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Analysis of Potential Effects of the Idoho-QIT Oil Spill on River-Estuarine Fisheries in Nigeria

Larry E.D. Inyang[1], Gloria E. Essien.[1], B.S. Moses[2], Erich R. Gundlach[3]
Edward S. Gilfillan[4] and David S. Page[5]

[1] Mobil Producing Nigeria Ultd. Mobil House, Lekki Expressway, Victoria Island, PMB 12054, Lagos, Nigeria;
[2] Dept of Fisheries, Faculty of Agriculture, University of Uyo, Uyo, Akwa-Ibom State, Nigeria; [3] E-Tech International Inc., P.O. Box 2976. Acton, MA 01720 USA;
[4] Bowdoin College, Environmental Studies Program, Brunswick, Maine 04011 USA;
[5] Bowdoin College, Chemistry Department, Brunswick, Maine 04011 USA.

Abstract

The rupture of a 24-inch pipeline offshore of the Mobil Qua Iboe Terminal (QIT) on 12 January 1998 resulted in the release of approximately 40,000 bbls of light Nigerian crude oil. Most of the oil was dispersed by natural process and applied dispersants (299 bbls). Contact with the shoreline and estuaries of Nigeria was fortunately very limited. To determine the possible effects of the spill, a number of short and long term scientific, health related and socio-economic studies were undertaken. This report focuses on the evaluation of artisanal river-mouth fisheries using pre-spill data, data obtained during the spill and then 9-12 months later. For this analysis we reviewed catch rates, fisheries composition and fish-tissue chemistry.

Catch rates in the spill zone and control areas were within the historical range of expected rainy season values. No significant differences were found in species composition values for this study and those expected for the rainy season. Regarding fisheries composition, an extensive sampling program found a rich and diverse fish population in both the spill zone and control areas, indicating no detectable effects of the spill. The analysis of metals in fish tissue found that concentrations of Cu, Pb, Cd, Zn, Hg, Ni and V below the limits recommended by FAO (1983). None of these metals are indicative of petroleum in fish tissues. Total lipids in up to 26 fish species sampled were well below the 25-ppm GESAMP standard and showed no increase in spill zone samples as compared with control samples.

1. Introduction

The term "artisanal fisheries" refers to the small scale, labour intensive fishing carried out by local fishers who are unable to acquire large industrial fishing boats (e.g. trawlers) and so have to make do with traditional dugout canoes as the craft and unsophisticated unmechanized fishing gear. Such fishers confine their operations to the shallow inshore waters (lagoons, estuaries/river mouths and the shallow low salinity coastal strip). Even though the productivity of, and incomes derived from such fisheries are generally low, small-scale fisheries account for about 45 percent of the world's fish catch (McGoodwin, 1984); nearly all the production from the sector is used for human consumption. Nigerian fisheries are predominantly at the artisanal level and landings from the inshore waters constitute, on the average 84.6% of the country's total salt water fish output. Artisanal fisheries and the fish populations exploited by these fisheries are sensitive to degraded habitats as a result of pollution from multiple sources.

The Mobil Idoho-QIT oil spill of 12 January 1998, approximately 40,000 barrels of crude oil into the Nigerian offshore waters. The Mobil Producing Nigeria Unlimited (MPN) at that time took immediate steps to assess the extent of the spread of the oil and the effect of the oil on the aquatic ecosystems and resources, including measurement of total lipids in estuarine/river mouth fishes and of fisheries populations in the study area. The longer-term studies, which were undertaken nine months after the spill, aimed at acquiring data on catch rates, species diversity and composition, growth and mortality parameters, gonad development and fecundity of the exploited fish stocks and the concentrations of trace (heavy) metals (HM) and total hydrocarbon (THC) in fish tissues. By comparing the acquired information with historical data, the impact of the spill on the fish population and fisheries could be assessed.

The fisheries study was a part of a comprehensive injury assessment/recovery study carried out immediately after the spill and 9 months post-spill. It compared the results of chemical and biological measurements at shoreline and offshore sampling stations within the spill zone and outside the spill zone (see Olagbende, etal., 1999a, 1999b, Abasiekong, et al., 1999). In addition, the socio-economic, fisheries and human health components of this study compared pre-spill and post-spill data as well as spill zone/non-spill zone data. No effect of the spill on shoreline and offshore communities was detected. In addition, the socio-economic, fisheries and human health components of this study compared pre-spill and post-spill data as well as spill zone/non-spill zone data.

2. METHODOLOGY

2.1 Field Work

Two lagoon systems (Badagry and Lagos) and nine estuaries/river mouths (Escravos, Forcados, Brass, Nun, Bonny, Andoni, Imo, Qua Iboe and Cross) were sampled during the period 15th September to 27th October 1998 (see Table 1). At each sampling locations two fishing units that were landing fish during the visit were randomly selected for detailed catch assessment survey (CAS) to obtain the total quantity (number and weight) of each species of fish caught, the number of fishers operating the unit, type of gear used by the unit and the total length (TL) and weight (W) of the individuals of the various species. A fishing unit (FU) consisted of a canoe, the fishers in it and the fishing equipment - gear, floats, sinkers, anchors and outboard motor or paddles.

Table 1. Field Work Schedule.

ZONE	LOCATION	STUDY TEAM & DATE	SAMPLING SITE
LAGOS	Badagry Lagoon Lagos Lagoon	Lagos 15-17/9/98	Badagry Beach by road Ajah Ilaje Beach (off Ekpe Expressway) and Maroko beach Market
DELTA	River Escravos River Farcados	Warri 17-22/9/98	Between Ndadagho and Kpokpo Between Burutu and Farcados
BAYELAS	River Brass	Yenagoa	Brass Estuary

	River Nun	22-26/9/98	Nun Estuary
RIVERS	River Bonny River Andoni	Port Harcourt 26-30/9/98	Bonny Estuary between Iyongile/ Okolobie and Bonny Andoni Estuary-Andoni Flats
AKWA IBOM	River Imo River Qua Iboe River Cross	Ikot Abasi 01-05/10/98 Eket 05-08/10/98 Uyo 08-11/10/98	Uta Ewa & WHYDAH Beaches; ATC beach Upenikang/Iwoachang Beaches Ibaka/Jamestown beach
CROSS RIVER	Calabar/Cross River		Fishing unit operating Tobacco-Parrot Islands, survey at Nsidung beach, Calabar
LAGOS	Lagos Lagoon	Lagos 27-29/10/98	This trip was repeated privately to replace fish samples lost through lack of sufficient ice between Lagos and Warri during 1st trip.

A set of 5 randomly selected individuals of 5 species chosen from among the following commonly caught fishes: *Chloroscombrus chrysurus, Chrysichthys nigrodigitatus, Ethmalosa fimbriata, Ilisha africana, Sardinella maderensis, Pomadasys jubelini, Liza grandisquamis, Polydactylus quadrifilis, Pseudotolithus elongatus and Tilapia guineenisis,* were purchased at each sampling station for use in the biological studies; similarly a set of 5 individuals of 6-7 species were purchased for use in the determination of the tissue concentrations of HM and THC.

Samples for biological studies were either chilled in ice or preserved in 10% formalin before they were transported to the laboratory. Samples for tissue analysis were chilled in ice, transported in plastic containers (for HM analysis) and glass containers (for THC analysis) and transferred to a deep freezer as soon as they reached the laboratory. Before freezing each specimen was cleansed and labeled after measuring the weight (to the nearest 1.0g for larger specimens and 0.1g for smaller ones and total length (TL) and standard length (SL) to the nearest 1.0cm for larger specimens and 0.1cm for smaller fish).

2.2 LABORATORY ANALYSIS

2.2.1 Analysis of catch rates

Mean catch by species per trip per fishing unit (FU) was calculated from the data and extrapolated to cash per FU/mo (see Bazigos 1974, Moses 1992, Moses 1997). The degree of effective contribution of each species to the overall catch in each zone was computed as the index of preponderance (IP) (Nataragan and Jhingram, 1961, Gulland, 1969, Moses, 1987) which takes account of both number and weight, thus:

$$IP = 100(\%N.\%W)/\Sigma(\%N.\%W) \quad (1)$$

Where %N is the percentage of the species (by number) in the catch and %W is the percentage of the species by weight.

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2.2.2 Length-Weight Relationship and Condition Factor

The weight of fish varies as some power of the length, thus

$$W = al^b \tag{2}$$

Where W is the weight, l the length and a and b are constants. The value of b was determined empirically by regressing logW on logTL for a reasonably large number (40-150 individuals) of the relevant species covering various representative sizes, b being the slope of the fitted curve. An index of the general well-being (or "fatness") of the fish, roughly represented by the intercept, a, was computed as Fulton's condition factor (k'), thus:

$$k' = 100(w/TL^3) \tag{3}$$

2.2.3. Length-Frequency Distribution, Growth and Mortality Rates

The measured TL of the given species were grouped into a length-frequency distribution (L-FD). Mean lengths of the various (synthetic) cohorts were obtained by analyzing the L-FD using the Bhattacharya approach (Bhattacharya, 1967; FAO, 1981; Lassen, 1988; Sparre and Venema, 1992) and used to obtain the von Bertalanffy growth function (VBGF) parameters ($L\infty$ and K) by the Ford-Walford plot (Sparre and Venema 1992). Growth performance index (ϕ) was computed from the expression of Pauly and Munro (1984), as

$$\phi = \log_{10}K + 2\log_{10}L\infty \tag{4}$$

where K is the curvature parameter of the growth curve (it measures the rate at which the growth curve approaches the upper asymptote) and $L\infty$ is the theoretical mean length of an infinitely old fish.

The instantaneous total mortality rate (or total mortality coefficient, Z) was determined by the length-converted catch curve as described by Pauly (1983) and Sparre and Venema (1992); natural mortality coefficient (M) was estimated using the relationship between M and the VBGF parameters (K and T_0), T_0 being the theoretical age of fish at zero length; thus:

$$M = 2.9957/[T_0 + (2.9957/K)] \tag{5}$$

(see Ehrhardt et al., 1983 and Moses 1990). The fishing mortality coefficient (F) was calculated as

$$F = Z - M \tag{6}$$

The exploitation ratio (E), which assesses the state of the stock, was computed as F/Z (Moses 1988, 1997).

2.2.4. Gonadosomatic Index and Fecundity

Measured and weighed specimens were dissected to remove the gonads [ovary (female) and testis (male)] for weighing. Ovaries with ova at advanced stages of development [i.e. stages III-V of Holden & Raitt (1974] were put in Gilson's fluid and shaken periodically to loosen the eggs and free them from the ovarian tissues. Relatively, large eggs were counted by the floatation method while small eggs (such as those of *Pellonula leonensis*) were counted in a Sedgwick-Rafter counting cell.

2.2.5 Fish Tissue Analysis

For trace metals 5.0g of tissue was cut from the lower part of the dorso-lateral muscle in the middle (caudal fin not counted) (Bernherd, 1976; FAO/SIDA, 1983; Cossa et al., 1992); - the muscles were dissected with a plastic knife. The weighed fillet was wet digested using a mixture of concentrated nitric acid and perchloric acid (Bernherd 1976). The digested sample was analyzed using atomic absorption spectrometry (AAS). For THC, 5.0g of fillet (cut with stainless steel instruments) was homogenized in a glass mortar-and-pestle and the oil extracted with analytical (spectroscopic) grade carbon tetrachloride. Absorption was measured with CE 2343 Grating Spectrophotometer at 420nm wavelength and also with UV/visible spectrophotometer (UNICAM 8700).

3. RESULTS AND DISCUSSIONS

3.1 Species Distribution, Composition and Diversity

Table 2 shows the species distribution and diversity in the catches of artisanal lagoon, estuarine/river mouth and contiguous coastal strip ecosystems stretching between the Badagri Lagoon and the Cross River. The indices of preponderance (IP) (Table 3), indicate the following (in order of magnitude) as the main components of the fauna in September - October: *Pseudotolithus spp* (24.29%), *Pomadasys jubeline* (15.40%). *Chrysichthys nigrodigitatus* (15.13%), *Ethmalosa fimbriata* (11.95%), *Liza grandisquamis* (9.74%*) Ilisha africana* (3.13%), *Polydactylus quadrifilis* (3.03%), *Cynoglossus browni* (2.85%), *Lutjanus sp* (2.73%), *Sphyraena guachancho* (2.71%), *Tilapia guineensis* (2.59%) and *Arius spp* (1.76%). Of the invertebrates the malacostracan decapod crustaceans, *Nematopalaemon hastatus* and *macrobrachium* spp were commercially important.

Table 2. Species distribution and diversity in the catches of artisanal fishing units surveyed in the various estuarine/river mouth zones along the Nigerian coast from Badagry to the Cross River in September to October 1998.

FAMILY	SPECIES CODE	SPECIES NAME	FISHING AREA											
			1	2	3	4	5	6	7	8	9	10	11	12
F.01 Ariidae	F.01.0	Arius spp			o	o	o	o	o			o		
F.02 Albulide	F.02.1	Albula vulpes		o	o									
F.04 Bothidae	F.04.1	Citharichthys Stampflit								o	o			
F.05 Cynoglossidae	F.05.1	Cynoglossue browni	o	o	o	o	o	o	o	o	o	o		o
F.06 Carangidae	F.06.1	Carnx hippos	o	o	o		o	o	o	o	o	o	o	o

	F.06.2	Selene dorsalis			o	o	o							
F.07 clupeidae	F.06.3	Ethmalosa fimbriata				o		o			o			
	F.07.1	Illisha africana		o	o		o	o		o	o		o	
	F.07.2	Pellonula leonensis	o		o			o			o	o	o	
	F.07.3	Sardinella maderensis		o		o			o		o	o	o	
F.08 Drepanidae	F.07.5	Drepane africana	o	o	o			o	o	o				
F.10 Elopidae	F.08.1	Elops lacerta				o		o			o			
F.11 Haemulidae	F.11.1	Brachydeuterus auritus		o		o					o			
	F.11.2	Pomadasys jubelini	o	o	o		o	o	o	o	o	o	o	o
F.12 Lutjanidae	F.12.0	Lutjanus spp		o	o				o		o			
F.13 Monodactylidae	F.13.1	Psettias sebae		o			o			o	o			o
F.14 Mugilidae	F.14.1	Liza falcipinnis		o	o				o	o	o			
	F.14.2	L. grandisquamis	o	o	o	o	o			o	o	o	o	o
F.15 Polynemidae	F.15.2	Polydactylus quadrifilis	o	o	o	o	o		o	o			o	o
F.16 Sciaenidae	F.16.1	Pseudotolithus elongatus	o	o	o	o	o		o		o			o
	F.16.0	Sciaenidae NEI		o			o		o		o	o	o	
F.17 Scombridae	F.17.2	Scomberomorus tritor									o		o	
	F.17.0	Scobridae NEI			o					o				o
F.18 Serranidae	F.18.2	Cephalopholis nigri		o						o				
	F.18.0	Serranidae NEI		o	o	o					o	o	o	o
F.20 Spyraenidae	F.20.2	Sphyraena sphraena						o			o			
	F.20.3	Sphyraena guachanho	o	o						o	o			
F.21 Trichiuridae	F.21.1	Trichiurus lepturus								o				
F.25 Hemiramphidae	F.25.1	Hemiramphus brasiliensis						o						
F.26.28 Selachii	F.26-28	Sharks and rays		o							o			
F.61 Gerridae	F.16.1	Eucinostomus melanopterus	o					o			o			
F.35 Chrysichthys	F.35.1	Chrysichthys nigrodigitatus	o	o	o	o	o		o	o				o
	F.35.4	C. auratus						o	o	o				o
F.39 Schilbeidae	F.39.1	Eutropius									o			
F.42 Cichlidae	F.42.4	Tilapia Guineensis	o	o			o			o	o			
	F.42.7	Sarotherodon melanotheron			o				o		o			o
F.46 Characidae	F.46.2	Brycinus sp					o				o			
F.57 Palaemonidae	F.57.1	Nematopalaemon hastatus												
	F.57.2	Macribrachium macrobrachion		o							o		o	

Explanation of Area Codes: 1 Badagry Lagoon, 2 Lagos Lagoon, 3 Escravos Estuary/River mouth, 4 Forcados Estuary/River mouth, 5 Brass estuary, 6 Non Estuary, 7 Bonny Estuary, 8 Andoni Estuary, 9 Imo Estuary/River mouth, 10 Qua Iboe Estuary, 11 Cross River Estuary/mouth (sampling location: Ibaka/Jamestown), 12 Cross-Calabar River Estuary, Off Tobacco-Parrott Island (sampling location Nsidung Beach, Calabar). NEI = not elsewhere included species codes are in Moses (1992)

Table 3. Indices of prepondeerance (IP) including the dominant species in the catches from the various Nigeria estuarine/river mouth zones. The index takes account both the weight and number of fish in catch/FU.

	Index of Preponderance (IP) (%)							
	L/B	**E/F**	**B/N**	**B/A**	**IMR**	**QIR**	**CR**	**Mean**
F.01 Arius spp	-	0.37	2.51	0.33	4.18	4.95		1.76
F.05.1 Cynoglossus browni	1.09	2.34	2.1	4.74	4.18	4.58	0.92	2.85
F.06.1 Caranx hippos	0.17	0.18	2.42	0.6	2.22	1.33	0.13	1.01
F.06.3 Chloroscombrus chrysurus		0.59	3.13	7.92				1.66
F.07.1 Ethmalosa fimbriata	29.34	25.77	6.1	8.59	3.4	10.46	10.46	11.95
F.07.2 Ilisha africana		3.03	13.49		1.12	4.41	0.03	3.13
F.07.3 Pellonula Leonensis	1.11				0.06			0.17
F.07.5 Sardinella maderensis		0.72					0.02	0.11
F.08.1 Drepane africana	0.46		0.13	0.32			0.04	0.14
F.11.2 Pomadasys jubelini	4.34	12.84	7.6	1.41	2.69	5.76	3.13	15.4
F.12.0 Lutjanus spp	0.32		4.64		0.37	3.85	9.96	2.73
F.14.2 Liza grandisquamis	22	7.21	3.89	7.52	27.55			9.74
F.15.2 Polydactylus quadrifilis	1.67	5.02	7.53	2.76	1.26	1.09	1.89	3.03
F.16.1 Pseudotolithus elongatus	22.12	26.96	20.74	36.26	31.16	23.56	9.22	24.29
F.16.0 Scanidae NEI	0.03		0.06					0.01
F.17 Scombridae				0				0
F.18 Serranidae		0	0.1	0.03				0.02
F.20.3 Sphyraena guachancho	8.39	1.67	3.3	0.4	1.45	2.41	1.36	2.71
F.21.1 Trichinurus lepturus			0.23	0.6				0.12
F.26-28 Sharps and Rays			2.47					0.4
F. 35.1 Chrysichthys nigrodigitatus	1.89	11.53	3.71	8.33	15.76	23.09	43.27	15.37
F.35.4 C. auratus							0	0
F.42.4 Tilapia guineensis	6.23	1.66		0.6	0.47		9.2	2.59
F.57 Palaemonidae	0.16							0.02
F0000 Miscellaneous	0.64	0.1	15.85	20.29	4.15	24.98	10.37	10.91
L/B = Lagos/Badagry, E/F = Escravos/Forcados, B/N = Brass/Nun, Bonny/Andoni, IMR = Imo River, QIR = Qua Iboe River, CR =- Cross River								

The species distributions and diversity did not show significant differences from the pre-spill conditions expected for the months of September - October. A notable feature of the diversity during the time of survey was the intrusion of some primary freshwater fishes, namely, *Chrysichthys auratus* (Bagridae), *Eutropius* (Schilbeidae), *tilapinie cichlids* and *Bryoinus* (Characidae) into the estuaries, taking advantage of the low salinity.

3.2 Catch Rates

The mean catch rates in number, weight (kg) and value (Naira ₦ per FU/mo are presented for all the zones in Figure 1. The catch (excluding catches by gears other than set gillnets) for all the estuaries/river mouths was 409.0 - 475.6 kg/FU/mo rate by sampling locations and type of fisheries are presented in Table 4. These catch rates were normal for the months of September to October when catch rates have been historically low in Nigeria (see Table 5).

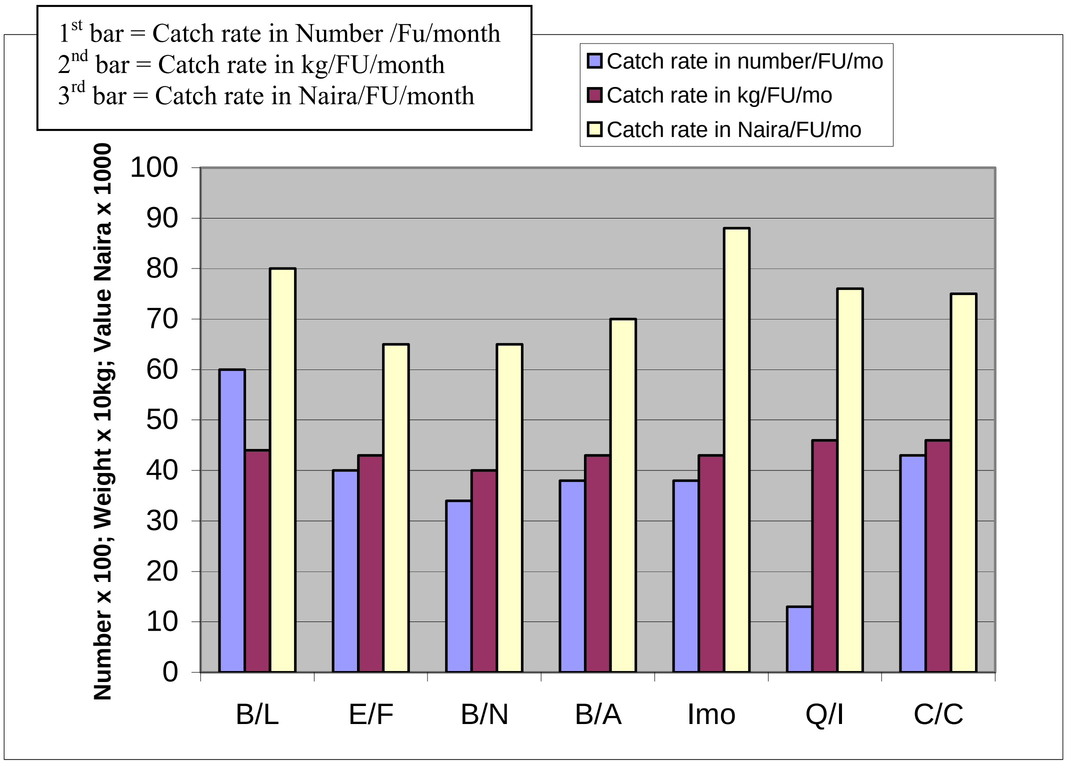

Figure 1: Mean catch rate per fishing unit (FU) per month in number, weight (kg) and value (Naira) of Nigeria's estuarine/river mouth artisanal fisheries surveyed in September – October 1998. B/L = Lagos/Badagri, E/F = Escravos/Forcados, BN=Brass/ Nun, BA=Bonny/Andoni, Imo=Imo River, QI=Qua Iboe, and C/C=Calabar/Cross Rivers.

Table 4. Catch Rate of Artisanal Estuarine/River Mouths and Contiguous Coastal Strip Fisheries of Nigeria based on survey in September - October 1998.

ZONE	LOCATION	Mean Catch/ FU/Trip			Computed Mean Catch/FU/mo		
		Num -ber	Weight (kg)	Value (₦)	Number	Weight (kg)	Value (₦)
1. Lagos	Badagry Lagoon	443	30.5	5899	5717	395.5	76687
	Lagos Lagoon	508	37.8	6650	6568	491.3	86446
Zonal Mean		323	31.9	5000	4190	414.9	64991
3. Bayelsa	Nun River Estuary/River mouth	255	36.5	5462	3315	473.9	71000
	Brass River Estuary/River mouth	259	29.2	4638	3367	379.8	60294
Zonal Mean		257	32.9	5050	3341	426.9	65647
4. Rivers							
	Bonny Estuary/River mouth	336	29.8	5184	4368	387.7	67431

	Andoni Estuary/River mouth	272	37.8	5539	3536	490.8	72007
Zonal Mean		304	28.8	5362	3952	439.3	69719
5. (I) AKWA IBOM							
	Imo Estuary/River mouth						
Imo River	*Setgillnet (GSN) fishery	301	34.8	6754	3913	452.4	87802
	* Beach Seine (BSN) fishery	3468	16.5	2083	45084	214.7	27079
(ii) AKWA IBOM							
	Qua Iboe Estuary/River mouth						
Qua Iboe River	*Set gillnet (GSN) fishery	106	35	5995	1378	455	77935
	*Drift gillnet (GDN) fishery	2185	61.7	5435	28405	802.1	70655
	*Hook-and-line (H&L) fishery	21	21.8	5006	294	305.2	70084
Zonal Mean		771	39.5	5479	26	520.8	72891
Cross River Estuary/River mouth							
* At Ibaka/Jamestown		365	39.1	5904	4688	509.1	76760
* Tobacco/Parrott Islands		387	37	5821	5031	480.7	75673
		376	38.1	5863	4860	495	76217

Table 5. Historical Catch Rates (South-Eastern Nigeria).

MONTH	**1998**	**Mean Catch/Boat 1979-82 (kg) (I)**	**Mean Catch/Boat 1992-93 (kg) (ii)**
January		670.2	527.6
February		603.9	579.2
March		864.2	834.4
April		988	845.7
May		458.9	728.1
June		308.1	542
July		162.9	376.2
August		240	267.5
September	}	288.9}	277.7}
	}Mean 448.7	Mean 428.3	} Mean 308.8
October	}	567.6}	339.9}
November		668.4	478.3
December		628.4	389.6
Source: (I) Moses (1988); (ii) Moses (1997).			

3.3 Mean Size, Length-Weight Relationship and Condition Factor

A large proportion of the fishes caught at the estuaries/river mouths were of small sizes (18.80 ± 5.00cm TL and 56.1 ± 28.7g both 95% CI); a high percentage of the landings were juvenile fish (see Table 6).

Table 6. Mean Total Length (TL), Mean weight (w, in parenthesis) of Catches of Nigerian Estuarine/River Mouth Artisanal Fisheries Based on a Survey in September to October 1998.

Sampling Zone	**F.07.1**	**F.07.2**	**F.11.2**	**F.14.2**	**F.16.1**	**F.35.1**	**Mean (X) all spp**
Lagos/Badagri	14		24.5	13.8	17.9	24.4	18.9
	[24.5]		[105.5]	[20.7]	[50.8]	[98.7]	[60.0]
Escravos/		14.9	20.1	13.3	23	21.2	18.5
Forcados		[26.0]	[91.5]	[25.0]	[71.0]	[70.8]	[56.9]
Brass/Nun	17.4		19.1	13.6	21.8	27.4	19.9
	[50.8]		[52.0]	[25.8]	[77.0]	[160.7]	[73.3]
Bonny/Andoni	17		22	13.6		24.5	19.3
	[50.0]		[78.4]	[20.4]		[160.7]	[56.9]
Imo	17.3		15	14.6	22	18.5	17.4
	[148.9]		[43.0]	[29.5]	[78.4]	[51.7]	[50.3]
Qua Iboe	20.1	14.4	15.2		23.5	22	19
	[71.1]	[28.8]		[43.2]	[74.0]	[108.3]	[65.1]
Cross	17.3	13.9	15.2		22	20.3	17.7
	[47.5]	[28.8]		[43.3]	[80.0]	[83.0]	[56.5]
Mean & 95% confidence interval	17.2 ± 2.2	14.4 ± 9.8	18.7 ± 3.2	13.8 ± 1.6	21.7 ± 2.2	22.6 ± 7.7	18.8 ± 5.0
(all Zones)	[48.8 ±16.7]	[27.9 ± 2.0]	[63.5 ± 24.5]	[25.5 ± 5.0]	[71.8 ±12.2]	[96.3 ± 34.0]	[56.1± 28.7]
Species codes: F.35.1 = Chrysichthys nigrodigitatus; F.07.1 = Ethmalosa fimbriata; F.07.2 = Illisha africana; F.14.2 = Liza grandisquamis; Moses (1988), (ii) Moses (1997).							

The value of the length exponent, b, of the length-weight relationship (LWR) (Table 7) ranged from 2.750 for grey mullet, *Liza grandisquamis* in the Bonny estuary/Andoni flats, to 3.300 for the catfish, *Chrysichthys nigrodigitatus* in the Brass/Nun estuaries (Table 7). The mean value [¯¯ь] for all the 5 species analyzed in each zone was lowest in the Lagos/Badagry lagoon system (2.970) and highest in the Brass/Nun estuaries (3.138); in the rest of the zones Б fell within the 95% CI (3.008 - 3.110) indicating that in these zones ¯¯ь did not differ significantly from 3.

Table 7. Mean length exponent (b) of the length-weight relationship and Fulton's condition factor (k') (in parenthesis) of 5-6 species of fish sampled per location from Nigerian estuarine/river mouth environments in September - October 1998.

	Mean length exponent (b) & condition factor (k') (in parenthesis)						
Sampling Zone	**F.07.1**	**F.07.2**	**F.11.2**	**F.14.2**	**F.16.1**	**F.35.1**	**Mean (X) all spp.**
Lagos/Badagri	2.89		3.085	2.78	3.001	3.096	2,907
	[0.89]		[0.72]	[0.79]	[0.90]	[0.68]	[0.75]
Escravos/Forcados		3.173	3.085	2.875	3.009	3.083	3.045
		[0.79]	[1.13]	[1.06]	[0.57]	[0.74]	[0.86]
Brass/Nun	2.98		3.108	3.2	3.108	5.296	3.138
	[0.96]		[0.74]	[1.03]	[0.74]	[0.78]	[0.85]
Bonny/Andoni	2.98		3.42	2.75		3.296	3.008

	[1.01]		[0.74]	[1.05]		[0.78]	[0.96]
Imo	2.88		3.108	2.901	3.108	3.03	5.015
	[0.94]		[1.27]	[0.94]	[0.74]	[0.81]	[0.94]
Qua Iboe	2.98	3.17	3.108		3.19	3.01	3.092
	[0.80]	[0.89]	[1.23]		[0.57]	[1.02]	[0.92]
Cross	3.007	3.17	3.1		3.25	2.87	3.079
	[0.92]	[1.07]	[1.23]		[0.75]	[0.99]	[0.99]
Mean & 95% confidence interval (all Zones)	2.953 ± 0.090	3.171 ± 0.003	3.145 ± 0.120	2.901 ± 0.220	3.110 ± 0.111	3.040 ± 0.144	3.054 ± 0.144
	[0.93 ± 0.08]	[0.92 ± 0.05]	[1.01 ± 0.25]	[101 ± 0.08]	[0.71 ± 0.14]	[0.88 ± 0.17]	[0.91 ± 0.12]
Species codes: F.35.1 = Chrysichthys nigrodigitatus; F.07.1 = Ethmalosa fimbriata; F.07.2 = Illisha africana; F.14.2 = Liza grandisquamis;							

The negative allometry in the Lagos/Badagry zone is probably due to the polluted condition of the lagoon environment (see Okoye et al., 1991, Calamari & Naeve, 1994); the positive allometry in the Brass/Nun zone could also indicate that these estuaries are still in a perturbed state. It should be noted, however, that the value of b is affected also by other factors such as the time of the year, the amount of food in the environment and the feeding intensity particularly just before capture (and hence on the stomach fullness) and the state of development of the gonads. Furthermore, b can be easily biased if the investigator is not careful with his measurement of lengths and weights. All these tend to reduce the usefulness of b as an environmental indicator. The principal use of LWR is for the conversion of length to weights and vice versa; it finds wide application in the study of fish population dynamics and stock assessment.

The allometric condition factor (w/l^b) calculated using the value of b determined empirically for the stock suffers the same disadvantage as the use of b as an environmental indicator. Fulton's condition factor (k') (Ricker, 1975), which uses the cube of length no matter the computed value of b, is a better indicator of environmental condition (which condition is reflected in the well-being or "fatness" of the fish inhabitants of the particular ecosystem). The lowest k' was shown by fishes from Lagos/Badagry lagoon system (0.75), followed by those of the Brass/Nun (0.85) and Escravos/Forcados (0.86). In all the other zones k' was above 0.9; the highest k' was 0.99) or approx. = 1) for fishes of the Cross River which was regarded as the control (unimpacted zone).

3.4 Gonadosomatic Index (GSI) and Fecundity (Fc)

The reproductive investment of the various species analyzed, as indexed by the GSI were quite low; only C*hrysichthy auratus* from Calabar/Cross River estuary had GSI above 5.0. The GSI of other species ranged from 0.17 to 3.72. Over 14% of the sample examined had no weighable gonads because they were juveniles (see Table 8). On the whole the mean GSI (all species that had weighable gonads) was lowest in the Lagos/Badagry zone (0.43 ± 0.25) and there was a progressive increase in GSI towards the Cross River. The high mean GSI in the Cross River zone was derived principally from C. *auratus,* many females of which were in the pre-spawning stage with fully mature ova.

Table 8. Ganodosomatic indices of some species of fish caught by artisanal fisheries of Nigeria in the estuaries/river mouth/contiguous coastal waters.

Species of Fish	Mean Gonadosomatic Index (GSI)						
	Badagri/ Lagos	Escravos/ Forcados	Brass /Nun	Bonny/ Andoni	Imo	Qua Iboe	Cross
F.07.1 Ethmalosa fimbriata (bonga)	0.28	0.77	0.79	0.83	1.72	1.13	3
F.07.2 Illisha africana (shad)	0.22	NWG	NWG	0.7	0.88	1.18	1
F.07.3 Sardinella madarensis (Guinean sprat)	0.94	ND	ND	ND	1.14	1.1	0.9
F.11.2 Pomadasys jubelini (grunter)	0.42	NWG	0.22	NWG	0.71	NWG	NWG
F.14.2 Liza grandispuamis (grey mullet)	0.17	0.18	0.44	NWG	3.72	2.31	3
F.14.3 Mugil cephalus	0.71	ND	ND	NWG	ND	ND	NWG
F.16.1 Pseudotolithus elongatus	0.16	0.31	0.47	NWG	1.44	0.69	0.53
F. 35.1 Chryscichthys nigrodigitatus	0.55	0.97	1.11	1.03	1.02	1	1.02
F.35.4 C. auratus	NWG	ND	ND	ND	ND	ND	9.31
F.42.4 Tilapia guineensis	0.5	0.55	0.57	0.83	0.88	0.8	0.59
F.61.1 Eucinostomus melanopterus	0.32	ND	ND	ND	NWG	ND	ND
ND = no data; NWG = no weighable gonad (indicating mostly small juvenile fish).							

The populations of fish in the estuaries/river mouths in September to early October contained large proportions of sexually immature fish partly because during the peak of the rainy season large fish move offshore to avoid the low salinity in the estuaries. Young fish which use the estuaries as nursery grounds are more tolerant of low salinity. The very low mean GSI in the Lagos/Badagry zone was due, at least in part, to the fact that Lagos lagoon is a polluted environment with contaminants coming principally from urban and industrial wastes (Okoye et al., 1991; Calamari and Naeve, 1994); and this might be affecting the reproductive processes of the fish populations.

Only a few species had ovaries the conditions of which made them suitable for the determination of fecundity. These were *Chrysichthys nigrodigitatus* (Brass estuary) with 3300 eggs/female, C. *auratus* (Cross estuary) with 2490 eggs/female, *Ilisha africana* (Lagos Lagoon and Qua Iboe estuary) 2000 - 9000 eggs/female and *Pellonula leonensis* (Imo estuary) 9300 - 16000 eggs/female.

3.5 Growth and Mortality

The growth pattern of a fish is specified by the parameters of the selected growth model. The growth function commonly and generally used is that of *von Bertalanffy* (VBGF) because of the ease with which it can be incorporated into fish population models for the estimation of potential yields. Table 9 shows the VBGF parameters $L\infty$ and K, the growth performance index (ϕ), the total, natural and fishing mortality coefficients (Z, M and F respectively) as well as the exploitation ratio (E) of 5 commercially important species, namely bonga (*E. fimbriata*), longfinned herring (*I. Africana*), croaker (P. *elongatus*), the grunt (*Pomadasys jubelini*) and the catfish *C. nigrodigitatus*.

Table 9. Von Beretalanffy Growth Function Parameters (L∞ & K), Growth Performance Index f), the Instantaneous Total Natural and Fishing Mortality Rates (Z, M, and F, respectively) and Stock Assessment Based on the Exploitation ratio (E) of five of the economically important fishes commonly caught by artisanal fishers from estuaries / river mouth and contiguous coastal waters of Nigeria (based on Survey September - October 1998). Figures in parenthesis are the pre-spill date.

Species	Area	L∞ (cm)	Kyr^{-1}	f	Zry^{-1}	Myr-1	Fyr^{-1}	E=F Z	State of stock
F.07.1	SEN	214-28.7	0.4	2.52	1.63 - 1.82	0.55 - 0.62	1.18	0.66	Heavily exploited (h.expl) > MSY
E. Fimbriata	L/B	(30.0 - 33.6)	(0.36 - 0.54)	[26.0]	1.04 - 1.19)		[10.70]		
F.07.2	SEN	18.9 - 22.0	0.98 - 1.88	2.54 - 2.96	1.23 - 1.80	0.47 - 0.53	0.79 - 1.36	0.69	h.expl. > MSY
I. Africana	L/B	[22.0]	[2.33]	[3.05]	[1.80]				
	B/N								
F.11.2	SEN	25.6 - 42.2	0.24 - 0.43	2.87 - 3.45	1.21 - 1.63	0.46 - 0.58	0.75 - 1.02	0.63	h. expl.> MSY
P. Jubelini	L/B	[Nil]	[Nil]	[Nil]	[Nil]				
	B/N								
F.16.1	SEN	28.2 - 51.2	0.20 - 0.28	2.20 - 2.87	1.50 - 1.55	0.48 - 0.52	0.99 - 1.05	0.68	h.expl. > MSY
P. elongatus	L/B	[48.0 - 60.0]	[0.28 - 0.38]	[2.81 - 3.16]	[1.42]				
	B/N								
F.35.1	SEN	65.9 - 81.5	0.17 - 0.28	2.87 - 3.26	1.45 - 1.53	0.57	0.88 - 0.96	0.62	h.expl. > MSY
C. mga digitatus	L/B	[81.7 - 126.0]	[0.19 - 0.24]	[3.20 - 3.48]	[1.20]		[0.74]		
	B/N								

SEN=South Eastern Nigeria; L/B=Lagos/Badagri; BN =Brass/Nun; E/F=Escravos/Forcados; L8= length of fish at infinite age; K=curvature parameter of the growth curve; ?=Growth performance index; Z=total mortality coefficient (or instantaneous total mortality rate); M=natural mortality coefficient; F=fishing mortality coefficient; E=exploitation ratio (=F/Z).

Length at infinite age (L∞) determined for *E. fimbriata* and *P. elongatus* in this study were slightly smaller than existing estimates; the curvature parameter (K) was lower in bonga and croaker than existing estimates in South Eastern Nigeria (SEN), as well as that of *I. Africana* in Lagos/Badagry lagoon system. Z for all the species was higher than existing estimates. However, the effect of environmental conditions on Z was obscured by the fact that the stocks are heavily exploited, some far above the maximum sustainable yields (MSY) (i.e. have been overfished). This overfishing, which was brought about by a continuous, unchecked rise in fishing effort reached its highest level in 1984-87 (Essen 1995 and Moses 1997). There was a slight recovery in 1989 - 92 following the down-turn in the country's economy. The recovery did not last long and, at present, the stocks are still in a depressed state.

3.6 Trace (Heavy) Metal Concentrations in Fish Tissues

The mean concentration of eleven heavy metals in fish tissues is shown by zone in Table 10. The values were generally within acceptable international limits allowed for detection in seafood. The highest concentration was recorded for copper in the muscle tissues of the crayfish, *Macrobrachium sp.* in the Lagos zone, but even this was below the World Health Organization's (WHO's) limit of 30 µg/g in fish tissue (see Calamari and Naeve 1994). The mean concentration of lead (Pb) in fishes from the Lagos lagoon (2.29 ± 1.06 µg/g) but quite in agreement with that (2.28 µg/g) given by Okoye (1991) and Ajao et al. (1996) for the same area. This very high concentration of lead in Lagos waters is not connected with the January 12 oil spill.

Table 10. Mean trace (heavy) metal concentrations in tissues of estuarine/river mouths and contiguous coastal strip fishes of Nigeria; Samples collected September - October 1998. The means and standard deviations (in parenthesis) are for the six (sometimes seven) species.

System	Metal Concentration, µg/g Wet weight										
	Cu	**Pb**	**Cd**	**Fe**	**ZN**	**Ni**	**Cr**	**Mn**	**Co**	**V**	**Hg**
Lagos Zone											
Badagri and Lagos Lagoons	11.42 [0.47]	2.29 [1.06]	ND-0.05	7.23 [3.51]	6.06 [0.97]	2.11 [0.17]	ND	0.83 [1.31]	ND-0.17	ND	ND-0.01
Delta Zone											
Escravos and Forcados Estuaries/river mouths	1.47 [0.14]	1.11 [0.17]	ND-0.04	7.5 [1.42]	5.01 [0.83]	1.74 [0.94]	ND	-0.197 [0.07]	ND-0.05	ND	ND
Bayelsa Zone											
Brass & Andoni Estuaries/River mouths	1.54 [0.45]	0.96 [0.27]	ND-0.10	7.57 [2.24]	7.62 [3.45]	1.37 [1.09]	ND	0.16 [0.09]	ND-0.07	ND	ND-0.08
Rivers Zone											
Bonny and Andoni Estuaries/River mouths	1.89 [0.40]	1.2	ND	15.72 [14.55]	6.75 [1.39]	2.4 [0.71]	ND	0.58 [0.37]	ND	ND	ND-0.05
Akwa Ibom Zone I											
Imo Estuaries/river mouth	1.32 [0.44]	1.18 [0.43]	ND-0.06	33 [34.10]	8.65 [6.29]	2.22 [0.59]	ND	0.47 [0.15]	ND	ND	ND-0.008
Akwa Ibom Zone II											
Qua Iboe Estuaries/River mouth	1.62 [0.46]	1.33 [0.40]	0.08 [0.02]	10.35 [3.06]	7.75 [3.81]	2.12 [0.45]	ND	1.05 [0.40]	ND	ND	ND-0.008
Akwa Ibom Zone III											
Cross River	2.03	1.28	ND-	9.8	8.47	2.76	ND	0.46	ND	ND-	ND-

mouth	[1.061]	[0.32]	0.05	[4.81]	[2.82]	[1.17]		[0.32]		0.05	0.001
Cross River Zone											
Cross River Estuaries	2.14	1.31	ND	9.66	7.13	2.56	ND	0.56	ND	ND	ND
	[0.82]	[0.34]		[3.81]	[1.97]	[0.40]		[0.36]			
WHO LIMITS	30	2	2		1000						0.5
* Total mercury, ND = not detected, Est/R.mth = Estuary/River mouths.											

3.7 Total Hydrocarbon (THC) Concentrations in Fish Tissues

The mean THC concentrations in muscle tissues of 5 species of commercially important fishes are presented in Table 11. The mean concentrations,, which were higher between Forcados and Qua Iboe estuaries than in the Lagos/Badagri lagoons and the Cross River estuary were all below the Joint Group of Experts on the Scientific Aspect of Marine Pollution's (GESAMP's) detection limit of 25 mg/kg in seafood. A qualitative analysis of the CCI_4 extract using UNICAM 8700 UV/visible spectrophotometer indicated that the detected concentrations contained some petroleum-derived residues such as chlorobenzene, aniline and nitrobenzene.

Table 11. Mean Total Hydrocarbon (THC) concentration in muscle tissues of fish caught in estuaries/river mouths of Nigeria in mouths of Nigeria in September to October 1998.

Species	**Mean total hydrocarbon (THC) concentration mg/kg**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
F.05.1 Cynoglossus browni	4				5.11	5.23	9.71	7.75	7.01	10.11	5.22	5.43
F.07.1 Ethmalosa fimbriata	7.17	6.44	7.32	7.33	12.65	10.09	11.51	12.82	12.22	12.83	9.12	9.14
F.11.2 Pomadasys jubelini	8.88		9.71		8.42	13.51	13.41	10.33	9.22	9.87	6.92	6.55
F.14.2 Liza grandisquamis	5.61	7.91		12.52		12.21	11.03	9.08	10	10.16	9.8	5.07
F.15.2 Polydactylus quadriffilis		3.51	4.73		9.01		9.11	8.42	10.33	10.59	12.63	9.47
F.16.1 Pseudotolithus elongatus	7	6.33	11.8	13.5	14.52				11.85	12.92	12.2	10.73
F.20.3 Sphyraena guachancho			8.11	7.37		8.15	6.36	9.05			6.72	4.98
F.35.1 Chrysichthys nigrodigitatus	7.67	3.72		5.24	8.77	6.86			5	4.95	4.39	
F.42.4 Tilapia guineensis	5.44					7.38						5.99
F.57.0 Macrobrachium												
Mean & Standard Deviation all spp	6.54	5.58	8.33	9.19	9.78	9.06	10.19	9.58	12.95	10.2	8.38	7.07
	± 1. 63	± 1. 90	± 2. 64	± 3. 61	± 3. 34	± 3. 00	± 2. 40	± 1. 80	± 2. 63	± 2. 65	± 3. 07	± 2. 34

1. Badagry Lagoon, 2. Lagos Lagoon, 3. Escravos, 4. Forcados, 5. Nun, 6. Brass, 7. Bonny, 8. Andoni, 9. Imo, 10. Qua Iboe, 11. Cross River Mouth, 12. Cross River Estuary.

4. Summary

- The mean individual sizes of the caught fish (based on length and weight) in the various zones were lower than previous measured annual averages. This could, at least in part, be the result of environmental perturbation. It is however, not easy to separate the effect of very low salinity at the estuaries during the peak of the rainy season during which large fishes usually move offshore leaving the estuaries/river mouths to juvenile fishes which are more tolerant of low salinities.
- The estimated growth parameters ($L\infty$ K) and the growth performance index (ϕ) were lower than found from others studies for those species (*E. fimbriata, I africana,. P elongatus and C nigrodigitatus*) for which such data were extant. On the other hand the total mortality coefficient (Z/yr) was higher in all cases than existing data. All these imply reduced growth and higher mortality rates which could, at least in part, be attributed to the effect of environmental perturbation. It is to be noted, however that the influence of environmental perturbation on these parameters are obscured by the fact that these stocks have for some time now been exploited at levels (measured by the exploitation ratio, E) above their carrying capacity (or maximum sustainable yields (MSY); overfishing implies very high mortality and reduced individual sizes in the catch.
- The low condition factor and the low state of the reproductive investment (as shown by the GSI indicate a perturbed environment especially in the Lagos area and time of sampling.
- Concentrations of THC of petroleum origin in the fish tissues were all below 25mg/kg limit given by GESAMP.
- The concentrations of trace (heavy) metals in fish tissues were well within internationally (WHO's) acceptable limits of detection in seafood. An exception to this was the concentration of lead (Pb) in fishes from Lagos/Badagry lagoon system which was significantly higher than WHO's allowable detection limit, but agreed with results given by earlier workers in the same area before the spill, so is linked to lagoonal contamination not associated with the oil spill.

The overall adverse effects of the spill on biological communities, including the artisanal fisheries were very limited in extent and duration due to the lack of heavy and extensive shoreline impact, particularly in sheltered mangrove areas (Olagbende, et al, 1999). The fisheries effects observed here are consistent with the longer-term decline in fisheries status due to over utilization of the resource and not a spill-related effect.

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