Journal of Environmental Protection, **2011, 2, 982-995**
doi:10.4236/jep.2011.27113 Published Online September 2011 (http://www.SciRP.org/journal/jep)

Downstream Changes on a Tropical Fish Community Structure by Effluent from Wood Processing Factory

Benedict Obeten Offem*, Irom Bassey, Gabriel Ujong Ikpi

Department of Fisheries and Aquatic Sciences, Cross River University of Technology, Cross River State, Nigeria.
Email: *benbeff06@yahoo.com

Received June 1st, 2011; revised July 6th, 2011; accepted August 5th, 2011.

ABSTRACT

In order to plan a management programme for ensuring maximum production of fish in Cross River, impacted downstream changes in the fish community structure by effluents from wood processing industry, six years after establishment, was examined. Monthly samples were collected between January and December each year from 2000 *to* 2006 *in three reaches* (*Upriver: I, Mid-river: II and Downriver: III*) *along the length of Cross River. Representatives of the fish families Osteoglossidae* (*i.e. Heterotis niloticus*), *Cichlidae* (*Tilapia melonopleura*) *and Characidae* (*Bryocinus nurse*), *Clupeidae* (*Cynothrissa sp*), *Mormyridae* (*Mormyrus deliciosus*), *Clariidae* (*Clarias gariepinus*), *Bagridae* (*Bagrus bayad*) *and Cyprinidae* (*Barbus occidentalis*) *were found to have declined in their importance compared to pre-industry period. On the other hand, Bagridae* (*Chrysichthys nigrodigitatus*), *Cichlidaae* (*Orechromis niloticus*), *Claridae* (*Clarias anguillaris*) *and Mochokidae* (*Synodontis clarias*) *have currently emerged as most important. Estimated value of growth coefficient* (*b*) *of the length-weight relationship changed from isometry* (*b approx.* $= 3$) *to negative allometry* ($b \leq 3$), *condition factor values decreased from range between* 0.53 *and* 1.30 *to range between* 0.22 *and* 0.62. *Main feeding groups of fish; planktivores, carnivores and insectivores declined in numbers while omnivores and detritivores increased, resulting in dominance of benthic and semi-pelagic omnivores. Values of fecundity distribution varied from* $56{,}012 \pm 5234$ *eggs, mode* 12,500 *and median* 58,345 *to mean value* $23{,}122 \pm 232$ *eggs, mode* 2500 *and median* 20,349, *egg size from mean value;* 1.82 ± 0.07 *mm, mode* 2.2, *and median;* 1.8 *to values of* 0.8 ± 0.04 *mm, mode;* 1.3 *and median* 1.1 *and Gonadosomatic index from* 20.5 ± 3.2, *mode* 19.1 ± 2.2 *and median* 21.4 *to values of* 12.4 ± 2.3, *mode* 4.5 *and median* 9.5 *respectively. Three species found to have appeared in the river were Tilapia monody, Chrysichthys maurus and Synodontis violaceus. The appearance of these species and disappearance of* 36 *others indicates the restructuring of the fish community of the Cross River by effluents from the wood processing industry.*

Keywords: *Fish Community, Fish Composition and Abundance, Diet Changes, Length-Weight Relationship, Reproductive Biology*

1. Introduction

In Africa, a large proportion of both rural and urban populations live in vicinity of inland or coastal waters. Examples are Cairo on River Nile, Khartoun at Confluence of blue and white nile, Kampala (Lake Victoria), Kinshasa and Brazaville (River Zarie/Congo), Banjul (River Gambia), Niamey and Bamako (River Niger) and some national capitals located along the coast e.g Abidjan, Dakar, Rabat, Da Es Salam and Luanda [1]. Settlements close to natural waters offer man's greatest hopes for livelihood and material supplies. Egypt's Delta Lakes supply 50% of annual fish consumption [2]. Large basins in Africa: Niger, Benue, Sokoto, Ouema, Shire, Barotse, Kafu flats, Massili & Okarango have at least 100 species each [3]. However, Potential annual yield of small systems is about 2 million metric tons [4]. In some coastal cities: Zaire, Ethiopia, Keyna, Madagascar and Tazania freshwater fish are more important than marine fish and may contribute up to 90% of the total landings [4,5]. Nigerian inland water bodies are primarily used for fishing and the fisheries, is private sector driven and operates mainly in remote rural areas [6]. It contributes 86% of domestic fish production [7]. It is source of employment and provides income and nutrition for about 3 millions rural dwellers that depend on fish for livelihood. Nigeria could be self-sufficient in fish production and major exporter of fish if these water bodies are properly managed.

However, the fish yields of most inland waters are generally on the decline [8], which has been attributed to causes ranging from environmental degradation of the water bodies due to anthropogenic inputs from neighbouring communities and industries [9,10]. Impacted changes in water quality are reflected in the biotic community structure with the vulnerable dying, while the most sensitive species act as indicators of pollution [11-14] listed major industries responsible for water pollution in Nigeria to include petroleum, mining, wood, pulp, pharmaceuticals, textiles, plastics, iron and steel, brewing, distillery, fermentation, paints, beverages, food and agriculture. It was reported [15] fertilizer effluents from industrial city of Kano polluted Jakara reservoir. High levels of toxic heavy metals including copper, zinc, chromium, iron and manganese were detected [16,17] in fish from Warwade Reservoir also in Kano. An increased in the pollution levels of the Cross River estuary by petroleum product spillage has been reported [18] which is a problem to the fishery industry.

To achieve management goals, it is necessary to know the changing pattern of fish populations in water bodies. This paper assesses the state of the fish community of the Cross River, before and after the establishment of wood processing industry at the shoreline of the upper portion of the river, in relation to species composition, food habit groups, length-weight relationship, fecundity and condition factor. It is expected that the information provided from the study will contribute to the formulation of management interventions for optimum utilization and sustainable socio-economic development of the Cross River.

2. Materials and Methods

2.1. Study Site

The study site is the Cross River, a floodplain river located at the South Eastern part of Nigeria (**Figure 1**) on Latitude 4°25′ - 7°00′ N, Longitude 7°15′ - 9°30′ E. It is bounded in the South by the Atlantic Ocean, East by the Republic of Cameroun, the Nigerian states of Benue in the North, Ebonyi and Abia in the West and Akwa Ibom; South West. Climate of the study area is defined by dry season and wet season. The wet season (April-October) is characterised by high precipitation (3050 mm ± 230 mm), while the dry season (November-March) is marked by low precipitation (300 mm ± 23 mm). Mean annual temperature ranged from 15.5℃ ± 7.6℃ (wet season) to 32.6℃ ± 5.4℃ (dry season). For the purpose of this study three sampling sites were selected along the length of the river, with one site randomly selected in each of the following reaches; upriver, middle river and downriver. The effluent point of a wood processing industry was located at the shoreline of the upper portion of the river which was covered by savanna grassland and 3 km from the river source with rocky, gravel and sandy substratum. The middle river was 100 km from river source with rocky substratum and shoreline sparsely shaded by forest and savanna grassland. Downriver had a muddy substratum and opens up into the Cross River estuary, with shoreline thickly shaded with rainforest.

2.2. Ichthyofaunal Sampling

The ichthyofuana of the river was sampled at the same time of physico-chemical sampling in all the reaches using variety of fishing gears which included; gill net (22 - 76 mm stretched mesh size), seine net (10mm stretched mesh size) and cast net (10 mm stretched mesh). On each occasion sampling was between 09.00 and 12.00 am. Genus and species identifications was carried out for the Cyprinids [20]; Bagrids [21], Clariidae [22]; Clupeidae and Mugilidae [23]. Species abundance of each reach was presented as a numerical contribution by each species. This was determined by calculating the percentage each species represented of the total catch for each reach based on the number of species.

2.3. Length-Weight Relationship And Condition Factor

Fish weights were measured to nearest 0.1 g and total length (TL) to nearest 1mm. Length- weight relationship (LWR) was estimated from the equation; $W = aL^b$ [24] and was logarithmically transformed into $\log W = \log a + b\log L$. W = weight of fish in grams, L = total length of fish in centimeters, a = constant of proportionality and b = allometry coefficient. The parameters a and b are estimated by method of least squares regression [25] using the log trans -formed data. The condition factor was determined using the expression [26] as $K = W \cdot 100/L^3$. K = Condition factor, W = Total body weight, L = Total length.

2.4. Gut Content Analysis.

To determine changes in food habit groups of fishes samples were transported to the laboratory under ice to minimize post mortem changes. Each specimen was measured for total length (cm) and weight (g) with date, time and location [27]. Fish samples were preserved in deep freezers at –10℃. The fish were later dissected, gutted and preserved in 4% formalin for subsequent analysis. Each stomach contents were emptied into a Petri-dish and observed under a binocular microscope. Individual

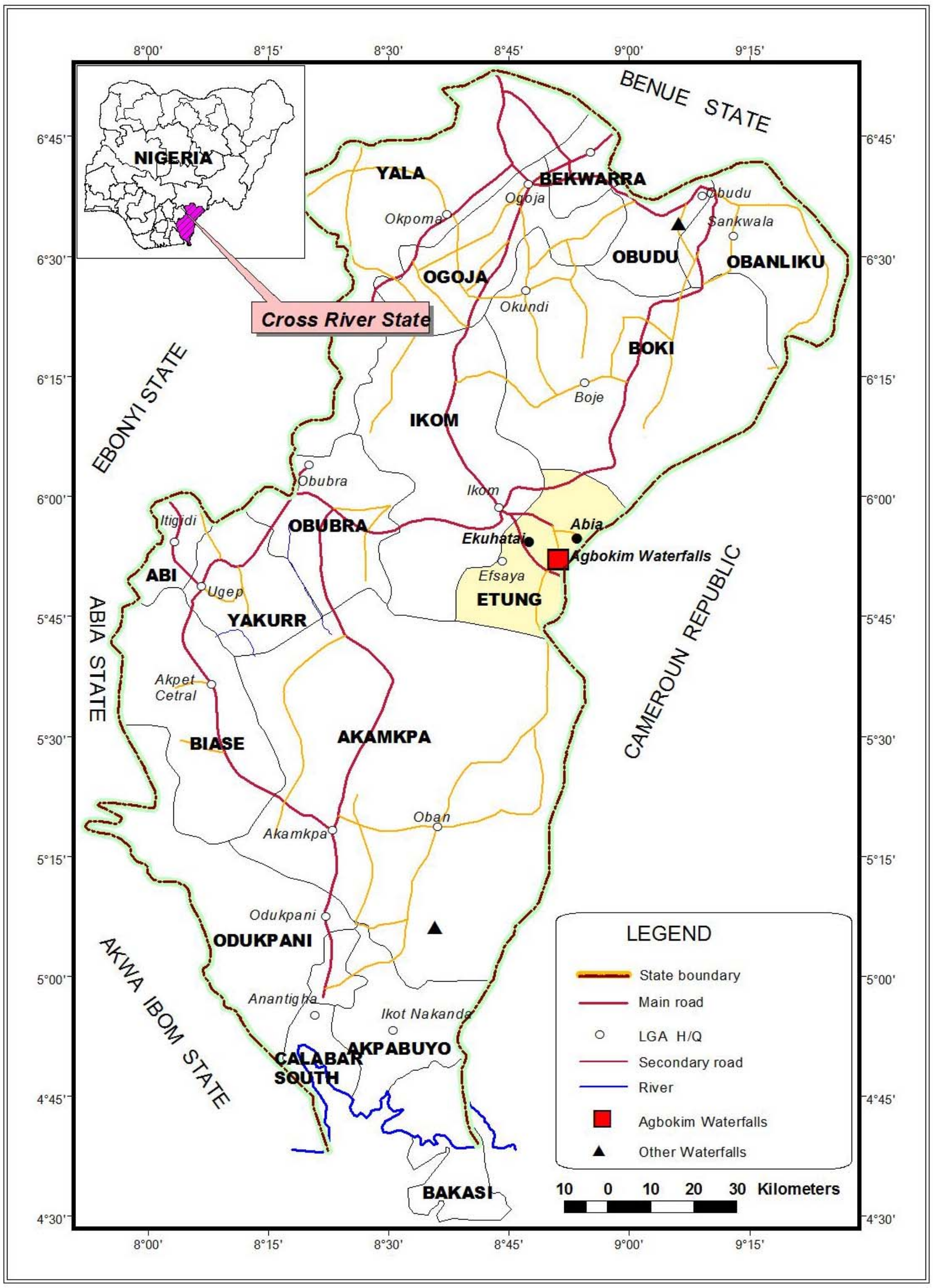

Figure 1. Map of Cross River State showing study area.

food items were identified to the lowest taxonomic level and the entire content analysed using frequency of occurrence [26].

2.5. Fecundity, Gonadosomatic Index, Egg Size

Analysis of fecundity was limited to the peak spawning period (May-July) and only ripe female fish (494) were used for the estimation. Ovaries were excised from body cavity of each fish and preserved in Gilson fluid [28]. Only the largest eggs (0.5 - 3.0 mm) in each sample were used for fecundity estimation. Fecundity was calculated by multiplying the total weight of eggs by the number of eggs per gram weight [29].

Gonad cycle was determined from gonado - somatic index (I_G) expressed according to De Vlaming *et al.* [30] as:

$$I_G = \frac{Gonad\ weight \times 100}{Body\ weight}$$

I_G was used to follow seasonal changes in the gonads.

Egg diameter was measured from samples collected from different parts of the ovary (anterior, middle and posterior parts) using ocular micrometer mounted on a binocular microscope Imevbore [31].

2.6. Data treatment and analysis

The mean and standard deviation of each of the physico-chemical parameters were calculated. Analysis of variance (ANOVA) was used to test for statistical differences between the means of the physical and chemical parameters of the sampling years. Presence – absence data (quantitative scale issue) was used as a measure of community composition. Based on the information obtained, fish species were qualitatively categorized as follows:

Disappeared: Species not sampled in all subsequent studies after first appearance.

Declined: Species that are either absent or present in relatively low numbers or observed in commercial catches but not encountered in later years.

Appeared: Species not present in all pre-impoundment and post-impoundment studies except after establishment of wood processing industry.

Valuable: Species present in the river and contributing at least 10% to sampled fish in terms of weight and numbers.

Permanent: Species present in all pre-impoundment and post-impoundment studies conducted on the river.

3. Results

3.1. Fish Species Composition and Status

Table 1 presents all fish species identified in both pre-industry (2000) and post-industry (2001-2006) establishment studies undertaken on the Cross river. Important freshwater species categorised as 'disappeared' include Sarotherodon melanopleura, H.fasciatus, (Cichlidae); Mormyrus rume, Mormyrus tapirus, M. anguilloides, P. bovei, G. cyprinoides, G. senegalensis, H. occidentalis, M. isidori (Mormyridae); Hydrocyanus vittatus, Bricynus macrolepidotus, Bricynus chaperi (Characidae); Polypterus senegalensis, Polypterus endlicheri, Calamoichthys calabaricus (Polypteridae) (**Table 2**). while three species namely Synodontis violaceus (Mochokidae); Chrysichthys maurus (Bagridae) and Tilapia monody (Cichlidae) appeared in the Cross River for the first time. These species are grouped as 'appeared' in this study.

Table 1. List of species identified in Cross River during the 13 years of study.

Family/species	1997	2000	2003	2006	2010
Cichlidae					
Oreochromis niloticus	***	***	*	*	**
Tilapia galilaeus	**	**	*	*	**
Tilapia mariae	*	*	*	*	*
Tilapia zilli	**	**	*	*	*
Tilapia monody			*		*
Sarotherodon galilaeus	**	**	*	*	*
Sarotherodon melanopleura	*	*	*		
Sarotherodon melanotheron	**	*	*	*	*
Hemichromis fasciatus	*	*			*
Hemichromis bimaculatus	*	*		*	*
Protopteridae					
Protopterus annectens	**	**			*
Polypteridae					
Polypterus senegalus	*				*
Polypterus endlicheri	*	*			
Calamoichthys calabaricus	**	**			
Denticeptidae					
Denticeps clupeoides	**	*			*

Distichodontidae					
Distichodus rostratus	*	*	*	*	*
Clupeidae					
Cynothrissa sp	**	**	*	*	*
Pellonula vorax	*	**			
Osteoglossidae					
Heterotis niloticus	**	**	*	*	**
Mormyridae					
Mormyrus rume	**	**	*		**
Mormyrus deliciosus	**	**	*	*	*
Mormyrus tapirus	*	*		*	*
Mormyrops anguilloides	*	*			
Petrocephalus bovei	**	**			**
Petrocephalus. Ansorgii	**	**	*	*	*
Gnathonemus cyprinoides	*	*			*
Gnathonemus senegalensis		*			
Hyperopisus occidentalis	*	*	*		
Marcusenius isidori	*				*
Marcusenius psittacus					*
Hepsetidae					
Hepsetus odoe	*	**			*
Characidae					
Hydrocyanus vittatus	*	*			*
Bricynus nurse	**	**	*	*	*
Brycinus chaperi	**	*			
Bricynus macrolepidotus	*	**	*		*
Clariidae					
Clarias anguillaris	***	***	**	**	**
Clarias cameronensis	**	**	**	**	**
Clarias gariepinus	**	**	**	**	**
Clarias pachynema	*	*			
Clarias aboinensis	*	*	*	*	*
Heterobrachus longifilis	**	**	*	*	*
Heterobranchus bidorsalis	*	*	*	*	*
Bagridae					
Bagrus docmak	*	*		*	*
Bagrus bayad	**	**	*	*	*
Chrysichthys auratus	***	***	*	*	**
Chrysichthys nigrodigitatus	***	***	*	*	**
Chrysichthys walker	*	*	*	*	*

Chrysichthys furcatus	*	*	*	*	*
Chrysichthys maurus			*	*	*
Chrysichthys filamentosus	**	**			*
Mochokidae					
Synodontis membranaceus	***	**			*
Synodontis omias	*	*	*		
Synodontis rabbianus	*	*	*		*
Synodontis nigrita	*	*	*	*	*
Synodontis schall	***	***			**
Synodontis obesus	**	**	*	*	*
Synodontis courteti	*	*	*		
Synodontis eupterus	*	*			*
Synodontis gambiensis					*
Synodontis ocellifer	*	*			
Synodontis velifer	*	*			
Synodontis sorex	*	*			*
Synodontis violaceus			*	*	*
Malapteruridae					
Malapterus electricus	*	*	*	*	*
Cyprinidae					
Barbus occidentalis	**	**	*	*	*
Barilius senegalensis	*	*	*		
Barbus macrops	*				
Barilius loati	*	*			
Labeo coubie	*	*	*	*	*
Labeo senegalensis	*	*	*	*	*
Labeo parvus	*	*	*	*	*
Schilbeidae					
Eutropius niloticus	**	**	*	*	*
Eutropius micropogon	**	**	*	*	*
Schilbe mystus	**	*	*	*	*
Schilbe intermedius	*	*			*
Charanidae					
Parachanna obscura	*	*	*	*	*
Centropomidae					
Lates niloticus	*	*	*		*
Icthyoboridae					
Phago loricatus	*	*			

*: Scarce, **: Common, ***: Abundant.

Table 2. Qualitative description of current status of fish species identified in Cross River during period of study.

Disappeared	Declined	Appeared	Permanent	Valuable
Cichlidae	Cichlidae	Mochokidae	Charanidae	Cichlidae
S. melanopleura	T. galilaeus	S. violaceus	P. obscura	O. niloticus
H.fasciatus	T. melanotheron	Bagridae	Cyprinidae	Clariidae
Protopteridae	Clupeidae	C. maurus	L. coubie	C. anguillaris
P. annectens	Cynothrissa sp	Cichlidae	L. senegalensis	Bagridae
Polypteridae	Osteoglossidae	T. monody	L. parvus	C. nigrodigitatus
P. senegalensis	H. niloticus		Malapteruridae	C. auratus
P. endlicheri	Mormyridae		M. electricus	Mochokidae
C. calabaricus	*M. deliciosus*		Mochokidae	S.membranaceus
Denticeptidae	P. Ansorgii		S. nigrita	
D. clupeoides	Characidae		Bagridae	
Clupeidae	B. nurse		C. furcatus	
P. vorax	Clariidae		C. walker	
Mormyridae	C. anguillaris		Clariidae	
M. rume	H. longifilis		C. aboinensis	
M. tapirus	Bagridae		C. gariepinus	
M. anguilloides	B. bayad		C. cameronensis	
P. bovei	Centropomidae		H. bidorsalis	
G. cyprinoides	L. niloticus		Distichodontidae	
G. senegalensis	Cyprinidae		D. rostratus	
H. occidentalis	B. occidentalis		Cichlidae	
M. isidori	Schilbeidae		T. mariae	
Hepsetidae	E. niloticus		T. zilli	
H. odoe	E. micropogon		S. galileus	
Characidae	S. mystus		H. bimaculatus	
H. vittatus				
B. chaperi				
B. macrolepidotus				
Clariidae				
Clarias pachynema				
Bagridae				
C. Filamentosus				
Mochokidae				
S. omias				
S. rabbianus				
S. schall				
S. courteti				
S. eupterus				
S. ocellifer				
S. velifer				
S. sorex				
Cyprinidae				
B. senegalensis				
B. macrops				
B. loati				
Schilbeidae				
S. intermedius				
Icthyoboridae				
P. loricatus				

Species grouped as 'declined' include Tilapia galilaeus, Tilapia melanotheron (Cichlidae); Cynothrissa sp (Clupeidae); H. niloticus (Osteoglossidae), Mormyrus deliciosus, Petrocephalus ansorgii (Mormyridae); Bricynus nurse (Characidae); Heterobranchus longifilis (Clariidae) Bagrus bayad, Synodontis obesus (Mochokidae); Barbus occidentalis (Cyprinidae); Eutropius niloticus, Eutropius macropogon (schilbeidae). 5 fish species which have been grouped as 'valuable' in the Cross River are Oreochromis niloticus (Cichlidae), Clarias anguillaris (Clariidae), C. auratus, C. nigrodigitatus (Bagridae); and Synodontis membranaceus (Mochokidae). Chysichthys furcatus, Chrysichthys walker (Bagridae); Clarias aboinensis, Clarias gariepinuss (Clariidae); Tilapia mariae (Cichlidae) were grouped as permanent.

3.2. Changes in the Length-Weight Relationship and Condition Factor

Before establishment of wood processing industry distribution of values of allometry coefficient (b) ranged between 1.2 and 3.65 and mean b-value for all the species was 2.64 ± 0.32 and the mode; 3.5 (**Figure 2**). These values diminished considerably after six years to a range from 1.2 - 2.2, mean value of 1.82 ± 0.23 and mode of 2.0. The distribution of b values after six years deviate significantly from the cube value (b = 3, P > 0.05). The condition factor of the fish sampled varied from 0.53 to 1.30 with mean value of 0.772 ± 0.12, mode; 1.20 and median; 0.72 to a range between 0.22 and 0.62 with mean 0.45 ± 0.06, mode; 0.55 and median 0.40 (**Figure 3**).

3.3. Changes in Food Habit Groups of Fishes

Analysis of frequency of occurrence of food objects in the different fish families showed that intake of phytoplankton, fish fry, insects, crustaceans and mollusk declined six years after the establishment of the industry (**Table 3**). Ingestion of detritus, seeds, fish parts and macrophytes increased considerably.

3.4. Distribution of Major Food Items in the Study Area

Distribution of four selected fish species and their prey indicated that these fish were predominantly located in a few specific areas six years after the establishment of the industry (**Table 4**). *Nymphaea* and *spirogyra* are the main diet of *O. niloticus* in the pre-industry era (2000) and it was found that these food items were distributed in reaches II and I respectively with a percentage occurrence of between 0.1% - 10.0% for spirogyra and 0.1% - 20.0% for nymphaea. Meanwhile, for *H. niloticus*, Reach I and II had the highest abundance of *spirogyra* and *nymphaea* respectively with the percent abundance of 0.1 - 20.0% for *spyrogyra* and 0.1% - 10.0% for Nymphaea. *Pellonula* sp and detritus were the main diet of *C. gariepinus* and the abundance of this diet was higher in Reach I and III respectively. *C. nigrodigitatus* consumed mainly *Macrobrachium* sp and *Nertina* sp distributed predominantly in Reach II and III respectively. However, nine years after, major food items in the diet of all the main fish species were detritus and macrophytes particularly in Reach I.

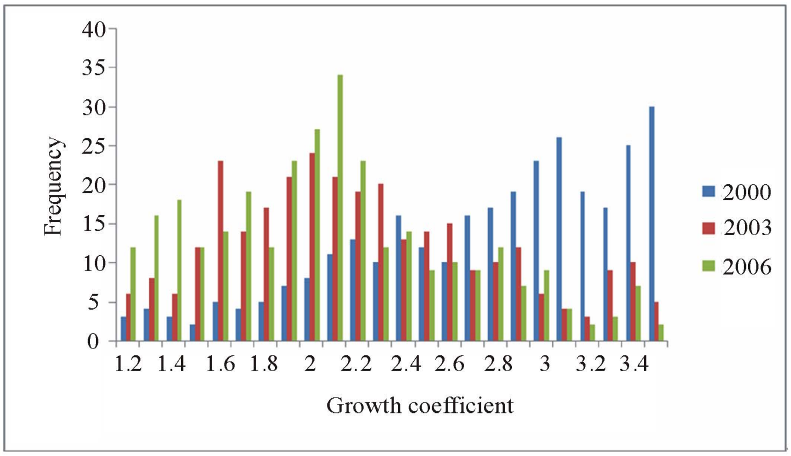

Figure 2. Changes in the frequency of the mean growth coefficient of the fish community.

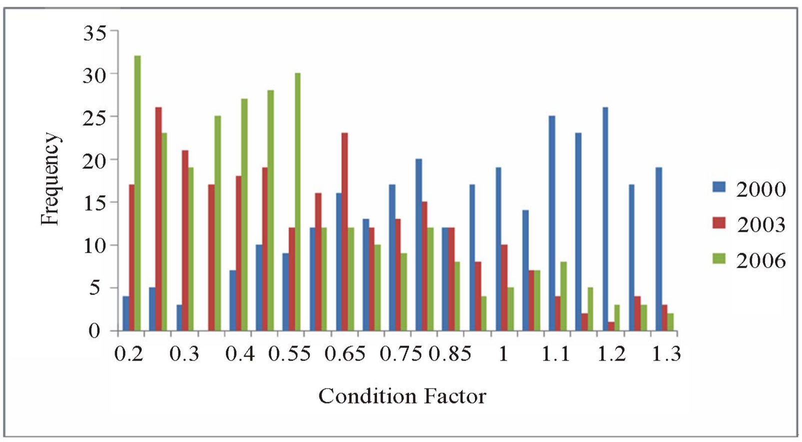

Figure 3. Changes in the frequency of the mean condition factor of the fish community during six years.

Table 3. Changes in the food habits in the different fish families.

	Feeding habits during pre and post establishment of wood industry				
Fish families	1997	2000	2003	2006	2010
Cichlidae	Phytoplankton 43%	Phytoplankton 15% Macrophytes 28%	Phytoplankton 5% Macrophytes 34%	Macrophytes 33% Detritus 21%	Phytoplankton 29% Macrophytes 8%
Cyprinidae	Phytoplankton 24%	Phytoplankton 10% Seeds 34%	Seeds 37% Detritus 40%	Seeds 23% Detritus 44%	Phytoplankton 17% Detritus 32%
Bagridae	Mollusk 33% Crustacea 25%	Fish parts 38% Mollusk 15% Crustacean 8%	Fish parts 40% Detritus 32%	Fish parts 34% Detritus 44%	Molluscs 10% Fish fry 39% Crustacean 18%
Clariidae	Fish fry 34%	Fish fry 10% Fishparts 29%	Fish parts 39% Macrophytes 21% Detritus 23%	Fish parts 31% Macrophytes 33% Worms 10%	Fish fry 28% Detritus 18%
Schilbeidae	Detritus 41%	Detritus 51%	Detritus 45%	Detritus 40%	Detritus 34% Insects 24% Fish fry 12%
Mormyridae	Detritus 22%	Detritus 32%	Detritus 44%	Detritus 39% Seeds 23%	Detritus 24% Worms 18%
Clupeidae	Insects 20%	Insects 6% Worms 21%	Detritus 23%	Detritus 34%	Insects 28% Fish fry 20%
Osteoglossidae	Insects 15% Macrophytes 13%	Insects 8% Macrophytes 24%	Seeds 40% Macrophytes 21%	Seeds 32% Macrophytes 28%	Seeds 12% Insects 27% Macrophytes 23%
Distichodontidae	Insects 12%	1nsects 5% Detritus 24%	Detritus 32%	Detritus 42%	Detritus 12% Insects 18%
Mokochidae	Insects 10%	Insects 3% Detritus 23%	Detritus 25%	Detritus 31%	Insects 25%

Table 4. Distribution of dominant preys with reaches (in parenthesis). Or: *Oreochromis niloticus*, Cl: *Clarias gariepinus*, Ch: *Chrysichthys nigrodigitatus*, He: *Heterotis niloticus*, La: *Labeo coubie*, Br: *Bricynus sp*.

Fish species	Or	Cl	Ch	He	La	Br
No of fish	220	190	201	118	136	343
Empty stomach	0		0	12	171	
Food items						
Crustacea						
Macrobrachium		0.1 - 20.0(III) 2006	0.1 - 10.0(II) 2000			
Insecta						
Dipteran adult		0.1 - 20.0	0.1 - 20.0(I) 2006	0.1 - 20.0(I) 2000	0.1 - 10.0(III)	
Molluscs						
Nertina sp			0.1 - 20.0(III) 2000			
Fish (prey)						
Pellonula sp		0.1 - 20.0(I) 2000	0.1 - 20.0(I) 2006			
Plants						
Nymphaea	0.1 - 20.0(II) 2000	0.1 - 20.0(I) 2006	0.0 - 20.0(I) 2006	0.1 - 20.0(I) 2000	0.1 - 10.0(II)	
Spirogyra	0.1 - 10.0(I) 2000			0.1 - 10.0(II) 2000		
Detritus	0.1 - 20.0(I) 2006	0.1 - 10.0(I) 2006	0.1 - 20.0(I - III) 2006	0.1 - 20.0(I) 2006		

3.5. Fecundity, Egg Size and Gonadosomatic Index

Distribution of fecundity values varied from 56012 ± 5234 eggs, mode 12500 and median 58345 in 2000 to mean value 23122 ± 232 eggs, mode 2500 and median 20349 in 2006 (**Figure 4**), gonadosomatic index from 20.5 ± 3.2 eggs, mode 19.1 ± 2.2 and median 21.4 to values of

12.4 ± 2.3, mode 4.5 and median 9.5 (**Figure 5**) and egg size from mean value; 1.82 mm ± 0.07 mm, mode 2.2, and median; 1.8 to values of 0.8 mm ± 0.04 mm, mode; 1.3 and median 1.1 (**Figure 6**) and respectively.

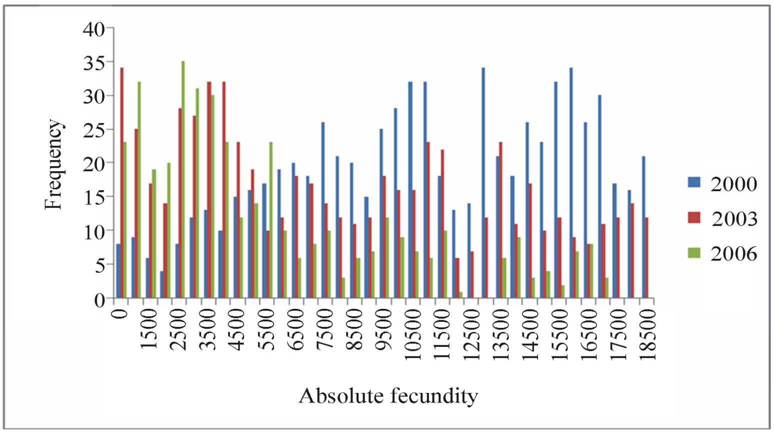

Figure 4. Changes in the frequency distribution of fecundity of the fish species during the six years.

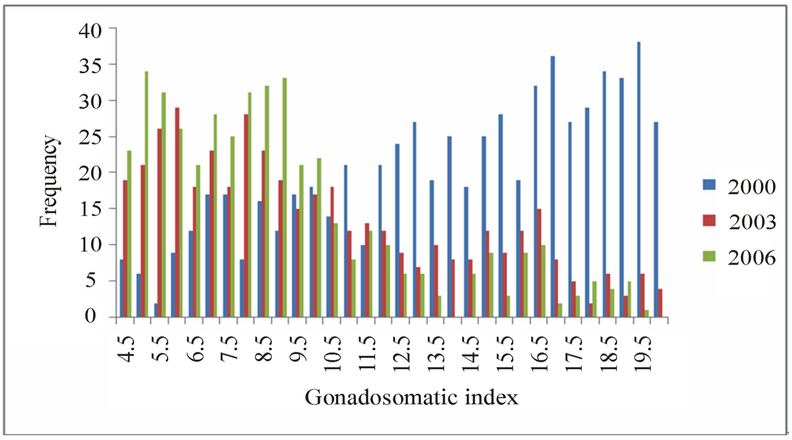

Figure 5. Changes in the frequency distribution of the gonadosomatic index of fish species during the six years.

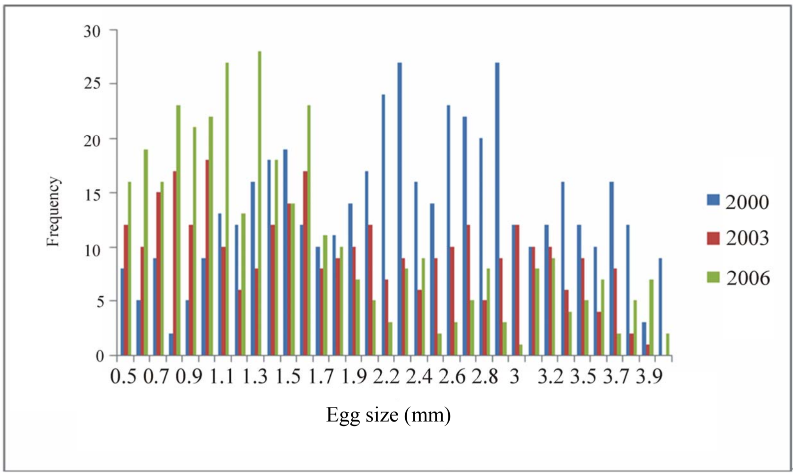

Figure 6. Changes in the frequency distribution of egg sizes of fish species during the six years.

4. Discussion

4.1. Changes in Fish Species Composition and Status

The list of fishes shown in this study is the current fish assemblage in the Cross River as a result of restructuring of the communities that previously occupied the Cross River and its floodplains by effluent from an associated wood industry and the recovery effect after closing down the industry by law. Disappearance of some components of the original fish community and alterations in the abundance of some species has resulted in the current fish assemblage. It has been reported [32] that wood factory waste are toxic when they cover the bottoms of water bodies, they decrease the amount of pH and dissolved oxygen. The lower pH range could be as a result of high acid content of organic effluents from the wood processing factory located upriver. This could lead to the disintegration of the river ecosystem resulting in the decline or disappearance of those species whose life cycles have been disrupted by these changes. The fish community of the Cross River appears to have been gradually transformed from those adapted to unpolluted river conditions to those adapted to polluted conditions. It was shown that the disintegration of river ecosystem has led to a reduction in the number of fish species in the world's watersheds [33].

Species which were predominant one year before establishment of wood processing industry appear to have been affected by changes in the physical and chemical conditions of the water following effluents and this had led to species either disappearing or becoming reduced considerably in terms of numbers. The once abundant but now scarce fish species give indication of changes in fish populations and relative abundance in Cross River. This observation could result from the fact that these species experienced the greatest natural mortality during the early years of establishing the wood processing industry because most of them were at top level of the food chain resulting in a faster decline in their abundance.

In the different years fish species sampled were 72 (1997), 70 (2000), 46 (2003), 36 (2006) and 62 (2010) indicating that the fish species composition of the Cross River was undergoing changes. This observation could be attributed to the disappearance of fish species from the river due to disintegration of the river ecosystem and alteration of living conditions after establishment of industry. Fish species whose life cycles have been particularly disrupted by the establishment of industry are unable to adapt to new conditions and may disappear from the community [34]. The disappearance of fish species from the Cross River within the short time still raises conservation concerns, especially when as many as thirty six even species were involved.

4.2. Changes in Relative Abundance of Fish Species

Many fish species adapt to environmental changes in water bodies to varying degrees and continue to exist at changed abundance [35]. Whereas some species have maintained their populations at about the same level when compared with the pre-industry period, others have declined while others have increased in their numbers as a result of favourable environmental changes. Changes in relative abundance are underpinned by alteration of the existing ecological and biophysical processes after establishment of industry such as the obvious reduction in the population of invertebrates and the invasion of aquatic weeds upriver close to effluent point. The industrial effluents created new conditions that were favourable to herbivorous fish species and detritus species which responded with increase in numbers of individuals and total biomass [35-38]. Some of these fish species include *Labeo coubie, Clarias aboinensis, Clarias cameronensis, Tilapia mariae, Distodontus rostratus, Heterobranchus bidorsalis and Malapterurus electricus.* The conditions created in the Cross river by the industrial effluents appeared to have been unfavourable to some fish species such as *T melonotheron, H niloticus, Cynotrissa sp, M deliciosus, P ansorgii, B. occidentalis and B. Bayad, Lates niloticus, Labeo spp and Bagrus* spp. resulting in their decline. The effluents could have contaminated food supply and their spawning grounds. On the other hand, Cichlidae (*Oreochromis niloticus*) Bagridae (mainly (*Chrysichthys nigrodigitatus* and C. *auratus*), Clariidae (*Clarias anguillaris*) and Mochokidae (*S. Schall* and *S. membranaceus*) have currently emerged as most important. Notwithstanding the general decline in relative abundance of Bagrids, however, *Chrysichthys nigrodigitatus* has continued to remain most abundant species in terms of number even after the period of existence of the wood processing industry. The reason for the extreme proliferation of this species is not clear despite a common phenomenon in tropical water bodies that no one species dominates the fishery for a long time hence it is expected that over time other species apart from *Chrysichthys nigrodigitatus* are suppose to dominate the Cross River fish community. In terms of numbers, Cichlids have declined slightly in relative abundance compared with pre-industry figures. Of the Cichlids in the Cross River, *Tilapia melanotheron* was not doing well in relative abundance compared with *T. mariae* over the period of existence of the industry, a situation which is similar to what pertained in the Weija Reservoir after 28 years of impoundment [39].

4.3. Changes in the Length-Weight Relationship and Condition Factor

Seventy six percent of the species presented in this study exhibited a trend of isometric growth (b = 3) depicting dimensional equality before the establishment of wood processing industry [24]. This trend contrast greatly from the species during the existence of the industry where the pattern indicated an acute negative allometry. This may be attributed to the change in ecological parameters at the freshwater environment after establishment of the industry in which these species have carved their ideal niche. The riverine environment is characterized mainly by high oxygen content, low salinity, high nutrient content and higher productivity in contrast to the contaminated post-industry condition [40]. To counter the scarcity of nutritional resources at post-industry establishment somatic growth is less important and energy is diverted to reproductive processes [41]. The general trend of negative allometry exhibited by some most fish species after establishment of industry compared to the isometry observed in most of the species in the study area before existence of industry may be regarded as floodplain adaptations to survive in the polluted river.

The fact that 65% of the entire 78 species examined had condition factor above mean and that the overall mean condition factor did not significantly deviate from the value of 1.0 showed that the majority of the fish in the populations of Cross River inland wetlands were in good condition before the establishment of wood processing industry, thus justifying the dimensional equality of their growth pattern. The high condition factor of the fish species in the river pre-industry era is an indication of abundant food. Low condition factor showed during existence of industry indicates that food resources had diminished.

4.4. Changes in Food Habit Groups of Fishes

Though herbivores and detritivores were the least important in terms of weight and numbers in pre industry establishment studies undertaken in the Cross River, they have currently increased significantly in numbers and weight becoming the most important in terms of numbers. From reports of studies undertaken after establishment of industry, benthic carnivores have declined in their importance probably due to contamination by effluents that have reduced food resources and spawning grounds for benthic and pelagic invertebrates and fish preys. Further downstream in Reaches II and III, however, benthic omnivores have continued in their importance and have maintained their dominance in the Cross River. The omnivores together (i.e. both semi pelagic and benthic omnivores) have, however, become most important in the Cross River after the existence of the industry.

Importance of herbivores after six years of the existence of the industry has increased considerably compared with the period before the establishment of industry, possibly due to declining food sources.

The composition of piscivores after six years of establishment of wood industry declined compared with one year pre industry existence. The general decline in the importance of piscivores in the Cross River during the period of existence of industry could be attributed partly to the disappearance of some piscivorous fishes as well as their restricted distribution due to decline of fish preys and their preference for unpolluted river conditions which have reduced over the period of existence of the industry. *Clarias gariepinus* has maintained its importance as a "fish-eating fish" in the Cross River during the period of existence of wood industry whereas *Hemichromis fasciatus* has disappeared and *Clarias anguillaris* has declined in abundance. The wider food spectrum exhibited by *C. anguillaris* , *C. nigrodigitatus* and *O. niloticus* revealed trophic flexibility [42]. The ecological advantage of this is that it enables a fish to switch from one category of food to another in response to fluctuation in their abundance. Another advantage is the ability of the species to utilize many different food objects effectively and this probably accounts for their higher abundance in the study area during pre-industry period [43,44].

The fact that detritus dominated the gut contents of the freshwater species in the study area during the existence of the industry implied that most of the fish species in the Cross River inland wetlands are detritivores during this period.

4.5. Fecundity, Gonadosomatic Index and Egg Size

Disparity was noted between fecundity of fish in this study area before establishment of industry and that of fish populations six years after the existence of the industry. The higher values of fecundity among populations before establishment of industry can be attributed to the greater abundance of food in the river pre-industry period. Pre-industry fish species of the Cross River were therefore more superior than post-industry and can be better broodstocks in the farms. Such related differences in fecundity had been observed [45-48] and were attributed to environmental factors such as differential abundance of food and water quality.

Fecundity may be reduced if individual fish mature at a smaller size, and individuals in poorer condition may experience increased mortality during environmentally stressful period [49]. Small egg size implies that survival rate of the progeny will be low [29]. Therefore, the larger egg sizes of fish species during pre-industry period implied that pre-industry Cross River provided more suitable habitat for the species.

The low GSI, fecundity and variation in the egg sizes observed for species during post-industry period may be attributed to the sudden change in the environmental factors due to effluents discharged from the wood processing industry. Similar observations have been reported [50]. A change in the environmental factors results in significant changes in the egg size [51]. The implication of these results is that the reproductive potential of fish species in Cross River is greatly affected by the environmental factors and human activities.

REFERENCES

[1] Food and Agriculture Orgnization (FAO), African Fisheries and the Environment: in Food and Agriculture Organization of the United Nations, Italy, 1991.

[2] J. Elkington, "Beware of the Wrath of Dsiris," *New Science*, Vol. 68, 1975, pp. 626-268.

[3] R. L. Welcome, "River Fisheries," *FAO Fisheries Technical Paper*, Vol. 262, 1985, pp. 330.

[4] Food and Agriculture Organization (FAO), "Role of Fisheries Technology in Development of Inland Floodplain in Africa," In: Symposium on River and Floodplain Fisheries in Africa, CIFA Technical Paper, No. 5, 1988, pp. 12-18.

[5] Food and Agriculture Organization (FAO), Training for Agriculture and Rural Development, Rome, 1986.

[6] B. D. Olaosebikan and A. Raji, "Field Guide to the Nigerian Fresh Water Fishes," Federal College of Freshwater Fisheries Technology, New Bussa, Nigeria, 1998.

[7] Federal Department of Fisheries, Presentation on the Fisheries Sub-Sector at the Presidential Forum, Abuja, 2003.

[8] D. M. Jamu and O. A. Ayinla, "Potential for the Development of Aquaculture in Africa," NAGA, Vol. 693, 2003, pp. 9-13.

[9] R. P. King, "New Observations on the Trophic Ecology of Liza Grandisquamis (Valenciennes, 1836) (Pisces: Mugillidae), in the Bonny River, Niger Delta, Nigeria," Cybium, Vol. 12, No. 1, 1988, pp. 23-36.

[10] P. M. Rosenberg, H. V. Danks and D. M. Lemhkyhi, "Importance of Insects in Environmental Impact Assessment," *Environmental Management*, Vol. 10, 1986, pp. 773-783.

[11] N. S. Clair, L. M. Perry and F. P. Gene, "Chemistry for Environmental Engineering and Science," 5th Edition, Mcgraw-Hill, New York, 2003.

[12] Federal Environmental Protection Agency, Our National Environmental Goals, Special Publication No.3, Lagos, 1989.

[13] E. O. Ita, "Inland Fisheries Resources of Nigeria," CIFA, Food and Agriculture Orgnization, Rome, 1993.

[14] I. A. Butt, Report on the Industrial Pollution of Jakara Dam. Ministry of Health, Kano State, Nigeria, 1985.

[15] H. A. Adeniji and I. G. Mbagwu, Study of Physico-Chemical Characteristic of Some Heavy Metals in Jankara Reservoir, NIFFR Annual Report, Kano State, 1990.

[16] E. O. Anko and A. A. Eyo, "Fisheries Department, Ministry of Agric. Nigeria with Special Reference to Cross River State," *Abstracts of the 17th Annual Conference of Fisheries Society of Nigeria* (*FISON*), 2001.

[17] American Public Health Association, Standard Methods for the Examination of Water and Waste Water, Washington D.C., 1987.

[18] M. Elvira, "Taxonomic Revision of the Genus Chondrostoma Agassi 1835 (Pisces: Cyprinidae)," Cybium, Vol. 11, 1987, pp. 111-198.

[19] F. Erk'akan, T. T. Nalbant and S. C. Ozeren, "Seven New Species of Barbatula Three New Species of Schistura and a New Species of Seminemacheilus (Ortariophysi: Balitoridae: Nemachellinae) from Turkey," *Journal of Fisheries International*, Vol. 2, 2007, pp.69-85.

[20] G. G. Teugel, "Prelimnary Results of Morphological Study of Five African Species of the Subgenus Clarias (Pisces: Clariidae)," *Journal of Natural History*,Vol. 16, 1982, pp. 439. doi:10.1080/00222938200770351

[21] W. Fischer, M. Schneider and M. L. Bauchot, "Mediterranee et Mer Noire Zone De Peche 37," Revision 1, Volumn II, Vertebres, Rome, 1987.

[22] D. Pauly, "Fish Population Dynamics in Tropical Water: A Manual for Use with Programmable Calculators," *Iclarm Studies and Reviews*, Vol.8, 1984, pp.325.

[23] J. A. Zar, "Biostatistical Analysis," Prentice Hall, New Jersey, 1984.

[24] W. E. Ricker, "Computations and Interpretations of Biological Statistics of Fish Populations," Bulletin of the Fisheries Research Board of Canada, Vol. 191, 1975, pp. 201-210.

[25] V. O. Sagua, "Aquaculture and Fisheries Development in Nigeria," *The 12th Annual Conference of Agriculture Society of Nigeria*, University of Ife, 1979.

[26] A. C. Simpson, "The Fecundity of Plaice," UK Ministry of Agriculture and Fisheries, Fisheries and Food Investigation, Vol. 217, 1951, pp. 3-27.

[27] T. B. Bagenal, "Age and Growth," In: T. B. Bagenal, Ed., *Fish Production in Freshwater*, Blackwell, Oxford, London, 1978, pp. 120-128.

[28] V. L. DE Vlaming, "The Effect of Temperature and Photoperiod on Reproductive Cycling in the Estuarine Gobiid Fish (Gillichthys mirabilis)," *Fishery Bulletin*, Vol. 73, 1982, pp. 1137-1157.

[29] A. M. A. Imevbore, "Some preliminary observation on the sex-ratio and fecundity of the fish in River Niger," In: S. A. Vissar, Ed., *Kainji—A Nigerian Man-Made Lake*, NISER, Ibadan, 1970.

[30] P. B. Bayley, Caracteristicas de inundacion de los rios y areas de Captacion en la Amazonia peruana. Inf. No. 81 Institute del mar del peru (IMARPE), Peru, 1981.

[31] P. McCully, "Silenced Rivers: The Ecology and Politics of Large Dams," Zed Books Ltd., 1996.

[32] T. Bhukaswan, "Management of Asian Reservoir Fisheries," *FAO Fisheries Technical Paper*, Vol. 207, Rome, 1980.

[33] W. A. Evans and J. Vanderpuye, "Early Development of the Fish Populations and Fisheries of Volta Lake," *Geophysical Monograph*, Vol. 17, 1973, pp. 114-120. doi:10.1029/GM017p0114

[34] E. K. Balon and A. G. Coche, "Lake Kariba, a Man-Made Ecosystem in Central Africa," *Monographiae Biologicae*, Vol. 24, 1974, pp. 767.

[35] T. Petr, "Hydrobiology and Fisheries Problems of the Nyumba ya Mungu Man-Made Lake in Tanzania," *The African Journal of Tropical Hydrobiology and Fisheries*, Vol. 4, No. 1, 1975, pp. 39-50.

[36] T. Quarcoopome and F. K. Y. Amevenku, "Fish Fauna of the Weija Reservoir—28 Years After Impoundment," CSIR-WRI Technical Report, 2006.

[37] M. Abhijit, "Origin and Evolution the Deep-Sea Fauna," *Journal of the Indian Ocean*, Vol. 5, pp. 251-253.

[38] P. A. Large, P. Loranze and J. G. Pope, "Survey Estimates of the Overall Size Composition of the Deep-Sea Fish Species before and after Exploitation," ICES, Center for Environment, Fisheries and Aquacultural Sciences, Lowesoft, U.K., 1999.

[39] R. J. Wooton, "The Effect of Size of Food Ration on Egg Production in the Female Three-Spined Stickleback, Gasterosteus Aculeatus," *The Journal of Fish Biology*, Vol. 5, 1979, pp. 89-96.

[40] R. P. King, O. M. Udodiong, E. C. Ekwali and N. A. Nkanta, "Some Aspects of the Trophic Biology of Iiisha Africana (Teleostei, Pristigasteridae) in Qua Iboe Estuary, Nigeria," *African Journal of Ecology*, Vol. 105, 1991, pp. 261-274.

[41] E. R. Akpan, "Seasonal Variability in Phytoplankton Biomass in Relation to Physico-Chemical Changes in the Cross River Estuaries of Eastern Nigeria Ph.D Thesis," University of Calabar, 1994.

[42] G. A. Rounsefell and W. H. Everhart, "Fishery Science, its Methods and Applications," John Wiley and Sons Inc., New York, 1957.

[43] T. K. Pitt, "Fecundity of American Plaice, Hippoglossoides Platessoides (F) Fromgrand Bank and New Found Land Areas," *Journal of the Fisheries Research Board of Canada*, Vol. 21, 1964, pp. 507-512.

[44] F. Nagasaki, "The Fecundity of Pacific Herring, Clupea Pallasi, in British Columbia Coastal Waters," *Journal of the Fisheries Research Board of Canada*, Vol. 15, 1958, pp. 313-330.

[45] S. S. E. Palacious, Estudio biologico pesquero de la tilapia Oreochromis aureus (Steindachner, 1864) en la Presa Benito Juarez, Oaxaca, Mexico, en 1993, Ciencia Pesquera, No. 11, 1995, pp. 54-61.

[46] B. J. Shuter, J. A. MacLean, F. E. J. Fry and H. A. Regier, "Stochastic Simulation of Temperature Effects on First-Year Survival of Small-Mouth Bass," *Transactions of the American Fisheries Society*, Vol. 109, 1980, pp. 1-34.

[47] F. E. Asuquo, E. E. Ntekim, A. O. Eja, A. O. Ekwu, O. O. Ogri and E. S. Bassey, "Post Impact Assessment of Cross River Coastal Areas Affected by Mobil (Idoho) Oil Spillage," Report submitted to Cross River State Government, 1998.

[48] W. O. Odiete, Environmental Physiology of Animals and Pollution, Diversified Resources, Lagos, 1999.

