4 ENVIRONMENTAL AND SOCIO-ECONOMIC BASELINE

4.1 INTRODUCTION

This chapter provides a description of the current environmental and socio-economic situation against which the potential impacts of the Jubilee Field Phase 1 development can be assessed and future changes monitored. The chapter presents an overview of the aspects of the environment relating to the surrounding area in which the Jubilee Field Phase 1 development will take place and which may be directly or indirectly affected by the proposed project. This includes the Jubilee Unit Area, the Ghana marine environment at a wider scale and the six Districts of the Western Region bordering the marine environment.

The Jubilee Unit Area and its regional setting are shown in *Figure 4.1*. The project area is approximately 132 km west-southwest of the city of Takoradi, 60 km from the nearest shoreline of Ghana, and 75 km from the nearest shoreline of Côte d'Ivoire.

Figure 4.1 Project Location and Regional Setting

The baseline description draws on a number of primary and secondary data sources. Primary data sources include recent hydrographic studies undertaken as part of the exploration well drilling programme in the Jubilee field area, as well as an Environmental Baseline Survey (EBS) which was commissioned by Tullow and undertaken by TDI Brooks (2008). An electronic copy of the EBS is attached to this EIS. It is noted that information on the offshore distribution of marine mammals, turtles and offshore pelagic fish is limited due to the lack of historic research in offshore areas.

Secondary data sources include various research studies and published literature including socio-economic data from the District profiles provided by the District administrations, the latest published population and housing census, and living standards surveys. It is noted that many of these sources are several years old and are currently under revision.

This chapter is structured in three main parts including a separate section on fisheries given its importance and potential interactions with the project. The chapter is organised as follows.

Environmental Baseline:
- Climate and Meteorology;
- Hydrography and Oceanography;
- Bathymetry and Seabed Topography;
- Water and Sediment Quality;
- Fauna and Flora;
- Habitat Types;
- Nature Conservation and Protected Areas.

Fisheries Baseline:
- Fisheries Regulatory Framework;
- Fish Landings;
- Fisheries Infrastructure;
- Industrial Fleets;
- Fish Biomass.

Socio-economic Baseline:
- Administrative Structures;
- Demographics;
- Livelihoods;
- Education;
- Health;
- Social Infrastructure and Services.

For areas where little or no baseline information exists, for example offshore noise and air quality, a programme of monitoring will be undertaken in consultation with the EPA (see *Chapter 7*).

4.2 *ENVIRONMENTAL BASELINE*

4.2.1 *Climate and Meteorology*

The regional climate in the Gulf of Guinea is influenced by two air masses, one over the Sahara desert (tropical continental) and the other over the Atlantic Ocean (maritime). These two air masses meet at the Inter-Tropical Convergence Zone (ITCZ) and the characteristics of weather and climate in the region are influenced by the seasonal migration of the ITCZ (*Figure 4.2*).

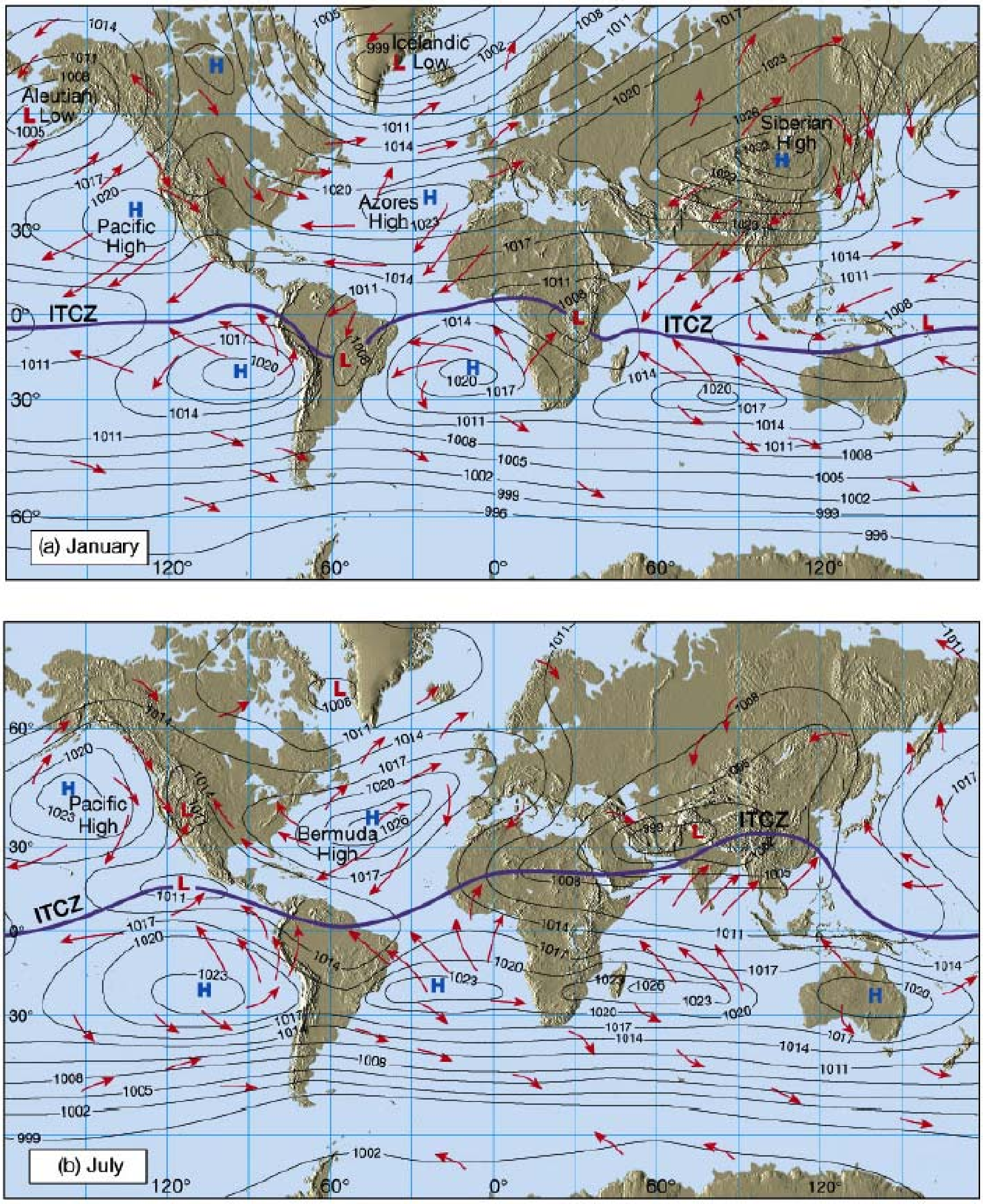
During the boreal winter months, the tropical continental air from the northern anticyclone over the Sahara brings in north-easterly trade winds which are dry and have a high dust load (on occasion these penetrate over the Atlantic as far south as 2°N in January). These winds bring a period of dry weather over the region.

The northward migration of the ITCZ (during boreal summer) results in warm humid maritime air reaching further inland over the region. In March, the ITCZ is located between 9°N and 12°N and by May-June, it is located approximately between 15°N and 16°N. During these periods, the region generally experiences the rainy seasons. The most northerly limit of the ITCZ is approximately 18-24°N and occurs between July and August.

In general, two seasons are characteristic of the climate in the region, namely the dry and wet seasons. The occurrence of these seasons corresponds with periods when the tropical continental and maritime air masses, and their associated winds, influence the region. The peak of the rainy season occurs from May to July and again between September and November. The maximum northern location of the ITCZ between July and August creates an irregular dry season over the region, whereby rainfall and temperatures decline. Meso-scale disturbances which also influence weather patterns in the region include thermal convections, resulting in showery weather over large areas and line squalls (storms) which usually move from east to west or north-east to south-west.

Annual rainfall in the region ranges from 730 mm to 3,500 mm with rainfall figures decreasing from the coast inland. The annual percentage of rainy days is generally greater than 60 percent. Solar radiation in the region generally varies between 275 and 300 Langley units (ly) per day during the rainy season and about 300 and 350 ly per day during the dry season. The distribution of solar radiation and temperature follow the same pattern in the region. Diurnal temperature range in the region is between 26°C and 33°C while the annual variation in temperature ranges is relatively small, ranging between 2°C and 4°C. Mean values of relative humidity for the region are high, generally more than 60 percent throughout the year but may be as greater than 80 percent in the mornings.

Figure 4.2 Location of the Intertropical Convergence Zone during January and July



Source: Noble Denton, 2008

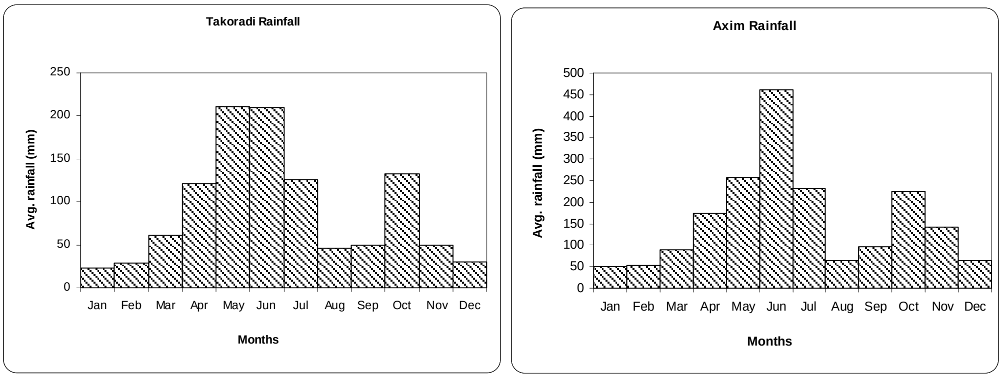
Specific climate and weather information for the Jubilee Field is drawn from Noble-Denton(1) (2008) metocean report and from Ghana meteorological recording stations located in Takoradi and Axim in the Western Region. Takoradi and Axim are the only coastal towns with long term climatic data within the vicinity of the Jubilee Field. The coastal parts of the Western Region are influenced by the dry North-East Trade Winds and the wet South-West Monsoon Winds of West Africa.

(1) Noble-Denton was appointed by Tullow to undertake a broad scale desk study of the meteorology and oceanography of the area in line with the appropriate recommended practice. Wind, wave and current data was available from a variety of

Rainfall

Takoradi and Axim experience rainfall throughout the year. A bi-modal pattern is observed with peaks in May-June and October (*Figure 4.3*). Axim, however, records twice as much precipitation as Takoradi during the peak periods. Mean peak value for Takoradi in May-June is about 210 mm and the mean peak value for Axim is about 460 mm, normally in June. Both stations experience lowest rainfall in January of 23 mm and 51 mm for Takoradi and Axim respectively. Rainfall over the sea is similar to that over land with the months of highest observed rainfall in May-June and September-October (Noble-Denton, 2008). *Table 4.1* below shows monthly percentages of rainfall over the sea.

Figure 4.3 ***Average Monthly Rainfall for Takoradi and Axim from 1999 to 2008.***



Source: Ghana Meteorological Service Department

Table 4.1 ***Monthly Percentage of Rainfall over the Sea***

Month	**% rainfall Observations**	**Month**	**% rainfall observations**
January	2	July	8
February	4	August	5
March	7	September	14
April	10	October	21
May	14	November	11
June	13	December	9

Source: Noble-Denton, 2008

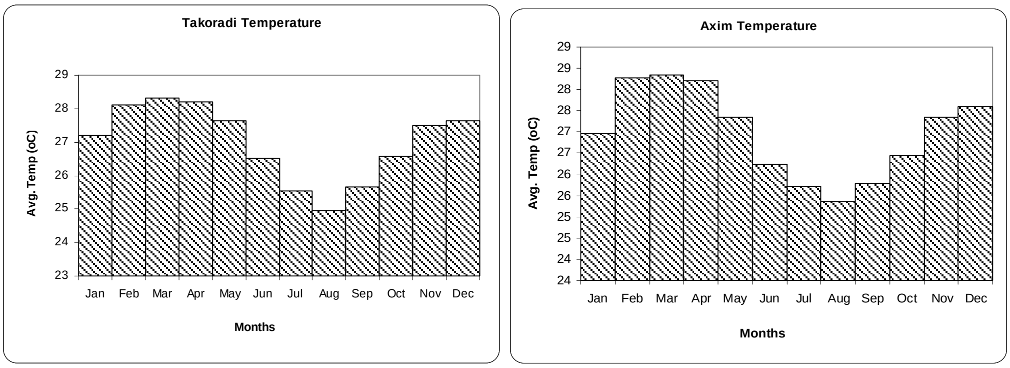
Temperature and Relative Humidity

Temperature patterns in Takoradi and Axim are generally similar and annual temperatures range between 24 and 30°C (*Figure 4.4*). Temperature is generally high from February to May and from November to December with peak temperatures recorded in March. Lower temperatures for the two areas were recorded between June and October with the coolest month usually

sources leading to reasonably reliable results. Data sources included satellite measurements, computer simulations (Global Wave Model), Voluntary Observing Fleet (VOF), atlases and publications (average conditions and extremes).

being August. The 10 year average for Takoradi and Axim was 24.9ºC and 28.3°C respectively between 1998 and 2008.

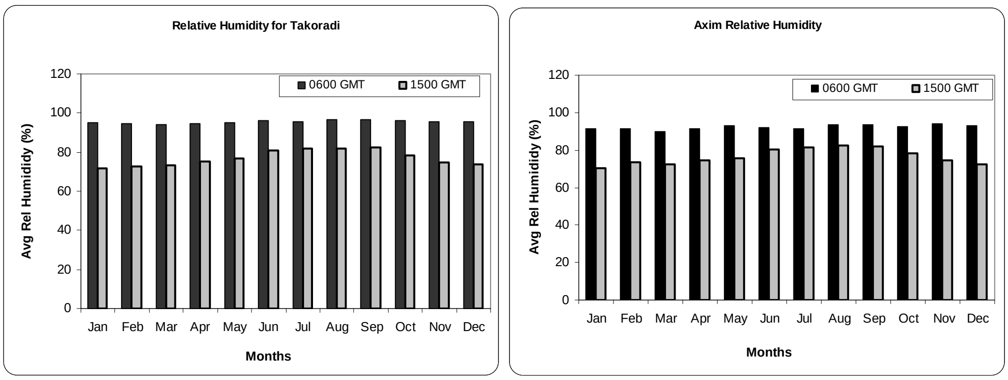
Figure 4.4 Monthly Average Temperature for Takoradi and Axim from 1999 to 2008



Source: Ghana Meteorological Service Department

Mean monthly relative humidity (RH) values for early morning (at 0600 GMT) and mid-afternoon (at 1500 GMT) for Takoradi and Axim are presented in *Figure 4.5*. The morning values range from 89.7 percent to 93.7 percent and 94.0 percent to 96.6 percent for Axim and Takoradi respectively. This suggests a westward decrease in morning humidity regimes.

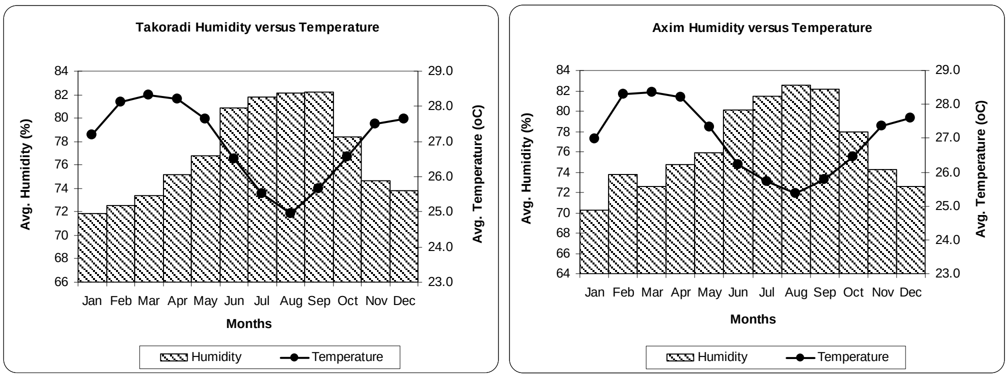
Figure 4.5 Average Monthly Relative Humidity for Takoradi and Axim from 1999 to 2008



Source: Ghana Meteorological Service Department

Humidity showed an inverse relationship with temperature whereby an increase in temperature resulted in decreased humidity (*Figure 4.6*). Humidity over the sea, according to the US Navy Marine Climatic Atlas of the World, varies between 80 and 85 percent throughout the year.

Figure 4.6 ***Relationship Between Average Monthly Humidity (Columns) and Temperature (Line) for Takoradi and Axim from 1999 to 2008***



Source: Ghana Meteorological Service Department

Wind

Surface atmospheric circulation in the region is largely influenced by north and south trade winds and the position of the ITCZ. Extreme winds are caused by squalls (storms), associated with the leading edge of multi-cell thunderstorms.

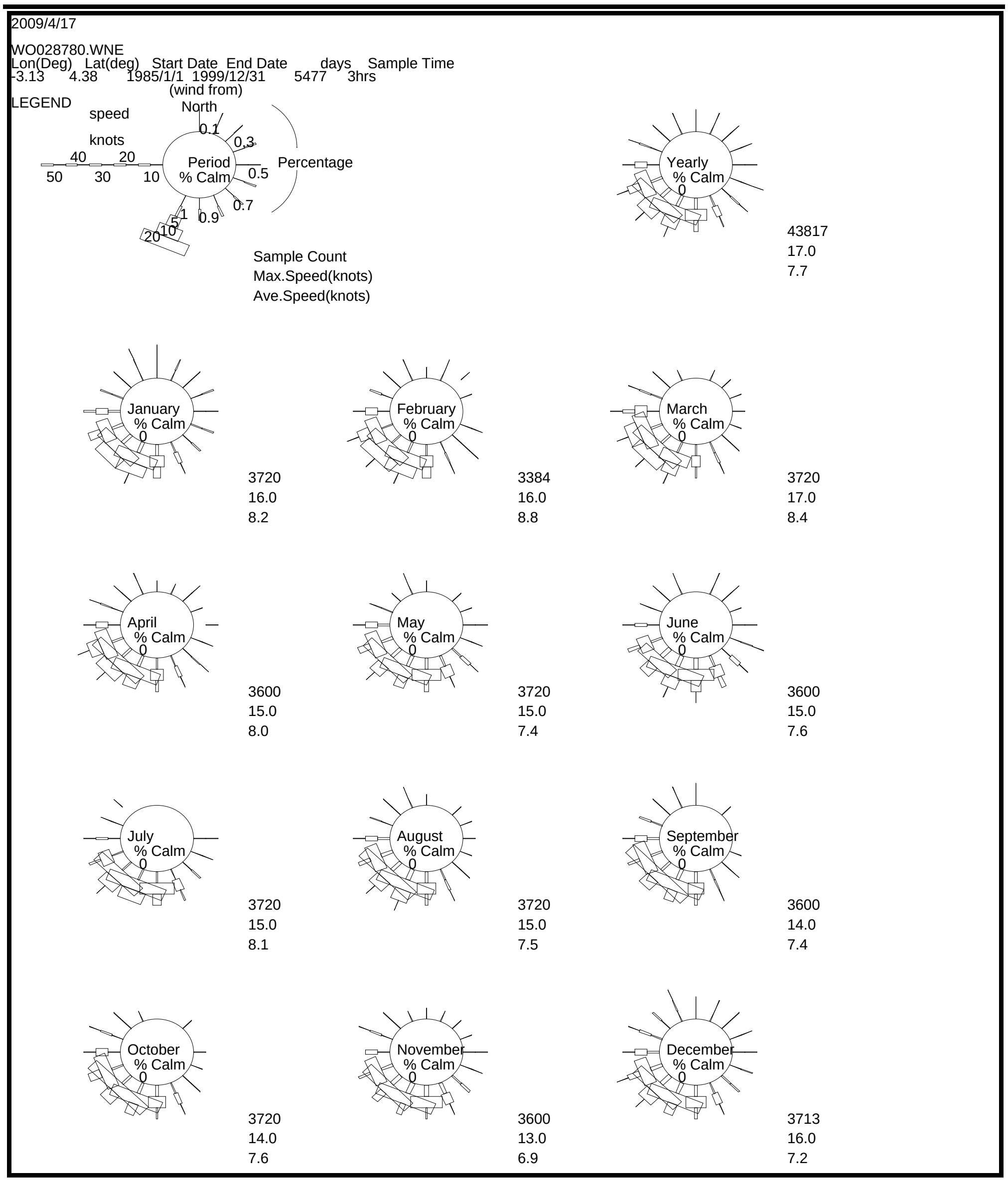
Offshore wind data sources included two hindcast models, NOAA's NCEP[(1)] atmospheric model re-analysis as well as WANE [(2)] data from three locations in the vicinity of the Jubilee field. These datasets show the same predominant south-western wind direction, with average wind speeds of 3.7 - 4.0 m/s and maximum winds speeds of 8.8 - 10.8 m/s. There is very little difference in wind speeds and directions over the course of the year. Monthly wind roses generated using the WANE dataset is provided in *Figure 4.7* (see *Annex D* for further details).

Onshore wind direction for Takoradi and Axim are generally south-westerly. However, inter-annual variability in direction occurs for some months. The average monthly wind speed for these areas ranges from 2-4 knots (*Figure 4.8*).

(1) Hindcast wind data was obtained at a 10 m height for the Ghana offshore region from NOAA's National Centres for Environmental Prediction (NCEP) atmospheric model re-analysis. Two NCEP stations are located in the in the vicinity of the Jubilee Unit area and provide winds for the time period of 1985 to 2009.

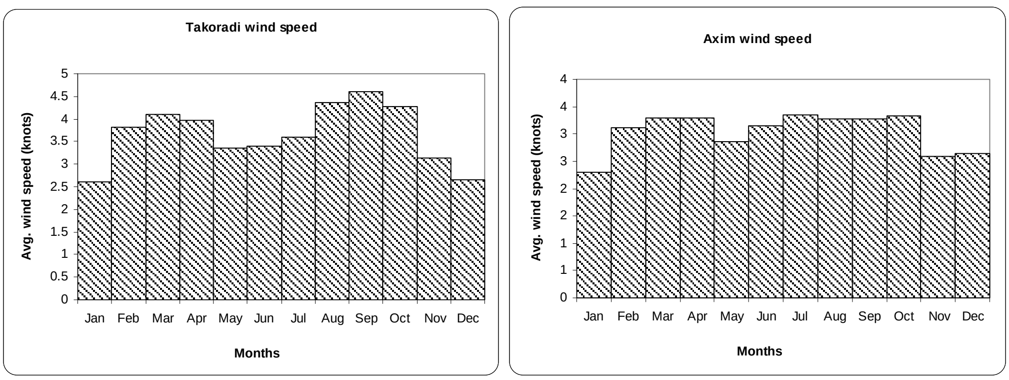
(2) West Africa Met-Ocean Normals and Extremes wind file (WANE 28780). WANE, an Oceanweather product, is a South Atlantic wind, wave and current database of model-generated time series data. It comprises a continuous, 10-year (18 years for the wind and wave data) hindcast study, as well as summary reports and statistics.

Figure 4.7 Wind Rose of Monthly Averaged WANE Wind Data Offshore Ghana



Source: ASA 2009

Figure 4.8 Average Monthly Wind Speed for Takoradi and Axim from 1999 to 2008



Source: Ghana Meteorological Service Department

4.2.2 *Air Quality*

The Jubilee Field is located approximately 60 km offshore and therefore away from any industries, urban areas or other onshore sources of air pollution. The only offshore source of air pollution would be vessels travelling along shipping lanes approximately eight nautical miles south of the field as well as vessels involved in exploration and appraisal well drilling in the vicinity.

In addition the air quality at the Jubilee Field would be affected by regional air quality. The principal source of atmospheric pollution across central Africa is biomass burning due to burning of firewood for cooking and heating, and controlled burning in savannah areas for agriculture (including slash and burn agricultural practices). It has been estimated that Africa accounts for almost one half of the total biomass burnt worldwide (Andrae, 1993). The result of this biomass combustion is the emission of carbon monoxide (CO), oxides of nitrogen (NOx), nitrous oxide (N_2O), methane (CH4), non methane hydrocarbons and particulate matter.

In term of exposure to fishermen and other users of the area the consentration of pollutants in the air in the location of the Jubilee field from these and other sources are expected to be very low due to the high level of atmospheric dispersion in the offshore environment.

4.2.3 *Hydrography and Oceanography*

The oceanography of the Gulf of Guinea comprises the principal water types of the South Atlantic, but is largely influenced by the meteorological and oceanographic processes of the South and North Atlantic Oceans, principally their oceanic gyral currents (Fontaine *et al*, 1999; Merle and Arnault, 1985). Surface waters are warm (24 - 29 ^{o}C) with the daily sea surface temperature cycle showing annual variability. Hydrographic data collected in the Gulf of Guinea indicate that a thermal cycle occurs only in the upper two elements of the water column which together comprise the tropical surface water mass. The oceanic gyral currents of the North and South Atlantic Oceans spurn a counter current, the Equatorial Counter Current which flows in an eastward direction. This becomes known as the Guinea Current as it runs from Senegal to Nigeria.

Stratification of Water Masses

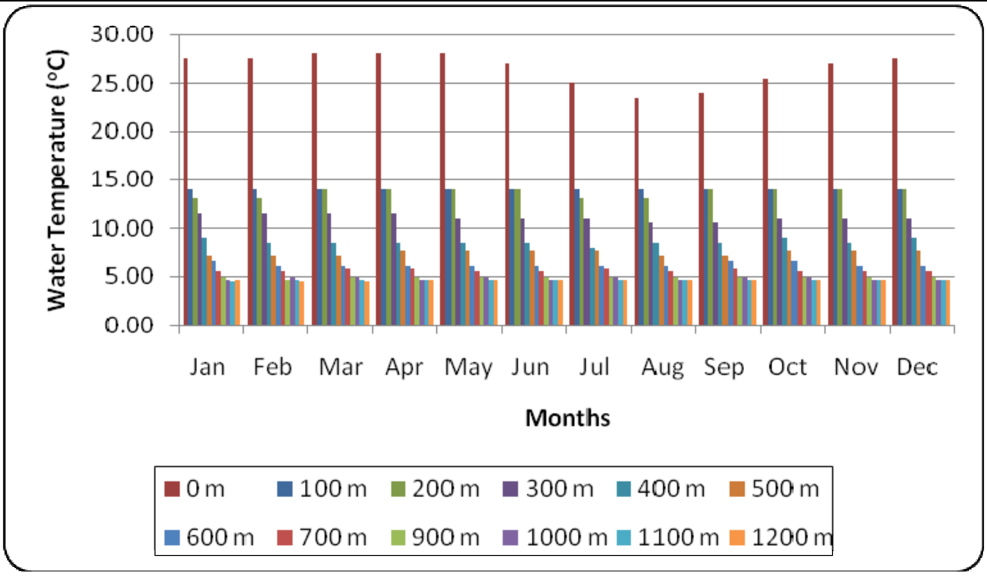
Water masses offshore the Ghanaian coast consist of five principal layers (Longhurst, 1962). The topmost layer is the Tropical Surface Water (TSW), warm and of variable salinity which extends down to a maximum of about 45 m depending on the seasonal position of the thermocline. Below the thermocline (which varies from 5 to 35 m) occurs the South Atlantic Central Water (SACW, cool and high salinity) down to a depth of about 700 m. Below this are consecutively, three cold layers, namely the Antarctic Deep Water (ADP, 700-1,500 m), the North Atlantic Deep Water (NADP, 1,500-3,500 m) and the Antarctic Bottom Water (ABW, 3,500-3,800). Sea surface temperature typically vary between 27 and 29°C, although strong seasonal cooling occurs during the season related to coastal upwelling processes.

Data available from the World Ocean Atlas and the US Navy Marine Climatic Atlas of the World (NOCD, 1995) shows the mean monthly water temperature at various water depths in Ghana waters (*Figure 4.9*). Surface waters are generally much warmer than waters at greater depths.

Upwelling

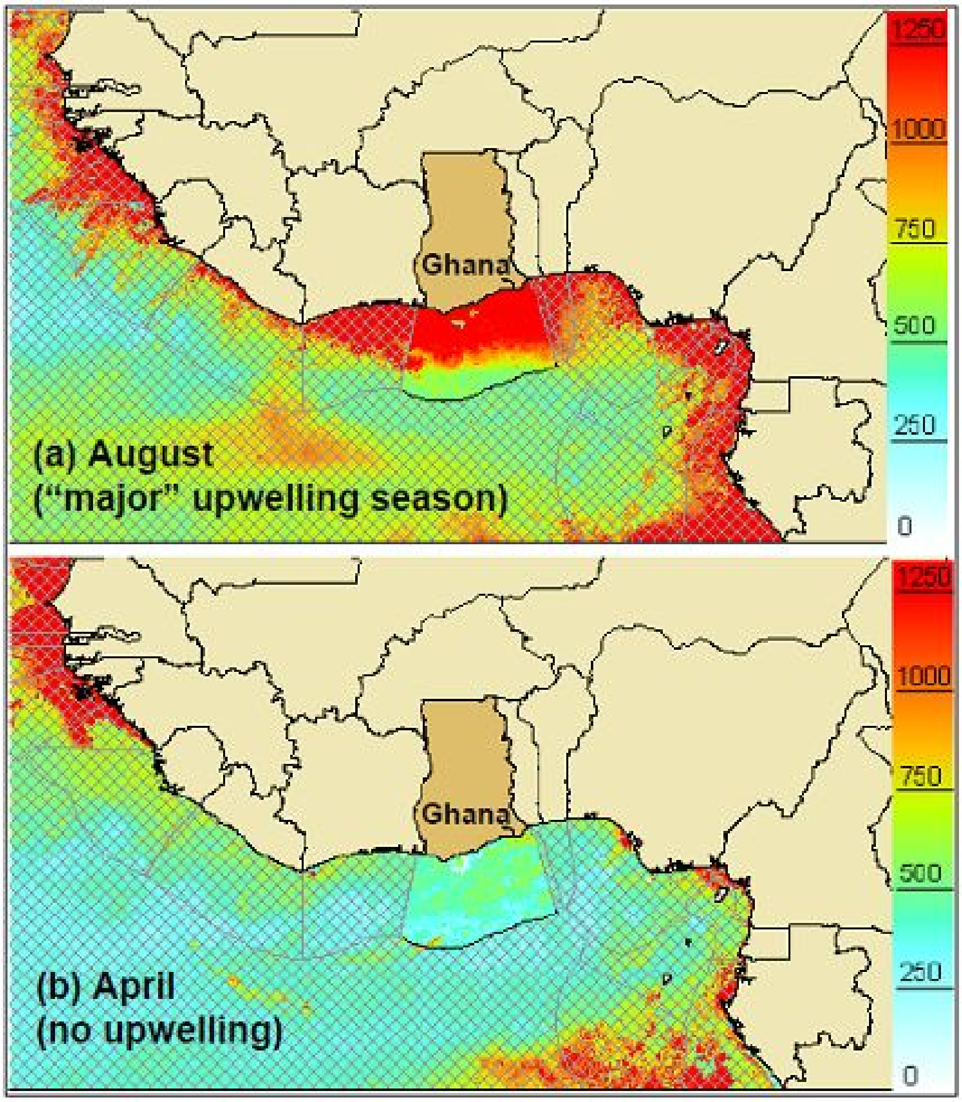
Upwelling is the term used when cold, nutrient-rich, water moves from depth up to the surface, resulting in increased plankton productivity in the surface waters. The major upwelling season along the Ghana coast occurs from July through to September/October, while a minor upwelling occurs between December and January/February (see *Figure 4.9* for water temperature profiles). The rest of the year is characterised by a strong thermocline, which fluctuates in depth between 10 and 40 m. The increased plankton productivity during the periods of major and minor upwelling attract pelagic fish species into the upper layers of the water column, thereby increasing fish catch (eg Sardinella fishery). The effect of upwelling on primary productivity is illustrated in *Figure 4.10*, which shows productivity as estimated from satellite imagery during upwelling (August) and non-upwelling (April) seasons. It is noted that this upwelling is widespread throughout the Gulf of Guinea.

Figure 4.9 Vertical Profile of Water Temperature Offshore Ghana



Source: Adapted from Noble-Denton, 2008

Figure 4.10 Primary Productivity (mg C m-2 d-1) Offshore Ghana During August and April



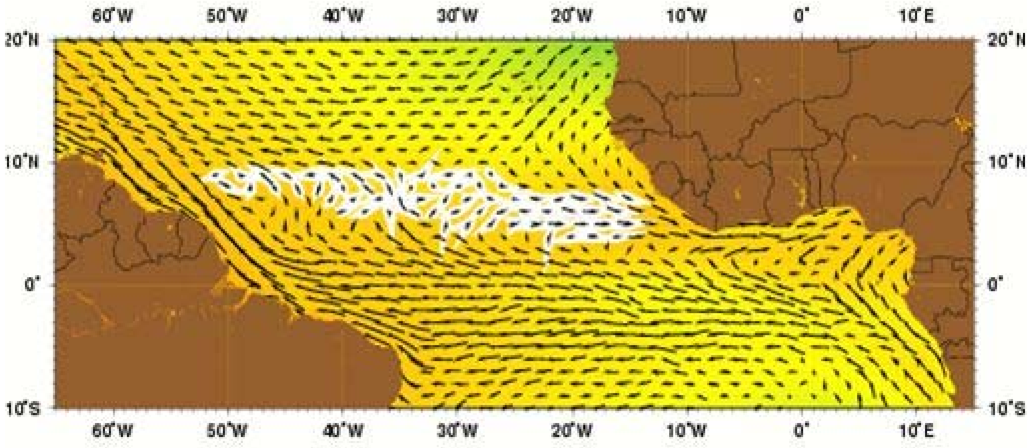
Source: Sea Around Us Project, 2008

An upwelling index has been developed which is a product of the upwelling duration (change in time) and intensity (change in temperature) which shows a strong positive correlation with fish catches in the region. Regular beach temperature monitoring has revealed that the upwelling intensity is greater within the vicinity of Takoradi where sea surface temperatures are usually lower than elsewhere in Ghanaian waters.

Currents

The principal current along the Ghana coastline is the Guinea Current, which is an offshoot of the Equatorial Counter Current (see *Figure 4.11)* and is driven by westward wind stress. When this subsides during February to April and October to November, the direction of the current is reversed. A small westward flowing counter current lies beneath the Guinea Current. Below 40 m depth the westward flowing counter current turns to the south-west with velocities ranging between 0.5 m/s to 1.0 m/s and 0.05 m/s to 1.02 m/s near the bottom. The cold subsurface water could be a branch of the Benguela Current that penetrates and dominates the Equatorial Counter Current.

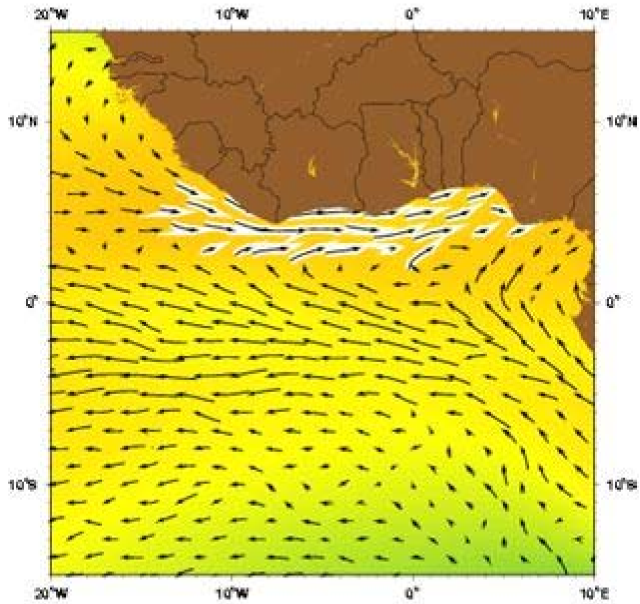
Figure 4.11 ***Equatorial Counter Current***



Source: Noble-Denton, 2008

The Guinea Current (*Figure 4.12*) reaches a maximum strength between May and July during the strongest South-West Monsoon Winds when it peaks at 1 to 2 knots [approximately 1 m/s]. For the rest and greater part of the year, the current is weaker. Near the coast, the strength of the current is attenuated by locally generated currents and winds. The current is less persistent near-shore than farther offshore. Geotropic effects[(1)] induce the tendency of the Guinea Current to drift away from the coast especially during its maximum strength.

Figure 4.12 ***The Guinea Current***



Source: Noble-Denton, 2008

(1) Geotropic currents result from the balance between gravitational forces and the Coriolis Effect.

The coastal surface currents are predominantly wind-driven and are confined to a layer of 10 to 40 m thickness. The direction of tidal current around the coast of Ghana is mostly north or north-east. The velocity of the tidal current is generally less than 0.1 m/s and the maximum velocity of tidal current observed in a day of strong winds is about 0.5 m/s. The wave induced longshore currents are generally in the west to east direction which is an indication of the direction the waves impinge the shoreline. The longshore currents average approximately 1 m/s and vary between 0.5 and 1.5 m/s. The magnitude increases during rough sea conditions.

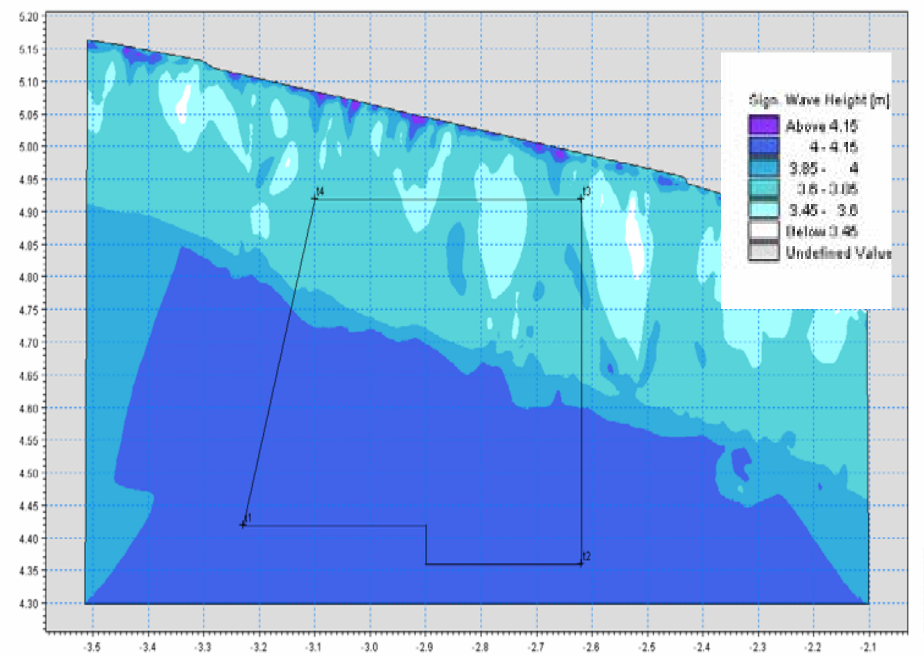
Local currents were assessed from data collected using Acoustic Doppler Current Profiler (ADCP) and WANE predicted currents. ADCP current data was collected at two sites located in the Jubilee Field during two deployment periods, covering one continuous time span of approximately six months from September 2008 to March 2009. Observations near the surface were only available for one of the ADCP sites. Between September and November, surface currents exhibited a strong westward component while surface currents become generally weaker and have a more eastward orientation from December. The WANE currents data exhibit a strong easterly component near the surface and do not show the westward trend in the surface currents noted in the ADCP data.

Currents at depths greater than 50 m were weaker than surface currents and did not display any consistent directional trends. Similar to the ADCP currents, the WANE currents also show decreasing speed with depth. The exception to this is the strong north-northeast to south-southwest orientation of currents near the bottom, particularly noticeable at the Mahogany-1 well site. It is thought that these anomalous observations may be related to tidal currents in the deep waters.

Waves

Waves reaching the shores of Ghana consist of swells originating from the oceanic area around the Antarctica Continent and seas generated by locally occurring winds (Noble-Denton, 2008). The significant height (*Figure 4.13*) of the waves generally lies between 0.9 m and 1.4 m and rarely attains 2.5 m or more. The most common amplitude of waves in the region is 1.0 m but annual significant swells could reach 3.3 m in some instances. Swells attaining heights of approximately five to six meters occur infrequently with a 10 to 20 year periodicity. The peak wave period for the swells generally falls in the range of seven to fourteen. The swell wave direction is almost always from the south or south-west. Other observations on the wave climate include a long swell of distant origin with wavelengths varying between 160 and 220 m. This swell has a primary period of 12 seconds and a relatively regular averaged height between 1 to 2 m. The swells generally travel from south-west to north-east.

Figure 4.13 ***Significant Wave Height Offshore Ghana***

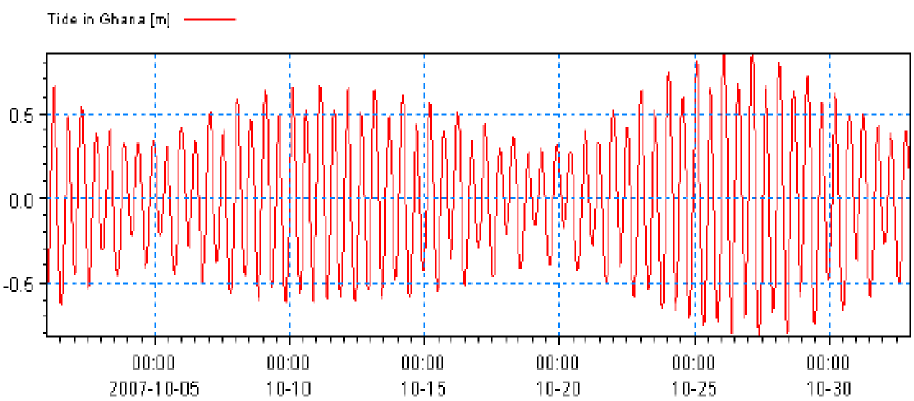


Note: Outline of Cape Three Points and Deepwater Tano concession blocks are shown in Figure.
Source: Noble-Denton, 2008

Tides

The tide on the coast of Ghana is regular and semi-diurnal (*Figure 4.14*). The average range varies along the coast, as shown in *Table 4.2* for the main cities. As can be seen, the tidal wave has virtually the same phase across the coast of the country. The average range of Neap and Spring tides increases from west to east. Tidal currents are low and have an insignificant influence on coastal processes except within tidal inlets. Other possible sources of intermittent increases of local water levels include line squalls and the transfer of energy from internal to surface tides. These processes could result in additional increases of about 0. 30 m.

Figure 4.14 ***Astronomical Tide in 4°N 2.5°W in October 2007***



Source: Noble-Denton 2008

Table 4.2 Tidal Range for the Coast of Ghana

Location	Tidal Range (m)			Phase
	Neap	Mean	Spring	
Takoradi	0.58	0.90	1.22	107°
Accra	0.62	0.94	1.26	107°
Tema	0.64	0.96	1.28	107°
Aflao	0.68	1.00	1.32	108°

4.2.4 *Bathymetry and Seabed Topography*

The Jubilee Field is located on the continental shelf offshore Ghana in water depths of 1,100 to 1,700 metres. The continental shelf (200 m water depth contour) has a generally regular bathymetry with isobaths running parallel to the coast. The continental shelf is at its narrowest (20 km wide) off Cape St. Paul in the east and at its widest (90 km) between Takoradi and Cape Coast in the west (Armah and Amlalo, 1998). The shelf drops off sharply at about the 75 m depth contour.

Ghana's nearshore area comprises various sediment types, varying from soft sediment (mud and sandy-mud), sandy bottoms to hard bottoms (Martos *et al*, 1991) (*Figure 4.15*). On the continental shelf, seabed sediments range from coarse sand on the inner shelf to fine sand and dark gray mud on the outer shelf (Armah *et al*, 2004).

Sediments on the shelf and upper continental slope are predominantly terrigenous (derived from erosion of rocks from land), with smaller amounts of glauconite-rich (iron silicate) sediments, and biogenic carbonate from mollusc shells. Offshore the mouth of the Volta River is a large submarine delta formed by river deposits. This is incised by a radial canyon system consisting of eight canyons (Nibbelink and Huggard, 2002). The delta is located away from the Jubilee Field.

Seabed surveys undertaken by Gardline Surveys(1) (2008) indicated that the seabed in the Jubilee Field comprise of soft to firm clays and silts that form a generally smooth and sloping seabed to the south-west (*Figure 4.16*). The Jubilee Unit is crossed by three submarine channels, which appear to be localised drainage points of the continental shelf. All three channels exhibit an active central gulley which meanders within each channel.

Key seabed features in the area include the following.

- **Channels:** The most significant features are two broad seabed canyons occurring in the western portion of the West Cape Three Points block. The seabed slope is generally between 1° and 6° in the area outside the seabed canyons. Within the canyons, gradients range from 7° to 20°. Isolated

(1) A pinnacle summary of the Geophysical surveys (C&C Technologies in June 2008 together with some preliminary 3D Geohazards survey) is presented in Summary of Geophysical Survey Data (10-01-INT-G15-0001)

seabed gradients reaching up to 25° occur along the flanks of channels in the north-west of the study area. Otherwise, the seabed is featureless. The proposed FPSO location is above the confluence of the western and central channel.

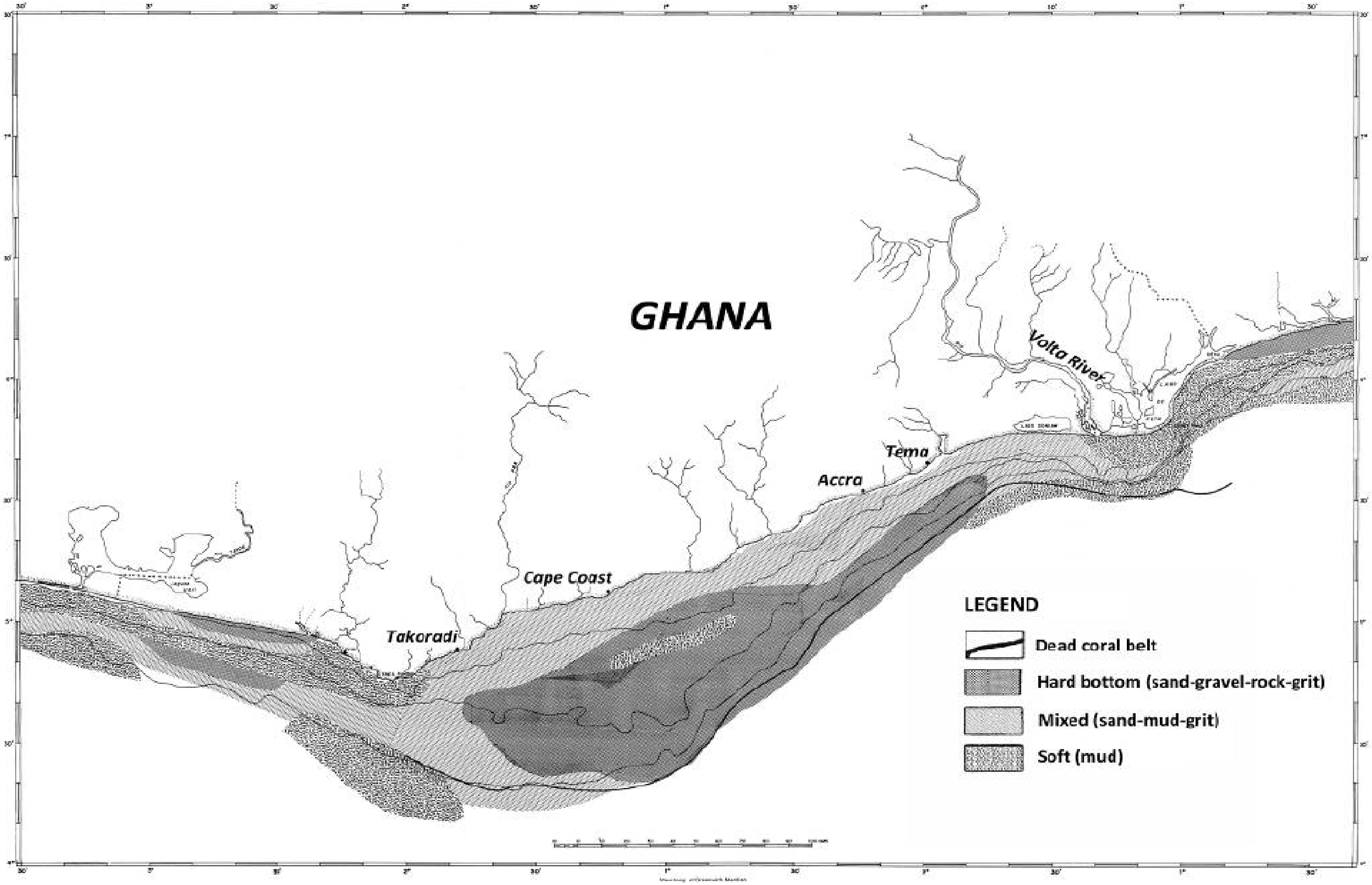
- **Large Sediment Waves.** Large sediment waves are mainly found on the western and eastern ridges. These waves are 1,500 to 2,500 m long and occur at a frequency of approximately 500 m and 10 - 50 m height. These waves are most notable in the central portion of the survey area, surrounding the central channel. Sediment waves also exist within the southern regions of the central and eastern channels. These sediment waves create localised dams, which pond sediments flowing down the channels.

- **Mega Ripples.** Along the channel banks, semi-parallel mega ripples exist probably formed during high flow events. These mega ripples are isolated to the channel banks that display relatively lower gradients, and steeper banks have no mega ripples.

- **Depressions.** Two large depressions exist in the southern central survey area on the ridges. The western ridge depression has a compound feature measuring approximately 550 m across north to south, and 350 m across east to west. The primary depression is 17 m deep, and the smaller depression is 4 m deep. The Eastern Ridge depression measures 200 m across, and is 12 m deep. These features are likely a result of expelled fluids or gasses.

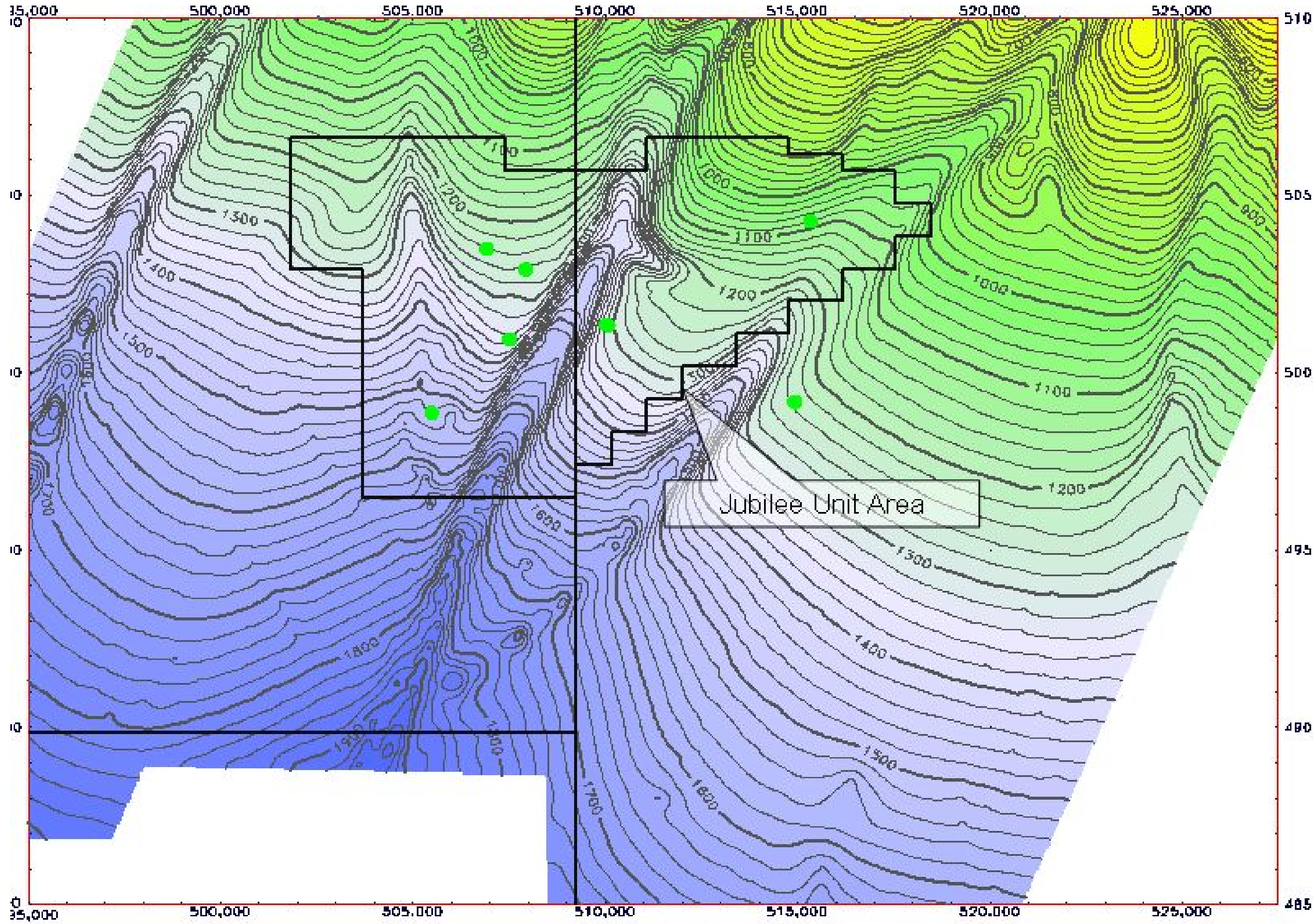
- **Faults.** One fault displaying seafloor displacement of 1.5 m exists in the northern central survey area adjacent to the central channel. Numerous small, buried faults or fractures were mapped. Most of the zones are located deeper than 10 to 20 m below the seafloor.

Figure 4.15 Distribution of Seafloor Types Offshore Ghana



Source: Martos *et al*, 1991

Figure 4.16 High Resolution Geophysical Map of Jubilee Field Area Showing 20 m Contour Intervals



Source: Tullow 2009

Chemosynthetic Communities

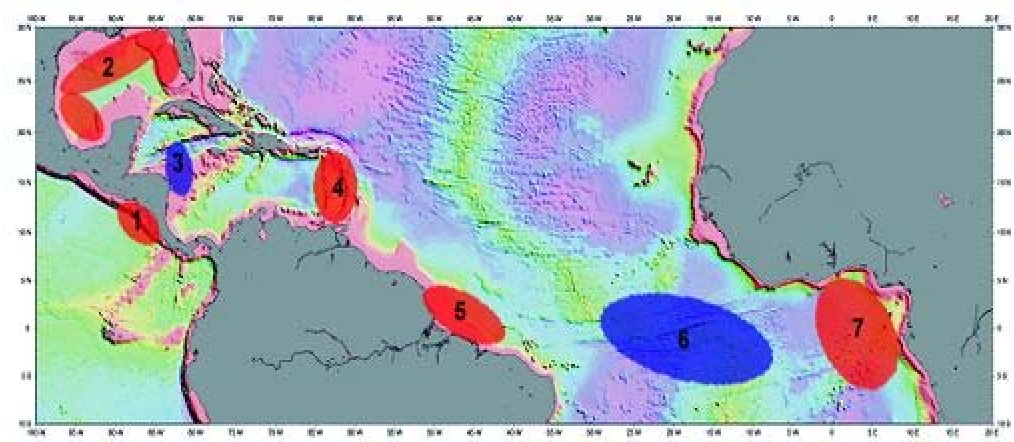
Chemosynthesis is the biological conversion of one or more carbon molecules and nutrients into organic matter using the oxidation of inorganic molecules (eg hydrogen sulphide) or methane as a source of energy, rather than sunlight, as used in photosynthesis. In water depths where there is no light penetration and where seepage of hydrocarbons, venting of hydrothermal fluids or other geological processes supply abundant reduced compounds, microorganisms can use chemosynthesis to produce biomass and can become the dominant component of the ecosystem. Chemosynthetic communities can have unusually high biomass (MacDonald, 2002).

The potential for chemosynthetic communities exists in the Gulf of Guinea (*Figure 4.17*). Brooks and Bernard (2006) reported finding two sites with chemosynthetic communities using coring samplers over small mounds associated with presumed deeper faulting in water depths of between 1,600 and 2,200 m offshore Nigeria. The communities comprised a high density of mussels and associated tubeworms, clams, shrimps, limpets, crabs, brittle stars, heart urchins and sponges.

In a study of submarine canyons offshore the Volta River Delta in Ghana, Nibbelink and Huggard (2002) noted evidence of gas seeps on seismic data and oil slicks on radar images. They interpreted the flat floors of the canyons as carbonate formed by chemosynthetic communities that feed on hydrocarbons seeping from the depleted free gas zones below the canyons. Studies conducted in the Gulf of Mexico indicate that high-density chemosynthetic sites typically are associated with recognisable features such as mounds, faults and craters.

A geohazard study in the Jubilee field undertaken by Gardine Surveys (2008) indicated there are no features likely to support chemosynthetic communities in the project area. Sediment sampling undertaken as part of the EBS also did not indicate the presence of any chemosynthetic communities in the survey area.

Figure 4.17 Atlantic Equatorial Belt (AEB) Deep-water Chemosynthetic Ecosystems



Source: ChEss AEB, 2006

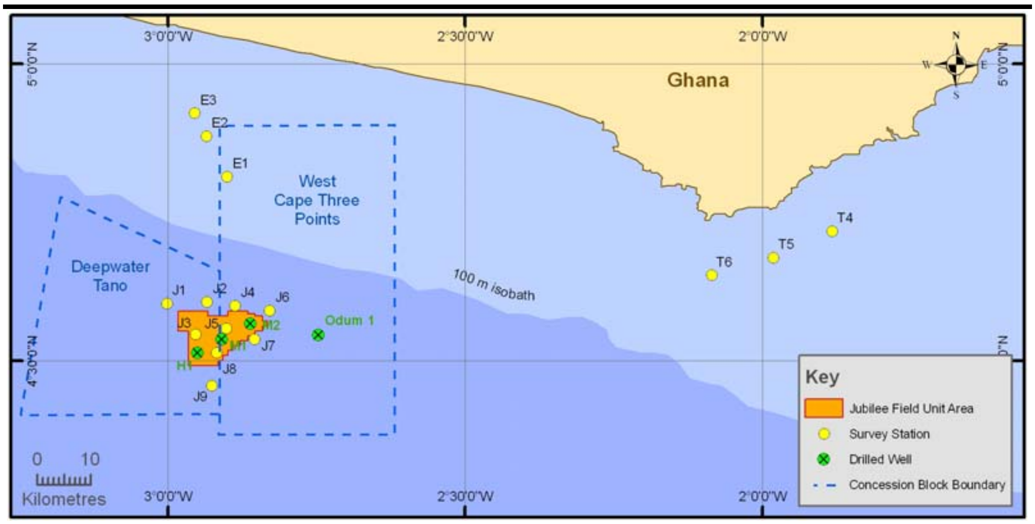
4.2.5 *Water and Sediment Quality*

The principal source of information on water quality and sediment quality for the project area is the Jubilee Field EBS [1] (TDI Brooks 2008). The survey was conducted off the R/V JW Powel from 9 to 13 September 2008 (*Figure 4.18*). A map of the sampling locations in relation to the Phase 1 Jubilee wells is presented in *Figure 4.19*.

Figure 4.18 EBS Survey Vessel R/V JW Powell

Source: TDI Brooks 2008

Figure 4.19 Environmental Baseline Survey Stations and Previously Drilled Wells



Water and sediment samples were collected in the vicinity of the Jubilee field. Additional samples were taken along two potential gas pipeline routes, from

(1) Details of the survey, including station location and coordinates, sampling and analytical protocols and parameters are presented in the Ghana Jubilee Field Technical Report TDI-Brooks International #08-2161 (2008)..

the field to the onshore location of the power barge at Effasu and the other from the field to Takoradi. Water depths varied from 16 m to more than 1,800 m. The objective of the survey was to characterise water and sediment quality parameters, including sediment physico-chemical and benthic faunal community data and physico-chemical characteristics of the water column.

Water Quality

Conductivity, Temperature and Depth (CTD) profiles of water quality and water samples were acquired using a 2,000 m SeaBird Instrument, SBE-19 SeaCat (*Figure 4.20*). CTD profiles were taken approximately 1 m below the surface to close to the seabed. Salinity was derived from the conductivity and temperature measurements. In addition, the CTD unit measured dissolved oxygen along depth profiles. Water column samples were taken at two depths, namely at sub-surface and at 100 m depth. Water alkalinity (pH) was measured on a subsample. Water samples were collected for metal analyses, nutrients, total dissolved solids and suspended solids. All samples were preserved and stored appropriately and shipped to College Station, Texas for analyses.

A CTD profile is shown in *Figure 4.21* for a sampling station J9 at the Jubilee field. Similar CTD profiles were plotted for all the sampling stations. The results show salinity decreasing slightly with depth. Maximum change in salinity values were observed between the surface and 400 m water depth. The dissolved oxygen profile at all the stations exhibited a minimum value between 200 m and 300 m depth where after it increased with depth. It is observed that stations with depth greater than 1,200 m recorded the highest concentrations of dissolved oxygen, generally more than 4 ml/l, possibly as a function of water temperature among others. There is an abrupt change in temperature between the surface and 600 m depth for all the samples. Water samples were analysed for pH and the results showed that , generally, pH values decreased from the surface to 100 m water depth. The only exception was station J-3 where the reverse occurred. The pH of the water column was slightly alkaline, ranging from pH 7.33 to pH 8.22.

Water samples were analysed for a range of determinants including metals and nutrients and the results are discussed below.

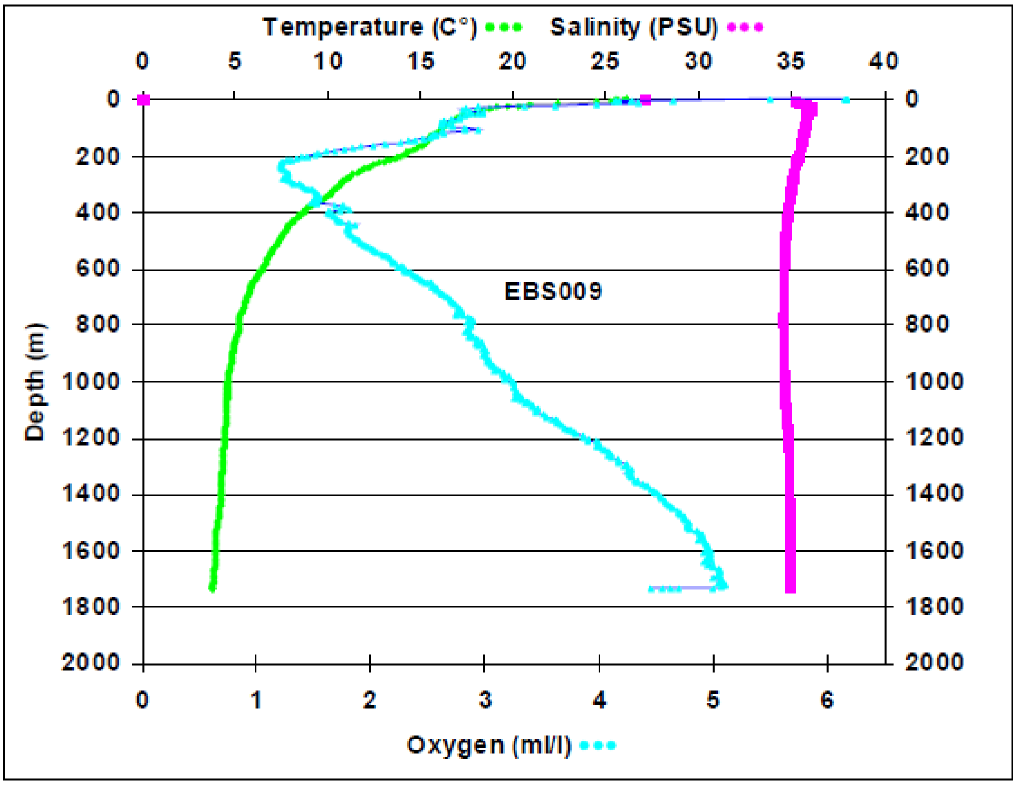
Mercury (Hg). Most stations had Hg concentrations (*Figure 4.23-A*) below the detection limit (ie below 0.2 mg/l). The exceptions were samples from stations J-1, J-2 and J-7 where Hg was detected. Hg concentrations ranged between 0.22 mg/l (100 m only) at station J-2 and 0.28 mg/L at stations J-1 and J-7.

Barium (Ba). Figure 4.23-B shows Ba concentration at the stations. Ba was higher in the surface samples and ranged from 5.96 ppb (J-2) to 5.43 ppb (J-4) for the surface samples, and between 5.43 ppb (J-1) and 5.00 ppb (J-8). There was very little variation in Ba concentrations between the sampling sites.

Figure 4.20 SeaBird SBE 32-C Carousel Water Sampler

Source: TBI Brooks 2008

Figure 4.21 Temperature, Salinity, Oxygen Profile for Station J9



Cadmium (Cd) and Lead (Pb). Neither Cd nor Pb was detected in any of the samples.

Total Nitrogen (TN). Generally, TN concentrations were higher for the 100 m depth samples than for the sub-surface samples except at station J-3 where the reverse occurred (*Figure 4.23-C*). TN concentrations for the surface samples ranged between 0.190 mg/l (J-3) and 0.044 mg/l (J-8). TN concentrations for the 100 m samples ranged from 0.437 mg/l (J-6) to 0.181 mg/l (J-3).

Total Phosphorus (TP). The concentrations of total phosphorus were higher for samples from the 100 m depth than for samples from sub-surface for all the stations (*Figure 4.23-D*). The highest TP concentration recorded for the sub-surface samples was 0.0192 mg/l (J-6) and the lowest concentrations was 0.0145 mg/l (J-2). At 100 m depth, phosphorus concentration was highest at J-4 (0.0455 mg/l).

Total Suspended Solid (TSS). Total suspended solids were highest for station J-5 (45.23 mg/l) and lowest for station J-3 (6.3 mg/l) for sub-surface samples. Station J-7 recorded the highest amount of suspended solids (30.26 mg/l) at the 100 m depth whilst station J-2 recorded the least amount of suspended solids (11.22 mg/l) at the 100m depth (*Figure 4.23-E*).

Sediment Quality

Sediment samples were analysed for a range of determinants including metals, organics and nutrients and the results are discussed in the following sections. Sediment samples were collected using a 50 by 50 cm box corer. Digital photographs were taken of the surface of each core sample and subsamples were taken using a 22 by 22 cm template pushed into the box core and two 8 cm diameter push cores (*Figure 4.22*). Chemistry samples were collected outside the sub-sampling equipment.

Figure 4.22 Boxcore (right) and Template and Sub-sampling for Boxcore (left)

Source: TDI Brooks 2008

Sediment grain size analysis was carried out on sub-samples for the various stations (J-1 to J-9). Sediment type was classified based on the mean size of the sand grains. Generally, three main sediment types were identified in the area, namely; sand, silt and clay. Most stations were dominated by clays and silts with the exception of station J-5 where sand fractions dominated (*Figure 4.23-F*).

Sediment oxidation-reduction potential (ORP) was determined at 3 cm, 6 cm and 9 cm beneath the surface of sediment in the box corer for each station. The results are presented graphically in *Figure 4.23-G*. From the results, the sediment samples were reduced at 9 cm depth except for station J-2 and J-8. The sediment samples were also largely oxidised at 3 cm depth except samples from station J-6 and J-9 which showed reduced conditions at all depths.

Barium and Lead. Ba was present in all the samples from the stations, ranging from 144 ppb to 291 ppb. The highest value was recorded from Station J-8 and the lowest value was Station J-5. Comparison with samples taken in shallow coastal waters as part of the EBS (TDI Brooks 2008) showed that all the offshore stations sampled within and close to the Jubilee field had elevated concentrations of barium compared to the stations closer to shore (Ba range 23 to 42 ppb). Pb concentrations were similar at all the stations within the field (*Figure 4.23-H*).

Mercury and Cadmium. Hg was not detected in any of the samples (method detection limit = 0.1 ppb) for all the stations within the Jubilee field. Cadmium concentrations were also not detected in the samples (method detection limit = 0.1 ppb) except at stations J-2, J-4 and J-7 where a concentration of 0.2 ppb was recorded for each station (*Figure 4.23-I).*

Organics analyses included determination of Total Organic Carbon (TOC) and Polycyclic Aromatic Hydrocarbons (PAH). TOC values were low and ranged from 1.21 percent (J-5) to 2.99 percent (J-4) (*Figure 4.23-J*). PAH concentrations recorded varied between the stations and ranged from 81 ng/dry g (J-5) to 176 ng/dry g (J-2 and J-4) (*Figure 4.23-K*).

The sediment samples were analysed for Total Phosphorus (TP) and Total Nitrogen (TN). TP ranged from 400 mg/kg (J-9) to 690 mg/kg (J-1). TN ranged from 570 mg/kg (J-5 and J-8) to 960 mg/kg (J-3) (*Figure 4.23-L*).

4.2.6 *Plankton*

Information on plankton (phytoplankton and zooplankton) was sourced from previously documented surveys in the Gulf of Guinea including EIAs for the West Africa Gas Pipeline Project (WAPC 2004) and other research programmes (eg Guinea Current Large Marine Ecosystem project Fisheries Resource Surveys, 2006-2007) and available published sources (eg Wiafe 2002). Phytoplankton and zooplankton form a fundamental link in the food chain. Plankton community composition and abundance is variable and depends upon water circulation into and around the Gulf of Guinea, the time of year, nutrient availability, depth, and temperature stratification.

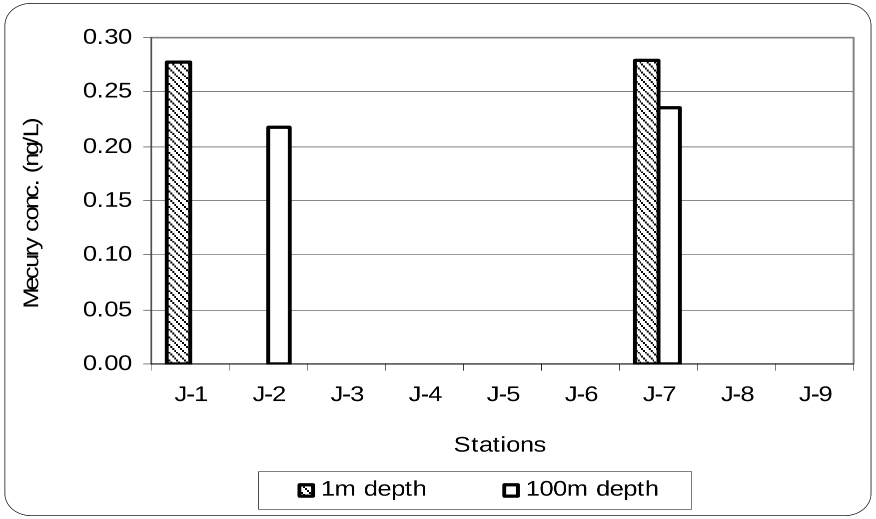
Phytoplankton

Phytoplankton, grouped as diatoms, dinoflagellates and coccolithophores, are microscopic and range between 30 mm and 60 mm in size. Primary production is linked to the amount of inorganic carbon assimilated by phytoplankton via the process of photosynthesis. Primary production determined for the Gulf of Guinea is about 4,305 to 5,956 mg $C/m^2/day$ (see *Figure 4.10*). Typically, productivity in the offshore ecosystems (100-200 m water depth) range from 10 mg $C/m^3/day$ to 100 mg $C/m^3/day$ in terms of volume, or from 75 mg $C/m^2/day$ to 1,000 mg $C/m^2/day$ in terms of area. Thus, the values obtained within the nearshore areas indicate a system of relatively high productivity. This is not unexpected since the coastal ecosystem of the area undergoes seasonal upwelling that commences in July which coincided with the WAPC survey period.

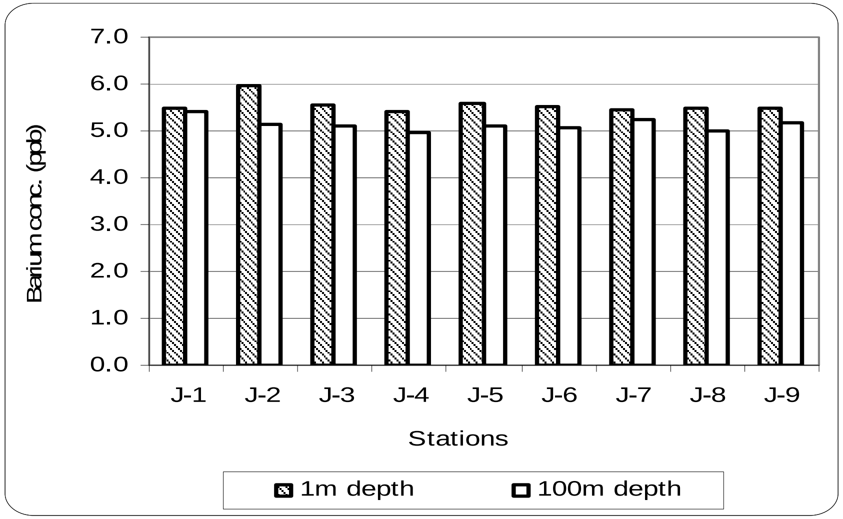
The phytoplankton biomass concentrations in the eastern tropical Atlantic is low compared to some other coastal upwelling systems, however, the spatial extent and temporal stability of the enrichment processes allows the development of large phytoplankton cells, consequently there is high zooplankton concentration and this is conducive to high fish production (Jones and Henderson, 1987).

Figure 4.23 Water and Sediment Quality Graphs

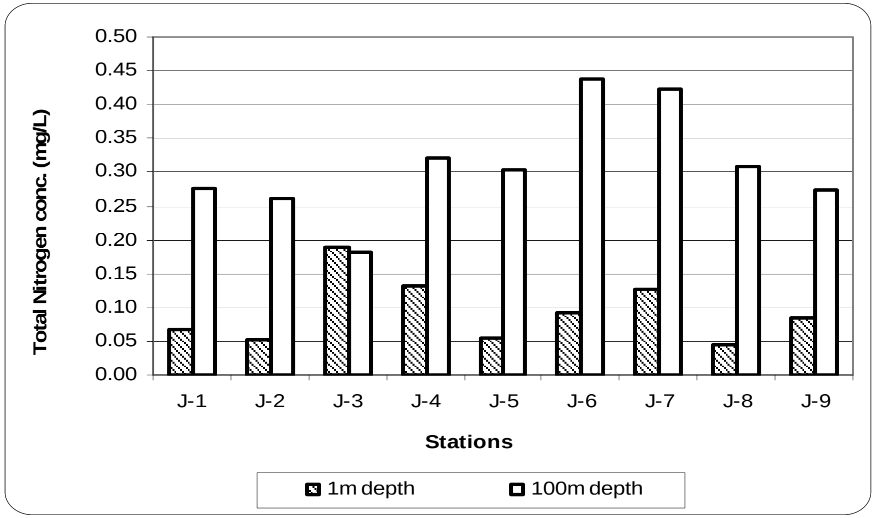
A: Variations in the Concentrations of Mercury at Different Depths of the Stations



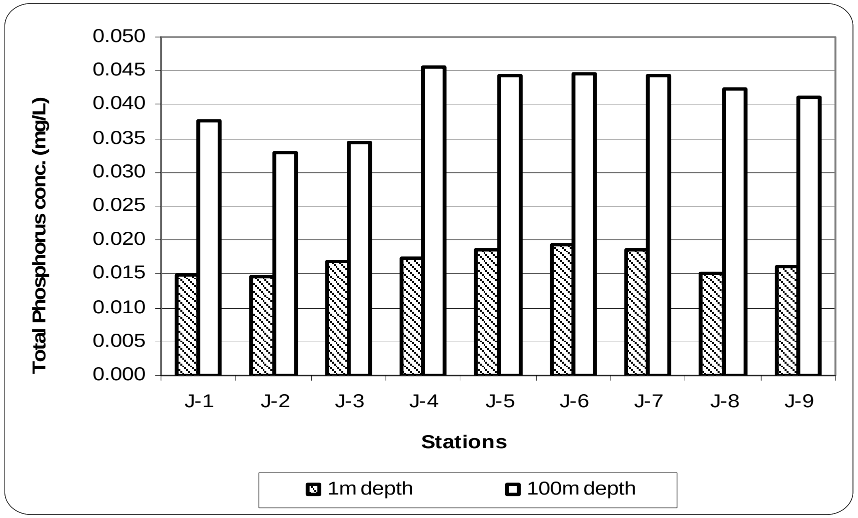
B: Variations in the Concentrations of Barium at Different Depths of the Stations



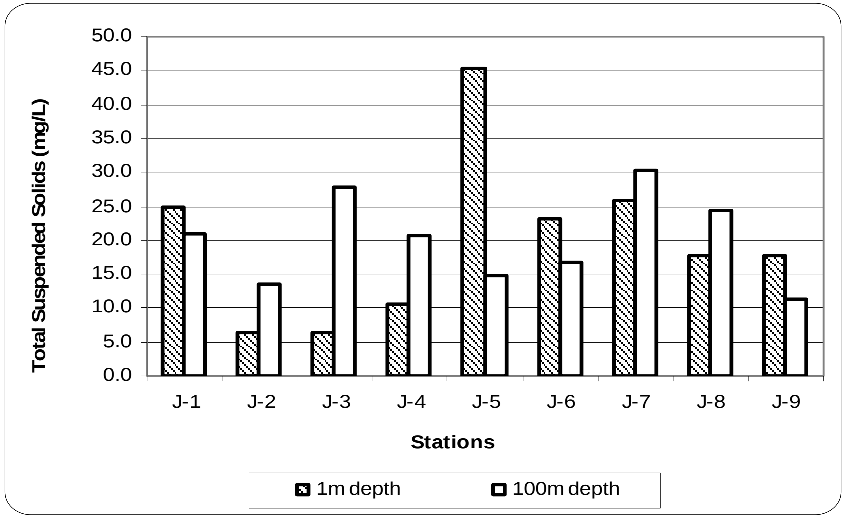
C: Variations in Total Nitrogen Concentration at Different Depths



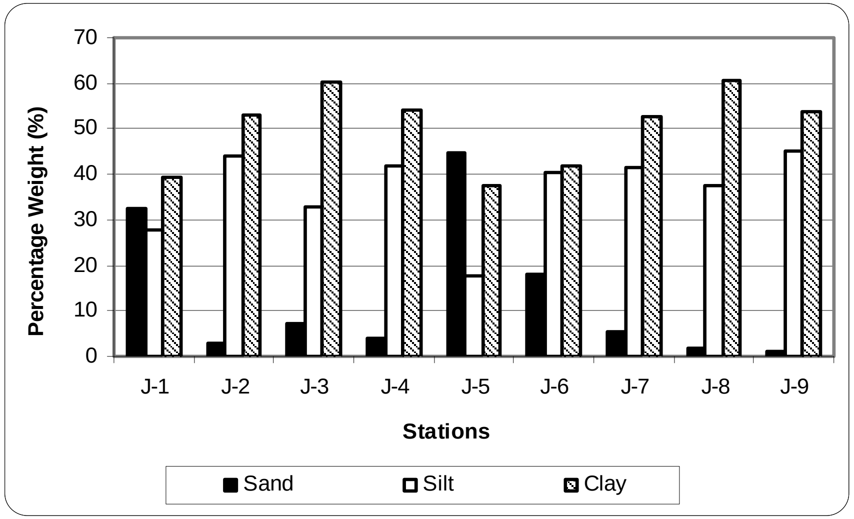
D: Variations in Phosphorus Concentration at Different Depths between the Stations



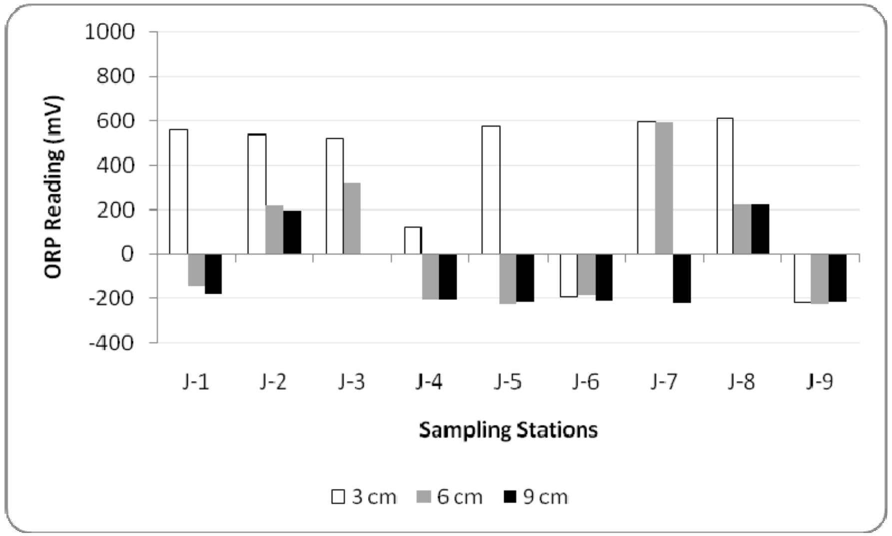
E: Variations in TSS Concentration at Different Depths



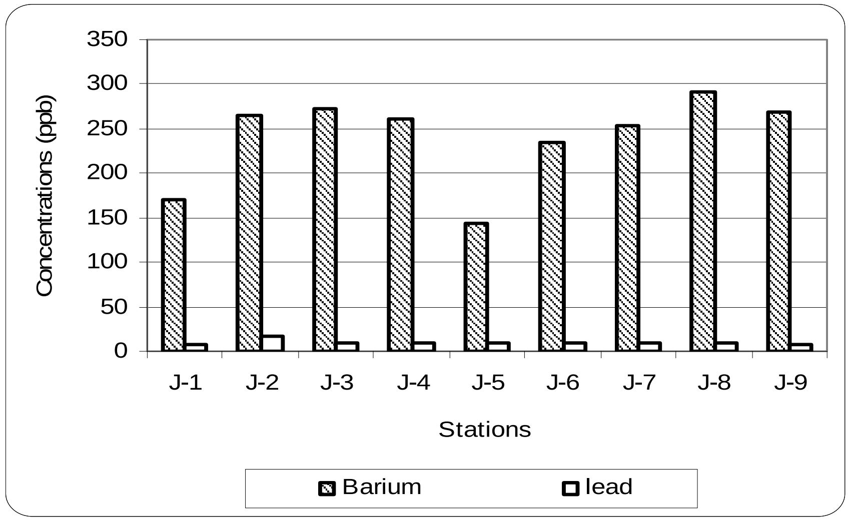
F: Grain Classification Analysis for the Jubilee Field



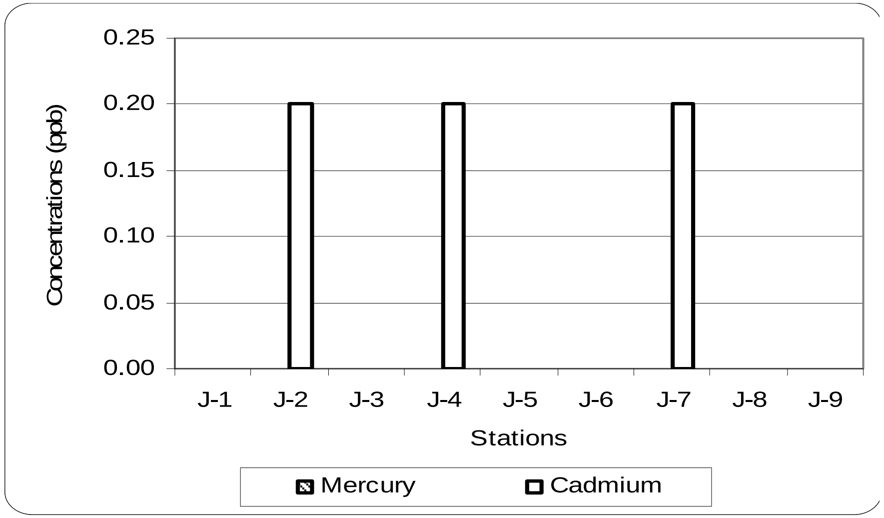
G: Oxidation Reduction Potential (ORP) of Sediments at the Stations taken at three depths (3cm, 6cm and 9cm)



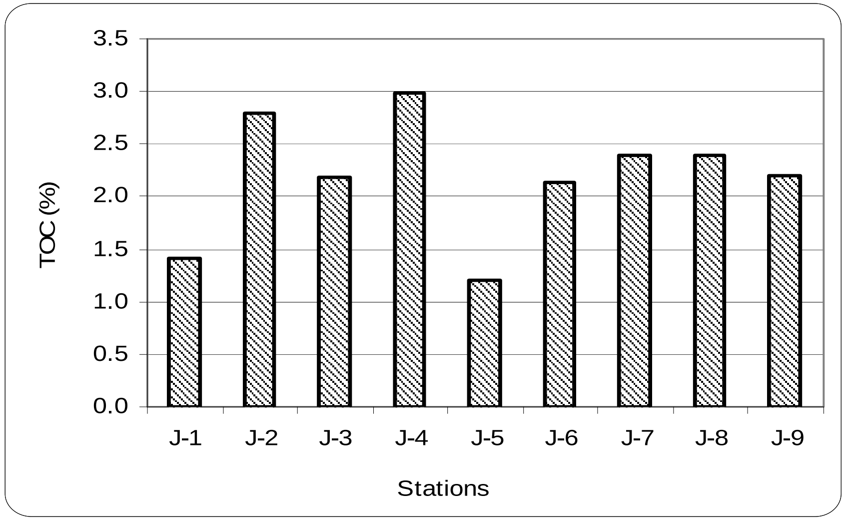
H: Variations in the concentrations of Barium (striped bar) and Lead (open bars) at the stations



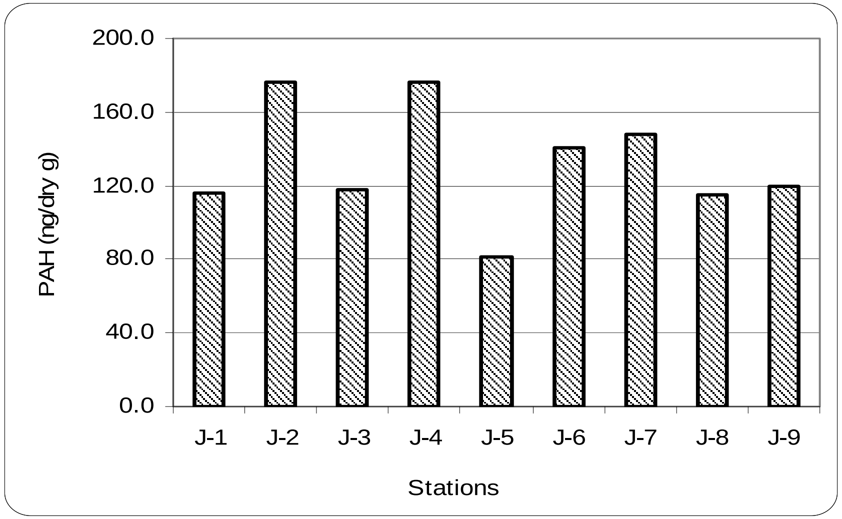
I: Variations in the Concentrations of Mercury (Striped Bars) and Cadmium (Open Bars) at the Various Stations



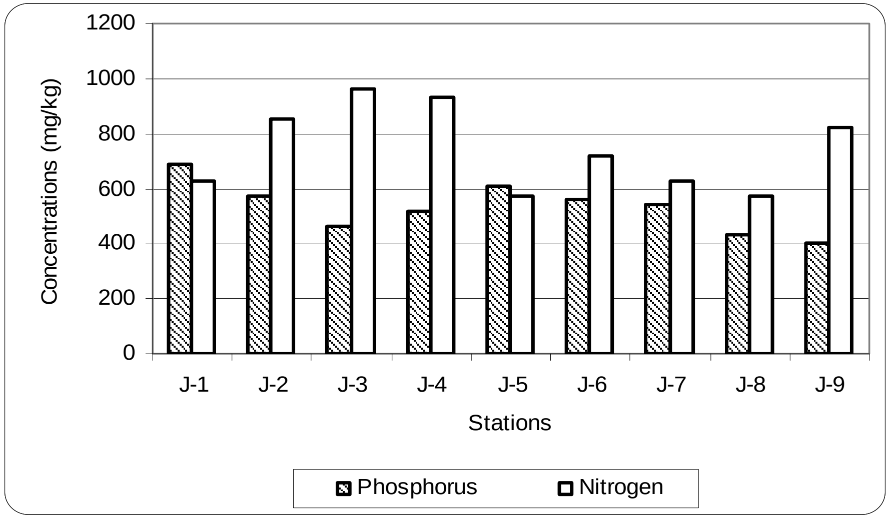
J: Variations in Total Organic Carbon (TOC) between the Stations



K: Variations in Polycyclic Aromatic Hydrocarbons between the stations



L: Variation in the Concentrations of Phosphorus (Striped Bars) and Nitrogen (open bars) in the Sediment Samples from the Station



The environmental baseline study for the West African Gas Pipeline project (WAPC, 2004) was carried out within the nearshore area (15-65 m depth) of the Gulf, between Nigeria and Ghana, and identified 69 species of phytoplankton. The phytoplankton community was dominated by *Chaetoceros spp*. possibly a result of planktonic responses to seasonality of the hydrographic regime (Wiafe, 2002). Other planktonic species included *Dinophysis acuta*, which is a harmful microalgae with the potential to cause diarrhetic shellfish poisoning in bloom condition at high concentrations (Anderson *et al*, 2001). Distribution of the species indicated that *Penilia avirostris*, a cladoceran, dominated the community in terms of number of individuals. However, a dinoflagellate species, *Chaetoceros spp*., occurred in high numbers at all locations sampled. The diversity of phytoplankton species for the WAGP study ranked highest off the shelf of Ghana compared to the other locations studied (ie Togo, Benin, and Nigeria).

Studies within the nearshore areas of the Western Region of Ghana (ie, Saltpond, Elmina, Takoradi and Half Assini) show that the dominant phytoplankton species were *Ceratium, Cheatoceros, Rhizosolinia*, and *Peridinium* with the *Ceritium spp*. being the dominant taxa.

Zooplankton

Offshore zooplankton assemblages are dominated by copepods, followed by Ostracods(1), Appendicularians(2) and Chaetognaths(3). Maximum abundance is during the primary upwelling although they are also abundant during the secondary upwelling(4).

WAGP 2004 surveys identified 52 zooplankton species. *Penilia avirostris*, *Temora stylifera* and *Para-Clausocalanus* spp. dominated the zooplankton community. Species of zooplankton recorded in the nearshore environment in the Western Region of Ghana included *Cyclopoids: Oncaea, Corycaeus, Farranula; Calanoids: Acartia, Clausocalanus, Calanoides, Temora, Centropages, cirripid nauplius, Podon, Evadne, Penilia, Lucifer protozoa, Appendicularia/Oikopleuara, Pontellia nauplius* and *Sagitta*.

Benthic decapod larvae and large crustacean numbers are at their highest between February-June and October -December. Carnivorous species dominate the plankton during the warm season and diversity is high but abundance low. Herbivorous zooplankton, dominated by *Calanoides carinatus* is highly abundant in upwelling conditions. These are later replaced by omnivorous species (eg *Temora turbinate* and *Centropages chierchise*).

(1) Ostracoda is a class of the Crustacea, sometimes known as the seed shrimp because of their appearance.
(2) Larvaceans (Class Appendicularia) are solitary, free-swimming underwater saclike filter feeders found throughout the world's oceans.
(3) Chaetognatha is a phylum of predatory marine worms that are a major component of plankton worldwide.
(4) The major upwelling begins between late June or early July when sea surface temperatures fall below 25°C and ends between late September or early October. The minor upwelling occurs either in December, January or February and rarely lasts for more

4.2.7 *Benthic Invertebrates*

Benthic fauna forms an important part of the marine ecosystem, providing a food source for other invertebrates and fish as well as cycling nutrients and materials between the water column and underlying sediments. The benthos is made up of diverse species which are relatively long-lived and sedentary, and which exhibit different tolerances to stress, making them useful indicators of environmental conditions. The Ghana marine environment has not been extensively studied for its macrobenthos, particularly in deeper waters. This section is mainly based on information obtained on marine macrobenthic faunal assemblages from the Jubilee field and surrounding area during the EBS (TDI Brooks, 2008). The survey assessed macrobenthic fauna from 15 sediment sample grabs in deep water stations within the Jubilee field and at site closer to shore along potential future pipeline routes (*Figure 4.24*). The EBS report attached to this EIS on CD provides details on sampling methodology and analytical laboratory procedures.

The sediment samples were collected with a 50 by 50 cm box corer. A 22 by 22 cm template (surface area = 0.484 m^2) was inserted into the box corer to about 0.15 m to subsample the macrobenthic infauna. The subsamples were screened through a sieve of mesh size 0.5 mm (*Figure 4.25*). The samples were washed into a jar and subsequently fixed with 10 percent buffered formalin.

The results of the macrobenthic faunal community from the baseline study yielded a total of 1,415 individuals (mean density of 195±1.5 individuals per m^2) comprising 252 species belonging to polychaetes, crustaceans, molluscs and echinoderms.

Figure 4.24 Grab Sample Locations and Community

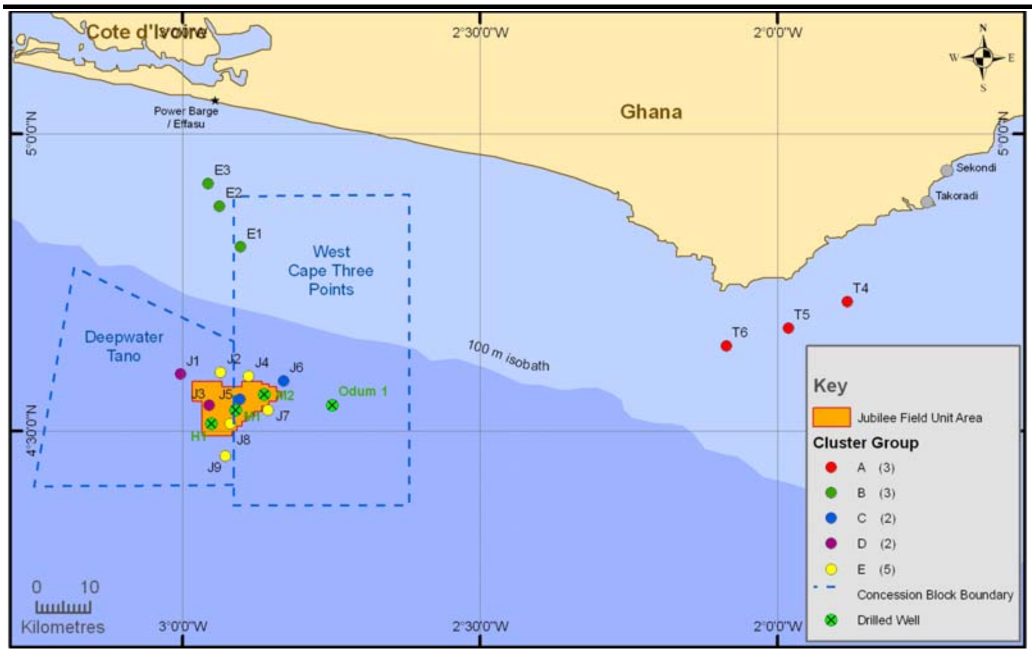


Figure 4.25 EBS Survey: Sieving of Boxcore

Source: TDI Brooks 2008

The number of macro benthic taxa recorded per station ranged from 20 to 78 with a mean of 39.1. The species density (ie number of individuals per m^2) ranged from 25 to 385 with a mean of 102. Station T6, located along the Takoradi line, had the highest abundance, as well as the highest number of taxa. The biological community within and around the Jubilee Field was only moderately rich compared to samples taken along the Takoradi and Efasu lines. The calculated values of the Shannon-Wiener diversity index (1) varied between 2.97 and 3.95, with a mean of 3.3. Pielou's Evenness (2) ranged from 0.8 to 0.98, with a mean of 0.93, which suggest high diversity without over-dominance by any particular taxa.

The station cluster dendrogram using macrobenthic fauna abundance data from each station is shown in *Figure 4.26*, along with overlays to indicate the proportions of different sediment fractions at each station. The samples as a whole grouped together at about 15 percent similarity and five cluster groups (A-E) were recognised at 30 percent similarity. Of these, Groups C-E were broadly similar and are considered together in some of the following discussions. The spatial distribution of the samples assigned to different cluster groups is shown in *Figure 4.24* above. The characteristics of the cluster groups are discussed in *Table 4.3*.

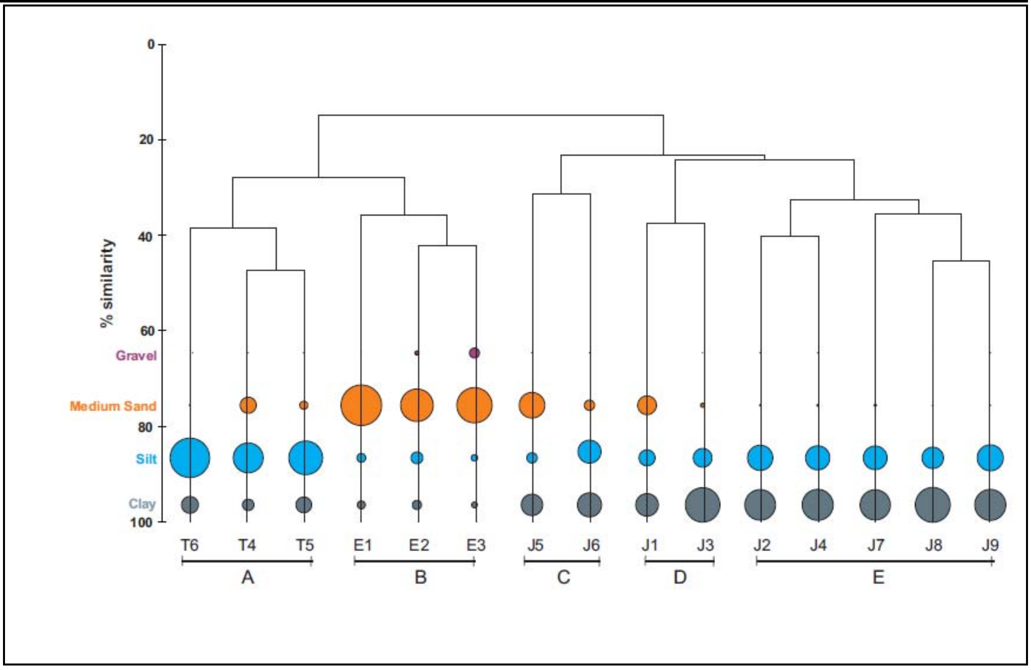
(1) Shannon-Wiener diversity index is one of several diversity indices used to measure diversity in categorical data. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having a greater species evenness.
(2) Pielou's Eveness Index is the ratio of observed diversity to the maximum possible diversity of a community with the same species richness.

Table 4.3 Fauna Community Cluster Groups

Cluster Group	Samples	Description
Group A – Thyasirid Community	T1, T2, T3	Group A had the highest diversity and abundance of the cluster groups, with large numbers of thyasirid bivalves, brittlestars (Ophiuroidea) and spionid worms (Prionospio). Many other infaunal taxa were present in moderate numbers. The stations are about 10 km offshore at between 39 and 52 m water depth, with sediment dominated by silt.
Group B semelid/ampeliscid community	E1, E2, E3	The diversity and abundance of fauna in Group B was higher than for stations near the Jubilee field but less so than for Group A. Semelid bivalves and ampeliscid amphipods were almost equally dominant and there were moderate numbers of several other infaunal taxa. The sediment was characterised by high dominance of medium sand.
Group C *Prionospio* community	J5, J6	The most common taxon, the sedentary polychaete *Prionospio*, was more abundant in Group A and the other taxa present were mostly also found in other groups. The sediment was a mixture of clay, silt and medium sand, with depths of 1346 m and 943 m, respectively.
Group D maldanid/spionid community	J1, J3	The most common taxon, sedentary polychaetes in the family Maldanidae ('bamboo worms') were more common in Group C and the second taxon, spionid polychaetes, include *Prionospio*, also abundant in Group C and the other taxa present were mostly also found in other groups. The sediment was mainly clay, with moderate amounts of silt and medium sand. The samples were at depths of 1264 m and 1386 m, respectively.
Group E 'bivalve' community	J2, J4, J7, J8, J9	Unidentified bivalves were the most common taxon and these were also widespread in other groups. Similarly, Prionospio was common in Groups C-E but the third most common taxon, Thyasiridae, was more typical of Group A. The sediment was mainly clay, with a secondary dominance of silt; depths were between 985 m and 1767 m.

The samples shows a clear three-way divide on the basis of fauna, which relates to depth and sediment composition. Samples from the Takoradi line (cluster Group A) belong to a relatively rich, shallow water community dominated by thyasirid bivalves in silt. Those from the Effasu line (cluster Group B) are relatively deeper and a little less rich, with semelid bivalves and ampeliscid amphipods in medium sand. The biological community within and around the Jubilee Field (cluster Groups C-E) was only moderately rich, with varying mixtures of maldanids, spionids and bivalves in mainly silt-dominated sediments in much deeper water. This depicts a clear distinction of shallow and deep water macrobenthic community with community structure being a function of water depth and sediment textural properties.

Figure 4.26 Cluster Dendrogram of Macrofaunal Data



The density and frequency of occurrence (F) of macrobenthic taxa encountered in the EBS survey is presented in *Table 4.4*. The reported taxa were selected based on a frequency of more than 25 percent (Guille 1970). Those taxa with frequency of less than 25 percent were considered rare taxa as they seldom offer any critical information.

Sixteen (16) taxa (contributed 31.03 percent to the total abundance) had F>25 percent. Only five macrobenthic taxa occurred in 50 percent of the sample locations. The polychaete *Prionospio sp.* ranked highest for species abundance and density.

Table 4.4 Abundance, Density and Frequency of Occurrence (F) of Macrobenthos from the EBS survey

Taxa (Family/Genus/ species)	Abundance (No. of individuals)	Density (individuals.m^{-2})	F (%)
Bivalvia	58	7.98898	75
Cirratulidae	28	3.85675	60
Nuculana	21	2.89256	55
Prionospio sp.	66	9.09091	55
Maldanidae	28	3.85675	50
Rhynchocoela	18	2.47934	45
Nucula	31	4.26997	45
Levinsenia gracilis	23	3.16804	45
Sipuncula	26	3.58127	40
Ophiuroidea	32	4.40771	40
Nepthyidae	10	1.37741	35
Terebellidae	9	1.23967	30
Aplacophora	13	1.79063	30
Campylaspis	9	1.23967	30
Ampharetidae	33	4.54545	30
Ampelisca sp.	34	4.6832	30

In summary, the macrobenthos revealed a diverse community assemblage in shallow water areas compared to the deep waters in the Jubilee field. The community assemblage was a function of water depth and sediment granulometric properties. A total of 252 species were recorded belonging to polychaetes, crustacean, molluscs and echinoderms, with a total mean density of 195 (±1.5). The polychaete, *Prionospio sp.* and an unidentified bivalve occurred in a number of the sampling locations in notable densities.

Within the Jubilee field, a total of 414 individuals (mean density: 95.04 indiv/m^2) belonging to 124 macrobenthic faunal taxa were identified. Of this number, polychaetes constituted 36 percent, molluscs 31 percent, and crustaceans 24 percent, echinoderms 3 percent and other taxa constituted 6 percent. In terms of density and frequency of occurrence, the taxon bivalvia ranked first, followed by the polychaete *Prionospio sp*.

4.2.8 Fish Ecology

The composition and distribution of fish species found in Ghanaian waters, and the wider Gulf of Guinea, is influenced by the seasonal upwelling that occurs between Nigeria and the Ivory Coast mainly in July to September and to a lesser extent in December to February. The transport of colder, dense and nutrient-rich deep waters to the warmer, usually nutrient-depleted surface water during periods of upwelling stimulates high levels of primary production in phytoplankton. This primary productivity in turn increases production zooplankton and fish. The fish species found in Ghanaian waters can be divided into four main groups, namely:

- small pelagic species;
- large pelagic species (tuna and billfish);
- demersal (bottom dwelling) species; and
- deep sea species.

These groups are discussed in more detail below followed by a list of protected species expected in the area.

Small Pelagic Species

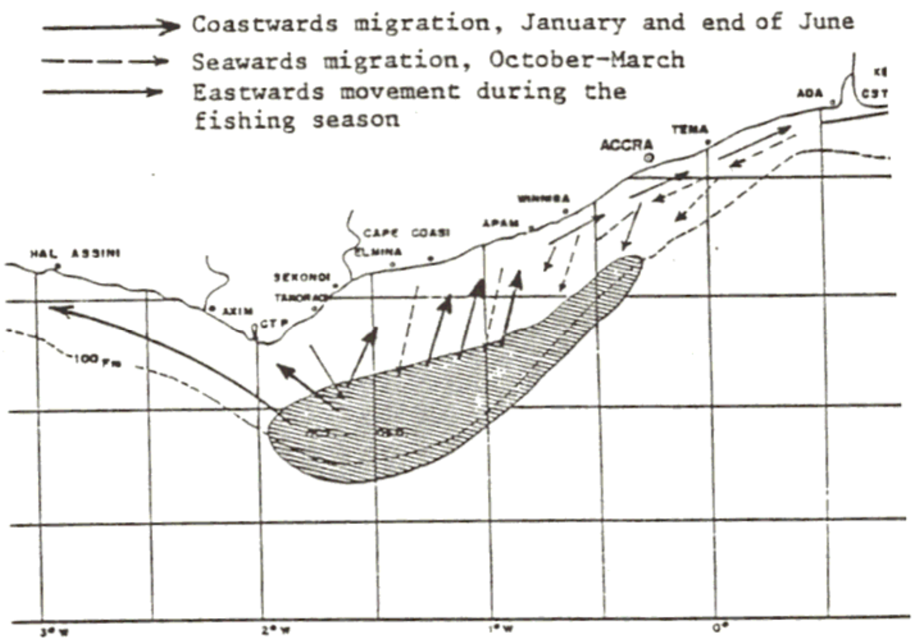
The pelagic fish assemblage consists of a number of species that are exploited commercially but are also important members of the pelagic ecosystem, providing food for a number of large predators, particularly large pelagic fish such as tuna, billfish and sharks. The most important pelagic fish species found in the coastal and offshore waters of Ghana are:

- round sardinella (*Sardinella aurita)*;
- flat sardinella (*S. maderensis)*;
- European anchovy (*Engraulis encrasicolus)*; and
- chub mackerel (*Scomber japonicus)*.

These species are important commercially as they represent approximately 80 percent of the total catch landed in the country (approximately 200,000 tonnes per annum). In terms of biomass, acoustic surveys have shown that the two sardinella species and the European anchovy represent almost 60percent of the total biomass in Ghanaian waters (FAO & UNDP, 2006).

Sardinella. Both sardinella species are found throughout Ghanaian coastal waters and the local population is part of the Central Upwelling Zone stock which is one of three stocks along the West African coast. The eggs and larvae of the sardinellas are found all year but distinct peaks in spawning are seen between July and August during the upwelling periods. The eggs are planktonic and found in the upper mixed layer and upon hatching the larvae feed on plankton in the upper layers. Adults exhibit seasonal migration towards the shore (see *Figure 4.27*). Juveniles remain in shallow water until maturation when they migrate into deeper shelf waters to join the adult stock.

Figure 4.27 Migratory Pattern of the Sardinellas



Source: Ansa-Emmin 972

European Anchovy. The European anchovy is found throughout European waters and all along the West African coast as far as Angola. European anchovy are mainly a coastal marine species but they can tolerates a wide range of salinities and may be found in lagoons, estuaries and lakes, especially during spawning. This species shows a tendency to extend into more waters further north in summer where it moves into the surface water layers. During the winter the populations retreat and descend to deeper water where they can be found as deep as 400 m in West Africa and deeper in more northerly areas. This species forms large schools and feeds on planktonic organisms, especially copepods and mollusc larvae and the eggs and larvae of fish. Spawning takes place over an extended period from April to November with peaks usually in the warmest months.

Chub Mackerel. Chub mackerel are a cosmopolitan species and inhabit the warm and temperate transition waters of the Atlantic, Indian and Pacific oceans and adjacent seas. They are primarily coastal pelagic species and are found from the surface down to depths of 300 m. However, they may extend into the epipelagic[(1)] (to 200 m) or mesopelagic (200 to 1,000 m) waters over the continental slope. Seasonal migrations may be very extended, with entire populations in the northern hemisphere moving further northward with increased summer temperatures and southwards for overwintering and spawning. In Ghanaian waters spawning, in common with most pelagic species, coincides with the seasonal upwelling. The chub mackerel is an opportunistic and non-selective predator, feeding on copepods and other crustaceans, fish and squid. Its predators include tuna, billfish and other fishes, as well as sharks and pelicans.

Other Pelagic Species. Other pelagic species found in Ghanaian water which are commercially important to local fisheries include:

- horse mackerel (*Trachurus* sp.);
- little tunny (*Euthynnus alletteratus*);
- bonga shad (*Ethmalosa fimbriata*);
- African moonfish (*Selene dorsalis*);
- West African Ilisha (*Ilisha africana*);
- largehead hairtail (*Triciurus lepturus*);
- crevalle jack (*Caranx hippos*);
- Atlantic bumper (*Chloroscombrus chrysurus*); and
- Barracuda (*Sphyraena* sp.).

The distribution of these fish generally extends to the south as far as Angola.

Large Pelagic Species

Large pelagic fish stocks off the coast of Ghana include tuna and billfish. These species are highly migratory and occupy the surface waters of the entire tropical and sub-tropical Atlantic Ocean. They are important species in the ecosystem as both predators and prey for sharks, other tuna and cetaceans as well as providing an important commercial resource for industrial fisheries. The tuna species are:

- skipjack tuna (*Katsuwonus pelamis*);
- yellowfin tuna (*Thunnus albacares*); and
- bigeye tuna (*Thunnus obesus)*.

Billfish species occur in much lower numbers and comprise:

- swordfish (*Xiphias gladius*);
- Atlantic blue marlin (*Makaira nigricans*); and
- Atlantic sailfish (*Istiophorus albicans*).

(1) Of or relating to the part of the oceanic zone into which enough sunlight enters for photosynthesis to take place.

Skipjack Tuna. Skipjack tuna is a cosmopolitan species found in schools in tropical and subtropical waters. This wide distribution accounts for the number and variety of fisheries that have developed all around the world. The species is epipelagic generally inhabiting open waters with aggregations associated with convergences, boundaries between cold and warm water masses, and other hydrographic discontinuities. Depth distribution ranges from the surface to about 260 m during the day, however, they remain close to the surface during the night.

In the Eastern Atlantic skipjack tuna spawn over a wide area on either side of the equator, from the Gulf of Guinea to 20º to 30ºW. Spawning seasons differ according to the zone, in the southern part of their range (Liberia, Ivory Coast, Ghana and Cape Lopez) spawning mainly takes place during the first and fourth quarters of the year (Cayré and Farrugio, 1986).

In common with other tuna species, skipjack tuna is an opportunistic predator with the principal prey being fish (mainly mackerels and pilchards), cephalopods and crustaceans.

Yellowfin Tuna. Yellowfin are found in open waters of tropical and subtropical seas worldwide where they are generally confined to the upper 100 m of the water column with their vertical distribution being influenced by the thermal structure of the water column.

Yellowfin tuna found in Ghana form part of an Atlantic population which spawns off Brazil and in the Gulf of Guinea and migrates to the Equatorial East Atlantic in the austral summer. The Gulf of Guinea is one of the most important areas for yellowfin tuna in the Atlantic population and large aggregations are found in near-surface waters, often associated with floating debris. Yellowfin tuna feed near the surface, mainly on epipelagic fish.

Bigeye Tuna. Bigeye tuna form part of an Eastern Atlantic population whose core distribution extends from north-west Africa to southern Angola. Generally this species is epipelagic and mesopelagic in oceanic waters, occurring from the surface to about 250 m in depth. Vertical distribution is influenced by water temperature and thermocline depth, although their range differs from yellowfin tuna.

Spawning takes place throughout the year in a vast zone in the vicinity of the equator with temperatures above 24ºC. The Gulf of Guinea is one of the most important spawning areas for this species.

The diet of bigeye tuna includes a variety of fish species, cephalopods and crustaceans, however, they forage over a greater vertical range and feed on a wider range of fish and cephalopod species than yellowfin tuna, due to the latter's more narrow temperature range.

Atlantic Blue Marlin. Atlantic blue marlin is an epipelagic oceanic species, found in wide open waters. Adults spends over 80% of their time in the surface water, however, they undergo frequent, short duration dives to depths of between 100 and 200 m. Blue marlin display extensive migratory patterns, making trans-equatorial movements between the eastern and western Atlantic, although they are less abundant in the eastern Atlantic than the western Atlantic. Off the west coast of Africa they mostly occur between 25°N and 25°S, with important concentrations being found within the Gulf of Guinea. Spawning takes place during austral spring-summer and boreal summer. Most spawning takes place in the western Atlantic.

Blue marlin feed near the surface and in deep water where they feed opportunistically on schooling stocks of flyingfish, small tunas, dolphinfish and squid.

Swordfish. Swordfish are a cosmopolitan species found in tropical, temperate and sometimes cold waters of all oceans, including the Mediterranean Sea. They are mainly found in open oceanic waters but may occasionally be found in coastal waters, generally above the thermocline (Colette, 1995). Migrations consist of movements toward temperate or cold waters for feeding in summer, and back to warm waters in autumn for spawning and overwintering.

Swordfish spawning grounds are known to be present in the western Atlantic and the Mediterranean and spawning takes place throughout the year in the western Atlantic with a peak from April to September.

Adult swordfish are opportunistic feeders. Over deep water, they feed primarily on pelagic fish, including tuna, dolphinfish, flyingfish, barracuda and pelagic squid. In shallower waters their diet consists mainly of mackerel, herring, anchovy, sardines and needlefish. Large adults often make feeding trips to the bottom to feed on demersal fish including hake, redfish and lanternfish.

Sailfish. Sailfish are found throughout the tropical and temperate Atlantic Ocean. In the eastern Atlantic its distribution extends from the Bay of Biscay to the Cape of Good Hope. It is an epipelagic and coastal to oceanic species, often found above the thermocline, although it is known to frequently make short dives to depths of up to 250 m.

Sailfish spawning areas in the Atlantic are mainly found in the tropical areas of both hemispheres. In the eastern Atlantic, spawning has been observed in West African shelf waters throughout the year. Sailfish migration routes are not fully understood, however, it is thought that most adults remain in the same location and there are few, if any, trans-Atlantic migrations. Adult sailfish feed opportunistically on schooling stocks of halfbeaks, jacks, small tunas, and cephalopods. Larvae sailfish feed on copepods.

Juveniles and small adults of skipjack, yellowfin and bigeye tuna school at the surface either in mono-species groups or together and these schools are often associated with floating objects such as floating seaweed, pieces of wood and stationary, anchored or drifting vessels (Røstad, Kaartvedt, Klevjer and Melle, 2006). The attraction is likely to be linked to predator avoidance and a focus of aggregation behaviour. Marlin, swordfish and sailfish are also attracted to floating objects probably for the same reason as tuna but also to feed on readily available prey that is attracted to floating objects. Fishermen exploit this by using floating aggregation devices (FADs) to attract schools of tuna.

Demersal Species

Trawl surveys have shown that demersal fish are widespread on the continental shelf along the entire length of the Ghanaian coastline. Species composition is a typical tropical assemblage including the following families.

- Three Porgies or seabreams (Sparidae), eg *Pagellus bellottii*, *Pagrus caeruleostictus*, *Dentex canariensis*, *Dentex gibbosus*, *Dentex angolensis* and *Dentex congoensis*;
- Two Grunts (Haemulidae), eg *Pomadasys incisus*, *P. jubelini* and *Brachydeuterus auritus*;
- One Croakers or drums (Sciaenidae), eg *Pseudotolithus senegalensis*;
- Goatfishes (Mullidae), eg *Pseudupeneus prayensis*;
- Snappers (Lutjanidae), eg *Lutjanus fulgens* and *L. goreensis*;
- Groupers (Serranidae), eg *Epinephelus aeneus*;
- Threadfins (Polynemidae), eg *Galeoides decadactylus*; and
- Emperors (Lethrinidae), eg *Lethrinus atlanticus*.

The seasonal upwelling of cold and saline waters over the Ghanaian shelf provokes changes in the geographical distribution of many of the demersal fish species. During the upwelling season, the bathymetric extension of the croakers is reduced to a minimum, while the deep water porgies are found nearer the coast than at other times of the year.

The demersal species that are most important commercially (in terms of catch volumes) are cassava croaker (*Pseudotolithus senegalensis*), bigeye grunt (*Brachydeuterus auritus*), red pandora (*Pellagus bellottii*), Angola dentex (*Dentex angolensis*), Congo dentex (*Dentex congoensis*) and West African Goatfish (*Pseudupeneus prayensis*). These species are discussed further below.

Cassava croaker (*Pseudotolithus senegalensis*) is considered to be the most economically important demersal fish in West African waters, although it is reported (Froese and Pauly, 2009) that in recent years in Ghana their importance has declined. They are distributed along the west coast of Africa as far south as Namibia and as far north as Morocco. They are a demersal species occupying both marine and brackish water down to a depth of 70 m. They are mainly found in coastal waters over muddy, sandy or rocky bottoms. Smaller individuals are found in shallow waters, occasionally entering estuaries. Their diet includes fish, shrimps and crabs. Spawning in the Gulf of Guinea takes place between November and March in waters of 22 to 25°C.

Big eye grunt (*Brachydeuterus auritus*) are common along the coast of West Africa and may also extend into the waters of Morocco. In Ghana, big eye grunt inhabit coastal waters with sandy and / or muddy bottoms at depths of between 10 and 100 m, but are mostly found between 30 and 50 m. This species remains near the bottom during the day and migrates vertically at night, feeding on invertebrates and small fishes. Other important grunt species of this group include sompat grunt (*Pomadasys jubelini*) and the bastard grunt (*Pomadasys incisus*).

Red pandora (*Pellagus bellottii*) are found along the west African coast from the Canaries to Angola. They are mainly benthopelagic(1) but demonstrate demersal behaviour. Red Pandora inhabit inshore waters, with hard or sandy bottoms, to a depth of 250 m, with their preferred depth being greater than 120 m. Their diet is omnivorous, with benthic invertebrates, cephalopods, small fish, amphioxus (lancelets) and worms dominating. Once fish are mature (at 1 to 4 years) they migrate to the coast and intermittent spawning occurs between May and November.

Angola dentex (*Dentex angolensis*) occur along the West Coast of Africa from Morocco to Angola. In common with the large eye dentex, this species is benthopelagic with a predominantly demersal behaviour. They are found on varied substrates but mainly occupy sandy mud substrates on the shelf and upper slope between 15 and 700 m. Adults feed predominantly on crustaceans, but fish, molluscs and worms also form part of their diet.

Congo dentex (*Dentex congoensis*) are distributed along the West African coastline from Senegal to Angola. Congo dentex is a benthopelagic species that inhabits various bottoms types on the continental shelf and upper slope, to a depth of at least 200 m. The species is carnivorous feeding chiefly on fish, and to a lesser extent on tunicates and molluscs.

West African goatfish are distributed along the West African coast between Morocco and Angola. They inhabit the coastal waters of the continental shelf, over sandy and muddy bottoms, where they feed on benthic invertebrates such as amphipods and polychaetes.

Deep Sea Species

Froese and Pauly (2009) lists over 180 species of deep-sea fish, including 51 bathydemersal species that are associated with the bottom and a further 106 are listed as bathypelagic (1000 to 4000 m). The remaining species are generally considered to occupy depths to 1000 m (ie epipelagic or mesopelagic) but may venture into deeper water during part of their lifecycle.

Froese and Pauly (2009) lists 89 species from 28 families that are likely to be found in Ghanaian waters within the depth range in the Jubilee field (1,100 and 1,700 m). *Table 4.5* provides a list of the families and representative species that potentially occur on the seabed in the project area.

(1) Living in the water column just above the seabed

There is little information on the distribution of these species within the project area and within Ghanaian waters generally. However, studies have been conducted elsewhere in West Africa (Mauritania, Nigeria and Angola) by the SERPENT project which uses Remotely Operated Vehicles (ROVs) around oil and gas installations to investigate deep sea fauna (see serpentproject.com). In Nigerian waters, which have similar fish fauna to that of Ghana, sharks (squalidae), chimaera (chimaeridae), grenadiers (macrouridae), rays (rajidae) and *Guentherus altivela* (Ateleopodidae) were observed in deep water. In Angola, at depths only slightly below those of the Jubilee field Portuguese dogfish (*Centroscymnus coelolepis*), arrowtooth eel (*Synaphobranchus kaupii*), white-head hagfish (*Myxine ios*), several species of snailfish, snub-nosed eel (*Simenchelys parasitica*) and eelpout *Pachycara crassiceps* were recorded.

Table 4.5 Deep Water Fish Families Potentially Present in the Project Area

Family	Species
Alepocephalidae	*Asquamiceps caeruleus, Bathytroctes microlepis, Xenodermichthys copei, Herwigia kreffti, Einara macrolepis, Alepocephalus rostratus, Talismania antillarum, Leptoderma macrops, Talismania homoptera, Talismania mekistonema, Talismania longifilis*
Bathysauridae	*Bathysaurus mollis*
Carapidae	*Snyderidia canina*
Centrophoridae	*Centrophorus lusitanicus*
Congridae	*Bathyuroconger vicinus*
Dalatiidae	*Dalatias licha*
Gempylidae	*Lepidocybium flavobrunneum, Nesiarchus nasutus, Nealotus tripes*
Gonostomatidae	*Diplophos taenia, Cyclothone braueri, Bonapartia pedaliota, Cyclothone pallida, Cyclothone microdon, Cyclothone alba, Cyclothone livida, Gonostoma atlanticum, Sigmops bathyphilus, Cyclothone obscura*
Halosauridae	*Halosaurus ovenii*
Ipnopidae	*Bathymicrops regis, Bathytyphlops sewelli, Bathypterois atricolor , Bathypterois quadrifilis, Bathypterois grallator*
Macrouridae	*Malacocephalus occidentalis, Malacocephalus laevis, Nezumia aequalis, Nezumia duodecim, Nezumia micronychodon, Bathygadus melanobranchus*
Myctophidae	*Diaphus perspicillatus, Ceratoscopelus warmingii, Notoscopelus resplendens, Diaphus lucidus, Lobianchia dofleini, Diaphus splendidus, Lampadena anomala, Lampanyctus alatus, Benthosema suborbitale*
Nemichthyidae	*Nemichthys scolopaceus, Nemichthys curvirostris*
Neoscopelidae	*Scopelengys tristis*
Nettastomatidae	*Nettastoma melanurum, Venefica proboscidea*
Notosudidae	*Ahliesaurus berryi*
Ogcocephalidae	*Dibranchus atlanticus*
Ophidiidae	*Monomitopus metriostoma*
Opisthoproctidae	*Dolichopteryx binocularis, Winteria telescopa*
Paralepididae	*Dolichosudis fuliginosa*
Phosichthyidae	*Vinciguerria nimbaria*
Platytroctidae	*Barbantus curvifrons, Holtbyrnia innesi, Sagamichthys schnakenbecki, Platytroctes apus, Maulisia mauli, Searsia koefoedi*
Rajidae	*Bathyraja hesperafricana, Rajella barnardi, Dipturus doutrei*
Serrivomeridae	*Serrivomer beanie*
Squalidae	*Squalus uyato*
Sternoptychidae	*Sternoptyx pseudobscura, Argyropelecus hemigymnus, Argyropelecus sladeni, Argyropelecus affinis, Sternoptyx diaphana*
Stomiidae	*Astronesthes macropogon, Flagellostomias boureei, Stomias affinis, Stomias longibarbatus, Borostomias elucens, Malacosteus niger, Pachystomias microdon, Bathophilus brevis, Heterophotus ophistoma*

Source: Froese and Pauly (2009)

Maintenance of deep-sea fish communities depends on the presence of large fish to break up the bulk of the carrion falls, allowing the majority of fish species to access a vital food source and the presence of small amphipods (small crustaceans) at the basis of the food chain that support many of the larger fish.

Protected or Endangered Species

The sensitive species in Ghanaian waters according to the IUCN red list (IUCN, 2008) are presented in *Table 4.6*. Of these only the tuna and swordfish species are likely to occur in the water depths found in the Jubilee field area. A number of these species are commercially important and are subjected to heavy exploitation, particularly Albacore tuna and swordfish. It should be noted that Albacore catches in Ghanaian waters are not currently recorded (ICCAT Fishstat data). Of the listed species, bigeye tuna, yellowfin tuna and swordfish are recorded as being present in the project area. These species are all found within the surface waters of the area (the first 100 m below the surface). Swordfish and bigeye may also be found at depths up to 250 m.

In the global context there is concern about the bigeye tuna stocks. The International Commission for the Conservation of Atlantic Tunas (ICCAT) has listed it as the species of greatest concern, after the bluefin, in terms of its population status and the unsustainable levels of exploitation exacted on this species.

Table 4.6 Threatened Fish Species in Ghanaian Waters (IUCN Red List 2008)

Scientific name	Common name	Red List Category
Epinephelus itajara	Goliath Grouper	Critically Endangered
Epinephelus marginatus	Dusky Grouper	Endangered
Thunnus obesus	Bigeye Tuna	Vulnerable
Epinephelus aeneus	White Grouper	Near Threatened
Thunnus albacares	Yellowfin tuna	Lower Risk
Cephalopholis taeniops	African Hind	Data Deficient
Epinephelus caninus	Dogtooth Grouper	Data Deficient
Epinephelus costae	Goldblotch Grouper	Data Deficient
Epinephelus goreensis	Dungat Grouper	Data Deficient
Epinephelus haifensis	Haifa Grouper	Data Deficient
Hippocampus algiricus	West African Seahorse	Data Deficient
Thunnus alalunga	Albacore Tuna	Data Deficient
Xiphius gladius	Swordfish	Data Deficient

4.2.9 Marine Mammals

The ecological significance of Ghana's coastal waters for dolphins and whales has only recently become the subject of scientific studies, which partially explains the lack of population abundance estimates and why their natural history remains largely unknown. The conditions created by the seasonal upwelling in the northern Gulf of Guinea is likely to create conditions favourable for marine mammals as well as for fisheries.