



## RESEARCH ARTICLE

## Histopathological and Biochemical Response of *Chrysichthys Nigrodigitatus* to Environmental Stressors from Two Polluted Lagoons, Southwest Nigeria

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### Abstract

Stressful environmental conditions are ecological force in modulating adaptive responses of fish populations in aquatic ecosystems with a large number of biochemical and physiological effects associated with increased fluxes of oxyradicals. This study was aimed to examine the impacts of oxidative stress and histological changes in organs of *Chrysichthys nigrodigitatus* from Ologe and Badagry lagoons. Biomarkers such as biochemical markers [malondialdehyde (MDA) and superoxide dismutase (SOD) and catalase (CAT) and glutathione (GSH)] and histological marker were analysed in *C. nigrodigitatus* using standard protocols. The biochemical response of *C. nigrodigitatus* indicated that there was significant increase ( $p < 0.05$ ) in the activities of MDA and SOD, as well as CAT and GSH in the gill, liver and muscle of the fish samples of both lagoons. The CAT activities in the muscle negatively correlated with MDA in gill ( $p < 0.05$ ,  $r = -0.848$ ) in Ologe lagoon. The histological changes in the gill exhibited mild epithelial lifting, fusion of secondary lamellae; inter-lamella hyperplasia, desquamation and necrosis of secondary lamellae. Furthermore, the hepatic tissue showed disseminated moderate microvesicular vacuolation of hepatocytes, moderate vascular congestion and mild presence of eosinophilic fluid within the interstitial. The renal tissue also showed mild hemorrhagic lesion, mild moderate ballooning degeneration of renal tubules and thickened blood vessel. The study provides baseline information that can be useful for effective biomonitoring and future comparative studies of oxidative stress and histomorphological changes in aquatic biota from polluted coastal ecosystems.

### Keywords

Biomonitoring, Biochemical responses, Histopathology, Fish, Polluted lagoons

### Introduction

Biomarker for biomonitoring environmental quality in aquatic ecosystem had raised a great deal and promising tool of interest caused by its economical method, early warning signal, adequate in the assessment of overall toxicities of complex mixtures and measurement precision [1]. Industrial effluents and other admixtures of toxic substances are discharged in our coastal environment which can cause changes in the physical, chemical and biological characteristics of the aquatic ecosystem thereby creating an ecological imbalance. The released xenobiotic substances bioavailable in the aquatic system tends to bind to specific cellular structures called receptors that are localized on the cell surface or inside the cell either in its cytoplasm or on cell organelles. The binding of a xenobiotic with its receptor may induce cellular processes that have toxic or other adverse effects on the cell. Biochemical markers are measurable responses of the exposed aquatic organism to xenobiotic compounds present in the water [2].

The systematic use of aquatic organisms to evaluate changes in water quality is defined as biomonitoring. Fish are often used to monitor urban and industrial effluents as well as to assess contaminant levels of coastal environments. Aquatic organisms such as fish and molluscs serve as bioindicators of pollution, due to a great deal of response and sensitivity to changes in the aquatic environment, which plays an increasingly important role in biomonitoring of environmental pollu-

tion. Biomarker was considered as the reliable method to evaluate the biological response towards environmental risk so that preventive measures can be taken [3,4].

Biomarkers have been classified by the extent that they reflect exposure to environmental stressors, or adverse health effects from contaminant exposures [5]. A biomarker has the advantage to elucidate the stress level through bioassay on the organism at various stages from biomolecular, histologically to physiological alteration induced by environmental stressors. The underlying principle in biomarker approach is the analysis of an organism with reference to the response to persistent pollutant exposure in terms of sub-organismic (cellular, biochemical, molecular, or physiological) changes, [6]. Histopathological changes have been widely used as biomarkers in the evaluation of the health of fish exposed to contaminants [7]. Gill, kidney and liver are responsible for vital functions, such as respiration, excretion and the accumulation and biotransformation of xenobiotics in the fish. One of the great advantages of using histopathological biomarkers in environmental monitoring is that this category of biomarkers allows examining these specific target organs [8].

Aquatic organisms has complement of antioxidant enzymes which comprise antioxidant defenses, including enzymatic components such as superoxide dismutase (SOD), catalase and glutathione peroxidases) as well as small molecule antioxidants (e.g. glutathione). Since antioxidant defenses can be quantitatively altered on exposure to contaminants, this has led to their exploitation as biomarkers in the field [5,9].

In Nigeria, Doherty, et al. [10] investigated biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in some selected fishes in Lagos; Otitolaju and Olagoke [11] studied lipid peroxidation and antioxidant defense enzymes in *C. gariepinus* as useful biomarkers for monitoring exposure to polycyclic aromatic hydrocarbons, while Ejimadu, et al., [12] assessed cellular biomarker responses of *C. nigrodigitatus* in contaminated coastal ecosystems in Lagos.

Ologe and Badagry Lagoons are among the nine continuous Lagoon systems found along the coast of Nigeria. These aquatic ecosystems like other coastal waters are faced with threats from inputs of compounds which have the potential to alter biochemical processes in fishes and shell fishes. According to Akoachere, et al. [13] and Onuorah and Wim, [14], these Lagoons are under intense pressure from increasing human and industrial activities around them; ultimately serving as sink for domestic and industrial waste. However, little information is available relative to the biochemical and histopathological changes in fish species in Ologe and Badagry lagoons. Consequently, studies on fish biomarker are of great significance as they can help to evaluate organ alterations, enzymatic responses, and histological changes when exposed to polluted aquatic environment.

## Materials and Methods

The Ologe and Badagry Lagoons are part of the Lagos Lagoon complex within the southwestern region of Nigeria (Figure 1). Ologe Lagoon is a freshwater body which opens into the Atlantic Ocean via the Badagry creeks and the Lagos harbour. The Badagry Lagoon

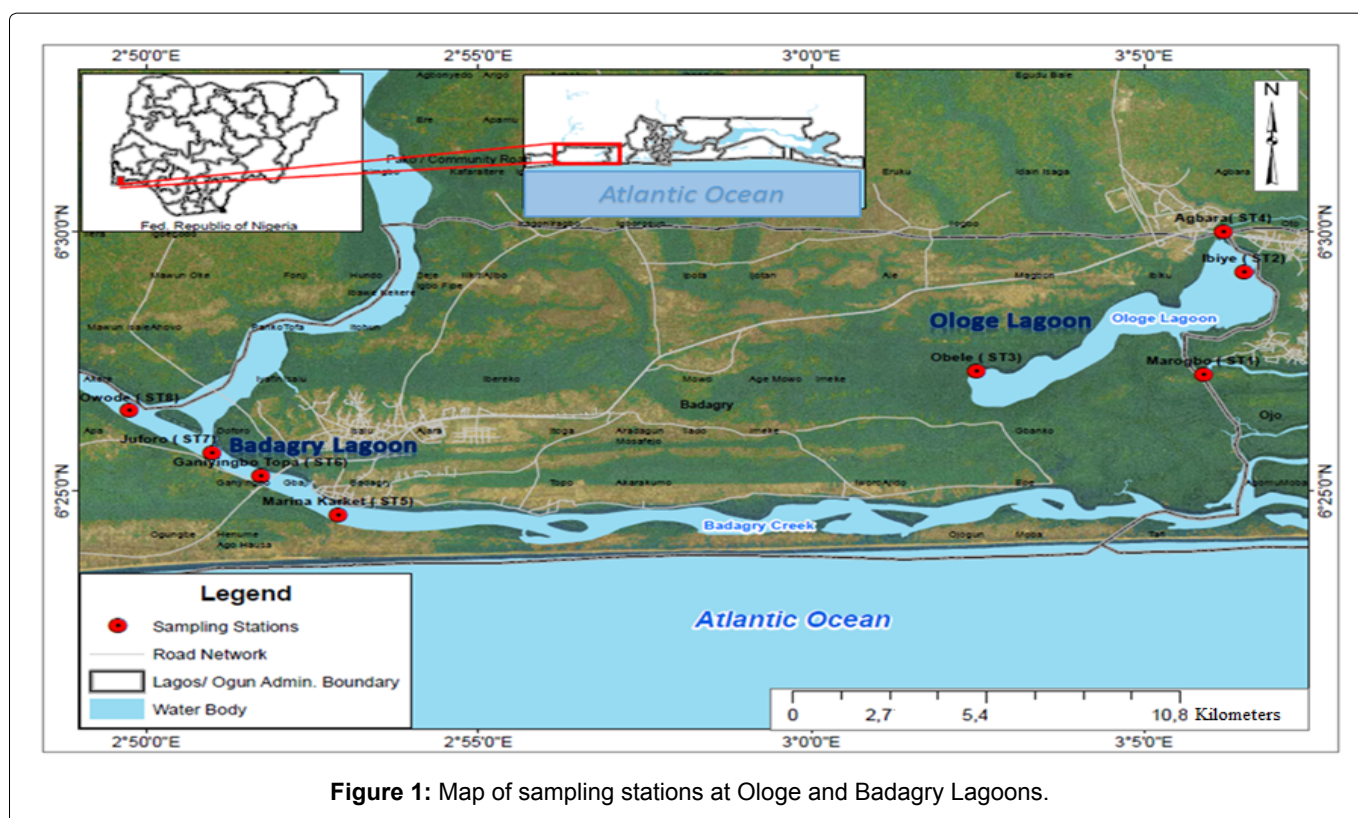


Figure 1: Map of sampling stations at Ologe and Badagry Lagoons.

which is approximately 60 km long and 3 km wide, lies between longitudes 3°0' and 3°45' E and between latitudes 6°25' and 6°30' N. It is part of a continuous system of lagoons and creeks along the coast of Nigeria from the border with the Republic of Benin to the Niger delta. Its water depth ranges from 1 m to 3 m. These lagoons meet several socio-economic needs (aquaculture, fishing, sand dredging and drainage) of the various towns and villages bordering it [15].

### Sample collection

Fish samples (*Chrysichthys nigrodigitatus*) were caught with trap basket by local fisher folks set at the bottom of the lagoons, due to the habitat of the fish species been bottom dwellers (demersal). A total of 192 fish sample were collected in triplicates from Ologe and Badagry lagoons in four ecological seasons (4 dry and 4 wet seasons). Sampling was done on the basis of proximity to anthropogenic activities as hotspots across eight (8) sampling stations.

Tissues were removed from the *Chrysichthys nigrodigitatus* after decapitation. The gill, liver, and muscle tissues were excised, weighed, and washed in ice-cold buffer. The minced tissues were rinsed clear of blood with cold isolation buffer and homogenized on ice in a glass Potter-Elvehjem homogenizing vessel with a motor-driven pestle. The isolation buffer contained 100 mM Tris-HCl; pH of 7.20 was adjusted with HCl.

### Biochemical analysis in gill, liver and muscles of *C. nigrodigitatus*

**Determination of catalase activity:** The Catalase activity was determined by measuring the decrease in absorbance at 240 nm due to the decomposition of H<sub>2</sub>O<sub>2</sub> in a UV recording spectrophotometer [16]. The reaction mixture (3 ml) contained 0.1 ml of tissue homogenate in phosphate buffer (50 mM, pH 7.0) and 2.9 ml of 30 mM H<sub>2</sub>O<sub>2</sub> in phosphate buffer pH 7.0. An extinction coefficient for H<sub>2</sub>O<sub>2</sub> at 240 nm of 40.0 M<sup>-1</sup> cm<sup>-1</sup> was used for the calculation [16]. The specific activity of catalase was expressed as moles of H<sub>2</sub>O<sub>2</sub> reduced per minute per mg protein.

**Determination of superoxide dismutase activity:** Superoxide dismutase (SOD, E.C. 1.15.1.1) activity in supernatant was determined according to Kostiuik, et al. [17]. The reaction mixture (3 ml) contained 2.95 ml 0.05 M sodium carbonate buffer pH 10.2, 0.02 ml of tissue homogenate and 0.03 ml of epinephrine, 0.005 N HCL was used to initiate the reaction. The reference cuvette contained 2.95 ml buffer, 0.03 ml of substrate (epinephrine) and 0.02 ml of water. Enzyme activity was calculated by measuring the change in absorbance at 480 nm for 5 minutes.

**Determination of reduced glutathione activity:** The reduced glutathione content of the tissue as non-enzymatic was estimated according to the method described

by Jollow, et al. [18]. To the tissue homogenate, 10% TCA was added, centrifuged. 1.0 ml of supernatant was treated with 0.5 ml of Ellman's reagent (19.8 mg of 5, 5-dithiobisnitro benzoic acid (DTNB) in 100 ml of 0.1% sodium nitrate) and 3.0 ml of phosphate buffer (0.2 M, pH 8.0). The absorbance was read at 412 nm.

**Determination of Malondialdehyde (MDA) Activity:** Malondialdehyde (MDA) an index of lipid peroxidation was determined using the method of Buege and Aust [19]. 1.0 ml of the supernatant was added to 2 ml of (1:1:1 ratio) TCA-TBA HCL reagent (thiobarbituric acid 0.37%, 0.24N HCL and 15% TCA) tricarboxylic acid-thiobarbituric acid-hydrochloric acid re-agent boiled at 100 °C for 15 minutes, and allowed to cool. Flocculent materials were removed by centrifuging at 3000 rpm for 10 minutes. The supernatant was removed and the absorbance read at 532 nm against a blank. MDA was calculated using the molar extinction coefficient for MDATBA- complex of 1.56 × 10<sup>5</sup> M/Cm.

**Histopathological analysis in the organs of *C. nigrodigitatus*:** Ten fish species from each lagoons were collected, anesthetized, while the organs (gill, liver and kidney) were removed. Tissues were placed in pre-labeled, individual glass vials in which Bouin's fixative was added. After 24 h immersion fixation, tissues were transferred to coded glass vials containing 70% ethanol. Tissues dehydrated in concentrations of alcohol, and embedded in paraffin wax for microtome sectioning (5 µm) [20]. Sections were mounted onto slides and after hydration in ethanol series, and then stained with standard hematoxylin and eosin (H&S) stain. Ten sections of each tissue from each fish were examined by light microscope [21].

### Statistical analysis

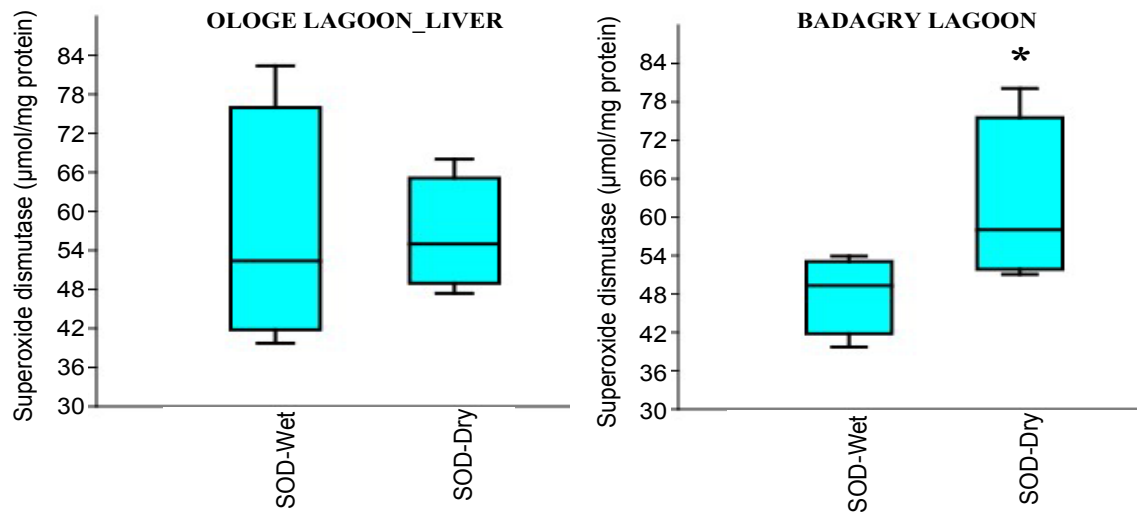
All data are presented as means ± standard error media (S.E.M). Analysis of variance (ANOVA) was set at 0.05 level of significance, Duncan multiple-range test (DMRT) was used to detect the source of the differences and Pearson correlation coefficient for biochemical parameters analysed using PAST 3.16 and SPSS 20.0 software [22].

## Results

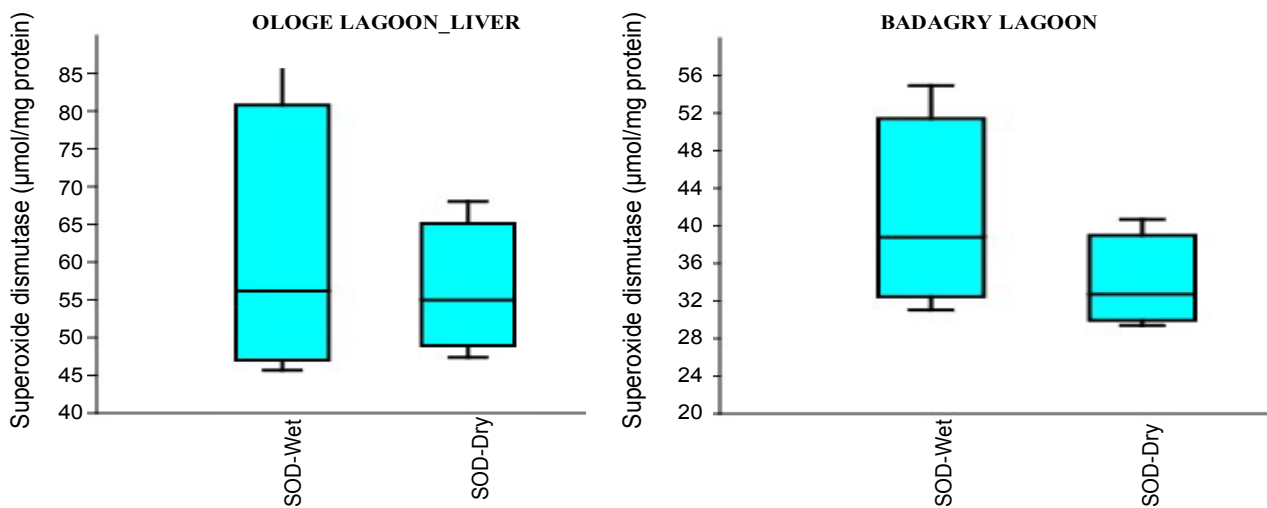
The biochemical response (Superoxide dismutase- SOD, Catalase- CAT, Glutathione- GSH and Malondialdehyde- MDA) and histopathological changes in the organs of *C. nigrodigitatus* from Ologe and Badagry lagoons.

### Superoxide dismutase (SOD)

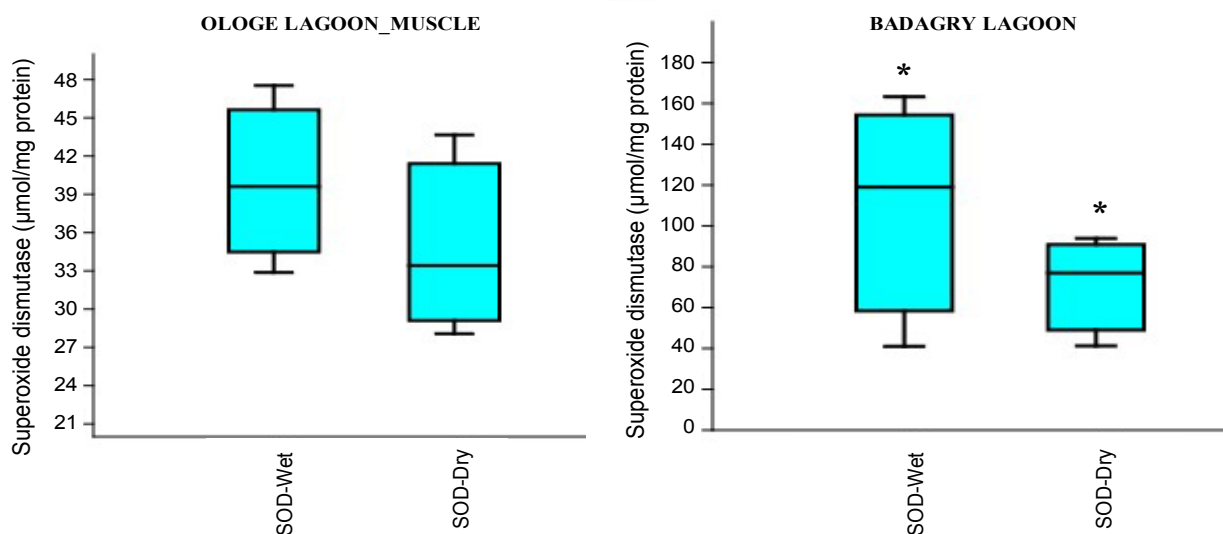
The mean highest activities of SOD significantly increased in the liver with 61.33 µmol/mg during the wet season and lowest in the muscle with 34.64 µmol/mg during the dry season at Ologe Lagoon. At Badagry lagoon, the mean highest activities of SOD also increased significantly in the muscle with 110.56 µmol/mg during the wet season and lowest in the liver with 33.88 µmol/



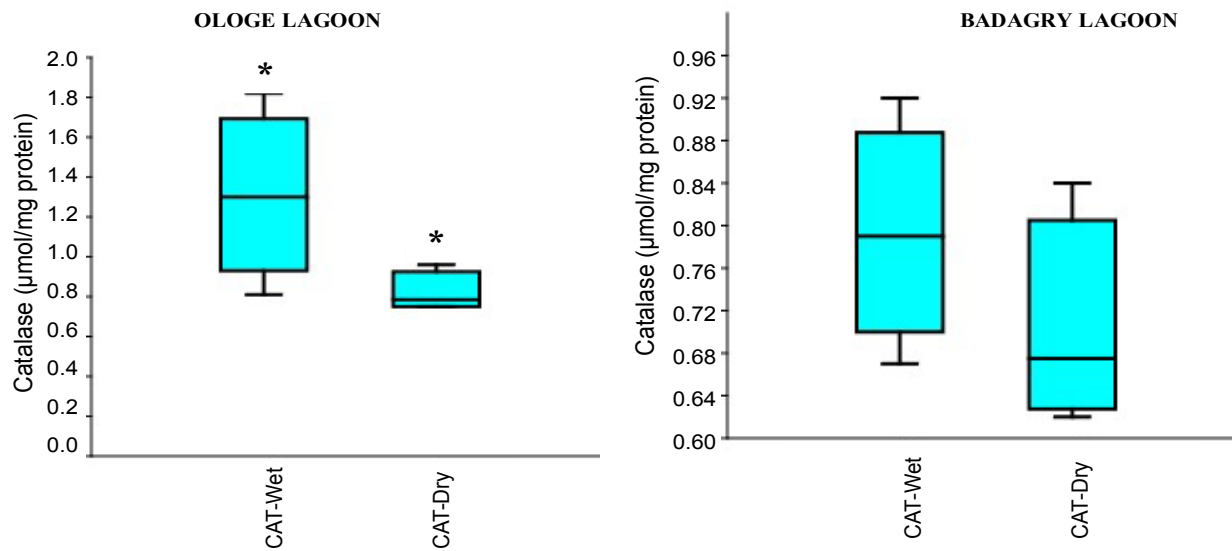
**Figure 2a:** Seasonal variations of Superoxide dismutase (SOD) in the gill of *C. nigrodigitatus* at Ologe and Badagry Lagoons.



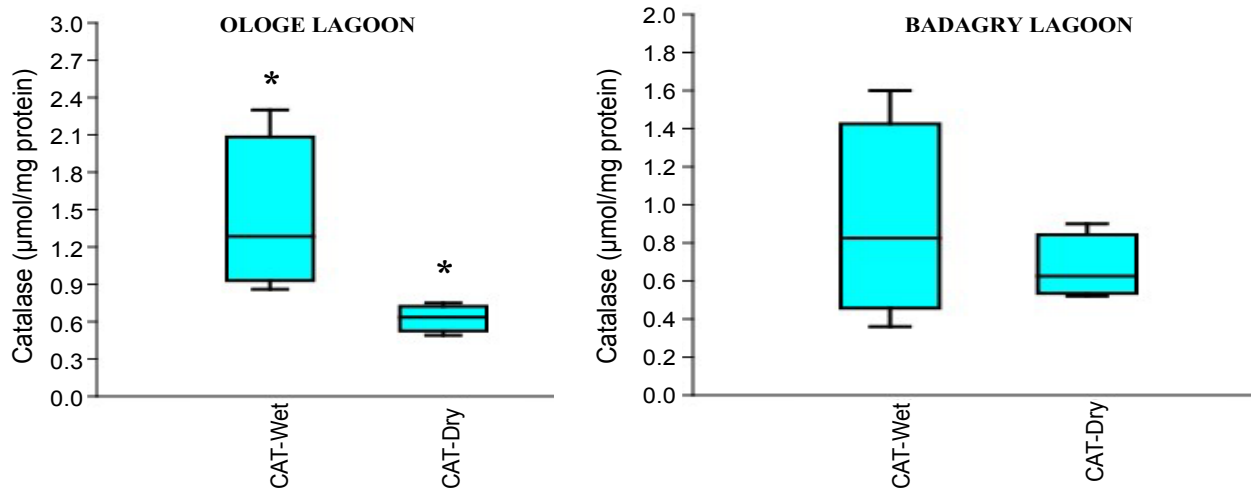
**Figure 2b:** Seasonal variations of Superoxide dismutase (SOD) in the liver of *C. nigrodigitatus* at Ologe and Badagry Lagoons.



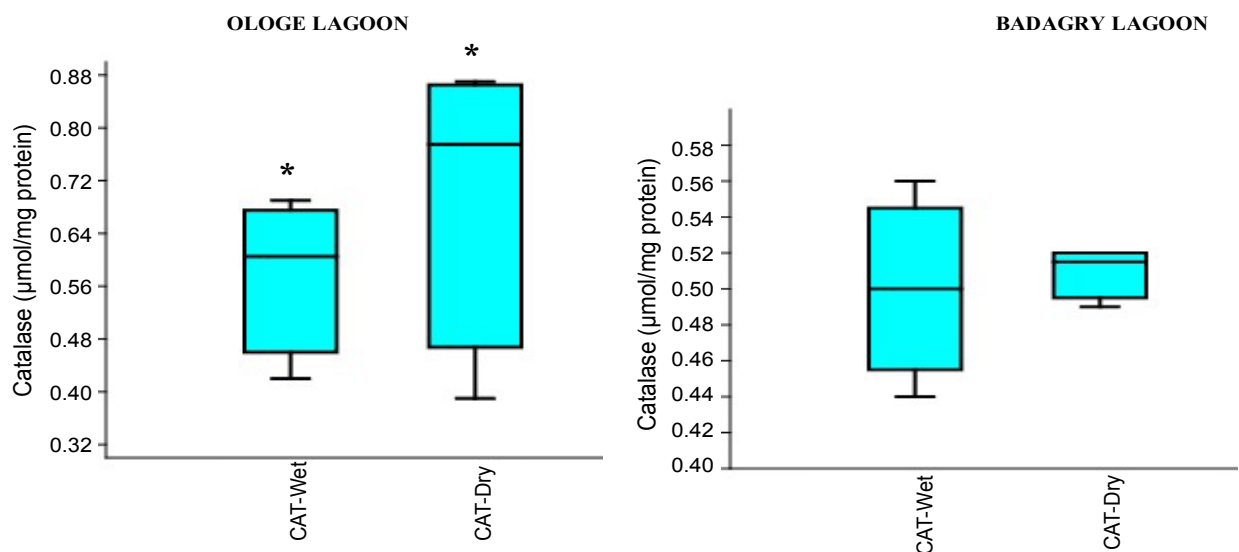
**Figure 2c:** Seasonal variations of Superoxide dismutase (SOD) in the muscle of *C. nigrodigitatus* at Ologe and Badagry Lagoons.



**Figure 3a:** Seasonal variations of Catalase (CAT) in the gill of *C. nigrodigitatus* at Ologe and Badagry Lagoons.



**Figure 3b:** Seasonal variations of Catalase (CAT) in the liver of *C. nigrodigitatus* at Ologe and Badagry Lagoons.



**Figure 3c:** Seasonal variations of Catalase (CAT) in the muscle of *C. nigrodigitatus* at Ologe and Badagry Lagoons.

mg in the dry season (Figure 2a, Figure 2b and Figure 2c).

Analysis of variance (ANOVA) showed that there was a significant difference ( $p < 0.05$ ) in SOD activities of the gill during the dry season as well as in the muscle of *C. nigrodigitatus* in both wet and dry seasons at Badagry lagoon. The seasonal variations of SOD activities in the gill showed significant increase in wet season at Ologe lagoon and decreased activities in the dry season at Badagry lagoon.

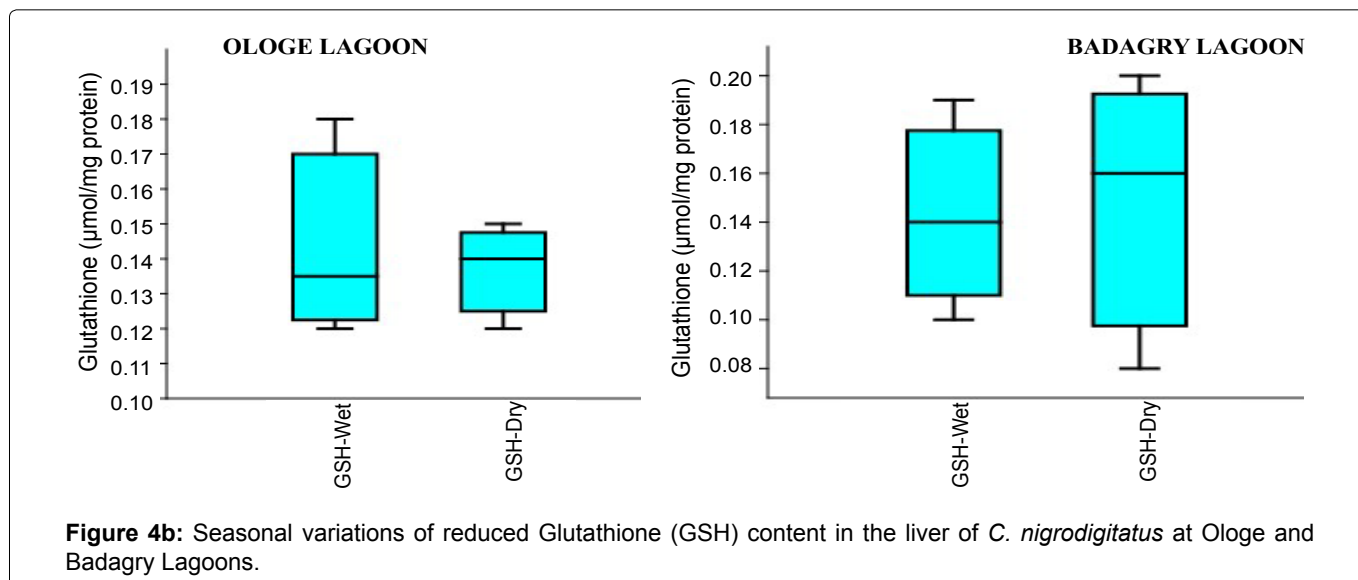
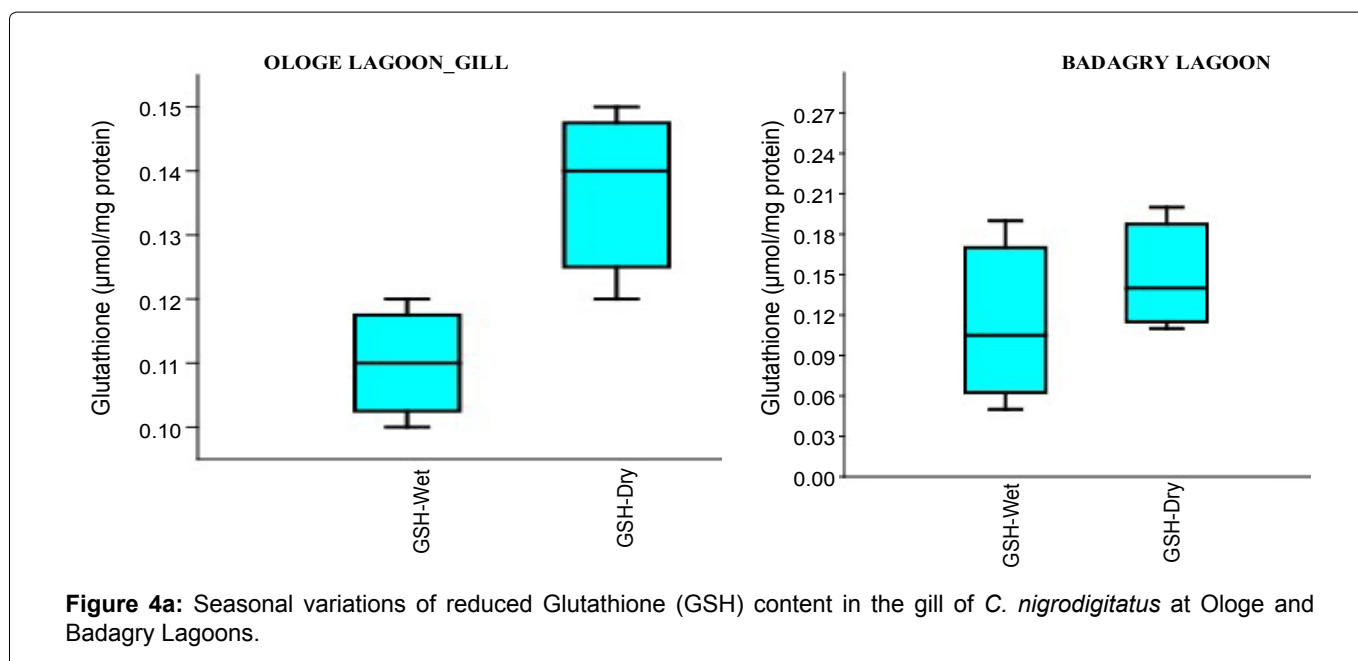
### Catalase (CAT)

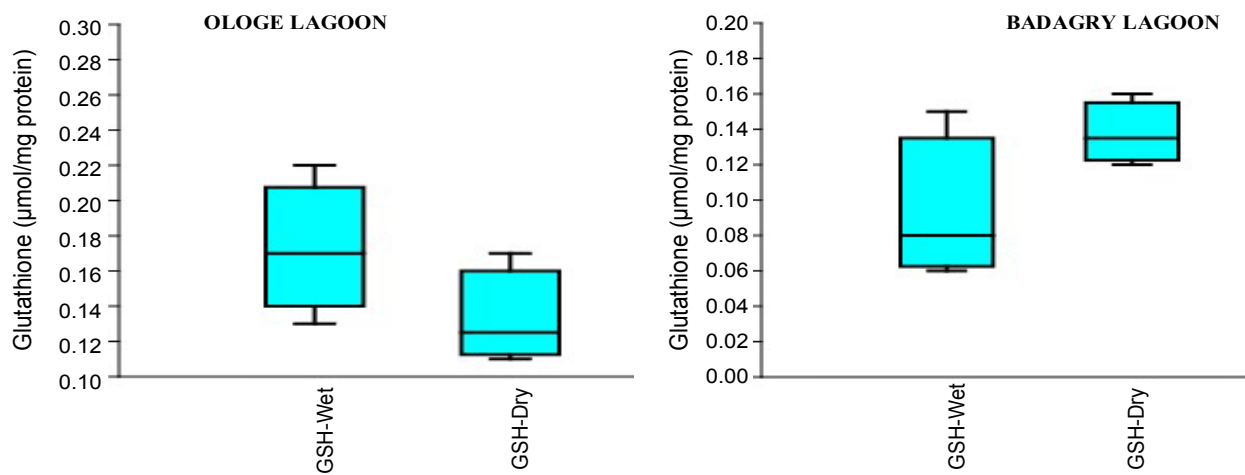
The mean activities of CAT decreased significantly in the muscle with  $0.51 \mu\text{mol}/\text{mg}$  during the dry season and slightly increase in the liver with  $1.43 \mu\text{mol}/\text{mg}$  during the wet season at Ologe Lagoon. While, at Badagry Lagoon, the activities of CAT decreased significantly in the gill and muscle with  $0.70 \mu\text{mol}/\text{mg}$  during the dry season and slightly increase in gill ( $0.79 \mu\text{mol}/\text{mg}$ ), and liver ( $0.90 \mu\text{mol}/\text{mg}$ ) in the wet season (Figure

3a, Figure 3b and Figure 3c). The ANOVA showed that there was a significant difference ( $p < 0.05$ ) in CAT activities in the organs of *C. nigrodigitatus* in Ologe lagoon across the seasons.

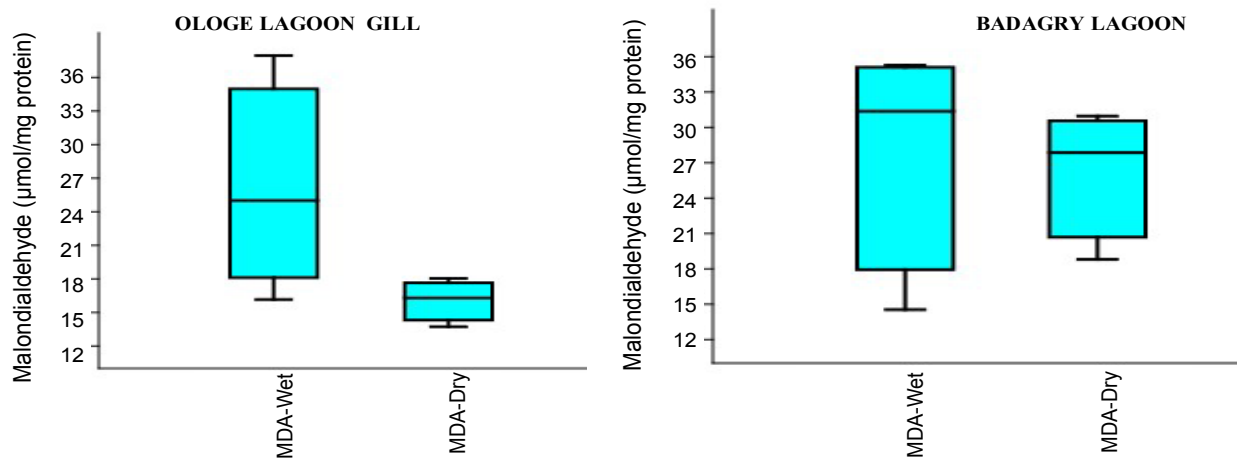
### Reduced glutathione (GSH)

The mean content of GSH observed highest in gill and liver with  $0.15 \mu\text{mol}/\text{mg}$  during the dry season, and lowest mean GSH activities in the muscle with  $0.09 \mu\text{mol}/\text{mg}$  during the wet season at Badagry Lagoon. While at Ologe Lagoon, the mean GSH content observed highest in the gill and liver with  $0.14 \mu\text{mol}/\text{mg}$  during the dry season, and lowest in the gill with  $0.11 \mu\text{mol}/\text{mg}$  during the wet season respectively (Figure 4a, Figure 4b and Figure 4c). ANOVA showed that there were significant differences ( $p < 0.05$ ) in GSH content in liver and muscle during the dry season at Ologe lagoon. Although, there were observable increase in the GSH content in the gill and liver of the fish species at the dry season in Ologe and Badagry lagoons. This could be

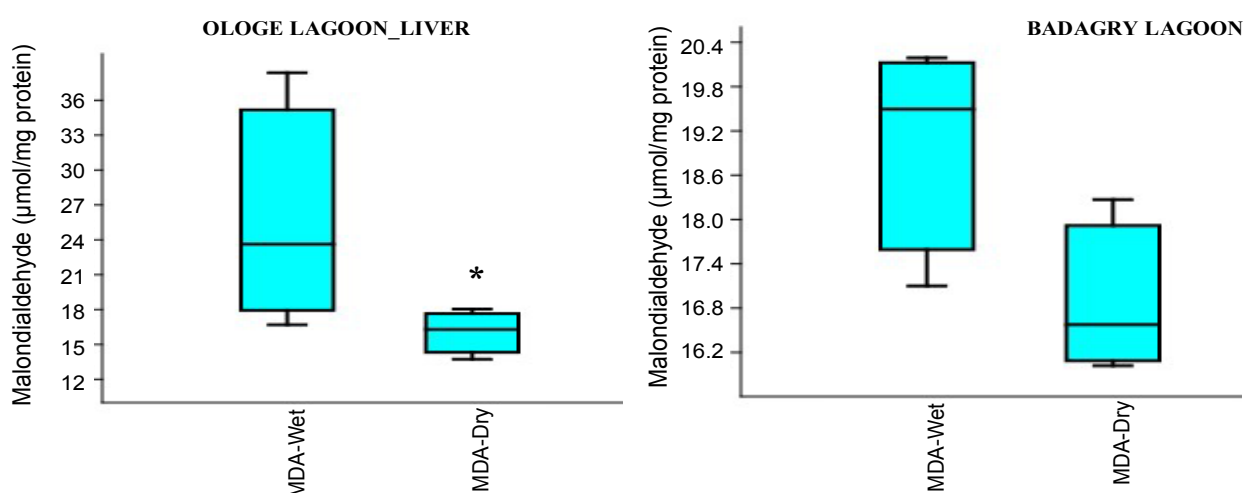




**Figure 4c:** Seasonal variations of reduced Glutathione (GSH) content in the muscle of *C. nigrodigitatus* at Ologe and Badagry Lagoons.



**Figure 5a:** Seasonal variations of Malondialdehyde (MDA) in the gill of *C. nigrodigitatus* at Ologe and Badagry Lagoons.

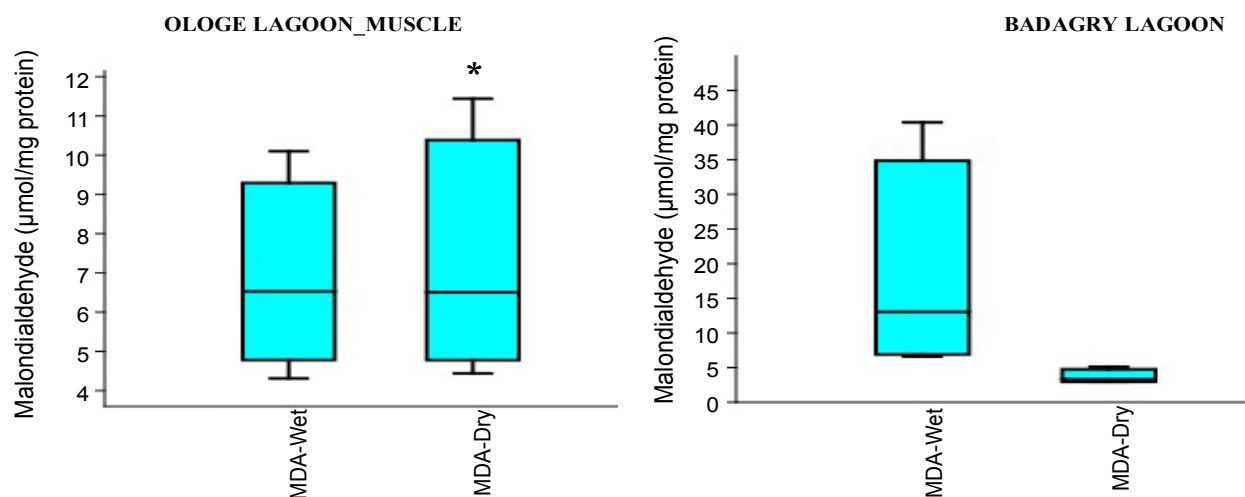


**Figure 5b:** Seasonal variations of Malondialdehyde (MDA) in the liver of *C. nigrodigitatus* at Ologe and Badagry Lagoons.

interpreted as the cellular adaptation response to initial oxidative stress during the dry season as the diluents of contaminants (admixture of chemical constituents) are far concentrated in the gill and liver of the fish species.

### Malondialdehyde (MDA)

The MDA activities observed a significant increase ( $p < 0.05$ ) in the gill with mean values of  $26.37 \mu\text{mol/mg}$



**Figure 5c:** Seasonal variations of Malondialdehyde (MDA) in the muscle of *C. nigrodigitatus* at Ologe and Badagry Lagoons.

**Table 1:** Pearson correlation coefficient of biochemical responses in *C. nigrodigitatus* from Badagry lagoon.

	CAT_G	SOD_G	MDA_G	GSH_G	CAT_L	SOD_L	MDA_L	GSH_L	CAT_M	SOD_M	MDA_M	GSH_M
CAT_G												
SOD_G	0.406											
MDA_G	0.126	-0.168										
GSH_G	-0.015	0.66	-0.521									
CAT_L	0.488	-0.231	0.461	-0.847*								
SOD_L	0.927**	0.205	0.34	-0.318	0.701							
MDA_L	0.411	-0.386	-0.125	-0.194	0.202	0.505						
GSH_L	-0.684	-0.471	-0.691	0.058	-0.396	-0.68	0.133					
CAT_M	0.144	0.445	0.103	-0.034	0.281	0.02	-0.773	-0.386				
SOD_M	0.52	-0.169	0.656	-0.691	0.851*	0.627	-0.015	-0.648	0.47			
MDA_M	0.679	-0.256	0.441	-0.706	0.880*	0.879*	0.594	-0.442	-0.104	0.734		
GSH_M	-0.099	0.718	-0.689	0.909*	-0.735	-0.356	-0.274	0.228	0.067	-0.765	-0.711	

\*\*Correlation is significant at the 0.01 level (2-tailed); \*Correlation is significant at the 0.05 level (2-tailed); G - Gill; L - Liver; M - Muscle.

**Table 2:** Pearson correlation coefficient of biochemical responses in *C. nigrodigitatus* from Ologe lagoon.

	CAT_G	SOD_G	MDA_G	GSH_G	CAT_L	SOD_L	MDA_L	GSH_L	CAT_M	SOD_M	MDA_M	GSH_M
CAT_G												
SOD_G	-0.064											
MDA_G	0.940**	-0.298										
GSH_G	-0.558	0.482	-0.719									
CAT_L	-0.008	-0.375	0.058	-0.633								
SOD_L	-0.224	-0.15	-0.223	-0.397	0.947**							
MDA_L	-0.258	0.085	-0.493	0.468	0.172	0.35						
GSH_L	-0.087	0.62	-0.14	0.339	-0.233	-0.156	-0.255					
CAT_M	-0.78	0.242	-0.848*	0.404	0.409	0.648	0.545	0.238				
SOD_M	0.679	-0.292	0.778	-0.714	-0.011	-0.22	-0.535	-0.514	-0.824*			
MDA_M	0.188	-0.763	0.441	-0.556	0.038	-0.182	-0.474	-0.691	-0.593	0.732		
GSH_M	0.034	0.531	0.032	-0.173	0.246	0.283	-0.4	0.801	0.267	-0.209	-0.519	

\*\*Correlation is significant at the 0.01 level (2-tailed); \*Correlation is significant at the 0.05 level (2-tailed); G - Gill; L - Liver; M - Muscle.



and 28.13  $\mu\text{mol}/\text{mg}$  in the dry and wet season at Badagry Lagoon, while 16.08  $\mu\text{mol}/\text{mg}$  and 26.03  $\mu\text{mol}/\text{mg}$  in the dry and wet season at Ologe Lagoon respectively (Figure 5a, Figure 5b and Figure 5c). ANOVA exhibited significant differences ( $p < 0.05$ ) in MDA activities in the organs of *C. nigrodigitatus* at Ologe lagoon across the seasons.

### Pearson correlation coefficient

The Pearson correlation coefficient showed that MDA activities in gill and CAT in muscle exhibited a negative significant correlation ( $r = -0.848$ ,  $p < 0.05$ ); SOD activities in muscle and CAT in muscle showed negative significant correlation ( $r = -0.824$ ,  $p < 0.05$ ) in *C. nigrodigitatus* in Ologe lagoon. While, the GSH activities in gill and CAT activities in liver exhibited a negative significant correlation ( $r = -0.847$ ,  $p < 0.05$ ); CAT activities in liver and SOD activities in muscle exhibited a positive significant correlation ( $r = 0.851$ ,  $p < 0.05$ ); MDA activities in muscle and CAT activities in liver showed positive significant correlation ( $r = 0.880$ ,  $p < 0.05$ ); while SOD activities in liver and MDA activities in muscle ( $r = 0.879$ ,  $p < 0.05$ ) in *C. nigrodigitatus* in Badagry lagoon (Table 1 and Table 2).

### Histopathological changes in organs of *C. nigrodigitatus*

The histopathological changes in the gill of *C. nigrodigitatus* from the control group showed normal arrangement pattern of primary and secondary lamellae. Varied morphological changes occurred in the gill tissue of the affected *C. nigrodigitatus* and the gill exhibited marked mild epithelial lifting. Thus, there was fusion at adjacent secondary lamellae as a result of hyperplasia. Inter-lamella hyperplasia, desquamation and necrosis of secondary lamellae were observed. The mild stunted growth of primary lamellae in the histological sections of gills of the *C. nigrodigitatus* affected with aquatic pollutants of Ologe lagoon (Plate 1, Plate 2 and Plate 3).

### Discussion

The aquatic ecosystems are extensively contaminated with admixtures of chemical compounds including heavy metals, persistent organic pollutants released from industrial and other anthropogenic sources causing potent harm on the ecological equilibrium of the aquatic environment and organisms in particular due to accumulation of these toxic compounds in their tissues. Histological and biochemical responses in organs of *C. nigrodigitatus* were used as effective biomarkers to evaluate the pollution status of Ologe and Badagry lagoons. Antioxidant enzymes are considered as sensitive biomarkers in environmental stress before hazardous effects occur in fish, and are important parameters for testing water for the presence of toxicants [23].

Increased oxidative stress has been suggested to enhance the antioxidant enzymes activities in fish, as a

protective action towards oxidative stress. Superoxide dismutase (SOD) is one of the main antioxidant defense enzymes generated in response to oxidative stress. It converts the highly toxic superoxide anions into hydrogen peroxide. In the present study, SOD activity significantly increased ( $p < 0.05$ ) in the gill of *C. nigrodigitatus* at Ologe and Badagry Lagoons. The pollutants in these Lagoons gives rise to higher production of superoxide anions which is countered by higher production of SOD enzyme in gills to neutralize the adverse effect. The antioxidant enzymes from this study have shown that the SOD activities in the organs work in a cooperative and synergistic manner to protect against oxidative stress and tissue-specific damage from stress-induced contaminants discharged into the lagoons. These enzyme systems have been proposed as biomarkers of reactive oxygen species (ROS) mediating contaminant exposure and as a potential tool in environmental risk assessment [23].

The enzyme SOD is known to provide cytoprotection against free radical induced damage by converting superoxide radicals ( $\text{O}_2^-$ ) generated in peroxisomes and mitochondria to hydrogen peroxides. The hydrogen peroxide is then removed from the system by the enzyme CAT, which converts it to water and molecular oxygen ( $\text{O}_2$ ). The inhibition of the enzyme SOD leads to increased oxidative stress in tissues as a result of the damaging activities of the superoxide radicals ( $\text{O}_2^-$ ) [24]. Furthermore, the inhibition of the enzyme SOD will expectedly result in a reduction in the activity of the enzyme CAT, due to a decrease in  $\text{H}_2\text{O}_2$  generation from SOD activities [25]. This indeed proved to be the case in this study as there was a reduction in CAT activity from wet to dry season in the gill, liver and muscles of *C. nigrodigitatus* from Ologe Lagoon, as well as a reduction in CAT activity in gill and liver of the fish. Catalase (CAT) is a major primary antioxidant defense component that catalyses the decomposition of Hydrogen peroxides ( $\text{H}_2\text{O}_2$ ) which is produced by the action of superoxide dismutase to  $\text{H}_2\text{O}$ .

The GSH are non-enzymatic primary intracellular antioxidant agent represented by ROS scavengers. The depletion of GSH level at Ologe Lagoon, would probably be seem to enhance the risk of oxidative stress in liver and muscles of the *C. nigrodigitatus*. However, there was a significant increase in GSH of the fish observed across the seasons at Badagry lagoon. The depletion of GSH level is an indication that the Ologe lagoon is polluted, as compared Badagry lagoon which with slight pollution usually generated by domestic, dredging and fishing activities. This result agreed with those of Sharma, et al. [26] where they reported that, the glutathione metabolism contains crucial antioxidant molecules to defend the organisms against oxidants. GSH importantly contributes as a primary nucleophile in numerous protective detoxification reactions as also in

the maintenance of cellular redox status [27].

MDA is used as marker of oxidation of membrane phospholipids through lipid peroxidation. An increase in MDA levels in organisms can be related to degradation of an environmental site by decreasing the water quality. An increase in level of lipid peroxides (measured as MDA), indicative of oxidative stress in the liver and gill of the fish exposed to admixtures of chemical constituent from the Ologe Lagoon, while in muscle the MDA decreased from the wet to dry seasons. The increases in activities of MDA are due to an inhibitory effect on mitochondrial electron transport system leading to stimulation in the production of intracellular ROS [28]. However, this study observed a significant decrease of MDA in the gills, liver and muscle of *C. nigrodigitatus* at Badagry lagoon across the seasons, as indicative that there are less oxidative stress at Badagry lagoon. The environmental factors which play key roles toward the generation of oxidative radicals like ROS are minimally produced due to less human activities and industrial inputs which constitutes admixtures of chemical or xenobiotics were observed in Badagry lagoon, and therefore the measured MDA level were decreased in the organs of the fish species.

Histology is a useful technique towards the assessment of toxic substances in aquatic organisms from polluted ecosystems. Such a study also offers opportunity to locate the effect of pollutants in various organs and systems of animals. Variations in the epithelial surface of gills showed important physiological adaptations relating to the area available for increased gaseous exchange [29]. The lamellar reduction of the fish from Ologe lagoon must have been caused by respiratory stress as the sum of all the physiological responses by which an animal tries to maintain or re-establish a normal metabolism in the face of a physical or chemical force [29]. Cellular hyperplasia is an important feature in gills affected by pollution [30,31]. A number of pathological changes have been reported in fishes exposed to different heavy metals [32,33].

Liver are the main metabolic factory of the body serves several basic functions like metabolism, storage and secretion of bile. Liver accumulates more toxicants than other organs of body [29]. The morphology in the liver showed diffuse changes in hepatic tissue with disseminated moderate microvesicular vacuolation of hepatocytes, moderate vascular congestion and mild presence of eosinophilic fluid within the interstitial induced by admixture of chemicals from Ologe lagoon.

Kidney acts as a detoxifying organ by collecting and removing toxic materials along with nitrogenous waste products. Kumar, et al. [29] reported histological changes in kidney of *Notopterus notopterus* and *Oreochromis mossambicus* exhibiting degeneration and dissolution of epithelial cells of renal tubules, vacuolization,

loss of nuclei, shrunken and ruptured glomerulus at some places, tubular necrosis, especially in the convoluted portion, and inflammation of glomerulus leading to impaired kidney functions like polyuria, polydipsia, and increased build-up of non-protein nitrogen. Renal tissue of *C. nigrodigitatus* from Ologe and Badagry lagoon showed mild haemorrhagic lesion, mild moderate ballooning degeneration of renal tubules and thickened blood vessel.

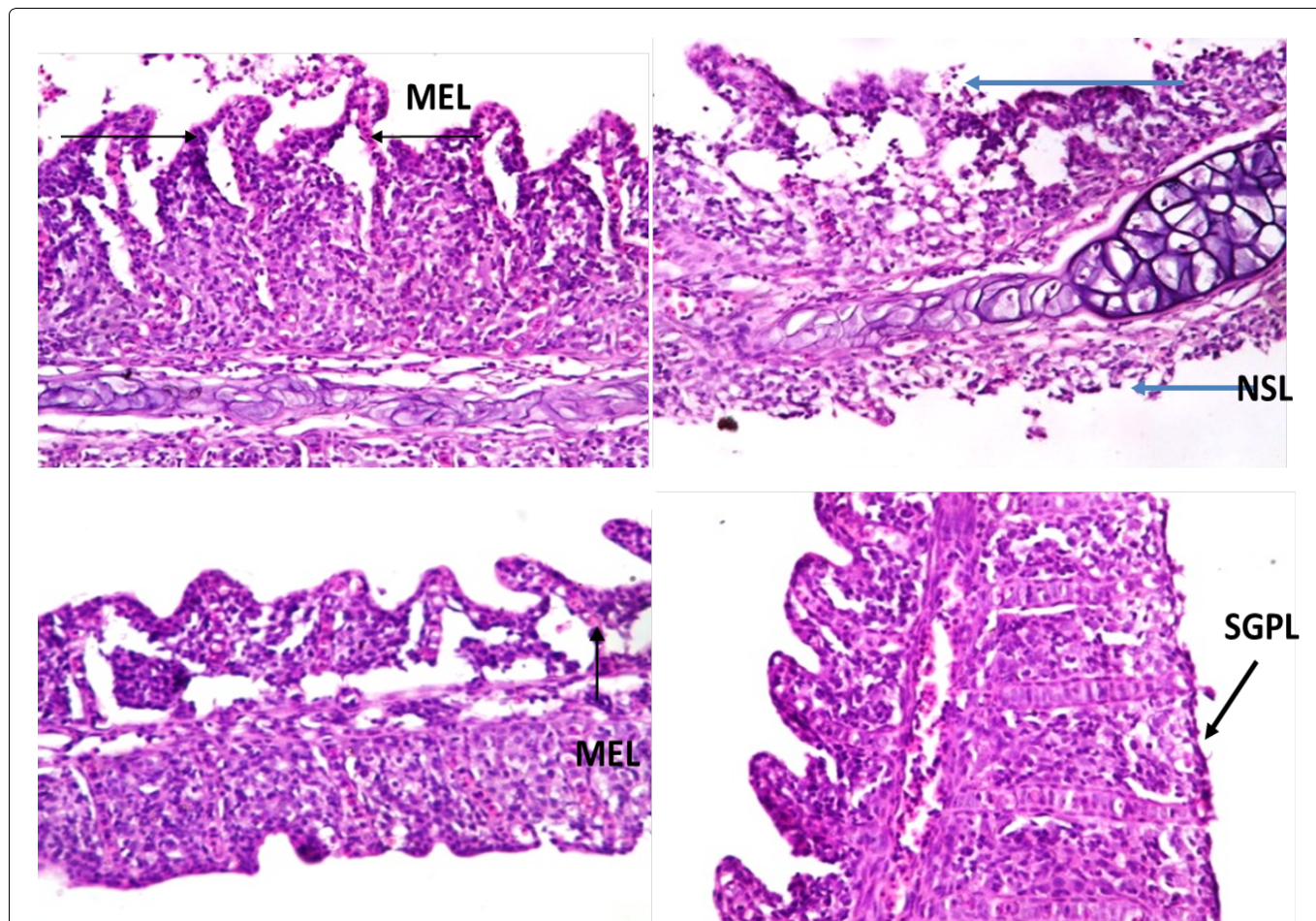
## Conclusion

This study showed that there was an increased level of oxidative stress due to the presence of heavy metals alongside other toxicants induced by anthropogenic discharges comprising of admixtures of pollutants, and that an imbalance is generated between pro-oxidants and antioxidants as observed across seasons at Ologe Lagoon. However, the Badagry Lagoon poses less ecological risk with a decreased level of oxidative stress and a slight balance in pro-oxidant and antioxidant enzymes in the organs of *Chrysichthys nigrodigitatus* across seasons. The noticeable histological alterations in the organs of the *C. nigrodigitatus* are clear indications of the presences of xenobiotics or chemical compounds originated from industrial and other anthropogenic activities in Ologe lagoon. Therefore, the results of these studies also provide guidance to selection of tissues to be considered in the field of biomonitoring, designed to detect the bioavailability of aquatic pollutants and early-warning indicators of aquatic pollution in fish.

## References

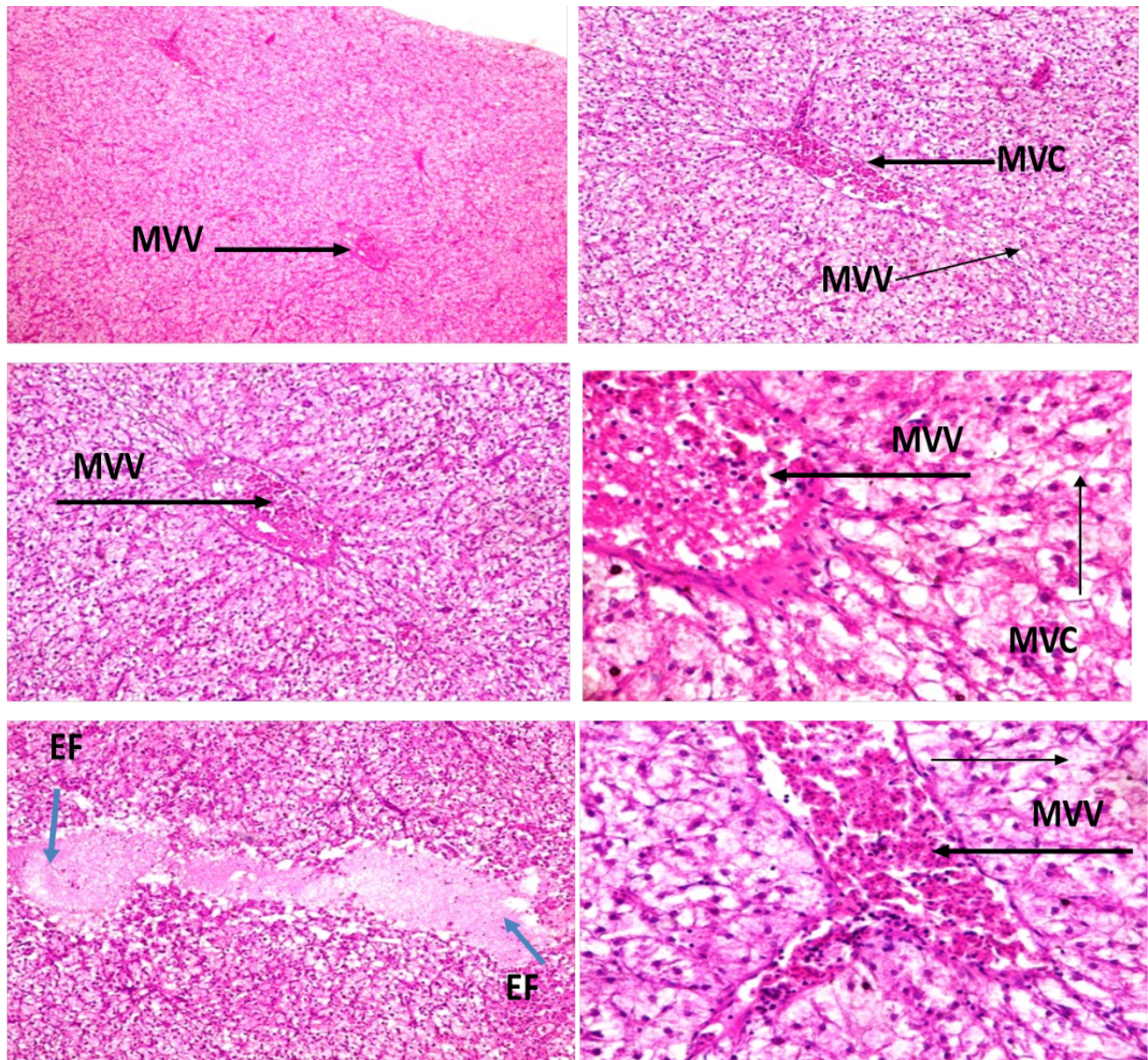
1. Sabullah MK, Ahmad SA, Shukor MY, Gansau AJ, Syed MA, et al. (2015) Heavy metal biomarker: Fish behavior, cellular alteration, enzymatic reaction and proteomics approaches. *International Food Research Journal* 22: 435-454.
2. Havelková M, Randák T, Blahová J, Slatinská I, Svobodová Z (2008) Biochemical markers for the assessment of aquatic environment contamination. *Interdiscip Toxicol* 1: 169-181.
3. Aazami J, Esmaili-Sari A, Abdoli A, Sohrabi H, Van den Brink PJ (2015) Monitoring and assessment of water health quality in the Tajan River, Iran using physicochemical, fish and macroinvertebrates indices. *Journal of Environmental Health Science and Engineering* 13: 29-41.
4. Dalzochio T, Rodrigues GZ P, Petry IE, Gehlen G, Da Silva LB (2016) The use of biomarkers to assess the health of aquatic ecosystems in Brazil: A review. *Int Aquat Res* 8: 283-298.
5. Hook SE, Gallagher EP, Batley GE (2014) The role of biomarkers in the assessment of aquatic ecosystem health. *Integr Environ Assess Manag* 10: 327-341.
6. Lam PK S (2009) Use of biomarkers in environmental monitoring. *Ocean & Coastal Management* 52: 348-354.
7. Thophon S, Kruatrachue S, Upathan E, Pokethitiyook P, Sahaphong S, et al. (2003) Histopathological alterations of white seabass, *Lates calcarifer* in acute and subchronic cadmium exposure. *Environ Pollut* 121: 307-320.
8. Gernhofer M, Pawet M, Schramm M, Müller E, Triebkorn

- R (2001) Ultrastructural biomarkers as tools to characterize the health status of fish in contaminated streams. *Journal of Aquatic Ecosystem, Stress and Recovery* 8: 241-260.
9. Farombi EO, Adelowo OA, Ajimoko YR (2007) Biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in African catfish (*Clarias gariepinus*) from Nigeria Ogun River. *Int J Environ Res Public Health* 4: 158-165.
  10. Doherty VF, Ogunkuade OO, Kanife UC (2010) Biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in some selected fishes in Lagos, Nigeria. *American-Eurasian J Agric Environ Sci* 7: 359-365.
  11. Otitolaju A, Olagoke O (2011) Lipid peroxidation and antioxidant defense enzymes in *Clarias gariepinus* as useful biomarkers for monitoring exposure to polycyclic aromatic hydrocarbons. *Environ Monit Assess* 182: 205-213.
  12. Ejimadu CU, Obinna CL, Amaeze HN (2015) Cellular biomarker responses of bagrid catfish, *Chrysichthys nigrodigitatus* in a contaminated coastal ecosystem. *African Journal of Biotechnology* 14: 2114-2123.
  13. Akoachere JT K, Oben PM, Mbivnjo BS, Ndip LM, Nkwelang G, et al. (2008) Bacterial indicators of pollution of the Douala lagoon, Cameroon: Public health implications. *Afr Health Sci* 8: 85-89.
  14. Onuoha PC, Wim V (2010) Hydrochemistry and plankton dynamics of eutrophic tropical Lagoon. *Nature and Science* 8: 140-149.
  15. Clarke EO, Anetekhai MA, Akin-Oriola GA, Onanuga AIS, Olarinmoye OM, et al. (2004) The Diatom (Bacillariophyta) diversity of an open access lagoon in Lagos, Nigeria. *J Res Rev Sci* 3: 70-77.
  16. Aebi H (1984) Catalase in vitro. *Methods Enzymol* 105: 121-126.
  17. Kostiuik VA, Potapovich AI, Kovaleva ZhV (1990) A simple and sensitive method of determination of superoxide dismutase activity based on the reaction of quercetin oxidation. *Vopr Med Khim* 36: 88-91.
  18. Jollow DJ, Michell JR, Zampaglione N, Gillete J (1974) Bromobenzene- induced liver necrosis. Protective role of glutathione an evidence for 3,4 bromobenzene oxide as the hepatotoxic metabolite. *Pharmacology* 11: 151-169.
  19. Buege JA, Aust SD (1978) Microsomal lipid peroxidation. *Methods Enzymol* 52: 302-310.
  20. Poosti AS, Marvdasti S (1999) Atlas of fish histology (normal and pathological forms). Tehran University Press, 328 (in persian).
  21. Naeemi A, Jamili S, Shabanipour N, Mashinchian A, Shariati Feizabadi S (2013) Histopathological changes of gill, liver and kidney in Caspian kutum exposed to Linear Alkylbenzene Sulfonate. *Iranian Journal of Fisheries Sciences* 12: 887-897.
  22. Ogbeibu AE (2005) Biostatistics: A practical approach to research and data handling. Mindox Publishing, Ltd., Nigeria.
  23. EL-Gazzar AM, Ashry KE, El-Sayed YS (2014) Physiological and oxidative stress biomarkers in the freshwater Nile Tilapia, *Oreochromis niloticus* L., exposed to Sublethal doses of cadmium. *Alexandria Journal of Veterinary Sciences* 40: 29-43.
  24. Divakaran N (2014) Responses of antioxidants and lipid peroxidation in villorita cyprinoidesto mercury exposure. *International Journal of Innovative Research and Development* 3: 38-44.
  25. Olagoke O (2008) Lipid peroxidation and antioxidant defense enzymes in *clarias gariepinus* as useful biomarkers for monitoring exposure to polycyclic aromatic hydrocarbons. University of Lagos, Lagos, Nigeria, 70.
  26. Sharma CM, Basnet S, Kang S, Rosseland BO, Zhang Q, et al. (2013) Mercury concentrations in commercial fish species of Lake Phewa, Nepal. *Bull Environ Contam Toxicol* 91: 272-277.
  27. Saliu JK, Bawa-Allah KA (2012) Toxicological effects of lead and zinc on the antioxidant enzyme activities of post juvenile *Clarias gariepinus*. *Resources and Environment* 2: 21-26.
  28. Stohs SJ, Bagchi D, Hassoun E, Bagchi M (2000) Oxidative mechanisms in the toxicity of chromium and cadmium ions. *J Environ Pathol Toxicol Oncol* 19: 201-213.
  29. Kumar SV, Pascal LF, Tennyson S, Pandeewari M, Dhinamala K, et al. (2018) Histopathological studies of *Anabas testudineus* Bloch 1792 on exposure to aquatic toxicants of Buckingham canal, Chennai, Tamil Nadu, India. *International Journal of Biology Research* 3: 125-133.
  30. Sultana M, Sharief DS (2004) Effect of heavy metals on the histopathology of gills and brain of *Tilapia mossambica*. *Journal of Aquatic Biology* 19: 165-168.
  31. Altinok I, Capkin E (2007) Histopathology of lethal toxin induced effects and histopathological rainbow trout exposed to sub-lethal concentrations study of common carp (*Cyprinus carpio*). *Toxicologic Pathology* 35: 405-410.
  32. Tilak KS, Veeraiah K, Reddy JV (2001a) A study on nitritenitrogen effect on haemoglobin content of the fish *Puntius sophore* and *Channa punctatus*. *Pollution Research* 20: 179-181.
  33. Tilak KS, Veeraiah K, Yacob K (2001b) Studies on histopathological changes observed in the gill, liver, and kidney of *Ctenopharyngodonidella* exposed to technical fenvalerate and EC 20%. *Pollution Research* 20: 387-393.



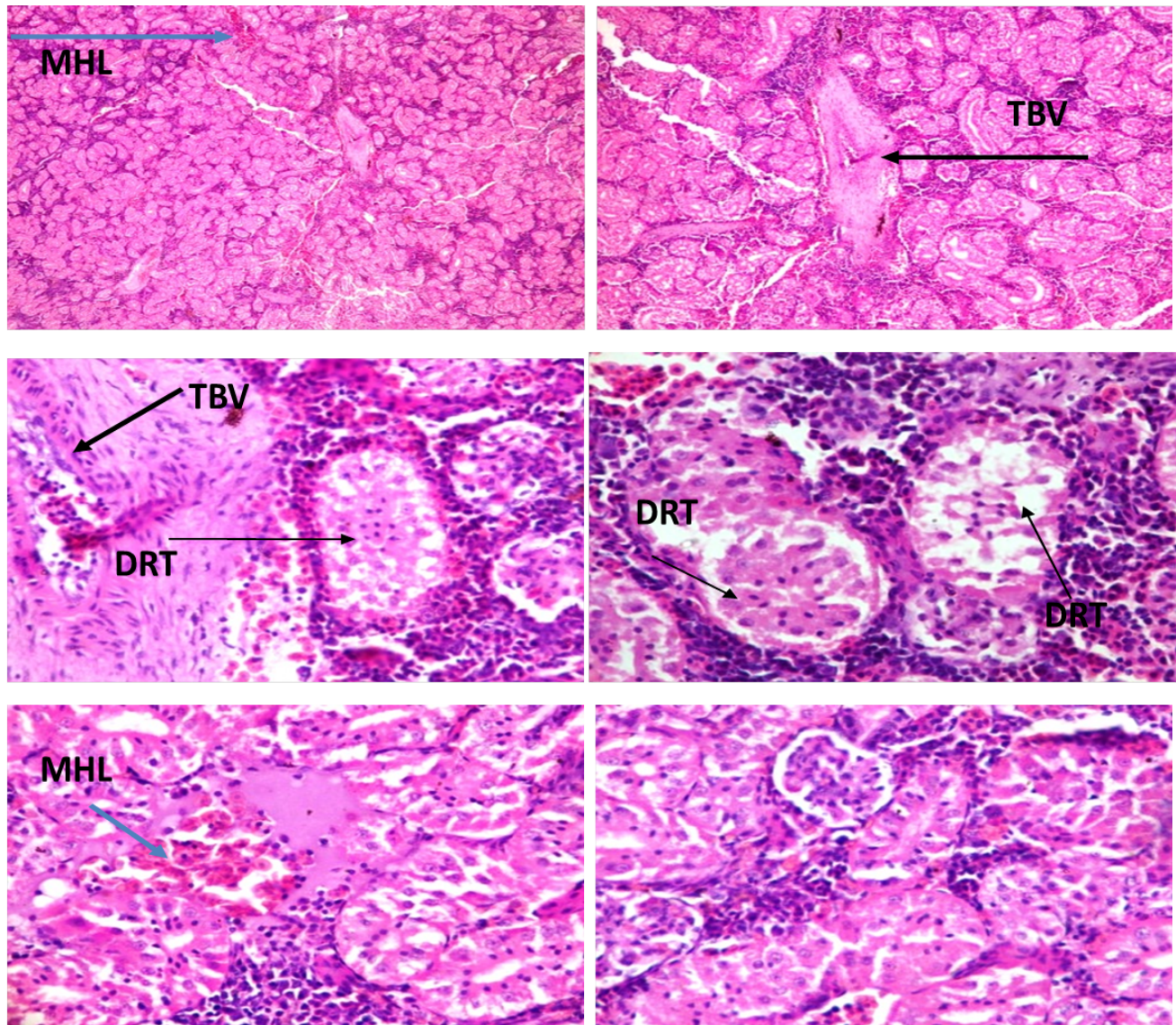
**Plate 1:** Photomicrographs of gill show mild stunted growth of primary lamellae (SGPL), mild epithelial lifting (MEL), fusion of secondary lamellae (FSL), inter lamella hyperplasia, desquamation and necrosis of secondary lamellae (NSL).

The histomorphology in the liver of *C. nigrodigitatus* exposed to aquatic pollutant from Ologe and Badagry lagoons showed diffuse changes in hepatic tissue with disseminated moderate microvesicular vacuolation of hepatocytes, moderate vascular congestion and mild presence of eosinophilic fluid within the interstitial.



**Plate 2:** Photomicrographs of hepatic tissue show disseminated moderate microvesicular vacuolation (MVV) of hepatocytes, moderate vascular congestion (MVC) and mild presence of eosinophilic fluid (EF) within the interstitial.

Lesions were observed in the histological studies of affected kidney of *C. nigrodigitatus*. Renal tissue showed mild haemorrhagic lesion, mild moderate ballooning degeneration of renal tubules and thickened blood vessel.



**Plate 3:** Photomicrographs of renal tissue show mild haemorrhagic lesion (MHL), mild moderate ballooning degeneration of renal tubules (DRT) and thickened blood vessel (TBV).