water samples were collected and analysed by standard methods for physicochemical parameters and pollution indicators (nitrate and total hydrocarbon content – THC). Zooplankton samples were collected by filtration of 50L of water through a plankton net (65 μm for mesh size). Clear horizontal patterns were observed for conductivity (20600 to 28500 µS/cm), total dissolved solids (14420 to 19997 mg/L) and salinity (12.4 to 17.7 PSU), with the values at St 1 being the highest and a progressive reduction down to Stn 5. ANOVA showed significant difference between stations and seasons for conductivity, TDS and salinity ($p<0.001$); there was also significant interaction. Tukey tests showed that for the three parameters (conductivity, TDS and salinity) Stn 1 > Stn 2 > Stn 3 > Stn 4 > Stn 5, with the interaction between station and season reflected in the lack of seasonal variation at Stn 5. The spatial variation represents the natural downstream – upstream gradient within the estuary, and is not a reflection of anthropogenic inputs. There was a significant difference in the concentration of nitrates but Tukey tests showed that value at the Stn 3 (Control) was higher than some of the Jetty stations. Also, there was no significant difference in THC values between sites. In conclusion, the spatial differences in abundance and community indices indicate that jetty operations per se were not a major determinant of the dynamics of zooplankton. Rather, the natural salinity gradient had more putative effects on the zooplankton community structure of the upper Bony Estuary

Keywords: *Jetty; Niger Delta; Bonny Estuary; Water Quality; Zooplankton*

Introduction

In the Niger Delta, the problem of water and sediment pollution has been of concern to all stakeholders, following the rate and extent of degeneration of the environment and water bodies by human activities, particularly from industrial and domestic sources (Powell, 1995, Ekweozor *et al*., 2004). The Bonny Estuary is one of the richest estuaries in the Niger Delta aquatic ecosystem, with a network of creeks/tributaries linking various habitats of highly economic and ecological importance. The system is vulnerable to pollution by organic, industrial and chemical pollutants/wastes from several industries and human habitats located by the banks and water fronts.

Marine logistics operations entail loading of petroleum products as fuel and lubricants which could cause pollution. The human traffic inadvertently also lead to the generation of wastes that are often disposed of indiscriminately into the water bodies. Several studies have been conducted in the upper Bonny Estuary both in the main channel (e.g. Snowden and Ekweozor, 1990; Daka and Abby Kalio 1997; Daka and Abby Kalio, 2002) or creeks emanating therefrom (e.g. Ikomah *et al*., 2005; Ogamba *et al*. 2005; Miebaka and Daka 2013, Daka *et al*., 2018). However, the effects of jetty activities have not received any attention by researchers. In this paper, we present the spatial and seasonal variation of physicochemical parameters at jetties along the upper Bonny Estuary with a variety of anthropogenic activities, including passenger transit, logistic terminals for company operations, as well as the petroleum product loading jetty of the Nigerian National Petroleum Company. The attributes of the zooplankton communities proximal to the jetty operations were also determined.

Materials and Methods

Study Sites

Four jetties in the upper Bonny Estuary with different levels of activity, and a control location were selected for this study. The sampling sites were: Stn 1- NNPC Refinery petroleum products loading jetty; Stn 2 – Okrika passenger Jetty; Stn 3- Kalio George-Ama axis (presumed Control with no jetty activity); Stn 4 – Abuloma passenger jetty and logistics bases for some companies; Stn 5- Marine Base passenger jetty. (Fig. 1).

Sample Collection and Analyses

Samples were collected in September 2018 for wet season and December 2018 for dry season. Surface water samples were collected in triplicate for the analysis of physicochemical parameters and total hydrocarbon content. In situ measurements were obtained for temperature, dissolved oxygen (DO), conductivity, total dissolved solids (TDS) and salinity. Laboratory analysis of samples were undertaken using standard methods (APHA, 1995) for nitrate and phosphate.

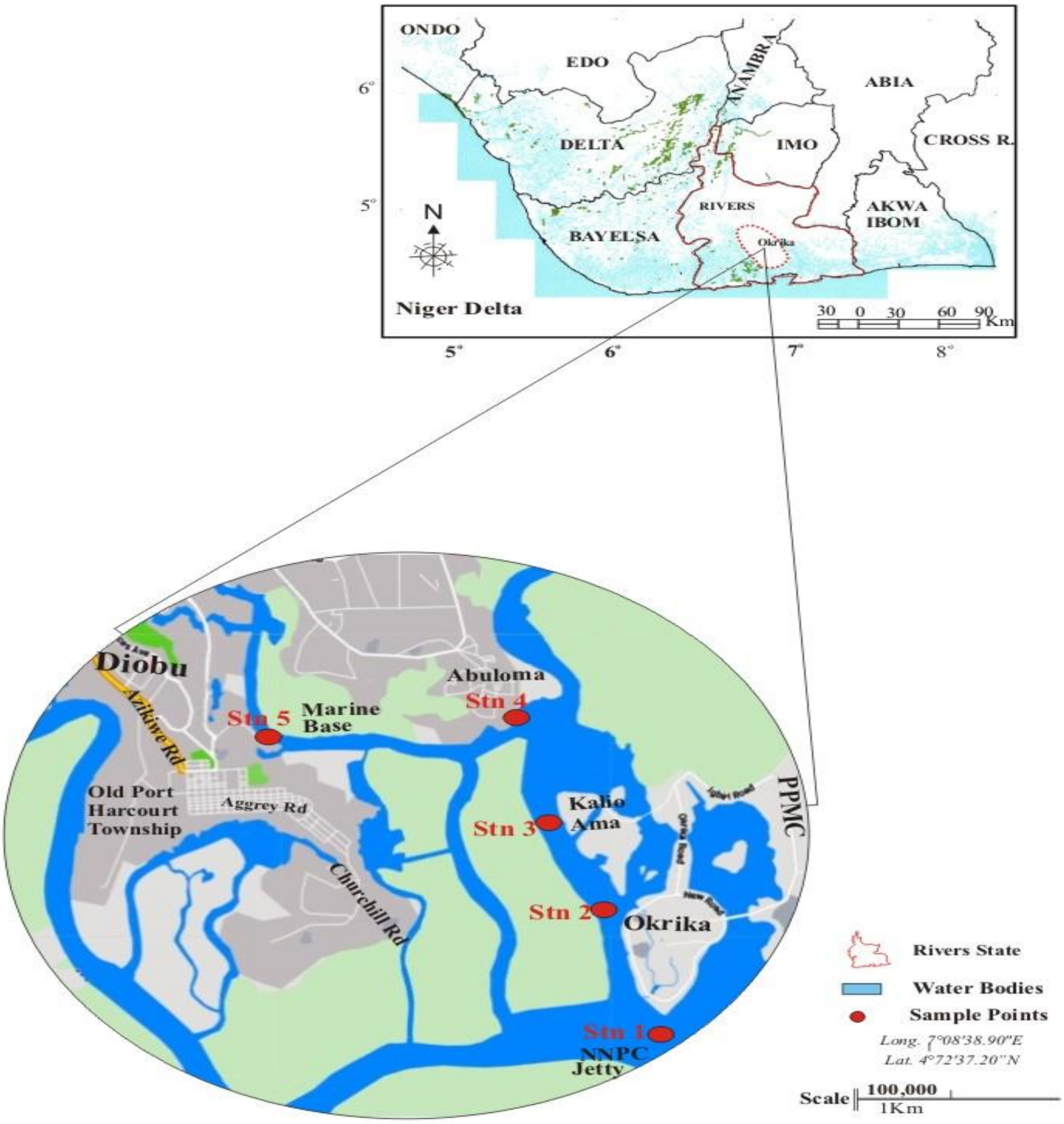

Fig 1: Map of study area showing sampling locations

Zooplankton samples were collected by filtration of 50L of water through a plankton net (65 µm for mesh size, 30 cm diameter). The content of the collection bottle was rinsed into sample containers and fixed immediately with a 5% formaldehyde-water mixture. In the laboratory, samples were made up to a uniform volume of 50 ml. Following a thorough agitation and homogenization, 1 ml sub-samples were taken using a Pasteur pipette and transferred to a Bogorov counting chamber for observation under a binocular compound microscope. The organisms were simultaneously identified and enumerated with the aid of a binocular microscope using appropriate keys (Barnes (1980, Suthers, (2008), Newell and Newell, (1977) were used as guide for the identification and classification.

Data Analysis

A number of statistics were used as measures of the attributes of community structure of the, zooplankton samples. These include measures of species richness (Margalef, d) diversity (Shannon-Weiner H') and equitability (Pielou, J') and dominance (Simpson λ). The formulae

for the calculation of the various indices are as follows (Pielou, 1975, Heip et al., 1988, Magurran, 1991):
Margalef index: $d = (S-1) / \log N$
Shannon-Weiner Index: $H' = - \Sigma_i p_i \log(p_i)$
Pielou Evenness: $J' = H'/H'_{max} = H' / \log S$
Simpson Index: $\lambda = \Sigma pi^2$

These were computed using the Plymouth Routines of Multivariate Experimental Research (PRIMER) software.

Analysis of Variance was used to test for significant spatial and seasonal differences in physicochemical parameters and faunal indices. Tukey tests were applied for pair-wise comparisons between stations, where ANOVA gave a significant difference.

Results and Discussion
Surface water temperature ranged from 29.3 ºC to 31.7 ºC with minimal horizontal variation, but obvious seasonal variation (Fig 2A). There were significant differences in temperature between stations and season, as well as an interaction ($p<0.001$, Table 1). Tukey tests show that the spatial differences were only clear-cut between Stn 4 and Stn 1, while dry season temperatures were higher than wet season values. The pH values which ranged from 6.7 to 7.2 were generally lower in the wet season (Fig 2B). Significant spatial differences and seasonal variations were recorded ($p<0.001$). Clear horizontal patterns were observed for conductivity (20600 to 28500 μS/cm, Fig 2C), total dissolved solids (14420 to 19997 mg/L, Fig 2D) and salinity (12.4 to 17.7 PSU, Fig 2E), with the values at St 1 being the highest and a progressive reduction down to Stn 5. ANOVA showed significant difference between stations and seasons for conductivity, TDS and salinity ($p<0.001$); there was also significant interaction (Table 1). Tukey tests showed that for the three parameters (conductivity, TDS and salinity) Stn 1 > Stn 2 > Stn 3 > Stn 4 > Stn 5, with the interaction between station and season reflected in the lack of seasonal variation at Stn 5. The spatial variation represents the natural downstream – upstream gradient within the estuary, and is not a reflection of anthropogenic inputs. Turbidity values were higher at Stn 4 and Stn 5 (Fig 2F) but with variable seasonal patterns (higher in the dry season at Stn 4 and wet season at Stn 5). Wet season turbidity values were also higher at Stns 1 and 2 but no seasonality was recorded at Stn 3. There were no significant spatial differences ($p=0.291$) in the DO values. The lowest BOD values (Fig. 2H) were obtained at Stn 3, while the highest was at Stn 5 (but no wet season values were available). The concentrations of nitrate ranged from 0.4 to 1.4 mg/L in the dry season and 0.7 to 2.0 in the wet season (Fig. 2I). The values increased from Stn 1 to Stn 5, and there was a significant difference between sites and season ($p=0.002$). Tukey tests gave Stn 5=Stn 3 = Stn 4; Stn 5> Stn 1 = Stn 2.

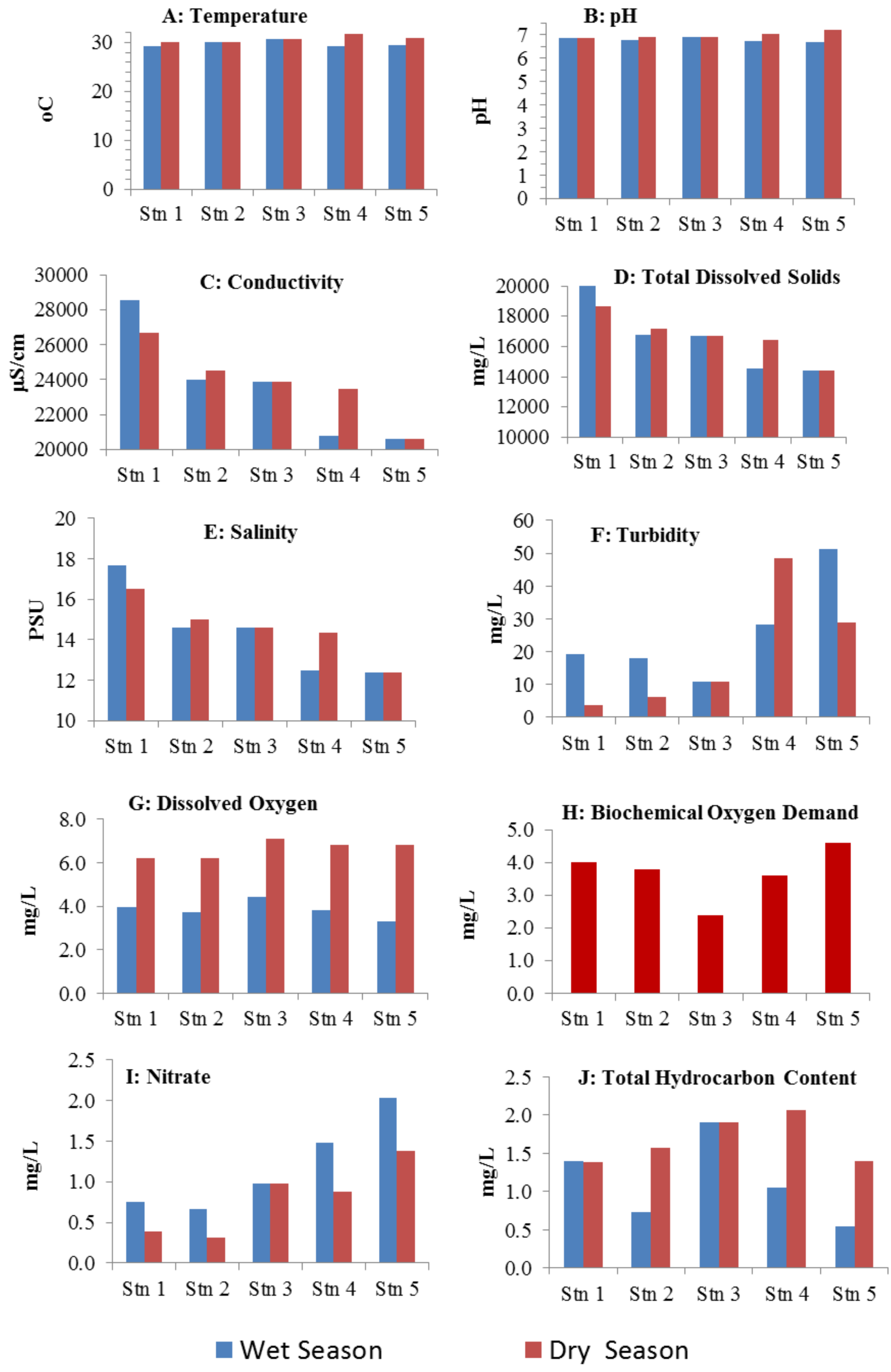

Fig 2: Physicochemical parameters of water

THC values in water ranged from 0.6 to 1.4 mg/L in the wet season and 1.4 to 1.9 mg/L in the dry season (Fig 2J). There was no significant difference between sites (p=0.910, Table 1). No clear seasonal patterns were apparent across the stations, but overall, dry season values were but without statistical significance (p=0.077).

The values of physicochemical parameters compare favourably with Moslen *et al.* (2005) for Azuabie and Obufe Creeks, George *et al.* (2009) in Okpoka Creek and Ogamba *et al* (2005) in the Elechi Creek. The spatial variations in salinity, conductivity, TDS were akin to the natural down-stream upstream conditions, with dilution from river inflow leading to lower values in the upstream stations with a progressive and significant increase downstream. The jetty operations do not appear to be influencing these parameters in any noticeable way as the Control location neatly fitted in with the natural pattern. The spatial differences in nitrate and THC do not attest to significant impacts of jetty operation on these parameters. Although significant differences in nitrate were observed between sites, the control location (Stn 3) did not show any significant difference when compared to the location with the highest value of nitrate (Stn 5).

Table 1: Summary of Analysis of Variance for physicochemical parameters of water

Parameter	**Site**		**Season**		**Interaction**	
	F	**p-Value**	**F**	**p-Value**	**F**	**p-Value**
Temperature	21.74	<0.001	234.24	<0.001	48.12	<0.001
pH	259.88	<0.001	5700	<0.001	800.88	<0.001
Conductivity	131168	<0.001	17689	<0.001	18791	<0.001
Salinity	58519	<0.001	9025	<0.001	8425	<0.001
TDS	131168	<0.001	17689	<0.001	18791	<0.001
Turbidity	139.35	<0.001	59.05	<0.001	46.31	<0.001
Dissolved Oxygen	1.81	0.291	170.70	<0.001	0.077	
Nitrate	12.45	0.002	10.81	<0.001	0.19	0.939
Total Hydrocarbon Content	0.24	0.910	3.87	0.077	0.37	0.823

Seventeen zooplankton forms belonging to five taxonomic groups were recorded over the study period (Table 2). Copepods accounted for the highest number of genera density. Copepods accounted for 100% of the zooplankton fauna record at Stn 1 in both seasons, Stn wet season in Stn 2 and Stn 4, and dry season in Stn 4, as well >85% of other samples (Fig. 3). The most widely distributed forms (found in all stations) were copepod nauplius, *Paracalanus parvus, Pseudocalanus* spp, *Parvocalanus crassirostris*. *Labidocera spp* was recorded only in the wet season at all sites except Stn 1. Other taxa had limited distribution. The number of species generally increased from Stn 1 to Stn 5 with a dip at Stn 4 (Fig 4A) but ANOVA did not indicate a significant difference between sites (Table3).

Table 2: Composition and abundance (no/L; mean *X*, standard error SE) of zooplankton in the study area. WS=Wet Season; DS=Dry Season

Taxa	**Station 1**				**Station 2**				**Station 3**				**Station 4**				**Station 5**			
	WS		**DS**		**WS**		**DS**		**WS**		**DS**		**WS**		**DS**		**WS**		**DS**	
	X	**SE**	***X***	**SE**	***X***	**SE**	***X***	**SE**	***X***	**SE**	***X***	**SE**	***X***	**SE**	***X***	**SE**	***X***	**SE**	***X***	**SE**
COPEPODA																				
Copepod nauplius	1.4	0.5	0.6	0.2	0.4	0.4	0.8	0.4			1.8	0.4			1.6	0.7	0.6	0.6	2.0	0.8
Labidocera spp					15.2	6.3			19.6	3.7			2.0	0.9						
Paracalanus parvus	3.6	0.9	0.6	0.4	16.6	3.4	1.8	0.4	12.4	2.2	0.4	0.2	11.8	3.2	23.8	3.1	33.0	6.2		
Parvocalanus crassirostris	0.8	0.6	2.8	1.2	2.2	1.4	18.0	3.8	0.6	0.6	88.2	11.3	2.2	1.6			36.8	11.3	93.0	5.5
Pseudocalanus spp	0.2	0.2			0.8	0.8	4.6	1.2			75.2	2.7			0.8	0.2	4.8	4.8	44.6	2.7
Tortanus spp					5.6	3.2	1.6	0.7	0.2	0.2	75.2	2.4	1.2	0.7			8.0	3.7	17.6	2.2
Anomalocera spp							2.6	0.7			0.2	0.2								
Eurytemora spp							1.2	0.5			11.4	1.6			2.2	0.6			19.0	2.7
Temora spp									0.2	0.2					0.8	0.4	3.6	2.9		
Oithona colcarva									1.6	0.8										
Acartia spp																	5.0	3.3		
DECAPODA																				
Litopanaeeus satiferus									0.2	0.2							3.2	1.3		
ANNELIDA																				
Oligochaete									0.8	0.6							0.2	0.2		
Polychaete larvae									0.2	0.2							0.0	0.0		
HYDROZOA																				
Eutima mira																	1.6	1.0		
Dipurena strangulata															1.2	0.7	9.4	6.1	1.4	0.7
CHAETOGNATH																				
Sagitta bipunctata							1.2	0.8	1.0	1.0							2.0	0.9	0.6	0.6

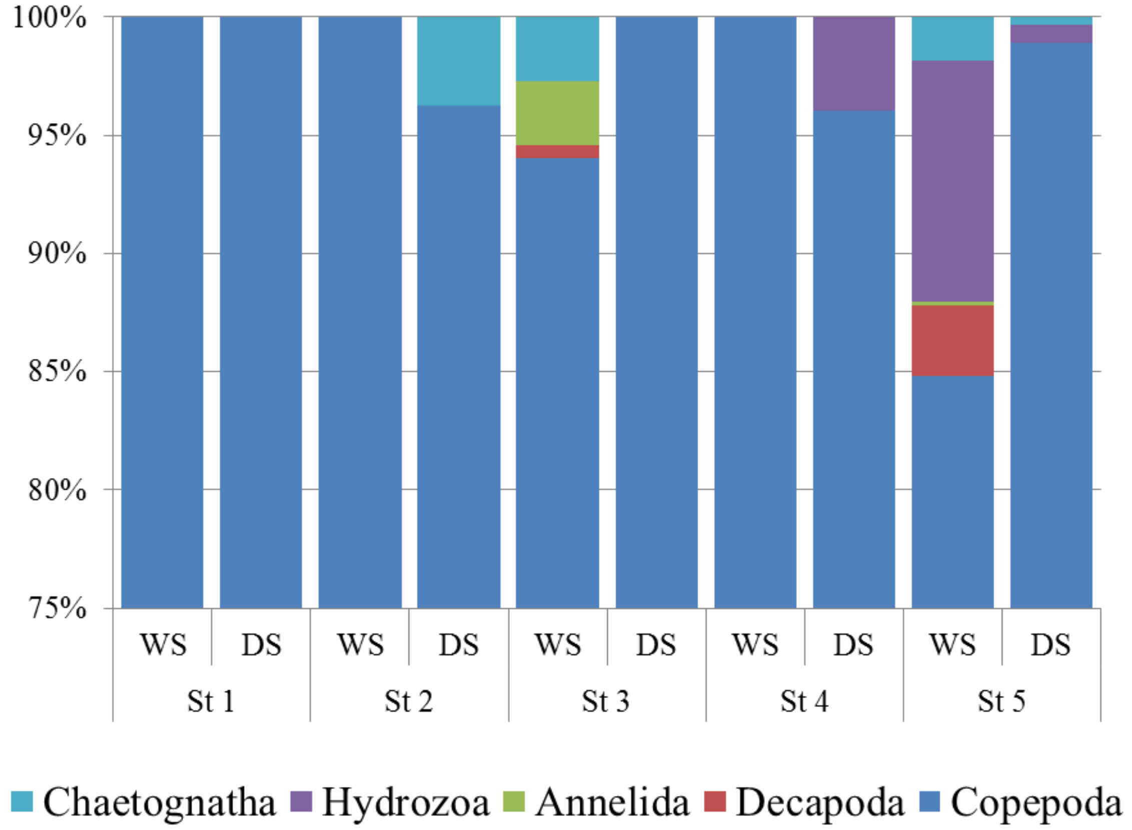

Fig. 3: Relative abundance of zooplankton taxa in the wet (WS) and dry (DS) seasons

Table 3: Summary of analysis of variance for population and community indices

Index	Station			Season		
	MS	F	p-Value	MS	F	p-Value
No of species S	12.150	2.56	0.193	2.500	0.53	0.508
Density N	9208	2.10	0.245	8283	1.89	0.241
Margalef d	0.0922	0.21	0.919	0.3058	0.70	0.449
Pielou J’	0.0105	1.29	0.406	0.0028	0.35	0.586
Shannon-Weiner H’	0.1529	3.86	0.109	0.0366	0.92	0.391
Simpson λ	0.025649	5.73	0.060	0.0078	1.75	0.257

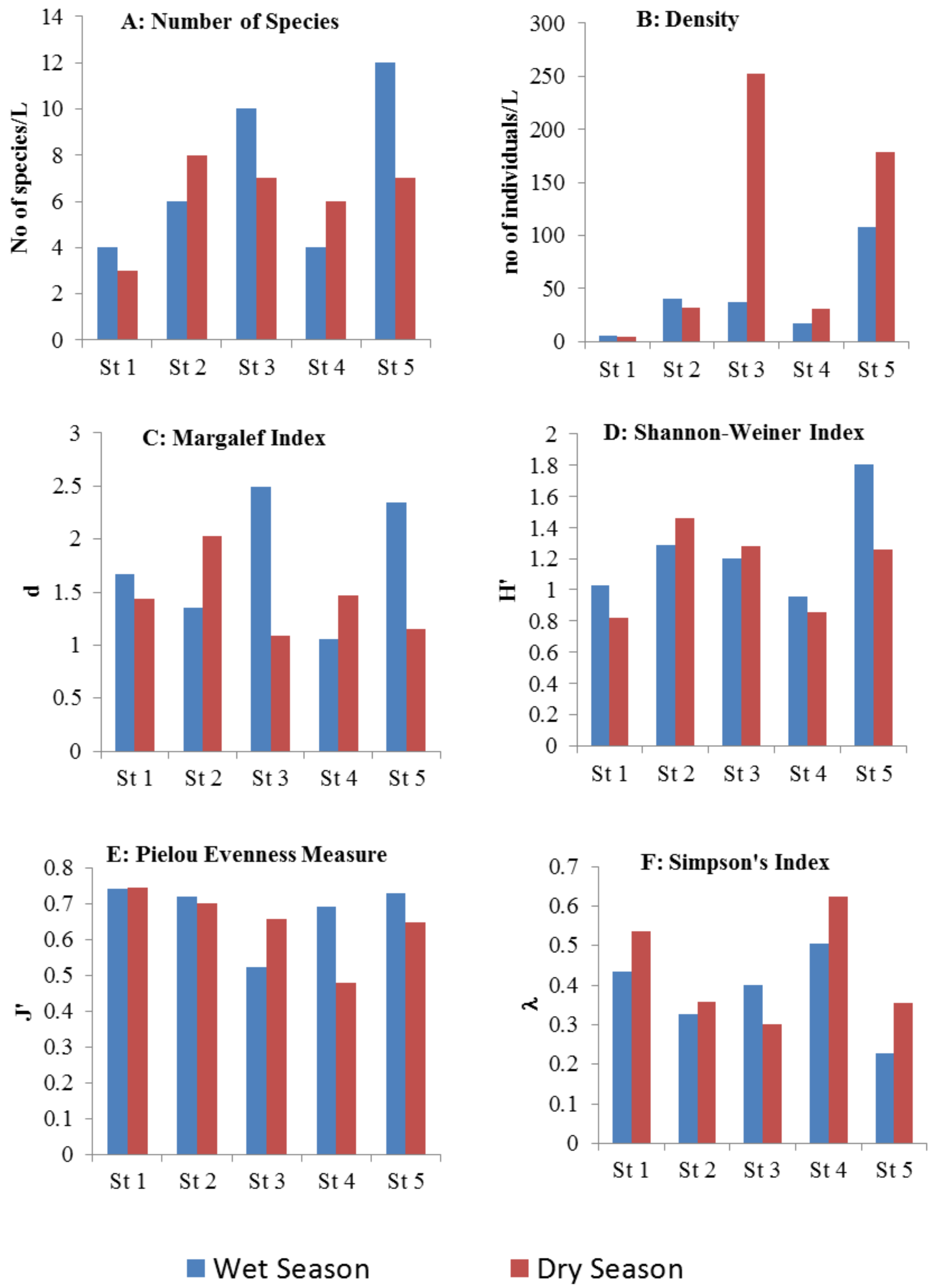

Fig. 4: Community indices of zooplankton

There were negative correlators between the number of species and salinity, conductivity, TDS and THC but none was significant (Table 4). Zooplankton densities (Fig 4B) were generally higher in the wet season (although the reverse was the case at Stns 1 and 2) but with no significant difference (p=0.241). The lowest and highest densities were observed in Stn 1 and Stn 3 respectively but no significant spatial difference was found (p=0.245). No consistent seasonal distribution patterns were observed for Margalef richness index (Fig 4C), Shannon-

Weiner diversity (Fig 4D), Pielou evenness measure (Fig 4E) and Simpson dominance index (Fig 4F). Also, there was no significant spatial difference for any of these community indices (Table 3). The profile of cumulative dominance in each site is also presented in Fig 5). Apart from the correlation between THC and Pielou evenness measure (r-0.702, $p<0.05$), no correlation between community indices and physicochemical parameters showed a significant relationship (Table 4).

The densities of zooplankton observed in this study were similar to the values reported by Ogamba *et al.* (2005) from the Elechi Creek although the Margalef index was lower in our study. However, the values were lower both in terms of composition (taxonomic groups) and abundance when comparted to the findings of Miebaka and Daka (2013) for the Aziabie Creek.

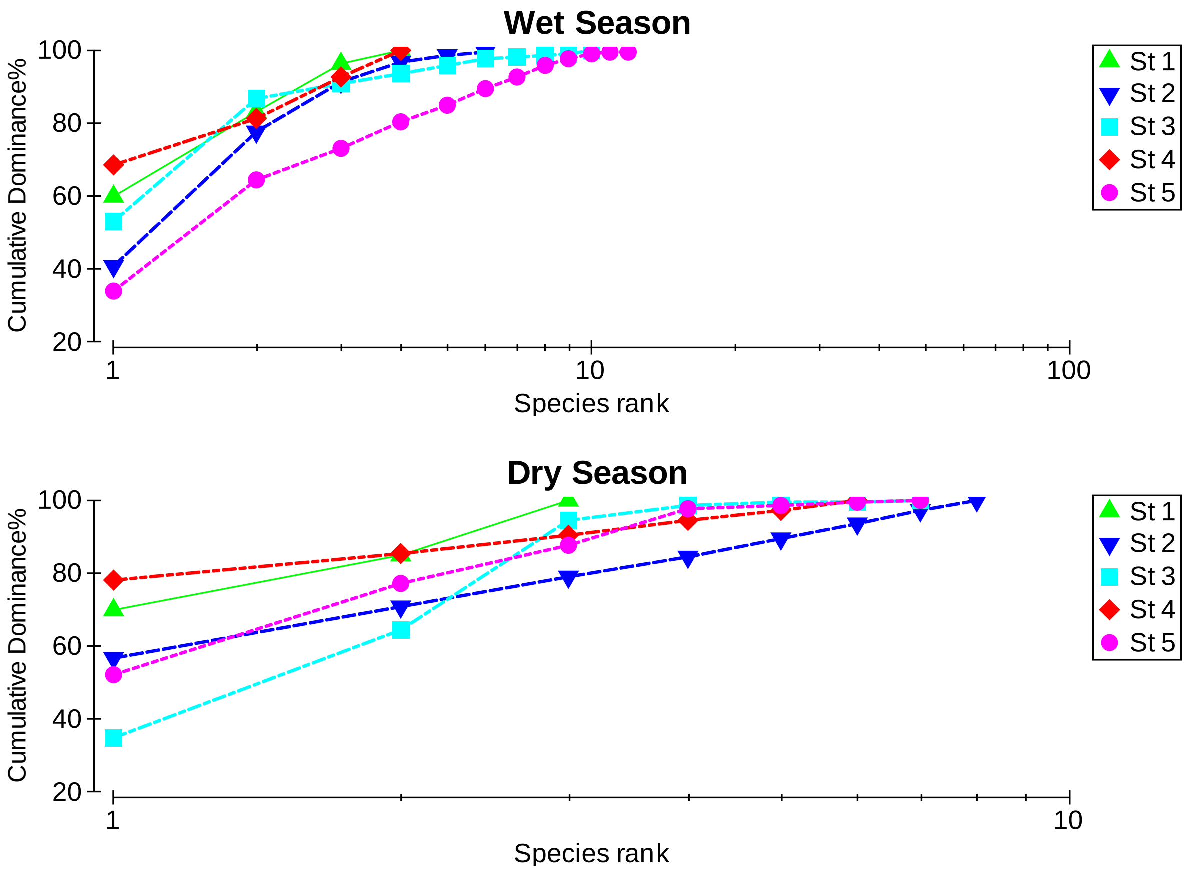

Fig. 5: K-dominance curves of zooplankton

Table 4: Product moment correlation coefficients between water quality variables and zooplankton community indices

Index	pH	Temp.	Cond	Sal	TDS	Turb.	Nitrate	THC
No of species S	-0.064	0.118	-0.490	-0.488	-0.490	0.332	0.497	-0.118
Density N	0.357	0.303	-0.415	-0.413	-0.415	0.074	0.379	0.129
Margalef d	-0.245	-0.129	0.073	0.076	0.073	0.058	0.088	-0.045
Pielou J’	-0.508	-0.801*	0.207	0.201	0.207	-0.280	-0.035	-0.702*
Shannon-Weiner H’	-0.261	-0.225	-0.432	-0.435	-0.432	0.215	0.453	-0.467
Simpson λ	0.246	0.293	0.288	0.295	0.288	0.041	-0.360	0.463

*$p<0.05$

Conclusion

Spatial and seasonal profiles of physicochemical parameters showed a natural gradient with no discernible effect of jetty operations. Indictors of pollution such as nitrate and THC were not significantly influenced by jetty operations as Control values were not significantly different from the Jetty sites. The spatial differences in abundance and community indices indicate that jetty operations *per se* were not a major determinant of the dynamics of zooplankton. Rather, the natural salinity gradient had more putative effects on the zooplankton community structure of the upper Bony Estuary.

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