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OIL SPILL IMPACT ON THE FINFISH OF AZHIWARI SWAMP, JOINKRAMA IN THE NIGER DELTA OF SOUTHERN NIGERIA

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Abstract
The impact of an oil spill on surface water, sediment and finfish assemblage characteristics in a freshwater swamp forest was assessed by dividing the wetland into four zones on the basis of spilled oil cover on the water surface – High Impact Zone (HIZ >60%), Medium Impact Zone (MIZ 30 – 60%), Low Impact Zone - (LIZ 5 – 30%) and No Impact Zone (NIZ <5%) which served as control. Samples of water, sediment and fish were collected over a period of 6 months and analyzed using standard methods. Species richness determined by Fischer's α; similarity in assemblage by P_{pos}, and percentage incidence of lesions, finrot and empty stomachs evaluated by physical examination of specimens were carried out. Dissolved oxygen followed the trend - HIZ < MIZ < LIZ < NIZ while BOD_5 exhibited a reverse trend (NIZ < LIZ < MIZ < HIZ). Other physicochemical parameters did not show any trend. Species loss declined from HIZ (100%) >MIZ (70%)> LIZ (10%) > NIZ (0.0%) while richness increased from HIZ (0) < MIZ (1.3) < LIZ (3.6) < NIZ (5.1). Species similarity was NIZ vs LIZ (0.86); NIZ vs MIZ (0.43); LIZ vs MIZ (0.46). Stress indicated by empty stomachs and finrot were (MIZ (65.7-72.3) > LIZ (26.0 37.5) > NIZ (17.5-21.1) and MIZ (20-25) > LIZ (0-5) > NIZ (0 – 0) percent respectively. The results indicate that the impact of oil spills on finfish goes beyond the immediate fish mortality observed during oil spills and includes stress on surviving finfish resulting from changes in water and sediment quality. Loss in finfish species richness, reduction in diversity, and abundance are other impacts of oil spills in freshwater swamps.

Key Words: Oil spill, fish diversity, richness, stress, Niger Delta.

Introduction
The lowland rainforest region of the Niger Delta is largely a vast wetland consisting of discrete enclosed water bodies often covered by floating and emergent vegetation in the dry season, but connecting to flowing larger open water bodies in the flood season (NDES, 2000). This linking of wetlands to open river/creek channels of the Niger Delta such as the Orashi River enables spawning migrations of finfish in and out of them (Chindah and Osuamkpe, 1994). Wetlands are important ecological and economic components of the environment (Davis, 1993; Alieu, 2002) with very high productivity due to the varied resources derivable from it (Davis, 1993; NEPAD, 2002). These ecologically valuable wetlands are fragmented and degraded by oil pipelines that rupture to cause oil spills (NDES, 2000; Ibiebele *et al.*, 1987). This paper investigated an oil spill that occurred within the southern buffer zone of the Upper Orashi Forest Reserve, highlighting the impact of spilled crude on finfish assemblage and some water quality characteristics in the affected area.

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Materials and methods

The study area

The study area is a lowland freshwater swamp forest bordered by the Taylor Creek to the west, Orashi River to the east and to the north the proposed Upper Orashi forest reserve (Fig. 1). It lies within latitude 5°08.00′′ – 5°10.01′N and longitude 6°28.09′′ – 6°29.45′E. The vast wetland that makes up much of this forest has numerous drain channels that help drain the flood waters of the Niger River from the land. One such drain channel about 25m wide and 1.3m deep runs in a roughly north-south direction to feed a creek that drains into the Orashi River.

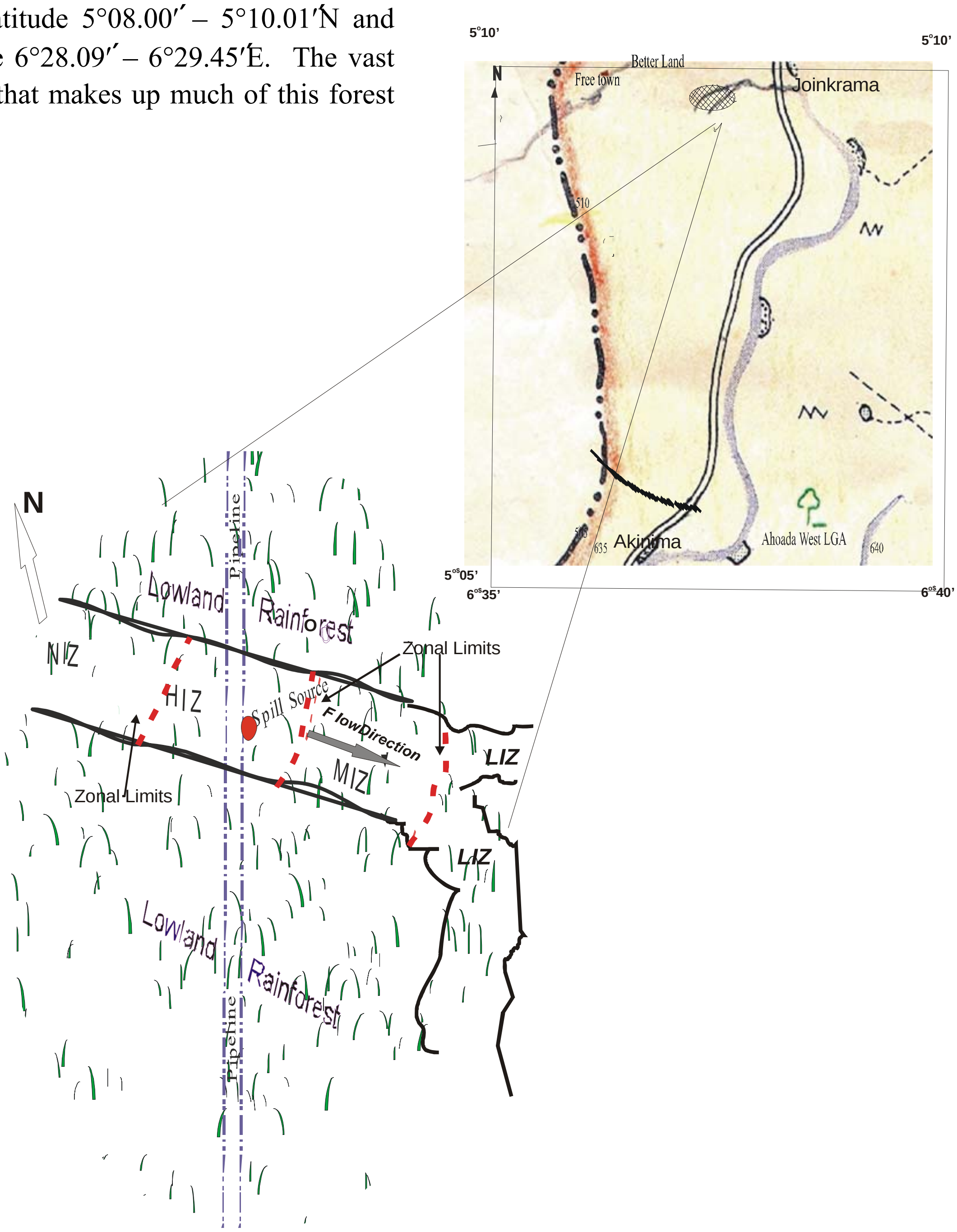

Fig. 1: Sketch of the Oil Spill site at Azhiwari swamp, Niger Delta

Another arm of the channel is linked to an inland lake about 2.5 hectares in size where fishing is forbidden by local taboos. The diversity of ecological niches present in the forest makes it an important finfish species reservoir (NEPAD, 2002).

During the dry season, the water of the floodplain becomes restricted to natural and man-made ponds. Dry season exploitation of fish resources from the study area consists of manually bailing out the pond's water with buckets and fish picked from the bottom sediment. In the wet season, due to the area becoming flooded, short gillnets (less than 25m long) with mesh size ranging from 20mm to 40mm with sinkers attached to hold the net close to the bottom, and floating rods with hooks attached to it with a short line are the main fishing gears. These rod and lines are usually left on the water and inspected every few hours. A fisherman may set as many as 100 such rod and lines during a fishing trip.

Flora tolerant of wetlands such as raffia palms occur within the channel while medicinal plants and a number of economic timber trees dominate the vegetation at the edges and drier sections of the forest. Various mammals, reptiles, amphibians and gastropods occupy the various habitats that are present in the study area (NDES, 2000).

A major oil pipeline (Okordia – Rumuekpe) bisecting this drain channel ruptured in May 2007 at latitude 5°08.11′N and longitude 6°28.13′E spilling oil into the rising flood waters that spread it all the way into the Orashi River.

The limits of three (3) distinct zones in the oil spill impacted freshwater swamp were geo-located with a GPS (*Garmin etrex* model). These zones were differentiated on the basis of degree of pollution by petroleum crude and labeled as *Heavily Impacted Zone* (HIZ) – oil covering over 60% of water surface and totally coating emergent vegetation (*Paspalum* sp., *Eichornia crassipes*, *Nymphea* sp.); *Moderately Impacted Zone*; (MIZ) – oil covering between 30% and 60% of water surface, emergent vegetation are not as totally coated with oil; and *Lightly Impacted Zone* (LIZ) – oil cover on water surface is less than 30%. A fourth zone upstream of the NIZ exhibited patches of oil sheen on <5% of its water surface; this was used as control or *No Impact Zone* (NIZ) (Fig. 1). The length of HIZ was approximately 2km (latitude 5°08.06′N–5°08.36′N and longitude 6°28.11′E – 6°28.32′E); NIZ stretched from latitude 5°08.36′N and longitude 6°28.32′E north-eastwards while MIZ stretched for about 1km south-westwards from latitude 5°08.06′N and longitude 6°28.11′E; LIZ was sampled at a distance more than 5km from the beginning of MIZ inside a creek that empties into the Orashi River around latitude 5°09.26′N and longitude 6°29.37′E.

In each zone, surface water was collected approximately 150mm below the surface into 500ml clean pre-labeled glass containers while sediment was collected with an Ekmann grab into sheets of pre-labeled aluminum foil and taken to the laboratory for analysis using standard analytical methods as described by APHA (2005). Sampling of sediment followed the order:

$$\text{NIZ} \rightarrow \text{LIZ} \rightarrow \text{MIZ} \rightarrow \text{HIZ}$$

This order was followed to avoid transferring oil from one zone to the other by using grab contaminated by oiled sediment in more polluted zones in 'cleaner' zones of the study. Physico-chemical results obtained were subjected to *Student's t*-test to determine level of significance of observed differences in means.

Fish specimens were also collected over a period of 6 months using gill nets of 10mm, 25mm, and 40mm mesh size with floats and sinkers attached. The gill nets were set about 1400hr the previous day and inspected twice a day at 0730hrs and 1800hrs over two consecutive days before removal at each sampling trip. Additional specimens were obtained with rod and line fitted with fish hook (No.12). Fifty such rod and line hooks were deployed in each zone and inspected at 3-hour intervals starting from 0700hrs to 1800hrs. Finfish sampling was carried out on two consecutive days in a week. Thus, gillnet specimens were obtained over 96 net inspections while for the hook, 240 inspections were carried out. Fishing gears were left in position overnight during sampling periods.

The finfish catch from each zone were identified to genus level using appropriate finfish identification keys such as Idodo-Umeh (2003) and the species listed in a table. From the occurrence of the species in the landings, a frequency of occurrence table was drawn for the species present and the assemblage characteristics described using Fischer's α index of species richness (Kempton and Taylor, 1974). This index also has the advantage over traditional indices of taking into account species dominance and is unaffected by sample size (Kaemingk *et al.*, 2007). Further comparison of zonal finfish assemblage was carried out using the P_{pos} statistic (Graham and Bull, 1998). P_{pos} values range from 0 (no similarity) to 1 for completely identical assemblage.

Morphological deformities and disease symptoms indicative of stress (number of empty stomachs and lesions/finrot) on specimens were evaluated by dissection of specimens and physical examination of specimens respectively and observations recorded in a data sheet.

Results

Surface water

Physicochemical characteristics of surface water and sediment are shown in Table Ia and Table Ib respectively. Table I(a) shows an inverse relationship between oil and grease levels and DO in the water column; oil and grease increased from NIZ to HIZ while DO decreased from NIZ to HIZ. Sediment oil and grease values showed similar pattern of being highest at HIZ and lowest at NIZ (Table 1b). The difference between the mean value of these parameters in HIZ and MIZ and LIZ/NIZ was significant ($p>0.05$). Also, BOD increased with increase in oil and grease levels (Figs. 2 and 3) and therefore had inverse relationship to DO. Oil and grease levels were always higher in the sediment than in the water column. Even though these nutrients did not show any trend across the zones, Phosphate (PO_3), ammonium (NH_4) and nitrite (NO_2) values in sediment samples at all zones were higher than their value in surface water for the same zone (Fig. 4). Also, no particular trend was observed for the other physico-chemical parameters in both sediment and water column.

Table 1a. Range of physico-chemical characteristics of surface water of Azhiwari swamp, Joinkrama

Zones	pH	Temp. °C	Cond µS/cm	DO (mg/L)	NO_2 ppm	NO_3 ppm	NH_4 ppm	PO_4 ppm	BOD_5 mg/L	Oil & Grease mg/L
HIZ	6.4-6.8	26.8-30.4	15-20	0.5-0.8	0.05-0.24	0.27-0.36	0.05-1.3	0.1-0.4	1.4-4.3	0.3-0.5
MIZ	6.2-6.7	27.2-27.0	15-19	0.9-1.9	0.03-0.12	0.05-0.18	0.1-0.5	0.1-0.5	0.7-2.6	0.06-0.2
LIZ	5.7-6.8	27.3-28.2	14-19	1.5-2.8	0.02-0.10	0.06-0.12	0.1-0.5	0.2-1.2	0.2-1.5	0.01-0.08
NIZ	5.8-6.8	26.8-28.5	14-17	2.4-4.8	0.02-0.11	0.06-0.15	0.07-0.3	0.1-0.3	0.1-0.9	<0.01

Table 1b. Range of sediment physico-chemical characteristics of Azhiwari swamp, Joinkrama

Zones	pH	Temp. °C	Cond µS/cm	NO_2 ppm	NO_3 ppm	NH_4 ppm	PO_4 ppm	Oil & Grease mg/L
HIZ	5.7-6.8	26.1-27.5	16-18	0.46-0.96	0.27-0.57	0.6-2.0	0.9-3.6	0.6-3.9
MIZ	5.6-6.8	26.4-28.0	15-20	0.71-3.6	0.24-0.42	0.3-1.6	0.4-4.8	0.4-1.5
LIZ	5.5-6.6	26.6-28.2	17-21	0.62-0.94	0.26-0.51	0.4-1.1	0.4-2.6	0.3-0.6
NIZ	5.6-6.9	26.0-28.3	16-19	0.57-0.85	0.30-0.48	0.2-1.3	0.4-2.6	0.2-0.4

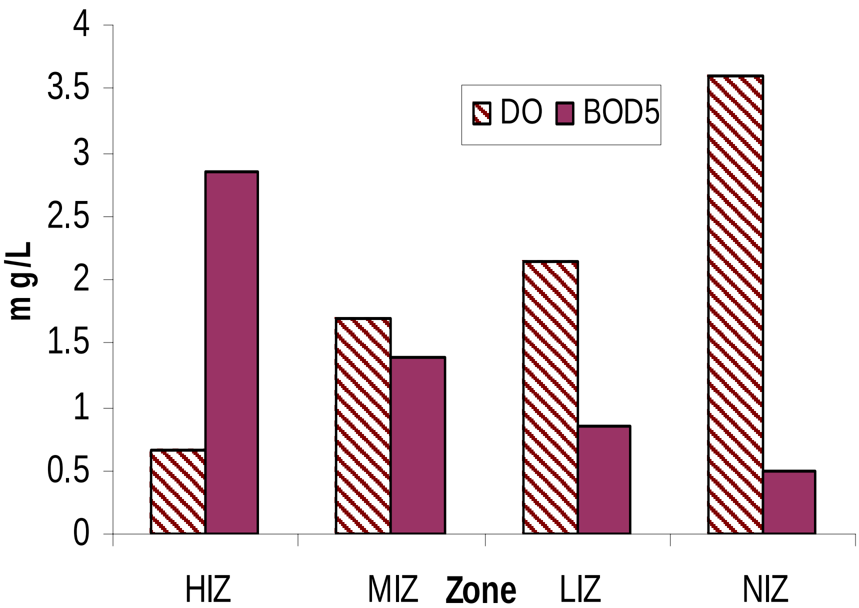

Fig. 2. Mean Dissolved Oxygen and BOD_5 levels in Azhiwari swamp water

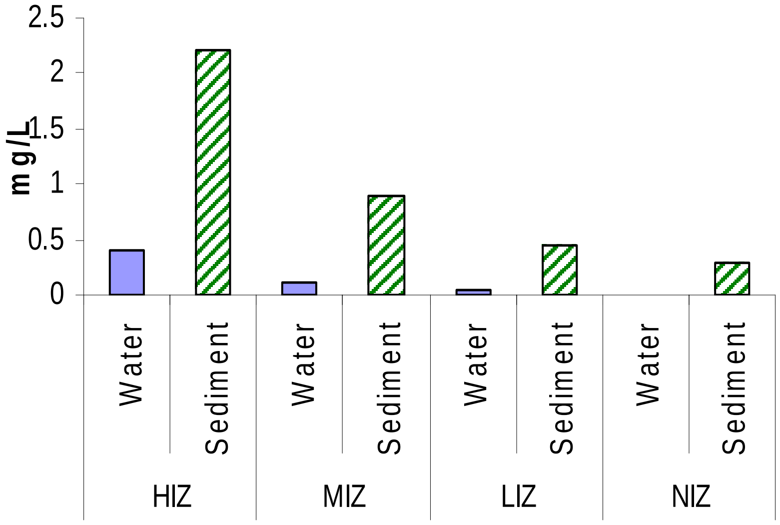

Fig. 3. Mean Oil and Grease levels in Sediment and Water of Azhiwari swamp

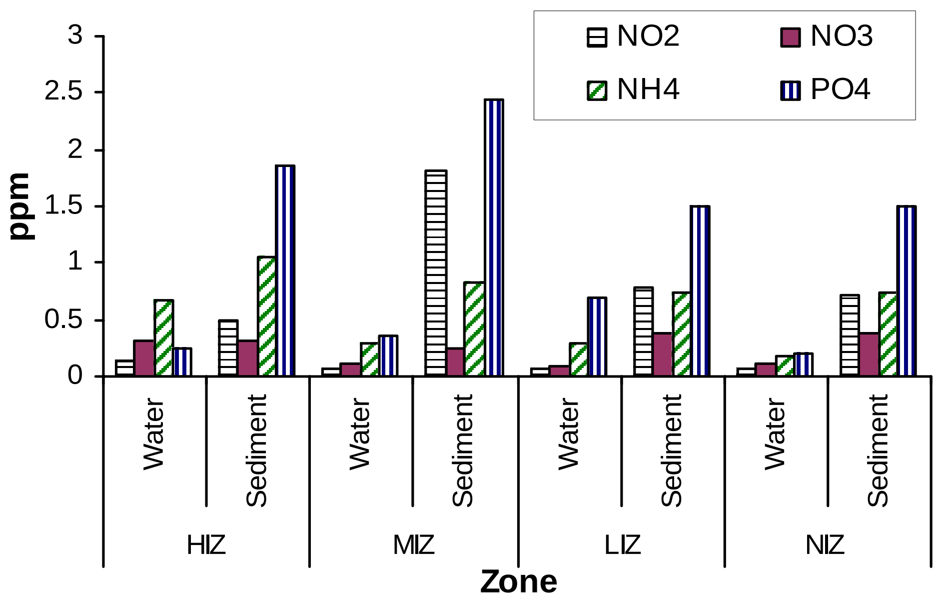

Fig. 4. Mean Nutrient levels in Sediment and Water of Azhiwari swamp

Species richness

Fischer's index of species richness (α) estimated for the zones were - HIZ (0), MIZ (1.3), LIZ (3.6) and NIZ (5.1). The trend exhibited by the index corroborates the frequency of occurrence of species in samples obtained from the zones (Table II). No specimens were obtained from HIZ accounting for the 0.0 value estimated in the Fischer's index and the percentage frequency of occurrence table. However, the number of representative species and their abundance increased in this order NIZ > LIZ > MIZ > HIZ >. MIZ was represented by 3 species, LIZ by 10 species and NIZ by 11 species; difference in species occurrence was least between LIZ and NIZ.

Table 2. Percentage frequency of occurrence of common finfish species in fish catch from the various zones impacted by oil spill.

Family	Genus	HIZ	MIZ	LIZ	NIZ
Anabantidae	*Ctenopoma* sp.	0	0	20	40
Pantodontidae	*Pantodon bucholzhi*	0	0	0	10
Cyprinodontidae	*Aplochielichthys* sp.	0	0	10	35
	Epiplatys sp.	0	0	15	25
Clariidae	*Clarias* sp.	0	35	70	85
Channidae	*Parachanna* sp.	0	10	37	45
Notopteridae	*Xenomystus nigri*	0	0	24	38
Phractolaemidae	*Phractolaemus* sp.		1	3	7
Hepsetidae	*Hepsetus odoe*	0	0	1	15
Malapterinidae	*Malapterus* sp.	0	0	5	9
Nandidae	*Polycentropsis* sp.	0	0	1	3

Note: Frequency of occurrence is rounded up to the nearest whole number.

Similarity in finfish assemblage between the zones

Similarity in finfish assemblage amongst the zones is presented as a matrix in Table III. The table indicates that the highest level of species similarity occurred between LIZ and NIZ (0.86) while MIZ had slight similarity with LIZ and NIZ (0.46 and 0.43) respectively. The absence of specimens in HIZ makes the zone totally dissimilar to all the others even though it is contiguous to them.

Stress symptoms

A higher percentage of empty stomachs occurred in MIZ (65.7 to 72.3%) followed by LIZ (26.0 to 37.5%) and least in NIZ (17.5 to 21.1%) (Table IV).

Lesions and fin rot were more common in specimens obtained from MIZ than in those obtained from LIZ and NIZ (Table V). Finrot occurrence amongst the specimens was over a narrow range - MIZ (20 – 25%), LIZ (0-5%), and NIZ (0%) – with *Clarias* sp. being most affected followed by *Phractolaemus* sp., in MIZ. The two species so affected are bottom dwellers, often remaining at the same spot on the bottom sediment.

Table 3. Similarity of finfish assemblage between the oil spill impacted zones of Azhiwari Swamp in Joinkrama

	HIZ	MIZ	LIZ	NIZ
MIZ	0	1.0		
LIZ	0	0.46	1.0	
NIZ	0	0.43	0.86	1.0

Table 4. Mean percentage empty stomachs of fish common to the oil spill impacted zones of Azhiwari Swamp in Joinkrama

Finfish Genus	HIZ	MIZ	LIZ	NIZ
Clarias sp.	NS	65.7 ± 11.1	33.5 ± 5.0	17.5 ± 3.5
Parachanna sp.	NS	72.3 ± 8.8	26.0 ± 4.7	21.1 ± 2.8
Xenomystus sp.	NS	NS	37.5 ± 5.2	19.5 ± 1.4

NS = No Specimens

Table 5. Percentage specimens with lesions and finrot (in parenthesis) in the oil spill impacted zones of Azhiwari Swamp in Joinkrama

Genus	HIZ	MIZ	LIZ	NIZ
Aplochielichthys sp.	NS	NS	0 (1)	0 (0)
Epiplatys sp.	NS	NS	0 (1)	0 (0)
Clarias sp.	NS	25 (25)	2 (0.0)	0 (0)
Parachanna sp.	NS	5 (20)	0 (0)	0 (0)
Xenomystus nigri	NS	NS	0 (2)	0 (0)
Phractolaemus sp.	NS	0 (22)	0 (5)	0 (0)

Note: NS = No Sample

Discussion

The range of surface water quality values presented in the report is indicative of forest swamp freshwater of the Niger Delta (RPI, 1985; NDES, 2000) except for the slightly elevated but not significant ($p<0.05$) surface water temperature in HIZ. This elevated temperature may be attributed to warming of surface water by heat trapped by floating oil (US EPA, 2009). Further, oxygen for aerobic degradation in sediment and water is harvested from the water column thus causing high BOD values to be recorded (US EPA, 2009) in HIZ and MIZ where considerable oil was present on the surface of the water and recharge of water column oxygen from the atmosphere limited by floating oil that sealed the surface (Powell, 2006; ITOPF, 2009; Akpofure *et al.*, 2000). It is this limiting of dissolved oxygen in the water that created the distinct inverse relationship between oxygen and BOD values recorded. The values recorded were within limits recorded in previous oil spill impacted aquatic environments (Akpofure *et al.*, 2000; IPS, 1986).

Crude oil contains different fractions and it is normal that the heavier fractions (waxes and tars) should settle on the bottom sediment increasing the levels of the parameter there while part of the lighter fractions (aromatics) that are more volatile evaporate leaving behind that which is observed floating on the surface (ITOPF, 2009; USEPA, 1998; IPS, 1994).

The observed differences in finfish species richness index value and frequency of occurrence amongst the zones may be explained by total mortality in HIZ, while in MIZ and LIZ lower mortality caused a reduction in species number and abundance.

Migration out of the zones due to the presence of the oil spill may also contribute to the species richness and frequency of occurrence trend observed (Squire, 1992; Powell, 2006).

Further, similarity indices indicate that though all four zones were within the same rain forest swamp, finfish assemblage characteristic in the zones had changed due to the mortality, and emigration of more mobile species evading the polluted sites especially in HIZ (ITOPF, 2009; Buges, 2007; Squire, 1992; Powell, 1987). Percentage of empty stomachs amongst the samples in the zones suggest that one pathway of stress to fish during an oil spill is starvation (AMSA, 2002). Macro-invertebrates such as insects and shrimps, juvenile/larval fish and amphibians form the diet of these fish. These groups of organisms are more vulnerable to hydrocarbon spills and high mortality is sure to occur since one characteristic of wetlands is to slow down the flow of flood waters (NEPAD, 2002), creating retention of the oil over the water surface for a longer time. The difficulty of finding food items and the additional stress on the fish by the irritating presence of the oil may be the reason for the higher incidence of empty stomachs recorded in the MIZ and LIZ (Powell, 2006).

Parachanna sp., stay close to the bottom of aquatic systems but rarely remain stationary on the bottom sediment; they are more of water column inhabiters (Idodo-Umeh, 2003). Therefore, habitat preference that brings specimens in contact with contaminated bottom sediment may be the reason for the high incidence of finrot in *Clarias* sp. and *Phractolaemus* sp. *Clarias* sp., also exhibited the highest incidence rate of lesions on their body. These symptoms of stress may be an expression of weakened immunity or susceptibility due to starvation (AMSA, 2002); higher incidence rates of both empty stomachs and lesions/finrot were observed in MIZ. The dramatic decrease of the incidence of these morphological symptoms (lesions and finrot) in LIZ and their total absence in NIZ implicates the oil spill as causative agent.

Conclusion

The study reveals that the impact of oil spills on freshwater swamps goes beyond the immediate fish kills usually observed during such incidences and include loss in finfish species richness and diversity, reduction in finfish abundance, starvation and consequent increase in susceptibility to diseases such as lesions and finrot. The occurrence of recruitment failure is implied by total absence of specimens from heavily impacted areas and poor catch from moderately impacted areas because stock is drastically reduced.

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