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MACROBENTHIC INFAUNAL ASSEMBLAGE STRUCTURE IN NEARSHORE AND OFFSHORE SEABEDS OF GHANA

BY

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DECLARATION

This thesis is the result of research work undertaken by Nii Amarquaye Commey in the Department of Marine and Fisheries Sciences of the University of Ghana, under the supervision of Mr A. K. Armah and Dr E. Lamptey. No portion of this research has been included in any thesis or dissertation submitted for a degree or qualification to any institution. All works cited or quoted, have been duly referenced comprehensively.

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ABSTRACT

The increased need for energy self-sufficiency has caused an extensive search for various sources of energy (especially, oil and gas) in the marine environment. Globally, the magnitude of impacts of the activities on the marine environment is increasing over the years and most felt on the seafloor. The study of seafloor (benthic) organisms therefore, are vital determinants of impacts on the seafloor. This thesis sought to determine the community structure of nearshore and offshore benthic macrofaunal assemblages and sediment characteristics of the two environments. It further provides a baseline of benthic macrofaunal assemblages prior to the proposed coal-powered facility at Ekumfi Aboano (nearshore), as well as, determine the current (2015) state of benthic macrofaunal assemblages in the Jubilee Fields (deep-sea). The study was carried out within the nearshore Ekumfi Aboano (av. depth–15 meters) and offshore regions (av. depth–1250 meters) of the Jubilee Fields. Sediment samples were obtained using a Van Veen grab and box corer for the nearshore and deep-sea environments respectively. Benthic macrofaunal distribution was investigated using PRIMER. Using GRADISTAT, nearshore sediment (mean grain size of 99.80 µm) was characterized as moderately sorted with very fine sand. Conversely, offshore sediment (mean grain size of 109.79 µm) was characterized as poorly sorted with very coarse silty fine sand. From the macrobenthic infauna analyses, 1113 individuals with an average density of 38 individuals/m^2 were found at the nearshore environment and 2205 individuals with an average density of 47 individuals/m^2 were found in the deep-sea environment. Numerical abundance showed polychaetes were 194 and 983, crustaceans were 827 and 696, molluscs were 35 and 229, echinoderms were 14 and 37 and "others" (foraminiferans, nematodes, nemerteans, sipunculids) were 43 and 260, for the nearshore and offshore environments respectively. The order of dominant taxa was; crustaceans > polychaetes > molluscans > others > echinoderms–for shallow Ekumfi seabed and; polychaetes > crustaceans > molluscans > others > echinoderms–for the offshore Jubilee seabed. Species identified nearshore were 116, whereas 188 species were identified within the deep-sea environment. Both sites were evenly spread (J’ > 0.8) and showed high diversity (H’ > 4; 1-D > 0.9). Polychaetes dominated (44.58 %) offshore as arthropods dominated nearshore (74.30 %). Macrobenthic infauna abundance was higher deep-sea than nearshore and were 75 % dissimilar, possibly due to varied anthropogenic influence within the two environments.

DEDICATION

To Mr and Mrs Commey, who have dependably been a steady wellspring of help and motivation amid the trying times with unconditional love.

To Maclean and Enoch Commey, your examples have taught me to endure for the things that I seek to accomplish.

To Ataa Naa Nyɔŋmɔ.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Majority of the Earth's surface (70%) is covered by water (Gray & Elliot, 2009) making the marine environment the largest and most diverse biological community (Garrison, 2012; Huston, 1994). The marine environment encompasses intertidal zones within continental shelves (0–200 meters), abyssal plains (2000–6000 meters), seamounts (> 1000 meters) and hadal troughs (6000–10000 meters) (Lalli & Parsons, 2006). Heterogeneity in environmental features is its most important feature, thus being a highly diverse ecosystem, the ocean serves as the habitat for many organisms, either found in the water column or linked to the seafloor (Lalli & Parsons *ibid*).

The water column (pelagic zone) and the sediment (benthic zone) on which it rests are the two interdependent zones which constitute the aquatic ecosystem. The benthic zone is second to the pelagic environment in respect to habitat size but first in relation to spatial cover (Bacci *et al.*, 2009). These sediments are either autochthonous (originating where it is found) or allochthonous (found in a location other than where constituents were formed) (FAO-FIGIS, 2007). The benthic ecosystem is governed by the processes and variables of interconnected relationships and serves as the community of bottom-dwelling organisms which interact with the sediment-water interface or environment. Physicochemical variables (sediment characteristics, water movement, pH, dissolved oxygen, temperature, etc.), provide the rudimentary conditions which constitute a fundamental niche colonised by benthic organisms (environment-biology relationships). Predator-prey relationships and competition are biological interactions (biology-biology relationships), capable of altering the biological community structure. Through organism interactions, sediment structure and chemistry can be modified (biology-environment relationships). The extent of interaction or modification is uncertain in most cases but can be predicted (Gray & Elliot *op cit*; Elliot *et al.*, 2006). Man's activities are overlaid on these processes.

Over the course of time, man's search for self-sufficient energy to meet pressing energy demands has led to the destruction of environments (terrestrial and aquatic). According to the IEA (International Energy Agency) Renewable Energy Working Party (2002), globally, energy is being driven primarily by non-renewable resources (fossil fuels) which are dwindling. Reductions in non-renewable resource quantities make them expensive and damaging to the environment as we consistently mine for them. Renewable sources of energy pose a lesser threat to the state of environments and can potentially exceed the world's energy demands.

Renewable resources (such as wind, rain, sunlight and geothermal heat) are replenished constantly on a shorter human timescale, unlike non-renewable resources which are replenished over longer timescales. Most of these renewable and non-renewable resources are managed along continental shelves (Halpern *et al.*, 2008). Some sources of the anthropogenic impacts on the marine environment are underwater noise (Solan *et al.*, 2016; Williams *et al.*, 2015), gaseous emissions (Wilding *et al.*, 2017) and electromagnetic fields (Woodruff *et al.*, 2013).

Man's energy demands focus on electricity generation, air and water cooling and heating, transportation, rural energy services (REN21, 2010; World Energy Assessment, 2001).

Energy sufficiency is based on energy security, environmental impact mitigation and economic benefits and energy losses (International Energy Agency, 2012). About 19 % of human global energy consumption is from renewable resources, namely biomass energy, hydropower, solar energy, wind energy and geothermal energy (REN21, 2016; Ellabban *et al.*, 2014).

Most African countries have important potentials of energy generation namely, hydropower, marine energy, solar energy, marine energy and biomass energy. Kenya is believed to be the world's leader in the number of solar power systems installed per capita, which is more than 30000 very small solar panels sold annually in Kenya. This reduces the cost of energy while increasing sustainability (Bullis, 2012). Ethiopia, Kenya, Mozambique and Nigeria are a few of the African countries patronising clean, cheaper, sustainable and renewable energy by the use of liquid bioenergy (ethanol and methanol) from plant matter, to fuel domestic cooking stoves (REN21, 2011). Poverty reduction and alleviation are benefits of this clean energy implementation. Moreover, the transition to industrialisation and urbanisation is shortened (Wesseh & Lin, 2016). The 2007 discovery of crude oil in Ghana served as the commencement of oil and gas exploration on its continental shelf, thereby providing an avenue for perturbation of the benthic ecosystem which is monitored regularly to avert and reduce incidences such as oil spills.

Anthropogenic happenings such as shipping and maritime industry activities, which include, but are not limited to, oil and gas exploration and extraction, sonar systems, fishing practices (bottom trawling), dredging, offshore mining (Hawkins & Popper, 2016; Coates *et al.*, 2015) have the potential to harm marine ecosystems and associated species. Their attributing effects include species mortality, organism physiological modification (that is, injury to organism tissues, defects from chemical ingestion), alteration to organism behaviour, ocean acidification and changes in benthic species community structure and assemblages. The magnitude of anthropogenic impact on the marine environment especially on the seabed and associated organisms is unknown (Mesa, 2013; Halpern *op cit*; Borowski, 2001). Changes to the marine benthic community structure signify the loss of key functions played by this ecosystem, therefore necessitating the need for periodic assessment (MacDonald *et al.*, 2012; Tagliapietra and Sigovini, 2010).

Marine benthic communities and their organisms are vital for healthy marine ecosystems. They contribute to elemental cycling, benthic remineralization and ultimately sequestration of carbon (Jones *et al.*, 2014; Pavithran *et al.*, 2009), as well as, serving as indicator species monitored to ascertain and determine the extent of perturbation to marine and aquatic environments. The acquisition of macrobenthic baseline information will serve as a guide, to environmental policy and biodiversity management within Ghana’s Exclusive Economic Zone (EEZ), in particular the deep-sea environment (Froján *et al.*, 2016).

1.2 Justification

Continual disturbance (for example bottom trawling, dredging and oil and gas exploration) of seabeds of the continental shelves is increasing. With the surge in oil and gas exploration and monitoring programmes, more corporations are being given the opportunity to mine the seafloor for non-living resources.

However, a surge in anthropogenic disturbances to the seafloor such as drilling, and construction activities are bound to change habitats, terrains and features of the seafloor (Mesa *op cit*). These disturbances lead to alterations in sediment characteristics within the water column.

Unfortunately, macrofaunal assemblage abundance and diversity is reliant on sediment characteristics, thus the sediment nature (rough, smooth, clayey, sandy, muddy, anoxic, etc.) determines the type of benthic organism present. Consequently, the type and abundance of benthic organism biodiversity influences demersal fisheries abundance and diversity.

Further, marine fisheries in Ghana contributes about 70 % to the total fish supply and plays a role in poverty alleviation, especially in coastal communities. Nonetheless, capture fisheries in Ghana are bedevilled with a string of threats including over-exploitation, rising fishing efforts, declension in fish catches, increment in marine pollution and marine based exploration (ATFALCO, 2012).

In spite of widely known impacts of marine based exploration activities on the state of macrobenthos in many coastal areas like Alaska, Argentina, Romania, Russia and China (Carcedo *et al.*, 2015; Kokarev *et al.*, 2015; Blanchard *et al.*, 2013; Shou *et al.*, 2009), inadequate scientific investigations have been carried out in Ghana (Lamptey, 2015; Allotey, 2010).

1.3 Objectives

The primary aims of this study involves unfolding the community structure of the macrobenthic infauna and assessing the relationship of macrobenthic infaunal assemblages between nearshore and deep-water seabeds. This study focused on testing the hypothesis that, the macrobenthic infaunal assemblage structure of nearshore seabeds is significantly different from that of deep-water seabeds.

The specific objectives of the study were to:

- determine the relationship between nearshore and deep-water macrobenthic infaunal assemblages and sediment characteristics,
- provide a baseline of macrobenthic faunal assemblage prior to disturbance at Ekumfi Aboano, and
- determine the state of macrobenthic fauna in the Jubilee Field.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Benthos

Benthic organisms live at, on or in the bottom of an aquatic body (be it rocks, sediment, debris and aquatic plants) during a portion or all of their life. Benthos include poriferans, cnidarians, arthropods, polychaetes (aquatic worms), echinoderms, molluscs and macroalgae. Per their differences and similarities in their functions and other processes, benthic fauna can be classed in a number of ways (Tagliapietra & Sigovini, 2010; Gutt, 2007). Classification is an essential man-made system, as it presents an opportunity for orderly storage and retrieval of things or bits of information, thereby providing terminologies crucial in the exchange of knowledge and ideas in science (research and training). Benthos classification includes motility, size, feed preference, habitat substrate preference and ecosystem functions.

Motility is the ability of an organism to move independently or spontaneously without a relative change of location but a change in position. Benthic organisms can be either sedentary (being able to move from place to place) or sessile (fixed in one place, incapable of much activity). Benthic fauna type can either be plant or animal. Phytobenthos refers to the aquatic plants, mainly diatoms and macroalgae (seaweed) that are found in benthic regions with vascular tissues and holdfasts or roots. These serve as the base of the food chain with their photosynthetic properties, providing energy as food for organisms along the food chain. Whereas zoobenthos incorporates the animals in the benthos. Some being annelid worms and coelenterates which feed on available phytobenthos and other matter (Lalli & Parsons, 2006).

In relation to size, fauna and flora can be termed as mega-, macro-, meio- and micro-. These size variations exist based on the mesh size of sieves that are able to retain and separate them. Megabenthos often describes organisms greater than 10 millimetres (mm). Decapods and echinoderms are found in this size class. Macrobenthos denotes benthic organisms retained in sieves with mesh size between 0.5 mm and 1 mm. In some circles, the use of 0.3 mm sieves is employed and becoming popular, rather than the orthodox 0.5 mm. The taxonomic groups encountered in this size include sipunculids and nemerteans. Meiobenthos characterises benthic organisms held back by sieves with mesh size ranges between 0.063 mm and 0.5 mm or 0.3 mm. The upper limit is dependent on the mesh size for macrobenthos and meiobenthos separation. Benthic organisms represented in this size range are generally found in sediment interstices. They include nematodes, small molluscs, benthic copepods and foraminiferans, but not limited to these. Microbenthos comprises those benthic organisms that are retained in sieves of mesh size less than 0.1 mm. Examples of microbenthos are amoeba, flagellates, ciliates, bacteria and diatoms (Taylor *et al.*, 2017; Krone *et al.*, 2013).

The benthic fauna location can either be in (infauna), on (epifauna) or just above (hyper benthos- lesser recognised ecological category, in relation to zoobenthos habitat in substrates) the substrate. Infauna or endobenthic organisms reside in the sediment. They may be buried or burrowing in the sediment but often limit themselves to the top oxygenated layer of the waterbed or seafloor. Polychaetes, sand dollars and sipunculids are some infauna representatives. Epifauna or epibenthos characterises the benthic organisms living on top of the sediment. The sea cucumber and sea snail are examples of epifauna. Hyperbenthic organisms such as rock gods and the flatfish sole are benthic organisms that live just above the seafloor but can also operate temporarily above it (Lalli & Parsons, 2006).

Some organisms can be found as infauna or epifauna at some period of their life or due to the exercising of a role in the sediment. Some molluscs or polychaetes are known to burrow through sediment but can rise to the top of the sediment, possibly to feed or perform another function.

Based on substrate preference; being hard-bottom or soft-bottom, benthic fauna (epifauna and infauna) can be present. Soft-bottom substrates are dominated by infauna and epifauna are characteristic of hard-bottom substrates. The feeding modes of benthic fauna include being deposit-feeders, filter feeders, opportunistic feeders and detritivores. They could be sessile, sedentary or mobile (Tait & Dipper, 1998).

Benthic macroinvertebrate biodiversity and abundance is an indication of the health of a water system. As they are patchy in distribution, benthic organism presence is not guaranteed during sampling but dependent on the substrate nature, the degree of stability, oxygen, hydrogen sulphide and nutrition content in the community (water and sediment) (Anbuchezhian *et al.*, 2009). Pollution has adverse effects on the ecosystem and associated organisms, affecting the water quality, gravely leading to possible loss of species including adverse morphological and physiological impacts on organism nature and structure (Clarke & Warwick, 2001).

2.2 Ecological Importance of Macrobenthos

Macrobenthos play a variety of functions and provide many goods and services. The importance of an organism might be beneficial to other organisms in the ecosystem through trophic levels, to the ecosystem via ecological roles and to man for an assortment of uses.

Benthic organisms transfer materials through trophic levels, serving as an essential linkage in the energy processes ecosystem (van der Zee *et al.*, 2015; Afli, 2008). These organisms exchange energy with the surrounding environment as they compete for food and space within the niche (Pearson, 2001). Organic matter conversion below the redox layer and storage of food within the sediment by some organisms has an influence on the carbon budget in the ecosystem (Pavithran *et al.*, 2007).

The benthic community performs recycling functions to all material that get to the depths of aquatic bodies (Gerino *et al.*, 2003). There are occurrences and all the more, an increase in monitoring of pollution through analysing of benthic communities. Some organisms aid in community structure determination as they also play integral roles as indicators of change in the water quality and sediment nature of the community (Fabricius & McCorry, 2006). This they are able to do by being deposit feeders, having longer life cycles and limited motility (Thompson & Lowe, 2004). The time scale of the disturbance being short or long does not have a direct impact on their activity and functions. The changes serve as stressors elucidating changes in assemblage structure, diversity and abundance, thereby being utilised as indicator species across many areas being monitored.

Since the organisms are not able to escape the consequences of pollutants on the sediment and water, they consume these pollutants into their systems and accumulate them over many time scales. Studying them reveals the presence of these toxicants and other harmful matter (Borja *et al.*, 2007). Per their mode of feeding (deposit or filter), benthic organisms are able to retain traits of a disturbance in an area. Their reproductive properties and long-life cycles are not limiting, thus are capable of proliferating irrespective of the disruption in the community state. This makes benthic organisms excellent candidates for assessments and environmental quality monitoring of aquatic bodies (Albayrak *et al.*, 2006; Ysebaert *et al.*, 2003).

Primary producers and higher trophic organisms are linked by the action of benthic organisms through feeding activities on plankton (phyto- and zoo-) and other organisms. The higher trophic organisms (fishes, birds and man) then prey on some of these benthic organisms (Ysebaert *et al.*, 2003). Important economic marine species prey on benthos to survive and as such, benthic communities have control over the economic state of some communities and countries (Thoya *et al.*, 2015).

Water quality alteration by eutrophication and significant phytoplankton growth in some areas has been found to be reduced by the activity of benthic organisms. In this manner, they are able to cause changes in biogeochemical cycles within water beds. Benthic organisms were found capable of nutrient regeneration through the recycling of inorganic nitrogen and phosphorus into the water column (Grall & Chauvaud, 2002).

Biogenic reworking of sediment (bioturbation) by benthic organisms has the capacity to influence the organic and inorganic matter within the upper sediments (Michaud *et al.*, 2006). This activity has the tendency to improve oxygenation of the sediment-water interface, allowing for habitation by some benthic organisms. This sediment reworking allows the sediment-water interface to be mixed and some nutrients and oxygen made readily available to infauna. Sediment surface alteration can be manipulated via bioturbation, as surface topographies are changed and holes or pits trapping sediment and matter made available (Baranov *et al.*, 2016; Shull *et al.*, 2009).

Benthic communities provide services such as recreation and eco-tourism (Beaumont & Hadley, 2004). Snorkelling or SCUBA (self-contained underwater breathing apparatus) diving have been and are still popular pastimes. Colourful organisms and human adventure have developed into photographic books (Wisehart, Rempala & Leboffe, 2012) and nature channels on television networks either to supplement biology text or satisfy human curiosity. In satisfying part of this curiosity, man isolates chemicals from marine organisms for the treatment of ailments.

Current drugs are often derived from nature; aspirin from the willow tree and morphine from the opium poppy – and serve mans' many needs. Up to now, many of the natural sources of these drugs are from terrestrial organisms but in the search for new drugs, more anti-(biotic, inflammatory, tumour) substances are being found in marine invertebrates. The possibility for discovery of many other important drugs is high because of the vast seafloor awaiting exploration.

The study of benthos (chemosynthetic and coral communities) and their associated chemicals are therefore, key to breakthroughs in health and food among other areas. A few examples being, pullulanase, an enzyme from a mollusk (*Thermococcus* sp.), has been found healthier in sweetener production for food additives. Also, scientific research has deemed as promising, an exopolysaccharide produced by *Vibrio diabolicus* for disease and bone injury treatment. Cancer research and treatment has made strides through the discovery of ecteinascidin and bryostatin. Tunicates produce ecteinascidin which blocks transcription of DNA (deoxyribonucleic acid) thereby assisting in breast and ovarian cancer treatment. Bryostatin – an extract from *Bugula neritina* – is a potential drug to treat melanoma and leukemia by acting as a differentiating agent, forcing maturity in cancer cells, causing an arrest to errant cellular division. As anti-tumor agents, extracts from two sponges lasonolide (an extract from *Forcepia* sp.) and discodermalide (an extract from *Discodermia* sp.) are able to bind to DNA and interfere with microtubule networks, respectively (Sulak *et al.*, 2008; Fisher *et al.*, 2007; Maxwell, 2005; Mayer & Gustafson, 2003; van Dover *et al.*, 2003; Batchelder, 2001).

Marine benthos are being studied to determine their ability to cope and survive under difficult limiting conditions within great depths, as well as their ability to withstand many changes whiles accumulating material, possibly harmful to their structure and metabolism.

Phytobenthos are often reliant on sunlight and nutrient concentrations for growth and survival. Their abundance can be an indication of contaminated water. The presence or absence of an indicator species generally reflects the environmental condition of a community. Absence must be of multiple species previously found in the community and with varying levels of tolerance. The absence of a single indicator species is not necessarily indicative of pollution, as competition and predation can influence the presence, abundance and distribution of organisms in any community (Ramakrishnan, 2003).

Aquatic ecosystem health can be monitored through benthic macroinvertebrates due to their contact with chemical pollutants often stored in the sediment, presence in the water bottom for majority or all of their life, ease of sampling, restricted movement, tolerance variation to types of perturbation and diversity (taxonomic and functional). Changes in the environment have a considerable response on the benthic community and can determine the level of pollution. Organisms resident in the sediment are better indicators because the water is not bound to a geographic location unlike a bulk of the sediment. The low levels of dissolved oxygen at water beds, due to organic matter degradation inhibits the reaction time of many pollutants not consumed on by detritivores and micro-organisms (Tagliapietra & Sigovini, 2010).

2.3 Macrobenthos and Environmental Factors

Marine organisms are dependent on biological aspects of their environment, chemical composition of the oceans and physical features that affect marine life. These factors (biological, chemical and physical) serve as the potpourri that sustains marine life, as well as determine the distribution of organism populations within communities. A balanced interaction between factors has an effect on the community structure of macrobenthos (Lamptey & Armah, 2008).

Biological factors (recruitment and competition) influence on benthic communities has been a crucial component of benthic ecosystem variations and changes but not void of the impact of environmental factors. Benthic community structure, diversity and tolerance can vary per natural factors such as the ecosystem type, bottom water salinity, the bioclimatic region, the special morphologic features of resident organisms and the sediment type (Tagliapietra & Sigovini, 2010).

Physical factors are those aspects of the physical environment that affect the living organisms. The chemical nature of the oceans is characterised as the chemical factors. Organisms reside in and are gravely affected by environmental factors (physical and chemical) such as temperature, pH, salinity, conductivity, turbidity, dissolved oxygen, organic matter, sediment nature and water depth (Akindele & Olutona, 2015; Leo *et al.*, 2014). Understanding the dynamics of these environmental factors is the basis on which the influence of the factors on the community structure can be determined. This assists in region-specific management plans, policies and strategies being developed for coastal zones and aquatic bodies to be monitored and evaluated. Biotope and niche variation is dependent on different factors. A few being, the spatial spread of the influence, the resident time of the influence, the magnitude of the influence, vegetation response to the influence, seasonal climatic conditions and anthropogenic inputs. The relation between the water column production and benthos was suggested to be close (Levin *et al.*, 2001). Such that, the community structure of macrobenthos was determined to be subjective (directly or indirectly) to the physical and chemical parameters (Lamptey & Armah, 2008). Different species respond differently to perturbation and hence the expected variation in benthic ecosystems.

Sunlight is a primary ingredient for photosynthesis occurrence in plants. The marine environment requires similar sunlight amounts and intensities but photosynthetic autotrophs deal with selectively absorbed light. On reaching the water surface, some of the light is reflected, some are refracted and others penetrate the water interface to be absorbed. Light penetration, therefore, determines the depth to which photosynthetic matter reaches bottom sediments. The depth of light penetration is restrained by particulate matter present (number and characteristics), which can be suspended sediment, living tissue, organisms as well as the sunlight amount reaching the ocean. The water either absorbs or bends (reflection or refraction) the impacting light. The absorbed light energy generates heat within the system (Garrison, 2012).

Ocean temperature fluctuates over depth and latitude. The stratification of the water column and hydrographic regimes inform temperature distribution. The greater the mixing regime, the more uniform the water column temperature will become. The degree of mixing is dependent also on the abundance and latitudinal differences. Tropical-temperate temperature interactions determine nutrient mixing, oxygen availability and benthic ecosystem state (Lalli & Parsons, 2006). Biological activities (nutrition, reproduction and general behaviour) of organisms are driven by temperature differences and the rate at which reactions occur in organisms (metabolic rate) increases with temperature (Garrison, 2012). Chemical reactions occur faster within warmer temperature ranges. Most marine organisms require dissolved gases to function.

Oxygen concentration reduces with increasing depth in the aquatic environment. Hypoxia and anoxia are associated with benthic ecosystems but can occur at intermediate depths, thereby limiting the distribution of oxygen-dependent organisms and increasing the spatial spread of hypoxic or anoxic organisms (Vacquer-Sunyer & Duarte, 2008). Marine sediments are anoxic below a particular depth from the surface sediments, bringing about the redox potential discontinuity (RPD). The RPD is the zone of separation between surface aerobic dominant sediments and the subsurface anaerobic dominant sediments or sulphidic sediments. Oxygen penetration within sediments is by physical diffusion and that is only a few millimetres (mm) deep but can be enhanced by the burrowing and irrigation activity of infauna (Gray & Elliot, 2009).

The RPD extent is also affected by dissolved oxygen in the bottom water, organic matter sedimentation, temperature, pressure and sediment grain size. In areas with stagnant water columns and stratification, oxygen mixing is reduced and organic matter enrichment at water bottoms surges, leaving the sediment-water interface in high demand of oxygen (Levin *et al.*, 2009). The organic matter enrichment is attributed to the proliferation of eutrophication as well as high temperatures, leading to phytoplankton blooms and development of hypoxic conditions. The generated hypoxic condition leads to increased stress, pushing organisms to migrate, tolerate, resist or die off. The oxygen amount also influences the colour of the sediment. Bottom sediments tend to be brown in the aerobic layer, grey at the zone of variation (RPD layer) and black in the anaerobic layer (Woulds *et al.*, 2007).

Depth limits light, temperature, dissolved oxygen and essential nutrients (nitrate and phosphate) availability to the ocean depths. Phytobenthos is limited in most cases to the reduced penetration and reduced gravity occurring in aquatic bodies (the marine environment). Pressure increases with depth and limits many factors. The difference in pressure influences community structures, as some organisms are not able to adapt and survive under such conditions. These pressure differences tend to be uniform globally after some depth ranges (Tait & Dipper, 1998). Assemblage structure is believed to vary over small depth ranges, rather than species richness (Bergen *et al.*, 2001). With the increase in water depth over larger scales, species richness is seen to vary from 200 meters to less than

3000 meters before realising a decrease in increasing depth, greater than 5000 meters (Glud, 2008).

2.4 Sediment Characterization

Seafloor nature is determined by the geology speed of the bottom current, depth, type of suspended matter and the type of benthic ecosystem. Marine sediments cover a broad range of types and sizes. Sediments are the loose accumulations of organic or inorganic particulate matter. Characterization can be done by origin (biogenous, cosmogenous, terrigenous and hydrogenous), composed material (carbonate, clay, quartz, etc.) and by size (boulder, pebble, coarse sand, fine sand, silt, clay, etc.). Sediment presence or absence is due to prevailing current strength, sediment dissolution by hot upward percolating water from Earth’s inner regions or slow sediment accumulation rate in some areas (Garrison, 2012; Gray & Elliot, 2009).

Sediment deposition is controlled by three factors: settling velocity, roughness velocity and threshold velocity. The velocity required to transport particles of different sizes (roughness velocity) and the flow needed to pick up particles from the seabed (threshold velocity) determine the velocity at which particles settle (settling velocity) (Open University, 2002). Sediment nature (fine or coarse) may be packed tightly or loosely per the particle diameter possessed. This contributes to sediment porosity (size of pore spaces between particles) and permeability (amount of water flow through the particle pore spaces) (Eleftheriou & McIntyre, 2007). Fine sediments pack more tightly making it harder for water movement to pick up and transport particles, unlike coarse sediments that can be transported by water movement as they are loosely packed. In cases where particles are mixed (fine and coarse particles together), energy required for particle movement is between that for only fine packed particles and only coarse particles (Gray & Elliot, 2009). Therefore, coarse sediments retain little water, dissolved oxygen and organic matter whereas fine sediments retain more water, dissolved oxygen and organic matter.

Waterbeds are often heterogenous and composed of many sediment types. Knowledge of the degree to which the sediment is sorted gives an indication of the resident organisms. Sediment are either well-sorted with a dominant sediment type or poorly-sorted with varied sediment types. Wave and current activity influence sorting of sediments. High energy waves and currents produce well-sorted sediments. Sediment grain size and sorting can vary over minute distances and are guides to the determination of organism presence or absence in a community or ecosystem.

Sediment nature can determine the feeding modes (including but not limited to predatory feeding, deposit feeding, suspension feeding and filter feeding) of species in a community (Papageorgioua *et al.*, 2009). Faunistic distribution within communities is regulated by sediment particle size and influences species diversity. Burrowers either dig through, push aside or eat through the sediment. Coarse sediment which are often larger, and more difficult to ingest or move, than smaller sediment require more effort and therefore will lower abundance and species diversity. On the other hand, very fine sediment are given to compaction and respond as silty matter, which is uninhabitable for most species as it is hypoxic (Tait & Dipper, 1998).

2.5 Macrobenthos Patchiness

Organism populations, especially benthic populations throughout the world are patchy in abundance and distribution. The extent of patchiness can be caused by and scaled, per the outturn of perturbations in the environments, as well as other processes within the organism structure. The disturbance on the environment can be characterised by temporal scales (short or long term), spatial scales (latitudinal or longitudinal, small area (m^2) or large area (km^2)) and magnitude or intensity of disturbance. Further variations can be related to frequency and intensity of the disturbance agent. This, therefore, determines the presence or absence of organisms in any sampling location or area, as well as, influence the abundance, diversity and distribution of these populations (Wahl, 2009). The cause of benthic population patchiness can be anthropogenic or natural activities. Disturbance plays a role in benthic community structuring. Understanding these disturbance agents can help anticipate the extent to which they regulate benthic community structures and diversification.

Anthropogenic influence to benthic patchiness, refers to man's disruption of the structure and nature of benthic populations through activities such as, but not limited to, mining for seabed minerals, dredging, disposal of dredge spoils, seabed trawling, recreational fishing, anchorages, building of coastal infrastructure (reclamation) and research (Ministry for the Environment and Statistics New Zealand, 2016; Williams *et al.*, 2015; Goldfinger *et al.* 2014).

Natural activities are crucial factors with the tendency to gravely upset benthic population states. Wave activity, tidal differences, longshore transport (littoral drift), weather changes (storms, volcanic or mantle activity), sedimentation after landslides, flooding of inland aquatic bodies, drought on terrestrial environments, landslides–on a boulder or the intertidal zone is able to reorder organism populations (Lake, 2001). Erosion of coasts and assemblage loss due to large storm activities is a large-scale disturbance that causes a re-structuring of benthic organism populations.

Recruitment at unpredictable and variable patterns is believed to be a major contributor to patchiness (Sigurdsson & Tremblay, 2016). Settlement and post-settlement mortality differ at spatial scales within communities (Gray, 2016). The scale of disturbance can contribute to the predictability of the disturbance (Eleftheriou & McIntyre, 2007). Smaller scale disturbances, such as localised physical and biological processes (local environmental disparities or present assemblage) influence recruitment through interaction, thereby making it very variable, spatially and temporally, and unpredictable. In larger scale disturbances, predictability is possible as majority of the existing species are limited to their niches and peculiar habitats in a biogeographic range (Sahara *et al.*, 2015).

Predation can increase the absence of particular species at varying scales within confined spatial areas. Species that are heavily preyed upon have the tendency to settle in microhabitats to aid increase in numbers and to escape predation (Lalli & Parsons, 2006). The interaction between species, often in subtidal regions, consistently modifies species abundance, irrespective of any influence from the environment like currents and sediment transport. Species competition (inter- and intra-) balances abundance and thereby reduces elimination of species. Space and food are influential factors to assemblage patchiness. Migration of flora or fauna can be as a result of dislodgement or overgrowth of one species by another (Wahl, 2009). The relative strength of species, making them superior or inferior, controls presence and abundance, leading to patchy quantities. Algae, barnacles, sea urchins and at times sponges, straddle in intertidal habitats.

Per the spread, intensity and frequency of the perturbation, it is expected of larger long-living species to be eliminated, as the smaller short-living species dominate the ecosystem (Tomassetti & Porrello, 2005; Basset *et al.*, 2004).

2.6 Macrobenthos Diversity

Biological diversity is the variability among living organisms from all sources; terrestrial, marine and other aquatic ecosystems and their ecological complexes of which they are a part, including within species diversity, between species diversity and of ecosystems (Convention on Biological Diversity, 1992).

The diversity of benthic organisms can be regarded in terms of ecosystems, functional traits, genetics and species diversity. Diversity of organism communities varies ecologically, across gradients and scales (Cunha *et al.*, 2011; Frid *et al.*, 2008). Trophic levels show variances in the biodiversity of regions on either the primary, secondary or tertiary levels. Knowledge gleaned from these levels, including processes and patterns is essential to understanding and appreciating the management of marine ecosystems.

Marine ecosystems constitute more than half the Earth’s surface. Organisms are either found within the pelagic or demersal region. Resources in the marine ecosystem are abundant (oil and gas, fish, marine resources) but capture fisheries in Ghana, is currently over-exploited.

Every ecosystem has a number and range of functional traits which defines its functional diversity and is closely related to the use of resources and productivity (Lamptey, 2015). The peculiarity of functions in the ecosystem is a vital indication of the different organisms present (Hooper *et al.*, 2005; Mouillot *et al.*, 2006). Benthos functional diversity is characterised by the morphological traits possessed by the organisms (van der Molen *et al.*, 2013; Pacheco *et al.*, 2011; Bêche *et al.*, 2006; Bremner, 2005). These organism traits impact on the biotic and abiotic matter (Mermillod-Blondin *et al.*, 2005; Dumay *et al.*, 2004; Waldbusser *et al.*, 2004). Development of functional diversities is dependent on species similarities of functional roles (such as size, growth rate, growth form and trophic type), the number of these traits and their ecological relevance (Wahl, 2009).

Species genetic diversity is the fundamental biological trait employed in species categorization. Genetic material can only be interchanged if species are of the like population, which interbreed and sexually reproduce. Genetic differentiation exists among individuals and populations. Natural selection, genetic mutations, genetic drifting and genetic mixing are some of the factors that influence the divergent nature of populations over the course of time (Mitra & Zaman, 2016). Genetic diversity strength determines the amount of genetic material that is passed on to progeny or descendants.

The species abundance and richness in a given ecosystem defines the species diversity. The marine ecosystem being pelagic or demersal/benthic has its unique set of species. Each species set is important to its ecosystem. Presence or absence of species in an ecosystem is dependent on latitudinal/longitudinal positioning, water quality, sediment quality and type, climatic conditions, strength and frequency of disturbance in the ecosystem, (Tagliapietra & Sigovini, 2010; Lalli & Parsons, 2006).

2.7 Macrobenthic Research

Research on macrobenthic faunal assemblages, diversity and distribution along Ghana's seafloor and across Ghana's sea boundaries are limiting. The repository of works on macrobenthos assemblages throughout the globe are centred on temperate regions with relatively fewer works pertaining to tropical zones (Kokarev *et al.*, 2015; Blanchard *et al.*, 2013). The few works done are not sustained over definite or regular temporal scales to allow for the formation of trends and larger spatial coverage to allow benthic habitat mapping, ultimately leading to a better understanding of macrobenthic ecology within tropical seabeds.

The available research and literature on macrobenthos in Ghana includes Nicklès' (1950) study of molluscan (taxonomic and morphological) structure along the Western coast of Africa which serves as a reference and guide for taxonomic identification of molluscs, Tebble's (1955) survey of the polychaete fauna of the Gold Coast (Ghana), Clark (1955) studied echinoderms, a 1957 study by Buchanan on benthic fauna on the Ghanaian continental shelf and in 1977, Fauchald provided science with a guide of polychaetes worms, with definitions and keys to the orders, families and genera. Le Lœuff and Zabi (2002) further provided information on the variations (spatial and temporal) in communities and fauna of benthos of the Atlantic coast of Africa. Recent works pertaining to nearshore and offshore include Okyere, *et al.* (2011), Allotey (2010), Tullow Ghana Limited (2009), Lamptey and Armah (2008), Cosel (2006) and Le Lœuff (1993).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Sites

Ghana has a 550-kilometer (km) coastline Ghana bordered by the Guinea Current Large Marine Ecosystem (GCLME). The continental shelf extends outwards between 20 and 35 km, except off Takoradi which extends to about 90 km (ATFALCO, 2012). The study focused on two main sites along the coast of Ghana, namely Ekumfi and Jubilee Fields. Ekumfi Aboano was selected because it is currently the proposed site for the construction of a Coal Fired Power Plant, hence baseline information on macrobenthic fauna is needed for future comparison and assessment of changes post-production. Regarding the Jubilee study site, despite been operational for almost 10 years, the current state of macrobenthic fauna within its operational area remains unclear as past reports cannot be used to monitor trends.

Ekumfi Aboano (N 5°12’41.44”, W 0°49’51.00”) is located 78 km West of Accra and 50 km East of Cape Coast. Temperatures averaged at 28 °C and about 70 % relative humidity are experienced in this region (Ghana Statistical Service, 2014). The coastal boundary of the district is characterised by rocky shores and cliffs with short fringes of sandy beach. The coast is composed of some limestone and thin pebbly sand within the Cretaceous–Eocene marine sands (Ghana Statistical Service, 2014).

Jubilee Fields was discovered in 2007 between the Deepwater Tano and West Cape Three Points blocks the Jubilee Fields (N 4°29'34.0", W 2°55'00.0") is sited 60 km offshore from the nearest coast, at an approximate depth of 1400 m (Tullow Ghana Limited, 2009). The generally smooth seabed which is composed of soft to firm clays and silts (Tullow Ghana Limited *ibid*).

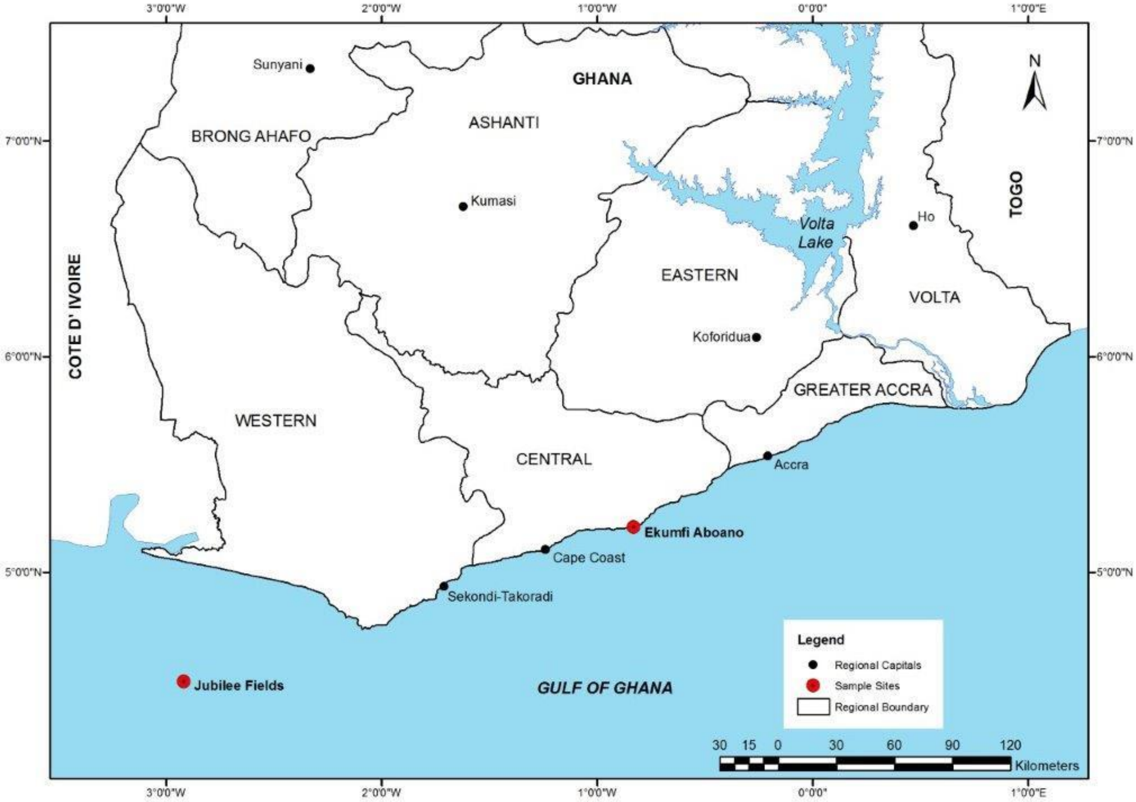

Plate 3.1 - Map of Ghana showing sampling locations (Ekumfi Aboano and Jubilee Fields).

3.2 Data Collection

Sampling was conducted at Ekumfi Aboano in January 2016 at an average depth of 15 meters and was conducted at Jubilee Fields in November 2015 at an average depth of 1250 meters. A Van Veen grab (used at Ekumfi Aboano) and box corer (used at the Jubilee Fields), with approximate surface areas of 0.25 square meters (m^2) were used in sampling the sediments with the aid of a winch to the seabed. Lowering was slowed to avoid disturbance to the superficial sediments and the epibenthos when impact with the seabed was near. Upon retrieval, samples were judged as acceptable when there was complete closure of the grab or corer, samples possessed a disinclined surface or no observation of substantial spillage during retrieval was realized. During sampling, sediment samples obtained on random basis were split into two portions, one for biological (benthos investigations) and the other for characterization of the sediment (Plate 3.2). The sediment samples labelled for macrobenthic infaunal analyses were emptied into 0.5 millimetres (mm) mesh-sized sieve and washed thoroughly with seawater using a flotation technique, which minimises trauma to the organisms and facilitates their separation from sediment (Tagliapietra & Sigovini, 2010).

Macrobenthic organisms, smaller than 0.5 mm were lost and fragile organisms or organisms remaining on equipment such as ophiuroids were picked using forceps into labelled containers. The remaining sample was backwashed with seawater into labelled storage containers.

Obtained samples were then fixed with 10% buffered formaldehyde for preservation and hardening of some organism tissues. Sample label records included the sampling date, sampling location, sample type (macrobenthos or sediment grain size analyses) and preservation type. Rose Bengal for staining the living tissues was added to samples, 10 millilitres (ml) to $5.03*10^{-4}$ m^3 and 20 ml to $7.54*10^{-4}$ m^3. All equipment was examined, freed of debris and rinsed before use at all sampling sites.

Sediment samples obtained for grain size analysis were labelled and stored in plastic containers, for analysis in the laboratory. Three replicate samples were taken per sampling station based on the patchy distribution of benthos.

In all, 64 samples were obtained, comprising 29 from Ekumfi Aboano and 35 from Jubilee Fields.

Plate 3.2 - Sample preparation for (A) physical analyses, and (B) biological analyses.

3.3 Laboratory Analyses

3.3.1 Macrobenthic infauna analyses

Macrobenthic samples were washed on 0.5 mm mesh-sized sieves thoroughly with freshwater to remove the formaldehyde and other fine sediments (lesser than 0.5 mm). Washed samples were spread evenly on a sorting tray, with a white background and a sufficient amount of freshwater added. Using fine forceps, the stained matter was picked and placed into storage vials containing a mixture of alcohol and glycerol, at a ratio of either 70:30 or 80:20. Alcohol allows for short-term preservation and the glycerol reduces alcohol evaporation whilst hardening. During sorting, stained matter or organisms identified were placed into broad taxa, including polychaetes, molluscs and echinoderms (Eleftheriou & McIntyre, 2007; Rumohr, 2009).

Further identification of organisms was done to the species level using a stereomicroscope (Plate 3.3). Acceptable taxonomic keys such as Nicklès (1950), Fauchald (1977) and Barnes (1994), articles and manuals such as Tebble (1955), Rupert & Fox (1988), Branch & Branch (1998), Rouse & Pleijel (2001), Ardovini & Cossignani (2004) and Martin & Davis (2001) were used as guides.

Plate 3.3 - Macrobenthic identification using the stereomicroscope.

3.3.2 Sediment granulometry

Sediment samples were oven dried at 60 °C for 8 hours and 120 grammes (g) constant weight and analysed using the Philip Harris A20002 measuring balance in the Marine and Fisheries Sciences Post-Graduate Laboratory. Clumped sediment samples were washed with a dispersing reagent (1 % $NaOH_{(aq.)}$) in a 63-micron (μm) mesh sieve. The retained sediment was oven dried at 60 °C for 6 hours, to constant weight. Differences in the weight represented the silt-clay fraction of the sediment. 100 g of the dried sediment was weighed and sieved through stacked sieves using the Octagon D200 Digital Sieve Shaker. The stacked sieves were arranged following a decreasing geometric scale, from 1 mm, 0.5 mm, 0.355 mm, 0.125 mm, 0.063 mm and the receiver. These sieve mesh sizes retain sediment representing very coarse, coarse, medium and fine sand respectively, the silt and clay fraction of the sediment are retained in the retainer. The weight of retained sediment on each sieve was determined with the Philip Harris A20002 measuring balance and recorded to the nearest 0.01 g. Using the Wentworth scale (Gray & Elliot, 2009; Blott & Pye, 2001) the obtained sediment grain sizes were classed.

3.4 Diversity Indices

Diversity indices which serves as an indication of community health on spatial and temporal scales can be measured using several indices (Magurran, 2004). However, diversity indices including Margalef's species richness, Pielou's evenness index, Shannon-Weiner and Simpson's diversity index were applied in this study.

3.4.1 Margalef's species richness (d)

Species richness which refers to the total number of different species present (without taking into account the proportion and distribution of each species) within the sample. Margalef index (Margalef, 1958) is represented by the equation:

$$d = \frac{(S - 1)}{lnN}$$

where S = the total number of species, and

N = the total number of individuals in the sample.

3.4.2 Pielou's evenness (J')

Pielou (1966, 1969) used the ratio of expected number of species against the recorded number of species as an index of evenness, with the assumption that all species were accounted for in the sample. This aids in qualifying organism distribution among sampled assemblages. The higher the attained value, the more evenly individuals are spread among the species. Species evenness is dependent on species richness and species diversity. The evenness measure is a ratio of the observed diversity to the maximum possible in a sample having the same number of species. The equation used was:

$$J' = \frac{H'}{H'max} = \frac{H'}{\log S}$$

where H' = the Shannon-Wiener diversity index

S = the total number of species

3.4.3 Shannon-Wiener’s diversity index (H’)

The Shannon-Wiener diversity index (also referred to as the Shannon diversity), characterises the state of an assemblage per the species richness and species abundance. It assumes all species are represented in the sample and that individuals are randomly sampled from an independently large population. The community diversity is defined by the obtained value; 0 to 1.5 for poor, 1.5 to 2.5 for moderate and > 2.5 for highly diverse. The Shannon-Wiener diversity value often falls between 1.5 and 3.5 but can exceed 4. The index increases as the community richness and evenness increases (Magurran, 2004). The equation used is:

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

where pi = the proportion of individuals found in species i

ln = natural logarithm

s = the total number of species

3.4.4 Simpson’s diversity index (D)

Simpson (1949) introduced this measure to determine the degree of concentration when species are classed. Values of Simpson’s diversity index range from 0 to 1, where 0 represents no diversity and 1 represents infinite diversity. The index is directly related to species evenness and richness. The Simpson index gives more weight to common or dominant species, therefore, a few rare species with only a few representatives will not affect the diversity.

The equation used to measure it was:

$$D = \sum \left(\frac{n(n-1)}{N(N-1)} \right)$$

where n = the total number of organisms of a particular species

N = the total number of organisms of all species

D is a measure of dominance, so as D increases, diversity (in the sense of evenness) decreases. Thus, Simpson's index is usually reported as its complement 1-D. This provides an intuitive proportional measure of diversity that is much less sensitive to species richness.

3.5 Sediment Granulometry Assessment

An essential property of sediment particle transport and deposition is the grain size (Blott & Pye, 2001), because it allows the determination of sediment nature of the ecosystems at the sampled stations (Gray & Elliot, 2009). Sediment was classed using modified scales from Udden (1914) and Wentworth (1922).

3.6 Statistical analyses

Univariate analyses performed include species abundance, species relative abundance, frequency of occurrence (FOQ), relative FOQ and species diversity indices. Multivariate analyses primarily sought to determine variability between sampled species, families and their sampling locations.

A graphical representation of macrobenthic assemblage patterns using dendrograms was done, to reveal the relationship between the sampling sites.

SIMPER (Similarity Percentage) tests were performed for assessing which species contribute to the observed differences between and within sites.

Grain size distribution was analysed using the GRADISTAT program, a statistical package that runs in Microsoft Excel.

Statistical tools used in univariate and multivariate analyses were Microsoft Excel tool Pac and PRIMER (Plymouth Routines In Multivariate Ecological Research) version 6 respectively. Hypothesis testing was done using IBM SPSS (Statistical Package for the Social Sciences) Statistics version 23.

CHAPTER FOUR

4.0 RESULTS

Species found and identified within the samples taken include polychaetes, crustaceans, molluscs, echinoderms and sipunculids. Plate 4.1 shows some of these organisms.

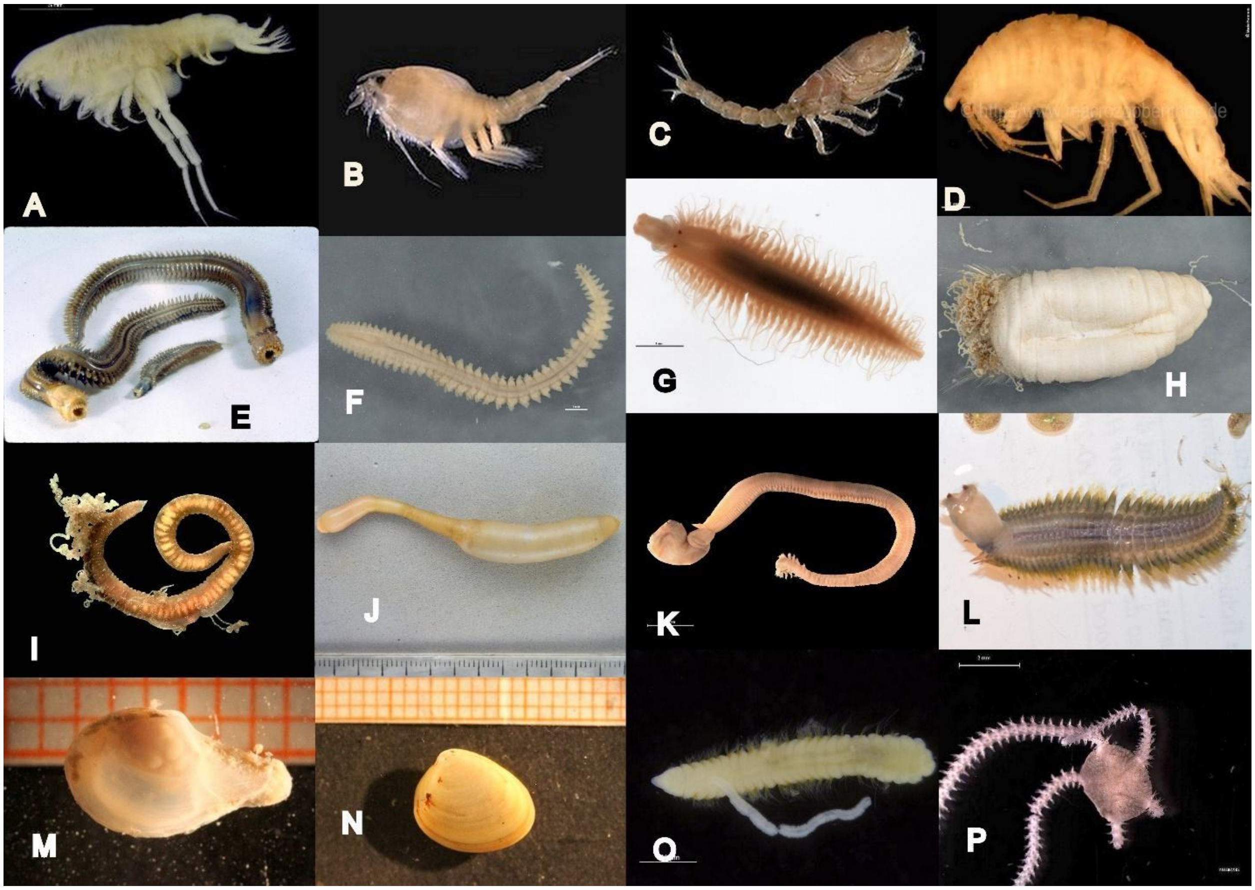

Plate 4.1 – Photo documentation of some macrobenthic fauna found at the study sites; (A) *Harpinia sp.* [Crustacea], (B) Phyllocarida [Crustacea], (C) Diastylidae [Crustacea], (D) Oedicerotidae [Crustacea], (E) Nepthyidae [Polychaeta], (F) Paralacydonidae [Polychaeta], (G) Hesionidae [Polychaeta], (I) Cirratulidae [Polychaeta], (J) Sipuncula, (K) Goniadidae [Polychaeta], (L) Polynoidae [Polychaeta], (M) Cuspidaria [Mollusca], (N) Nuculidae [Mollusca], (O) *Cossura sp*. [Polychaeta] and (P) *Amphiura sp*. [Echinodermata] (Photo credit: https://creativecommons.org/).

4.1 Macrobenthic Species Abundance and Relative Abundance

Table 4.1 - Abundance (No. of individuals) and relative abundance (%) of major macrobenthic faunal groups identified at the study sites.

TAXA	**EKUMFI ABOANO**			**JUBILEE FIELD**		
	No. of species	**Abundance (No. of individuals)**	**Relative Abundance (%)**	**No. of species**	**Abundance (No. of individuals)**	**Relative Abundance (%)**
POLYCHAETES	52	194	17.43	109	983	44.58
ARTHROPODA	53	827	74.30	47	696	31.56
MOLLUSCANS	6	35	3.14	22	229	10.39
ECHINODERMS	2	14	1.26	3	37	1.68
OTHERS	3	43	3.86	7	260	11.79
TOTAL	116	1113	100	188	2205	100

Table 4.2 - Densities (individuals/m^2) of major macrobenthic faunal groups.

LOCATION	**MAJOR TAXA**					**TOTAL**
	Polychaeta	**Crustacea**	**Mollusca**	**Echinodermata**	**Others**	
EKUMFI ABOANO (nearshore)	15	62	23	28	57	38
JUBILEE FIELDS (deep-sea)	36	59	42	29	157	47

Table 4.1 shows the diverse number of species encountered at Ekumfi and Jubilee. A total of 1113 individuals with an average density of 38 individuals/m^2 for the nearshore environment and 2205 individuals with an average density of 47 individuals/m^2, for the deep-sea environment. Obtained taxa from the analyses include polychaetes, crustaceans, molluscans and “others”. Species comprising of “others” included foraminiferans, nematodes, nemerteans and sipunculids.

Species numerical abundance for the nearshore environment showed polychaetes were 194, crustaceans were 827, molluscs were 35, echinoderms were 14 and others being 43. The average densities were 15, 62, 23, 28 and 57 respectively. The numerical abundance of species within the deep-sea environment showed polychaetes being 983, crustaceans as 696, molluscans as 229, echinoderms as 37 and others were 260. Their total densities were 36, 59, 42, 29 and 157 respectively (Table 4.2).

In respect to respective dominance orders, the taxa dominance for shallow Ekumfi seabed showed; crustaceans > polychaetes > molluscans > others > echinoderms, whereas taxa dominance for the offshore Jubilee seabed showed; polychaetes > crustaceans > molluscans > others > echinoderms.

4.2 Macrobenthic Species Richness and Diversity

Within the nearshore environment, Margalef’s index (d) was 15.68 and 0.88 for Pielou’s index (J’). The diversity was 4.13 and 0.98, for the Shannon-Weiner and Simpson index respectively.

In the deep-sea benthos, 24.16 was obtained for Margalef's index (d) and 0.88 for Pielou's index. Diversity indices, Shannon-Weiner's index at 4.43 and 0.98 for Simpson's index.

This shows species richness and diversity was greater in the deep-sea macrobenthos sampled. The significance in difference was tested through use of a Mann-Whitney test (Table 4.4).

Table 4.3 - Between-site species richness and diversity indices.

DIVERSITY INDICES	EKUMFI ABOANO	JUBILEE FIELDS
Margalef's index (d)	15.68	24.16
Pielou's index (J')	0.88	0.85
Shannon-Weiner index (H')	4.13	4.43
Simpson's index (1-D)	0.98	0.98

Table 4.4 - Significance test of difference between sampling sites.

α	0.05
P value	0.750

4.3 Cluster Analysis

A Bray-Curtis similarity cluster assessment between-site (Figure 4.1) and within-site (Figures 4.2 and 4.3) are displayed as dendrograms. Between-site similarity showed approximately 75 % dissimilarity. Within-site similarity for Ekumfi Aboano was averaged at 40 %. Approximately 35 % similarity was observed within-site for Jubilee Fields.

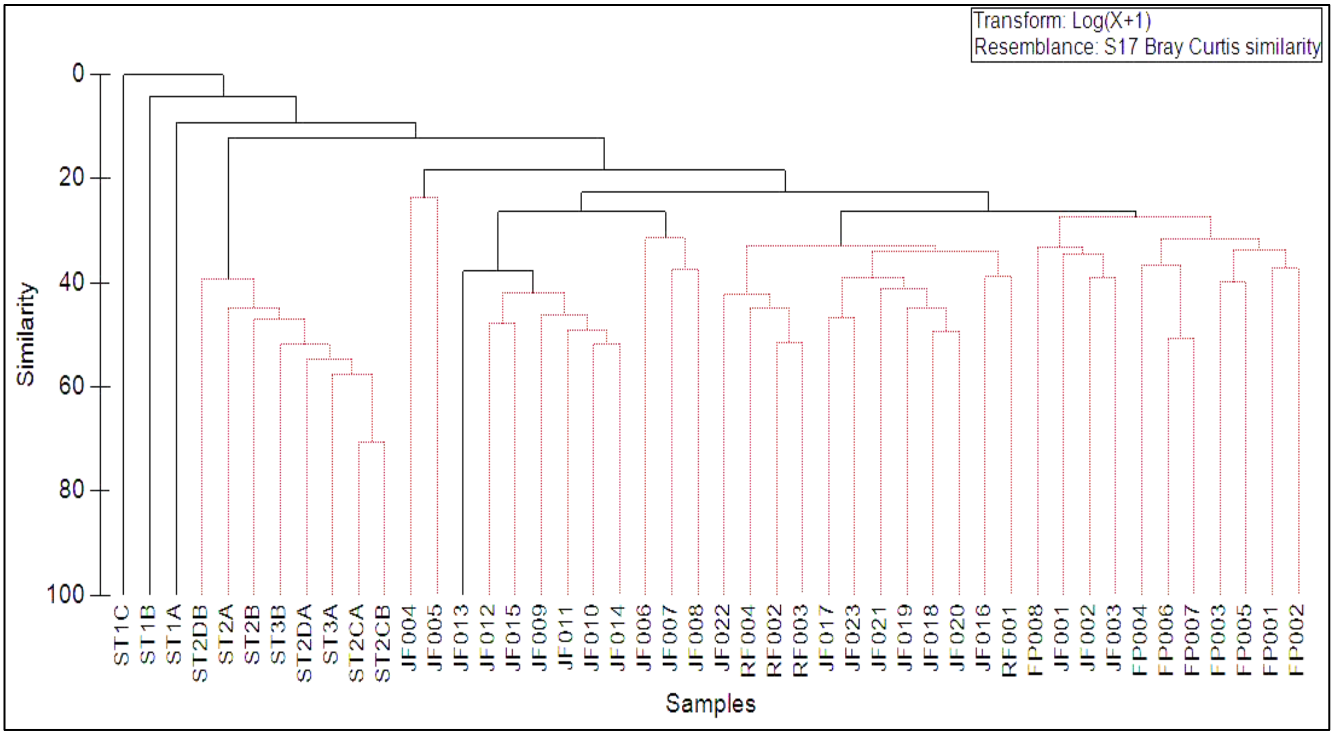

Figure 4.1- Significance test of difference between sampling sites.

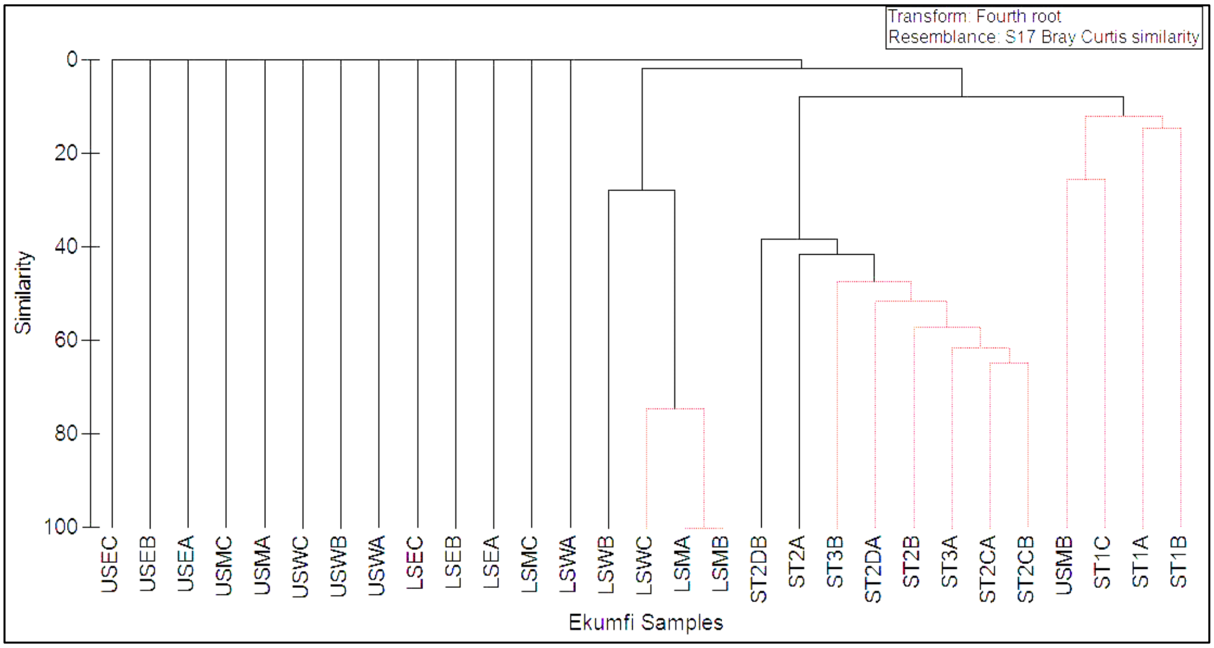

Figure 4.2 - Bray-Curtis similarity (%) dendrogram within Ekumfi sites.

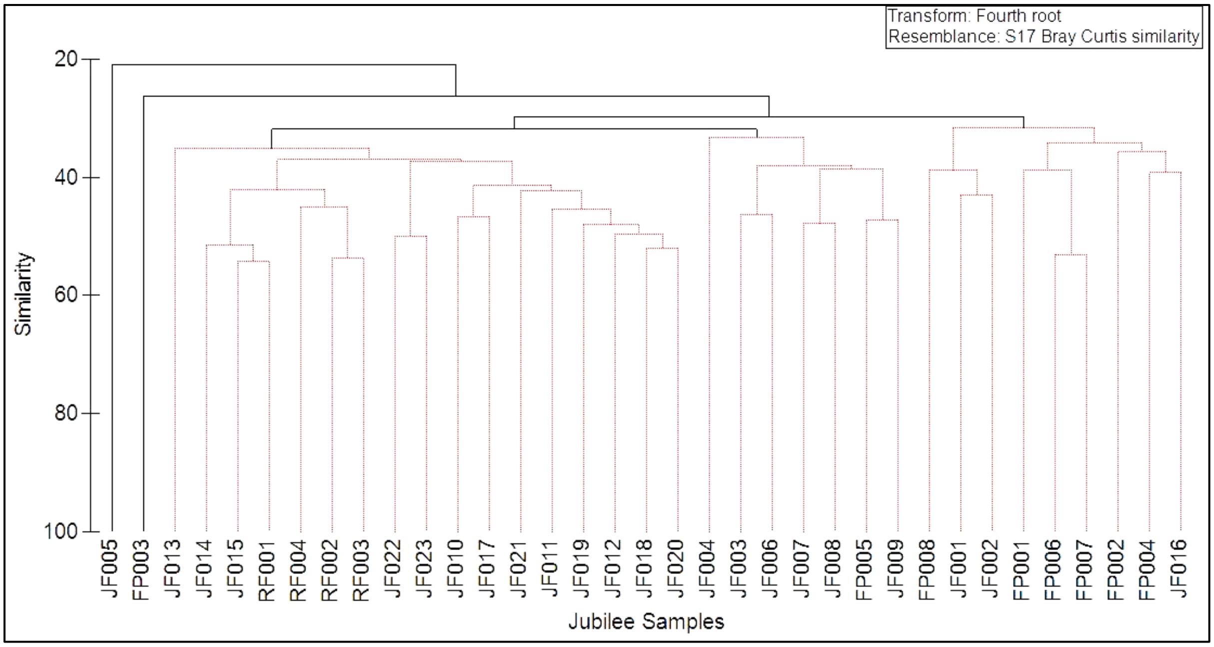

Figure 4.3 - Bray-Curtis similarity (%) dendrogram within Jubilee sites.

4.4 Sediment Characterization

Sediment grain size showed 'very fine sand' and well sorted at Ekumfi and 'very coarse silty fine sand' and poorly sorted at Jubilee (Table 4.5). Mean sediment grain sizes were found to be 99.80 µm and 109.79 µm, of the nearshore and offshore seabeds, respectively.

Table 4.5 - Summary of sediment grain size results for Ekumfi Aboano and Jubilee Fields.

	EKUMFI ABOANO	**JUBILEE FIELDS**
SIEVING ERROR:	3.9%	2.6%
SAMPLE TYPE:	Bimodal, Moderately Sorted	Trimodal, Poorly Sorted
SEDIMENT NAME:	Moderately Sorted Very Fine Sand	Very Coarse Silty Fine Sand

Correlation between abundance and grain size displayed a positive correlation (0.82) at Ekumfi and a negative correlation (-0.82) at Jubilee Fields (Table 4.6).

Table 4.6 - Correlation between abundance and sediment grain size.

EKUMFI ABOANO		
	Abundance	**Sediment Grain size**
Abundance	1	
Sediment Grain size	0.816	1
JUBILEE FIELDS		
	Abundance	**Sediment Grain size**
Abundance	1	
Sediment Grain size	-0.816	1

4.5 Species Frequency of Occurrence

Figures 4.4 and 4.5 show the dominant macrobenthic species found at Ekumfi Aboano and Jubilee Fields respectively, whereas Figures 4.6 and 4.7 show the dominant macrobenthic families found in Ekumfi Aboano and Jubilee Fields respectively.

The study of species frequency of occurrence (%) from Ekumfi showed nineteen (19) species of one hundred and sixteen (116) occurring most (> 20 %) (Fig. 4.4). The nineteen (19) dominant species comprised of arthropods (13 species), polychaetes (2 species), mollusc (1 species), echinoderm (1 species), nemertean (1 species) and nematode (1 species).

Fourteen (14) of the one hundred and eighty-eight (188) species from the Jubilee Fields occurred more frequently (> 50 %) (Fig. 4.5). Of these fourteen (14) species, six (6) were annelids (polychaetes), six (6) were arthropods (crustaceans), one (1) mollusc and one (1) nematode.

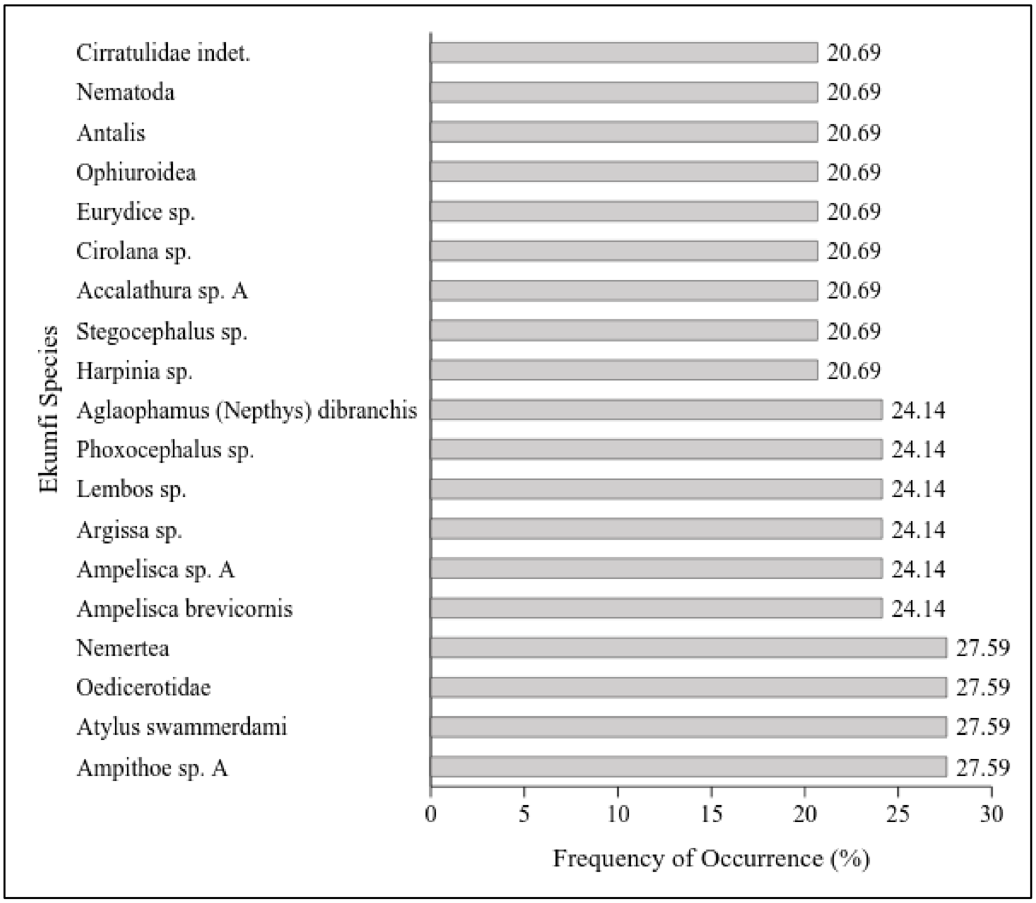

Figure 4.4 - Frequency of Occurrence for dominant (> 20 %) macrobenthic species in Ekumfi Aboano.

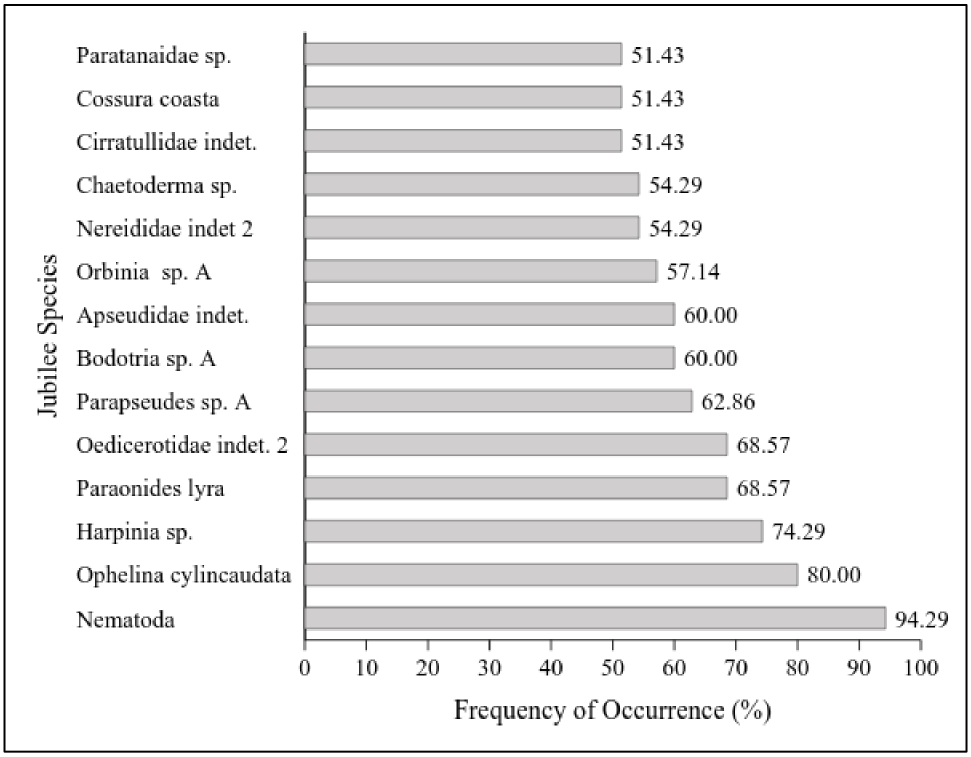

Figure 4.5 - Frequency of Occurrence for dominant (> 50 %) macrobenthic species in Jubilee Fields.

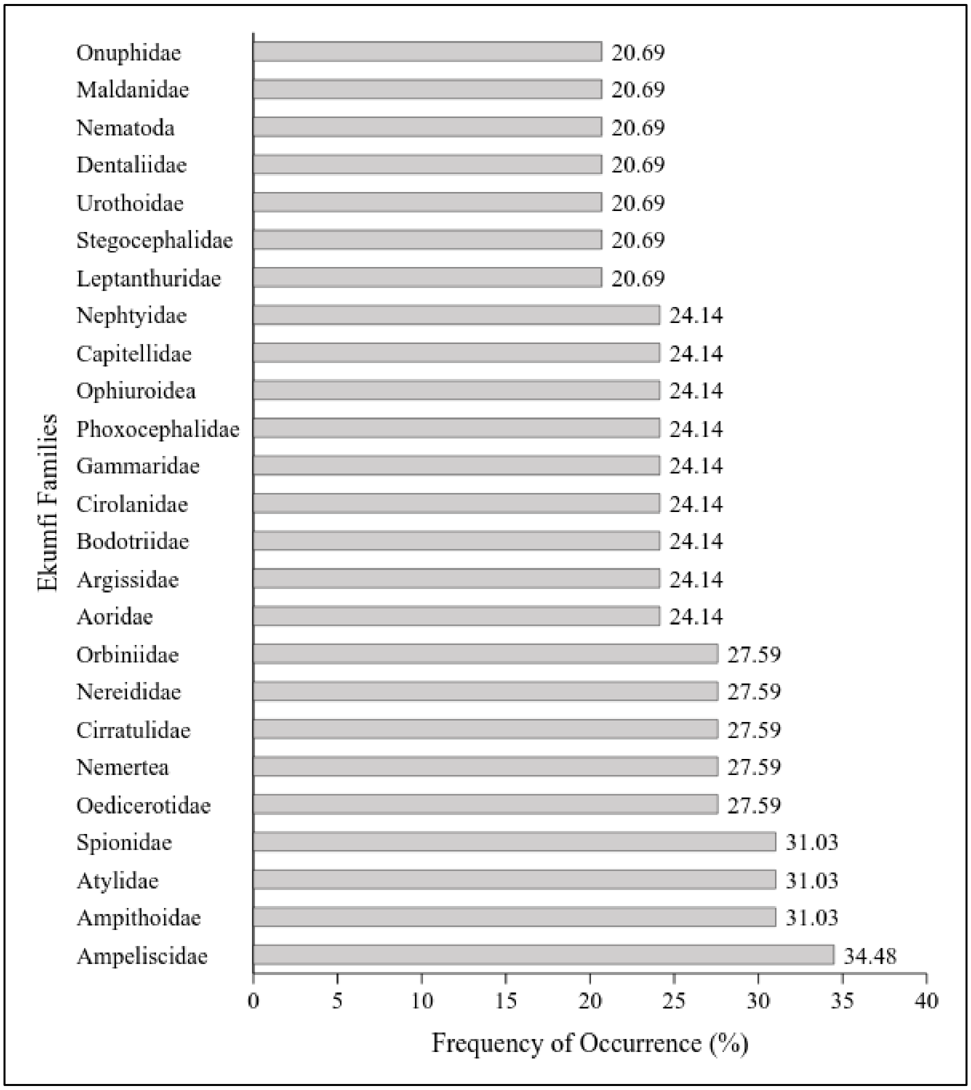

Figure 4.6 - Frequency of Occurrence for dominant (> 20 %) macrobenthic families in Ekumfi Aboano.

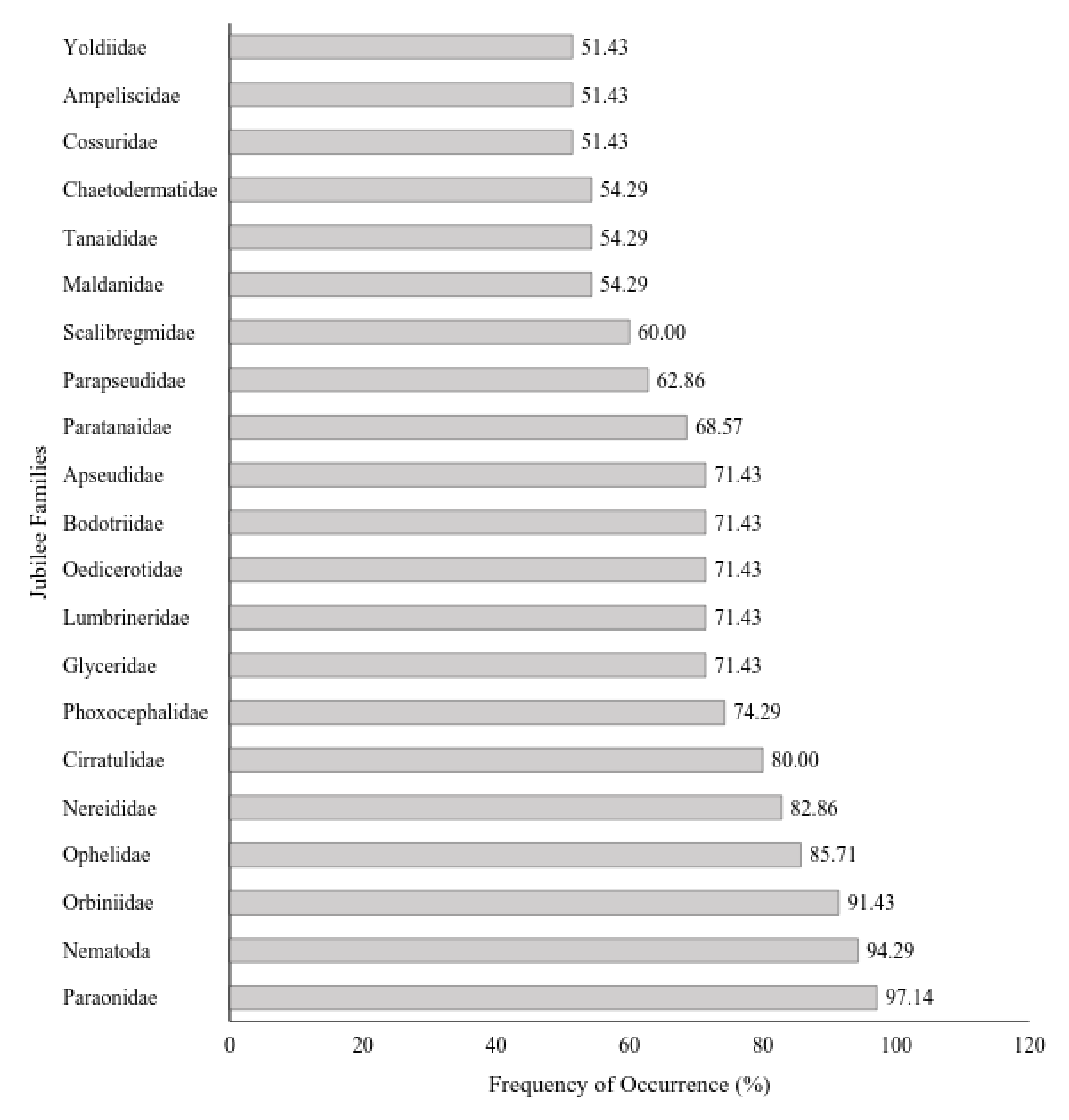

Figure 4.7- Frequency of Occurrence for dominant (> 50 %) macrobenthic families in Jubilee Fields.

4.6 Similarity Percentage (SIMPER)

The percentage contribution of species to the obtained sample between and within sites was assessed (Tables 4.7 – 4.11). Samples from Ekumfi had 11 species contributing to 70.3 % of the community structure which attributed to an average similarity of 5.68 %. Twenty-four species contributed to 70.4 % of the community structure and an average similarity of 28.41 % in the Jubilee Samples. Between the Ekumfi and Jubilee, 72 species contributed 70.3 % and an average dissimilarity of 95.52 % of the overall community structure.

Table 4.7 - SIMPER analyses for Ekumfi Aboano and the contributions of species to the average similarities.
(Organism taxa are indicated as such; A = Arthropoda, E = Echinodermata, M = Mollusca, O = Others, P = Polychaeta)

Ekumfi Sample - Average similarity: 5.68

Species	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib %**	**Cum.%**
Ampithoe sp. A (A)	0.38	0.63	0.32	11.07	11.07
Argissa sp. (A)	0.38	0.55	0.27	9.64	20.71
Lembos sp. (A)	0.36	0.48	0.28	8.4	29.11
Sipuncula indet. (O)	0.17	0.37	0.14	6.58	35.7
Harpinia sp. (A)	0.32	0.35	0.23	6.14	41.84
Stegocephalus sp. (A)	0.3	0.35	0.23	6.13	47.97
Nematoda (O)	0.25	0.32	0.22	5.55	53.52
Accalathura sp. A (A)	0.25	0.29	0.23	5.03	58.55
Cirratulidae indet. (P)	0.21	0.25	0.23	4.45	63
Atylus sp. (A)	0.25	0.21	0.19	3.7	66.7
Ampeliscidae indet. (A)	0.25	0.2	0.19	3.6	70.3

Table 4.8 - SIMPER analyses for Jubilee Fields and the contributions of species to the average similarities.

(Organism taxa are indicated as such; A = Arthropoda, E = Echinodermata, M = Mollusca, O = Others, P = Polychaeta)

Jubilee Sample - Average similarity: 28.41

Species	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib %**	**Cum. %**
Nematoda (O)	1.37	2.81	2.09	9.88	9.88
Ophelina cylincaudata (P)	1.08	1.69	1.2	5.96	15.84
Harpinia sp. (A)	0.94	1.51	1	5.31	21.15
Paraonides lyra (P)	0.83	1.32	0.86	4.65	25.81
Oedicerotidae indet. 2 (A)	0.77	1.18	0.86	4.14	29.95
Parapseudes sp. A (A)	0.79	1.07	0.75	3.77	33.72
Apseudidae indet. (A)	0.77	0.93	0.69	3.28	37.01
Bodotria sp. A (A)	0.67	0.84	0.7	2.96	39.97
Chaetoderma sp. (M)	0.67	0.77	0.61	2.71	42.68
Orbinia sp. A (P)	0.66	0.74	0.65	2.61	45.29
Nereididae indet 2 (P)	0.6	0.73	0.6	2.59	47.88
Paratanaidae sp. (A)	0.66	0.72	0.55	2.53	50.4
Nemertea indet. (O)	0.6	0.63	0.51	2.22	52.62
Cossura coasta (P)	0.56	0.61	0.56	2.14	54.76
Cirratulidae indet. (P)	0.56	0.59	0.57	2.08	56.84
Scalibregma inflatum (P)	0.51	0.49	0.52	1.71	58.55
Sipuncula indet. (O)	0.52	0.48	0.47	1.68	60.22
Cuspidaria sp. A (M)	0.53	0.47	0.48	1.67	61.89
Ampelisca sp. (A)	0.5	0.46	0.44	1.63	63.53
Eulimidae sp. (M)	0.49	0.42	0.38	1.47	65
Paraonis gracilis (P)	0.45	0.41	0.45	1.45	66.44
Lumbrineris sp A (P)	0.44	0.39	0.42	1.36	67.81
Cirratulus africanus (P)	0.44	0.38	0.41	1.35	69.16
Calanus sp. (A)	0.44	0.35	0.38	1.24	70.4

Table 4.9 - SIMPER analyses for Jubilee Fields and the contributions of species to the average similarities (Pg 48–50).
(Organism taxa are indicated as such; A = Arthropoda, E = Echinodermata, M = Mollusca, O = Others, P = Polychaeta)

Ekumfi and Jubilee Samples - Average dissimilarity = 95.52

Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib %**	**Cum. %**
Nematoda (O)	0.25	1.37	2.8	1.61	2.94	2.94
Ophelina cylincaudata (P)	0	1.08	2.32	1.55	2.43	5.37
Harpinia sp. (A)	0.32	0.94	2.07	1.25	2.17	7.54
Paraonides lyra (P)	0	0.83	1.99	1.19	2.08	9.62
Parapseudes sp. A (A)	0.03	0.79	1.79	1.1	1.88	11.49
Oedicerotidae indet. 2 (A)	0	0.77	1.79	1.19	1.88	13.37
Apseudidae indet. (A)	0	0.77	1.67	1.06	1.74	15.11
Paratanaidae sp. (A)	0	0.66	1.47	0.89	1.54	16.66
Chaetoderma sp. (M)	0	0.67	1.46	0.97	1.53	18.19
Bodotria sp. A (A)	0.19	0.67	1.43	1.03	1.49	19.68
Nereididae indet 2 (P)	0	0.6	1.41	0.96	1.47	21.15
Nemertea indet. (O)	0	0.6	1.4	0.85	1.46	22.61
Orbinia sp. A (P)	0	0.66	1.39	0.97	1.45	24.07
Cossura coasta (P)	0	0.56	1.22	0.91	1.28	25.35
Eulimidae sp. (M)	0	0.49	1.21	0.7	1.27	26.61
Cirratulidae indet. (P)	0.21	0.56	1.19	0.94	1.24	27.86
Sipuncula indet. (O)	0.17	0.52	1.18	0.83	1.23	29.09
Ampelisca sp. (A)	0	0.5	1.15	0.78	1.21	30.3
Cuspidaria sp. A	0	0.53	1.1	0.82	1.15	31.45
Iphinoe sp. A (A)	0.16	0.39	1.07	0.71	1.12	32.57
Scalibregma inflatum (P)	0.03	0.51	1.03	0.86	1.08	33.65
Calanus sp. (A)	0	0.44	1.03	0.71	1.08	34.72
Glyceridae indet. (P)	0.14	0.4	1.01	0.74	1.06	35.78
Cirratulus africanus (P)	0	0.44	1.01	0.74	1.05	36.83
Lumbrineris sp A (P)	0	0.44	1	0.77	1.04	37.88

Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib %**	**Cum. %**
Paraonis gracilis (P)	0	0.45	0.99	0.77	1.04	38.91
Lembos sp. (A)	0.36	0.25	0.98	0.74	1.02	39.94
Orbiniidae indet. 1 (P)	0.1	0.36	0.95	0.64	1	40.94
Nereididae indet. 1 (P)	0.14	0.39	0.95	0.74	0.99	41.93
Bivalve indet. (M)	0	0.42	0.94	0.68	0.98	42.91
Maldanidae indet. 1	0	0.4	0.93	0.65	0.98	43.89
Spionidae indet. (P)	0	0.37	0.93	0.62	0.97	44.86
Lumbrineris aberrans (P)	0.07	0.37	0.92	0.68	0.96	45.83
Atylus sp. (A)	0.25	0.25	0.87	0.68	0.91	46.73
Argissa sp. (A)	0.38	0.12	0.86	0.63	0.9	47.63
Joreopsis sp. (A)	0	0.36	0.83	0.63	0.87	48.5
Nephtys sp. A (P)	0	0.43	0.82	0.71	0.86	49.36
Polyphysia crassa (P)	0	0.36	0.79	0.66	0.83	50.19
Aricidea cf. jeffreysi (P)	0	0.33	0.78	0.6	0.81	51
Ampithoe sp. A (A)	0.38	0.06	0.72	0.63	0.76	51.76
Glycera s p. A (P)	0	0.32	0.72	0.6	0.76	52.52
Amphipod indet. (A)	0.14	0.24	0.71	0.56	0.75	53.26
Accalathura sp. A (A)	0.25	0.16	0.71	0.61	0.74	54.01
Tellina sp. A (M)	0.1	0.26	0.7	0.6	0.73	54.74
Prionospio sp. A (P)	0	0.29	0.67	0.53	0.7	55.44
Ananthura sp. A (A)	0.16	0.24	0.63	0.59	0.66	56.1
Yoldiella sp. A (M)	0	0.3	0.63	0.52	0.66	56.76
Paraonides lyra lyra (P)	0	0.28	0.63	0.55	0.66	57.42
Asteroidea sp. A (E)	0	0.25	0.61	0.49	0.64	58.06
Pseudoparatanais sp. (A)	0.03	0.21	0.61	0.45	0.64	58.69
Ostracoda indet. (A)	0	0.25	0.6	0.53	0.63	59.33
Armandia intermedia (P)	0	0.34	0.6	0.61	0.63	59.96
Paraonidae indet. 2 (P)	0	0.27	0.58	0.55	0.61	60.56

Species	**Av. Abund**	**Av. Abund**	**Av. Diss**	**Diss/SD**	**Contrib %**	**Cum. %**
Tanaidae sp. A (A)	0	0.27	0.58	0.51	0.61	61.17
Gastropod indet. (M)	0.08	0.21	0.58	0.52	0.6	61.77
Ampeliscidae indet. (A)	0.25	0.09	0.57	0.54	0.6	62.37
Lumbrineris latreilli (P)	0.04	0.28	0.55	0.58	0.58	62.95
Sea urchin juvenile (E)	0	0.23	0.55	0.5	0.58	63.52
Stegocephalus sp. (A)	0.3	0.03	0.55	0.52	0.57	64.09
Tanaidacea indet. (A)	0	0.24	0.5	0.5	0.52	64.62
Oedicerotidae (A)	0	0.38	0.49	0.54	0.52	65.13
Atylus swammerdami (A)	0	0.36	0.48	0.53	0.5	65.63
Nemertea (O)	0	0.29	0.47	0.51	0.49	66.12
Cirrophorus branchiatus (P)	0	0.18	0.46	0.44	0.49	66.61
Polyopthalamus pictus (P)	0	0.19	0.46	0.43	0.48	67.09
Ophiuroidea indet. (E)	0.03	0.18	0.46	0.43	0.48	67.57
Phtisica marina (A)	0.24	0.03	0.45	0.46	0.48	68.05
Nephtys sp. B (P)	0	0.2	0.45	0.44	0.47	68.52
Ampelisca sp. A (A)	0	0.27	0.44	0.48	0.46	68.97
Paraonis gracilis (P)	0	0.18	0.43	0.38	0.45	69.43
Tanaidacea sp. A (A)	0.08	0.15	0.43	0.41	0.45	69.87
Sternaspis scutata (P)	0	0.24	0.43	0.47	0.45	70.32

Table 4.10 - SIMPER analyses for Ekumfi Aboano and the contributions of macrobenthic families to the average similarities.
(Organism taxa are indicated as such; A = Arthropoda, E = Echinodermata, M = Mollusca, O = Others, P = Polychaeta)

Ekumfi Sample - Average similarity: 8.58

Families	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib %**	**Cum. %**
Pisionidae (P)	0.17	1.06	0.12	12.34	12.34
Ampeliscidae (A)	0.54	0.55	0.38	6.37	18.71
Nemertea (O)	0.35	0.47	0.23	5.47	24.18
Atylidae (A)	0.52	0.43	0.34	5.07	29.25
Spionidae (P)	0.42	0.39	0.32	4.56	33.81
Ampithoidae (A)	0.45	0.38	0.35	4.39	38.2
Oedicerotidae (A)	0.5	0.34	0.3	3.92	42.12
Orbiniidae (P)	0.34	0.33	0.28	3.81	45.93
Phoxocephalidae(A)	0.43	0.24	0.26	2.75	48.68
Nereididae (P)	0.35	0.23	0.3	2.73	51.41
Argissidae (A)	0.38	0.23	0.26	2.71	54.13
Gammaridae (A)	0.38	0.21	0.26	2.5	56.63
Aoridae (P)	0.37	0.21	0.26	2.46	59.09
Cirratulidae (P)	0.29	0.21	0.3	2.44	61.53
Capitellidae (P)	0.25	0.2	0.25	2.29	63.82
Mellitidae (A)	0.24	0.19	0.15	2.27	66.09
Nephtyidae (P)	0.31	0.19	0.26	2.22	68.3

Table 4.11 - SIMPER analyses for Ekumfi Aboano and the contributions of macrobenthic families to the average similarities.
(Organism taxa are indicated as such; A = Arthropoda, E = Echinodermata, M = Mollusca, O = Others, P = Polychaeta)

Jubilee Sample - Average similarity: 50.37

Families	**Av. Abund**	**Av. Sim**	**Sim/SD**	**Contrib %**	**Cum. %**
Paraonidae (P)	1.39	4.21	3.06	8.37	8.37
Nematoda (O)	1.37	4	2.38	7.93	16.3
Orbiniidae (P)	1.15	3.32	1.97	6.59	22.89
Opheliidae (P)	1.24	3.13	1.56	6.22	29.11
Nereididae (P)	1.01	2.57	1.4	5.11	34.22
Cirratulidae (P)	0.99	2.45	1.27	4.87	39.09
Phoxocephalidae (A)	0.95	2.15	1.06	4.28	43.37
Apseudidae (A)	0.91	1.97	0.98	3.91	47.28
Paratanaidae (A)	0.87	1.87	0.89	3.72	51
Bodotriidae (A)	0.85	1.87	0.97	3.72	54.72
Oedicerotidae (A)	0.82	1.85	0.98	3.67	58.39
Glyceridae (P)	0.83	1.84	0.98	3.66	62.05
Lumbrineridae (P)	0.83	1.83	0.98	3.63	65.68
Parapseudidae (A)	0.81	1.58	0.78	3.14	68.83

CHAPTER FIVE

5.0 DISCUSSION

In relation to densities (Table 4.2), an ideal situation will be the expectation of 38 organisms within every square meter in the Ekumfi Aboano seabed and 47 organisms within the Jubilee Fields seabed. However, due to benthic species patchiness, this is not to realised.

In Jubilee (H’ = 24.16; 2205 individuals), species macrobenthic assemblage richness was higher than Ekumfi (H’ = 15.68; 1113 individuals). This can be accredited to the number of samples taken, that is, species richness has a direct relation with sample size, as well as the scale and level of perturbation (Magurran, 2004). Species evenness was 0.9 in both instances. This indicates a fairly spread of species in both sampling sites which may be attributed to macrobenthos patchiness, predation and underwater current, tidal or wave activity (Macdonald *et al.*, 2012). Diversity or variety of taxa within sites is an indication of the ecosystem ability to support varied taxa and the community structure strength (Erftemeijer *et al.*, 2012) (Table 4.3).

The overall abundance of nematodes in the study shows that both regions had substantial quantities of detritus, bacteria and fungi. Leading to the general abundance and greater frequency of occurrence of nematodes (Table 4.6) in both sampling locations. Varying ratios over a regular time scale can indicate if the food web is disturbed, maturing, structured or degraded (Krumins, 2013).

Correlation between abundance and grain size displayed a strong positive trend (0.82) at the nearshore environment and a strong negative trend (-0.82) at the deep-water environment. Sediment composition (including sediment grain size) is affected by species activity (bioturbation, organic matter presence and feeding modes of organisms), species numbers, species kinds, species sizes (Wahl, 2009; Mermillod-Blondin *et al.,* 2005). Some studies suggest no close relationship (Seiderer & Newell, 1999) and others, little correspondence (Arrighetti & Penchaszadeh, 2010) between benthic communities and sediment composition. From the study, mean sediment grain size increase led to a reduction in deep-water macrobenthos abundance and a relative increase in the nearshore macrobenthos abundance. Transport of inland sediment to nearshore has a tendency to alter the sediment characteristics of the nearshore seabed (Logan, 2007).

An 82 % dissimilarity between the nearshore and deep-water macrobenthic assemblages was indicated in the cluster analysis of this study. Such dissimilarities are due to natural and anthropogenic influences including but not limited to sediment nature, pressure differences, temperature variations, competition for food and space trawling and anchorages. Food supply or availability controls marine benthic community structure, as current speeds influence sediment composition and food supply (Wieking & Kroncke, 2005).

Sediment distribution within deep-sea and nearshore regions vary, as they influence macrobenthic fauna distribution and abundance. Depth influences sediment nature (Allotey, 2010) and can determine macrobenthic fauna structure. The deep-sea was characterised as having sediment which was finer than the characterised sediment from the nearshore. Variations in sediment nature is attributable to differences in hydrodynamic regimes (wind velocity and direction, current and tidal motions) influence weather patterns, physicochemical or biochemical processes and species biological activities (Open University, 2002).

In Ekumfi Aboano (nearshore), the Bray-Curtis similarity test showed about 90 % dissimilarity between sampled sites. The dominant families (> 20%) occurring frequently were arthropods (14 families) and polychaetes (8 families). Within Jubilee Fields (deep-sea), Bray-Curtis similarity was about 70 % dissimilarity for Jubilee Fields. Most occurring (> 50 %) dominant families were polychaetes (10 families) and arthropods (8 families). The nearshore environment which constituted mainly very fine sand, was dominated by arthropods than polychaetes and in the deep-sea of silty fine sand, polychaetes were more abundant than arthropods, as also observed by Patel & Desai (2009).

Comparison of contributing species and families to the respective community structure was determined by use of SIMPER test on species and family level (Table 4.7 – 4.11). Within the nearshore seabed, the polychaete family Pisionidae and crustacean family Ampeliscidae contributed 18.71 % to the macrobenthic community structure. Pisionids are active burrowers with a high affinity for soft, silty bottoms and often found within interstitial groups, whereas Ampeliscids are tube dwellers found within fine sand and mud. Both families are cosmopolitan and survive within shallow to deep waters. In Jubilee, the greatest contributors to the community structure were polychaete families (Paraonidae [8.37 %], Orbiniidae [6.59 %], Opheliidae [6.22 %], Nereididae [5.11 %], Cirratulidae [4.87 %]) and nematodes [7.93 %]. These polychaete families were found to be burrowers with a high preference for sandy mud sediment nature (Rouse & Pleijel, 2001; Day,1967). The species obtained were cosmopolitan and characteristic of the sediment nature, similar to observations made by Gray & Elliot (2009).

Crustacean species (including *Ampithoe* sp. [11.07 %], *Argissa* sp. [9.64 %] and *Lembos* sp. [8.4]) contributed most to the Ekumfi macrobenthic community structure. This follows crustacean dominance within sandy environments, especially nearshore similar to that observed by Gray (2002). Nematodes, *Ophelina cylincaudata* and *Harpinia* sp. contributed 21.15 % to the community abundance and structure. Of these species, nematodes outnumber the other species due to their free-living or parasitic state, especially in an oxygen reduced and organic enriched environment (Abbott & Murphy, 2003). The average dissimilarity between Ekumfi and Jubilee was 95.52 %, validating the significant difference ($p = 0.05$) between the nearshore and deep-sea macrobenthic infauna.

The current macrobenthic assemblage structure of the Jubilee Field, which was sampled in 2015, showed polychaetes (44.58 %) and arthropods (31.56 %) accounting for 76.14 % of the community structure. Within the Jubilee Field, a highly diverse polychaete structure (109 species) was encountered. It was discovered that there is a greater propensity to find an arthropod (59 individuals/m^2) or mollusc (42 individuals/m^2) within a square meter than a polychaete (36 individuals/m^2), which was not anticipated. No exotic or invasive species was found during this study. The sediment is characterised as very coarse silty fine sand, which is heterogenous and typical of areas having low wave or current activity, experienced in deep-sea ecosystems (Gray & Elliot, 2009; Cartes *et al.*, 2002). The abundance of organisms can be attributed to the region being fluxed by the exploration activities.

Ekumfi Aboano on the other hand, displayed low numbers in taxa spread as polychaetes and arthropods contributed to 105 species (92 % abundance) in the 116 species obtained. Of these, arthropods contributed more than half of the overall abundance with a density of

62 individuals/m^2. With the high energy experienced in the region from waves and current activity, the prevailing sediment nature was found to be well sorted and having a homogenous sediment mix of grain sizes, possibly influenced by terrestrial run-off from inland waters, aeolian deposition or weather activities.

CHAPTER SIX

6.0 CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

The study discovered that deep-seabed sediment from Jubilee Fields (silty fine sand) recorded more polychaetes than arthropods, whereas in the nearshore seabed sediment from Ekumfi Aboano (very fine sand) held more arthropods than polychaetes.

The relationship between depth (nearshore and deep-sea), sediment and macrobenthic fauna, shows that increasing depth provides finer sediment with more macrobenthic species.

Macrobenthic community structure in the nearshore seabed (Ekumfi Aboano) and the offshore seabed (Jubilee Fields) are not significantly different.

From the Jubilee Field, this study revealed that:

- 76.14 % of the community structure, composed of polychaetes (44.58 %) and crustaceans (31.56 %) dominated the macrobenthic fauna.
- the macrobenthic fauna were evenly distributed (0.85) and highly diverse (H' – 4.43; 1-D – 0.98).
- taxa dominance order was: polychaetes > crustaceans > molluscans > others > echinoderms.

This study further revealed Ekumfi Aboano to have:

- a highly diverse (H' – 4.13; 1-D – 0.98) and evenly (0.88) distributed macrobenthic community.
- majority (91.73 %) of the macrobenthic fauna abundance as polychaetes (17.43 %), with crustaceans (74.30 %) dominating.
- taxa dominance order was: crustaceans > polychaetes > molluscans > others > echinoderms.

6.2 Recommendations

It is recommended that studies on macrobenthic relationships between-sites or within-sites should consider investigating the influence of more environmental factors (including but not limited to nutrient, heavy metal or organics concentration).

Scales over which macrobenthic assemblage relationships are analysed between-site and within sites should be increased or well-structured for accurate estimations and predictions. Possibly over defined and regular temporal and wider spatial scales.

The size-frequency distribution of macrobenthos should be examined to establish seasonal growth cycles or rates since it affects biological productivity and fisheries by extension.

The Centre for Productivity and Biodiversity assessment in the Guinea Current Large Marine Ecosystem (GCLME) should have a national macrobenthic database for further research into benthic assemblage influence on productivities, nearshore and offshore.

The exposure of macrobenthos to pollutants should be investigated to determine macrobenthic susceptibility to anthropogenic stress (habitat modification and pollution).

Finally, an assessment after the harbour construction and other facilities are completed at Ekumfi Aboano should be undertaken to establish the level of project-induced impacts.

7.0 REFERENCES

Abbott, L. & Murphy, D. (2003). *Soil biological fertility: A key to sustainable land use in agriculture*. Netherlands: Springer. http://www.dx.doi.org/10.1007/978-1-4020-6619-1_1

Afli, A., Ayari, R. & Brahim, M. (2008). Trophic organization of the macro-zoobenthic assemblages within coastal areas subjected to anthropogenic activities. *Journal of the Marine Biological Association of the UK*, *88*(4), 663–674. https://doi.org/10.1017/S0025315408001318

Akindele, E. O. & Olutona, G. O. (2015). Environmental variables and benthic macroinvertebrate assemblage in the headwater streams of an Afro-tropical reservoir. *Water and Environment Journal*, *29*(4), 541–548. https://doi.org/10.1111/wej.12117

Albayrak, S., Balkis, H., Zenetos, A., Kurun, A. & Kubanç, C. (2006). Ecological quality status of coastal benthic ecosystems in the Sea of Marmara. *Marine Pollution Bulletin*, 52(7), 790-799.

Allotey, L. C. (2010). *Spatial assemblages of macrobenthic fauna off the continental shelf of Ghana*. MPhil. thesis. University of Ghana

Anbuchezhian, R. M., Ravichandran, S., Rameshkumar, G. & Ajithkumar, T. T. (2009). Influence of crab haemolymph on clinical pathogens. *International Journal of Advanced Biological Research*, *3*(3–4), 104–109.

Ardovini, R. & Cossignani, T. (2004). *West African Seashells*. Ancona: L'Informatore

Piceno.

Arrighetti, P. & Penchaszedeh, P. E. (2010). Macrobenthos– sediment relationships in a sandy bottom community off Mar del Plata, Argentina. *Journal of the Marine Biological Association of the United Kingdom, 90*(5), 933–939. Retrieved from https://doi.org/10.1017/S0025315409991524

(ATFALCO) The Ministerial Conference on Fisheries Cooperation among African States Bordering the Atlantic Ocean (2012). Fishery and aquaculture industry in Ghana. Series Report n°1 of the Review of the fishery and aquaculture industry in the 22 ATLAFCO Member States. 51 pp.

Bacci, T., Trabucco, B., Marzialetti, S., Marusso, V., Lomiri, S., Vani, D. & Lamberti, C. V. (2009). Taxonomic sufficiency in two case studies: Where does it work better? *Marine Ecology*, *30*(SUPPL.1), 13–19. https://doi.org/10.1111/j.1439-0485.2009.00324.x

Baranov, V., Lewandowski, J., Krause, S., Roskosch, A., Hette, N., Hupfer, M. & Kleeberg, A. (2016). Bioturbation enhances the aerobic respiration of lake sediments in warming lakes. *Biology Letters*, *12*(8), 269–281. https://doi.org/10.1098/rsbl.2016.0448

Barnes, R. S. K. (1994). *The Brackish-Water Fauna of Northwestern Europe: A Guide to Brackish-Water Habitats, Ecology and Macrofauna for Field Workers, Naturalists, and Scientists*. Cambridge, UK: Cambridge University Press.

Basset, Y., Mavoungou, J., Mikissa, J., Missa, O., Miller, S. E., Kitching, R. L. & Alonso, A. (2004). Discriminatory power of different arthropod data sets for the biological monitoring of anthropogenic disturbance in tropical forests. *Biodiversity Conservation, 13*, 709-732.

Batchelder, T. (2001). Natural products from the sea: Ethnopharmacology, nutrition and conservation. *Townsend Letter for Doctors and Patients*, Feb, 2001. Retrieved from http://www.findarticles.com/p/articles/mi_m0ISW/is_2001_Feb/ai_70777319/pg_1.

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*. CSERGE, Norwich. Retrieved from http://www.ecoserve.ie/projects/cost-impact/datatool/management_manual.pdf

Bêche, L. A., McElravy, E. P. & Resh, V. H. (2006). Long-term seasonal variation in the biological traits of benthic-macroinvertebrates in two Mediterranean-climate streams in California, U.S.A. *Freshwater Biology, 51*(1), 56–75. https://doi.org/10.1111/j.1365-2427.2005.01473.x

Bergen, S. D., Bolton, S. M. & Fridley, J. M. (2001). Design Principles for Ecological Engineering. *Ecological Engineering*, *18*, 201–210.

Blanchard, A. L., Parris, C. L., Knowlton, A. L. & Wade, N. R. (2013). Benthic ecology of the northeastern Chukchi Sea . Part II . Spatial variation of megafaunal community structure , 2009 – 2010 $. *Continental Shelf Research*, *67*, 67–76.

https://doi.org/10.1016/j.csr.2013.04.031

Blott, S. J. & Pye, K. (2001). Technical Communication Gradistat : A Grain Size Distribution and Statistics Package for the Analysis of Unconsolidated Sediments, *Earth Surface Processes and Landforms, 26*(11), 1237–1248. https://doi.org/10.1002/esp.261

Borja, A., Josefson, A. B., Miles, A., Muxika, I., Olsgard, F., Phillips, G., Rodríguez, J. G. & Rygg, B. (2007). An approach to the intercalibration of benthic ecological status assessment in the North Atlantic ecoregion, according to the European Water Framework Directive. *Marine Pollution Bulletin, 55*, 42–52.

Borowski, C. (2001). Physically disturbed deep-sea macrofauna in the Peru Basin, S.E. Pacific, revisited seven years after the experimental impact. *Deep-Sea Res.* II, *48*, 3809-3840.

Branch, M. & Branch, A. (1998). *The Living Shores of Southern Africa*. Cape Town, South Afirca: Struik Publishers Ltd.

Bremner, J. (2005). *Assessing ecological functioning in marine benthic communities*. PhD thesis. University of Newcastle. http://hdl.handle.net/10443/153

Buchanan, J. B. (1957). The bottom fauna communities across the continental shelf off Accra, Ghana. *Proceedings of The Zoological Society of London, 130*, 1–56.

Bui, E. N., Mazullo, J. & Wilding, L.P. (1990). Using quartz grain size and shape analysis to distinguish between aeolian and fluvial deposits in the Dallol Bosso of Niger (West Africa). *Earth Surface Processes and Landforms, 14*, 157–166.

Bullis, K. (2012). *In the Developing World, Solar Is Cheaper than Fossil Fuels*. Retrieved from http://www.technologyreview.com/s/426718/in-the-developing-world-solar-is-cheaper-than-fossil-fuel/

Carcedo, M. C., Sandra M. Fiori, S. M., Piccolo, M. C., Abbate, M. C. L. & Bremec, C. S. (2015). Variations in macrobenthic community structure in relation to changing environmental conditions in sandy beaches of Argentina. *Estuarine, Coastal and Shelf Science,3*(5), 1–9. http://dx.doi.org/10.1016/j.ecss.2015.03.005

Cartes, J. E., Brey, T., Sorbe, J. C. & Maynou, F. (2002). Comparing production-biomass ratios of benthos and suprabenthos in macrofaunal marine crustaceans. *Canadian Journal of Fisheries and Aquatic Sciences, 59*(10), 1616-1625.

Clark, A. N. (1955). Echinodermata of the Gold Coast. *Journal of the West African Science Association*, *1*, 16–56.

Clarke, K. R. & Warwick, R. M. (2001). *Change in marine communities: an approach to statistical analysis and interpretation*. Second edition. Plymouth, UK: PRIMER-E Ltd.

Coates, D., van Hoey, G., Colson, L., Vincx, M. & Vanaverbeke, J. (2015). Rapid Macrobenthic Recovery after Dredging Activities in an Offshore Wind Farm in the Belgian Part of the North Sea. *Hydrobiologia*, *756*(1), 3–18.

Convention on Biological Diversity (CBD) (1992). Convention on Biological Diversity. http://www.cbd.int/

Cosel, R. V. (2006). Taxonomy of tropical West Africa bivalves. VI. Remarks on Lucinidae (Mollusc, Bivalvia), with description of six new genera and eight new species. *ZOOSYSTEMA*, *28*(4), 805–851.

Cunha, M. R., Paterson, G. L. J., Amaro, T., Blackbird, S., de Stigter, H. C., Ferreira, C. & Billett, D. S. M. (2011). Biodiversity of macrofaunal assemblages from three Portuguese submarine canyons (NE Atlantic). *Deep-Sea Research Part II: Topical Studies in Oceanography*, *58*(23–24), 2433–2447. https://doi.org/10.1016/j.dsr2.2011.04.007

Day, J. H. (1967). *A monograph on the polychaete of Southern Africa* Part-I and II, Trustees of The British Museum (Natural history) London. https://doi.org/10.1017/S0025315400019299

Dumay, O., Tari, P. S., Tomasini, J. A. & Mouillot, D. (2004) Functional groups of lagoon fish species in Languedoc Roussillon, southern France. *Journal of Fish Biolog*y, *64*, 970–983.

Eleftheriou, A., & McIntyre, A. (2007). *Methods for the Study of Marine Benthos: Third Edition*. *Methods for the Study of Marine Benthos*. Third Edition. Oxford, UK: Blackwell Publishers. https://doi.org/10.1002/9780470995129

Ellabban, O., Abu-Rub, H. & Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews*, *39*, 748–764. http://dx.doi.org/10.1016/j.rser.2014.07.113

Elliott, M., Burdon, D. & Hemingway, K. L. (2006). *Marine ecosystem structure, functioning, health and management and potential approaches to marine ecosystem recovery: a synthesis of current understanding*. Unpublished report YBB092-F-2006 for the Countryside Council of Wales by the Institute of Estuarine and Coastal Studies, University of Hull.

Erftemeijer, P. L. A., Riegl, B., Hoeksema, B. W. & Todd, P. A. (2012). Environmental impacts of dredging and other sediment disturbances on corals : A review. *Marine Pollution Bulletin*, *64*(9), 1737–1765. https://doi.org/10.1016/j.marpolbul.2012.05.008

Fabricius, K. E. & McCorry, D. (2006). Changes in octocoral communities and benthic cover along a water quality gradient in the reefs of Hong Kong. *Marine Pollution Bulletin*, *2*, 22–33.

Fauchald, K. (1977). The polychaete worms: definitions and keys to the orders, families and genera. *Natural History Museum, Los Angeles, CA (USA), Science Series*, *28*, 1–190.

Fisher, C., Roberts, H., Cordes, E. & Bernard, B. (2007). Cold seeps and associated communities of the Gulf of Mexico. *Oceanography*, *20*, 118–129. Available online at http://www.tos.org/oceanography/issues/issue_archive/20_4.html

Food and Agriculture Organization (FAO-FIGIS) (2007). *Squalus acanthias*. In: A world overview of species of interest to fisheries. SIDP-Species Identification and Data Programme. FIGIS Species Fact Sheets. www.fao.org/fi

Frid, C. L. J., Paramor, O. A. L., Brockington, S. & Bremner, J. (2008). Incorporating ecological functioning into the designation and management of marine protected areas. *Hydrobiologia*, *606*(1), 69–79. https://doi.org/10.1007/s10750-008-9343-y

Froján, C. Cooper, K. & Bolam, S. (2016). Towards an Integrated Approach to Marine Benthic Monitoring. *Marine Pollution Bulletin*, *104*(1-2), 20-28.

Garrison, T. (2012). *Oceanography: an invitation to marine science. Sixth Edition*. Belmont, CA : Thomson Brooks/Cole. Retrieved from http://books.google.com/books?id=Xvilxa1pz1wC&pgis=1

Gerino, M., Stora, G., François-Carcaillet, F., Gilbert, F., Poggiale, J.-C., Mermillod-Blondin, F., Desrosiers, G. & Vervier, P. (2003). Macro-invertebrate functional groups in freshwater and marine sediments: a common mechanistic classification. *Vie et Milieu 53*, 221–232.

Ghana Statistical Service (2014). *2010 population and housing census. District analytical report: Ekumfi District*. Accra: Ghana Statistical Service Retrieved from http://www.statsghana.gov.gh/docfiles/2010_District_Report/Central/Ekumfi.pdf

Glud, R. N. (2008). Oxygen dynamics of marine sediments. *Marine Biology Research*, *4*(4), 243–289. https://doi.org/Doi 10.1080/17451000801888726

Goldfinger, C., Henkel, S., Romsos, C., Havron, A. & Black, B. (2014). Benthic Habitat Characterization Offshore the Pacific Northwest Volume 1: Evaluation of Continental Shelf Geology. Report by Oregon State University. pp 161. Retrieved from https://tethys.pnnl.gov/publications/benthic-habitat-characterization-offshore-pacific-northwest-volume-1

Grall, J. & Chauvaud, L. (2002). Marine eutrophication and benthos: The need for new approaches and concepts. *Global Change Biology*, *8*(9), 813–830. https://doi.org/10.1046/j.1365-2486.2002.00519.x

Gray, C. A. (2016). Tide , time and space : Scales of variation and influences on structuring and sampling beach clams. *Journal of Experimental Marine Biology and Ecology*, *474*, 1–10. https://doi.org/10.1016/j.jembe.2015.09.013

Gray, J. S. (2002). Biomagnification in marine systems: the perspective of an ecologist. *Marine Pollution Bulletin 45*, (1–12), 46–52. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/12398366

Gray, J. S., & Elliot, M. (2009). Ecology of marine sediments: from science to management. Second edition. Oxford University Press: Oxford. Retrieved from https://global.oup.com/academic/product/ecology-of-marine-sediments-9780198569015?cc=us&lang=en&

Gutt, J. (2007). Antarctic macro-zoobenthic communities: a review and an ecological classification. *Antarctic Science*, *19*(2), 165. https://doi.org/10.1017/S0954102007000247

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R. & Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. *Science*, *319*(5865), 948–952. http://dx.doi.org/10.1126/science.1149345

Hawkins, A. & Popper, A. (2016). A Sound Approach to Assessing the Impact of Underwater Noise on Marine Fishes and Invertebrates. *ICES Journal of Marine Science*, *74*(3), 635–651. Retrieved from https://icesjms.oxfordjournals.org/content/early/2016/12/24/icesjms.fsw205.abstract

Hooper, D., Chapin, F., Ewel, J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J., Lodge, D., Loreau, M. & Naeem, S. (2005) Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs*, *75*, 3–35. Retrieved from https://tropicalbiodiversityinitiative.files.wordpress.com/2013/04/hooper-et-al-2005-ecolog-monogr-effects-of-biodviersity-on-ecosystem-functioning-a-consensus-of-current-knowledge.pdf.

Huston, M. A. (1994). *Biological diversity: the coexistence of species on changing landscapes*. Cambridge, UK: Cambridge University Press. Retrieved from https://doi.org/10.1017/S0025315400015393

IEA Renewable Energy Working Party (2002). *Renewable energy into the mainstream*. IEA Renewable Energy Working Party. Retrieved from https://library.umac.mo/ebooks/b1362376x.pdf

International Energy Agency (2012). *Energy Technology Perspectives 2012*. International Energy Agency. Retrieved from https://www.iea.org/publications/freepublications/publication/ETP2012_free.pdf

Jones, D. O. B., Walls, A., Clare, M., Fiske, M. S., Weiland, R. J., O'Brien, R. & Touzel, D. F. (2014). Asphalt mounds and associated biota on the Angolan margin. *Deep Sea Res. I, 94*, 124–136. http://dx.doi.org/10.1016/j.dsr.2014.08.010

Kokarev, V. N., Kozlovsky, V. V. & Azovsky, A. I. (2015). Current State of Macrobenthic Communities in Baydaratskaya Bay (Kara Sea). *Oceanology*, *55*(5), 724–729. https://doi.org/10.1134/S0001437015050069

Krone, R., Gutow, L., Brey, T., Dannheim, J. & Schröder, A. (2013). Mobile Demersal Megafauna at Artificial Structures in the German Bight - Likely Effects of Offshore Wind Farm Development. *Estuarine, Coastal and Shelf Science*, *125*, 1-9.

Krumins, J. A., van Oevelen, D., Bezemer, T. M., De Deyn, G. B., Hol, W. H. G., van Donk, E., de Boer, W., de Ruiter, P. C., Middelburg, J. J. & Monroy, F. (2013). Soil and freshwater and marine sediment food webs: their structure and function. *BioScience*. *63*, 35–42.

Lake, P. S. (2001). Disturbance, patchiness, and diversity in streams. *Journal of the North American Benthological Society*, *19*(4), 573–592.

Lalli, C. M. & Parsons, T. R. (2006). *Biological Oceanography: An Introduction*. Second edition. New York: Elsevier.

Lamptey, E. (2015). *Eco-Functional Benthic Biodiversity Assemblage Patterns in the Guinea Current Large Marine Ecosystem*. PhD thesis. University of Ghana. Retrieved from http://ugspace.ug.edu.gh:8080/xmlui/handle/123456789/8483

Lamptey, E. & Armah, A. K. (2008). Factors Affecting Macrobenthic Fauna in a Tropical Hypersaline Coastal Lagoon in Ghana, West Africa. *Estuaries and Coasts, 31*(5), 1006-1019. Retrieved from https://link.springer.com/article/10.1007/s12237-008-9079-y

Le Lœuff, P. (1993). La faune benthique des fonds chalutables du plateau continental de la Guinée. Premiers résultats en référence à la faune de la Côte-d'Ivoire. *Revue d'Hydrobiologie Tropicale, 26*, 229–252.

Le Lœuff, P. & Zabi, G. S. F. (2002) Spatial and temporal variations in benthic fauna and communities of the tropical Atlantic Coast of Africa. *In* McGlade, J.M., Cury, P., Koranteng, K.A. and Hardman-Mountford, N.J. (Eds), *The Gulf of Guinea Large Marine Ecosystem: environmental forcing and sustainable development of marine resources* (pp. 147–160). New York: Elsevier.

Leo, F. C., De Vetter, E. W., Smith, C. R., Rowden, A. A. & Mcgranaghan, M. (2014). Deep-Sea Research II Spatial scale-dependent habitat heterogeneity in fl uences submarine canyon macrofaunal abundance and diversity off the Main and Northwest Hawaiian Islands. *Deep-Sea Research Part II, 104,* 267–290. https://doi.org/10.1016/j.dsr2.2013.06.015

Levin, L. A., Boesch, D. F., Covich, A., Dahm, C., Erséus, C., Ewel, K. C. & Weslawski,

J. M. (2001). The function of marine critical transition zones and the importance of sediment biodiversity. *Ecosystems*, *4*(5), 430–451. https://doi.org/10.1007/s10021-001-0021-4

Levin, L. A., Whitcraft, C. R., Mendoza, G. F., Gonzalez, J. P. & Cowie, G. (2009). Oxygen and organic matter thresholds for benthic faunal activity on the Pakistan margin oxygen minimum zone (700-1100 m). *Deep-Sea Research Part II: Topical Studies in Oceanography*, *56*(6–7), 449–471. https://doi.org/10.1016/j.dsr2.2008.05.032

Logan, O. D. (2007). Effects of fine sediment deposition on benthic invertebrate communities. *Masters of Science Thesis*, 171. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Effects+of+fine+sediment+on+river+biota#3

Macdonald, T. A., Burd, B. J. & van Roodselaar, A. (2012). Size Structure of Marine Soft-Bottom Macrobenthic Communities across Natural Habitat Gradients: Implications for Productivity and Ecosystem Function. PLoS One, *7*(7). Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3401224/

Magurran, A. E. (2004). *Meausuring Biological Diversity*. Blackwell, Oxford.

Margalef, R. (1958). Information theory in ecology. *General Systems*, *3*, 36–71.

Martin, J. W. & Davis, G. E. (2001) An Updated Classification of the Recent Crustacea. *Science Series, 39.*

Maxwell, S. (2005). An Aquatic Pharmacy: The Biomedical Potential of the Deep Sea. *Current*, *21*(4), 31–32. Available online at http://www.mcbi.org/what/what_pdfs/Current_Magazine/Pharmacy.pdf

Mayer, A. M. S. & Gustafson, K. R. (2003). Marine pharmacology in 2000: Antitumor and cytotoxic compounds. *International Journal of Cancer, 105*, 291–299. Available online at http://marinepharmacology.midwestern.edu/docs/MP2000_Anticancer_Mayer_Gustafson.pdf

Mermillod-Blondin, F., François-Carcaillet, F., & Rosenberg, R. (2005). Biodiversity of benthic invertebrates and organic matter processing in shallow marine sediments: An experimental study. *Journal of Experimental Marine Biology and Ecology*, *315*(2), 187–209. https://doi.org/10.1016/j.jembe.2004.09.013

Mesa, L. M., Reynaga, M. C., del V. Correa, M. & Sirombra, M. G. (2013). Effects of anthropogenic impacts on benthic macroinvertebrates assemblages in subtropical mountain streams. Iheringia, *Série Zoologia*, Porto Alegre, *103*(4), 342-349.

Michaud, E., Desrosiers, G., Mermillod-Blondin, F., Sundby, B. & Stora, G. (2006). The functional group approach to bioturbation: II. The effects of the *Macoma balthica* community on fluxes of nutrients and dissolved organic carbon across the sediment–water interface. *Journal of Experimental Marine Biology and Ecology*, *337*, 178–189.

Ministry for the Environment & Statistics New Zealand (2016). *New Zealand's Environmental Reporting Series: Our marine environment 2016*. Ministry for the

Environment & Statistics New Zealand. Available from www.mfe.govt.nz and www.stats.govt.nz.

Mitra, A. & Zaman, S. (2016). *Basics of Marine and Estuarine Ecology*. Berlin: Springer.

Mouillot, D., Spatharis, S., Reizopoulou, S., Laugier, T., Sabetta, L., Basset, A. & Chi, T. Do. (2006). Alternatives to taxonomic-based approaches to assess changes in transitional water communities. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *16*(5), 469–482. https://doi.org/10.1002/aqc.769

Nicklès, M. (1950) Mollusques testacés marins dela Côte occidentale d'Afrique pp 269.

Okyere, I., Blay, J. & Aggrey-Fynn, J. (2011). Hydrographic conditions and macrobenthos of a coastal wetland in Ghana. *International Journal of Ecology and Environmental Sciences*, *37*(1), 15–22.

Open University (2002). *Ocean Chemistry and Deep-Sea Sediments*. Second edition. Oxford: Pergamon Press.

Open University. (2002). *Waves, tides and shallow water processes*. Second edition. Oxford: Pergamon Press.

Pacheco, P., Aguilar-Støen, M., Borner, J., Etter, A., Putzel, L. & Vera Diaz, M. C. (2011). Landscape transformation in tropical Latin America: Assessing trends and policy implications towards REDD+. *Forests, 2,* 1–29 http://dx.doi.org/10.3390/f2010001

Papageorgioua, N., Sigalaa, K. & Karakassis, I. (2009). Changes of macrofaunal functional composition at sedimentary habitats in the vicinity of fish farms. *Estuarine Coastal Shelf Science, 83*, 561–568.

Patel, S. J. & Desai, B. G. (2009). Animal-Sediment Relationship of the Crustaceans and Polychaetes in the Intertidal Zone Around Mandvi, Gulf of Kachchh, Western India. *Journal of the Geological Society of India, 74*(2), 233–259.

Pavithran, S., Ingole, B., Nanajkar, M. & Nath, B. N. (2007). Macrofaunal diversity in the Central Indian Ocean Basin. *Biodiversity, 8*(3), 11-16. http://dx.doi.org/10.1080/14888386.2007.9712824

Pavithran, S., Ingole, B., Nanajkar, M. & Goltekar, R. (2009). Importance of sieve size in deep-sea macrobenthic studies. *Marine Biology Research*, *5*(4), 391–398. https://doi.org/10.1080/17451000802441285

Pearson, T. H. (2001). Functional group ecology in soft sediment marine benthos: the role of bioturbation. *Oceanography and Marine Biology: An Annual Review, 39,* 233–267.

Pielou, E. C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology, 13*, 131–144.

Pielou, E. C. (1969). *An Introduction to Mathematical Ecology*. New York: Wiley.

Ramakrishnan, N. (2003). “Bio-Monitoring Approaches For Water Quality Assessment In Two Waterbodies At Tiruvannamalai, Tamil Nadu India” in Martin J. Bunch, V.

Madha Suresh and T. Vasantha Kumaran, Eds., *Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15-17 December, 2003*. Chennai: Department of Geography, University of Madras and Faculty of Environmental Studies, York University, 374 – 385.

REN21 (2010). *Renewables 2010 Global Status Report*. REN21. Retrieved from www.ren21.net/renewables-2010-global-status-report/

REN21 (2011). *Renewables 2011: Global Status Report*. REN21. Retrieved from www.ren21.net/renewables-2011-global-status-report/

REN21 (2016). *Global Status Report 2016*. REN21. Retrieved from www.ren21.net/wp-content/uploads/2016/05/GSR_2016_Full_Report_lowres.pdf

Rouse, G. W. & Pleijel, F. (2001). *Polychaetes*. First edition. Oxford, UK: Oxford University Press.

Rumohr, H. (2009). Soft bottom macrofauna: collection and treatment and quality assurance of samples. *ICES Techniques in Marine Environmental Sciences*, *43*, 20 pp.

Rumohr, H., Karakassis, I. & Jensen, J. N. (2001). Estimating species richness , abundance and diversity with 70 macrobenthic replicates in the Western Baltic Sea. *Marine Ecology*, *214*, 103–110.

Rupert, E. E. & Fox, R. (1988). *Seashore animals of the Southeast.* University of South Carolina Press: Columbia, S.C.

Sahara, R., Fukaya, K., Okuda, T., Hori, M., Yamamoto, T., Nakaoka, M. & Noda, T. (2015). Larval dispersal dampens population fluctuation and shapes the interspecific spatial distribution patterns of rocky intertidal gastropods. *Ecography*, *39*(5), 487–495. https://doi.org/10.1111/ecog.01354

Seiderer, L. J. & Newell, R. C. (1999) Analysis of the relationship between sediment composition and benthic community structure in coastal deposits: implications for marine aggregate dredging. *ICES Journal of Marine Science*, *56*, 757–765.

Shou, L., Huang, Y. J., Zeng, J. N., Gao, A. G., Liao, Y. B. & Chen, Q. Z. (2009). Seasonal changes of macrobenthos distribution and diversity in Zhoushan sea area. *Aquatic Ecosystem Health & Management*, *12*(1), 110–115. https://doi.org/10.1080/14634980802697902

Shull, D. H., Benoit, J. M., Wojcik, C. & Senning, J. R. (2009). Infaunal burrow ventilation and pore-water transport in muddy sediments. *Estuarine, Coastal and Shelf Science*, *83*(3), 277–286. https://doi.org/10.1016/j.ecss.2009.04.005

Sigurdsson, G. M. & Tremblay, M. J. (2016). Patchiness in American lobster benthic recruitment at a hierarchy of spatial scales. *Marine Science*, *73*(2), 394–404. Retrieved from https://doi.org/10.1093/icesjms/fsv175

Simpson, E. H. (1949). Measurement of diversity. *Nature*, *163*, 688 pp. http://www.dx.doi.org/10.1038/163688a0

Solan, M., Hauton, C., Godbold, J. A., Wood, C. L., Leighton, T. G. & White, P. (2016). Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties. *Scientific Reports, 6*, 1–9. Retrieved from http://www.dx.doi.org/10.1038/srep20540

Sulak, K. J., Randall, M. T., Luke, K. E., Norem, A. D. & Miller, J. M. (Eds.). (2008). Characterization of Northern Gulf of Mexico Deepwater Hard Bottom Communities with Emphasis on *Lophelia* Coral - Lophelia Reef Megafaunal Community Structure, Biotopes, Genetics, Microbial Ecology, and Geology. USGS Open-File Report 2008, 1148. Available online at http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/index.html

Tagliapietra D. & Sigovini M. (2010). Benthic fauna: collection and identification of macrobenthic invertebrates. NEAR curriculum in natural environmental sciences. *Terre et Environ.*, *88*, 253–261.

Tait, R. V. & Dipper, F. A. (1998). *Elements of Marine Ecology*. Fourth edition. Oxford: Butterworth Heinemann.

Taylor, J., Krumpen, T., Soltwedel, T., Gutt, J. & Bergmann, M. (2017). Dynamic benthic megafaunal communities: Assessing temporal variations in structure, composition and diversity at the Arctic deep sea observatory HAUSGARTEN between 2004 and 2015. *Deep–Sea Research Part I*, *122,* 81–94.

Taylor, J., Krumpen, T., Soltwedel, T., Gutt, J. & Bergmann, M. (2017). Deep – Sea Research I Dynamic benthic megafaunal communities : Assessing temporal variations in structure , composition and diversity at the Arctic deep-sea observatory HAUSGARTEN between 2004 and 2015. *Deep-Sea Research Part I*, *122*(August

2016), 81–94. https://doi.org/10.1016/j.dsr.2017.02.008

Tebble, N. (1955). The polychaete fauna of the Gold Coast. *Bulletin of the British Museum of Natural History*, *3*(2).

Thompson, B. & Lowe, S. (2004). Assessment of macrobenthos response to sediment contamination in the San Francisco estuary. California, USA. *Environmental Toxicology and Chemistry*, *23*, 2178–2187.

Thoya, P., Bastardie, F., Dinesen, G. E., Hansen, J. L. S. & Nielsen, J. R. (2015). Detecting ecological-economic effects of marine spatial plans from displacing the bottom fishing pressure. Paper presented at ICES Annual Science Conference 2015, Copenhagen, Denmark.

Tomassetti, P. & Porrello, S. (2005). Polychaetes as indicators of marine fish farm organic enrichment. *Aquaculture International*, *13*, 109. http://www.dx.doi.org/10.1007/s10499-004-9026-2

Tullow Ghana Limited (2009). *Ghana Jubilee Field Phase 1 Development*. Tullow Ghana Limited.

Udden, J. A. (1914). Mechanical composition of clastic sediments. *Bulletin of the Geological Society of America*, *25*, 655–744.

van der Molen J., Aldridge J. N., Coughlan C., Parker E. R., Stephens D. & Ruardij, P. (2013) Modelling marine ecosystem response to climate change and trawling in the North Sea. *Biogeochemistry*, *113*, 213–236.

van der Zee, E. M., Tielens, E., Holthuijsen, S., Donadi, S., Eriksson, B. K., van der Veer, H. W. & van der Heide, T. (2015). Habitat modification drives benthic trophic diversity in an intertidal soft-bottom ecosystem. *Journal of Experimental Marine Biology and Ecology*, *465*, 41–48. https://doi.org/10.1016/j.jembe.2015.01.001

van Dover, C. L., Aharon, P., Bernhard, J. M., Caylord, E., Doerriesa, M., Flickinger, W., Gilhooly, W., Goffredi, S. K., Knick, K. E., Macko, S. A., Rapoport, S., Raulfs, E. C., Ruppel, C., Salerno, J. L., Seitz, R. D., Sen Gupta, B. K., Shank, T., Turnipseed, M. & Vrijenhoek, R. (2003). Blake Ridge methane seeps: characterization of a soft-sediment, chemosynthetically-based ecosystem. *Deep-Sea Research Part I*, *50*, 281–300. (Available as a PDF file at http://www.mbari.org/staff/vrijen/PDFS/VanDover_2003DSR.pdf)

Vaquer-sunyer, R. & Duarte, C. M. (2008). Thresholds of hypoxia for marine biodiversity. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(40), 15452–15457.

Wahl, M. (2009). Marine Hard Bottom Communities: Patterns, Dynamics, Diversity, and Change. *Biological Reviews*, *206*. Retrieved from https://doi.org/10.1007/978-3-540-92704-4

Waldbusser, G. G., Marinelli, R. L., Whitlatch, R. B. & Visscher, P. T. (2004). The effects of infaunal biodiversity on biogeochemistry of coastal marine sediments. *Limnology and Oceanography*, *49*(5), 1482–1492.

Wentworth, C. K. (1922). A scale of grade and class terms for clastic sediments. *Journal of Geology*, *30*, 377-392.

Wesseh, Jr., P. K. & Lin, B. (2016). Is renewable energy a model for powering Eastern African countries transition to industrialization and urbanization? *Renewable and Sustainable Energy Reviews*, *709*, 909–917. Retrieved from http://dx.doi.org/10.1016/j.rser.2016.11.071

Wieking, G. & Kröncke I. (2005). Is benthic trophic structure affected by food quality? The Dogger Bank example. *Marine Biology*, *146*, 387-400.

Wilding, T., Gill, A., Boon, A., Sheehan, E., Dauvin, J., Pezy, J., O'Beirn, U., Janas, U., Rostin, L. & Mesel, I. (2017). Turning Off the DRIP ('Data-Rich, Information-Poor') - Rationalising Monitoring with a Focus on Marine Renewable Energy Developments and the Benthos. *Renewable and Sustainable Energy Reviews*, *74,* 848-859.

Williams, R., Wright, A., Ashe, E., Blight, L., Bruintjes R., Canessa, R., Clark, C., Cullis-Suziku, S., Dakin, D., Erbe, C., Hammond, P., Merchant, N., O'Hara, P., Purser, J., Radford, A., Simpson, S., Thomas, L., & Wale, M. (2015). Impacts of Anthropogenic Noise on Marine Life: Publication Patterns, New Discoveries, and Future Directions in Research and Management. *Ocean & Coastal Management*, *115*, 17–24.

Wisehart, G. D., Rempala, E. C. & Leboffe, M. J. (2012). *A photographic atlas of marine biology*. Englewood: Morton Publishing Company.

Woodruff, D., Cullinan, V., Copping, A., & Marshall, K. (2013). Effects of Electromagnetic Fields on Fish and Invertebrates - FY2012 Progress Report. Report by Pacific Northwest National Laboratory (PNNL). pp 62.

World Energy Assessment (2001). *Renewable energy technologies*. World Energy Assessment. p. 221. Retrieved from http://www.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/sustainable-energy/world-energy-assessment-energy-and-the-challenge-of-sustainability/World%20Energy%20Assessment-2000.pdf

Woulds, C., Cowie, G. L., Levin, L. A., Andersson, J. H., Middelburg, J. J., Vandewiele, S., … Schwartz, M. (2007). Oxygen as a control on seafloor biological communities and their roles in sedimentary carbon cycling. *Limnology and Oceanography*, *52*(4), 1698–1709. https://doi.org/DOI 10.4319/lo.2007.52.4.1698

Ysebaert, T., Herman, P. M. J., Meire, P., Craeymeersch, J., Verbeek, H. & Heip, C. H. R. (2003). Large-scale spatial patterns in estuaries: estuarine macrobenthic communities in the Schelde estuary, NW-Europe *Estuarine*, *Coastal and Shelf Science*, *57*(1-2), 335–355. Available online at https://doi.org/10.1016/S0272-7714(02)00359-1

8.0 APPENDICES

APPENDIX I

List of species and abundance from Ekumfi Aboano.

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Amphinomidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Sigalioninae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Mellitidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	4	0	0	1	0	0	0	0	0
Mellitidae indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
Ampelisca brevicornis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	3	13	3	0	6	3
Ampelisca sp. A	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	4	6	0	4	11	0
Ampeliscidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	7	5	2	0	4	0
Amphithoe gammaroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	3	0	0	0	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Amphithoe rubricata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4	0	0	0	0
Ampithoe sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	4	2	2	3	5	5
Aora sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	0	2	0
Argissa sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	7	6	3	0	8	6	14
Atylus guttatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	3	0	0	7
Atylus swammerdami	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	9	10	4	6	11	8
Atylus sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	7	6	0	0	4
Bathyporeia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0
Dexamine sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	2	3	0
Gammarus salinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	0	4	0	5	0
Gammarus zaddachi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4	0	3	2	0
Gammarus sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	8	5	0	0	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Harpinia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	8	6	8	0	12	3
Harpinia indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	6	2
Lembos sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	7	9	2	4	7	0
Leucothoe sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	4	7	0	0	5	9
Lysianassa ceratina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5	12	6	0	9	0
Melita palmata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	3	0	0	0	0	0
Oedicerotidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	11	8	9	8	2	11	10
Oedicerotidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	6	2	0	7	0
Orchomene nana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Phoxocephalus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	11	7	5	0	7	3
Phtisica marina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	4	2	6	0	1	0
Pontocrates sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Stegocephalus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	6	3	0	0	6	7
Urothoe brevicornis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	3	3	0	1	0	0	2
Urothoe elegans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	4	0	2	1
Amphipod indet	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	9	0	0	0	0	0	0	0
Apseudes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0
Parapseudes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Pseudoparatanais sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Tanaidacea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0
Accalathura sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	2	0	1	3
Ananthura sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	3	0	0
Cirolana sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	3	1	1	2	0
Eurydice sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	1	1	1

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Limnoria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	1	0
Isopod indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	1
Erythrops elegans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Paramysis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Schistomysis sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bodotria sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	2	0	0	1	1	0
Iphinoe sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	1	2	0	0	0	0
Diastylis sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	0	0
Cumacean indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	0	0	0
Ophiuroidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	8	1	1	0	0
Ophiuroidea indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Agaronia acuminata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	5	0	3	0	0	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Gastropod indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0
Tellina sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0
Potamididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Brachyura indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	0	0	0	0
Antalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	1	1	0	1	0	1	0
Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	1	3	5	1	0	0	0
Nemertea	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	1	2	2	3	0	0	5	0	3	1
Ampharetidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0
Isolda pulchella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Capitella capitata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Capitellidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Dasybranchus sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Notomastus aberans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Notomastus latericeus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Cirratulus filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0
Cirratullidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	1
Cirriformia tentaculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cossura soyeri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	1	0	0	0
Cossura indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Diopatra neapolitana capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Diopatra neapolitana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Pycnoderma congoense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Glyceride indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0
Goniada maculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Gonida multidentata	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris aberrans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Lumbrineris coccinea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Lumbrineris latrielli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Magelona capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Magelona indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Axiothella indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Euclymene indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Euclymene lombricoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Maldanella cf. capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1
Maldanidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Aglaophamus (Nepthys) dibranchis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	4	2	2	2	2
Micronereides capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	8	0	3	4	0
Nereis indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	1	0	1
Diopatra neapolitana capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epidiopatra indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Onuphis indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	0	1	1	0
Orbiniidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
Orbiniide cuvieri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phylo capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	2	0	0	0	3
Naineris laevigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Scoloplos madagascariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Scoloplos indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	2	0	0	0
Aricidea curviseta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Aricidea sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ancistrosyllis parva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Pilargidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pisionide africana	0	2	8	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pisionide indica	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scalibregma inflatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Prionospio pinnata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	1	0	7	0	0	0	1
Prionospio indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Prionospio cirrifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

SPECIES	**LSWA**	**LSWB**	**LSWC**	**LSMA**	**LSMB**	**LSMC**	**LSEA**	**LSEB**	**LSEC**	**USWA**	**USWB**	**USWC**	**USMA**	**USMB**	**USMC**	**USEA**	**USEB**	**USEC**	**ST1A**	**ST1B**	**ST1C**	**ST2A**	**ST2B**	**ST2CA**	**ST2CB**	**ST2DA**	**ST2DB**	**ST3A**	**ST3B**
Spionidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	6	0	5	0
Sternaspis scutata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Sipunculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	0	0	1	0	0

APPENDIX II

List of species and abundance from Jubilee Fields.

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Marphysa cf. adenensis	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marphysa sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Nematonereis unicornis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunice sp. A	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunicidae indet.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Flabelligeridae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Glycera cf. capitata	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Glycera longipinnis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Glycera cf. papillosa	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	2	1	0	0	0	0	0	0	0
Glycera tesselata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera sp. A	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	2	1	0	1	0	1
Hemipodus sp. A	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glyceridae indet.	0	0	0	0	2	0	1	1	1	0	0	2	1	0	1	0	1	0	0	2	0	0	2	0	0	2	0	0	0	0	0	0	0	2	1
Goniada capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Goniada maculata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Goniada sp. A	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0

SPECIES	FP 001	FP 002	FP 003	FP 004	FP 005	FP 006	FP 007	FP 008	JF 001	JF 002	JF 003	JF 004	JF 005	JF 006	JF 007	JF 008	JF 009	JF 010	JF 011	JF 012	JF 013	JF 014	JF 015	JF 016	JF 017	JF 018	JF 019	JF 020	JF 021	JF 022	JF 023	RF 001	RF 002	RF 003	RF 004
Goniada sp.B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goniadella sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ophiodromus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris aberrans	0	0	2	0	1	2	0	1	1	1	1	1	0	2	0	0	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris latreilli	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	1	0	2	0	0	0	1	0	0	0	0	2	0	1	0
Lumbrineris magalhaensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris sp A	1	1	0	1	2	1	2	0	0	0	0	0	0	1	2	0	2	0	0	0	0	0	0	1	1	0	2	1	0	0	0	7	0	0	0
Lumbrineridae indet.	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Aglaophamus cf. lyra	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Aglaophamus (Nepthys) lyrochaeta	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nepthys capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Nephtys sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	4	1	0	3	3	0	0	2	1	0	1	3	0	0	0	0	1	1	2	0
Nephtys sp. B	4	0	0	0	0	0	0	0	0	0	0	1	2	2	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Nephtyidae indet.	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leonantes decipiens	2	0	0	0	3	3	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neanthes sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Nereis sp A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Nereis sp. B	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Nereidae indet 1	0	2	0	2	0	0	0	1	0	0	3	0	0	0	0	0	0	1	1	0	0	0	3	3	0	1	0	0	1	0	0	3	0	1	0
Nereidae indet 2	7	0	0	1	4	0	2	1	1	1	1	2	0	1	0	0	3	0	0	0	1	1	1	2	0	0	0	0	0	0	0	1	1	2	1
Phyllodoce sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Phyllodoce longipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllodocidae indet.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Antinoe sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polynoidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	2	0	0	0	0	1	0	0	0	0	0	0	0
Ampharetidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Notomastus latericeus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Pulliella armata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caulleriella cf. acicula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caulleriella capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Cirratullidae indet.	0	1	0	0	1	1	0	0	0	0	2	1	1	1	0	0	0	1	3	2	1	1	0	2	0	0	2	1	0	0	0	2	2	2	0
Cirratulus africanus	0	1	0	0	0	2	2	3	1	1	1	0	1	0	2	2	4	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Cirratulus sp. A	1	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cirriformia saxatalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0
Tharyx sp.A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Tharyx filibranchia	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Cossura sp.A	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cossura soyeri	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cossura coasta	1	1	1	1	3	1	3	0	0	0	0	0	0	1	0	0	1	0	1	3	1	0	3	0	0	2	1	1	1	0	1	0	0	0	0
Magelona capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magelona cincta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magelonidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clymenura sp. A	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Axiothella jarli	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euclymene sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Maldanella sp A.	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Maldanidae indet. 1	0	0	0	0	0	0	0	1	1	0	4	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	3	0	3	1	3	0	2	2
Maldanidae Indet. 2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nicomache lumbricalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Praxillella sp. A	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Armandia intermedia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	3	1	1	3	0	1	0	0	0	0	0	1	1	0	0	1
Polyopthalamus pictus	2	2	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0	0	0	0
Ophelina acuminata	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophelina cylincaudata	1	1	0	1	8	0	1	1	0	2	1	0	0	8	15	10	14	2	1	9	3	5	7	3	3	7	1	11	1	0	5	6	2	0	1

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Opheliidae indet.	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	5	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Orbiniidae indet. 1	5	0	0	0	0	0	0	3	0	0	1	3	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	2	5	0
Orbiniidae indet 2	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Orbinia sp. A	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	1	5	1	3	3	1	0	1	4	2	1	1	1	3	2	3	5	0	0	0
Orbinia sp. B.	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orbiniella Sp. A	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naineris laevigata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phylo capensis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Proscoloplos cygnochaetus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Scoloplos madagascariensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Scoloplos sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Scoloplella capensis	0	0	0	0	0	0	0	2	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scoloplella sp. A	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Owenia fusiformis	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paraonidae indet. 1	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aricidea curviseta	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Aricidea cf. jeffreysi	1	0	0	0	1	1	1	0	0	3	0	1	1	1	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Aricidea sp. A	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Aricidea sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Cirrophorus branchiatus	2	0	2	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
Paraonidae indet. 2	0	1	1	1	1	0	0	0	0	0	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Paraonides lyra	1	3	4	3	4	2	2	3	1	3	3	4	1	0	4	1	3	0	3	0	0	1	2	1	2	2	0	0	0	0	0	0	0	1	2
Paraonides lyra lyra	1	0	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	5	0	0	0
Paraonides lyra cf. capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0
Paraonis gracilis	2	1	0	0	0	1	1	0	0	2	2	0	0	1	1	0	3	0	1	0	0	1	0	1	1	0	1	0	0	0	0	1	0	0	0
Paraonis gracilis cf. gracilis	1	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Paraonis gracilis cf. oculata	0	0	1	0	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parasclerocheilus capensis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Polyphysia crassa	4	0	0	0	0	0	0	0	1	0	1	1	0	1	1	2	1	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	0
Scalibregma inflatum	2	0	0	0	0	0	0	0	2	0	1	1	1	1	1	1	2	2	2	1	0	0	1	0	0	0	1	0	1	0	0	1	0	1	0
Scalibregma sp.A	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirorbis indet.	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Prionospio cirrobranchiata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Scolelepsis lefebvrei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

SPECIES	FP 001	FP 002	FP 003	FP 004	FP 005	FP 006	FP 007	FP 008	JF 001	JF 002	JF 003	JF 004	JF 005	JF 006	JF 007	JF 008	JF 009	JF 010	JF 011	JF 012	JF 013	JF 014	JF 015	JF 016	JF 017	JF 018	JF 019	JF 020	JF 021	JF 022	JF 023	RF 001	RF 002	RF 003	RF 004
Spio filicornis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	0	0	3	1	2	5	0	0	0
Spionidae indet.	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0	3	1	4	3	3	3
Sternaspis scutata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	3	0	0	1	0
Terebellidae indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Ampelisca sp.	1	0	3	0	5	0	0	0	2	2	2	0	0	0	5	2	0	1	0	4	0	0	0	0	1	2	0	0	0	0	0	1	0	1	1
Ampeliscidae indet.	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ampithoe sp. A	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Argissa sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	3	1	0
Atylus sp.	0	0	2	1	3	0	0	1	0	0	2	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Harpinia sp.	0	6	0	1	3	0	7	0	1	0	0	1	1	0	0	3	7	2	1	4	0	4	1	1	2	1	3	5	4	3	4	6	2	3	2
Harpinia indet.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lembos sp.	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	3	1	4	0	0	0	0	0	0	1	1	0	0	0	0
Oedicerotidae indet. 1	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oedicerotidae indet. 2	1	0	2	4	3	1	0	0	1	3	2	1	0	0	3	0	1	1	1	5	1	1	0	0	3	1	4	1	0	0	1	0	1	1	1
Stegocephalus sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phtisica marina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Amphipod indet.	0	0	0	0	3	0	0	0	0	0	3	0	0	0	4	1	0	0	1	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0
Bradyetes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calanoidea indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	2

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Calanus sp.	0	0	1	0	2	0	0	0	0	0	1	0	0	2	0	0	2	0	0	7	0	0	0	0	1	1	0	12	0	1	1	0	0	1	2
Iphinoe senegalensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bodotria sp. A	2	0	0	0	0	3	2	0	1	1	0	0	4	1	1	1	0	0	1	1	2	2	2	1	0	1	0	2	0	0	3	2	1	1	0
Iphinoe sp. A	1	0	0	1	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	7	1	1	4	0	3	0
Iphinoe sp. B	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diastylis denticulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diastylis sp. A	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Diastylis sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacea indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Decapoda indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Joreopsis sp.	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	5	0	0	1	0	1	2	0	0	7	1	1	2
Pargnathia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Accalathura sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	0	1	0	0	0	2	1	0
Ananthura sp. A	0	2	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	7	2	0	0	0	0	0	0	0	0	3	0	0	0
Isopod indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apseudes sp.	0	0	0	0	0	0	0	0	0	2	3	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paratanaidae sp.	0	0	0	0	5	0	0	0	0	3	2	0	3	0	0	0	2	0	0	1	1	7	2	0	3	2	5	3	0	2	0	5	3	2	2
Pseudoparatanais sp.	1	0	2	1	0	5	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parapseudes sp. A	3	3	2	0	1	0	1	5	0	1	0	0	0	0	0	0	6	8	0	5	4	1	3	0	1	3	1	3	4	2	1	0	0	3	2

SPECIES	FP 001	FP 002	FP 003	FP 004	FP 005	FP 006	FP 007	FP 008	JF 001	JF 002	JF 003	JF 004	JF 005	JF 006	JF 007	JF 008	JF 009	JF 010	JF 011	JF 012	JF 013	JF 014	JF 015	JF 016	JF 017	JF 018	JF 019	JF 020	JF 021	JF 022	JF 023	RF 001	RF 002	RF 003	RF 004
Parapseudes sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0
Tanaidae sp. A	0	0	0	0	0	0	0	0	0	0	5	0	5	1	6	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Tanaidacea sp. A	1	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apseudidae indet.	2	0	3	0	5	0	0	0	0	0	0	1	0	2	4	4	1	0	1	5	0	6	8	0	1	5	4	4	4	1	1	2	2	0	0
Paratanaidae indet.	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Tanaidacea indet.	0	0	0	0	5	1	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Calanoida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	3	0	0	0
Harpacticoida	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Cyclopoida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	5	1	0	0
Copepoda indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Ostracoda indet.	0	0	0	1	0	0	1	1	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	3	0	0	0
Cirrepedia indet.	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllocarida indet.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cuspidaria sp. A	0	1	0	2	0	0	0	0	1	0	0	0	2	0	1	2	3	1	0	0	2	7	1	2	0	2	0	1	1	0	3	0	0	0	0
Limatula indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malletia obtuse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Malletia johnsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Kurtiella sp. A	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Tellimya sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Neilonella sp. A	0	1	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Ennucula sp. A	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nucula cf. sulcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nucula sp. A	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0
Tellina sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7	0	0	0	0	2	1	2	1	0	0	1	0	2	0
Tellina hyalina	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thyasira sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf. Hydatinia physis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yoldiella sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	3	1	0	0	0	0	0	3	3	2	1	2	0	0	0	0
Yoldiella indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Bivalve indet	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	1	0	1	1	1	0	0	1	0	2	2	0	5	3	1	1

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Eulimidae sp.	9	0	0	6	2	1	3	0	2	0	3	0	0	2	0	0	0	0	0	0	0	0	5	3	0	0	0	0	0	8	0	0	1	3	0
Fusinus sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Gastropod indet.	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0
Scaphopoda indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Chaetoderma sp.	2	4	3	0	4	0	0	3	2	1	0	0	0	0	0	2	3	0	0	0	4	2	5	2	0	2	2	1	0	0	0	3	2	1	0
Asteroidea sp. A	0	0	0	0	0	0	0	0	2	0	0	2	1	0	1	0	0	0	0	0	0	1	0	3	0	0	0	0	2	0	0	1	0	0	0
Amphiuridae sp. A	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiuroidea indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	2	0	0	1	0	0
Spatangoida indet.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

SPECIES	FP001	FP002	FP003	FP004	FP005	FP006	FP007	FP008	JF001	JF002	JF003	JF004	JF005	JF006	JF007	JF008	JF009	JF010	JF011	JF012	JF013	JF014	JF015	JF016	JF017	JF018	JF019	JF020	JF021	JF022	JF023	RF001	RF002	RF003	RF004
Sea urchin 'shell'	0	1	1	1	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0	2	1	0	0	0
Foraminifera indet.	0	0	0	0	1	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Nematoda	9	6	9	7	9	9	4	1	1	3	1	1	0	7	5	4	7	1	6	4	10	14	3	5	5	1	5	8	0	2	2	3	12	8	7
Nemertea indet.	0	0	0	0	0	3	0	1	2	4	2	0	0	0	0	0	0	2	1	2	0	0	9	3	1	4	4	1	3	0	0	4	0	0	1
Sipuncula indet.	0	0	0	2	0	0	0	0	0	0	0	2	0	0	2	1	1	1	2	2	1	1	0	0	2	3	2	3	2	0	1	0	0	0	0