THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Preliminary assessment of Benthic Infauna at Cape Three Points in the Western Region of Ghana

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Abstract:
Many of the potential impacts of oil and gas exploration and production activities in benthic environments are well-known in shallow waters but relatively little-known in deep water environments. Ghanaian commercial oil discovery in June 2007 is located at depths of 1,100 m and 1,700 m within the Jubilee Oil and Gas Field between the Deep water Tano and West Cape Three Points blocks. The data for the study was collected in May, 2009 to obtain baseline information on the benthic ecology of the Jubilee Field and its environs for future impact assessments. In order to ascertain gradients in biological variables, sediment samples were collected along defined depths between 25 m and 1200 m along three transects. Abundance and biomass of major infaunal groups were assessed. Univariate techniques using distributional trends of diversity indices and multivariate techniques such as agglomerative cluster analysis and Non-metric Multidimensional Scaling (MDS) were employed in the analyses of the data. A total of 265 individuals (average density = 176 ind. /m^2) comprising 77 species belonging to four major taxonomic groups were recorded. Polychaetes constituted 72% of the abundance followed by crustaceans (14%), echinoderms (6%) and others (eg. cnidarians, sipunculids, etc.) (8%). No species of the phylum Mollusca were recorded. The spatial distribution and occurrence of species showed sipunculids appearing in 47% of the sampled stations, making them the most commonly distributed in the area. The echinoderm Ophiotrix sp., and polychaete Magelona cincta occurred in 40% of locations. Fifty-four percent of the species were recorded in only one or two samples. Species diversity and richness revealed a general declension from the west to the east of the Jubilee oil rig. The findings indicated a decreasing trend of species diversity from 500 m and beyond, suggesting that future disturbances may not have any effect on the benthic fauna. It may just affect the distribution of a few rare species in the deep water areas.

Keywords: *benthic fauna, community structure, abundance, biomass, species diversity*

1. Introduction

Drilling for oil in the ocean is one of the greatest technological breakthroughs in recent decades, with many novel techniques having been developed to profit from the abundance of oil underneath the ocean floor on all continents. Though the practice has been around for decades to centuries in various forms, the effective extraction of petroleum from beneath the sea floor did not materialize until the last 40 years (Doscher, 2008). Kropp (2004) and Currie and Isaacs (2005) have reported in different studies that activities associated with oil and gas production may undesirably affect the ecology of the local ecosystem, remarkably the benthic and pelagic environments mainly through habitat degradation and destruction.

In June 2007, the Jubilee Oil and Gas Fields was discovered offshore Ghana when the Mahogany-1 exploration well in the West Cape Three Points Block was drilled by Kosmos Energy, an oil and gas company from the United States of America. The field is located approximately 60 km from the nearest coastline in deep water (1,100 m to 1,700 m), and is approximately 110 km^2 in area. Over the past eight years, exploration for commercial hydrocarbons in Ghana intensified with the exploration activities of Tullow, Kosmos, Hess Corporation, Hunt Oil, Afren and Norsk Hydro Oil and Gas, amongst others.

Marine benthic organisms have been used the world over to monitor the impacts of ecosystem health in different studies (e.g. Boesch *et al*., 1977; Gray *et al*., 1990; Simboura *et al*., 1995; Gregory, 2007; and Bamikole *et al*., 2009). This, according to several researchers, is due to their inherent ability to incorporate into the system several attributes they possess such as their sedentary nature (Boesch *et al.,* 1977; Simboura *et al.,* 1995), longevity (Gray, 1992) and differential response to environmental conditions (Gregory, 2007; Bamikole *et al*., 2009).

These benthic organisms are plants and animals that generally live on the bottom of any water body, and may be either infauna (burrow into the substrate), or epifauna (living on the surface of the substrate). Many of the benthic organisms are infauna - burrowing into the sediments. Many of the infauna, which include invertebrates that are suspension feeders and eat drifting detritus and plankton from the water column, are filter feeders that actively filter the water to obtain suspended particles

(Nybakken, 1988). Soft-bottom suspension feeders include many types of clams which collect detritus and microscopic organisms with their siphons or specialized appendages (Castro and Huber, 2000). Common benthic suspension feeders include a diverse array of corals, sponges, gorgonians, sea pens, echinoderms, brachiopods and bivalves. Patches of these organisms can further modify hydrodynamics over a wide range of spatial scales. These significantly influence both the vertical and horizontal flux of food and larvae on the seafloor (Snelgrove and Butman, 1994). These feeding processes are adversely affected by turbidity of the water column, which normally results from disturbance of the bottom of the seabed due to human activities like trawling and drilling for oil in recent times.

Kropp (2004), in reviewing the literature on the determinants of benthic community structure, said that ecological features of biological communities are usually separated into structural, functional, or process elements. The structural elements of biological communities, according to Kropp, include the fauna and flora of the community . Structure is usually determined by obtaining a sample of the community and determining its constituent taxa. Several metrics are used to characterize a community's structure. Three of the commonest are abundance, composition and biomass. Abundance is typically estimated simply by counting the number of individuals in the sample. The number and composition of identifiable species in a sample is also determined. Biomass, essentially the weight of the community members, is sometimes also included in estimates of community structure and is often estimated by determining the wet weight of the community constituents, most frequently as grouped into major taxonomic categories (Kropp, 2004).

All phases of oil and gas operations may impact adversely on the immediate environment, from the evaluation of the sea floor (seismic surveying) through the development and production phases (Neff *et al*., 1987).

Many of the potential impacts of oil and gas exploration, drilling, and production activities in benthic environments are well known, especially in relatively shallow water (Kropp, 2004). The impacts identified include changes in the abundance and diversity of invertebrates inhabiting the sediment around platforms (Peterson *et al.,* 1996), increase in animal densities near the platforms, attributable to an increase in worms in those sediments (Montagna and Harper, 1996), abundance of crustaceans and echinoderms farther away than near platforms (Kropp, 2004), and polychaete abundance near platforms with high hydrocarbon levels (Gomez and Dauvin, 2000). For this reason, benthic communities are widely-used in monitoring of effects of marine impacts as the organisms are mostly sessile and integrate effects of pollutants over time (Gray *et al*., 1990); since benthic organisms are able to integrate both short- and long-term environmental effects into their system due to their sedentary nature.

Drilling for oil is a fairly new industry in Ghana and the Cape Three Points area in particular. It is therefore important to characterize the benthic community upon which future analysis and impact predictions and evaluations could be based.

This study therefore sought to obtain information concerning the deep-sea benthic ecology of the area and how that information might be used to monitor potential impacts of oil and gas production activities in the Jubilee fields. Specifically, the study determined the abundance, species composition and community structure of benthic infauna in and around the Jubilee Field oil platform.

2. Materials and Methods

2.1. Study Area

The study area is the Cape Three Points which forms part of the Gulf of Guinea. This is shown Figure 1.

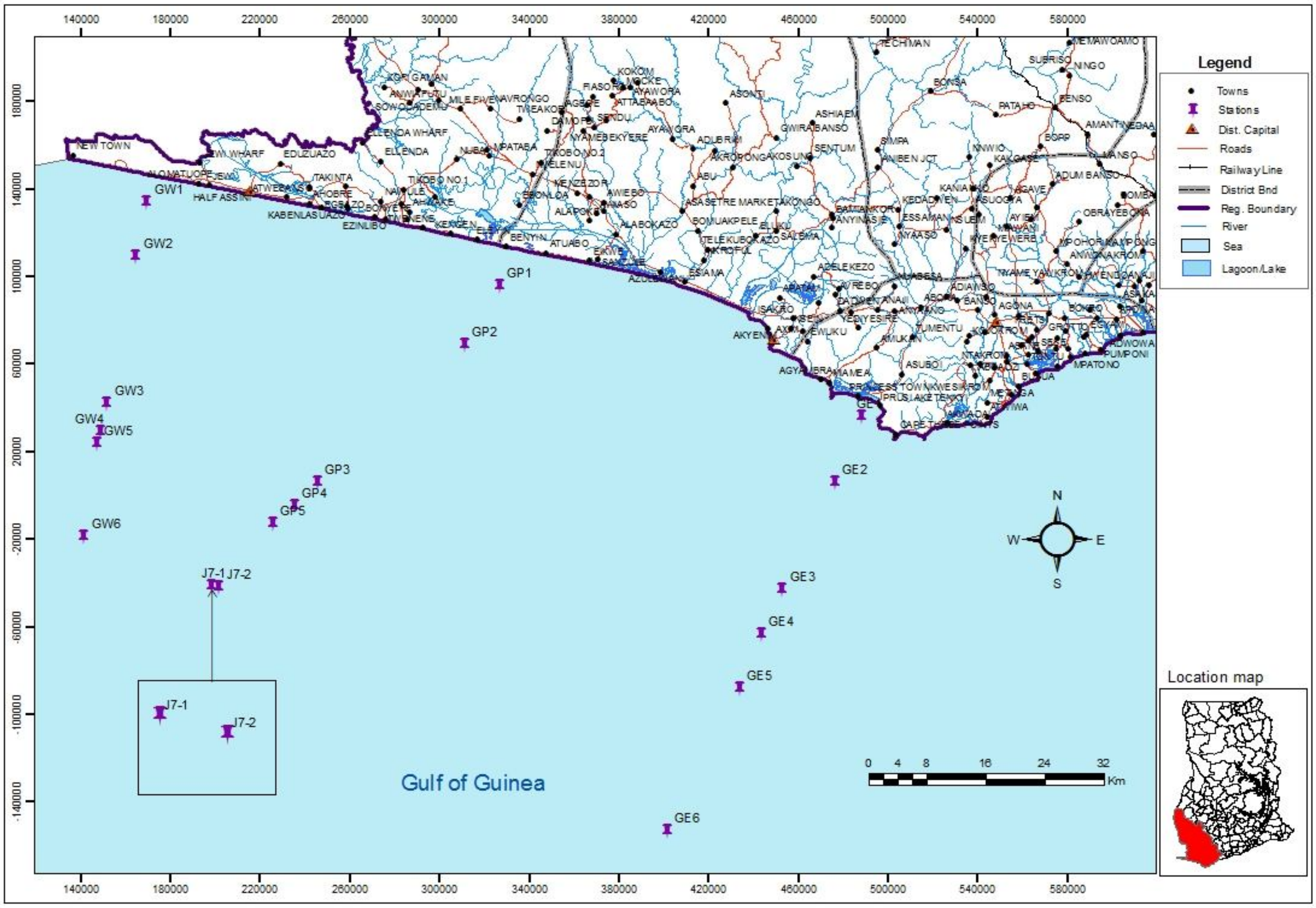

Figure 1: Map of the coast of Ghana showing the various sampling sites in the Gulf of Guinea.

The area forms a part of the Gulf of Guinea (2° S - 5° N 8° W - 12° E) situated on the equatorial western coast of Africa. The region is particularly influenced by the Benguela Current, with mid-year upwellings off the coast of the Gulf of Guinea having notable effects on water temperature resulting in relatively lower temperatures (Longhurst, 1962). This and other ocean dynamics that result in the seasonal upwelling and downwelling affect the climate and the fisheries to a great extent and make the region economically viable (Wiafe, 2002). Notable features in this area include the West African Gas Pipeline, and the Jubilee Oil fields, discovered in 2007 by Tullow Oil Ghana. Further explorations and drilling are currently on-going in the area.

2.2. Sampling Protocol

Sampling was carried out on board the Dr. Fridtjof Nansen research vessel in May, 2009. Three transects on north-south axis along the marine ecosystem, (i) Ghana East (GE), (ii) Ghana West (GW) and (iii) the Gas Pipeline (GP) were used for sediment sampling. The GW and the GE transects had a depth range of 25-1200 m with six stations on each transect. The GP transect had a depth range of 25-500 m with five stations on the transect. A total of 17 grab stations located within the three transects, ranging from 25 - 1200 meters depth in the Eastern coast of Ghana's offshore environment and some samples at pre-drilled areas at the Jubilee field area (J7-1 and J7-2), making up a total of 19 grab stations. The samples from the Jubilee fields were taken at a depth range of 1200-1300 m. Replicates were taken at each station.

2.3. Sampling Design

The sampling design was based on the Oslo Paris Commission for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) guidelines for sediment monitoring for biological analysis. There were 19 Grab Stations.

2.4. Sediment Sampling and Handling

All the positions of the sampling locations were geo-referenced with the ship's Global Positioning System (GPS). The sediment sampling sites were spread out along three transects at predefined depths of 25 m, 50 m, 100 m, 250 m, 500 m and 1200 m depth, according to Olsgard and Gray (1995). Sediments were sampled using a *Van Veen* grab with surface area of 0.1 m^2. The maximum volume of the grab was 21 litres. At each sampling station, two grab samples were taken. Only samples from grabs completely closed with open space between the sediment surface and the lid were accepted for chemical investigation. The height (cm) of space from the surface of the sediment to the lid of the grab was measured using a graduated ruler to determine the volume of sediment grabbed. Sub-samples were scooped from the upper layer (0-5 cm) into labeled Rilsan plastic bags and immediately frozen. The samples for the benthic infauna were sieved through a 0.5 mm sieve. Retained materials in the sieves were placed in 500-1000 ml plastic containers, and borax pre-buffered formalin (40%) added. They were then labelled and stored on board.

2.5. Sorting and Identification of Benthos

Sediment samples for the taxonomic analysis were washed with clean water to remove excess mud and get rid of the formalin, then spread on white trays and sorted into broad taxonomic groups (i.e., polychaetes, crustaceans, echinoderms, mollusks, etc.). The various taxonomic groups were identified using taxonomic manuals and guides (Day, 1967a, 1967b; Fauchald, 1977; Edmunds, 1978) and museum referenced collections. The identified organisms were later counted. Organisms that could not be identified were coded for further taxonomic resolution.

2.6. Biomass Estimation

Biomass estimation was based on wet weights of the sorted benthic fauna. The estimation was carried out for the various taxonomic groups, and samples were air-dried before subjecting them to weighing using a top-loading balance.

2.7. Data Analysis

Univariate and multivariate statistics were used to describe the macro infaunal communities and the environmental parameters.

The univariate analysis involved descriptive analysis using basic summary statistics such as mean density, frequency of occurrence and percentage to give broader information on the abundance and biomass of the macro benthic infauna. Also, graphical or distributional analysis revealing patterns within the abundance and biomass structure of samples was utilized.The Multivariate techniques utilized were found in the PRIMER-5 software package (Plymouth Routine in Multivariate Ecological Research). Data analyses with the the software were done based on a transect and depth profile. For the transect profile, only stations with corresponding depths where used; thus, GE-1 to GE-5, GP-1 to GP-5, and GW-1 to GW-5. This was done because the various software used are not robust for unequal data entries. For the depth profile, only stations with corresponding depths among transects were used for the analyses.

For the diversity indices analysis, PRIMER-5 software was utilized. The DIVERSE analysis tools used to determine the total number of species and the total numbers of individuals were the Margalef's species richness (d), Shannon-Wiener's Diversity index (H) and Pielou's Evenness (J). The Shannon-Weiner Diversity Index (from PRIMER-5) was applied to assess species diversity per sample, as was recorded from the respective stations. The following assumptions were made.

A One-way- ANOVA test was also applied to test for the differences in species diversity/evenness and species richness between transects, using Statistica version 7.

Analysis to reveal community structure was performed using the PRIMER software version 5 employing the use of dendograms, SIMPER (Similarity Percentages) and Bray Curtis similarity matrices. The species abundance data was subjected to a fourth-root transformation and standardized. The resulting Bray-Curtis similarity matrices were subjected to hierarchical, agglomerative classification employing a group-average linkage to classify the stations based on faunal composition or grouping. The purpose of the dendogram plots was to reveal stations that clustered or fell into groups with respect to their species compositions. This process was repeated among transects.

SIMPER (Similarity Percentages) analyses were meant to investigate the contribution of each species to the average similarity and dissimilarity between groups of samples observed in the dendograms. One important aspect of the SIMPER is the issue of discriminating or indicator species. The ratio of the Average similarity to the standard deviation of the similarity (Sim/SD) together with the percent contribution (Contri%) are used to tell which species should be considered a discriminatory/indicator species. According to Clarke and Warwick (1994), if the ratio Sim/SD is greater than the percentage contribution of the species to the total similarity to the group, then that organism can be considered a discriminating species, and later as an indicator species whose presence or absence in the area can inform on the condition of that area. ANOSIM (Analysis of Similarity) test was also applied to test the differences in community composition among the three groups of organisms. The ANOSIM method uses a test statistic that measures the difference between the within group variation and the between group variation. If the difference between the within group similarity and between group similarity is large, then there is evidence that the association among the three time periods is different. The underlying null hypothesis is that there is no difference among the groups in terms of association. The approach procedure is a so-called one-way ANOSIM. The method is non-parametric and a multivariate extension of ANOVA.

3. Results

3.1. Species Abundance, Biomass and Diversity

<u>3.1.1. Abundance and Biomass of Macrobenthic infauna</u>

A total of 265 individuals comprising 77 species were recorded from 15 grab samples (3 transects) (Mean density= 176 ind./ m^2). Of the total numerical abundance, polychaetes contributed 72% of the total, with crustaceans, echinoderms and others contributing 14%, 6% and 8% in that order (Table 2). Three taxonomic groups namely polychaetes (72%), crustaceans (14%) and echinoderms (6%) in that other dominated in terms of abundance. These same groups dominated the infauna biomass thus: polychaetes (82%) crustaceans

(9%) and echinoderms (4%). The polychaetes showed higher richness recording a total of 62 species representing 81% followed by the crustaceans with 9 species (11%). The echinoderms and species placed in the "Others" group made up 6 species (8%) each. In terms of frequency of occurrence (FO), Sipunculids ranked the highest occurring in 47% of the samples. This was followed by the echinoderm, *Ophiotrix* sp. and the polychaete, *Magelona cincta*, both recording FO = 40 %. Fifty-four (54%) of the species were represented by one or two individuals. The polychaetes that dominated the samples were: *Magelona cincta, Prionospio pinnata*, *Paralacydonia paradoxa*, *Onuphis* sp. and *Magelona* sp.; all recording FO of 27 %. Four stations were recorded at depths beyond 1000 m (J7-1, J7-2, GE-6 and GW-6). Stations J7-1, J7-2 and GE-6 recorded single species with single individuals each. The various species recorded at these three stations were Mysidae indetermined (shortened indet.) (J7-1), Sipuncula (J7-2) and Maldanidae indet. (GE-6). Station GW-6 recorded 4 species with 5 individuals.

Biomass also followed a similar pattern in that polychaetes accounted for 11.77 g (82%) of the total macrobenthic faunal biomass (14.29 g). This was followed by crustaceans with a total weight of 1.27 g making up 9 % of the total biomass. The Echinoderms and the "Others" group contributed 0.52 g and 0.73 g to the total biomass making up 4% and 6% of the total biomass, respectively. These are captured in Figure 2 below.

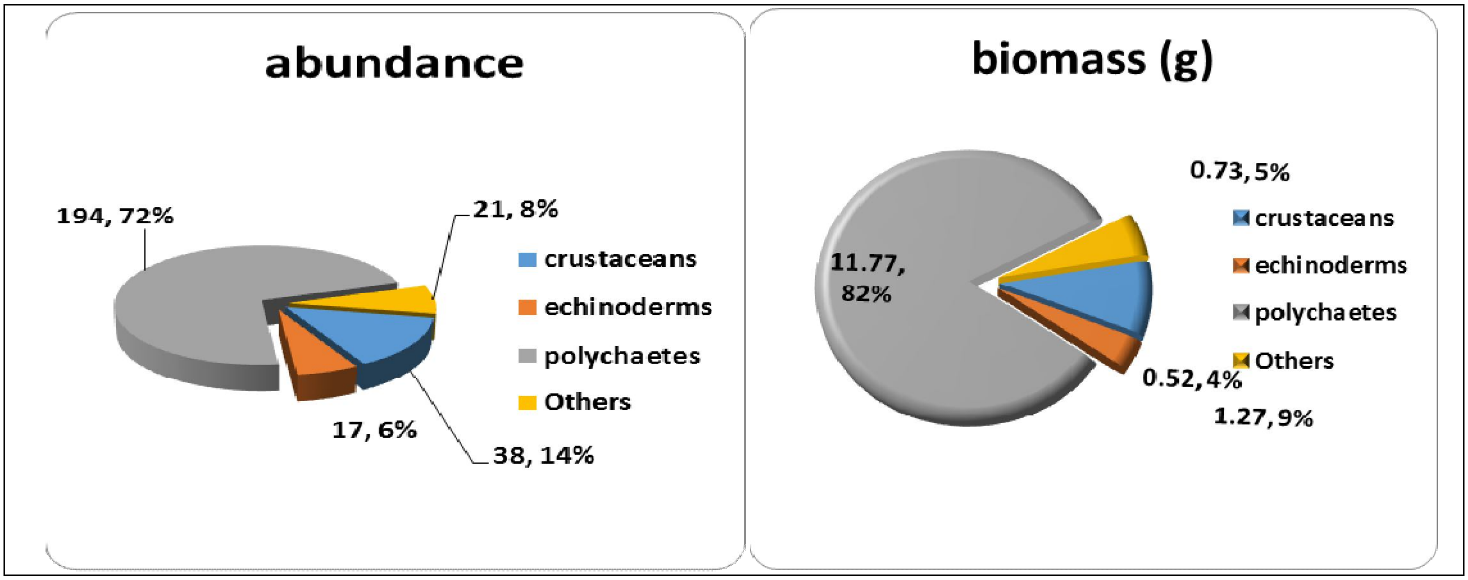

Figure 2: Chart showing the abundance and biomass of major taxa and their contributions

3.1.2. Species Diversity

Diversity indices were calculated for all the stations using untransformed abundance data. From the distribution, Margalef's species richness (d') was highest in Stations GE-3 and GW-5 recording values of 5.98 and 5.92, respectively. The Margalef species richness was lowest at stations GE-2 (0.62) and GP-5 (0.96).There was no trend in species richness across transects except on the GW-transect where species richness decreased with increasing depth. The Shannon-Wiener diversity index ranked highest in Stations GW-1 and GE-3 recording values of 2.96 and 2.95, respectively. The lowest values for the index occurred at Stations GE-2 (0.5), GW-5 (0.69) and GP-5 (0.73). Generally, the Shannon-Wiener diversity decreased with increasing depth along the transects.

Among the transects, GW (Ghana-West) showed the highest mean values in terms of the number of species (28.50 ± 10.61), number of individuals (49.00 ± 9.90), Shannon-Wiener diversity (H'= 3.13 ± 0.40), and evenness (J'=0.94 ± 0.01). This was followed by GE (Ghana-East): mean number of species (26.00 ± 11.31), number of individuals (52.50 ± 24.75), Shannon-Wiener diversity (H'=2.95 ± 0.38), and evenness/equitability (J'=0.92 ± 0.01). The mean values for the GP (Gas Pipeline) transect were: number of species (20.00 ± 1.41), number of individuals (34.50 ± 3.54), species diversity (2.82 ± 0.01), and evenness/equitability (0.94 ± 0.02).

There was a general trend of increasing values with increasing depth on the GW-transect for all the indices. In particular were the species richness, species evenness and species diversity which all decreased with increasing depth. A similar trend was observed for the GP-transect. However, the GE-transect showed no trend with depth (Figure 3).

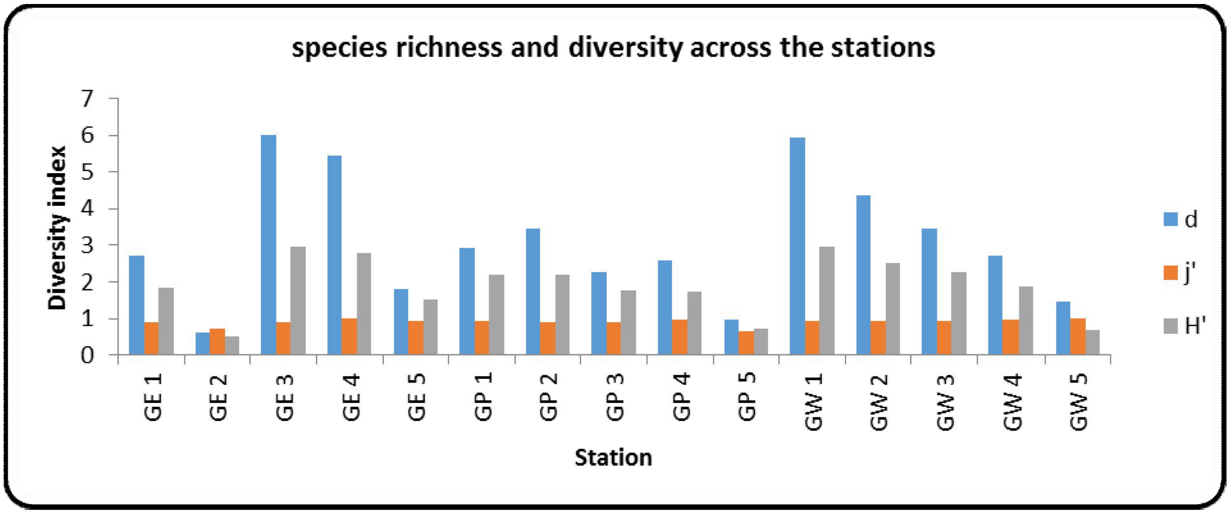

Figure 3: Spatial distribution of diversity indices: d=species richness, H'=species diversity, and J'=species evenness.

A one-way Analysis of Variance (ANOVA) test showed that benthic infauna differed in diversity along the sampling gradient at different depths (*p=0.05*), and among the different transects (*p=0.05*)

3.2. Community Structure Analyses

3.2.1. Similarity Analysis

The dendogram plots for all the stations showed three cluster groups Group 1 (GE-1, GP-1, and GW-5), Group 2 (GW-2, GP-3, GW-1, GE-3) and Group 3 (GW-4, GP-5, GP-4, GE-4, GP-2, GW-3 and GE-5) in terms of species assemblages (Figure 4).

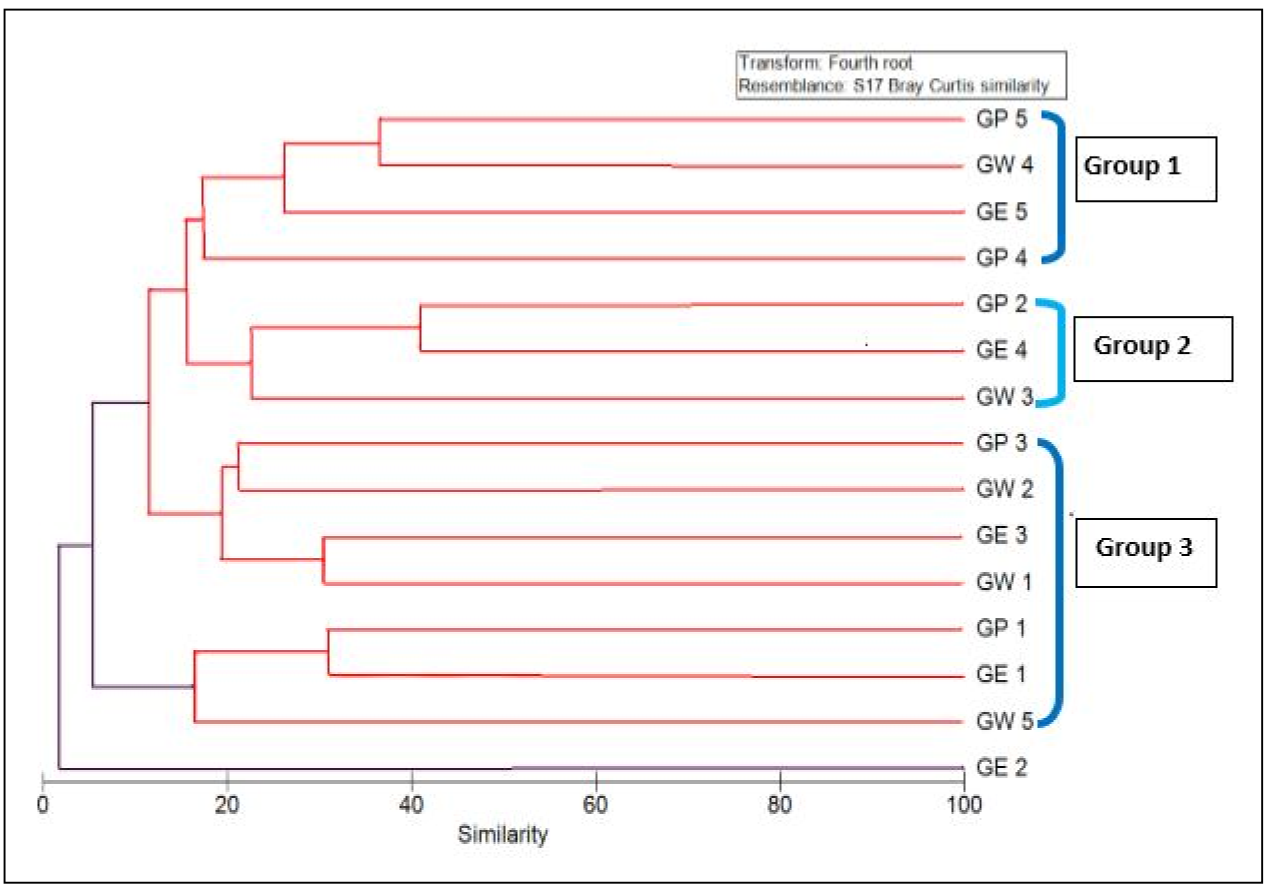

Figure 4: Cluster analysis results using Group linkage of agglomerative property to produce dendrograms of sampled stations based on species abundance. Bray-Curtis model was used to compute for the similarity index of species in the respective stations with fourth root transformation.

Station GE-2 was found not clustering with any other station in terms of similarity (hence the black line).

A SIMPER (Similarity Percentages) analysis performed on the cluster groups showed the different species that contributed the most to the similarity and dissimilarity and discriminated between the stations and the cluster groups. For instance, *Onuphis* sp. and *Glycera* sp. contributed 74.27% to the similarity of Group 1 with average abundances of 1.67 and 2.00, respectively. Six species, crustacean indet., Capitellidae indet., *Prionospio* sp., Tanaid, Phyllodocedae indet., and *Paralacydonia paradoxa* collectively accounted for 72% of the similarity in Group 2. In Group 3, Sipuncula, *Magelona cincta, Ophiotrix* sp.*, and Aricidea fauveli* accounted for 75% of the similarity within the group. The species that discriminated between the groups are shown in Table 2. Between Groups 2 and 3, there was an average dissimilarity of 87.40% and species that contributed to the dissimilarity included Crustacean indet. (Percentage contribution, = 5.18), Capitellidae indet. (Percentage contribution = 4.09), Sipuncula (percentage contribution = 3.87 %), *Prionospio* sp. (percentage contribution = 3.51 %) and *Magelona cincta* (percentage contribution = 3.31 %). Between Groups 2 and 1, there was an average dissimilarity of 93.26%. Species contributing to the dissimilarity included *Onuphis* sp. (5.90%), Shrimp (4.42%), Capitellidae indet. (4.17%), *Glycera* sp. (3.65%), *Prionospio* sp. (3.58%). Between Groups 3 and 1, there was an average dissimilarity of 95.30%. Species that contributed to the dissimilarity included *Onuphis* sp. (9.15%), Sipuncula (6.88%), *Orbinia* sp. (5.13%), *Magelona cincta* (4.90%), *Ophiotrix* sp. (4.67%).

Group 1 Average similarity: 25.47%					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Onuphis sp.	1.67	14.76	3.98	57.96	57.96
Glycera sp.	2.00	4.15	0.58	16.31	74.27
Group 2 Average similarity: 21.14%					
Species	**Av.Abund.**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Crustacean indet	3.50	4.01	0.81	18.95	18.95
Capitellid indet.	1.75	3.71	0.89	17.54	36.49
Prionospio sp	1.00	2.33	0.88	11.03	47.52
Tanaid	1.50	2.16	0.89	10.22	57.74
Phyllodocidae indet	0.75	2.02	0.90	9.55	67.28
Paralacydonia paradoxa	1.75	1.16	0.41	5.50	72.78
Group 3 Average similarity: 20.51					
Species	**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Sipuncula	1.57	6.92	0.86	33.72	33.72
Magelona cincta	1.00	4.63	0.87	22.55	56.27
Ophiotrix sp	1.29	2.61	0.58	12.71	68.98
Aricidea fauveli	0.57	1.30	0.39	6.34	75.33

Table 1: SIMPER analyses showing the similarities among the three groups and the contributions of each species to the average similarities

Groups 2 and 3 Average dissimilarity = 87.40%						
	Group 2	**Group 3**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Crustacean indet.	3.50	0.00	4.52	1.27	5.18	5.18
Capitellid indet.	1.75	0.00	3.58	1.50	4.09	9.27
Sipuncula	1.50	1.57	3.38	0.95	3.87	13.14
Prionospio sp.	1.00	0.00	3.07	1.11	3.51	16.65
Magelona cincta	0.75	1.00	2.90	1.14	3.31	19.96
Tanaid sp	1.50	0.43	2.69	1.13	3.07	23.04
Ophiotrix sp.	0.50	1.29	2.66	1.02	3.04	26.08
Tharyx sp.	1.00	0.00	2.59	0.83	2.96	29.04
P. paradoxa	1.75	0.29	2.39	0.92	2.73	31.78

Table 2: SIMPER analyses results: Species contributing to the average Bray-Curtis dissimilarity between the three groups.

Groups 2 and 1						
Average dissimilarity = 93.26%						
	Group 2	Group 1				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Onuphis sp	0.25	1.67	5.51	1.52	5.90	5.90
Shrimp	3.50	0.33	4.12	1.04	4.42	10.32
Capitellidae indet.	1.75	0.00	3.89	1.43	4.17	14.49
Glycera sp	0.00	2.00	3.40	1.26	3.65	18.14
Prionospio sp	1.00	0.00	3.34	1.05	3.58	21.73
Orbinia sp	0.00	0.33	3.13	0.63	3.36	25.09
S. madagascarensis	0.00	1.00	2.86	1.26	3.07	28.15
Tharyx sp	1.00	0.00	2.84	0.80	3.04	31.20
Tanaid sp	1.50	0.00	2.82	1.36	3.02	34.22
P. paradoxa	1.75	0.00	2.67	0.87	2.87	37.09
Groups 3 and 1						
Average dissimilarity = 95.30%						
	Group 3	**Group 1**				
Species	**Av.Abund**	**Av.Abund**	**Av.Diss**	**Diss/SD**	**Contrib%**	**Cum.%**
Onuphis sp	0.00	1.67	8.71	1.83	9.15	9.15
Sipuncula	1.57	0.00	6.56	1.08	6.88	16.03
Orbinia sp	0.57	0.33	4.89	0.70	5.13	21.16
Magelona cincta	1.00	0.00	4.67	1.23	4.90	26.07
Ophiotrix	1.29	1.67	4.45	1.01	4.67	30.74
Glycera sp	0.43	2.00	4.37	1.19	4.58	35.32
S. madagascarensis	0.00	1.00	3.79	1.31	3.98	39.30

Table 3

An ANOSIM (Analysis of Similarity) test for differences in community composition among the three groups under the null hypothesis of "no site differences" indicated a global R of 0.597, $p = 0.001$. Table 4 shows results of pair-wise tests. This revealed differences between all paired groups.

Groups	R statistic level	Significance Difference	Significant permutation	Actual observed	Number ≥
Gp. 1, 2	0.852	0.029	Yes	35	1
Gp.1, 3	0.71	0.008	Yes	120	1
Gp2, 3	0.426	0.015	Yes	330	5
Global R=0.569 , significance level, p= 0.001					

Table 4: Pair-wise tests for the three groups using a one way ANOSIM

4. Discussion of Results

4.1. Macrobenthic Faunal Community Structure

Community structure analysis deals with quantitative determination of the macrobenthic fauna in space. Several metrics such as numerical abundance, biomass and composition as documented by previous studies (e.g., Kropp, 2004; Surugiu, 2002; Branch *et al*., 2002; Bamikole *et al*., 2009; among others) were employed in the community structure assessment. These measures aid in revealing subtle patterns of variation between the habitats under investigation.

Among the major taxa encountered in the study, polychaetes ranked highest in terms of numerical abundance and biomass, while echinoderms; 'Others' and crustaceans follow in that order. This is in agreement with other studies (e.g., Băcescu *et al*., 1971; Surugiu, 2002; Bamikole *et al*., 2009). According to Branch *et al.* (2002), polychaetes are the commonest and most diverse creatures occurring in the benthic environment. Polychaetes contributing to 72% of the total abundance is also in line with studies by Knox (1977) who indicated in a study of benthic soft bottom communities that polychaetes constituted about 75% of the total organisms. This pattern of observation may be due to the muddy nature (muddy sand) of the sediment that favours burrowing and tube dwelling activity of the polychaetes. The sediment type probably also favours the feeding habits of majority of the observed species since most of the polychaetes encountered in the study are deposit feeders well adapted to live in soft sediments (Kropp, 2004), feeding on the detritus and the organic matter in the sediment (Ajao, 1990; Bamikole *et al*., 2009), which were relatively high during the study.

Generally, the benthic infauna found at all the sites were composed of a small number of abundant species and a large number of rare species; indicated by 54 % of the species being represented by just one or two individuals. This finding is in line with similar work by

Bamikole *et al*. (2009) in Nigeria. The observation or occurrence could possibly be attributed to the nature of sediment distribution across the sampled areas. This assertion is based on the fact that the substrate types in the study were homogenous and may support the distribution and abundance of the polychaetes (Lalli and Parsons, 1997) as many are deposit feeders and acquire nutrition from the sediment. Generally, sediment types and distribution affect the abundance and distributions of organisms in the marine environment (Lindroth, 1935; Rhoads and Young, 1970; Glemarec, 1973). The sediment types and distributions in turn are largely influenced by the effects of the winds, currents, near-bottom stress, flow regimes, rainfall pattern, biological activities and anthropogenic activities (Duineveld *et al.,* 1991; Hall, 1994). These may have accounted for the observed patchy distribution of organisms in the study area. The patchy distribution of benthic organisms was evidenced by the lack of organisms recorded at certain stations.

The presence of some fish larvae in the “Others” taxa might be an indication that the area might also be a nursing ground for some fish species since the fish larvae is likely to be the juvenile stage of a demersal fish species.

There was a low abundance of echinoderms and crustaceans in the study contrary to known trends (Ajao, 1990 and Bamikole *et al*., 2009; all in the Gulf of Guinea, Nigeria). This is especially intriguing because many echinoderm groups show a great variation in feeding habits, one obvious prerequisite for survival (Brusca and Brusca, 2003). This could be attributed to the nature of sediment not being most suitable to these groups and also to disturbance events leading to emigration of these groups from the study area. A possible explanation could be the fact that the response of organisms to a disturbing agent depends on the nature, frequency and severity of the disturbance (Kropp, 2004). Thus, a single disturbance may lead to measurable responses in the organisms, associations or communities, followed by compensation or return to a dynamic equilibrium. Under a severe disturbance, benthic communities undergo changes in both biological and trophic structures (Netto *et al*., 2004). When these disturbances lead to changes in chemical and physical properties of the sediment, the benthic community is affected, and one community tends to be replaced by another since many morphological and physiological adaptations of the fauna are related to the substrate. When the disturbances lead to organic enrichment, faunal changes lead to a progressive reduction in the complexity of the benthic community structure. This possibly explains the observed community structure in which “other” taxa were low in abundance.

This same explanation may also be appropriate for the observed absence of mollusks in all the samples from all transects; in discordance with popular observations of benthic taxa inhabiting marine soft-bottom substrates (Ajao, 1990; Barnes, 1980; Oyenekan, 1975, 1983 and 1987). Mollusks have been described by Merlano and Hegedsus (1994) as the second diverse group of marine invertebrates, which may represent 38% of the invertebrate fauna on tropical and sub tropical continental shelves (Longhurst and Pauly 1987), and occupy all marine environments from the wave-splashed zone of rocky shores to hydrothermal vents in the deep sea. But since their distribution is dependent on the particle grain size, stability of sediment, light and temperature (Earll and Erwin, 1983), it is reasonable to assume that these conditions were not met in the study area and hence their absence.

4.2. Infaunal Species Composition and Diversity across the Stations

High species richness is considered as a desirable property of any community or ecosystem and this criterion has dominated most methods for ecological conservation evaluation techniques (Usher, 1986). Furthermore, species richness is regarded as a fundamental measure of both local communities to regional diversity, since this forms the basis of ecological models and conservation strategies (Nicholas and Colwell, 2001). Benthic samples from the deep sea have been known to show high diversity (e.g., Grassle and Maciolek, 1992; Carney, 2001; and Gage, 2001; among many others). The species diversity from the results indicate a relatively medium diversity, since the indices obtained (0.69 to 2.96) lie within the range of the Shannon-Weiner diversity index which fall between 1.5 and 3.5 (Kent and Coker, 1992). The high species diversity according to Molles (1999) occurs in areas where there is a mixture of different species and where the number of individuals in the total population is evenly distributed.

Comparing the two stations from the Jubilee fields with stations from similar depths from other transects showed that species diversity and richness at all depths greater than 1000 m were low. Hence the low diversity could be attributed to depth rather than any form of anthropogenic impact, since the relationship of diversity to depth has already been established (Molles, 1999). In fact, earlier research has documented a general exponential decline in benthic standing stock (biomass and abundance) with depth (Rowe, 1983; Gage and Tyler, 1991) which seems to corroborate the findings in this current study.

Generally, species diversity and richness decreased with increasing depth which is contrary to known trends (Duxbury *et al*., 2003). This may be due to reduced availability of sunlight and other optimum conditions necessary for productivity (Kropp, 2004). The Ghana West transect showed a decreasing trend in species diversity and richness with increasing depth. Generally the trend in decreasing diversity of species with increasing depth became clearer as one moved from East to West. This may possibly be due to the presence of supporting infrastructure such as underwater pipelines laid for the transport of the oil and gas onshore; and also to the hydrodynamics and wind systems in the region (Longhurst, 1962), particularly to the westerly movement of the Benguela current in the area. Seasonal variations in ecological parameters may also be attributed to the observations since these have been found to exert a profound effect on the distribution and population density of both animal and plant species (Odum, 1971).

Generally, the Ghana East and Ghana West transects recorded highest values for the diversity indices with the Gas pipeline transect recording the lowest values. This may be due to the proximity of these stations to the coast. In all, the Ghana West transect showed the highest number of species evenness giving an indication of a fair distribution of all species among the stations. Nonetheless all the sampled stations (also the transects) showed an even distribution of species.

5. Conclusions and Recommendations

5.1. Conclusions

The polychaetes dominated the macrobenthic infauanal assemblage of Cape Three Points both in abundance and biomass. There were distinct spatial and bathymetric differences in the distribution and abundance of the benthic infauna. Spatially, species assemblages decreased from west to east. In terms of a depth profile, species assemblages decreased with increasing depth. The community patterns of the infauna at the Cape three Points were patchy in their distribution with few species depicting widespread distribution.

5.2. Recommendations

Subsequent studies should endeavour to measure the concentrations of pollutants not only in the sediment but also in the biota and the overlying water so as to be able to quantify the total concentrations of particular pollutants in the environment; as well as other physical, chemical and biological parameters that this study could not cover.

Studies should be done periodically to assess changes to the pristine environment upon which this study was conducted. Future studies should also consider holistic assessment of trace metals notably Strontium, Iron, Mercury, and total hydrocarbons since these have been found to affect the community structure of oil drilling environments.

6. References

i. Ajao, E.A. (1990). The influence of domestic and industrial effluents on population of sessile and benthic organismsinLagos lagoon. PhD Thesis, University of Ibadan, pp: 413.
ii. Aller, R.C. (1983). The importance of diffusive permeability of animal burrow linings in determiningmarine sediment chemistry. Journal of Marine Research, 41, 229-233.
iii. Băcescu, M., Müller, G., & Gomoiu, M. T. (1971). Analiza cantitativa, calitativa si comparativa a faunei bentale pontice.- Ecologie Marina, 4, 1-357.
iv. Baird, C. (2000). Environmental Chemistry (3rd ed.). New York: W.H. Freeman and Company.
v. Bamikole, W. A., Ndubuisi, A., Abohweyere, O. P., & Olawusi-Peters, O.O. (2009). Macrobenthic fauna of Snake Island area of Lagos lagoon, Nigeria. Nigerian Institute of Oceanography and Marine research, Lagos, Nigeria. Research Journal of Biological Sciences, 4 (3), 272-276.
vi. Barnes, R.S.K. (1980). Coastal lagoons. The natural history of a neglected habitat. Cambridge studies in modern Biology: Cambridge: Cambridge University Press.
vii. Beaumont, N., & Hadley, D. (2004). Managing the effects of trawl fishing on the benthic environment: a management manual. An output of the COST-IMPACT project: costing the impact of demersal fishing on marine ecosystem processes and biodiversity. 42pp
viii. Boesch, D.F., Kraeuter, J.N., & Serafy, D.K. (1977). Distribution and structure of communities of macrobenthos on the outer continental shelf of middle Atlantic Bight: 1975-1976 Investigations. Virginia Institute of Marine Science Special Report in Applied Marine Science and Ocean Engineering, No. 175.
ix. Branch, G.M., Griffiths, Branch, M.L., Beckley, L.E. (2002). Two Oceans. A guide to the marine life of Southern Africa (5th ed.). Cape Town, South Africa: David Philip Publishers.
x. Brusca, R. C., & Brusca, G. J. (2003). Phylum Echinodermata, pp 801-837 In: .Brusca, R.C., & Brusca, G.J. (eds). Invertebrates Sinauer Associates, Inc., Publishers.
xi. Carney, R.S. (2001). Management Applicability of Contemporary Deep-Sea Ecology and Reevaluation of Gulf of Mexico Studies. Final Report. OCS Study MMS2001-095. U.S. Department of the Interior Minerals Management Service, Gulf of Mexico OCS Region Office, New Orleans, LA. 174.
xii. Castro, P., & Huber, M. E. (2000). Marine biology (3rd ed.). New York: McGraw-Hill Companies.
xiii. Castro, P., & Huber, M. E. (2007). Marine Biology (6th ed.). New York: McGraw-Hill Companies.
xiv. Currie, D.R., & Isaacs, L.R. (2005). Impact of exploratory offshore drilling on benthic communities in the Minervagas field, Port Campbell, Australia. Marine Environment Research, 59, 217-233.
xv. Day, J.H. (1967b). A monograph on the Polychaeta of Southern Africa. Part II, sedentaria, Trustees of the British Museum London.
xvi. Day, J.H. (1967a). A monograph on the Polychaeta of Southern Africa. Part 1 Errantia. Trustees of the British Museum London.
xvii. Doscher, T.M. (2008). Petroleum. Microsoft® Encarta® 2009 [DVD]. Redmond, WA: Microsoft Corporation, 2008.
xviii. Duineveld, G.C.A., Künitzer, A., Niermann, U., Wilde, P.A.W.J., & Gray, J.S. (1991). The macrobenthos of the North Sea. Netherlands Journal of Sea Research, 28 (1/2), 53–65.
xix. Duxbury, A.C., Duxbury, A.B., & Sverdrup, K.A. (2003). An introduction to the world's oceans (6th ed.). NY: McGraw-Hill Company.
xx. Earl, R., & Erwin, D. G. (1983). Sublittoral ecology (the ecology of the shallow sublittoral benthos). New York: Oxford University Press.
xxi. Edmunds, J. (1978). Sea shells and other molluscs found on West African coast and estuaries. Accra: Ghana University Press.

xxii. Fauchald, K. (1977). The polychaete worms: definitions and keys to the orders, families and genera. Science series 28. Natural History Museum of Los Angeles County. Los Angeles, CA.
xxiii. Fauchald, K. and Jumars, P. A. (1979). The diet of worms: a study of polychaetes feeding guilds. Oceanogr. Mar Biol Ann Rev. 17, 193– 284.
xxiv. Gage, J.D. (2001). Deep-sea benthic community and environmental impact assessment at the Atlantic frontier. Continental Shelf Research, 21, 957-986.
xxv. Gage, J.D., & Tyler, P.A. (1991). Deep-Sea Biology: a natural history of organisms at the deep-sea floor. Cambridge: Cambridge University Press.
xxvi. Glémarec, M. (1973). The benthic communities of the European North Atlantic continental shelf. Oceanography and Marine Biology Review, 11, 263–289.
xxvii. Grassle, J.F., & Maciolek, N.J. (1992). Deep-sea species richness: regional and local diversity estimates from quantitative bottom samples. American Naturalist, 139, 313-341.
xxviii. Gray, J.S., Clarke, K.R., Warwick, R.M., & Hobbs, G. (1990). Detection of initial effects of pollution on marine benthos - an example from the Ekofisk and Eldfisk Oilfields, North-Sea. Marine Ecology Progress Series, 66, 285-299.
xxix. Gray, J.S. (1992). Biological and ecological effects of marine pollutants and their detection. Marine Pollution Bulletin, 25, 48-50.
xxx. Gregory, A. (2007). Response of macrobenthic communities to oil spills along the Goa Coast. Dissertation submitted to Environmental Science Department, Institute of Science, Mumbai University.
xxxi. Hall, S. J. (1994). Physical disturbance and marine benthic communities: life in unconsolidated sediments. Oceanogr. mar. Biol a Rev, 32, 179-239.
xxxii. Ingole, B.S (2005). Indian Ocean Coast, Coastal Ecology. Western Washington University, WA, U.S.A.Encyclopedia of Coastal Science. Springer Publisher, Netherlands. 546-554. Maurice L. Schwartz, ed.
xxxiii. Jackson, D.A. (1993). Multivariate analysis of benthic Invertebrate communities: the implications of choosing particular data standardisations, measures of association and ordination methods. Hydrobiologia, 268, 9- 26.
xxxiv. Jorgensen, C. B. (1966). Biology of suspension feeding. Oxford: Pergamon Press.
xxxv. Karbassi, A.R, Nabi-Bidhendi, G.R., & Bayati, I. (2005). Environmental geochemistry of heavy metals Iran. Journal of Environmental Health Science, 2, 255-260.
xxxvi. Kelly, J.R., Kropp, R.K., Uhler, A.D., Zielinski, M.B., &Tawatchai, S. (1998). Environmental response and recovery at drilling platforms in the Gulf of Thailand. Proceedings of the 1998 Society of Petroleum Engineers International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production. Caracas, Venezuela. 21 pp.
xxxvii. Kennicutt, M.C., II, Boothe, P.N., Wade, T.L., Sweet, S.T., Rezak, R., Kelly, F.J., Brooks, J.M., Presley, B.J. and Wiesenburg, D.A. (1996a). Geochemical patterns in sediments near offshore production platforms. Canadian Journal of Fishery and Aquatic Science., 53, 2554-2566.
xxxviii. Knox, G.A. (1977). The role of polychaetes in benthic soft-bottom communities. In: D.J. Reish nd Fauchald, K. (eds), Essays on Polychaetous Annelids in memory of Dr. Olga Hartman, pp.547-604. Allan Hancock Foundation, Los Angeles.
xxxix. Kropp, R.K. (2004). Review of deep-sea ecology and monitoring related to deep-sea oil and gas operations. Battelle Marine Sciences Laboratory Sequim, Washington. Prepared for the U.S. Department of Energy.
xl. Lalli, C. M., & Parsons, T. R. (1997). Biological oceanography: An introduction. Oxford: Bulterworth Heinemann.
xli. Lindroth, A. (1935). Die association der marinen Weichdoden. Zool Bidrag Uppsala, 15, 331–366.
xlii. Longhurst, A.R. (1962). A review of the Oceanography of the Gulf of Guinea. Bulletin De I.N.F.A.N.T. XXIV, Ser. A, 24 (3), 633-663.
xliii. Longhurst, A. R., & Pauly, D. (1987). Ecology of tropical oceans. New York: Academic Press.
xliv. Molles, M. (1999). Ecology: concept and applications (1st ed.). Boston: McGraw Hill Companies. Inc.
xlv. Montagna, P.A., & Harper, D.E. (1996). Benthic infaunal long-term response to offshore production platforms in the Gulf of Mexico. Canadian Journal of Fisheries and Aquatic Sciences, 53, 2567-2588.
xlvi. Neff, J.M., Rabalais, N.N., & Boesch, D.F. (1987). Offshore oil and gas development activities potentially causing long-term environmental effects. Pp. 149-174, In, D.F. Boesch and N.N. Rabalais (eds.). Long-term environmental effects of off shore oil and gas development. New York: Elsevier Applied Sciences.
xlvii. Nicholas, J.G., & Colwell, R.K. (2001). Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters, 4 (4), 379-391.
xlviii. Nybakken, W. J. (1988). Marine Biology: an ecological approach (2nd ed.). NY: Harper Collins Publishers, Inc.
xlix. Odum E.P. (1971). Fundamentals of ecology. Japan: Toppan Company Ltd.
l. Peterson, C.H., Kennicutt II, M.C., Green, R.H., Montagna, P. Harper Jr., D.E., Powell, E.N., & Roscigno. P.F. (1996). Ecological consequences of environmental perturbations associated with offshore hydrocarbon production: a perspective on long-term exposures in the Gulf of Mexico. Canadian Journal of Fisheries and Aquatic Sciences 53:2637-2654.
li. Rhoads, D. C. , & Young, D. K. (1970). The influence of deposit-feeding organisms on sediment stability and community trophic structure. Journal of Marine Research, 28, 150–178.
lii. Rowe, G.T. (1983). Biomass and production of the deep-sea macrobenthos. In: The Sea, volume 8, ed. G. T. Rowe. New York: Wiley Interscience.

liii. Simboura, N., Zenetus, A., Panayotides, P., & Makra, A. (1995). Changes in benthic community structure along an environmental pollution gradient. Marine Pollution Bulletin, 30, 470-474.
liv. Snelgrove, P.V.R., & Butman, C.A. (1994). Animal-sediment relationships revisited: cause versus effect Oceanography and Marine Biology: an Annual Review, 32, 111-177.
lv. Surugiu, V. (2002). Populați le de polichete (Annelida) de la litoralul românesc al Mări Negre şi din sistemul lagunar şi rolul lor ecologic. Teză de doctorat, Universitatea "Alexandru Ioan Cuza" din Iaşi.
lvi. Usher, M.B. (ed.). (1986). Wildlife conservation evaluation. Chapman and Hall, London. In: Kent, M. and Coker, P. (1992). Vegetation description and analysis. A practical approach. John Wiley and Sons Ltd, West Sussex- England.
lvii. Wiafe, G. (2002). Spatial and temporal dynamics of planktonic communities in the Gulf of Guinea Ecosystem. University of Ghana. 205 pp.