Research article

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INFLUENCE OF ECOTOXICOLOGICAL STRESSORS ON SHRIMP COMMUNITY DYNAMICS IN A POLLUTED NIGER DELTA ESTUARY - IKO RIVER, EASTERN OBOLO, NIGERIA

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Abstract

Shrimps are highly nutritive seafood widely consumed in the Niger Delta. As benthic feeders, they interact with sediments that may contain environmental toxicants capable of altering their habitat's physicochemical balance. To evaluate the ecotoxicological effects of environmental pollution on shrimp community dynamics in the Iko River Estuary, Eastern Obolo, Nigeria. Standard procedures were used to assess physicochemical parameters of water and sediments, and to determine shrimp diversity, abundance, and population structure as indicators of ecological health. Water temperature (27.50–28.05°C) and pH (7.13–7.55) were within limits, while conductivity, salinity, total dissolved solids, total hydrocarbons (122.39–141.60 mg/L), and nutrients exceeded NESREA standards, suggesting hydrocarbon and nutrient enrichment. Sediment pH (6.31–6.74) was slightly acidic with high conductivity and hydrocarbon content (139.09–156.14 mg/kg), dominated by sand (62.39–76.28%). Seven shrimp species were recorded, ranked in abundance as *P. atlantica*>*P. setiferus*>*P. sculptilis*>*P. kerathurus*>*N. hastatus*>*M. rosenbergii*>*P. monodon*. Sex ratios deviated significantly (χ^2, $P < 0.05$), and females showed higher condition factors. Low diversity indices (Simpson 0.63–0.74; Shannon 0.14–1.51) correlated negatively with hydrocarbon levels, indicating pollution-driven shifts. Shrimp communities in the Iko River Estuary exhibit low diversity and altered structure due to toxic contamination, emphasizing the need for sustained ecotoxicological monitoring and pollution control.

Keywords: *Ecotoxicology; Hydrocarbon contamination; Sediment toxicity; Shrimp community structure; Iko River Estuary.*

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Introduction

Shrimps are not only abundant but also a highly adaptable species that have potential for use as indicators in the field. They eat living and dead plant matter, and potentially impacting the biomes of aquatic macrophytes (macroscopic plant life) and macro invertebrates (animals without a backbone that are large enough to be seen with the naked eye[1]. Shrimps lie at the bottom of the food chain, providing food to many predators such as other invertebrates, fish, amphibians, reptiles, birds and mammals[2]. In fact, they are highly nutritive seafood well sought for by the people of the Nigerian Niger Delta region. Shrimps feed at the bottom of the river, sifting through sediments and soil, which may be contaminated[2]. Lagoons, rivers, and streams have turned into trash drains, making water body pollution a serious issue in developing countries. The majority of the time, waste is dumped into receiving bodies of water with little to no consideration for their capacity for assimilation. These discharges have an impact on the receiving water body's physicochemical characteristics. For example, the discharge of raw effluents into the River Challawa in Kano led to elevated levels of both chemical and biochemical oxygen demand (COD and BOD)[3].The increasing human population commonly associated to areas of oil exploration activities and the consequent increase in the levels of anthropogenic pollutants have caused serious water quality deterioration problems world-wide[3]. Environmental contamination and pollution a threat to the environment; and is of serious concern[4]. These chemical pollutants can be accumulated in three basic reservoirs: water, sediment and biota[5]. A timely assessment of the dynamics in the Community Structure of Shrimps in the Iko River Estuary, Eastern Obolo L.G.A., Nigeria threatened by pollution becomes quite expedient, and this work was designed to accomplish this goal. This pollution may have a detrimental effect on the population structure of shrimp species in the ecosystem, which has become concerning because it has the potential to render these highly nutritious seafoods scarce and unavailable.

Methodology

Description of The Study Area: The Iko River Estuary is located in the Eastern Obolo Local Government Area of Akwa Ibom State, Nigeria's Niger Delta, between latitudes 7o 3/N and 7o 45/N and longitudes 7o 30/E and 7o 40/E (Fig. 1). The Iko River estuary has an average width of about 16 m[6] and is more than 20 km long. It has shallow depths of 1 to 7 meters during flood and ebb tide, and its tides are semi-diurnal.The Qua Iboe River catchments are the source of the Iko River, which empties into the Atlantic Ocean at the Bight of Bonny[6,7]. The estuary's neighboring creeks, channels, and tributaries are important because they provide a decent fishing ground for artisanal fishermen, a suitable breeding site for the variety of aquatic resources that are abundant in the area, and opportunities for petroleum exploration and production. Additionally, a portion of the river empties into the Imo River Estuary, which empties into the Atlantic Ocean at the Bight of Bonny[7].The region has a humid tropical climate with annual rainfall of around 3,000 mm[7]. There are different rainy and dry seasons in the region. The dry season starts in November and lasts until March, whereas the wet season starts in April and lasts until October.

July and August often see a brief period of draught, whe reas December through February typically sees a period of harmattan marked by chilly, dry winds and lower te mperatures[8]. The area's average annual daily evaporation is 4.6 mm[9]. Tides have an impact on the Iko River's hydrology, but seasonal factors linked to the climatic regime are also noticeable. The estuary serves as a significant land intake and is frequently used by locals as their primary means of transportation. Fishing is the most prevalent application of this multipurpose resource. Additionally, the estuary acts as a receiving body of water for industrial and household waste[10].

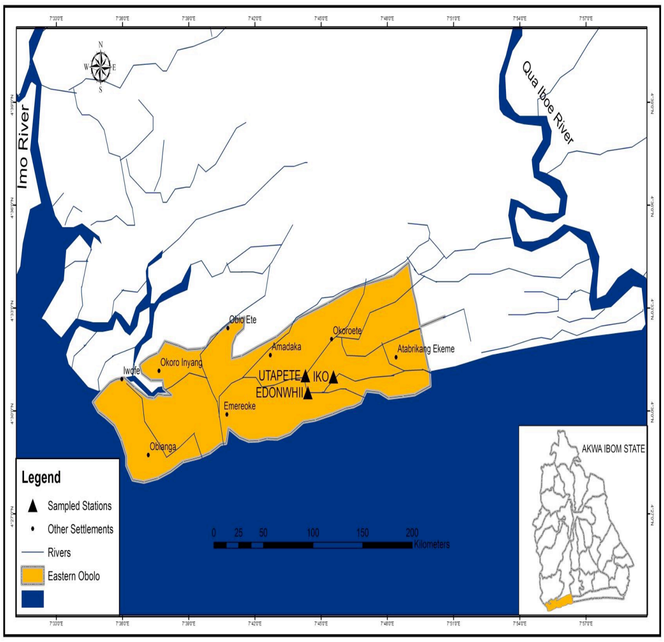

Figure 1: A map of South Akwa Ibom State that displays the stations that were sampled (Source: Ministry of Lands and Town Planning, Akwa Ibom State)

Sampling Procedure: For sample purposes, the research area was divided into three stations. Subjective classification was used for the sample stations labeled as Station 1 (ST 1) - Utapete, which is close to an abandoned well-head; Station 2 (ST 2) - Iko, where dredging operations were conducted; and Station 3 (ST 3) - Edonwhii, which opens onto the Atlantic Ocean. For a full year, sampling was done on a monthly basis to cover the main wet and dry season periods. At each site, additional samples were gathered concurrently for physicochemical examination.

Collection of Samples: Each station's surface water samples were gathered using a 1-liter water sampler, placed in a well cleaned 1-liter glass container, and kept for physicochemical examination. Samples were brought to the University of Uyo's Zoology Laboratory in an ice-chest container for additional parameter investigation. Each sample bottle was appropriately labeled with information about the various stations, the date, and the sampling time.

The top 1–5 cm of intertidal mudflats was scooped using a short core sampler (Kajak corer model 13.030) to obtain sediment samples. The subsamples were then blended for homogeneity and placed into polytene bags. Samples of shrimp were gathered simultaneously at each site. Samples of harvested prawns were gathered, cleaned with estuary water, preserved in a 5% formalin solution, and then brought to the lab for identification and examination.

Physiochemical Analysis: In accordance with Maiti (2004), the physico-chemical characteristics of sediment and water sites were evaluated both in situ and ex situ. Calibrated portable probes (EXTECH types) were used to monitor TDS, pH, temperature, DO, BOD, and EC. Nutrients (NO_3^-, NO_2^-, PO_3^{2-}, SO_4^{2-}) were assessed using conventional colorimetric/turbidimetric techniques, whereas total organic carbon was quantified with the Lange TOC cuvette-test (Hatch Lange LCK 385). Analytical reagents were acquired from Sigma-Aldrich and BDH. Samples that were air-dried and passed through 2 mm were used to evaluate the texture of the sediment. The hydrometer technique, as outlined by Gee and Bauder[11], was used to measure the particle-size distribution of fifty grams (50 g) of sediment.

Shrimp Species Identification and Analysis: Powell[12,13], and Holthius[14] keys were used in the lab to identify the collected shrimp to species levels. Using vernier calipers, the total length (TL) was measured to the closest 0.01 mm from the rostrum tip to the telson tip. A weighing balance (Ohaus top balance) was used to determine the total weight to the closest 0.01g. After that, measurements were made for every monthly collection and reported appropriately. Linear regression was used to assess the shrimp's length-weight relationship[15,16].

Data Analysis: SPSS software, version 21, was used to analyze all of the data. When applicable, percentage analysis, ANOVA, and Fisher's exact tests were employed.

Results

Physiochemical Attributes of the Estuarine Surface Water Samples

As presented in Table 1, water temperature ranged from 27.50 ± 2.22°C (Station 2) to 28.05 ± 2.58°C (Station 1) with an overall mean of 27.73°C, which was within the NESREA recommended range (20–32°C). The pH values (7.13 ± 0.67 – 7.55 ± 0.75) were within NESREA and WHO limits (6.5–8.5)[19], indicating slightly alkaline conditions typical of tropical estuarine waters.

Electrical conductivity (EC) varied significantly ($P < 0.05$) from 1450.05 ± 503.43 µS/cm at Station 3 to 1849.86 ± 712.37 µS/cm at Station 1. Total dissolved solids (TDS) ranged from 466.96 ± 228.51 mg/L to 613.83 ± 296.21 mg/L, with a mean of 535.14 mg/L, slightly exceeding the NESREA limit (500 mg/L). Salinity values (20.28 ± 3.46 – 24.55 ± 4.39‰) also differed significantly ($P < 0.05$), reflecting tidal influence.

Dissolved oxygen (DO) concentrations (6.94 ± 0.94 – 7.58 ± 1.32 mg/L) remained within the acceptable range (4–8 mg/L), whereas biochemical oxygen demand (BOD_5) values (3.06 ± 1.01 – 3.93 ± 1.25 mg/L) slightly exceeded the NESREA limit (<3 mg/L), indicating mild organic enrichment.

Total hydrocarbon content (THC) ranged from 122.39 ± 12.37 mg/L to 141.60 ± 29.10 mg/L and differed significantly ($P < 0.05$), far surpassing the NESREA permissible limit (10 mg/L), suggesting crude-oil contamination. Nitrate (29.04 ± 4.41 – 38.35 ± 4.36 mg/L) and phosphate (24.01 ± 3.28 – 31.06 ± 6.35 mg/L) levels were also significantly elevated ($P < 0.05$) beyond WHO standards (9.10 mg/L and 5 mg/L, respectively)[19], indicating nutrient enrichment. In contrast, sulphate (44.05 ± 10.05 – 46.94 ± 8.65 mg/L), chloride (142.15 ± 9.81 – 147.20 ± 15.94 mg/L), and ammonium (2.51 ± 0.44 – 2.55 ± 0.47 mg/L) remained within permissible limits.

Physical and Chemical Characteristics of the Sediments in Iko Estuary

Sediment characteristics showed moderate spatial variation among stations (Table 2). pH values (6.31 ± 0.11–6.74 ± 0.35) indicated slightly acidic to neutral conditions ($P < 0.05$). Electrical conductivity (1384.36 ± 606.39–1708.70 ± 697.76 µS/cm) and salinity (23.56 ± 6.12–27.64 ± 6.50%) were moderately high. Total hydrocarbon content (139.09 ± 31.14–156.14 ± 35.62mg/kg) and total organic carbon (11.93 ± 2.74–14.65 ± 4.53%) were elevated, reflecting hydrocarbon enrichment. Nitrate (19.90 ± 6.78–25.85 ± 5.75 mg/kg), phosphate (35.13 ± 8.44–41.21 ± 8.78 mg/kg), sulphate (36.96 ± 6.93–48.53 ± 4.62 mg/kg) and ammonium (3.49 ± 1.00–4.54 ± 0.90 mg/kg) varied significantly ($P < 0.05$–0.001), suggesting nutrient accumulation. Sediment texture was dominated by sand (62.39 ± 8.80–76.28 ± 9.23%), with lower proportions of silt (10.32 ± 4.89–17.46 ± 7.30%) and clay (10.27 ± 2.98–27.28 ± 5.53%), indicating a predominantly sandy substrate.

Table 1: Physiochemical Parameters of Iko River Estuary.

Parameters	Station 1	Station 2	Station 3	Overall Mean	Significant	NESREA (2011)	WHO (2011)
	$\overline{X}$ ± S.D	$\overline{X}$ ± S.D	$\overline{X}$ ± S.D				
Temperature (° C)	28.05±2.58	27.50±2.22	27.65±2.80	27.73			20-32
pH	7.13±0.67	7.50±0.57	7.55±0.75	7.40		6.5-8.5	6.5-8.5
EC (µs/cm)	1849.86±712.37	1639.40±639.79	1450.05±503.43	1646.46	P<0.05		250
TDS (mgl^{-1})	524.65±287.98	466.96±228.51	613.83±296.21	535.14		500	600
Salinity (‰)	22.10±2.84	20.28±3.46	24.55±4.39	22.3	P<0.05		
DO (mgl^{-1})	6.94±0.94	7.03±1.04	7.58±1.32	7.18		6	4-8
BOD_5 (mgl^{-1})	3.12±0.49	3.06±1.01	3.93±1.25	3.37			<3
THC (mgl^{-1})	141.60±29.10	122.39±12.37	124.32±12.86	129.43	P<0.05		10
SO_4^{2-}(mgl^{-1})	44.05±10.05	46.32±8.00	46.94±8.65	45.77		500	500
Cl^-(mgl^{-1})	147.20±15.94	144.32±10.37	142.15±9.81	144.55		250	250
NH_4^+(mgl^{-1})	2.55±0.47	2.51±0.47	2.51±0.44	2.52			
NO_3^- (mgl^{-1})	38.35±4.36	32.78±9.56	29.04±4.41	33.39	P<0.05	50	9.10
PO_4^{2-}(mgl^{-1})	31.06±6.35	24.01±3.28	26.25±4.00	27.01	P<0.05	5	5
Rainfall (mm)	191.20±116.83	191.20±116.83	191.20±116.83				

Table 2: Physical and Chemical Characteristics of the Sediments in Iko Estuary

	Station 1		Station 2		Station 3		
Parameters	Range		Range		Range		Significance
	Min – Max	X±SD	Min - Max	X±SD	Min – Max	X±SD	(2- tail)
pH	6.21-6.58	6.31±0.11	6.27-7.17	6.74±0.35	6.23-7.11	6.67±0.38	P<0.05
EC (µs/cm)	964.80-2947.50	1708.70±697.76	912.60-2092.60	1497.40±472.22	920.10-2118.30	1384.36±606.39	
Salinity (%)	20.10-34.20	26.72±5.35	15.30-32.70	23.56±6.12	17.60-35.20	27.64±6.50	
THC (mg/kg)	117.30-219.60	156.14±35.62	101.40-192.30	139.09±31.14	110.60-203.80	147.75±31.51	
TOC (%)	8.60-16.70	11.93±2.74	10.10-17.70	13.39±2.39	8.30-20.60	14.65±4.53	
T.N (%)	0.19-0.50	0.35±0.11	0.20-0.44	0.31±0.09	0.15-0.46	0.33±0.10	
PO_4^{2-} (mg/kg)	28.00-51.50	41.21±8.78	24.60-48.20	35.13±8.44	26.10-50.20	38.63±8.69	
NO_3- (mg/kg)	19.50-35.40	25.85±5.75	11.60-30.20	19.90±6.78	18.70-36.00	25.38±4.81	p<0.05
SO_4^{2-} (mg/kg)	41.30-54.10	48.53±4.62	27.30-47.50	36.96±6.93	35.10-51.80	44.25±5.98	p<0.001
NH_4^+ (mg/kg)	2.28-5.11	3.49±1.00	2.96-6.01	4.54±0.90	2.41-5.72	4.05±1.01	p<0.05
Cl^- (mg/kg)	123.80-193.20	160.16±26.71	101.80-166.50	138.25±24.73	113.00-191.00	148.65±27.53	
Sand (%)	50.28-73.54	62.39±8.80	58.03-81.05	70.53±8.85	62.91-87.01	76.28±9.23	P<0.01
Silt (%)	4.08-19.08	10.32±4.89	9.43-28.65	17.46±7.30	5.64-23.15	13.36±6.55	P<0.05
Clay (%)	18.29-37.24	27.28±5.53	6.95-19.19	11.99±3.53	6.04-13.94	10.27±2.98	P<0.01

Table 3: Specie composition and Population structure in sex of shrimps from Iko river estuary

Family	Species	N (Combined sex)	Female	Male	Sex ratio M:F	Chi-square	P	Significant
Penaenidae	*P.atlantica*	3658	2135	1523	1: 1.40	539.85**	0.001	S
Penaenidae	P. *kerathurus*	627	344	283	1: 1.22	135.57**	0.001	S
Penaenidae	P. *setiferus*	1218	1150	68	1: 16.9	244.91**	0.001	S
Penaenidae	P. *scuptilis*	798	532	266	1: 2.0	29.56**	0.001	S
Penaenidae	P. *monodon*	16	5	11	1: 0.45	0.33	0.564	NS
Palamonidae	*N. hastatus*	86	63	23 (M)	1: 2.74	0.14	0.709	NS
Penaenidae	*M. rosenbergii*	59	50	9 (M)	1: 5.55	5.98*	0.048	S

S=Significant; NS=Non significant; C=Combined Sex

Table 4: Mean Length, Weight and Condition Factor (K) for the Shrimp Species in Iko River Estuary

	Female				Male				Combined Sex			
Family/Species	**N**	**MTL (cm) X± SE**	**MTW (g) X± SE**	**K**	**N**	**MTL (cm) X± SE**	**MTW (g) X± SE**	**K**	**N**	**MTL (cm) X± SE**	**MTW (g) X± SE**	**K**
Penaenidae												**0.82**
P. atlantica	2135	87.22±0.36	5.47±0.06	0.82	1523	84.40±0.36	4.81±0.05	0.80	3659	86.02±0.26	5.20±0.04	
Penaenidae												
P.kerathurus	344	74.32± 0.67	3.23± 0.09	0.78	283	74.57± 0.65	3.18± 0.09	0.76	627	74.43± 0.47	3.21± 0.06	**0.77**
Penaenidae												
P.setiferus	1150	64.58± 0.29	1.62± 0.02	0.61	68	57.87± 1.32	1.33 ± 0.16	0.68	1218	64.20 ± 0.28	1.60 ± 0.02	**0.60**
Penaenidae												
P.scuptilis	532	90.22 ± 0.79	5.92± 0.14	0.81	266	78.96± 0.70	3.96 ± 0.11	0.80	798	86.46 ± 0.60	5.27 ± 0.11	**0.82**
Penaenidae												
P.monodon	5	195.22 ± 24.78	73.69 ± 23.23	0.99	11	190.67 ± 10.09	61.62 ± 6.49	0.88	16	192.09 ± 9.90	65.39 ± 8.15	**0.92**
Palaemonidae												
N. hastatus	63	49.76 ± 0.98	0.60 ± 0.03	0.48	23	45.15± 1.20	0.47± 0.03	0.51	86	48.53 ± 0.81	0.57± 0.02	**0.49**
Palaemonidae												
M. roseenbergii	50	65.10 ± 2.35	4.04 ± 0.77	0.15	9	60.25± 4.07	2.81± 0.66	0.13	59	64.36± 2.09	3.85 ± 0.66	**0.14**
Total	**4279 (62.2%)**				**2183 (37.80%)**				**5763**			

Temp	-	Temperature
pH	-	Hydrogen ion concentration
EC	-	Electrical Conductivity
DO	-	Dissolved Oxygen
BOD_5	-	Biochemical Oxygen Demand
SO_4^{2-}	-	Sulphate
Cl^-	-	Chloride
NH_4^+	-	Ammonium ion
NO_3^-	-	Nitrate
PO_4^{2}-	-	Phosphate
$\overline{x}$	-	Mean
SD	-	Standard deviation

Species Composition, Sex Ratio, and Condition of Shrimps.

Table 3 presents the species composition and population structure of shrimps from the Iko River estuary. Seven species belonging to four genera and three families were identified: *Parapenaeopsis atlantica*, *P. setiferus*, *P. sculptilis*, *P. kerathurus*, *Penaeus monodon*, *Nematopalaemon hastatus* and *Macrobrachium rosenbergii*(Figures 1 - 7 respectively). In percentage abundance by number, the order was *P. atlantica*>*P. setiferus*>*P. sculptilis*>*P. kerathurus*>*N. hastatus*>*M. rosenbergii*>*P. monodon*. *P. atlantica* dominated the catch, representing 56.61% by number and 66.68% by weight, whereas *P. monodon* and *N. hastatus* were the least abundant.The sex ratio varied among species: *P. atlantica* (1:1.40), *P. kerathurus* (1:1.22), *P. setiferus* (1:16.9), *P. sculptilis* (1:2.0), *P. monodon* (1:0.45), *N. hastatus* (1:2.74), and *M. rosenbergii* (1:5.55). Chi-square analysis revealed significant deviations from the hypothetical 1:1 ratio ($p < 0.05$) in *P. atlantica*, *P. kerathurus*, *P. setiferus*, *P. sculptilis*, and *M. rosenbergii*, but not in *P. monodon* and *N. hastatus*.

Table 4 revealed that female shrimps were generally larger and heavier than males. Mean total length (MTL) ranged from 48.53 ± 0.81 mm (*N. hastatus*) to 192.09 ± 9.90mm (*P. monodon*). Condition factor (K) was higher in females (0.15–0.99) than males (0.13–0.88), indicating better physiological condition in females.

Diversity indices (presented in Figure 8 and 9) varied Tempero-spatially: Simpson's index (0.63–0.74) and Shannon–Wiener index (1.14–1.54) indicated low species diversity, likely influenced by pollution stress. Overall, *P. atlantica* dominated the shrimp community, and sexual dimorphism was evident, with females attaining greater sizes and condition than males.

Fig. 1:*Parapenaeopsis atlantica*

Fig. 2:*Penaeus kerathurus*

Fig. 3: *Penaeus setiferus*

Fig.4: *Parapenaeopsis sculptilis*

Fig. 5:*Penaeus monodon*

Fig. 6:*Nematopalaemon hastatus*

Fig. 7: *Macrobrachium rosenbergii*

Fig. 1-5 : PENAEIDAE

Fig. 6&7: PALAEMONIDAE

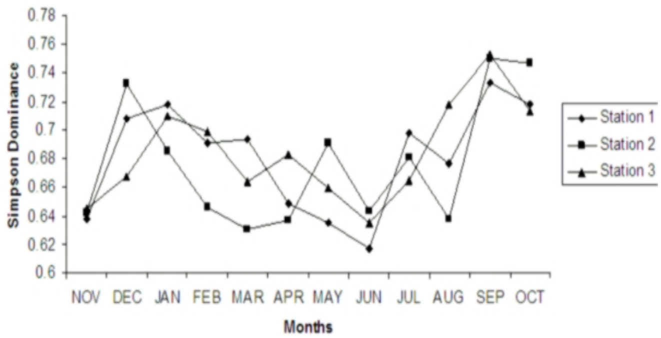

Fig. 8: Monthly Variations of Simpson Dominance Index in Iko River Estuary

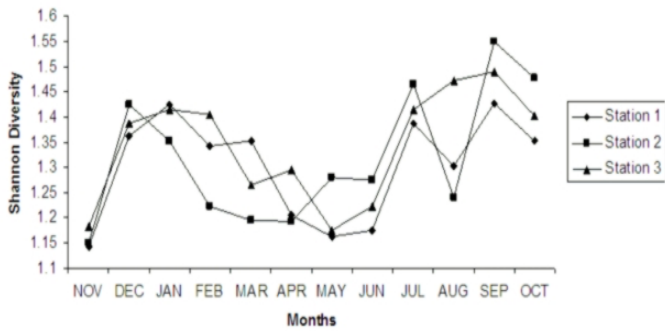

Fig. 9: Monthly Variations of Shannon-Weiner Diversity Index

Canonical Correspondence Analysis (CCA)

Canonical Correspondence Analysis (CCA) showed clear relationships between pollution-linked physicochemical parameters and shrimp distribution in the Iko River Estuary (Fig. 10). The first and second axes explained 64.51% and 25.41% of total variance, respectively. Sulphate was the most influential factor, followed by pH, phosphate, and ammonia. Ammonia positively influenced *Penaeus setiferus* along axis 1. On axis 2, sulphate, salinity, total hydrocarbon content (THC), and pH affected *Penaeus sculptilis*, indicating sensitivity to chemical and hydrocarbon pollution. Rainfall influenced *Macrobrachium rosenbergii* and *Nematopalaemon hastatus*, while phosphate affected *Penaeus monodon*, likely from agricultural runoff. Axis 2 parameters were negatively correlated with rainfall and phosphate, suggesting dilution effects.Axes 3 and 4 explained 6.63% and 2.03% of the variance. *Penaeus atlantica* and *Penaeus kerathurus* occurred near the origin, indicating tolerance to varying pollution levels. Eigenvalues for axes 1–4 were 0.039, 0.015, 0.004, and 0.01 (Table 5). Overall, sulphate, pH, phosphate, ammonia, and THC were the main pollution-related factors influencing shrimp abundance and distribution.

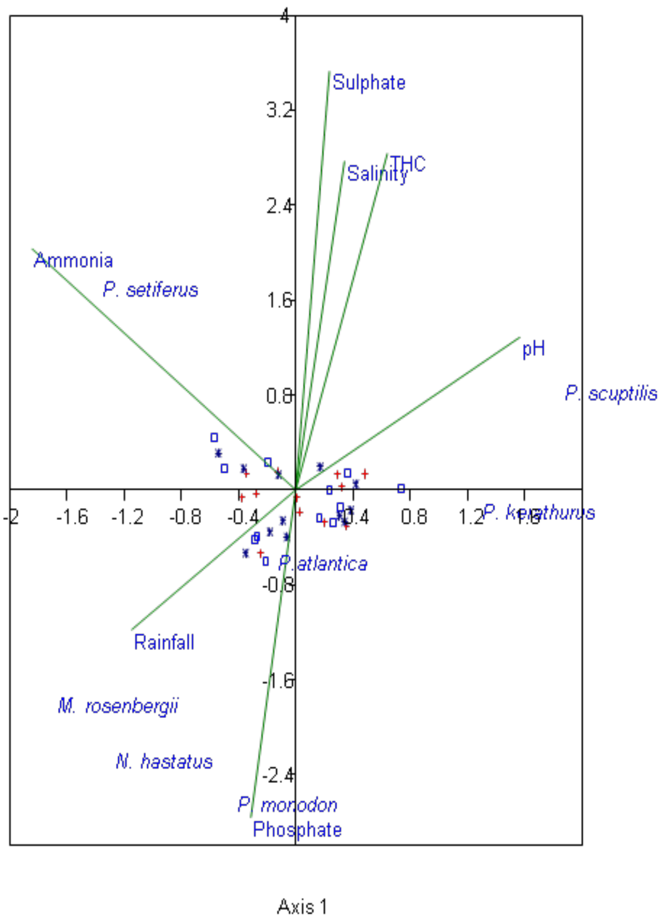

Figure 10: CCA Triplot Showing the Relation between Shrimps Composition and Environmental Parameters of Iko River Estuary.

Table 5: Eigenvalues of the CCA Axes and their Respective Cumulative Proportion of the Variance of the Species.

Axis	Eigenvalue	Percentage Variance
1	0.039687	64.51
2	0.015633	25.41
3	0.004083	6.637
4	0.0012501	2.032
5	0.00074884	1.0217
6	0.00012017	0.1953

Discussion

Habitat characteristics and reproductive strategies strongly influence the presence, abundance, and diversity of shrimp. Species in larger, connected water bodies benefit from higher habitat heterogeneity and access to brackish environments, promoting higher species richness[17,18].

Anthropogenic inputs such as industrial discharge, agricultural runoff and organic waste contamination may alter the physicochemical characteristics of a habitat, suggesting pollution, and this may significantly shape species composition in that habitat. Water quality analysis is essential for establishing baseline conditions, setting standards, and tracking temporal variations. Estuarine systems are highly dynamic, hence periodic evaluation is critical for conservation and resource management[3].For this present study, temperature ranged from 24.6–31.9°C, typical of tropical estuaries, with values remaining within the WHO limit (20–32°C)[19]. The observed variation among stations was minimal and not statistically significant, likely due to water mixing by wind and currents. Similar temperature ranges have been reported across the Niger Delta waters[20,21]. pH varied slightly between stations (6.18–8.40), remaining within WHO's acceptable range (6.5–8.5)[19]. Lower pH at Stations 1 and 2 may reflect domestic waste input, while higher pH likely resulted from increased biological and chemical processes, possibly influenced by oil residues. pH was positively correlated with temperature, salinity, and BOD_5, but inversely with DO and nutrients, indicating buffering effects influenced by biotic and abiotic factors. This aligns with the report of previous studies[22,23]. Electrical Conductivity (EC) ranged from 908–2780 µS/cm, reflecting saline intrusion. Values were between freshwater (<1000 µS/cm) and marine (>4000 µS/cm) limits[24].Total Dissolved Solids (TDS) ranged from 207–1079 mg/L, exceeding the NESREA limit of 500 mg/L[24]. Salinity ranged from 15.7–30.8‰, classifying the estuary as polyhaline[20]. Higher salinity recorded during the dry-season reflected low rainfall and increased evaporation. These values align with other Niger Delta estuaries [20,21]. Dissolved Oxygen (DO) levels (6.94–7.58 mg/L) were within WHO[19] limits (4–8 mg/L.Biochemical Oxygen Demand (BOD_5) ranged from 2.02–5.61 mg/L, slightly exceeding WHO's threshold (<3 mg/L). High values at Station 3 suggest organic contamination from faecal and domestic sources, though tidal flushing may enhance self-purification. This aligns with the position of Zieritz *et al*.[23]. Total Hydrocarbon Content (THC) varied slightly among stations, highest at Station 1 (189.2 mg/L) near the abandoned oil well. Increases likely reflected oil films, maritime traffic, and runoff, corroborating earlier Niger Delta findings[25].Sulphate (SO_4^{2-}) concentrations (30.3–59.7 mg/L) and Chloride (Cl^-) (127.5–175.6 mg/L) were below regulatory limits[24].Ammonium (NH_4^+) averaged 2.52 mg/L, reflecting anthropogenic inputs and organic degradation. Nitrate (NO_3^-) ranged from 21.5–43.8 mg/L, above NESREA limits[24] but below WHO's 50 mg/L[19], possibly from sewage or agricultural runoff. Phosphate (PO_4^{3-}) levels (20–37.9 mg/L) far exceeded permissible limits, likely from detergent and fertilizer wash-offs, promoting eutrophication. The nutrient level recorded in this present study differed from what were recorded for and Kafin Gana Dam, Jigawa State[26,27]. The geographical location of the two water bodies may be responsible for the observed disparity. Iko River estuary is in the mangrove swamp rain forest where heavy rain fall may generate so much storm water that empties into the river carrying with it nitrogen rich contaminants whereas, Gana Dam in Jigagawa located in the semi-arid region of northern Nigeria, primarily within the Sudan and Sahel savanna zones; and having low annual rainfall. Correlation analysis revealed strong interrelationships among parameters. Temperature correlated positively with pH, EC, and salinity but inversely with DO and rainfall. EC and TDS showed strong positive correlations with salinity and ionic constituents. DO inversely correlated with BOD_5, THC, and major ions, while rainfall positively affected DO and nutrient levels. Seasonal trends confirmed rainfall dilution and tidal mixing as key modulators of estuarine chemistry.

The community structure analysis of shrimps in this present study revealed that Iko river estuary has seven shrimp species identified as *Parapenaeopsis atlantica*, *P. setiferus*, *P. sculptilis*, *P. kerathurus*, *Penaeus monodon*, *Nematopalaemon hastatus* and *Macrobrachium rosenbergii*belonging to four genera and three families with *P. atlantica* dominating the catch;*P. monodon* and *N. hastatus*were the least in abundance.The sex ratio varied among species: *P. atlantica* (1:1.40), *P. kerathurus* (1:1.22), *P. setiferus* (1:16.9), *P. sculptilis* (1:2.0), *P. monodon* (1:0.45), *N. hastatus* (1:2.74), and *M. rosenbergii* (1:5.55). Chi-square analysis revealed significant deviations from the hypothetical 1:1 ratio ($p < 0.05$) in *P. atlantica*, *P. kerathurus*, *P. setiferus*, *P. sculptilis*, and *M. rosenbergii*, but not in *P. monodon* and *N. hastatus*. Female shrimps were generally larger and heavier than males. Mean total length (MTL) ranged from 48.53 ± 0.81 mm (*N. hastatus*) to 192.09 ± 9.90mm (*P. monodon*). Condition factor (K) was higher in females (0.15–0.99) than males (0.13–0.88), indicating better physiological condition in females. These results are similar to what were reported in previous studies[21-23]. Simpson dominance varied between 0.63 and 0.74. This result differed from the findings of earlier studies that reported Simpson dominance index range from 0.48 – 0.092 for Meghna river estuary[28]; 0.75 – 0.96 in shrimp farm[29] and 0.003 – 0.06 for River Benue[30]. The low dominance index observed in this study could be due to changes in environmental conditions as a result of anthropogenic activities. The Shannon-Weiner diversity index for shrimp in this study ranged monthly between 0.14 and 1.54. Station 2 had the greatest value in September, while Station 1 had the lowest in November. This showed that there was less species variety at Station 1 because it was more severely contaminated than Stations 2 and 3. The results of this study, however, are at contrast with those of Jaikumar et al. (2010), who reported Shannon-Weiner ranges of 2.07–2.92 for coastal waters in Tuticorin, 2.83–3.69 for the Meghna River Estuary in Bangladesh, and 0.26–0.92 for coastal waters in Ondo State.[32]; 0.60 to 0.94 for the Ediba River in Cross River State, Nigeria[25], and 1.81 to 2.91 for the River Benue[30]. An important approach for assessing the stock and yield potential of aquatic fauna, such as shrimp populations, is the evaluation of the length-weight relationship. There was a strong and substantial association between the overall length and weight of shrimp in the Iko River estuary, according to the results of the length/weight relationship (LWR) analysis (r = 0.550541 - 0.996758). This indicates that the shrimp's weight and length rise proportionately. The species' coefficient of determination (r2 > 0.5) demonstrated the model's fitness in this investigation.

The shrimp's slenderness or stoutness may be explained by the dimensional discrepancy seen in the Iko River. As the shrimp grew longer, it became thinner, indicating negative allometric growth, and it became plumper, showing positive allometric growth. For both sexes of N. hastatus, the growth coefficient showed negative allometric growth, indicating that the rate of increase in body weight is not proportionate to the rate of rise in body length. This also suggested that as the species ages, it becomes thinner. Additionally, N. hastatus (b = 2.92) from the Nigerian Cross River estuary showed negative allometric growth[32].

For N. tenuipes off the Indian coast of Maharashtra, b = 2.83 Male and b = 2.925 Female[33]; for the same species from the same region, b = 2.8 Female and b = 2.7 Male34; and for N. hastatus from Ayetoro, Ondo State[31]. Peneaid shrimp in the Iko River estuary showed positive allometric growth, which is comparable to a prior study that found b = 2.978 (M) and 2.958 (F) for P. stylifera from Calicut[35].For P. indicus from Tanzania's Bagamoyo Coastal waters, Teikwa and Mgaya[36] also observed positive allometric growth, b = 3.0 (M) and b = 3.0 (F).

P. notialis from Bugama Creek, Niger Delta, Nigeria, showed positive allometric growth, according to Yakubu and Ansa[37], whereas P. atlantica from Ondo State's coastal waters showed positive allometric growth (b = 3.3). Marsitah as well as Chong[38]. b = 2.5 from Selangor Water; moreover, b = 2.3 for females and b = 2.4 for males of P. kerathurus were found in the Amvrakikos Gulf, India[35]; while b = 2.0 for P. kerathurus from the East Ionian Sea (Western Greece) was reported by Alexis et al.[39]. Similarly, P. monodon from Buguma Creek in the Niger Delta, Nigeria, showed a negative allometric growth (b = 2.97)[37]. In Pichavaran Mangroves (Thailand), Gopalakrishna et al.[40] found negative allometric growth for males (b = 2.4) and females (b = 2.6). P. monodon was found to have b = 2.5 in the coastal waters of Ondo State, South West, Nigeria[31].The variations may result from the shrimp's growing conditions and geographic location. Medina-Reylia41 and Prasad42 claim that the little variance in the values of b and r makes sense since a species' length-weight relationship may change depending on its location and time of year. The sexes of shrimp in the Iko River estuary differed noticeably in terms of physical traits. These alterations have been seen in a number of crustaceans[38, 43]. Many species of economically significant penaeid shrimp exhibit the pattern of sexual dimorphism, in which females are bigger than males. According to earlier research, females weighed more and had longer carapaces than males with the same overall length, and this difference was more noticeable in bigger size groups [44, 46]. Larger female sizes may result from higher weight, which increases with each molt cycle and speeds up growth.

Conclusion

This study demonstrates clear ecotoxicological stress within the Iko River Estuary, where elevated hydrocarbons, phosphates, and BOD_5 indicate chronic organic and petroleum pollution. These contaminants have altered the physicochemical balance of the habitat, influencing shrimp diversity, abundance, and growth performance. Dominance of *Parapenaeopsis atlantica* and reduced diversity at polluted stations reflect selective survival of tolerant species. Deviations in sex ratios, condition factors, and growth coefficients suggest sublethal toxic effects on metabolism and reproduction. The coexistence of positive and negative allometric growth patterns indicates species-specific adaptive responses to environmental stress. Overall, shrimp community changes and contaminant levels signal ecological disturbance and potential bioaccumulation risks. Continuous ecotoxicological monitoring integrating physicochemical and biological indicators is recommended to mitigate further degradation and preserve estuarine ecosystem integrity.

Authors Contribution

This work was designed by the first and second authors (Ekpo, N. D. and Udoinyang E. P. respectively). All authors were involved in Data Curation, Formal Analysis, Funding Acquisition, Investigation, Methodology, Project Administration, Resources, Supervision, Validation, Visualization, Original Draft, as well as Review & Editing.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the conduct or publication of this study, no sponsorship funds from any organization, and all co-authors are academic supervisors who contributed within their supervisory roles with no connections that could be perceived to influence the study.

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