GROWING DEEP-SEA OIL AND GAS EXPLOITATION WITHIN THE GULF OF GUINEA; A SOURCE OF CONCENTRATED 'OBSTRUCTIONIST STRESS' FOR MARINE MAMMAL HABITATION IN THE PHASE OF CLIMATE CHANGE.

BEING A PhD. THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE

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By

Anthony Djaba, **SACKEY**

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ATTESTATION

I hereby do attest that I am the sole author of this Thesis and that its contents are only the results of readings and research I have undertaking.

Signature:

……………………………………

Anthony Djaba, SACKEY

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ABSTRACT

The offshore hydrocarbon resources explored, developed, and produced from West Africa within the Gulf of Guinea region, is currently on an exponential growth compared to developments directed at the sustenance of eco-biodiversity of the region. The relevance of countries exploiting offshore hydrocarbon resources while ensuring compliance to environmental impact assessment *(EIA)* regulations towards the destruction of the marine environment and the mammalian habitation was examined. Compliance with the *EIA* regulations before the approval of field developments was compared with the day-to-day subsea-to-surface (surf) operations of assigned marine vessels. The anthropogenic concerns regarding operations include risk to strike injuries for animals, destruction or altering of the natural biological importance (BIAs) of the area, extinction of species, and the challenge of irregular migration.

A series of field surveys layered over five years was conducted deploying various survey techniques per case examined –thus backed with interviews of expert professional, over Jubilee field, Tweneboa Enyenra Ntomme (TEN) fields; and the OCPT-Sankofa Gye Nyame oil fields of Ghana aboard several offshore construction vessels including Seven Borealis Nassau as platform-of-opportunity *(PO)* vessels. Surveys conducted were to define and investigate the nature of the marine environment, operations while delimiting the nature of possible disturbances arising from exploration and development activities; and current controls. Thus, against the mammalian habitation.

The study region situated near the equator south of the northern Atlantic Ocean has rich marine biodiversity. It fosters the presence of various marine animals –clustered along the wide web of the food chain. High levels of visibility at 12 nautical miles were common and good for operations and animals sightings. Atmospheric temperatures averaged at 29-degree Celsius (suggesting high levels of humidity), with sea surface and bottom temperatures at 29.9 and 4.5 degrees Celsius respectively. Dissolved Oxygen (DO) concentrations over 1235meter water depth showed a median value of 8.934279203mg/L *(SE = 0.01663382)* with a minimum of 6.267872443mg/L and maximum of 9.169776741mg/L at 100% saturation value under 1009.6mbar. Short-fin pilot whales were a dominant cetacean feature with a population estimate of 160 *(CV = 0.3728).* The flaring from FPSO units and construction vessels within the region resulted in high levels of air emissions, small oil spills, and slight animal interferences. The year 2017-2018 surf operations on OCTP-Sankofa Gye Nyame field development air emission alone, is estimated to have contributed 1,509,971.6 tonnes CO_2 equivalent in GHG *(GWP=1).*

CHAPTER ONE

1.0 GENERAL INTRODUCTION

1.1 Background of the Study

The Gulf of Guinea over the years has remained a viable habitat for all forms of marine lives. Today it is taxonomy can relate to few extinct species of marine animals and fauna –sad to say, mainly due to changing environmental phenomena within its domain. The impact believed, aligns directly with the distributions of the marine mammal population, precipitated by the shift in the food chain and the habitability of the entire ecosystem. Hence, reason Van Waerebeek et al., believe developed coastlines of Ghana, and Côte d'Ivoire devoid of any records of the species may already constitute such gaps in distribution (2015). Van Waerebeek et al. therefore, suggest the lack or scarcity of records do warn about formidable challenges for the survival of S. Teuszii dolphin in the long-term while insisting; innovative, workable protection measures are needed, soonest. They recommended the implementation of new border-straddling of marine protected areas (cf. Saloum Delta-Niumi National Park Complex) capable of bringing to bear significant conservation effect (K. Van Waerebeek, M. Uwagbae, Gabriel Segniagbeto, Idrissa L. Bamy, Isidore Ayissi, 2015pp2). With this challenges notwithstanding, the undying need for foreign exchange earnings to bolster local economies, aided by the availability of advanced technology to search vast unreachable natural resources (not long ago near-impossible now possible) and the accessibility of knowledge in building the needed skill and competencies, is fast transforming the marine landscapes of nations particularly, those of West and Central Africa, bordering the Atlantic Ocean. This overwhelming push though can partly be attributed to the outburst of population growth, economic drive for industrialisation and the need for an evenly distributed development for all its citizens, scarce resources are spearheading the leverage on exploitation beyond drylands and near-coast into the deep and deeper-sea at the expense of the rapidly changing environment, particularly the climate and the potential destruction of natural marine ecological environments. According to Knight R. & Westwood J. (2004), the Gulf of Guinea rated high worldwide in in-depth water exploration with its successes and prospect projected between the years 2001 to 2010.

Ghana, like many others Sub-Saharan African nations along the Gulf of Guinea, has made significant discoveries far beyond the 12nautical miles territorial maritime boundary into the Exclusive Economic Zone (EEZ), from Deep-water exploitation to ultra-Deepwater (along continental slope) thus in recent times— altering the natural course of the marine landscape of the region. The petroleum commission (PC) of Ghana reiterated this very fact when they indicated in a statement that the continuous growth of exploration and exploitation of oil and gas resources within the west to east of Ghana's maritime boundaries had had the continental margin area seen a significantly increased interest from major oil and gas operators. Furthermore, therefore the 'Offshore Activity Map' is frequently an updated record. There are currently seventeen (17) active Petroleum Agreements (PAs) between the government of Ghana and oil companies. All the agreements to date are for offshore concessions, mostly in the Western Basin (PC, 2019). Ivory Coast, Togo, Benin, Senegal, Serra Leone, Cameroon, among others, have secured similar arrangements with significant oil operators and have their continental margin expanded with offshore activity maps. These developments though believed to be a reasonable invasion of the ocean's wild where mammals have their habitation, the growing activities offshore are no doubt, gradually impacting on living mammals within those water depths ranging from below 100meters near-coast to approximately 4,800meters ultra deep-water exploitation and more (Government of Ghana, 2019).

1.2 Statement of Problem and Research Questions

Ghana's example of exploitation of Oil and Gas resource in the Gulf of Guinea is wealth noting as these developments have come with increased unnatural operational occurrences such as dense vessel movements and traffic routes, subsea-to-surface (surf) operations through water columns during the development installation of subsea infrastructures. All these are alien to these very mammals living in the region. Rhetorically, therefore, to what extent do these invasions alter the natural cause of the life of these living mammals? Thus inspire this very study as reports in the media have made several references to beaching of dead wild whales along Ghana's west coast over the last decade. Again, media reports in Ghana, suggest fisherfolks are first to discover these carcasses. A news report in an attempt to explain the cause referenced suggestion that the onset of offshore operations 2010, might be the reason for the deaths though the actual cause of deaths remains to be determined (Korateng K, 2017). The report proceeded to catalogue the much recent dead whale to have washed ashore the Sunday morning of September 17, 2017— raising the number of recorded whale' death count' under the decade to thirty-one (31) in Ghana. This mammal death does remain the highest number of deaths ever recorded within six years in the nation's history. This alarming situation is feared to worsen as the Environmental Protection Agency (EPA) still predicts more whale deaths in Ghana's waters since the cause of deaths is yet to be identified, and a solution where necessary referred (Korateng K, 2017).

Perhaps, the general claim that the traffic of activities in the marine environment naturally is bound to interfere with the life of marine organisms (thus, in terms of their movements, feeding and reproduction cycles and health), buttresses Smita's logic of heightened pollution levels significantly, noise pollution with the same outcome (Smita, 2011), and so forth. This logic goes to suggest that even waste food or pollutants introduced intentionally or unintentionally in the area do impact on these organisms (MARPOL 73/78) (B. L. Lamptey and A. D. Sackey, 2017). Again, ordinary navigation may also pose a challenge. Thus marine mammal encountering moving ships in these areas may be susceptible to vessel strikes [J. V. Redfern et al. (2013); Nichol et al. (2017); Calambokidis et al. (2019)]. Similar assumptions relate to the vertical movement through the water column by subsea structures and machinery. Such movements occur within the ocean (water column) during subsea heavy-lift loads (structures of all sizes and shapes), drilling pipes, ROVs (remotely operated vehicle), Crane wire, which become physical barriers, impediments or a source of entrapments, fostering scare traumas, stress injuries besides any direct physical injuries in the event of a collision strikes by ships, structural or machinery movement. This operations all eventually, will result in potential injuries and premature deaths, as emphasised by Leigh J. K. et al. (2007). Works by J. V. Redfern et al. (2013), Nichol et al. (2017) and Calambokidis et al. (2019) also highlights this problem of strikes faced by the whale species in North America. The dense intensity of nighttime lighting is another critical feature during offshore operations interfering with the behaviour and the natural biodiversity of the area [Davies TW, Coleman M, Griffith KM, Jenkins SR. (2016); Estuaries and Coasts (2019)]. How much of an impact this makes in the life of marine mammals which feed on smaller fishes like tuna which aggregate around installations (Jablonski, 2008; Sackey and Lamptey, 2019). Another salient event impacting on the habitations of living organisms, believe to be climate change cannot be excluded when listing the challenges of the marine mammal habitation, as the subject of climate change impact, is not fully understood [Union of Concerned Scientist, (2010); Ryan F. Heneghan, Ian A. Hatton and Eric D. Galbraith's (2019)]. To better appreciate the problem, it is essential to examine all these identified parametric anthropogenic effects closely, and the very relationships –underpinning their impact when fully measured. Herewith, the study views the incremental offshore developments in the Gulf of Guinea as a 'potential consequence of disturbance' (PCoD)— a concept (New et al., 2014) needed to be investigated. To address these problems, we must gain a total understanding of the issues of operations in the Gulf of Guinea by providing answers to the research questions including;

> What mammal species can be fully identified within the region? What are the types of offshore operations taking place capable of generating stressful injuries? How much of an impact are operations offshore having in their ecosystem in terms of the food chain, migration, reproduction and health? Are these changing events in the area monitored and measured? Are these anthropogenic stresses related to any level? If they do, what form do they take and how far do they go? How much of changes can be attributed to climate change of the region, and is it evidential in the habitation and behaviour of the living organisms? What are the various obstructions that can lead to stresses among mammals? What nature do these varying stresses take? How are they manifested in the mammal's behaviour? Are they identified, monitored or measured? To what extent are these stresses shaping the behaviour of the living mammals? How well are these mammals adapting to the constantly changing physical environment? What are the current protective mechanism in place as well as a measure for preserving their habitations? How much priority is given to mammal life by operators? To what extent are these measures achieved as much as practicable? Is the Environmental impact analysis properly structured and directed toward evaluating mammal living standards? Do they identify these risks for redress? Are these measures adequately addressing any of the obstructions introduce

by operations? Are these changes of implemented measures monitored and how is the monitoring carried out?

1.3 Objective of the Study

General Objective

The study here, seeks to examine the extent of oil and gas exploration operations within the Gulf of Guinea, are growingly becoming a source of obstructionist stress to the lives of living mammals, thus, in other words, a potential source of significant disturbance; while determining the degree of interrelated impact of the operations on the mammal habitation in the region, in order to suggest most appropriate measures in mitigating such impact in the phase of climate change menace.

Specific Objectives

The four strategic objectives of the study are:

O_1: *To define and investigate the nature of the offshore marine environment, thus within the Gulf of Guinea.* The first objective is to elicit a general expert understanding of the region, the type of resources within, the nature of exploitative operations and procedures, in order to describe the salience of the accumulating anthropogenic obstructions as a criterion of stressful impact for the living marine mammal.

O_2: *Identify and Investigate the varied nature of the offshore operation and possible disturbances associated with the increasing offshore Exploration and Developments as favourable conditions capable of generating stress within the mammal habitation.* This objective is to test the independent effect of these various abnormally per spatial distributions of co-occurrence of mammal population and anthropogenic activities offshore, and their cumulative interrelationships as a representative case for stress on the mammal species.

O_3: *Investigate the impact of the various identified 'obstructionist stressors' on the habitation in the phase of regional climate change effects.* The attempt will be to assess the conditions of mammal population dynamics (in terms of their frequency or abundance) in comparison to environmental conditions in order to predict associated risks of impact on the general mammalian species distribution dynamics of the region, consequential to their behaviour and the statistics of mortalities recorded officially.

O_4: *To examine the Environmental control measure in operations Offshore by delimiting all negative impacts and drawing a resolution model.* The final objective is to verify the current environmental impact assessment (EIA) modelled required of operators by regulators per regulatory controls, their enforceability and conservation management responses are in line with international standards, however, explicitly considering local actions focused on mitigating effects sort in providing resilience in the phase of the hydrocarbon developments.

1.4 Domain and Scope of the Study

The domain of the research study focuses on growing maritime and offshore oil and gas activities in the Gulf of Guinea within the North Atlantic Ocean which does require a tremendous amount of resource and time spent on the field. However, due to the limited availability of resources and time to the researcher, the scope of the study is thus limited to Ghana's thriving offshore operations, assessed to be among the fastest-growing deep-sea marine exploration industry (Robin Dupre, 2014; Tim McDonnell, 2018; CNBC Africa, 2019) in West Africa in light of recent discoveries. This phenomenon notwithstanding, the data gathered shall be a scalar representation of the natural ecological diverseness, potential developments across the vast gulf and predictable rise in deep-water exploitation within the Gulf of Guinea. The study makes a case for the mammal habitation and the ecology of the ocean environment in the western basins of Cape Three Point enclave within Ghana's maritime boundaries while examining the changes since the onset of oil and gas development and production in 2010.

1.5 Methodology of the Study

The two-phase research design spanning five years at the onset of Ghana's first deep-water oil development makes use of exploratory and explanatory components. The exploratory phase will seek to combine qualitative and quantitative case study methods in the gathering and analysis of data (mixed-method of approach). Essentially, it aims at describing the specific direct impact per the parameters measured, thus, insofar as simulating the consequence of the marine and subsea operations in modelling a response to the potentially identified environmental challenges.

The specific goals to this phase are designed to; (a) elicit the significant impact of the highly concentrated number of offshore marine and subsea operations in the area as an ‘obstructionist’ determinant for “stress” exposures to the mammal habitation and their surrounding environment, and (b) specify the design of mammal habitation-friendly *EIA* model requirements in consonance to aggregating operations in the region. This design could predict variation in the presence of mammals as well as the growing ‘obstructions’.

The data gathering process makes use of instruments based on ships’ official data record keeping, direct and indirect interviews, surveys and site qualitative observations. It is the primary means of the data collection process. Data gathered will include text-form, images, videos and sounds (acoustic). The study acquires these varying datasets stated, from the different data sources identified by taking into account; time spent on the field, and the attendance to specifically identified institutions; the time conveniently available to resource persons sampled; and the limitation to access to operational assets affecting researcher’s conduct on the field of study.

Direct specific observation of the mammal species within the sonar regions exceptionally, may not be possible without the use of remotely operated vehicles’ (ROV) fitted with underwater cameras, environmental survey sensors. However, primary field observation for marine mammal sightings depends on the surfacing of these marine mammals in determining their presence and distribution, while indirect observation achieved through documented records and third-party accounts. The main task will be to make a systematic record of day-to-day interactions with experts, site observations, and also through formal and informal conversations (Bernard 1994 pp180-207; Gravlee, and Bernard, 2014). Other data collected to aid in developing the study is the review of relevant secondary data, gathered through the newspaper articles (both online and hard paper), electronic pdf books, magazines, journals, and many other sources. The study will attempt to answer the questions raised by relating the problems of PCoD to the main identified elements of obstructions chosen as parameters.

These parameters to be tested concerning natural behaviours of the living organism are; (i) the impact of Surface and Underwater Noises generated by ship engine, ROVs, (ii) the Vertical Movement flow of subsea loads (in determining the level of impediment or potential strikes), (iii) the High-intensity Lightening effects around installations, (iv) the Pollution, thus, measuring the levels of pollutants (oil spills, Sewage discharges, Gas Flaring, and (v) the Black Carbon emissions potentially influencing the local climate of the area. The institutions from which data will be sort include; EPA, GNPC, GMA, ENI, GPHA, Aker Energy, Tullow Oil Ghana, Baker Hughes, Petroleum Commission (PC), Springfield, who are the main stakeholders of the upstream exploitation areas. Others to be engaged include a few International Experts. A survey shall cover the members of the local and international fishing community familiar with the area. Overall, the fundamental question to be answered is: Do the above-identified conceptual conditions risk any form of "obstructionist stress" in the region as a PCoD and if so, what mitigating measures are there in-place as a remedy the situation, are they enough?

Following a mixed-method approach, the general architecture of analysis structure for qualitative data obtained is most descriptive (thus resulting in comparative arguments) and simplified based on the modified Ellinor's (2013); Lamptey and Sackey (2017) analysis structure depicted in Figure 42 of Chapter 3.0.

The results representation will then have discussed simultaneously with the data analysis, thus with the expectation, the buildup of critical knowledge will birth new ideas in the lead up to the conclusion of the study while helping generate recommendable actions and decisions policy and engineering-wise.

1.6 Justification of the Study

The study, when concluded expects to contribute knowledge on environmental sustenance in the offshore marine industry within the Gulf of Guinea that will help shape national policies with regards to the exploitation of natural resources in the ocean. This contribution is partly because the literature will be available to neighbouring West African nations as well. The study will further contribute knowledge of a newer understanding concerning the challenges the various elements generate and how interruptedly impact on the natural ecology of the marine environment in the area.

Furthermore, the study promotes the need for environmental sustenance in the midst exploitation of the national maritime boundaries within the Gulf of Guinea, by providing appropriate and practicable recommendations capable of ensuring operations in the area have limited levels of stress for mammal species.

The study will also make use of an integrated modelling technique which is a novel approach purposed at isolating and measuring the various stresses—after the significant impact on the mammal habitation.

1.7 Organization of the Study

The study first is organised into five chapters. Whereas chapter one of the study begins with an introductory component describing the nature problem and its implication for marine environmental sustenance, Chapter Two (2) developed is in three sections of which the first section is the clarification of concepts, thus a review of documents defining identified stressors subject to this study. The second section is the review of various literature on the identified stressors per study case. It then concludes with the third section providing the theoretical framework on which the whole study establishes.

The next section is Chapter Three (3) which describes the entire method upon which the study conducted defines parameters measured and the suitable of the method to the researcher's goal set. Chapter Four (4) segregates into three sections –each dedicates to an environmental parameter and examines for analysis as a full case study. The first section (4.1) looks into the nature of the marine environment, habitations and the vulnerabilities associated therein. The second section 4.2 identifies and examines the mammalian population of the area. The final section 4.3 investigate the nature of surf operations and impact on the environment and marine life. Chapter Five (5) concludes the study by leading discussions, developing a summary respectively per relationships in the findings, and then concluding by developing pragmatic environmental sustenance recommendation. This chapter is then followed by a reference list, an acknowledgement and an Appendix.

1.8 Limitation of the Study

The work intended is to cover the entire offshore regions within the Gulf of Guinea currently undergoing some form of surf operations, however, due to limited access, logistical challenges and time, the study is hereby limited to surf operations with Ghana's active offshore oil and gas region and access route for the offshore ships. This work subsequently has limitations with enough travel interviews and time spent on the survey site as a result of Covid-19 restrictions. Thus there is also a challenge of direct data acquisition from the site.

CHAPTER TWO

2.0 CLARIFICATION OF CONCEPT, LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Clarity of Concepts

The study does seek to examine the Growing Deep-sea Oil and Gas Exploitation Within the Gulf of Guinea; as a Source of Concentrated' Obstructionist Stress' for Marine Mammal Habitation in the phase of Climate Change. Henceforth, preceding paragraphs in this section provide the historical relevance, operational working definitions on crucial concepts, namely: the *Gulf of Guinea, Deep-sea Oil and Gas Exploitation, 'Obstructionist Stress' (i.e., anthropogenic factors), Marine Mammal Habitation, and Climate Change*.

2.1.1 The Classifications of the Marine Environment

The world's oceans subdivided form several marine environments (shown in Figure 1, to encompass, the neritic (or inshore) pelagic zone, thus separated from the oceanic (or offshore) pelagic zone, stretching towards the edge of the continental shelf, which is at approximately 200 m depth generally. Benthic habitat extends the seabed onward into the oceans floor). Since vast portions of the ocean environment are in perpetual darkness, animal life within depends directly or indirectly on marine plant production. Such plants, however, are forced to rely upon limited essential nutrients such as phosphate and nitrate—present in minimal quantities. Scientists note that only 50 per cent of the sun's radiation can penetrate the ocean surface –however, disappearing rapidly along with depth. Essentially, environmental fluctuations are at the greatest at or near the surface of the ocean. This region is where the oceans' interactions with atmospheric conditions produce temperature and salinity variations generates water turbulence (winds) and leads to gaseous exchanges. Effectively, deeper along the water column, conditions such as temperature, salinity, density and velocity tends to be constant environmental parameters. These vertical gradients, therefore, are predominant features of the oceans environment— establishing depth zones that delineate the types of living conditions for organisms. Thus, not only does light diminish with depth, but temperature also decreases to constant values of 2-4°C. At deeper depths, food increasingly is scarce, while hydrostatic pressure increases and nutrients tend to be more concentrated (Lalli C. M. and Parsons T. R., 1993, 1997). Depth-related changes in environmental conditions delineate distinctive vertical zones, for which many marine animals tend to be restricted. Again, geographic barriers along a horizontal scale, also are delineated by physical and chemical differences within the water column in seawater.

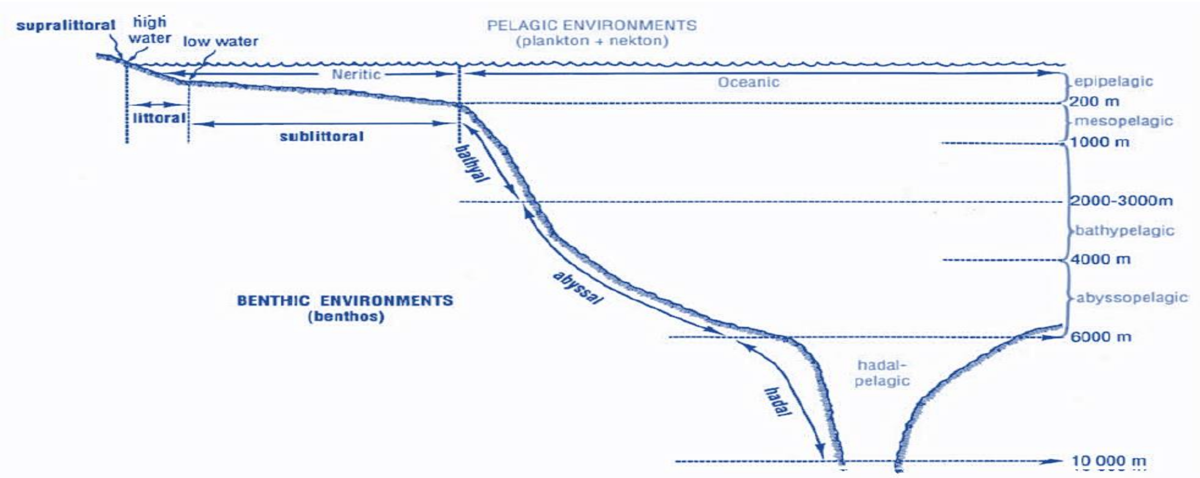


Figure 1: The schematic diagram (not to scale) showing the primary ecological divisions and subdivisions of the marine environment— the most basic division is what separates the 'pelagic' from the 'benthic' realms. The marine pelagic environment (thus, pelagic meaning 'open sea') refers to the water column, lining the surface to the greatest depths. In contrast, the benthic environment (thus, benthic meaning 'bottom') encompasses the seafloor and does include areas such as the shores, the littoral or intertidal areas, coral reefs, and the entirety of the deep seabed, Courtesy Lalli C. M. and Parsons T. R., (1993,1997).

Another such fundamental division that which separates the vast open ocean, referred to as the oceanic environment, from the inshore neritic zone (Figure 1). This division relies on the water depth and distance from land, hence, the separation is conventionally deduced at a 200 m depth limit which generally spans towards the edge of the continental shelf. Nonetheless, the west coast of South America where the continental shelf appears to be very narrow, the neritic zone does extend a distance from shore marginally. Other areas including the shelf off the north-east coast of the United States, for example, the ***neritic*** zone may appear to extend several hundred kilometres away from the mainland. In all, the total continental shelves across the globe assumed to underlie approximately 8% of the entire oceans, thus, forming a land coverage equivalent in approximation to the total of Europe and South America combined. There are further divisions of the pelagic and benthic environments. These refer to distinctive ecological zones based on depth and bottom topography for any marine life native to the areas. Marine organisms, therefore, can be classified under the marine environments they relatively inhabit. Thus imply, marine organisms are herewith tagged marine species or neritic species depending on whether these organisms are found natively within offshore or coastal waters, respectively. In a similar fray, marine plants or animals living in association with the seafloor are classically called benthos species. In other words, the benthos species consist of attached seaweeds, sessile animals (e.g. sponges and barnacles), and the crawling animals including those that burrow into the substrate (Lalli C. M. and Parsons T. R., 1993, 1997).

The concept of evolution suggests, there are three orders of mammals' lifeform spanning thousands of years that evolved with different terrestrial ancestry and have independently adapted to living in the sea. These three orders identified, include:

(a) the whales, dolphins and porpoises set: of the order referred to as Cetaceans,

(b) the seals, sea lions, and walruses set; of the order Pinnipeds, and

(c) The dugongs, manatees, and sea cows set belonging to the order Sirenians (or sea cows) respectively (Lalli C. M. and Parsons T. R., 1993, 1997; United Nations (2016)), all are occupying a wide range of marine and some freshwater habitats around the world. They are the only aquatic herbivorous mammals in totality, primarily feeding on submerged (underwater) vegetation.

According to United Nations, other marine mammals designated include the mustelids (sea otters and marine otters) and the polar bear – making 130 or more species in total, some inhabitations of freshwater, thus exclusively occupying rivers and lakes.

These all share the unique mammalian characteristics of being warm-blooded (***Homoiothermic),*** capable of nursing their young, and rely on the breath intake of atmospheric air. J. Kennedy (2019), reiterated that the order Cetacean is said to comprise of approximately eighty (80) species of marine mammals known among the whales, porpoises, and dolphins' family. Lalli and Parsons, however, suggest the Cetacean order has a makeup of approximately 76 species. This differences are as a result of lapse and further observations and do show the relevance of the classifications. The ancestry of this group historically, are said to be land animals that migrated into the sea about 55 million years ago (Lalli C. M. and Parsons T. R., 1993, 1997; J. Kennedy (2019)). Lalli and Parsons, further asserted that the largest of the marine mammals in the ocean are the *baleen whales* (shown Figure 2); and as such these included the most prominent marine animals that have ever lived, called the **Blue Whales** – capable of attaining a body length of 31 m long.

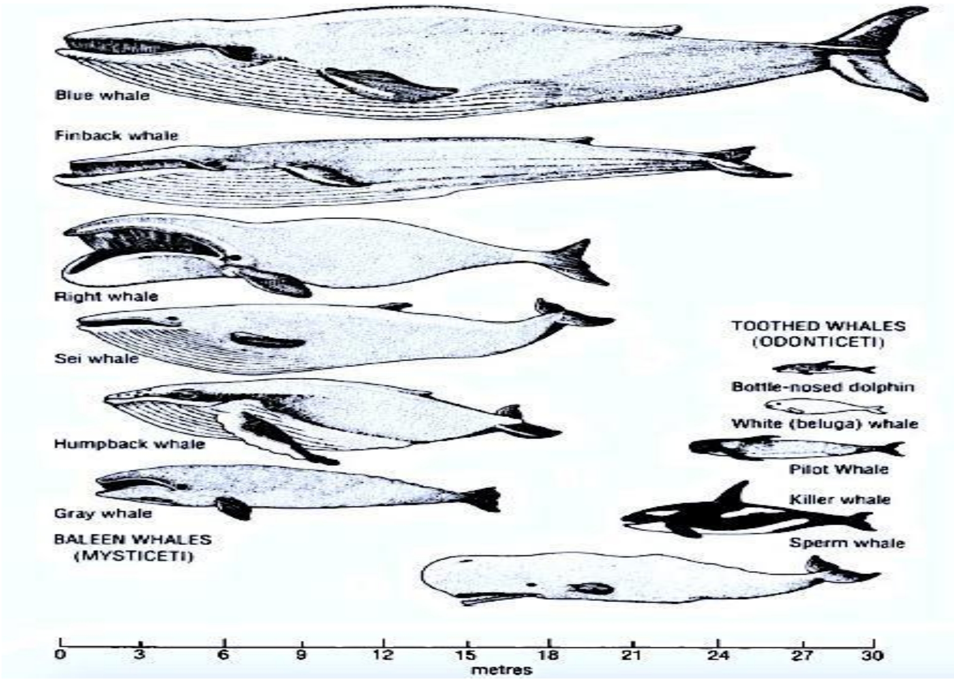


Figure 2: Image showing the relative sizes of baleen and toothed whales courtesy Lalli C. M. and Parsons T. R., 1993, 1997pp150.

Baleen whales subsequently, tend to form a separate suborder (*Mysticeti*) comprising of about ten unique whale species. The suborder of whales under ***Odonticeti*** order includes the over 66 (roughly 70) species of cetaceans, all of whom are equipped with teeth and sub-characterised with the feature of single blowholes instead of the two, as can be found in baleen whales. The **Odontocetes**, therefore, include the remaining whales, dolphins, and porpoises (all shown at the right lower end of the image in Figure 2). The toothed whales described are formidable predators in the sea, capable of taking squid or fish as Prey. According to Lalli and Parson, some scientists have suggested that when one considers the cetaceans as a whole, then perhaps the sperm whales alone, have consumed a greater quantity of Prey than that taken in by the world entire commercial fishery industry. Citing an example, they indicated that, between 1979 and 1982, eighteen (18) whale species of the cetaceans' order consumed between 46,000 to 460,000 tonnes of Prey annually near Georges Bank, off the north-eastern coast of the United States, compared with the commercial harvest of the same area amounting to 112,000 and 250,000 tonnes. In the Mediterranean, where squid catch figures are essential in the human diet, cetaceans estimated, eat about 2 or 3 times more squid than that taken by humans. It was suggested that before commercial whaling fleets decimating the whale populations of the Antarctic ocean, baleen whales might have been consuming approximately 190 x 10^6 tonnes of Krill annually – a figure representing more than twice the total world catch of all marine species by humans. It is, therefore, no surprise that fisher folks do often regard cetaceans as their competitors for fish and squid stocks (Lalli and Parsons, 1993, 1997 pp152). The western African sub-region is also home to many of these cetaceans of both beaked whales and small cetaceans, manatees and dugong, belonging to the order Sirenia (or sea cows). These identified species are therefore listed in Table 1 below, howbeit, conscious of the fact that insufficiency of information and research on small cetaceans within the western African region (although, too much at a lesser degree towards the northern part of Macaronesia), no list of the species in the country coastlines where they occur is yet available (UNEP CMS ANNEXE II, n. d.).

Table 1: Some identified marine mammals within the West African Marine Environment

MARINE MAMMALS OF WEST AFRICA REGION			
SMALL CETACEAN	S. Coeruleoalba	Kogia Breviceps	Pseudorca Crassidens,
	S. Frontalis	Kogia Sima	Orcinus Orca
	S. Clymene	Ziphius Cavirostris	Globicephala Macrorhynchus
	Delphinus Delphis	Cephalorhynchus Heavisidii	Globicephala Melas
	Delphinus Capensis	Sousa Teuszii	Phocoena Phocoena
	Lagenodelphis Hosei,	Tursiops Truncates	Mesoplodon Densirostris
	Grampus Griseus	Steno Bredanensis	Mesoplodon Bidens
	Peponocephala Electra	Stenella Attenuate	M. Europaeus
		S. Longirostris	Mesoplodon spp.
BEAKED WHALE SPECIES (CETACEA: ZIPHIIDAE) J. CETACEAN	Mesoplodon Mirus M. layardii, M. grayi, Lissodelphis peronii, Hyperoodon ampullatus, Lagenorhynchus obscurus		
SIRENIA	Trichechus senegalensis		

Table prepared base on Culik, B.M. (2004). Review of Small Cetaceans. Distribution, Behaviour, Migration and Threats. Marine Mammal Action Plan/Regional Seas Reports and Studies no. 177; MacLeod, C. D. et al. 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). J. Cetacean Res. Manage. 7:271-286). Courtesy (UNEP CMS ANNEXE I & II, n. d.).

2.1.2 The Phenomenon of Marine Mammal Migration

The Marine Mammal migration phenomenon is observed as the seasonal movement of marine animals from one place to another within the broader marine environment. In light of this, Kennedy (2019) reiterated that many of the whale species tend to migrate, thus alternating between their feeding zones and breeding grounds – with some travelling longer distances amounting to thousands of miles. Some whales, on the other hand, migrate along the latitudinal planes (between the north-south poles), while others observed alternate their travels near onshore and offshore areas, many others tend to do both. It is the belief that the over 80 species of whales, each have their movement patterns, many of which are not still fully understood according to J. Kennedy (2019).

However, there is a general assertion; whales migrate towards colder waters near the north and south poles during summer, and towards the more tropical waters for the warmth along the equator in the winter. These major patterns favour the whale population into taking advantage of productive feeding grounds in colder waters during summer, and then when productivity slows, allows them to migrate to warmer regions of the waters and where necessary, give birth to younger calves (as seen in Figure 3). Lalli and Parsons (1997) in agreement with Kennedy (2019) also suggested this is common with Baleen Whales. They assert that some of the large baleen whales (e.g. greys and humpbacks whales especially) make extensive seasonal migrations, while usually breeding in winter within tropical waters and subsequently, moving poleward for feeding in summer. It is, however, emphatically asserted that not all whales in a population might migrate, with an example being the juvenile humpback whales. Thus, they appear not matured enough to reproduce and may not travel as far as the adults do. Hence, they often stay in the colder waters of the temperate zones where they learn to exploit Prey that occurs there during winter. In other words, the smaller cetaceans do not undertake long migrations, but rather move in response to changing food supplies or any physical changes. Some of the whale species identified with fairly well-known migration patterns do include:

Grey whales have the longest migrations among any marine mammal, travelling distances over 10,000 to 12,000miles round trip from their breeding grounds along Baja California to their feeding grounds in the Bering and Chukchi Seas near Alaska and Russia. The tracking of a Grey whale reported in 2015 broke all marine mammal migration records –travelling from Russia to Mexico and back over a distance of 13,988 miles in 172 days [Journey North (2009)]. Humpback whales also migrate far - one humpback whale happened to have been sighted off the Antarctic Peninsula in April 1986 and then re-sighted off Colombia in August 1986, which suggested it had travelled over 5,100 miles. The **Grey whales** and **humpbacks** tend to migrate close to shore. However, the migration routes and distances of many whale species (the fin whale, for example) are still relatively unknown according to Clapham, Phil. (1999); Mead, J.G. and JP Gold. (2002); Geggel, L. (2015); Journey North (2009); J., Kennedy (2019).

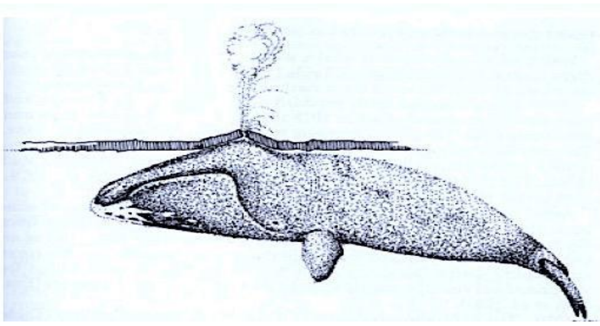
2.1.3 The Marine Mammal Navigation and their Use of Sound

Sound identifies as a critical component to marine mammal navigation or movement. To this effect, the University of Rhode Island and Inner Space Center (2019) in attempting to discuss this subject comprehensively alluded to the following; that the uses of sound for navigation by marine mammal cannot be overemphasised, and remains critical especially when other senses of these mammals are of limited uses. Predominantly during ***echolocation***[1] by **Odontocetes** (toothed whales) which have extensively been investigated by the scientist, studies suggest for instance that; they produce rapid series

[1] **Echolocation** is defined as the *"process for locating distant or hard-to-see objects using the reflection of sound waves. The distance of objects or depth of the seafloor can be determined by measuring the time it takes for reflected sound waves (echoes) to return to the sound source. Some whales and dolphins use echolocation to identify underwater objects and to help find food".*

of sound ***'clicks'*** with the returning echoes providing essential information concerning objects within their vicinity. A classic example is the deep diving **Sperm Whales *(Physeter Macrocephalus)*.** They tend to produce a series of 'clicks' sound before their dives. The interval between their clicks examined is consistent with target detection of multiple elements within their environment. Elements such as distance to the seafloor or the surface are a function of the operations [Zimmer, W. M. X., Tyack, P. L., Johnson, M. P., & Madsen, P. T. (2005); Jaquet, N., Dawson, S., & Douglas, L. (2001)].

Another example is the migrating Bowhead Whales, which rely on acoustic cues in detecting the presence of ice and the measurement of its thickness. The migratory path of **Bowhead Whales *(Balaena Mysticetus)*** takes them under the Arctic pack ice. According to the University of Rhode Island and Inner Space Centre, their migration usually commences in winter during which –it is very little or no sunlight and often under iced waters (i.e., no open waters). In such scenarios along their route, these whales tend to make use of the arched area around their blowhole in pushing up against the icy carp over waters, subsequently breaking through, and then creating what they described as their breathing holes/cracks [George et al., (1989); Elsner, R. (1999)]. The situation clearly is illustrated in Figure 4 and 5 above. When considering the acoustic capabilities of Bowhead Whale sounds and its scattering properties along the different stages of ice, scientists conclude with the view, the call of these whales would reflect differently off a thicker ice floe or ice keel concerning an area of thinner ice. Accordingly,



this perceived difference does allow the whales to detect thin, or new ice that is best suited for breaking through to form a breathing hole (as shown in Figure 5) [Ellison, W. T., Clark, C. W., & Bishop, G. C. (1987); University of Rhode Island and Inner Space Center, (2019)].

2.1.4 Understanding Marine Mammals Feeding Practice and their Use of Sound

University of Rhode Island and Inner Space Center (2019) attest marine mammals make use of sound in a variety of ways during feeding. One such feeding strategy is the echolocating of Prey described in detail. **Echolocation for Prey**: (as shown in 6 (a)) is one very much well-known to the scientist.

During this process, the mammal produces short pulses of sounds which consequentially reflected, echoes upon striking their target object. These animals use this returning echo information to learn of their immediate environment, including the distance to their potential prey items. Thus, the farther the object is from the mammal, the longer the echo of the sound takes to return. However, sounds of both low and high frequency over the years detected have been to be associated with specific feeding behaviours—implying, they resort to high-frequency sounds where the targeted low-frequency signals tend to return no information suggesting of no immediate prey within their vicinity. Hence, targeting preys further away [Payne, R., & Webb, D. (1971); Clark, C. C., & Ellison, W. T. (2004)].

It explains further that when echolocating mammal gets closer within the distance of its targeted prey item, the rate of the ***'click train[2]'*** produced becomes rapid and rapid at every closing distance of interval. Henceforth, the interval between clicks grow shorter, resulting in the capture attempt of the prey item; at this point, the **click train** starts to sound when heard like a ***buzz***. Again, the difference in the sound of the returning echoes from the original click produced by the animal is essential to determining specific properties of its prey item. Thus, the echolocating animal can determine the size, shape, orientation, direction, speed, and even the numerical composition of its subject from the difference in in the original clicks and the returning echoes [Jaquet, N., Dawson, S., & Douglas, L. (2001)]. Scientist claim, for example, Dolphins can detect and identify targets of the size of a golf ball at distances of 100

[2] *Click Train: Is a term used to refer to a series of echolocation sound clicks*

meters (of the size of a football pitch). The sound beam during echolocation clicks has also been described as directional and is controllable with slight turns of the head of the animal.

Blainville's Beaked Whales[3] , on the other hand, are silent near the surface of the water (as seen in Figure 6 (b)), and known to produce sounds when submerged at depths. At depth, scientist asserts there are two phases to their foraging dives of which during the descending phase of their foraging dive, these deep-diving whales tend to produce mid-frequency broadband sound ranges in underwater dB, different than their echolocation signals, produced before onset of the foraging clicks, before the deepest point in their dive. For the Blainville's beaked whales, scientists have determined the two distinct types of foraging clicks as: (i) search clicks and (ii) buzz clicks, each occurring at a different phase of the foraging dive.

(i) **Search clicks:** emitted during the approach phase, with intervals of 0.2-0.4 s at a frequency range of 26 to 51 kHz, this implies strong echoes received are from these clicks, which scientists believe functions in enhancing detection and classification of target prey. Essentially, when the targets evaluated are to be one body length away (2-5 m), these whales switch to *buzz clicks*.

(ii) **Buzz clicks:** are relatively short bursts of sound clicks at a frequency range of 25-80 kHz or higher. Usually, these sounds are highly repetitive clicks, which scientists estimate to be 300 or more times occurring within the last 3 meters of their approach to the potential target.

Coordinated feeding activities: comprises other feeding strategy deployed among Toothed Whales and Baleen Whales [Payne, R., & Webb, D. (1971); Tyack, P. L. (1999)]. In this feeding adventures, they tend to produce a variety of other associated sounds. Humpback whales, for instance, may display a wide variety of feeding strategies, inhabited in their broad acoustic repertoire capabilities which scientists claim relate to different feeding behaviours. They cite the western North Atlantic Ocean's

[3] *Blainville's Beaked Whales (dense beaked whales): are about 5m (16 ft) long and weigh about 1 metric ton. They are found in tropical/subtropical regions of the ocean worldwide. Their lower jaws are strongly arched, which, in males, house a prominent pair of teeth. These tusk-like teeth actually erupt through the upper jaw (shown here in figure 2.3b above)- this provides a distinctive profile for species physical identification.*

humpback whales for producing ***"paired burst"*** sounds when engaged in bottom-feeding behaviours during which other humpback whales sighted to be nearby. These sounds produced were short (thus <0.25 s), with broadband pulses at peak energy below 1 kHz frequency. Tagging data have shown that whales within this area feed on sand lances living on the seafloor; thus, in other words, they making flat-bottom dives at multiple rolls in coordination with one another.

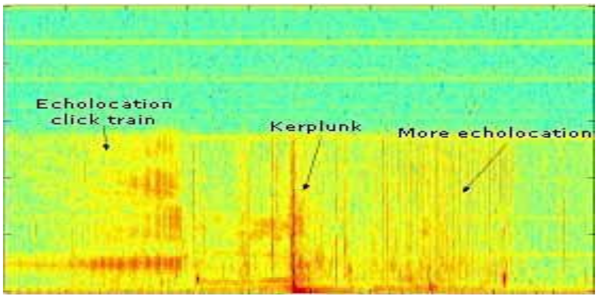
Another of the coordinated feeding strategy is the ***Lunge-feeding*** (this is as seen in Figure 7 and 8. Under this feeding behaviour, scientists studying these mammals in Southeast Alaska observed a pattern of humpback whales in large groups producing sounds at depth, preceding the group lunge-feeding. They explained that the whales remained silent at the surface before the feeding event in many of the events. As members within the group dive, they began producing low-level vocalisations, and throughout the dive, the vocalisations level increased, culminating in loud "***feeding cries***." Immediately, the large group of whales suddenly lunge to the surface of the water, having their mouths agape. This behaviour is also in a coordinated manner. ***Feeding Cries*** are at an interval range of 0.4 to 8.2 s, with short, frequency-modulated having an introductory and ending component. However, the main body of the feeding cries' call ranges with a fundamental frequency of 360-988 Hz.

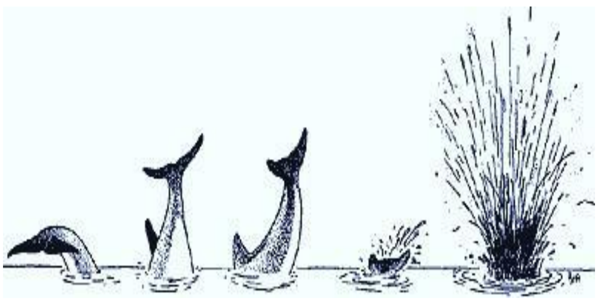
Scientist reckons the Humpback whales have over the years developed another lunge-feeding technique called the ***"Bubble Netting"*** (as shown in Figure 7 (a) and 7 (b)**.** With the technique, the mammals swim in upward spirals (or loops), during which they simultaneously blow rings of bubbles underwater. These set of bubbles surging upwards startle the fishes which are the ultimate Prey— causing them to densely aggregated. These more efficiently enable them to capture their Prey. The bubbles by the humpback whales are produced as continuous streams or at short bursts. There are sounds created that associate with bubble generated and at the time of explosive bursts when the bubbles rise and break at the water surface. It remains unclear to the scientist whether *startling* observed among fishes is due to the sound, the sighting of the bubbles, or perhaps both.

Furthermore, acoustic signals are observed among Hawaiian spinner dolphins groups to play a synchronising role in cooperative feeding (of either small fishes, shrimps, or squids) events at night offshore. Scientists used a multi-beam echo sounder in tracking their movements, which they notice a pattern of strict geometrical nature, having tight timing, towards herd prey into very dense patches. This observation is before having pairs of dolphins "take turns" feeding within the aggregated Prey.

The Clicks consistent among spinner dolphins during echolocation have been recorded and correlated to the timing and shape of their foraging stages, with the clicks produced often at periods the animals observed is changing their geometric formation. That is, for example, from a tight line into a circle. This observation is one reason why scientists hypothesise the clicks during foraging transitions by the dolphins. It thus allows them to gain information about their preying field or changing positions of members within the group.

Other feeding strategies: identified include the ***Kerplunking*** and the ***passively listening for Prey***. The Bottlenose dolphins noted are for making sound and bubbles, especially those observed foraging along seagrass beds near Australia and Florida. They deploy the foraging technique termed ***Kerplunking.*** In this instance, they tend to drive fishes from their seagrass protected habitats by lifting their tails, high above the surface of the water (as seen in Figure 9), while lowering the body out of the water and subsequently slapping it on the water surface. This behaviour results in loud splashes creating trails of bubbles underwater. In the event, this gets the fishes startled and flushes them out of their hiding places, making it easier for both visual and acoustic detect by the dolphins.





The spectrogram in Figure 9 above is a clear example of a Kerplunk technique recorded by a foraging dolphin in Australia. According to the scientist who made the observations, an example will start with series of echolocation clicks that develops to sound like a buzz, during which the kerplunking happens within 2.5 seconds producing a resounding splash sounds. It then is preceded with more echolocation sounds which gives an indication the dolphin is scanning for fishes driven out from the seagrass habitats. Other scientists who observed similarly in Florida found the dolphins producing ***"pop"*** sounds as additional flushing means for fishes. In effect, both the pops and Kerplunks tend to produce low-frequency sound energy capable of startling fishes. Pops differ from echolocation clicks in terms of having more energy transmitted at lower frequencies, spanning longer in duration, unlike the clicks produced in trains. Other Bottlenose dolphins, for example, those in Scotland, appear to use sound to startle or disorientate their Prey such as salmon by producing "*brays*.[4]"

Finally, ***passively listening for Prey*:** behaviour is another foraging strategy by mammals. Herewith, the marine mammals listen for any sound produced by other animals. It is peculiar amongst ***transient killer whales,*** which strategically cue into listening to vocalisations of their potential mammal prey. Besides, fishes noted also make varieties of sounds, cetaceans and pinnipeds are familiar with and capable of hearing. Seals and sea lions, on the other hand, benefits more from initial detection by listening for Prey while using their sensitive whiskers in tracking the path of fishes as they attempt to escape. There is also an assertion; foraging seals can hone into signals produced by acoustic tags placed on/inside fish, termed the "dinner bell" effect *(National Geographic Crittercam. 2013; Dosit.org, 2019).*

2.1.5 Challenges and Observed Changes in Marine Mammal Population and their Habitation

Historically, the Inuit race of North America as believed are hunters of marine mammals overages, but the earliest records of the whaling activity started along the stretch of northern Europe between AD 800 and 1000. Thus, whaling became the principal commercial enterprise between the 1700s and 1800s where whales were exploited primarily for oil used in lamps, and the whalebone (baleen) used in stiffening women's apparel. Whale meat was only of secondary importance, except amongst Japanese. The advent of increased mechanisation, motorised high-speed marine vessels, and the use of explosive

[4] Brays: is a type of burst-pulsed, low frequency (<2 kHz) call. Scientists believe the brays stun the fish. The calls may also advertise a feeding event to other dolphins and coordinate their activities.

harpoons in the early 1900s— marking the era of rapid human advancement and development, also did result in the rapid decline of the whale populations, and thus, threatening the extinction of some unique species. This event ushered in the International Whaling Commission (IWC) in 1946 as a regulatory body. Even after its establishment, the annual catches of whales continued to climb to an estimated figure of 65,000 in the 1960s.

Table 2: Past and present population estimates of whales. All estimates are from the International Whaling Commission, and most are highly speculative.

Common name	Scientific name	Population estimates	
		Pre-exploitation	Present
Baleen whales:			
Blue	*Balaenoptera musculus*	228 000	<10 000*
Fin	*Balaenoptera physalus*	548 000	150 000*
Sei	*Balaenoptera borealis*	256 000	54 000*
Bryde's	*Balaenoptera edeni*	100 000	90 000
Minke	*Balaenoptera acutorostrata*	140 000	725 000
Bowhead	*Balaena mysticetus*	30 000	7800*
Northern right	*Eubalaena glacialis*	No estimate	<1000*
Southern right	*Eubalaena australis*	100 000	3000*
Humpback	*Megaptera novaeangliae*	115 000	10 000*
Grey	*Eschrichtius robustus*	>20 000	21 000*
Toothed whales:			
Sperm	*Physeter catodon*	2 400 000	1 950 000*
Narwhal	*Monodon monoceros*	No estimate	35 000
Beluga	*Delphinapterus leucas*	No estimate	50 000

** Listed as an endangered or vulnerable species by the International Union for the Conservation of Nature or the United States Government.*

A reproduction of a table from the second edition of Biological Oceanography courtesy (Lalli C. M. and Parsons T. R., 1993, 1997).

The pre-exploitation and population estimates of 13 species given are in Table 2; of these same species, nine listed are endangered or vulnerable species since the dawn of 1970. Perhaps, given the low fecundity and slow developmental phase of times for the great whales, a severely depleted population could take several decades to recover. It is essential to note that only one species, the **Minke Whale,** is known to have significantly increased in abundance. These relatively small Minkes were the least heavily exploited. There is also a suggestion; the southern population might have increased due to decline of the larger baleen whale species to which it competed for Krill.

By 1986, the IWC voted subjectively to establish an indefinite ban on commercial whaling activities in the hope of re-establishing a sanctuary for the endangered stocks. The IWC subsequently designated 28 x 10^6 km square around Antarctica as the whale sanctuary in 1994, ensuring permanent protection for an estimated 90% of the world's whale population. However, these measures did not minimise the slow cetacean mortality as a result of other salient factors. Smaller dolphins and porpoises were at the mercy of fishing nets, trawlers, and hooks which tend to capture them incidentally; again, cetacean whales which did reside in, or entered temporarily, into coastal waters became subjected to increasingly habitat destructions and Marine Pollution. There is no doubt that marine Pollution does threaten the ***Beluga whale*** populations within St. Lawrence Estuary of eastern Canada and the river dolphins of many other areas. These changes according to the United Nations (UN) (2016) take the form assessed –in terms of;

(i) **Biological Diversity:** a global phenomenon over the last several centuries indicates that certain species within marine mammals' families have become extinct. The Steller's sea cow, the Caribbean monk seal, and the Japanese sea lion are classic examples of those under manatee order. The Yangtze River dolphin (baiji) has also earmarked a species quickly headed for extinction, although there was one unconfirmed sighting in the year 2005. Many of the populations have been reduced to a remnant status, playing no significant role in the ecosystem. ***Right Whales*** have from the eastern North Atlantic, and ***Walruses*** from a former stronghold in south-eastern Canada (the Gulf of St. Lawrence and Sable Island) are examples. According to Estes et al., 2006, it is therefore essential to note that the loss of marine mammal diversity is either due to actual and functional extinction, both of which have significant adverse effects at varying scales from localised areas ocean-wide-basins.

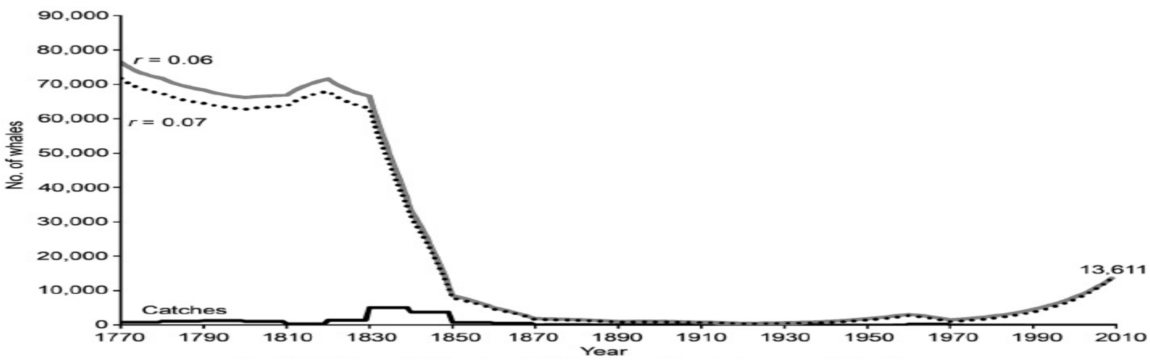
(ii) **The magnitude of changes:** other significant marine mammal populations have significantly reduced in terms of their numerical abundance (and biomass). These include all commercially valuable great whales sort through whaling. For example, the Antarctic blue whale population reduced into remnant status within the 20th Century, and of a current abundance at 5 per cent of original numbers, thus according to Branch et al. (2007). Busch (1985) also claimed that another mammals' population reduced to low levels; for example, the southern and northern hemisphere populations of fur seals and elephant seals harvested were for either fur or oil. Sirenians and sea otters' populations are not left out as they have reduced to small fractions of historic levels. It is worth mentioning that a number of them have since recovered after conservation measures design to protect from deliberate exploitation. Examples of the successes span the Eastern Pacific Grey whales, northern elephant seals, eastern Steller sea lions, humpback whales, and some populations of right whales. Other populations that remain at small fractions of historic levels include the western Pacific Grey whales, Arabian Sea Humpback Whales, Western Steller Sea lions, North Atlantic Right Whales, and Southern Right Whales (U.N., 2016).

2.1.6 The Population Trends and Conservation Status under the Aggregated Global Scale

The U.N. (2016) asserts that because marine mammal is of such great Diversity in species and habitation, there is some difficulty in characterising their conservation status and current population trends within an aggregate or global scale. Despite the challenge of commercial hunting reducing, massive changes of human demography and economy tend to have an unquestionable effect on the 'environmental carrying capacity,' particularly within coastal regions, according to the U.N. As a result, lesser suitable habitats and forage basins are the only available eco-environment left to support the marine mammal populations. These changes essentially leave the possibility of 'full' recovery unfeasible for relatively some species (U.N., 2016).

2.1.7.0 Population Trends of Major Taxonomic; to Geographic Subdivisions

(a) Large Whales: Commercial exploitation, which dates back to the 10th Century, resulted in severe depletion and even near-extinction by the end of the 19th Century with intensive whaling of some species and populations. This situation was exacerbated with the onset of Industrial mechanised whaling in the 20th Century, leading to further significant declines –reiterated by the U.N. However, some populations of large whales to include: humpback whales globally, the blue whales in some regions, and the southern hemisphere right whales –all considered as a single group, are recovering in many recent decades (thus, shown in the graphical analysis from IWC, (2013) depicted in Figure 11).



The U.N. posit at the time of this study, many other populations were failing to recover to anywhere near their original abundance, citing Jackson et al. study which found, (2011) right whales' population of the eastern North Atlantic effectively extirpated, and only barely surviving species to be those of the eastern North Pacific, the eastern South Pacific, and those around New Zealand.

(b) Pelagic dolphins and porpoises: the U.N. reiterated suggestion indicating; the marine pelagic (offshore) dolphins generally remain less susceptible to any human interactions than other marine mammals due to their relatively small size in nature. Moreover, they are of little commercial importance; they are wide-ranging (some species are also excessively numerous) and live far from most human activities. In the eastern tropical Pacific, they are subjected to fishing gears and military activities primarily. Due to symbiotic relationships with other pelagic animals such as yellowfin tuna, which is of commercial interest, several dolphin species in that region are significantly affected by human activities. For example, Purse seine fishermen have "learned to chase and encircle these dolphins to facilitate the capture of tuna," leading to large numbers of dolphins drowned in the fishing nets in the past. To this effect, Hedley confirmed the mortality reduced abundance of several dolphin species broadly towards the latter half of the 20th Century. Consequent to the issue, international efforts led to fishing methods changes and a significant reduction in the by-catch (Hedley, 2010; NMFS, 2009; U.N., 2016pp3).

(c) **Coastal and Estuarine dolphins and porpoises:** several States allow the hunting of Coastal dolphins and porpoises for food and bait. As alluded to earlier, they often are entrapped to their death accidentally in the fishing gear of coastal commercial and artisanal fisheries. Hence their population is said to remain at critical levels. The Vaquitas in the Gulf of California (Mexico), for example, declined by 57 per cent from 1997-2008 and continues to decline (Gerrodette et al., 2011). The Māui dolphin, a subspecies of Hector's dolphins in New Zealand, also declined to low levels (Currey et al., 2012; Hamner et al., 2012). CIRVA (2014) suggests, in each case, managerial interventions towards minimising these direct mortalities and entanglements need consideration. However, they assessed the current levels of the challenge; these trends expected are to remain for both the vaquita and the Māui dolphin, which are at risk of extinct within the next few decades.

It is relevant to reiterate that the mammalian marine habitation remains diverse in various regions, and several such species of 'small cetaceans[5]' observed are to live within estuaries and large rivers that are often close to human dwellings. As such, they remain threatened by artisanal fisheries, Pollution, and coastal development. Examples of cetaceans comprise the two South American river dolphins (i.e., the ***tucuxi*** and the ***boto***). In the Western Africa and Macaronesia region, small cetaceans are an important component of the marine biological Diversity, with over one-third of the world's known species of small cetaceans found are in this region (UNEP CMS, 2008). They further emphasised, claiming "conservation situation of small cetaceans in western Africa is not well known, in contrast to other regions of the world excluding South Africa and parts of Macaronesia."

For this study, we re-examine the small cetacean species of western Africa in terms of:

- **Species distribution:** The distribution of small cetaceans within the West African region is not a well-known phenomenon. However, there is an assertion 30 different species found are here, and that does include "the endemic Atlantic humpback dolphin (Sousa Teuszii) and largely isolated populations of long-beaked common dolphins (Delphinus capensis) and harbour porpoises" (refer to UNEP CMS ScC10, 2001: list of these species reproduced in Table 1). These are migrating wild species with expansive range habitats. Hence, the coastline concern encompasses the African Eastern Atlantic, at Morocco bound north and then towards South Africa (thus, hereinafter referred to as western Africa), to include Macaronesia.
- **Species Status:** Although 30 species of the small cetaceans' suborder identified are in western Africa and Macaronesia, only 11 of them are listed in UNEP CMS Appendix II (November 2005) and Table 1 of this study.

(for further reading, refer to WWF – Conservation of Dolphins, available at http://www.panda.org/about_wwf/where_we_work/africa/where/senegal/index.cfm?uProjectID=9F0781).

[5] Small cetaceans are defined as all species of toothed whales (Odontoceti), with the exception of the sperm whale (Physeter macrocephalus).

Among these listed species, the harbour porpoise, the striped dolphin, the short-beaked common dolphin, the long-finned and short-finned pilot whales, and the killer whale are those generally well documented biologically.

2.1.7.1 The West Africa Marine Population Trends

The appendices of CITES (2007) refer to only the Atlantic humpback dolphin (Sousa teuszii) in its Appendix I when listing species most endangered among CITES-listed animals and plants, threatened with extinction of which CITES prohibits international trade in specimens of these species except for non-commercial use. All other species listed were in Appendix II. In the year 2006, International Union for the Conservation of Nature's (IUCN)[6] *Red List of Threatened Species* identified and categorised 10 of the region's species as Data Deficient, with the natural history indicating no singularly known detail of small cetacean within the western African population (UNEP CMS, 2008).

It recorded that a critical change in manatee status occurred during the second half of the 20th Century, resulting in population fragmentation. It attributes this to the construction of dams and other developments projects. Regardless of the notion that major dams such as the Akosombo in Ghana and Kainji in Nigeria have created new areas of suitable manatee habitat, there is the problem of genetic isolation of populations and obstruction of movement along traditional waterways. Estimating their population size has not come easy and is still poorly known, though a few attempts to quantify populations of the animal in West Africa occurred. However, there is growing evidence to support a declining trend (UNEP CMS ANNEX I). According to Van Waerebeek et al. (2015), there is circumstantial evidence of population decline among small cetacean, Sousa teuszii. This cetacean naturally is found in the sea area that extends greater distance (>350 km) within core areas of the West African coast –in tandem with lack of sightings. They further explained it pre-suggests the familiar stocks of Dakhla Bay, Banc d'Arguin, and possibly Siné-Saloum may probably be reproductively isolated from each group; and from more southern stocks (Van Waerebeek et al. 2004; Collins 2012). Waerebeek et al. 2004, 2009, 2015; Van Waerebeek and Perrin 2010; Debrah et al. 2010 suggest further

[6] IUCN: represents the International Union for Conservation of Nature

that the lack of records for Ghana's coast could be due to extensive dolphin exploitation while insinuating Sausa teuszii now either may be absent or extremely rare and if the latter, contend the Volta River delta (eastern Ghana) identified could be a potential remnant habitat. Van Waerebeek et al. contend it is unclear as to whether the lack of sighting records stretching 1,900 km over four nations and thus include: Sierra Leone, 402 km; Liberia, 579 km; Côte d'Ivoire, 380 km; and Ghana, 539 km, can be described as a significant distribution gap or whether that considerably is a lack of reporting. On another breath, Van Waerebeek et al. (2003, 2004) suggested a probable Togo stock based on credible fishermen's reports. Howbeit, their existence became confirmed (Segniagbeto et al. 2014) when photographed in 2014 after a decade. In light of these, several authors argue S., teuszii spp. are being poorly managed and conserved and that there is a need for IUCN Red List classification ("Vulnerable," V.U.) to be modified (Van Waerebeek and Perrin 2007; Weir et al. 2011, Ayissi et al. 2013; Van Waerebeek et al. 2015). It was before Collins (2012), applying the Red List criteria suggested the species merited a classification status of ***"Critically Endangered" (C.R.).*** In summary, a similar claim saw at the international level; the West African Manatee been assigned the status in 1986— listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) on July 01, 1975, and Appendix II of CMS at the 7th Conference of Parties (COP7) in September 2002 (refer to UNEP-WCMC. August 10, 2008. UNEP-WCMC Species Database: CITES-Listed Species), thus, it is essential to allude to the fact that these reverse trends among the population dynamics as a result of anthropogenic interferences of the individual species (amounting to extinction, extirpation, under and overpopulation) are an outgrowing concern and have the tendency of influencing the marine environment's biological and physiological character in ways that may have further implications in the natural balance for the rivers, and oceans physical and chemical components in ways yet to be discovered. In order to develop an understanding of relationships existing in these fundamental variations in the mammalian populations, it is critical to the provision of a solution against the dangers they face. The ONR NOAA (2016) also suggests that the potential impacts on individual fitness documented in their study are consistent with recent reviews. The reviews discussed the impacts of noise on wildlife (Shannon et al., 2015), insisting on its extreme importance and usefulness in informing any conservation management of sound sources, thus providing a direct link between behavioural changes and any potential population-level consequences (Refer to NRC, 2005; ONR, 2016 for further reading). The study discusses this subject under the theoretical framework in Section 2.3. In comparison, they were considering the linking relationships between unintentional anthropogenic stressors affecting the marine mammal populations' dynamic and marine environment in Section 2.1.3 under Clarification of Concept 2.1.

2.1.8 A Brief Understanding of Deep-Water Oil and Gas Exploitation

Today, offshore oil and gas could not have been possible without advancements in innovative technology such as the platforms, underwater, and pressure tolerant equipment. It is therefore essential that in discussing deep-sea oil and gas exploration, the history of offshore revisited clarifies of purpose in order to be able to explain the developments of today's operations in deep-water west Africa. According to Silcox, et al. 1987; National Academy of Sciences (NAS) (2016); B. A. Wells (2019), Offshore drilling, which is the first step towards hydrocarbon production, began in 1897, just 38 years after Col. Edwin Drake successfully drilled the first oil well ever drilled on land.

In light of these events, H.L. Williams also is credited with drilling a well of a wooden pier in the Santa Barbara Channel in California (as shown in Figure 12). In 1896, B. A. Wells (2019) recounted explaining that, as enterprising businessmen with unravelled interest towards the newly found opportunities pursued California's prolific Summerland oilfield down to the beach, where the lure of offshore production enticed Henry L. Williams and his associates to build a pier 300 feet out into the Pacific –and then mount a standard cable-tool rig on it. He used the pier to support a land rig next to an existing field. Five years later, there were 150 "offshore" wells in the area. This first offshore oil well was a success, and soon, 22 companies joined initiating the boom, with 14 new pier constructions allowing them to drill over 400 wells over five years. It is on record that the Summerland offshore field produced for 25 years fuelled California's economic growth. In 1911, a significant event shifted the choice of platform technology for drilling; Gulf Refining Company (GRC), with reasons best known to them, had abandoned the use of piers. Wells, therefore suggested it is the reason Gulf Refining Company has frequently referred to as America's first real offshore drilling. GRC using a fleet of tugboats, barges, and floating pile drivers, drilled Ferry Lake No. 1 on Caddo Lake, Louisiana.

The well completed over water without a pier connection to shore returned 450 barrels of oil per day, allowing GRC to construct platforms of every 600ft on each 10-acre lakebed site— achieved under extreme conditions of labour and environmental difficulty, according to Wells references to Bowman's report. Wells' further citing of the historian, Bob Bowman, subsequently recounted that in 1911, a major petroleum company, Gulf Oil Corporation, based in Pittsburgh, Pennsylvanian initiated the first drilling of ***"over water"*** oil well. With the significant drilling still taking place around water inhabited lands in 1921, steel piers as the new frontiers were being used in Rincon and Elwood (California) to support the land-type drilling rigs. Subsequently, in 1932, a steel-pier island (60 × 90 ft. with a 25-ft air gap) was then built to operate over half (½) mile offshore by a small oil company, the Indian Petroleum Corp., as a support onshore-type rig. Although records proved the wells as disappointing before the island being destroyed in 1940 by a storm, it was the gateway to today's steel-jacketed platforms. Therefore, these historical antecedents set the stage for Deep-water exploration not until later parts of the 20th Century, as is discussed in the following paragraphs.

2.1.9 Hydrocarbon Exploration at the advancement of Marine Vessel Technology

Progressively, as the need for drilling moved from the shore in order to reach oil resources beneath the subdued lands under water stretched out farther, Pratt et al. (1997) explained that drilling from piers instead became impossible –requiring the use of Moveable barges from the 1930s. By 1938, the first free-standing structure's engineering and construction had successfully been placed at 1.5 miles offshore in the Gulf of Mexico to drill for oil. In effect, as demand for gas and oil products continued to increase during and after World War II, according to Priest (2008b), these free-standing structures were then placed at much deeper waters and in so doing, by 1947, the first well to be built out of sight and off any bare land was built on a platform 12 miles beyond the coast of Louisiana (Priest 2008b; National Academy of Science, 2016). By 1949, 44 exploratory Wells had built on eleven (11) oil and gas fields (NOIA 2015) in the Gulf of Mexico.

The early years of offshore oil and gas drilling characterised were by extremes of risks and rewards in an environment where governing legislation and regulation existed in the minute of terms. Therefore, the industry undertook a few safety initiatives during this period. Ever since companies gain the capabilities to discover and produce oil and gas profitably, their operations were fraught with many hazardous challenges. These challenges resulted from the attempt to adapt land-drilling methods in offshore areas.

Thus, from the need to fit complex drilling and production facilities onto the small steel platforms, the need to use untested designs and procedures on the go, and the need for proper handling of dangerous equipment as well as flammable materials, all in an adverse marine environment exposing workers and equipment to high winds, waves and the corrosive leaching of saltwater. In addition to these challenges, the high operational costs only intensified the pressure to produce results within the shortest possible time (Priest 2008a; National Academy of Science, 2016).

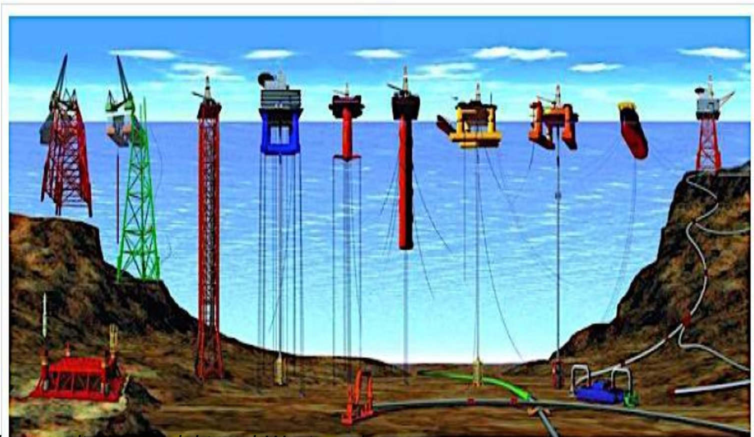
Fast-forwarding, it is refreshing to reiterate the assertion made in the latter part of the 19th Century by R.J. Howe (1986) that "we can drill exploratory wells in all ocean areas except those with ultra-deepwater or certain combinations of ice-types and water depths." The need to surmount this enormous challenge has been the new frontier driving exploration of oil and gas of the 21st Century today, with the active drilling taking place in the iced regions in the arctic and attempts at going from deep-water operations into ultra-deepwater from water depths of over 500meters to 1500meter and beyond (Endeavour Business Media, 2019). The evolution of mobile drilling units over the years place emphasis on drilling in deeper to ultra-deeper waters; hitherto, are in the increasingly harsh wind, wave, current, temperature, and ice environments and remained inaccessible. These patterns best discussed are by decade; thus, according to Howe (1986). When offshore drilling moved into deeper waters of up to 100 ft. water depth, ***fixed platform rigs*** were built until the demands for drilling equipment shifted from beyond a 100-ft. depth up to 400-ft. water depth of the Gulf of Mexico. Then, the first jack-up rigs began to appear from among the assets of specialised offshore drilling contractors such as ENSCO International. On record, the success chalked preceded the appearance of the world's first ***semisubmersible.*** This event coincidentally was as a result of an accident in 1961. Thus, the pontoon owned and operated by the Blue Water Drilling Company, while drilling for Shell Oil Company in the

Gulf of Mexico at the time, was accessed to be insufficiently buoyant to support the weight of the rig and consumables. Therefore, rigs are towed between locations at draught mid-way to the top of pontoons and decks' underside. They subsequently observed that the motions (instability) at this draught were relatively small; hence, Blue Water Drilling and Shell jointly decided that the rig could operate at this semi-floating mode. Subsequently, the first purposely built semisubmersible is the Ocean Driller. It launched in 1963, and ever since then, many semisubmersibles have been purpose-designed as part of the specialised offshore drilling industry mobile fleet. Soon to be ushered in was the first offshore drillship named, CUSS 1, developed for the Mohole project towards drilling into the earth's crust, and by June 2010, the mobile offshore drilling rigs (Jackups, Semisubmersibles, Drillships, barges) count available for service numbered over 620 in the competitive rig fleet. The quest for "greater mobility, floating stability, drilling stability, variable deck loads, storage capacity and safety" are well placed and timely in the development of the needed technology and competencies. All of this carried out has been within a framework of getting the job done at the lowest cost. As a result, the four types of mobile units which have evolved include; submersibles, semisubmersibles, jack-ups, and ships/ barges (shown in Figure 13) —have followed somewhat similar development patterns. Other areas across the world that benefitted from these developments and have experienced great interest in oil and gas exploratory drilling history included the Canadian side of Lake Erie in the 1900s and Caddo Lake in Louisiana in the 1910s. The Bibi Eibat well, which came on stream in 1923 in Azerbaijan and described as one the oldest subsea Wells just to mention a few. The Well, situated was on an artificial island within the shallow portions of the Caspian Sea (Offshore Energy Today, 2019). Knight and Westwood (2004), focusing on the west Africa side of the offshore oil and gas developments history, indicated that, from its insertion in the early 1960s at the tip of the Gulf of Guinea, exploration crowned with success in the shallow waters off the Niger Delta river, off the Port Gentil region of Gabon, and with the subsequent discovery of the Emeraude field off the Congo. Field development soon followed, and by March 21, 1965, the Okan field in Nigerian waters became active. Substantially, ever since 1965 through to the end of 1999, 233 fields in the West African region between Angola and the Ivory Coast became productive, making use of the services of seven hundred (100) platforms while producing up to 3.1 million barrels of oil per day from some 24.63 Billion BOE of accessible reserves. Knight and

Westwood further admit the region bears itself well comparative to other shallow water areas of the world including the North Sea and South East Asia. However, they assert that it is the immense promise of the giant deep-water 'elephant' fields fuelling the current boom in exploration and development in the region, as it promises to raise the levels of investment coming in the sector (Knight and Westwood, 2004). They went further to provide statistical data to support the trend of the shallow to deep-water drilling history per oil and gas reserves across the regions of world citing Infield Database, London, presented in Table 1-2 below.

Table 3: Deepwater vs Shallow Water Reserves (MTOE) 2000 – 2010

Region	Deepwater Reserves	Shallow Water Reserves
Asia Pacific	786.20	7,379.04
Brazil	739.99	102.17
Gulf of Mexico	936.95	124.81
Norway	1,030.20	745.89
Other	2,876.56	19,688.90
UK	189.70	1,037.64
West Africa	2,197.22	879.35
Total	**8,756.81**	**29,957.78**



Data courtesy Infield Database, London as cited by Knight and Westwood,

These data presented above went to show that the marine offshore deep-water reserves represented about 25% of the world's total offshore reserves as at 2004 –awaiting development in the time frame 2000 – 2010. They argued that claiming,

> "*The first giant deep-water fields of economic importance to be found in West African waters were Bonga in Nigerian Block OPL 212 and Girassol in Block 17 off Angola in the spring of 1996. Since then a total of forty-three further fields have been discovered in water depths ranging from 300 metres to 1458 metres and the region has risen to be the world's hot-spot in terms of new reserves found*" (Knight and Westwood, 2004pp.3).

The second on the list came on stream December 1999, in phase 1 of Chevron's Kuito development in Angola Block 14 and post 2010 today; there is more than three oil and gas field actively producing and also awaiting development in deep waters of Ghana, Ivory Coast, Nigeria, Cameroon, Senegal, all within the Gulf of Guinea, as exploration continues to expand. The coastal areas also feature a wide variety of ecological habitats, some of the rocky cliffs, a heathen of sandy beaches, extensive layers of seagrass beds northward toward dense mangrove forests, surrounding large deltas (thus, including the Niger and the Volta), amidst numerous estuaries farther south. It acknowledges its uniqueness for which some striking features refer to coral reefs of Cape Verde and the uniquely rich coastal upwellings of cold water characterising the Canary and Benguela Current systems – supporting some of the most diverse economically essential fishing zones of the world (UNEP CMS, 2008).

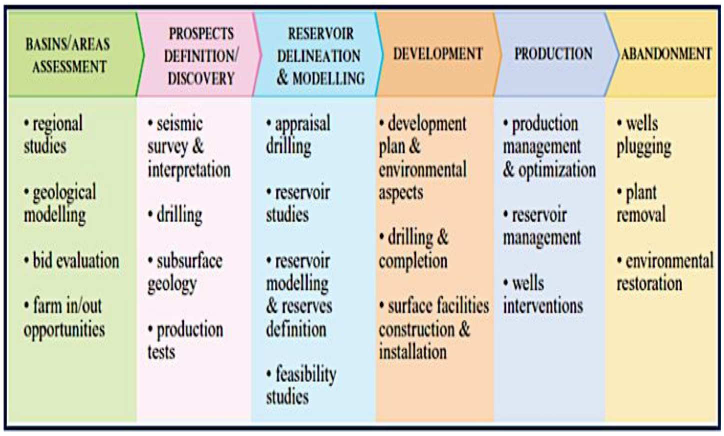
2.1.10 Understanding the Fundamental Field Development Process for Hydro Carbon Production

The offshore extraction of *hydrocarbon* process, (also referred to as upstream[7] activities) follows a series of engineering activities generally. These activities well within the marine environment, are carried out in several phases along typical operating cycle targeted at varied goals using specialized technologies to reach, production and decommission the oil and gas production. Below is a description of one such activity carried out in the leading to hydrocarbon production based on Serintel's (2017) online article. A typical hydrocarbon (also referred to as *Petroleum*[8]) exploration showing field cycle

[7]**Upstream** is a term used in the oil industry which refers to the searching for, the recovery and production of crude oil and natural gas. The upstream sector includes: (1) Exploration – the searching for potential onshore or offshore oil and gas reservoirs, and the drilling of exploratory wells, (2) Production and maintenance of wells and facilities to recover and bring the crude oil and/or raw natural gas to the surface plant and to process the produced hydrocarbons (Serintel, 2017;).

[8]**Petroleum,** refers to both crude oil and natural gas. These are mixtures of hydrocarbons which are molecules, in various shapes and sizes, of hydrogen and carbon atoms, and different mixtures of hydrocarbons have different uses and different economic values. ***Crude oil***, refers to hydrocarbon mixtures produced from underground reservoirs that are liquid at normal atmospheric pressure and temperature. ***Natural gas***

and the activities generally carried out on each phase is depicted in the schematic representation of Figure 14. Petroleum products naturally are discovered in various forms of solid, liquid and gas.



The primary commercial usable forms include Crude oil and Natural gas products. Scientific and Geological studies reveal that extremely variable compositional complexity of petroleum precipitates the combined effects of all the processes involved in originating petroleum accumulations and their history during the geological time. It is however made possible due to the presence of Hydrocarbon reservoirs (porous and permeable host rocks) are thousands of feet below the surface (*for detail reading see also Chapter 2, Section 2.2.5*).

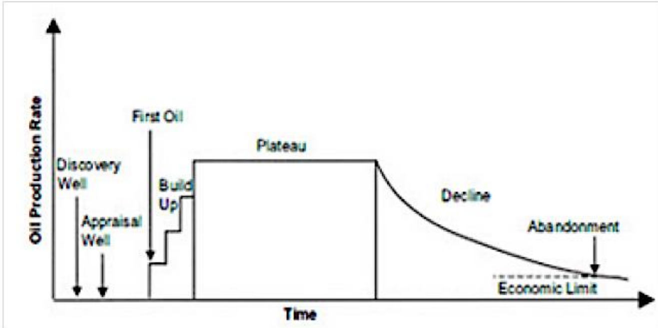
According to the upstream chart in Figure 14, the first phase of activity is the ***Petroleum Exploration*** which provides the information needed: to exploit the best opportunities presented by the areas (blocks); and to manage research operations on the acquired blocks. This phase is also carried out in stages, over some time, where various data of the specified evaluations made. Specialised ships, including seismic survey vessels; such as Gravimetric, Magnetometric, or Magnetollurgic survey vessels are for geological prospecting or geophysical data acquisitions. Offshore support vessels are for Remotely Operated Vehicle are for geological and environmental data acquisition surveys); and MODU (thus, Mobile Offshore Drilling Unit for drilling operations of the first exploratory well in oil discovery). In summary, the exploratory phase is to identify and locate a prospect, before proceeding to quantify the volume contained in the potential reservoirs and then evaluate the risk inherent the project development.

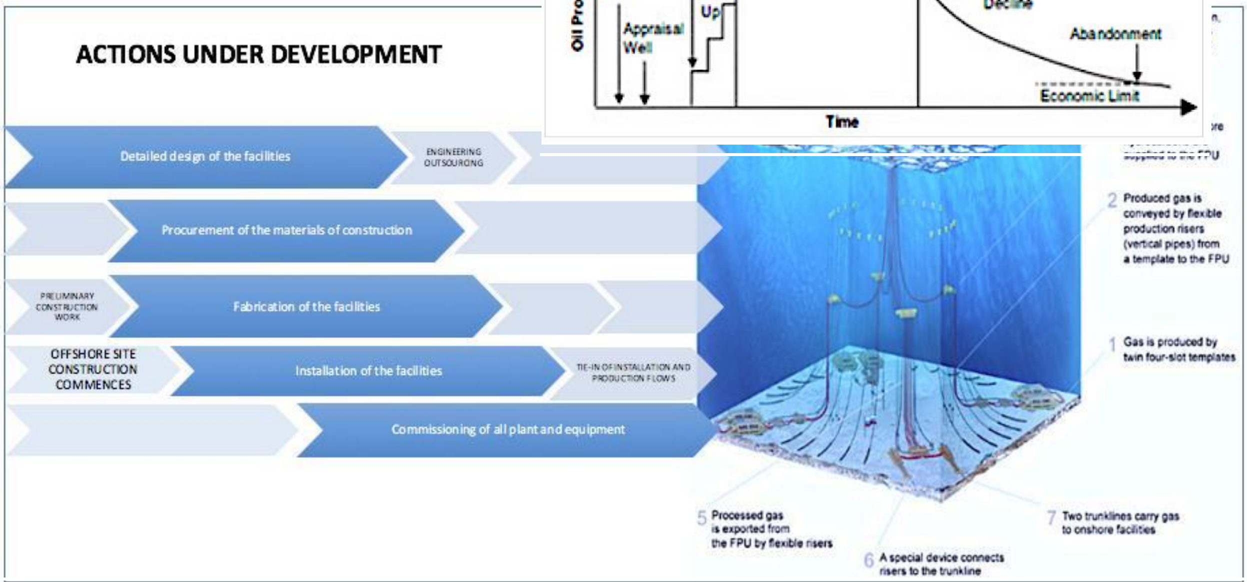
The second is the ***Field Appraisal Phase*** which provides cost-effective information used for subsequent decisions towards development. This phase utilises the services of MODUs for more Well drillings in order to collect information and samples from the reservoir. At this stage, other seismic surveys

product refers to hydrocarbon mixtures that are gaseous, at normal atmospheric pressure and temperature – the gas mixtures consist largely of methane – the smallest natural hydrocarbon molecule (CH4).

conducted is towards better delineating (Elsevier- Developments in Petroleum Science, 2003) the reservoir; hence, the schematic map of the appraisal phase.

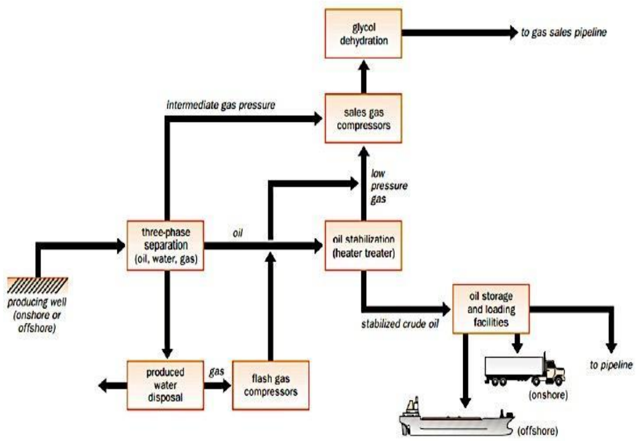
The next upstream activity, which is the ***Field Development Phase,*** can only take place where the appraisal assessment proves viably commercial production petroleum working system before the beginning of the field production. Before development, regulatory authorities required are to approve the design action plan contained in the Field Development Plans (*FDPs*), also known as Plan of Development (*POD*) documentation. These FDPs, which include all activities and processes required, provide all the necessary support for field development and optimization. The development of any oil and gas field costs several millions of dollars and may require a long time (5-10 years) to be fully realized. Hence, the *POD* should carefully consider; Objectives of the development, Petroleum engineering data, Operating and maintenance objectives, Description of engineering facilities, Cost and workforce estimates, and Project planning budget proposal— before the developing actions, shown in the flow-map of Figure 15, are taken ahead of first oil. At this stage, several connections of pipelines on various subsea platforms assembled, and pressure tested before flow tested ahead of commissioning of the production facility. Several marine vessels are engaged in this process, from simple offshore support and supply vessels, such as Security boats, Anchor Handling Towing Support vessel (AHTS) (tugs boats), Subsea survey vessels (ROV operated), to Light construction vessels, Heavy-lift Crane Construction and Pipe-lay vessels, supported by Marine Accommodation vessels where needed, with development drilling by MODUs, and subsequent anchoring of the Floating Production Storage and Offloading Unit (FPSO) vessel. The final stage of the upstream process is the ***Petroleum Production Phase***. Activities within this process are aimed at recovery of the reservoir fluids to surface before been processed, all the while ensuring production and maintenance activities carried out, strictly comply with safety and environmental policies and procedures. During the production phase, it is essential to (a) have control production and injection meet approved plans for volumes and quality of products, (b) monitor and record all data in order to efficiently manage the reservoir, wells and production facilities. Therefore, every offshore oil and gas production phase naturally begins with the flow of the first commercial volumes of hydrocarbons ("first oil") through the wellhead, as it marks a real turn from the exploratory expenditure of resource search to good cash flows. Hence, a typical production profile will consist of a three-phase forecast of operation (see Figure 16): **Build-up period** > during this period production well are progressively





brought on flow; **Plateau period** > a constant production rate is maintained; **Decline period** > all producers show declining of production rates. The production process is depicted in Figure 17, which illustrates the process, starting with the producing wells to storage units (FPSO) and then offloaded into shuttle tanker vessels or gas sales compressor chambers and then out through gas sales pile line for domestic or commercial usage (ELSEVIER – Developments in Petroleum Science, 2003; TRECCANI – Encyclopaedia of Petroleum; KBR – Publications, 2012; Serintel, 2017).

(To read more about typical field development refer to



http://www.kbr.com/Newsroom/Publications/Articles/Selecting-the-Right-Field-Development-Plan-for-Global-Deepwater-Developments.pdf).

2.1.11Understanding the Gulf of Guinea, its History and its People

The historical origin of the name "Guinea" given the delineated gulf in the Atlantic Ocean is not exact, but most sources are of the agreement that it is a name of a region in the area. According to Britannica (2019), the name derived was from the Berber word *Aguinaw*, or *Gnawa,* meaning "black man" (hence Akal n-iguinamen, meaning "land of the black men"). The term was subsequently adopted before the 14th century by the Portuguese (who were the first to arrive and trade) to the best of their linguistic abilities in forms such as Guinuia, Ginya, Gheneoa, and Ghinea, eventually featured on European maps onward.

Bovill (1995) also consent that the name adopted over the years was about; the south coast of West Africa (i.e., Upper Guinea) which covered the northern areas of the *Gulf of Guinea*, and the west coast of Southern Africa (i.e., Lower Guinea) encompassing the east area of the gulf. Britannica (2019) explains further that there is a distinction between Upper and Lower Guinea, which does lie westward and southward, respectively, of the line of volcanic peaks that runs northeast from Annobón (formerly Pagalu) Island through São Tomé to Mount Cameroon. Three other African countries then named after the term, namely Equatorial Guinea, Guinea-Bissau, and Guinea. Another nation referred to as Papua New Guinea occupying the eastern side of the island of New Guinea in the southwestern Pacific Ocean according to Bovill (1995), does share a resemblance despite the geographic distances apart and it been alien to the *Gulf of Guinea*. Narrowing down on the Gulf of Guinea, Maren Goldberg (Ed) (2019), indicates it came to refer to the part of the eastern tropical Atlantic Ocean off the coast of West Africa, extending westward between Cap López, near the Equator, and Cape Palmas at longitude 7° west. Its principal tributaries are the Volta River and the Niger River. The Gulf of Guinea is, therefore, a part of the Atlantic Ocean adjacent to these coastal areas. Their chief produce knew sections of the Guinea coast. For instance, Guinea pepper, Xylopia Aethiopica; the Ivory Coast referred to areas beyond Cape Palmas and now mostly in Côte d'Ivoire). The Grain Coast referred to Cape Mesurado to Cape Palmas, along with present-day coastal Liberia, becoming the source of the "grains of paradise," the Gold Coast referred to the east of Cape Three Points, south of present-day Ghana, and the Slave Coast referred to areas between the Volta River and the Niger River delta, along with present-day Togo, Benin, and Nigeria (Britannica (2019).

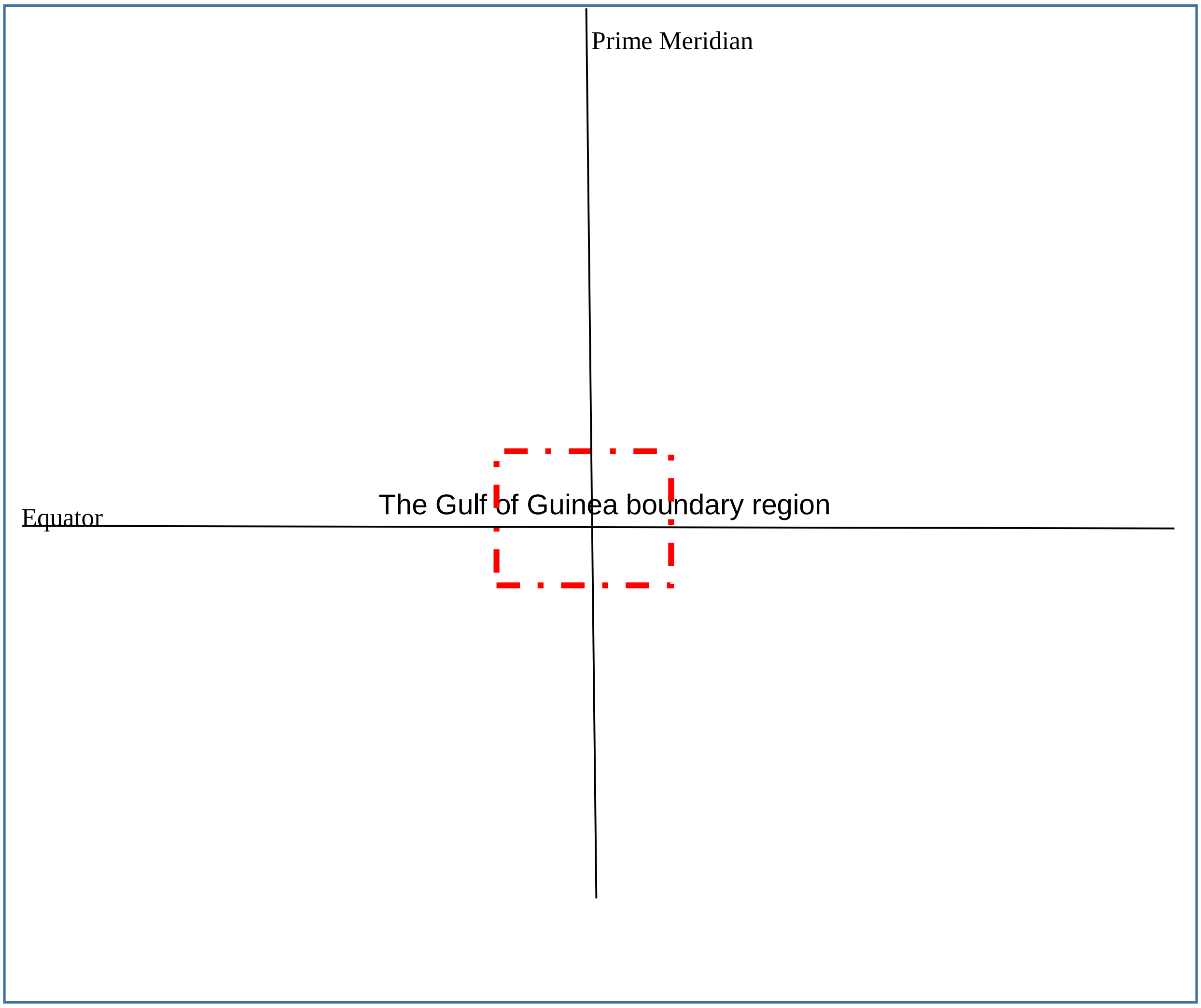
2.1.12 General Geography of the Gulf of Guinea Region

Geographically, the Gulf covers a surface area of 2,350,000 sq. km (910,000 sq. mi) of the continental shelf from the coasts of Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, Equatorial Guinea, Gabon, São Tomé and Príncipe, Republic of Congo, Democratic Republic of Congo, to Angola (see Figure 18). It centres near latitude 0°0′N and longitude 000°0′E on both the equator and prime meridian. Over the years, different definitions for the geographic limits of the Gulf of Guinea have been given. The International Hydrographic Organization (IHO) (2002) did define the southwest extent as;

"A line from Cap Lopez (0°37'S 8°43'E), in Gabon, northwestward to Ihléu Gago Coutinho (Ilhéu das Rôlas) (0°01'S 6°32'E); and thence a line from Ihléu Gago Coutinho northwestward to Cape Palmas (4°22'N 7°44'W), in Liberia".

The oceanographic conditions of the area feature ocean swell, guinea surface current and undercurrent, which Sackey and Lamptey (2019) and Henin and Hisard (1987) agreeably referred to them as the primary surface feature. They added that the surface guinea current altered course eastward from the North Equatorial Counter Current (NECC) on approaching the African continent. Vinhateiro et al. (2014) put this approximately at latitude 03° 00N and thus exhibit substantial surface velocity at a limit of 100cm/s. Sackey and Lamptey, (2019) also observed both surface and underwater current flow in the region with substantial velocity reaching 3 to 4 knots (i.e., between 150cm/s and 200cm/s) directed from the west. They contended that this, combined the long swells generated from the south as surface wind peaked up, exacerbated the pattern with constantly changing directional flow of the surface current. Heavy rains also characterise the atmosphere of the region in the wet season and intense wind storms that accompanied the rain.

The warm tropical water of Gulf of Guinea is relative of low salinity due to river effluents and averagely high rainfall along the coastal belt. The warm water is does distinguished from the deeper, more-saline, yet colder water by shallow thermocline[9].



[9] Thermocline refers to the layer of water that lay between upper and lower levels, usually less than 100 feet (30 m) deep in reference to temperature gradient (Editors of Encyclopaedia Britannica, revised by Micheal Goldberg).

2.1.13 Geological History of the Gulf of Guinea

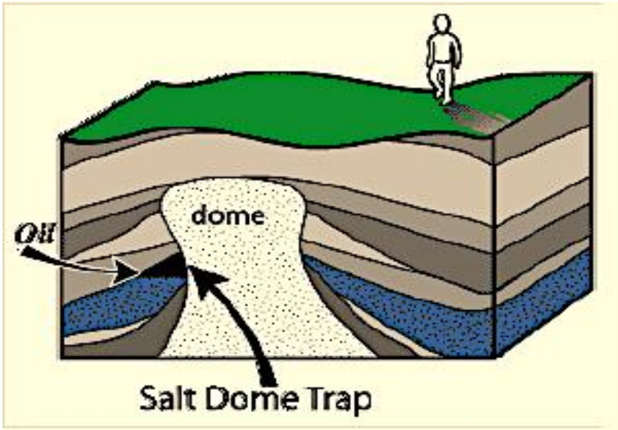
Knight R. and Westwood (2004) detailed an account of the hydro-carbon exploits within the Gulf of Guinea when he inferred. It has been eighty-five years since German scientist Alfred Wegener proposed the idea that the geographic fit between the west coast of Africa and the east coast of South America, pointed to the fact that the two continents had once joined together in the geological past. However, when that had been, they consent that is unknown while agreeing it remained a matter of some debate amongst geologist until the advances in marine geology forty years ageing Wegener's proposal, that the recognition of the two continents had been separated towards end of the Jurassic era and into the early beginnings of the Cretaceous period, by the processes described as rifting and oceanic suturing. Thus, splitting the supercontinent of Gondwanaland into several pieces occurring.

As the split between the continental landmasses developed, contemporaneous pre-and syn-rift deposits laid down were on both sides of the South Atlantic Ocean. Whence produced were two very similar hydrocarbon provinces to basin type, (i.e., source rocks and salt deposits). The salt deposits believed were to have been laid down in the regions of poorly circulating waters, lying north to the volcanic rocks that today constitutes the Walvis Ridge in the eastern South Atlantic and the Rio Grande Rise in the west, (Fainstein, 1998; Knight R., and Westwood, 2004). Effectively, the location of these two volcanic ridges delineates the hydrocarbon-bearing Lower Congo at the southern margins and that of Santos/Campos basins at the northern margin. However, in the southerly regions, such as areas off Namibia and the Falklands/Malvinas Islands, for example, more basins do occur and are undoubtedly essential for future exploration prospect.

After the period of evaporite deposition within the Albian and Aptian regions, there were further rifting that resulted in the opening up of the South Atlantic before the deposition of series of post-Aptian clastic and post-rift sediments when the marginal shelves subsided. Salt deposits (as shown in Figure 19) believed are to be of particular importance due to the effect salt had on post-depositional sediments that enveloped them when the ocean opened allowing in a massive basinward sediment influx of turbidites. At this point, other closely related Tertiary clastic deposits occurred within the region.

As time waded in, the fan deposits, and turbidites, such as Oligocene and Miocene ageing, begun to form the various bulk reservoir rocks within deep-water fields found in the Congo Basin areas.

Essentially, these sedimentary basins located are beyond the continental shelf, right below the continental slope at water depths beyond 300metres. Over the years since 1994 find in the Congo basin, Hydrocarbon finds have been discovered in them in water depths approximately 1,500 metres deep. Knight R., and Westwood, also argued that the recognition of these new deep-sea fan deposits beyond the shallow water *progradational*[10] shelf deposits; thus during which earlier offshore finds were made, only makes it one of the most critical discoveries. One to have resulted from deep-water exploration, off Brazil, within the Deepwater Gulf of Mexico and Gulf of Guinea in West Africa at a period where the world's energy demand was rising.



On related matters, Keaveny, (1998) reported that seismic survey work undertaking within the Angolan side of the Lower Congo Basin and in the Campos Basin over a g decade ago revealed post-depositional salt movements created various hydrocarbon trap types within overlying sediments. Moreover, the salt thickens only towards the African shore producing different structural form in the extensional tectonic environment lying in the upper margins of the basin. Again, those that occurred within regions compressional tectonics impact as in the western and deeper parts of the basin were not exempted, (Keaveny, 1998). Economic exploitation of the area comes from two main activities, namely; exploration of oil and gas and fishing (Sackey and Lamptey, 2019).

2.1.14 Recent Developments Offshore West Africa in the Gulf of Guinea Region

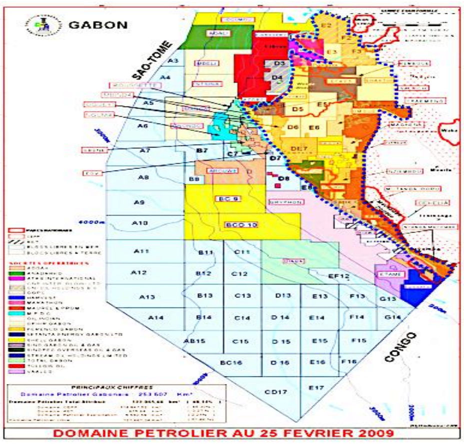
The following paragraphs discuss the progress made towards shallow to deep-water hydrocarbon find by each country bound to the Gulf of Guinea region, with a central focus on the primary blocks, and their potential. Despite the study's focus on Ghana's offshore oil and gas industry typically located in deep waters. At the same time, much detailed background given is in terms of its historical antecedent,

[10] Progradation used here means the building forward or outward the sea of a shoreline or coastline (as of beach, delta, or fan) by nearshore desposition of river-borne sediments.

current progress and future forecasts, it is wealth mentioning Ghana is not in isolation as all the progress made cuts across her neighbouring countries with emphasis on the prudent use of entire Gulf of Guinea.

(1) Gabon Oil and Gas Exploration

Gabon, currently the eighth largest oil producer in sub-Saharan Africa with production estimates of 198,000 barrels of oil per day (*bpd*) which is the primary source of public revenue according to World Bank estimates showing its export ratio at 80 per cent of GDP between 2010-2015, re-joined OPEC in the summer of 2016. Nonetheless, bad economic management of the resources has had Gabon sort help from the IMF in recent times. According to the U.S. Energy Information Administration, Gabon's mature oil fields are in decline, with peak production in 1997 at 370,000 bpd. Gabonese authorities' estimation for 2017 put production at 10.5 millions of tones amidst new prospect blocks identified farther offshore (shown in Figure 20).



□ **Petroleum domain : 253 507 km²**

- **Onshore Area : 50 227 km²** represents 19,81%
  - ✓ Under license : 90%
  - ✓ Open : 10%
- **Offshore Area : 203 280 km²** represents 80,19%
  - ✓ Under license : 44%
  - ✓ Open : 56%

□ **20 Oil companies in Gabon**

- 3 American, French, British
- 2 Chinese, Canadian
- 1 Dutch
- 1 Italian
- 1 Irish
- 1 Australian
- 1 Indian
- 1 Japanese
- 1 Saudi Arabian

110 Contracts between Gabon State and 20 Oil Companies

- Exploration : 42
- Production : 71

In conjunction with recent developments, Gabon organized a meeting on revisions to the 2014 oil code in 2018, in order to adapt to current realities. The changes mean Gabon obtains a minimum of 20% stake in oil projects, while country-owned Gabon Oil Co. (GOC) is entitled to a 15% further (US Embassies Abroad, 2019).

(2) Nigeria Oil and Gas Exploration

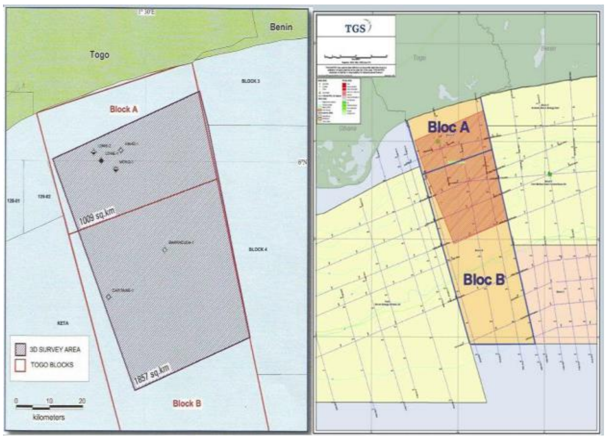
Nigeria is acclaimed Africa's largest oil producer, and eighth-largest, worldwide. Nigeria, as an oil-producing country is no news, having its deep-water oil and gas reserve blocks prove of 32.5 billion barrels and 187 trillion cubic feet respectively. Numerous investment opportunities still abound in upstream operations of its Petroleum industry.

Records indicate, the end of 1998 saw the deep-water operations resulting in: the acquisition of 21,000 km 2D Seismic Lines; the acquisition of 21,500 km 3D Seismic Lines; and the Drilling of 33 exploration/appraisal wells in depths ranging from 300-1460m. Significantly, new oil discoveries reportedly were accounted to provide an additional US$864million commitment for the first 6 (six) years of deep-water prospecting under a PSC (production sharing contract). Operators today, continue aggressive explorations— probing deeper waters and building upon shallow water projects, nonetheless (NNPC, 2019). The *Bonga deep-water field* currently developed, is an example of the recent development in the offshore oil and gas sector. Reports also indicate, Bonga southwest's oil reserves' probing dates back to the early-mid 90s, and only now, having the project initiator Shell Oil and partners (with Nigerian's NOC and NNPC in forming the SNEPCo) move ahead with full development, perhaps due to improved technology. The resources lie over 120km off the Niger Delta, at water depths of 1,000m, Shell has chosen an FPSO to get to these resources. The project is in its first phase and thus, involves full construction of an FPSO, the drilling of 20 deep-water wells, and finally, the installation of related subsea architecture infrastructure. The country also looks forward to an additional $48bn in projects to its portfolio in the coming decades (Africa Oil Week, 2019).

(3) Togo Oil and Gas Exploration

West Africa becoming a hot zone for the global oil and gas industry since discoveries in Ghana and Ivory Coast have opened up many opportunities in shallow water to offshore deepwater basins. These developments have led to massive turnouts for new hydrocarbon exploration opportunities in the Gulf of Guinea, in particular, lining the Atlantic Ocean general. These explorations have also become the phase of Togo, Ghana's closest neighbour. Togo's sedimentary basins (shown in Figure 21) are part of the larger "Keta-Togo-Benin" basin; that stretches across offshore and onshore areas within Nigeria, Ghana, Togo and Benin along the Gulf of Guinea. It is described as an abrupt marginal basin, having tick sedimentary fill adjacent the Niger delta basin towards the east and the Ivory Coast-Tano basin towards the Western boundary. Currently, the potential petroleum system source rocks are determined as the proved source rocks are: the Devonian shale; early cretaceous Laguna shales, marine Cretaceous shales. Identified reservoirs proved with clastic formations are; The Upper Cretaceous; the Early cretaceous, (Lomé-1 tested at ~ 500 barrel/day); and the Devonian (République Togolaise, 2018).

Though current developments have not led to many discoveries of great significance, nearby discoveries in Ghana suggest and preserves the hope of potential finds, driving the exploration in Togo further into deeper waters offshore.

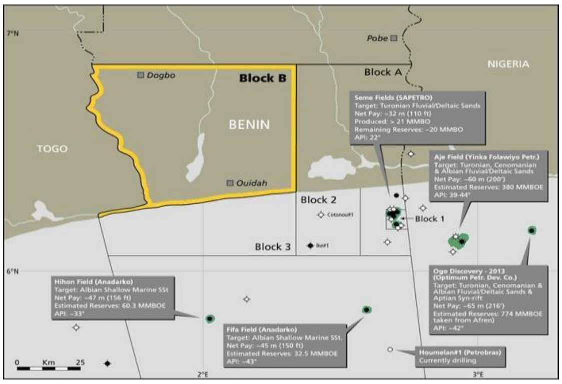


(4) Benin Oil and Gas Exploration

Benin, as a nation, also boast of several demarcated onshore and offshore oil blocks (shown in Figure 22). Benin's Onshore Block B is located in the Dahomey Embayment (Coastal Basin) and was acquired by Elephant Oil in 2013 and partnered by United Oil & Gas with 20 per cent interest PSC[11]. The Block covers an area of 4,590 sq km (approximately 1.1 million acres). The Block located is approximately several km west of Bénin's capital Cotonou continuing west to the Togo border. The Dahomey Embayment onshore basin is a frontier for Benin remains undrilled. Herewith notwithstanding, the licenced block assessed is to be surrounded by the prolific hydrocarbon producing reservoirs offshore, which all speak to the excellent positive indications of a working petroleum system. Unlike Benin, wells have been drilled along the coast of neighbouring countries in the same Dahomey Embayment in onshore Ghana and Nigeria with all encountering hydrocarbons. The working petroleum system has also been demonstrated in the offshore Shelfal area, where the Seme and Dahomey fields have approx. 100mmbbls of oil reserves. On another breath, there have been reports of oil and gas seeps coming out from simple water wells drilled within communities settled on Block B acreage. There is also the presence of extensive tar belt, potentially indicating migration of oil through the targeted Cretaceous stratigraphy, in the northeast area according to reports. Currently, its data is limited to a single seismic line plus a CGG-acquired airborne Falcon Gravity Gradiometer survey, which all goes to suggest the presence of numerous large structures with the potential hold >200mmbbls. Elephant Oil has already identified the Allada structure as a

[11] Production Sharing Contract (PSC): the state contracts for the services of a holder to explore for, and in the event of a discovery, to exploit hydrocarbons. The holder is responsible for financing the petroleum operations. Hydrocarbon production is shared between the State and the holder in accordance with the terms of the contract. The holder shall receive a share of production as reimbursement of its costs and as compensation in kind (cost oil), the remainder of the oil (profit oil) shall be shared between state and holder.

prospect. Like Togo, Benin has not commenced any commercial production and operations upstream remains at the probing stages in offshore and onshore blocks, respectively (ELEPHANT OIL LIMITED, 2014; Energy 365 Limited, 2017; Geoexpro.com, (2017)).



(5) Cameroon Oil and Gas Exploration

The Republic of Cameroon is to the eastern border of oil-rich Nigeria, and presently the fifth-largest oil producer in Sub-Saharan Africa –with 100,000 barrels per day production since 1999. The country's gas reserve estimates are at 110 billion cubic metres (*bcm*), making the upstream oil industry an essential part of the economy. The prospect of the Bakassi Peninsula with 740 million barrels of oil and 3.9 Tcf of gas reserves still awaits adjudication by the International Court of Justice (ICJ). While Cameroon remains a net exporter of crude, output has fallen between 6% and 12% in recent years, perhaps due to unfavourable terms offered by the government, and hence the inability to sufficiently attractive or encourage new exploration activities. By far, the arrangement has been under CC[12] and PSC.

Nonetheless, the oil buzz in the region is inspiring reforms and driving current exploratory agenda in the phase of renewable energy. The exploration phase, like in most countries sectioned, is into an initial period of three years (but providing for Special Petroleum Operations Zone extension up to five years where scenario warrants). Besides, this is renewable for two years only. Collectively, the exploration activity may not exceed the 7 or 9 years' period, respectively. Exploitation phase is scheduled for a maximum of 25 years for oil and 35 years for gas. These conditional agreements may also be renewed once, on the application, for a maximum of 10 years (Mbendi Website Review, 2018; Africa Oil Week, 2019).

(6) Liberia Oil and Gas Exploration

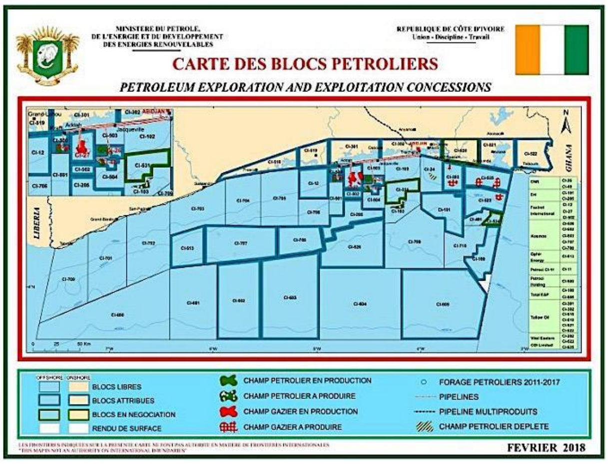
[12] A Concession Contract (CC) is entered into prior to the granting of a hydrocarbons exploration permit. In terms of the CC the holder is responsible for financing the petroleum operations and is entitled to the Hydrocarbons extracted during the period of validity of such contract, subject to the right of the State to collect royalty in kind.

To begin with, Liberia as a country, have demarcated its potential hydrocarbon sedimentary Basin to consists of thirty (30) concessionary blocks (as shown in Figure 23), out of which seventeen (17) lay along the continental shelf at water depths between 2500 meters and 4000 meters. The rest of thirteen (13) of the blocks considered, are at "ultra-deep" locations –in water depths 4500 meters deep and beyond. Currently, Liberia has not well-developed upstream hydrocarbon industry. Historically, offshore exploration activities in Liberian territorial waters begun in the late 1960s and ceased to continue for various reasons.

The Petroleum (Exploration and Production) Law and the NOCAL Act of 2014— also approved in 2016 to replace the repealed the "NOCAL Act of 2000" and the "Petroleum Law of 2002", respectively are clear examples. The Petroleum Law establishes two key institutions namely, Liberia Petroleum Regulatory Authority (LPRA) and National Oil Company of Liberia (NOCAL) for the regulatory (including Reconnaissance Licenses, Petroleum Agreements, and Licenses for Petroleum Transportation Systems) and commercial functions respectively (Government of Liberia, 2019; U.S. Embassies Abroad, 2019). This law goes to express the established interest of Liberia making the most of its resources in the Gulf of Guinea in pursuit for Hydrocarbon resources notwithstanding any possible environmental consequences or any genuine efforts at conservation of the ecological lives (Government of Liberia, 2019; U.S. Embassies Abroad, 2019).

(7) Cote d'Ivoire - Oil/Gas Field Equipment

According to US Embassies Abroad (2019), Côte d'Ivoire today is said to have a proven reserve (see Figure 24) of both oil and gas with current estimates at 100 million barrels in oil and 1 trillion cubic feet reserves of gas. The prospects of potentially becoming a medium-sized offshore oil producer in the upstream industry are on schedule with growing exploration activities. This line of business is partly vital since the country is a net exporter of petroleum, though imports crude oil refined locally. Approximately, 34,000 barrels of oil per day produced was with gas production reaching 216 million cubic feet per day in 2017 (and thus, makes Côte d'Ivoire is a net regional energy exporter). *(Retrieved from* http://www.energie.gouv.ci/hydrocarbure/pages/statistiques-des-activites*)*



Upstream Development: the growth within the Ivorian oil sector has been considerably linked to steady increases in regional electricity demand, but the production appears to have declined due to lack of investment. This situation follows some early favourable discoveries, but the offshore oil production has yet to take off compared to her neighbouring country Ghana. Howbeit, U.S. companies' report shows the Ivoirian authorities as very cooperative and in general projects, a suitable environment for future exploration interest, thus according the US Embassies Abroad (2019). Concurrently, Leanne de Bassompierre (2019) reported in its business news of the conclusion on six oil licensing blocks (shown in Figure 20) in June 2019, which Ivory Coast's plans to capitalise on the rising interest in the West African region from oil and gas supermajors towards increasing crude output. They reported that the government was talking with both French and Italian majors about the blocks –quoting the Minister of Petroleum, Energy and Renewable Energy, Abdourahmane Cisse as saying in an interview in Cape Town, the country was nearing the completion of production-sharing agreements with at least four blocks. They further mentioned some of the companies to include Total and Eni, among others and gave November 2019 for the completion, citing people familiar with the matter. Due to the favourable climate for business, the US Government admonished companies interested in exporting oil and gas production equipment to Côte d'Ivoire to work with the Ivoirian authorities understanding the related tax breaks available under the Ivoirian investment code. There are also investment credits offered for exploration in deep and ultra-deep waters. Many blocks delineated are now open for negotiation (U.S. Embassies abroad, 2019). Currently, Ivory Coast has 48 demarcated oil blocks (Figure 24), out of which four are in full production with another 24 others under exploration, thus according to Cisse referred to Blomberg. With average output hanging around 70,000 bpd, Cisse added: "the potential is a lot higher". Ivory Coast at this effort is seeking to diversify its economy with relative exports dominated by the shipments of cocoa and gold, just like its immediate neighbour, Ghana (Leanne de Bassompierre, 2019).

(1) Ghana's Offshore Industry, Oil Block Concessions & Developments

According to Petroleum Commission (PC) of Ghana, Ghana has four petroleum basins, and the Oil blocks whether prospecting or currently been exploited, whether near coast or far-out offshore and in-land; they all fall within four identified sedimentary basins, namely: The Tano-Cape Three Points Basin; The Saltpond Basin (is a Paleozoic wrench modified pull-apart basin); The Accra–Keta Basin (is a Cretaceous wrench modified pull-apart basin); and The Voltaian Basin (is an asymmetrical inland basin).

Ghana's oil boom did not begin several decades of exploration going back to the 19th century even with the near-coast, Saltpond production field until Kosmos Energy discovered commercial quantities of oil and gas in 2007— thus, and the Jubilee field. The development of the field was under 3.5 years, with first oil reached in December 2010. This developments, however, marked a new paradigm of deep-water and ultra-deepwater explorations in West Africa and Ghana. Thus with the deep **Western Tano Basin**, serving as the centre of epic finds to include; (1) additional site discoveries such as the pecan fields, and subsequent development of the Greater Jubilee field. This project is currently underway despite initial delays as a result of the Ivorian dispute settlement in 2017 in favour of Ghana. The project does encompass the Twenneboa, Enyenra, and Ntomme (TEN) fields that came on-stream August 2016. The cape three basins include the Sankofa Gye Nyame field with development and production start in May 2017, with additional exploratory discoveries Wells in adjacent Block 4 (in 2018/2019) –scheduled for development and tie-ins to FPSO unit JAK. Other discovered with projected development to commence in the nearest future include Deep Water Pecan fields of Aker Energy and partners, and Springfield's Block 2 (all presented are in Table 4).

Early 2018 saw the signing of a deal between the government and Exxon Mobil to explore for oil in Ghana's Deepwater Cape Three Points (Oxford Institute for Energy Studies, 2018). Details of these are present in Table 4).

Table 4: Ghana's offshore sites within the Western Sedimentary Basin

Current Production & Exploratory Blocks

West CTP Block
Size/ Portion of Jubilee Field: 48 sq. km.
Mahogany, Teak and Akasa Disc Areas: 416 sq.km
Water Depth Range: 1,100 -1,300 meters
Existing Discovery Production in Block: Odum 1, Jubilee (Mahogany 1, 2, & 3) fields
Available Data & Status: 2D, 3D, 4D seismic, POD, EIA, Production Reports, etc.
License Holder: Tullow and JV Partners

DEEPWATER TANO
Size/ Portion of Jubilee Field: 61 sq. km
TEN Development and Production Area: 450 sq. km
Wawa Discovery Area: 106 sq.km
Water Depth Range: 1,100 -1,500 meters
Existing Discovery Production in Block: Tweneboa 1, Hyedua 1 & 2 fields
Available Data & Status: 2D, 3D, 4D seismic, POD, Production Reports, etc.
License Holder: Tullow and JV Partners

WEST CAPE THREE POINTS BLOCK 2
Size: 673 sq.km
Water Depth Range: 100 - 1700m
Existing Discovery Production in Block: currently holds 1.2 billion barrels proven reserves (thus 30-35% recoverable in addition to sizable amount of gas) and is flanked by Jubilee, Sankofa and Sankofa East oil and gas fields
Available Data & Status: Licensed existing 2D and 3D seismic data over the block, Commenced reprocessing of seismic data. Plans of first commercial well drilling underway
License Holder: SPRINGFIELD and JV Partners

Offshore CTP Block
Size: 693 km²
Water Depth Range: 800 -1,400 meters
Existing Discovery Production in Block: Sankofa, Gye Nyame fields
Available Data & Status: 2D, 3D, 4D seismic, POD, Production Reports, etc.
License Holder: ENI and JV Partner Vitol

Deepwater Tano /Cape Three Points
Size: 2,100 sq.km
Water Depth Range: 1,600- 2,667 meters
Existing Discovery Production in Block: Pecan, Almond and Beech oil discoveries fields
Available Data & Status: 2D, 3D, 4D seismic, PoD under review, awaiting development and production.
License Holder: Aker energy and JV Partners

Cape Three Points Block 4
Size: 1127 sq.km
Water Depth Range: 600 to 1,000meters
Existing Discovery Production in Block: Ankoma Gas fields.
Available Data & Status: Completed 3D seismic acquisition, Processing of 3D seismic data and G&G are underway, development tie-in.
License Holder: ENI and JV Partner Vitol Upstream Ghana Limited, Woodfields Upstream Limited, Ghana National Petroleum Corporation (GNPC) & Explorco

Central Tano Block
Size: 277.9 sq.km
Water Depth Range: 800 -1,400 meters
Existing Discovery Production in Block: Prospects have been mapped within the Contract Area. Drill two (2) exploratory wells
Available Data & Status: Licensed existing 3D seismic data., etc.
License Holder: Amni International Petroleum Development Company (Ghana) Limited & partners

New Block Concessions under First Licensing Rounds by the Government of Ghana, 2018

As at March 2019, the first licensing rounds was carried out by the government of Ghana through the Petroleum commission for the six blocks. Fourteen (14) out of the sixteen bidders who showed great interest were successful in the pre-qualification stage. Two awards made have been with one reserved allocation to the Ghana National Petroleum Corporation (GNPC) for sole or PSC (PC, 2019). The original pool of companies that put in bids for the three oil blocks includes China National Offshore Oil Corporation, Cairn Energy, Qatar Petroleum, Global Petroleum Group, First E&P, Sasol, Equinor and Harmony Oil and Gas Corporation. The rest include ExxonMobil, British Petroleum, Tullow Ghana

Limited, Total, ENI Ghana, Vitol, Kosmos Energy and Aker Energy. Details of the process outcome presented are in Table 5 below.

Table 5: First Licensing Round Outcomes, 2018.

AVAILABLE ACREAGE	CURRENT LICENCE HOLDER/ AWARDEES	FEATURES, EXPLORATION AND DEVELOPMENT PROSPECTS
Block GH_WB_1 Size: 1900 sq. km Water depth range: 0 – 100 m Existing discoveries in block: none Existing wells in block: 1 Available data: 2D seismic, 3D seismic, Well reports and cuttings.	Reserved for the **Ghana National Petroleum Corporation (GNPC)**	Close to the producing Jubilee field & Atuabo & gas pipeline by ENI & from the jubilee field pass-through this acreage. The Area partially covered is by 2D & 3D seismic data. Currently has one well (WCTP-1X) which encountered oil.
Block GH_WB_2 Size: 1110 sq. km Water depth range: 50 – 1100 m Existing discoveries in block: none Existing wells in block: 1 Available data: 2D seismic, 3D seismic, Well reports and cuttings	***Eni Ghana Exploration and Production Limited*** in partnership with ***Vitol Upstream Tano Limited***	Axim 4-3X Oil & gas shows AGIP (1982) TD'd@ 4016m in Aptian. Negotiations of terms of the agreement currently ongoing
Block GH_WB_3 Size: 1380 sq. km Water depth range: 800 – 2800 m Existing discoveries in block: none Existing wells in block: 1 Available data: 2D seismic, 3D seismic, Well reports and cuttings	***FIRST E&P Development Company ltd and Elandel Energy (Ghana) Limited***	It extends over the southern portion of the Romanche Sub-basin within Tano-Ivorian basin of Ghana. Thus, between continental shelf break & topographically high marginal ridge associated with Romanche Fracture Zone. Negotiations of terms of the agreement currently ongoing

Block GH_WB_4 Size: 1340 sq. km Water depth range: 100 – 1700 m Existing discoveries in block: 1 (Dzata) Existing wells in block: 2 Available data: 2D seismic, 3D seismic, Well reports and cuttings	Government of Ghana yet to award this block from the licensing rounds.	Currently, with two existing Wells, 3D seismic data prospect generated and has a working petroleum system identified related to the Dzata discovery. Selecting and Awarding Negotiations currently ongoing per section 10(3) of Act 919.
Block GH_WB_5 Size: 1360 sq. km Water depth range: 1600 – 4800 m Existing discoveries in block: 1 (Dzata) Existing wells in block: 1 Available data: 2D seismic, 3D seismic, Well reports and cuttings	Government of Ghana seeking direct negotiations with oil major with capabilities for the area. ***ExxonMobil and British Petroleum (BP)*** have submitted interest	Ultra-deep-water acreage with one well, a working petroleum system due to nearby Dzata discovery. Selection and Awarding Negotiations currently ongoing per section 10(9) of Act 919.
Block GH_WB_6 Size: 1800 sq. km Water depth range: 2200 – 4300 m Existing discoveries in block: none Existing wells in block: 1 ODP site Available data: 2D seismic	Government of Ghana seeking direct negotiations with oil major with capabilities for the area. ***ExxonMobil and British Petroleum (BP)*** have submitted interest	It is an Ultra-deep-water acreage with only 2D seismic data, no 3D or wells except for several ODP sites found within the area. Selecting and Awarding Negotiations currently ongoing per section 10(9) of Act 919.

The Upcoming Pecan Development: Spearheaded by Norway registered Aker Energy, the Pecan field development cost estimated is at $4.4bn. Aker and partners, Lukoil and the Ghana National Petroleum Company filed its PoD (the plan of development) with Ghanaian authorities in March 2019, before completing an appraisal drilling campaign in April same year. According to Jan Arve Haugan, Aker

Energy CEO, the appraisal wells provided valuable information for the area development plan in the DWT/CTP block in a press release. The plan is to construct and position an FPSO to which subsea supply system on the Pecan South field will tie in. In the first phase, reserves across Pecan holding estimated oil at 334m barrels could record first flow as early as 35 months after the initial development per estimates Springfield Exploration and Production Limited (SEP) the only indigenous independent upstream company is reported on November 17, 2019, to have made its first significant discovery of more than 1.2 billion barrels of oil equivalent in its first deep-water well drilling offshore (Ghana Web, 2019). This discovery brings the number of potential planned developments and production activities in deep-water Ghana to four (4) as at November 2020 –including; the Greater Jubilee project of Tullow, the ENI Block 4 tie-in project, along with the Aker Pecan field project and Springfield Block 2 project (also refer to Table 5).

ExxonMobil and partners Ghana Oil company (GOIL) offshore ltd., and GNPC is the latest JV to join the fray in search of hydrocarbon off the cliffs of Ghana, having acquired PA with the Government of Ghana in 2018, and commenced its Ultra-deep water exploration in 2019, thus counting on the growing successes by far (Myjoyonline.com, 2020). These accumulating activities show no signs of easing and may account for significant anthropogenic changes to the natural marine environment with a consequential effect on living organism associate with the area dully discussed in the following paragraphs.

2.1.15 Understanding *‘Obstructionist Stress’* and the Various Marine Regulations

As the title of the study may suggest when referring to ‘Source of Obstructionist Stress,’ describing disturbing activities or interferences in the marine environment unambiguous, clarity of the definition in this context lies with its use concerning marine environmental science. ‘Obstructionist’ is referred to which Merriam-Webster (2019) defines as “deliberate interference with the progress of the business, especially of a legislative body.” This term is also conveniently used in the marine conservation discussion cycles all over the world. The Multilateral Environmental Agreement Negotiator’s Handbook also refers to it when providing guiding documents to conservationist with a statement of caution insisting, “if you are alone, you may wish to intervene with questions for other delegations (without being obstructionist) (University of Joensuu & United Nations Environment Programme (UNEP) 2007 pp84).” In relating this definition and context within marine environmental science concerns, in particular, the agitation with the US congress raised by Jeff Brax (2002 pp114) who in the book, Zoning the Oceans: Using the National Marine Sanctuaries Act and the Antiquities Act to Establish Marine Protection Areas and Marine Reserves in America; claimed, “the lack of express authority also raises a more subtle problem. By failing to mention marine reserves entirely, the Act fails to outline a procedure for consistently creating reserves. As a result, marine reserve proposals have proceeded along with ad hoc, drawn-out, and unbounded negotiations sessions that have exacerbated the obstructionist power of certain interest groups”.

In other words, one's conduct of an activity or activities should be useful in approach and not necessarily become an obstacle. Failure to go by this grand aim may result in unwarranted consequences on the ordinary conduct of a legitimate business of another individual or group. Hence, such a person or group of persons, whose actions become an obstacle referred is to as an *‘obstructionist’*. In scientific terms, human acts that tend to yield a response (obstruct) from the natural cause of the activity of another living organism described as ‘anthropogenic activities’. Therefore, Ansari and Matondkar (2014) mentioned the term anthropogenic to designate an effect or object resulting from human activity. Although the term anthropogenic and obstructionist have not been used interchangeably in environmental science literature, it is worth introducing in this context in order to highlight the legitimate concerns some of the significant anthropogenic factors have on the marine environment with the increasing rate of invasion. The impact of anthropogenic activity, in summary, tend to results in responses on the water ecosystems and its biota, which are either functional or structural. Others do term these responses as stress. Therefore, impact assessment of any anthropogenic activity is essential towards gaining an understanding of the biodiversity and ecology of not only the general delimited maritime coastal zonal boundaries of countries and the management of its resources. Unlike Mann and Lazier, (1991); Ansari and Matondkar (2014), it should encompass the constantly extending siting of artificial islands offshore –stretching the coastline outward and the impact the changes as a result of the stress, is having.

In defining stressors acting on both living marine organisms and marine environment, the study reviews literature –examining its merit in both contexts highlighted of this study. Therefore, Parker et al., better explains stress in the journal article, Stress in Ecological Systems (1999 pp. 179-184 (6 pages)) by addressing the question of what stress is? The following is a brief detail of their account on ecological Stress. Parker et al., begin by alluding to the assumptions that studying stress in ecological systems do presume a general or at least operational idea of the existence of a definition on stress, that the effects on biological entities can somewhat be easily identified, and that stress in itself –an ecological and evolutionary sense, is essential (Forbes in press) in that order.

Ideologically, disturbance and stress are used interchangeably in the often when applied to ecosystem dynamics. However, over the years, their application in the scientific literature has consequentially, led to a rise of non-synonymous interpretative meanings, making it difficult to relative to a universal definition of either term. Generally, stress is the detrimental effect on a single activity or several biological activities (whether on an individual, population, food web, community) which is as a result of some disturbance (or stressor). The above definition implies there is the need for the term 'detrimental' defined at each level of analysis on the biological organisation if it will avert any ambiguous or incomplete meaning. Therefore, some scientist including Parker et al., do define disturbance "in terms of stochastic or unpredictable events which cause 'species or population change' from increased mortality or changes in the resource base; and stress as that force that arises from the disturbance (or multiple of disturbances) as felt by the individual organism" (cf. Zajac and Whitlach, 1982; Parker et al. 1999 pp179). These very changes at both the individual and population-level somewhat confirmed that response of a stressor could therefore be defined to relate to a decrease in fitness, Parker et al., (1999) argued in agreement with Calow Berry 1989; Hoffman and Parsons, 1991; and Bijlsma and Loeschke, (1997). They added that many evolutionary and ecological assumptions of stress centred on the unpredictability of environmental heterogeneity, mainly relating to abiotic sensory ability or inability of organisms to track such changes associated with unpredictable or harsh environments, capable of resulting in an evolution of a particular life form genetically (Baker, 1965; Levin, 1965; and Parsons, 1983).

Others like Cullen et al., (1992) considered stressors as relating natural occurrence and environmental variability claiming some environmental variabilities are periodic and remain pacesetters for daily and seasonal events such as phytoplankton blooms, animal migrations, and sexual reproduction. However, the study of sedimentary fossil changes detection', carried out over a long-term can be episodic, (thus the case of the Permian-Triassic extinction, is an example) or periodic, where the sequence of significant mass extinctions occurs as during the Phanerozoic. They contend that the triggering mechanisms of such mass extinctions are not known in full, but suggest the primary productivity under the stress of global change do play an essential factor. To this effect, the study of the response of marine organisms inhabiting the upper ocean exposed to an increased influx of ultraviolet radiation due to depletion of stratospheric ozone is only now beginning (Cullen et al., 1992). The National Academy of Science (1994) also explained that environmental variabilities are evident in both the latitudinal and vertical changes within light spectral intensity. They are within the distribution and abundance of organisms; within the gradients of *temperature*, *hydrological pressure*, and *salinity*; within distributions of suspended particulate matter, the multitude of chemicals including biologically essential nutrients, carbon dioxide, oxygen, and all form of gas traces; and within effects of the ocean's hydrodynamic factors— thus include, surface and underwater currents, storms, fronts, eddies, and turbidity currents.

In summary, the term Stressors as a concept in the study, unlike Cullen et al., (1992) and National Academy of Science (1994) is herewith not limited to defined, resulting from conditions of actions of abiotic environmental variabilities. Thus generating a response –towards the survival of organisms (i.e., marine mammal species) or the altering of the natural pattern of their native environment throughout such an influence, but rather, it encompasses resulting responses from abiotic environmental variabilities as well as direct intentional or unintentional human (anthropogenic) interferences or natural activities that result in similar outcomes. That means, for example, any operations within the marine environment that may have a cause to result in either physical or emotional injure, harm or destroy marine mammals and their native environment, be it direct or consequential, can be described as a source of stress.

From the above definitions, statements, and explanations referred to, one thing stands out clear. That is to say, they all point to an ‘action,’ ‘approach’ or ‘event’ that can interfere with a due order of a process, event or activity (National Academies Press (US), 1994).

However, Parker et al. contend none of these attributes is sufficient enough singularly, to provide the complete with a description of environmental changes and their effect it has on biological organisms or a definition of stress. Hence, unlike Parker et al. who focused on abiotic agents as stressors causing detrimental effects on populations and communities, this study focuses preferably on the anthropogenic factors (stressors) and how they relate with natural abiotic agents to affect the marine mammal habitation.

Therefore, for this study, the term a source of obstructionist stress does refer to any direct and indirect anthropogenic actions, with abiotic factors or activity within the maritime environment consequential of which may result in unexpected changes in the natural course of flow of event in the lives of marine mammals and their native ecology. Such an action, event or activity herewith is referred to as the source of stress. The study further identifies this obstructionist stress forms as the parametric activities or events to be measured, while examining any possible relationships between them, and how much of an impact they make on the mammal habitation. These activities are determined to include, movements of heavy loads resulting from surf operations which involves deck-to-subsea by crane and ship machinery; ship overcrowding lighting intensity; operational noises; pollution; and issues of climate change.

2.1.16 Environmental Stressors and Management Strategies

The issue of natural environmental stressors, be it abiotic or biotic cannot be overemphasised when dealing with natural occurrences in the ecological system, and survival of organisms deemed crucial in maintaining a proper balance of the ecology. Howbeit, the need to sustain their survival remain a central epitome when we observe some fey and delicate mammals such as the whales and dolphins at sea injured or beached in the coast, sometimes we are unlucky and only tend to find their carcasses washed ashore. It is undoubtedly apparent, like humans, these beautiful wildlife ocean creatures no way are insulated from environmental stressors within their native habitations. This situation made more eminently problematic when considering the changes in patterns, behaviour and the natural order of ecosystems under additional stressors resulting for anthropogenic factors. Invasion of human in the exploitation of fossil fuel offshore has come with many challenges whose impact remains understudied whether to the environment, marine lives or human health. The section is a review on nature, causes, impact and actionable interventions against abiotic environmental stressors on ecosystems; that may have implications in conjunction with anthropogenic factors stemming from hydrocarbon exploration in the offshore marine environment.

Therefore, the first part considers the review summary presentation in Chapter Three of the book by the National Academies Press (US) (2014pp23-42), outlining stressors that can impact coastal and ocean ecosystems and possible management decisions and prevention strategies. Thus, with the first by the Chief Science Advisor of the NOAA, Paul A. Sandifer, describing how ecosystem stressors operate—focusing on rising temperatures, eutrophication, ocean acidification, habitat destruction and loss of biodiversity, and extreme weather events— relatively modifying ecosystems and services. The second half of the presentation describes a framework to allow decision-makers to optimize interventions for managing stressors to marine ecosystems in order to maximize the services that will positively impact human well-being. This session delivered was by Jonathan Garber, Acting Associate Director for Ecology affiliated to National Health and Environmental Effects Research Laboratory, U.S. Environmental Protection Agency. The third presentation provides an agency perspective (U.S. Geological Survey [USGS]) on the role of science in resource management decisions related to ecosystem services. That was by Ione Taylor, Director at Energy and Minerals, and Environmental Health, U.S. Geological Survey. The presentations which focused on the US government's efforts followed by a summary of the discussion that ensued. The review is contextualised with material relevance towards the implementation of sustainable use of the marine ecosystem and thus associated services within the Gulf of Guinea. They will also ensure the prudent management and exploitation of mineral resources buried under the seabed. The presentation is, therefore summarised as below.

2.1.17 the Relationship of Stressors Impact on Ocean-Coastal Ecosystems and Human Health

- **Rising Temperatures**

To begin, Paul A. Sandifer mentioned rising oceanic and atmospheric temperatures as one fundamental impact— suggesting, it is a by-consequence of earth's climate warming up. He indicated further that the heat stress ultimately results in a more direct and indirect severe human health problem (depicted in

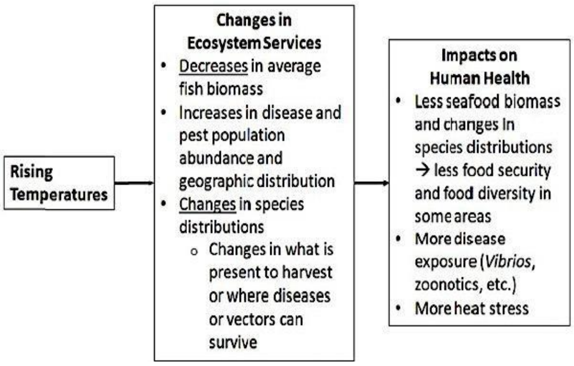


Figure 25, sighting the example of health impacts, especially among the elderly, in the more frequent and intense heatwaves in recent years). He suggested that the indirect impacts of rising temperatures tend to be somewhat more devastating to the ecosystems and their associated support systems – supporting all forms of life. Agreeably, the aggregate effect of an ongoing heatwave does affect fish biomass across oceans and also tend to instigate irregular migration patterns of associated marine mammal lives where they feel their habitats and feeding zones compromised.

Sandifer, therefore, described research undertakings by Cheung and colleagues (2013), who sort to theoretical study more than 600 species of marine fishes, evaluating the likely effects of the increasing temperatures associated with climate change phenomenon. According to Sandifer, the results of their work led the authors to suggest that rising water temperatures, is driving fish populations to change in terms of distribution, phenology, and productivity. When considering average fish body size, they assert a reduction with a decrease averaging 14 to 24 per cent by 2050. This condition essentially is because as expected, global warming will lead to a reduction of oxygen in the oceans, which is consequential to dwindling fish catches. That also goes to suggest that marine mammals are at risk as the implications may be dyer for their survival as species, considering their fish feeding intakes (thus, discussed under Section 2.1.3). Sandifer, therefore, reiterated that the collective sum of the overfishing, pollution, and other stresses, spells additional doom to global protein supply in a time of growing demand. From the assertions, it is obvious the impact is relatively grave for the fish biomass within the coasts of West Africa of the South Atlantic Ocean, considering fish remains the primary source of protein for the nations.

Another impact from rising temperatures is with food safety and increase in Pathogens, according to Sandifer. In this case, Sandifer explained that records show seafood poisonings remain underreported, or often misdiagnosed, and could be rising per estimates. Pathogenic Vibrio, whose spread thrives on warming ocean surface temperatures is one cause of seafood poisoning (L. Vezzulli, 2013). Sandifer also cites the outbreaks in 2004 of highly virulent V. parahaemolyticus in oyster beds in some parts of U.S. during a period of unusually warm waters. Most importantly, the outbreak resulted in 62 health cases confirmed among the human population (McLaughlin et al., 2005) in addition to those recorded among marine mammals. The *V. vulnificus* acclaimed is the leading cause of wound infections among seafood workers in the Gulf of Mexico from 1989 to 2004; according to US Centres for Disease Control (CDC, 2012). Examples found are in contaminated Shellfish beds. Again, the consideration of the distribution and occurrence of zoonotic diseases is said to be influenced by rising temperatures and other climate-related factors, according to Sandifer. Sandifer, therefore, described the fungal diseases ***lacaziosis*** (previously called lobomycosis) and ***Cryptococcus gattii***[13], which are two recent examples related to the diseases found in marine mammals, and humans— with current ocean trajectory northward. It is, however, unclear whether this distributional shift is related to climate change according to Sandifer, though the diseases are severe and now spreading into places and species with no prior record of its existence. Sandifer also described another zoonotic case of concern reported by Anthony and colleagues (2012) —involving harbour seals and the avian flu. The case resulted in a federally recognized unusual mortality event (UME) per the **InVest**-app model developed in the data analysis. The authors, therefore, noted the outbreak was significant, mainly because the virus' naturally acquired mutations were known to have rapid transmissibility and virulence in mammals in addition to the disease it brought on the seals. According to Sandifer, they emphasized continuous monitoring for spill-over effects and possible adaptation of avian viruses in mammalian species in order to understand the factors that could lead to future epizootic and zoonotic emergences. The National Research Council (US) Committee's (1994 pp6) confirmed there are techniques "that rapidly and specifically detect contaminants and pathogens are available but not implemented. These capabilities need to be developed more fully and implemented for rapid and inexpensive monitoring of the food quality of marine resources".

[13] Lacaziosis a tropical fungal disease typically reported in dolphins and humans. Cryptococcus gattii is an uncommon fungal pathogen that affects the lungs and can result in death.

- **Nutrient Pollution**

The second significant stressor Sandifer discussed was nutrient pollution claiming it caused many problems within coastal and marine environments –citing hypoxia and harmful algal blooms (HABs), also known as ***red tides***, which are the primary beneficiary of the nutrient pollution or eutrophication[14]. He indicated that red tides are probably the most commonly known HAB, among their specie. Eutrophication is, therefore, directly linked to the occurrence of HABs, which are growing environmental conditions of colossal concern worldwide. In offshore marine areas, it is unclear how much food waste discharges from ships contribute to nutritional resources for marine organisms such as fishes and algae near the coast. Sandifer posited the human and environmental health risks and can poses significant economic impact— suggesting their presence though common among coastal and ocean waters, some HABs are observed today in the Great Lakes and variety of freshwater lakes and ponds. This HABs threatens the lives of marine organisms with a variety of severe illnesses and eventual death, in line with the neurotoxins they produce. In humans, the toxicity of HABs causes several illnesses associated with gastrointestinal, respiratory, neurological, cognitive impairment and eventual death. Sandifer further states the "HABs are associated with amnesic shellfish poisoning, ciguatera fish poisoning, diarrheic shellfish poisoning, neurotoxic shellfish poisoning, and paralytic shellfish poisoning. Exposure to HAB toxins can occur via water, seafood (especially filter-feeding molluscan shellfish and some fish), and through aerosols in sea spray" (NOS NOAA, 2019pp4). In the citing an example, Sandifer explained, aerosolized toxins associated with Florida red tide *Karenia brevis* carried onto beaches and inland areas by ocean waves –several miles in where they, have cause respiratory irritation and distress in people, especially among asthmatic individuals. Agreeably, this challenge is also seen in along the West African coast.

Again, Myjoyonline news report (2014) reported that, between January and April 2012, Beach Seine fisher folks in the western region of Ghana had to suspend fishing when the HAB weed densities became too high. The Coastal Tourism industry was also not spared. It is as reported by the Daily Graphic of 23rd April 2014 news article titled; "Aquatic Weeds Take Over Cape Coast Beaches Preventing

[14] Eutrophication, is the over enrichment of water by nutrients such as nitrogen and phosphorus, which leads to hypoxia and may increase the occurrence of HABs

Travellers Who Normally Climax Their Easter Festivities With Beach Activities From Swimming In The Sea”. The trends observed of algae bloom was consistent with findings of the study by Lamptey, Sackey and Matey (2021). They further referred to EPA’s preliminary investigation findings which suggesting the phenomenon reported are among neighbouring West African nation (Sierra Leone, Liberia and Cote D’Ivoire) per their checks. The economic cost of HABs over past decade run into several millions of dollars (Shumway, 1988; Jewett et al., 2008; Bulent et al., (2013). However, in agreeing with Sandifer, it is essential to acknowledge that the economic impact of illnesses, lost productivity, recreational, and so forth are probably much higher and remain unknown, to marine mammals, birds and non-marine mammals (Landsberg et al., 2009). Sandifer also noted growing evidence for multiple species of HABs and geographic areas, suggesting a warming climate may result in increased frequency, duration, and geographic extent of HABs (Gilbert et al., 2005; Van Dolah, 2000; Moore, 2008, 2011).

- **Ocean Acidification**

According to Sandifer, today’s studies observe that ocean waters are 30 per cent more acidic than the preindustrial levels (NOAA, 2013). This conditions thus have adverse effects on ocean organisms – describing a recent meta-analysis’ (Kroeker et al., 2010). The findings related to survival, calcification (i.e., e.g., corals, mussels, phytoplankton except for crustaceans), growth, and reproduction, among other issues like the sensitivity of varieties of organisms. Corals observed are negatively affected by ocean acidification in particular. Ocean acidification negatively impacts on Molluscan shellfish and consequently threatens their availability and economics of seafood, among others. Others include Oyster production in terms of jobs (Washington State Blue Ribbon Panel on Ocean Acidification, 2012) and highlights the urgency of this problem and the value of ocean acidification research and monitoring (Barton et al., 2012) according to Sandifer. In addition to adverse effects on shellfish production, the health of coral reefs, and potentially food and economic security, Sandifer explained that the stress of dealing with oceanic acidification degraded coastal ecosystems resilience to other stressors, including extreme weather, nutrient pollution, while becoming less capable in its natural recovery.

- **Habitat Destruction and Biodiversity Loss**

Concerning habitat destruction and biodiversity loss, Sandifer explained that coastal habitats are among the most threatened in the world, emphasising the loss is primarily due to sea-level rise or coastal development. Sandifer citing an example, referred to oyster reefs that provided "many services, including seafood, filtration services, and water quality benefits, as well as shoreline protection and stabilization". Some of the developments are reshaping the coastlines significantly, developing countries (with particular focus on West Africa) seeking to boost their domestic economies with infrastructures such as ports and other waterfront properties. A recent example is Ghana's Tema and Takoradi port expansion work costing and US$450 million (Verdict Media ltd., 2019) with the latter's breakwater reaching 1.708km northward. It is worth mentioning here that many biodiversities and ecosystem services lost are through these constructions. There are also nesting grounds and homes for sea turtles (World Wide Fund for Nature, WWF, 2019), manatees, reptiles and birds and occasionally harbour small whales and dolphins migrating along the beaches (World Bank Group, 2017; World Wide Fund for Nature, WWF, 2019). Again, Sandifer reiterated that coral reefs provide various ecosystem services, to include the benefits of food, medicines and other products while serving as nursery habitat for other species, and recreational opportunities. The assertion that healthy dunes and beaches confer storm protection for shorelines and human habitations, among other services reemphasised, and any degradation or lost results in diminished storm surge protection, seafood supply, and decreases control resilience of coastal ecosystems to other stressors. Sandifer concludes by saying the cumulative effect much risk property damage and loss of life during storms, more risks of water-related illness. The next to be discussed is sea-level rise, though only mentioned by Sandifer in the earlier discussion, its impact on Africa needs reviewing, hence its future.

- **Sea-Level Rise**

All over the world, rising sea levels are a problem, and the western coast of Africa, stretching over 6500km from Mauritania to Cameroon for that matter, is at these perils. The impact of global warming, resulting in rising sea levels are fast eroding ecosystems and biodiversity's — in some places washing away 30 metres high of land per year. Generally, it is projected that sea levels are expected to reach more than 76 cm around the world by the end of the 21st century. However, the sea-level rise in West Africa is projected to be faster than the global average, where the coastal areas host an estimate of one-third of the region's population, generating 56% of its GDP. Recent World Bank study revealed that flooding and coastal erosion caused by sea-level rise brought the region approx. $3.8 billion in cost and resulted in 13,000 deaths under a single year. Ghana — adjudged the fastest growing economy in the world, partly due to its successes in hydrocarbon production, is unfortunately among the worst affected countries in the region. Coastal erosion along its 580km coastline of sandy beaches and outcrops mangroves, lining towns like Keta, Ada, and Shama have and are still being consumed. These certainly, have had a dire consequence on the biodiversity and ecosystem, notwithstanding, migration of fishing stocks triggered by rising temperatures and the salinisation of farmlands and freshwater reserves affecting millions of livelihoods of millions of fishers and farmers (Matteo Fagotto, 2016; Earth.org, 2019)

- **Extreme Weather Events**

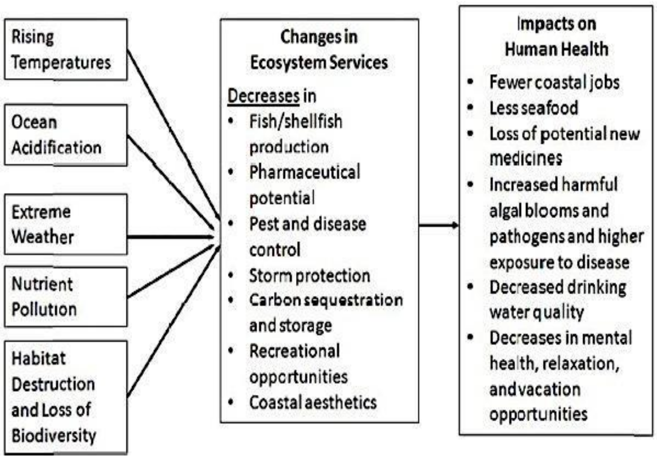
Sandifer concurred that degraded coastal habitats often exacerbate the impacts of extreme weather, and such extreme events often degrade or destroy coastal habitats and ecosystem services. According to him, such effects observed were in the aftermath of Deepwater Horizon oil spill 2010, with Hurricane Katrina, and post-tropical storm Sandy while rehashing the 14 weather and climate disasters experienced in the United States in 2011, of which each exceeded $1 billion in losses (Smith and Katz, 2013). The flooding in Mississippi, which produced near-record hypoxia in the Gulf of Mexico (NOAA, 2011) is an example he cited. In addition to the loss of lives, these events often impact the ecosystems and associated services in various ways. Storms frequently overwhelm sewer systems resulting in contamination of drinking water and recreational water use (Patz et al., 2010; Portier et al., 2010).

Storms are noted to damage human infrastructure, leading to leaks of pollutants that contaminate ecosystems. He related this assertion with the alleged concerns over the potential seafood contamination by radiation poisoning in the aftermath of the damages suffered by the Fukushima nuclear power plant in the March 2011 earthquake and tsunami (Reardon, 2011). In addition to the direct impacts of weather events on human health, Sandifer notes that the aftermath of such occurrences may duly include delayed effects on human, and environmental health, including the marine environment.

2.1.18 Understanding the Remedy to Counter the Effect of Environmental Stressors

In summarising, Sandifer therefore, noted that these five environmental stressors discussed are interrelated and therefore have broad range effects in an interrelation form on ecosystem services as demonstrates his schematic depiction (see Figure 26). To this regard, he suggested that several steps taken are to address the impact of stressors in order to sustain marine and coastal ecosystem services. These discussed are, as identified in the following: planning and development of ecosystem services' policies and decision making; protect and restore coastal "green infrastructure" (i.e., intact coastal habitat) towards the provision of natural storm surge protection, measures towards food security, and climate adaptation benefits; conduct of research understanding the effects of environmental stressors against marine species, habitats and systems, and humans, in order to determine how to mitigate best or adapt; and finally, implementing better monitoring and health warning systems. Sandifer, therefore, concluded reiterating the complexity in the interactions existing among the multiple stressors, ecosystem services, and human health, while highlighting the need to better understanding of the connections among the factors and their ultimate impact on human health, so their effect is easily minimized. He suggested a time scales to which for example climate and weather effects should be considered (see Figure 27), using the National Oceanic and Atmospheric Administration's (NOAA) well developed long-term outlooks for climate and weather— suggesting its refinement where needed, down to days, hours, and minutes of actual forecasts of upcoming events. These preventive or protective actions if will be effectively implemented, require the significant lead time possible.

According to Sandifer, NOAA currently, is seeking to extend this kind of approach agency-wide to improve ecological forecast, with specific attention to harmful algal blooms, hypoxia, and pathogens (mainly naturally occurring Vibrio bacteria) in both coastal and marine environments. Sandifer also noted that there would be the need for enhancing capability and resources (thus, including those purposed for "disease and health surveillance and epidemiological studies—to monitor, integrate data, model, and forecast impacts to coastal and ocean ecosystem services and the resulting human health threats"). This consideration was critical to providing timely warnings for better preparation towards mitigation, the implementation of control and prevention strategies, the reduction of impacts, and shortened time of recovery (Institute of Medicine, 2014).



2.1.19 Basic Framework for Assessing Marine Ecosystem Services and Human Health

In order to understand the framework for assessing marine ecosystems services and human health to stressor impacts, it is essential to identify the functional institutions by which nation-states decisively associate direct or indirect responsibilities. They implement programs that directly inure to the health and safety of the natural environment, and also, to emphasize developed legislative frameworks were establishing those functions while delimiting quasi bodies' modus operand. In light of this, Jonathan Garber, another of the panellist began his presentation reiterating that enhancing and protecting ecosystems and human health in the US, were explicitly central to the U.S.

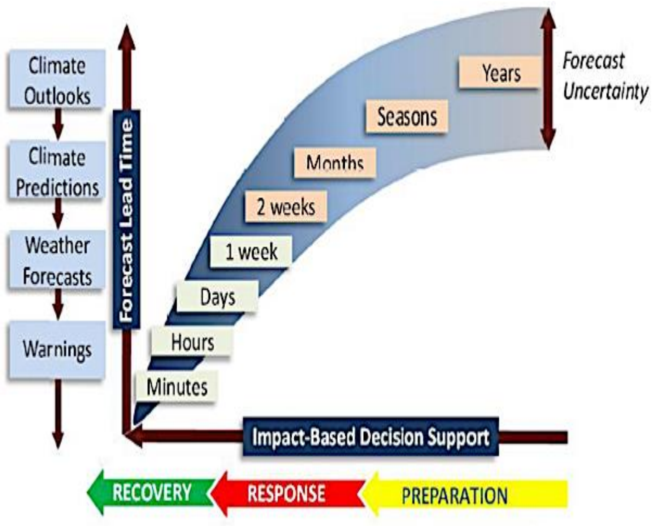
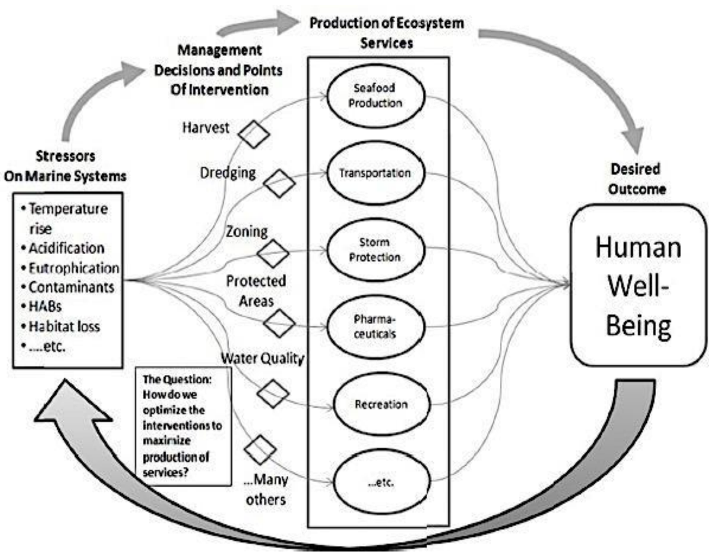


Figure SEQ Figure * ARABIC 26: Time scales and types of climate and weather forecasts. SOURCE: Sandifer, 2012.

Environmental Protection Agency (EPA) and the National Health and Environmental Effects Research Laboratory's respective missions. EPA organisations across the world, including those of West Africa nations, mostly share in this task. While emphasising on the efforts of the EPA's concerning the ecosystem, he stressed the need for developing the health connections and links in the area of their research are a continuing and increasing focus of the agency. In other words, ecosystems, whether inland, near-coast or offshore amidst all the complexities, there exist a general linkage between these systems –one worth researching in its entirety. This phenomenon buttresses the idea that all is not still understood within the ecosystem environments around the world, even for the most advanced countries, hence, some collaborative efforts among developing nations towards developing better understanding is required. This action will help with the sustenance efforts in marine eco biodiversities across the world. He added that the work of the (US) EPA is hence supported in function by regulatory and science arms which are underpinned by several statutory authorities such as the Clean Water Act, the Marine Protection Research and Sanctuaries Act, the Ocean Dumping Ban Act, the Shore Protection Act, among others. He then proceeded to discuss the critical functions of the EPA in line with issues.

- **Decision Framework towards the Management of Ecosystem Services**

Garber proceeded to describe the decision-making process used by the EPA to assessing the linkage between ecosystems and human health, based on a framework developed to assist the optimization of management decisions, affecting the productivity of coastal, marine and ocean ecosystem services. This framework, therefore, explicitly links all identified systems to human well-being (as shown in Figure 28). From the schematic diagram, Garber explained that the framework tends to begin on the left side where the potential stressors on marine systems including but not limited to temperature rise, eutrophication, and habitat loss are identified and consolidated.



On the far right is the linkage to the desired outcome of human well-being. This outcome reinforced, is with the vital understanding gained through the feedback loop. Ultimately, this framework ensures the decision-maker has the chance to optimize decisions on potential interventions geared towards maximizing the production of services with the end goal of relaying impacts that are positive on human well-being.

In support of the framework, Garber reiterated the critical paths for making connections between ecosystem services and outcomes of human health. According to Garber, the first step in the path is (1) the *establishment of inventories to baseline ecosystem services and health conditions*. The second step is essentially the task of (2) *translating these conditions into quantifiable services*. The third step is to (3) *establish the linkages of these services to health outcomes of humans*. The fourth step, however, is (4) the ability of modelling and predicting potential impacts of the interventions identified for implementation and evaluation of feedbacks towards the complete cycle of activities. Garber proceeded to cite the use of the paths described in this framework in *'assessing coastal conditions and human health'* as an example of its effectiveness. To this effect, the results of the first step in the path, thus, establishing inventories of baseline ecosystem services and health conditions, are therefore captured in the proceeding paragraphs based on the National Coastal Assessment series of reports referred to by Garber.

Incitingly, research on sea-level rise, coastal erosion, fragile shorelines in coastal areas, and wetland vulnerabilities conducted are along with those concerning natural hazards such as earthquake and tsunami warnings and landslides. She also sorts to suggest there was more to be done to understand better the challenges in order to develop systems that go a long way to ensure environmental sustenance of coastal and marine systems— while raising some fundamental questions which also applies in the case of West African countries on the issues of sea-level rise.

2.1.20 General Discussions on the Environmental Stressors and Way Forward

A brief discussion of the panellists' succeeded in the presentations as they concluded the workshop. Lynn Goldman alluded to the much progress made in line with the scientific discussion concerning climate change, the impact of temperature rise, and the role of human activities on greenhouse gases.

She, however, decried the US as nation's inability in managing the ecosystems holistically, to include the human component of the equation. She, therefore, believes it as the reason for the failure in preparing for changes related to climate. His assertion resonates with many other scientists across the world who decry the lack of political will and commitment to working with climate policies. The fallout of the Paris Climate agreement is an example (DWTV, 2017; UN General Assembly, 2019).

Furthermore, she proceeded to inquire of the panel; as to why there was a lack of urgency towards better management of ecosystems. Again, how much is attributed to inadequate translation. Whether the message concerning the changes in ecosystems is not well communicated to policymakers and the public. All the panellists addressed her question affirmatively, responding that an improvement in communication to policymakers and the general public was critical. Sandifer proceeded further to note that improved and effective communication was central and needed to occur among the various sectors and various segments of the public. Sandifer, therefore, suggested the use of social media, if well harnessed could extend the reach and persistence of messaging on this topic to the public. In Garber's respond, he emphasised the need for us to create an environmental ethic.

Thus, reiterating that there are myriad of steps we can consider in our private personal lives that will help protect ecosystems; however, none will matter until we create an environmental ethic (behaviour). Christopher Portier, in his comment, referred to the agencies' own cultures, where they tend to approach issues from their specific perspective. Suggesting what is needed, Portier asserted, it is a systems perspective that is required while insinuating perhaps, the time was ripe to reassess working policies and regulatory frameworks of this institutions, developed decades ago and moved towards a holistic, systems perspective' (Source: Institute of Medicine. 2014).

2.1.21 Fundamentals of Our Climate and Climate Change on the Oceans

Climate discussion cannot happen with the mentioning of weather and seasonal patterns within the atmosphere. This assertion goes to suggest that weather is a microcosm of the prevailing climate and any subjected impacts. Therefore, the Public Health Institute/Center for Climate Change and Health (2016pp1) define weather as "the temperature, humidity, precipitation, cloudiness and wind that we experience in the atmosphere at a given time in a specific location," and Climate as "the average weather over a long time (thus, 30 – 50 years) in a region." Climates are also naturally and unnaturally subjected to natural and artificial variabilities like any other event of nature yielding to impact stressors in its lifecycle, respectively. These two impact phenomena are classically named 'climate variability' and 'climate change'. ***Climate variability*** (also called natural variability), thus refers to any natural variation in climate occurring over months to decades. A perfect example of such natural climate variability is the El Niño phenomena that change temperature, rain and wind patterns in many regions over 2 – 7 years (Public Health Institute/Center for Climate Change and Health, 2016). ***Climate Change,*** on the other hand, is "a systematic change in the long-term state of the atmosphere over multiple decades or longer [Uejio, C.K., Tamerius, J.D., Wertz, K. & Konchar, K.M. (2015)]." In this instance, the Scientists' burden is the task of using statistical testings — similar to the statistical tests used in clinical trials, in determining whether the potential changes in the climate set are within the range of the natural variability. In other words, did the change occur by chance? For example, it documents that since 1950, there is less than 1% chance the warming of the atmosphere could have been the result of the natural climate variability (Public Health Institute/Center for Climate Change and Health (2016)). That presupposes large portions of the changes recorded in recent times, points to the event of climate change rather than natural variability.

2.1.22 Identified Causes Climate Change

Current evidence suggests climate change results from a change in the earth's energy balance —thus, the amount of the sun's (solar) energy entering the earth (and its atmosphere) not balancing out with that released (reflected) back into space. It asserts that since the Industrial Revolution began two centuries ago, activities of humans have added enormous quantities of greenhouse gases (GHG) into Earth's atmosphere. In effect, these GHG tend to have a greenhouse (or a blanket or car windshield) phenomena (Figure 25 (a)), and thus trapping the sun's energy and heat, rather than allowing the natural course of reflecting much back into space. Higher concentrations of GHG in the atmosphere simply means to heat is trapped, and for that matter, the earth's temperature rises outside the range of natural variability. An opine of The Hill on November 09 2019, suggested that opponents of offshore drilling continue to cite the need for a reduction in greenhouse gas (GHG) emissions in their calls for a ban on exploration of the exploration on the Outer Continental Shelf (OCS). Offshore drilling is not just about energy security. It also funds conservation efforts onshore. Royalties pay, in large part, for some of our most treasured conservation programs like the Land and Water Conservation Fund (LWCF) by the US (Reps. Lizzie Fletcher (D-Texas) And Garret Graves (R-La.), 2019). There are many identified GHG.

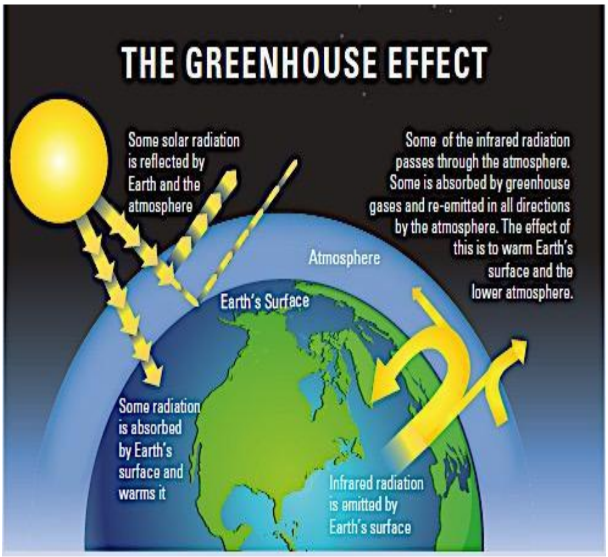


*Figure SEQ Figure * ARABIC 29: (a) Greenhouse gases in the atmosphere, including water vapour, carbon dioxide, methane, and nitrous oxide, absorb heat energy and emit it in all directions (including downwards), keeping Earth's surface and lower atmosphere warm. Adding more greenhouse gases to the atmosphere enhances the effect, making Earth's surface and lower atmosphere even warmer. Image based on a figure from US EPA courtesy: http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-basics.pdf, (2014).*

Each has a different heat entrapment ability referred to as its ***"global warming potential"*** and different half-life (decay time) within the atmosphere. GHG also referred to as "***climate active pollutants***" due to additional effects on living organisms, notably associated with human health [Public Health Institute/Center for Climate Change and Health (2016); US EPA, 2014]. According to scientists, when all factors of both human and nature considered, studies show the Earth's climate balance altered towards warming, due primarily to increase CO_2 concentration (dels.nas.edu, 2014). Other equally important GHG identified include methane, nitrous oxide, black carbon, and various fluorinated gases and their estimated Global Warming Potential (GWP) value.

2.1.23 Impact of the Changing Climate to the Critical Global Environmental Changes

The Table 6 below is a compilation of the five critical global environmental changes define and attributed to the rapidly changing climate in the Earth's atmosphere based on articles of the Public Health Institute/Center for Climate Change and Health (2016) and US EPA, (2016).

Table 6: Climate Change Effect on the Global Environment

ELEMENTS OF THE GLOBAL ENVIRONMENTAL CHANGE	WHAT DOES IT MEAN TO OUR EARTH AND ITS INHABITORS

• Warming temperature of the earth's surface and the oceans:	it has earth warmed at a rate of 0.13° C per decade since 1957, almost twice as fast as its rate of warming during the previous century.
• Changes in the global water cycle ('hydrologic' cycle):	Over the past century, there have been distinct geographical changes in total annual precipitation, with some areas experiencing severe and long-term drought and others experiencing increased annual precipitation. Frequency and intensity of storms increases as the atmosphere warms and can hold more water vapour.
• Declining glaciers and snowpack:	Across the globe, nearly all glaciers are decreasing in area, volume and mass. One billion people living in river watersheds fed by glaciers and snowmelt thus are impacted.
• Sea level rise:	Warmer water expands, so as oceans warm, the increased volume of water is causing sea-level rise. Melting glaciers and snowpack also contribute to rising seas.
• Ocean Acidification:	Oceans absorb about 25% of emitted CO2 from the atmosphere, leading to acidification of seawater. These global changes result in what we experience as changes in our local weather and climate: • Greater variability, with "wetter wets", "drier dries" and "hotter hots." ° *More frequent and severe extreme heat events* ° *More severe droughts* ° *More intense precipitation, e.g. severe rains, winter storms and hurricanes* • Higher average temperatures and longer frost-free seasons • Longer wildfire seasons and worse wildfires • Loss of snowpack and earlier spring runoff • Recurrent coastal flooding with high tides and storm surges • More frequent and severe floods due to intense precipitation and spring snowmelt • Worsening air quality: Higher temperatures increase the production of ozone (a key contributor to smog) and pollen, as well as increasing the risk of wildfires. • Longer pollen seasons and more pollen production

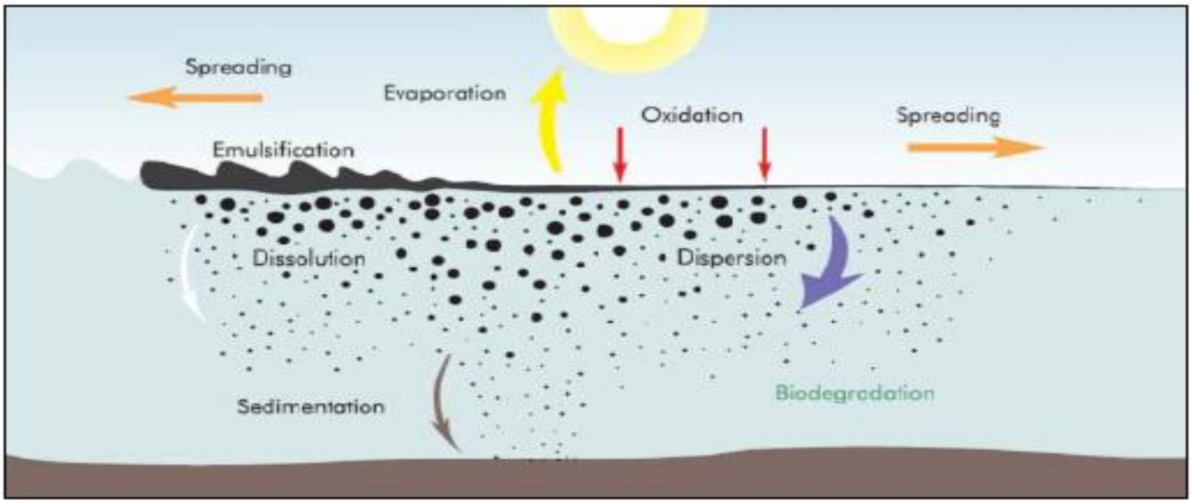
By these assertions in Table 6, it is essential to reiterate the need for monitoring, projecting and developing the capability towards limiting its impact globally, especially in the tropics, where there appear to report on issues with massive coastal erosions, [e.g., along the coast of West African countries like Ghana, Togo, and Ivory Coast bound to the Gulf of Guinea (BBC, 2019)].

2.1.24 Basic understanding of Marine Pollution with a focus on Oil

Oil can be categorized into four different types, based on their characteristics-thus considering the variation in the physical and chemical properties of the petroleum product, Rodrigues (2009) listed them as (a) very light oils (such as gasoline, jet fuels); (b) light oils (diesel); (c) medium oils (such as lubricants and light crude oils); (d) heavy fuel oils (asphalt, heavier crude oils) (Rodrigues, 2009). Agreeably, these differences present a correlative effect on the level of impact oil discharges have on the ocean, respectively. Relatively, Fingas' (2001) description of guidelines for estimating oil thickness using visual surveillance further reiterate the fact that, the variation in oil at spillage poses a significant challenge hence the need to assess the thickness of the slick effectively. He further claimed "oils appearance varies from silvery-sheen to dark brown" Fingas (2001); Maya et al., (2008) and this could indicate the type of oil spill observed. In a related argument, Rodrigues, (2009) in her attempts to identify factors affecting oil spillage claims " What happens to oil during and after oil discharge into the sea depends largely on the type of oil, but also the amount discharged, weather conditions, currents, and temperature (sea/air)" (Rodrigues, 2009 pp11). According to her, eliminating the weather and oceanographic factors lives oil spill in a condition that could be described as 'still stagnant fluid' with less much impact on the marine environment and life. Subsequently, weathering of oil will be unaided by the dispersant.

Furthermore, Oil as a variant commodity is said to absorb solar radiation and re-emits a portion of it as thermal energy, according to Fingas & Brown (1997).

What is weathering? Weathering is a generic term with no outright definition but does have a relative meaning to what has been implied. As such, it is essential to consider the broad implication. Rodrigues' (2009 pp 11) in her attempt to explain weathering concerning oil claimed that; "as oil is discharged and comes into contact with the seawater, several chemicals, physical and biological processes start acting on it (referred to as weathering)". These clearly are illustrated in Figure 30, which is a pictorial view of possible weathering processes oil is subject to when in contact with the sea.



Thus, it does render the marine ecosystem either partly or destroyed, metabolized, as well as excessive deposit amounts of hydrocarbons, transforming them into more familiar and safer substances (translated by Elena Cascio (13th September 2011) oil fate and behaviour during an oil spill in the sea. retrieved from "Environmental Impact of the Offshore Oil and Gas Industry", Stanislav Patin). In discussing the weathering process, Patin (2001) explained each process as follows;

Physical transport: in his view, the distribution of oil spilt on the sea surface occurs under the influence of gravitational forces as well as controlled by oil viscosity and the surface tension of water. It is agreeably so because, the varying Coriolis Effect created, result in the drag of water by wind-based on the centripetal and centrifugal pull and push, the earth experience.

The Oil slicks get thin (thus less than 1 mm) as oil continues to spread, covering an area of up to 12-kilometre square. Changes in slick may also be due to meteorological and hydrological factors thus depend mainly on the power and direction of wind, waves, and currents. The changes are because oil slicks usually drift in the same direction as the wind (Patin, 2001). Thin-oil slic0k, especially after the critical thickness of about 0.1mm, according to Patin (2001), disintegrates into separate fragments that spread over more extensive and more wide distant areas.

Dissolution: Most oil compounds are water-soluble to a certain degree, according to Patin (2001), especially the low-molecular-weight compounds. That is aliphatic and aromatic hydrocarbons. He explained further that, polar compounds also formed as a result of oxidation of oil fractions in the marine environment, dissolved in seawater. Compared with evaporation, dissolution takes more time according to him. Furthermore, this is due to the Hydrodynamic and physicochemical conditions of the surface waters strongly affecting the rate of the process.

Emulsification: further in Patin's accession, emulsification depended on the composition of the oil and the turbulent regime of the water mass. Supporting his argument, he stated the most stable emulsions contained between 30% to 80% water and usually appeared after intense storms in the spill zones. Putin explained that, is usually the case of spills of heavy oils with increased content of nonvolatile fractions (especially asphaltenes) which remain in the marine environment over 100 days. Stability of these emulsions usually increases with decreasing temperature. Nevertheless, the reverse emulsions, such as oil-in-water (i.e. droplets of oil suspended in water), are much less stable and due to the effect of surface tension, there is the decrease in the dispersion of oil. However, the dangers remain enormous.

Oxidation and destruction: The chemical transformations of oil on the water surface and in the water column naturally tend to reveal its nature not earlier than a day after the oil enters the marine environment according to Patin (2001). In Patin's view, they have an oxidative nature and often involve photochemical reactions under the influence of ultraviolet waves of the solar spectrum. Some trace elements catalyze these processes. Such elements include vanadium as well as inhibited (slowed) by compounds of sulfur. The final products of oxidation (as in hydroperoxides, phenols, carboxylic acids, ketones, aldehydes, and others) usually have increased water solubility. The reactions of photo-oxidation, photolysis, in particular, initiate the polymerization and decomposition of most complex molecules in oil composition as he reiterates GESAMP, (1977; 1993) assertion.

Sedimentation: Further in Patin's view, oil (up to between 10&30%) is adsorbed on to the suspended material and deposited to the bottom. This process mainly happens in narrow coastal zones and shallow waters where particulates are abundant with water subjected to intense mixing (turbulence).

In deeper seas, sedimentation of oil (except for the heavy fractions) is a prolonged process. Simultaneously, the process of bio-sedimentation takes place. Thus Plankton infiltrators and other organisms absorb the emulsified oil and sediment it to the bottom with their metabolites and remains.

Numerous experimental and field studies show that the decomposition rate of the oil buried on the bottom abruptly drops. The oxidation processes slow down, especially under anaerobic conditions in the bottom environment. The heavy-oil fractions accumulated inside sediments can be preserved for many months or years.

Microbial degradation: Patin (2001) discusses petroleum substances in the marine environment as ultimately defined by microbial activity. About a hundred known species of bacteria and fungi can use oil components to sustain their growth and metabolism. In areas polluted by oil, their proportion increases from 1-10% (Atlas, 1993). Biochemical processes of oil degradation by microorganism include several types of enzyme reactions based on oxygenases, dehydrogenases, and hydrolases. These result in aromatic and aliphatic hydro oxidation, oxidative deamination, and hydrolysis. Patin (2001) claimed, the degree and rates of hydrocarbon biodegradation depend, on the structure of their molecules. Thus paraffin compounds (alkanes) biodegrade faster than aromatic and naphthenic substances. The most important environmental factors include temperature, the amount of nutrient concentration, oxygen level, and species composition.

Aggregation: is another process, according to Patin (2001). Oil aggregates in the form of petroleum lumps, tarballs, or pelagic tar and can be presently found both in the open and coastal waters as well as on the beaches. The chemical composition of oil aggregates is most often, based on asphaltenes (up to 50%) and high-molecular-weight compounds of the heavy fractions of the oil. Oil aggregates look like light grey, brown, dark brown, or black sticky lumps with an uneven shape and vary from 1 mm to 10 cm in size (sometimes reaching up to 50 cm). Their surface serves as a substrate for developing bacteria, unicellular algae, and other microorganisms. Oil aggregates could exist from a month to a year in enclosed seas and up to several years in the open ocean as he cited (Benzhitski, 1980).

Self-purification: As discussed previously, oil in the marine environment rapidly loses its original properties and disintegrates into hydrocarbon fractions. These fractions have different chemical composition and structure and exist in different migration forms. They undergo radical transformations and slow after reaching thermodynamic equilibrium with the environmental parameters; thus, according to Patin (2001). The original and intermediate compounds gradually drop as a result of dispersion, degradation and eventually, disappear, to form carbon dioxide and water. Such self-purification of the marine environment inevitably happens in water ecosystems if, the toxic load does not exceed acceptable limits (Patin, 2001). Another major pollutant within the marine environment is marine plastic

(Kara Lavender Law, 2017). (For further reading, refer to *Plastics in the Marine Environment. Annu. Rev. Mar. Sci. 2017. 9:205–29. doi: 10.1146/annurev-marine-010816-060409)*

2.2 LITERATURE REVIEW

The Chapter provides a summary of various literary presentations discussing detailed reviews of the anthropogenic stressors, including noise, pollution, intensity lighting, and climate change in its introduction. This study identifies its anthropogenic stressors leading to various obstructionist stresses today, to include: Underwater Noises; Subsea Structural and Machinery Movements; High-Intensity Lighting at Night, Marine Pollution and Climate Change to be the critical stress parametric issues shaping the habitats and lives of marine mammals. Therefore, the chapter focuses on each of the various stresses detailing current developmental trends.

2.2.1 Preamble

All these activities are without environmental changes; neither do the environmental impact assessment carried out intentioned to absorb the entirety of the potential marine environmental changes. In effect, the marine environment becomes saturated with underwater sounds (noises) of all forms generated by various activities of different ships and equipment deployed within the area. Figure 31 is a clear illustration of underwater noise effects on marine lives. Nonetheless, there appear to be some quiet and stillness at specific water depths— helpful to marine lives. Underwater radiated noises introduced by ships primarily, into the ocean environment originates from several sources, either; deliberately produced during navigational thrust purposes, incidentally emitted as a function of mechanical operations of systems, or deliberate use of noise in design data acquisitions (JohnWiley&Sons, Ltd, 2017). The challenge, however, for example, arises at the contrasting of sound produced by Toothed whales (thus, sperm whales), who use sound in finding and identifying prey sources like squid and also for navigating and communicating with their family groups (NOAA Fisheries, 2019). Their ability to hear sounds, in this case, maybe impeded, misconstrued or overshadowed by the radiated noises.

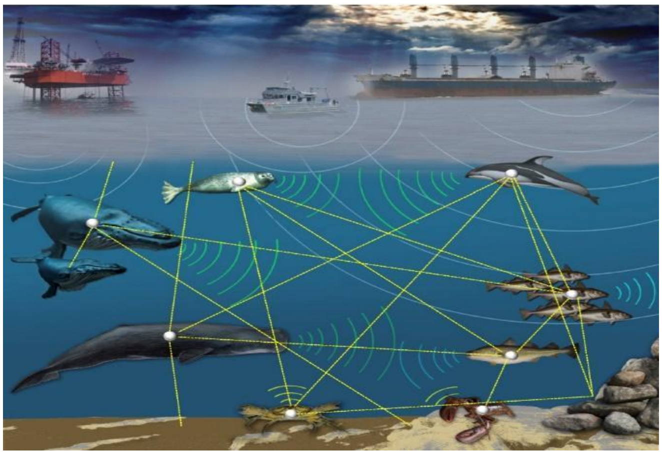


Figure 3.0-B: The Goals of the appraisal phase. courtesy:

Another example is the many baleen whales—like the humpback, blue, and fin whales— who regularly repeatedly sing for long-distance communications, and during reproduction. Besides marine mammals, fish populations and invertebrates are all as a catastrophic risk. Sounds produced by Oyster toadfish is to attract females. Raspy sounds made by Caribbean spiny lobsters is to help them escape predatory octopuses. It asserted that Tropical coral larvae also uses sound in detecting their ideal reef habitats (NOAA Fisheries, 2019). This assertion goes to suggest that the much sound these creatures make, the much they hear and can relate or identify their targets. Another anthropogenic impact associate with offshore upstream activities is are the continuous surface-to-subsea movement of infrastructural installations such as the risers, piles, jumpers, manifolds, by use of heavy-lift cranes and winch wires. Though it is unclear how of these movements have amounted to direct collusions, impediment of movements, or physical habitat damage, the potential impact cannot be underestimated on the marine environment. High-intensity lighting is another phenomenon associated with night operations in the offshore upstream sector (Davies, Coleman, Griffith, Jenkins (2015)). This condition tends to alter the water surfaces at concentrated locations, causing unintended aggregating of fishes, insects, which in turn draws predatory mammals close to installations. The dangers here are inherent. Marine pollutions (Lamptey, and Sackey, 2017) is another with grave implication for the marine environment, where the potential of oil discharges or spills and drill cutting and fluid leaked are unavoidable.

Moreover, the issue of climate change (Heneghan, Hatton and Galbraith, 2019) influences the atmosphere and the ocean with disastrous consequences. How much black carbon emissions estimated are released during upstream operations. Subject to this primary identified anthropogenic stressors with the potential of inhibiting the natural flow of life in the Gulf of Guinea, the following paragraphs dedicated, are to a detailed review of literature of each stressor impact.

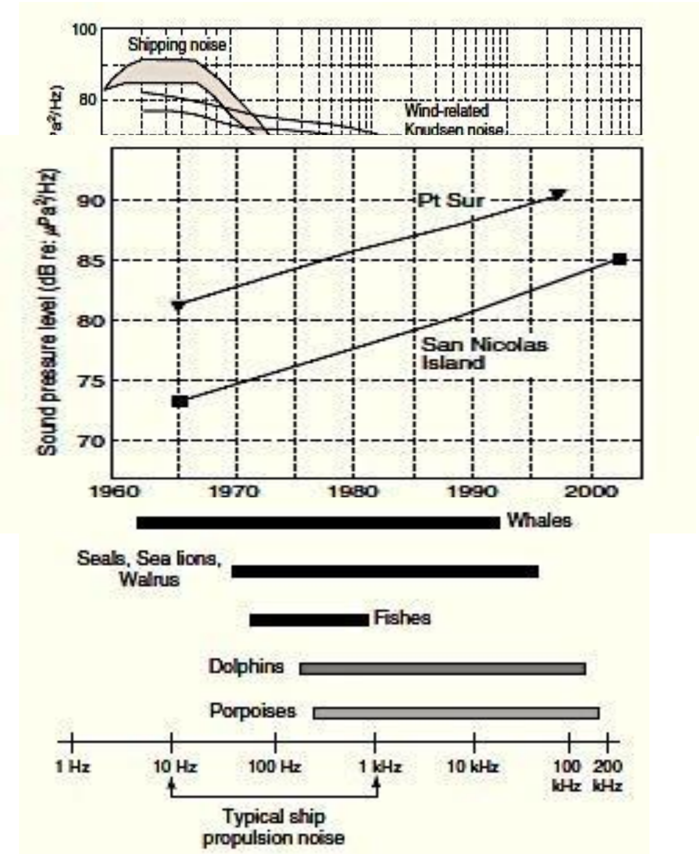
2.2.2 (A) Consequences of Ship Radiated Noise on Marine Life and Environment

All vessels generate noise consequential from their operation. Modern powered vessels of today typically generate low sound frequency (thus, measured averagely to be less than 1000 Hz) of hydrodynamic flow noise, onboard machinery, and, primarily, from propeller cavitation. It has been stated that some of the early characterizations of natural and anthropogenic ocean ambient noises (as shown in Figure 31 above), including the typical low-frequency noise spectra of differing levels of shipping activity (shown in Figure 32 below), were made by Wenz (1962).

Since then, measurements of radiated noise from different classes of large commercial vessels thus according to Ross, (1976, 2005); Arveson and Vendittis, (2000); and Wales and Heitmeyer, (2002), have availed the basis for broader characterizations of vessel radiated noises today (Hatch et al., 2008; Hildebrand, 2009; McKenna et al., 2012).

According to Hildebrand, (2009), though vessel-radiated noises are predominately low frequency in nature, there are occasions where higher frequencies (i.ee., up to tens of kHz) occur at relatively close (typically <1 km) ranges. There is, therefore a direct relationship between the overall radiated noise source level per the frequency spectrum and myriad of factors, such as vessel size, speed, load, condition, age, and engine type. Another worth mentioning is the nature of operations being undertaking. Thus, larger vessels with a length overall (LOA) exceeding 100 m, typically are observed to generate louder, lower-frequency sounds than smaller boats. Again, faster vessels are typically louder, although there are notable exceptions (Heitmeyer, Wales, and Pflug, 2004). According to Brandon L. Southall, et al. (2017), reviews conducted by Richardson et al. (1995), Hildebrand (2009), and McKenna et al. (2012) based on typical noise spectra and source-level characteristics of the various classes of modern commercial vessels, suggest vessel noise contributes substantially to low-frequency ambient noise environment already saturated with natural sounds generated by winds, ocean waves, and marine animals. Whereas, the longitudinal increases in low-frequency ambient levels are documented of several regions primarily to be associated with increases in the number of commercial ships typically en-route in the sea area (Curtis et al., 1999; Andrew, Howe, and Mercer, 2002; McDonald, Hildebrand, and Wiggins, 2006, 2008). They submit, low-frequency ambient noise increases were not steady with a uniform rate within the world's oceans –asserting, many factors (mostly economic) to be the reason driving distribution and magnitude of vessel traffic. The natural environment into which ship noises propagate also serves as host to natural ambient noises (such those from waves)—these influences environmental and biological variables. However, in agreeing with well-documented studies of the impact of increases in commercial vessel numbers and their concentration at specific areas along with the levels of low-frequency ambient noise they generate demonstrates that marine commercial traffics broadly interferes with average levels of low-frequency ambient noise on decadal time scales (as shown in Figure 33).

Furthermore, the National Research Council of the US National Academies (NRC) (2003) explained that current trends of the commercial shipping industry across the world suggest an increase to an extent underwater ambient noise. Whereas economic factors drive short-term changes in the numbers and distribution of commercial vessels, there was an approximate tripling of overall numbers of large commercial vessels between 1955 and 2011 (Lloyd's Register, 2013). According to Lloyd's Register, this broad trend is expected to continue to double or triple over the period from 2005 to 2030 per predicted forecast by industry analysts (Lloyd's Register, 2013); (JohnWiley&Sons, Ltd, 2017). Marine Life is the said to the most affected, with some mammal species (dolphins and porpoises) having sophisticated biosonar capabilities for near-range feeding and orientation (Au, 1993). Others, such as the large baleen whales, make use of communication systems adaptable to longer-range sounds for reproductive and social interactions (Clark, 1990; Lalli and Parsons (1997); Kennedy (2019)).



Furthermore, in events where there are overlaps between the frequencies of anthropogenic ship noise sources and sound frequencies utilised by marine life forms, this can interfere with their biological functions. Thus, predominately, there can directly overlap low-frequency communications sounds and hearing of many marine mammals, unusually large whales and some seals and sea lions, and the typical low-frequency sounds associated with the larger vessels. These illustrated are in Figure 34. The paper herewith shall proceed to review the case study by Ocean Noise Roadmap, NOAA Ocean Noise Strategy Roadmap (ONSR) (2016), which study assessed the risks related to chronic shipping noise issues impacting of Baleen Whales of California.

2.2.2 (B) Case Study Review: Assessing the Risk of Chronic Shipping Noise to Baleen Whales off Southern California

The study attempts to draw a comparison of Southern California with the situation in the Gulf of Guinea. They were thus assessing and correlating the impact in line with marine mammals in the area and their habitation. According to NOAA ONR, a version of this work has been reviewed for publication at the credit of Redfern et al.'s research article themed, "*Endangered Species"*.

2.2.2.1 Introduction

Miksis-Olds & Nichols (2016) reiterated that anthropogenic ocean noises produced had significantly increased at the beginning of the industrial era, although it is an uneven distribution within space and time. They cited an example at two locations away from major shipping lanes (one in the equatorial Pacific Ocean and one in the South Atlantic Ocean) between 2004 and 2012. According to Miksis-Olds & Nichols (2016), analyses of data collected showed decreases in the ambient sound floor and other sound level parameters. In contrast, the Northeast Pacific Ocean recorded low-frequency noise increase beginning in the 1960s (Andrew et al. 2011, Chapman & Price 2011) and over the last decade in the Indian Ocean (Miksis-Olds et al. 2013).

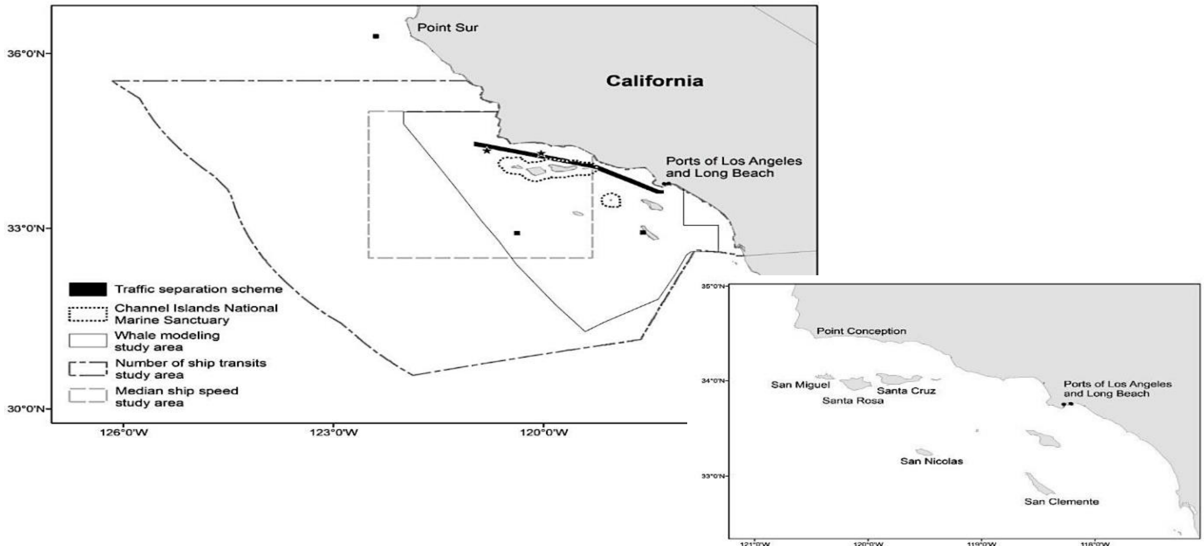
This increase has been described as a likely representative of noise increases in the deep sound channel of the Northeast Pacific Ocean as a result of increasing commercial shipping, in terms of the ship numbers and their gross tonnages and horsepower (McDonald et al. 2006). There have been more recent measurements of noise, thus between 1994 and 2007 at the Point Sur and San Nicolas Island locations. The areas showed low-frequency noise remaining constant or slightly increasing, with a single decreasing at 50Hz noise at Point Sur as an exception (Andrew et al. 2011).

Practically, these noise monitoring locations within the Northeast Pacific Ocean, are observed to overlap with the mammal habitation for baleen whales. A precise account put blue whales feeding grounds in the southern California waters from June to October (Calambokidis et al. 2015), with the humpback whales' feeding between March to November (Calambokidis et al. 2015). Also, the aggregations of fin whales in these waters have been observed all year- round (Forney et al. 1995). In all, a summary of seven-year of blue and fin whale calls detections within southern California waters recorded blue whale 'B calls[15]' between June and January, with a peak in September (Sirović et al. 2015), besides series of 'A Calls' and 'D Calls' at different intervals and frequencies for each whale species (blue, fin and humpback whales). Presently, all three listed species are of '***Endangered,'*** and ***'Depleted and Strategic'*** under the US Endangered Species Act (ESA 1973) and the Marine Mammal Protection Act (MMPA 1972) respectively. Although as at 1991, the fin and humpback whales' populations of the California coast observed are increasing (Calambokidis & Barlow 2004, Moore & Barlow 2011) alongside Monahan et al.'s (2014) suggestion of blue whales' population reaching their carrying capacity, the threat against these species still from ship strikes, entanglements, and anthropogenic noises remain high (NOAA ONR, 2016). Payne & Webb (1971); NOAA ONR, (2016) further asserted that the poorly understood use of sound by baleen whales, though assumed to include, but not be limited to, hearing conspecific calls, baleen whales are believed to rely on low-frequency sounds for feeding, breeding, and navigation. Payne & Webb (1971) indicate, the recognition of potential effects of noise on baleen whales' dates back to over 40 years ago and with more recent documented data on behavioural responses to shipping noise for all three species (e.g., Sousa-Lima & Clark 2008, Castellote et al. 2012, Melcón et al. 2012). Clark et al. (2009) identified problems of low-frequency noise to result in acoustic masking –impeding an individual's ability to either effectively perceive, recognize, or decode sounds of interest for a foreseeable; with areas associated with elevated noise consequently, suffering from degraded acoustic environments. In summary, large noise increases over the past within the Northeast Pacific Ocean have occurred in the lifetime of these baleen whales and so, at frequencies forming an essential part of the acoustic environment (NOAA ONR, 2016).

The importance of their choice of Southern California waters according to NOAA ONR, (2016), is because it is the first areas to be identified in both national and international discussions for management techniques towards reducing chronic underwater noise impacts because of its proximity to the Ports of

[15] The 'B calls' are (tonal calls with a down sweep in frequency) one of three blue whale calls that have been recorded in the southern California Bight (Sirović et al. 2015). Series of 'A calls' (a series of rapid, low-frequency pulses) and 'B calls' (~16Hz) are believed to serve a reproductive function (Oleson et al. 2007). Blue whale 'D calls' are more variable in their characteristics (~25-90Hz) and are believed to serve a social function (Oleson et al. 2007). Fin whale 20Hz calls (these downswept pulses can be produced in regular or irregular sequences, with regular sequences attributed to males) were detected year-round, but occur at the highest levels between September and December, with a peak in November (Sirović et al. 2015). Humpback whale calls (~150-1800Hz) have also been recorded in these waters (Helble et al. 2013) as cited by NOAA ONSR (2016: 63-64)

Los Angeles and Long Beach (Figure 35), ranked among the nation's largest in terms of port calls and cargo capacity (MARAD 2014). The Channel Islands National Marine Sanctuary (CINMS) is located within these waters under the local CINMS regulations enforced by National Marine Sanctuaries. Haren (2007) is also recorded reiterating the possibility of the U.S. government is requesting the International Maritime Organization (IMO) designate the CINMS and surrounding areas as Particularly Sensitive Sea Area (PSSA[16]). To better identify and define needed specific management measures (e.g., seasonal or dynamic slow speed zones and alternative shipping routes), NOAA ONR (2016) emphasises the need for better understanding of the risk of these noises to marine mammal species in the region. Again, Clark et al. (2009) and Hatch et al. (2012) suggest estimates of acoustic communication loses in space can become a valuable tool in the assessment of risks caused by low-frequency, chronic noise. Other risk assessments using spatial representations of species habitats and underwater noise generated by



human activities as having conducted in the Erbe et al.'s (2012) study, showed the mapping of cumulative underwater acoustic energy from shipping. The study made use of a simple model of sound transmission and Automatic Identification System (AIS) data. Erbe et al. (2014) subsequently, using audiogram weightings across a range of frequencies to identify species-specifics, they combined these data with species distributions per the various hotspots of ship noise. Williams et al. (2015) also applied

[16] A PSSA is an area that needs special protection because of its significance and vulnerability to shipping. Management measures associated with the PSSA could require or recommend that ships operate in a manner that reduces noise (e.g., travel at slower speeds or use alternative shipping routes).

the same data using a similar approach in identifying important species habitats occurring in areas of little noise.

The NOAA ONR's (2016) study, therefore, conducted a spatially explicit assessment of the risk associated with commercial shipping noises to the blue, fin, and humpback whale habitats in Southern California waters, using acquired AIS data in modelling the noise at two frequencies related to the acoustic environment for these species while the more capturing the variable contributions from shipping to noise. Notably, by selecting 50Hz to represent the peak in contribution from shipping-to-noise, and 100Hz to represent contributions where shipping-to-noise begins to diminish (National Research Council 2003), the predicted noise was then compared to noise measurements at two sites within the study area (NOAA ONR, 2016).

In the analyses, however, rather than concentrating on the masking of specific sound communication signals [e.g., the techniques that Clark et al. (2009) and Hatch et al. (2012) used], focused is had on the shipping-to-noise contribution in baleen whale habitats. Thus they assumed the species' use of low frequencies sound are for a variety of biological functions (feeding, breeding, and navigation). This low-frequency sound can broadly be impacted on by the low-frequency shipping noise occurring (NOAA ONR, 2016). The assessment identifying noise hotspots in species habitats compares to Erbe et al. (2014), and quiet areas of the sea within species habitats compares to Williams et al. (2015).

2.2.2.2 Review of the Methods Deployed

Review of their method deployed in the preceding paragraphs is crucial in understanding the interpretation given in the outcome of their study, this should also inform the approach of this study on growing noise hotspots in the Gulf of Guinea, and its intended objectives of promoting environmental sustenance.

1.0 Characterization of noise from commercial shipping

According to NOAA ONR (2016), their noise modelling approach used was based on Porter and Henderson (2013) approach briefly described here in the review. It is also used in the NOAA Fisheries CetSound project (http://cetsound.noaa.gov). However, the NOAA ONR's models relied on higher resolution shipping information obtained from AIS data (see below). Essentially, noise modelling requires the use of environmental information, such as bathymetry, bottom type, and sound speed. Such data help in the calculations of transmission loss for noise sources, and their distribution on a grid of the study area. The noise levels are then calculated by;

> "*Convolving the transmission loss with source-level densities estimated for specific activities (e.g., shipping, pile driving, or sonar). This two-stage approach provides a mechanism for quickly updating noise predictions to reflect changes in source-level densities. Our models currently only include noise produced by commercial shipping; however, this approach could be used to integrate noise from multiple human activities" (NOAA ONR, 2016, pp66).*

Their models essentially, relied on water depth data set from the SRTM30_PLUS (http://topex.ucsd.edu/WWW_html /srtm30_plus.html; Smith & Sandwell 1997, Becker et al. 2009), while seafloor bottom characterization was categorized using sediment thickness data retrieved from NOAA and Divins (http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html; Divins 2003), and seabed properties data from the Pacific States Marine Fisheries Commission (http://marinehabitat.psmfc.org /physical-habitat.html). However, these data sources provided only differentiate mainly between "hard" and "soft" bottom types. Therefore, using Bottom Sediment Type (Anonymous 2003), they define hard as cobbles to very coarse pebbles (phi = -6) and soft as fine silt (phi = 7.9). The Basalt laying below depths of the sediments as given in the NOAA sediment-thickness database, sound speed was calculated using average "Summer" and "Fall" temperatures and salinity climatologies obtained from World Ocean Atlas (Levitus et al. 2013). Finally, they deduced the scattering loss of sound due to sea surface roughness by incorporating model the use of significant wave height at 10-knot wind speed (e.g., H. Zhang at ftp://eclipse.ncdc.noaa.gov/pub/seawinds/SI/uv /monthly/IEEE) (NOAA ONR, 2016).

Substantially, the ***source-level densities*** employed in the various models obtained were from the measurements of shipping traffic, by relying specifically, on AIS data collected between August and November in 2009. This data was used in the calculation of the number of ship transits in approximately 1km x 1km grid cells. For more reading, further detail of their approach can be found in NOAA Ocean Noise 'Strategy' Roadmap (2016) publication and also at the credit of Redfern, J. et al.'s *Endangered Species Research*. A broader area though partly because low-frequency noises travelled over long distances, was also used in analyzing shipping data to ensure the models included noise from as many ships as possible affecting the whale modelling study area as possible.

Line Statistics: From the AIS datasets, various points joined were in chronological order towards forming a line where both points observed were to have same MMSI (thus indicating vessel change in position) and elapsed time between such points determined to be less than one hour. Again, where the elapsed time appears greater than one hour but less than six hours, points having less than 30-degree change in heading were joined. In this regard, where two successive points appear to fail in meeting these requirements, the current line under construction is ended while another is commenced at the position of the new heading change. Consequentially to this, is the total number of transits calculated using the Line Statistics Tool in ArcGIS (Environmental Systems Research Institute 2014, ArcGIS Desktop: Release 10.2.2. Redlands, CA) for four length-based ship categories, namely: (1) ≥ 18m and ≤ 120m; (2) > 120m and ≤ 200m; (3) > 200m and ≤ 320m and (4) > 320m for each grid cell. A search radius of approximately 0.5642km was implemented during calculations with the given area. The resulting circle was of the same value as that of the area of the grid cells.

Determining Source Level Densities (in noise extrapolations): source-level densities, were based on the number of ship transits per cell conversion using the source levels in Carey and Evans (2011) for the four length-based ship categories. These source levels in Carey and Evans (2011) which references vessels active during the 1970s and 1980s; are based on the noise model known as the Ambient Noise Directionality Estimation System (ANDES) associated with worldwide shipping estimates. As reported by Carey and Evans (2011), shipping noise source levels do vary from 130dB for smallest length vessel categories (“small tanker”, 18-120m) with the highest frequency at (400Hz) to 180dB for the largest length vessel categories (“supertanker”, >320m) with the lowest frequency at (50Hz). The various ships identified in all four categories; were modelled to reflect propeller depths at 6m while using source-level densities (dB re 1µPa2 / Hz at 1 meter) reported on frequency in 1-Hz bands.

Modelling the Noise for the four categories of Ships: NOAA ONR (2016) agreeably, asserted that ship size and speed influences the noise levels produced by ships (McKenna et al. 2013). Hence, their modelled noise encompassed the four ship-length categories, thus helping provide appropriate estimates for large-scale and long-term noise predictions. However, they did not incorporate variability associated with the individual ships within the length-category in noise modelling. Average speed per each length-category was estimated to determine a correspondence ‘within-cell’ residency times for each transit and associated source levels accumulations. They obtained the various ship speeds from the point-based AIS data collected between August and November 2009 by the U.S. Coast Guard (thus, because accurate speed data could not be obtained from the 2009 Marine Cadastre data). Specifically, the calculation of the median speed for all ships in each length category was within the boundary box shown in Figure 30 above. They further limited their analyses to the small box area, rather than applying all shipping data, in order to avoid the ships travelling into and out of main ports. This choice of analysis is primarily because ships speeds close to ports are slower and do not represent speeds throughout the broader areas. Citing McKenna et al. 2013, they contended that although reduced noise, is measured for some ships travelling at slower speeds (McKenna et al. 2013), the increased time ships spend in an area offset the noise reduction when travelling at slower speeds. Therefore, the median speed for modelling the noise was: (1) 6.40 knots for ships ≥ 18m and ≤ 120m, (2) 13.50 knots for ships > 120m and ≤ 200m, (3) 17.20 knots for ships > 200m and ≤ 320m, and (4) 21.00 knots for ships > 320m.

Determining Noise Transmission Loses: in determining a model for the transmission loss, the KRAKEN Normal Modes model (Porter & Reiss 1984, Porter & Reiss 1985) –was used. The Normal modes of the ocean; were calculated with the assumption the centre of each grid cell and sound field, is calculated using the adiabatic mode theory along imaginary fan radials around the centre of each grid cell (Kuperman et al. 1991). Subsequently, the resulting source-level densities; were convolved using the estimated transmission loss to determine noise levels (dB re 1μPa2 / Hz) per each cell at discrete depth (30m) under two specific 1Hz frequency bands (50 and 100Hz). The predicted levels; were then expressed as the equivalent, unweighted sound pressure levels (Lzeq), which represents the time-averaged across the specified duration, in this case, 122 days of August to November.

Predictions of Noise Models and comparisons: the noise model prediction, were then compared to empirical underwater acoustic data collected at the two sites in the region (McKenna 2011), thus, with one north of the Santa Barbara Channel Traffic Separation Scheme (TSS) between Santa Rosa and Santa Cruz Islands and the other one on the southwestern edge of the TSS (Fig. 3.2). The acoustic data collected using High-frequency Acoustic Recording Packages (HARPs); was developed at Scripps Institution of Oceanography (Wiggins & Hildebrand 2007). These HARP hydrophones were subsequently deployed approx—10m above the seafloor. In November 2009, the acoustic data collected were decimated to the sampling frequency of 2 kHz and then processed to calculate the monthly sound spectrum averages (NOAA Ocean Noise Strategy Roadmap (2016)). According to McDonald et al.'s (2008) estimation, pre-industrial noise levels accounted for 55dB at 40Hz at a site near San Clemente Island (Fig. 30). on another breath, Wenz (1962) generally represented "light shipping" conditions with approx. 65dB at 50Hz. Based on this literatures, 65dB was selected to approximate the upper bound for the 50Hz and 100Hz pre-industrial noise conditions in the study area (NOAA ONR, 2016). In utilizing the 10th, 50th (median), and 90th percentiles of predicted values, the modelled noise was consequently summarized, with the estimated pre-industrial noise conditions and percentiles then used in defining the five categories of predicted noise levels at 50Hz and 100Hz as (a) <65dB (pre-industrial noise conditions), (b) 65dB to the 10th percentile, (c) 10th to 50th percentiles, (d) 50th to 90th percentiles, and (e) >90th percentile. These five categories, thus in assessing their correspondence to different volumes of shipping traffic according to NOAA ONR, are then compared to the time series of noise measurements off Point Sur (Fig. 30) (NOAA ONR 2016).

2.0 Co-occurrence of whale habitat and noise

The NOAA ONR indicated that whale distribution data in their study –were obtained from three sources capturing the different elements of whale habitat. They concurred with Redfern et al. (2013) who developed ***Habitat Models*** for the blue, fin, and humpback whales within waters off southern California making use of data spanning seven years (1991, 1993, 1996, 2001, 2005, 2008, and 2009) in gathering by NOAA Fisheries' Southwest Fisheries Science Centre. Their assessment surveys were on systematic marine mammal and ecosystem. These surveys carried out throughout U.S. EEZ from August to November; consequently, resulted in the model predictions of species density (Fig. 30), capturing large-scale and long-term patterns of species distributions during a single season. However, fine-scale patterns, particularly near the coast, or seasonality –was not captured.

The boundaries for ***Biologically Important Areas (BIAs)*** in these waters (Fig. 30), was also developed by Calambokidis et al. (2015). These BIA boundaries; were mainly based on expert judgment drawn to encompass areas of concentrated animals feeding (thus, wherewith direct observation of feeding or surfacing patterns being indicative of feeding) consistent with multiple years' presence. With the non-systematic, coastal (i.e., within 50nm) surveys, these were the prerogative of a small boat in efforts to maximizing encounters with blue and humpback whales, particularly, for photo-identification and tagging. This surveys served as the primary data sources used in delineating the BIA boundaries. Resourcefully, the BIAs for these species did compare favourably to densities predicted under the habitat models developed based on data from the entire U.S. West Coast. It included that of the southern

California data used by Redfern et al. (2013). Differences observed were between the two models. This gap is because the two data sets only provide complementary information: with the small boat surveys used to delineate the ***BIAs***, better capturing areas nearshore, fine-scale distribution patterns, while the ***habitat models*** based on systematic surveys for broad-scale distribution patterns throughout captured fairly nearshore and offshore waters (Calambokidis et al. 2015). The NOAA ONR (2016) using **whale habitat models** developed for just southern California waters, then compared the BIAs to predicted densities by Redfern et al. (2013). Finally, the NOAA ONR relied on the CINMS, which over the years have been collecting opportunistic sightings (primarily from whale watching vessels) within the Santa Barbara Channel since 1999 (Fig. 35). These data though did not give information on relative densities or absences. Instead, it provides detailed information on areas where whales were present. This sighting was then used to calculate the number of cells within the five noise categories for which the highest occurrence of predicted densities, BIAs, and presence cells stood at 20% (NOAA ONR, 2016).

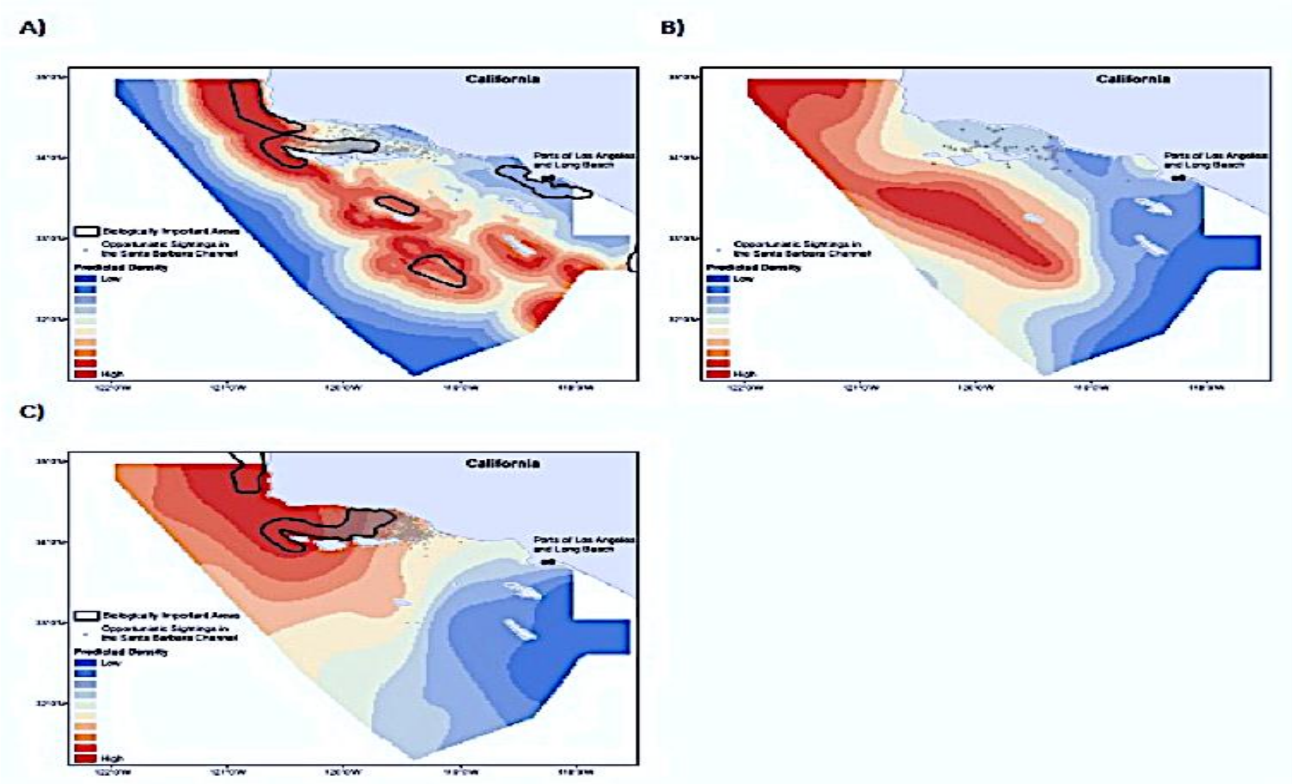
2.2.2.3 Review of the Results

The results obtained by the NOAA ONR is also reviewed here with the Gulf of Guinea situation in mind, having to do with the challenge of lack of sufficiently documented identified marine mammals.

1.0 Characterization of noise from commercial shipping

According to NOAA ONR's (2016) review, the summary of 1km x 1km grid per the number of ship transits between August and November 2009 showed, ships travelling within the broader area of both the south of the northern Channels Islands and in the TSS of the Santa Barbara Channel (Fig. 36 (A), (B), and (C)). Smaller ships were also observed to travel slower when closer to the coast than larger ships. These shipping traffic patterns are based on predicted 50 and 100Hz noise levels at 30m depth reflected (Fig. Again, predicted noise reflection was also indicative of longer-distance, low-frequency propagation resulting from distant shipping traffic in other regions, thus include offshore of Point Conception, west of San Miguel Island, and south of northern Channel Islands. In contrast, the Santa Barbara Channel had no noise recording attributable to distant shipping traffic. 88dB at 50Hz and 77dB at 100Hz (Fig. 32) were Median predicted noise levels. Again, the measurement of predicted 50 and 100Hz noise levels at the HARP north of the Santa Barbara Channel TSS between Santa Rosa and Santa

Cruz Islands, were between 5-12dB higher than measured noise (Table 7). For the median of predicted



50 and 100Hz noise levels at the HARP on the southwestern edge of the TSS, measured noise was closer to (within 3dB) (Table 7) (NOAA ONR, 2016).

Table 7: Comparison of predicted 50 and 100Hz noise levels (August to November 2009) to noise measured at two HARPS.

Location	Seafloor Depth	Noise predicted at the HARP (dB)	Noise measured at the HARP (dB)
50Hz			
North of the TSS* between Santa Rosa and Santa Cruz Islands	578	91	80
Southwestern edge of the TSS	777	89	86
100Hz			
North of the TSS between Santa Rosa and Santa Cruz Islands	578	80	75
Southwestern edge of the TSS	777	75	78

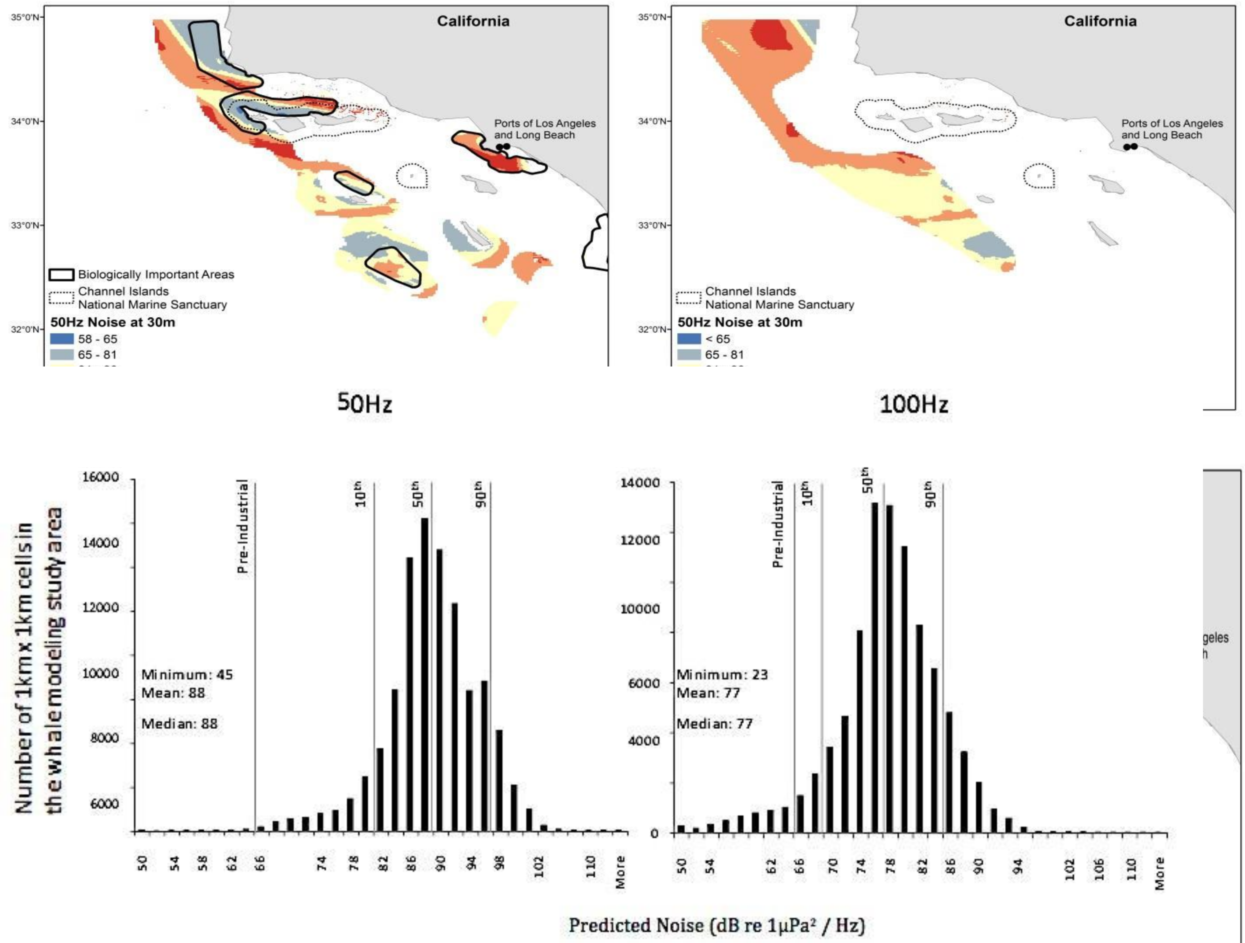
** Table reproduced from NOAA ONR (2016)*

According to NOAA ONR (2016), the predicted noise levels of 50 and 100Hz contained in the whale modelling study area were close to over 99% and 94%, respectively, and thus, above pre-industrial noise conditions. Records of noise levels predicted in CINMS also spanned the noise range levels predicted within the whale modelling study area. Hence, in considering the entire CINMS record and in comparison to predicted noise levels in the whale modelling study area, the CINMS values represented a quieter area (NOAA ONR (2016)). It contained some of the few remaining places within the whale modelling study area that are predicted to have pre-industrial noise conditions. Although a small per cent (4%) for pre-industrial noise levels were from portions of the CINMS at 50Hz (4%), half were associated with 50 and 100Hz noise levels (shown in Figure 37) and therefore categorized as either pre-industrial or lower traffic volumes. However, the CINMS also contained approx. 22-24% of predicted noise levels in or above levels generally associated with massive volumes of shipping traffic.

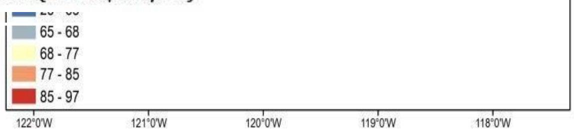
2.0 Co-occurrence of whale habitat and noise

The blue whale habitat: NOAA ONR reiterated Redfern et al.'s (2013) claim that blue whale habitat is associated with the 200-m isobaths, of which the shelf break in the region represents. The BIAs for blue whale generally is determined to overlap with that of higher densities prediction by habitat model. However, the BIA model tends to predict higher densities of blue whale throughout a much broader offshore region (Fig. 36). Therefore, regardless of the data source used to define habitat, no blue whale habitat, contained pre-industrial noise conditions. Again, predicted 50Hz noise levels were measured among the majority of the blue whale habitat associated with either moderate, bulky, or extreme traffic volumes from shipping. The NOAA ONR identifies noise risk hotspots occurring near the ports of Los

Angeles and Long Beach and along the Santa Barbara Channel (including areas inside the CINMS), as well as within discrete offshore locations (Fig. 38).



Within the coastal waters off Point Conception, BIA for blue whale observed overlapped with relatively quieter (low volumes of ship traffic area).



The Fin whale habitat: [refer to Fig. 38 in NOAA ONR (2016)] the NOAA ONR found its occurrence within offshore waters and generally with the least overlap for 50Hz predicted noise levels associated with shipping traffic at pre-industrial levels and low volumes (refer to Table 4 in NOAA ONR (2016)). In particular, the findings suggested no fin whale habitat contained any form of pre-industrial noise conditions, whereas, over 50% of the entire habitat were determined to contain 50Hz predicted noise levels primarily associated with massive and extreme volumes of shipping (Figure 36). The noise risk hotspots, therefore, occur in offshore areas of Point Conception, and also to the west and south of the northern Channel Islands (Fig. 38) (NOAA ONR, 2016).

The Humpback whale habitat: occurrence in the case was in the northernmost portions for the whale modelling study area. The BIAs for humpback whale also suggests an overlap with the higher densities predicted by the habitat model. However, the habitat model predictions estimate higher densities of humpback whale farther offshore than the BIAs. Humpback whale habitat is essentially as understood to contain a larger percentage area most associated with pre-industrial noise conditions, in comparison to either blue or fin whales (Figure 38). These quiet areas found occurred in the CINMS zone and also within coastal waters off Point Conception (Fig. 38 (C)). The identified noise risk hotspots therefore primarily occurred within the offshore habitat; however, some levels of occurrence were also in the Santa Barbara Channel and the CINMS (as shown Fig. 38(C)) (NOAA ONR, 2016).

2.2.2.4 Review of Discussion

Relationship between Predicted Noise Model and Measured Noise by HARP: According to NOAA ONR (2016), predicted shipping noise levels within southern California waters have suggested being on a high, with region-wide exposure. Over 99% and 94% of the whale modelling study area, for example, contained predicted noise levels at 50 and 100Hz, respectively, above our approximated pre-industrial conditions. Essentially, predicted noise levels were also broadly comparable to ocean noise time-series measurements made in central and southern California (Urick 1984, McDonald et al. 2008). Therefore, with the given agreements and differences related to predicted noise levels and HARP measurements, this goes to highlight the many sources of variability influencing predicted noise levels within particular locations, at determined frequencies, at specific periods influenced by vessel traffic patterns.

This traffic patterns also change after the California Air Resources Board implemented its Ocean-Going Vessel Fuel Rule (hereafter, referred to as *fuel rule*[17]) in July 2009. Notably, the majority of ships tend to travel through the Santa Barbara Channel within the TSS adopted by IMO before the fuel rule implementation. Therefore, a higher proportion of ships their route to the south of the northern Channel Islands in a bid to reduce transit time spent using expensive, cleaner fuels (McKenna et al. 2012a).

[17] The ***fuel rule*** is intended to reduce air pollution by requiring compliance of large, commercial ships in the use cleaner-burning fuels when traveling within the 24 nautical miles of the mainland coast (Soriano et al. 2008).

Differences in predicted noise versus actual measured noise could result from ship source levels. Therefore, ship source-levels noise models used is the estimated level data collected within the 1970s and 1980s (Carey & Evans 2011); and thus perhaps, overestimates noise produced among the modern fleet. Where 1Hz-band ship source-levels were used, noise models were approximately 10-15 dB higher than some of the more current, source-levels for newer ship designs with broader-band estimates (e.g., McKenna et al. 2012b). They generally found noise models improvements integrating vessel speed into predicted ship source levels, whereas, high-resolution, with spatially-explicit maps based on vessel speed was derived from AIS data. However, a small number of vessel types and length classes have algorithms to estimate changes in noise source level from speed (e.g., container ships; McKenna et al. 2013). Finally, with the increased resolution of bottom-type data for the waters, notably, off Southern California noise models can be improved, thus, because the nature of bottom type influences sound propagation. Therefore, a comparison between predicted and measured noise should be expanded spatially and temporally with more measurements of ocean noise become available in the area.

Noise Level Risk Assessment on Habitats: risk assessment carried out identified several areas within southern California waters where the acoustic environment is perhaps, degraded for blue, fin, and humpback whales, primarily since their habitat overlaps with areas predicted to have elevated noise per shipping traffic. Specifically, for blue and humpback whales, the Santa Barbara Channel, for instance, contains higher predicted densities and biologically important feeding areas overlapped with elevated noise attributed to the TSS. In 2013, in order to reduce the risk of ships striking whales, the TSS was revised. Therefore, NOAA ONR suggests there will be a need for risk assessments study in order to understand how the change affects the overlap between whale habitat and vessel noise, per traffic data collected after implementation. Higher predicted densities of all three species and elevated noise from commercial shipping were found in areas offshore of Point Conception, west of San Miguel Island, and Santa Rosa Island and south of San Miguel Island.

Fin whale habitat, in general, was predicted to occur in noisier waters compared to the blue and humpback whale habitat. Redfern et al. (2013) habitat models developed also predicted higher fin whale densities farther offshore compared to the higher blue whale densities. It, therefore, results in a higher overlap between predicted 50Hz noise levels and fin whale habitat. For humpback whale habitat, a general occurrence is in waters less influenced by noise compared to that of blue and fin whale habitat. Thus because humpback whales naturally occur near shore, where predicted noise levels for 50Hz and 100Hz were low. The NOAA ONR (2016) also confirmed the general assertion that noise levels occurrence predicted at 100Hz were comparatively lower than 50Hz levels. Thus because of large ships producing less noise at 100Hz than 50Hz (Carey & Evans 2011).

Additionally, the NOAA ONR (2016) assert that 100Hz could be considered as the lower bound for assessing noise risk to humpback whales. Thus also because of their conspecific vocalizations span for a broader range of low frequencies. However, the blue and fin whale habitat co-occurrence and noise levels predicted at 50Hz raises concerns of their acoustic environment quality and how at extremely low frequencies, can support their communication. "These long-lived animals evolved to take advantage of acoustic conditions that this study estimates have been entirely (fin whales) to near entirely (blue whales) eliminated within the habitats most important to sustaining their presence in Southern California waters" (refer to NOAA ONR, 2016 for further reading).

The NOAA ONR (2016) suggest their risk assessment framework employed could be used in evaluating the potential consequences of possible management actions concerning further changes in shipping traffic. Additionally, they suggest the need for a time series of annual noise predictions while highlighting the need also to incorporate uncertainty into developing the risk assessment metrics. Thus, explicitly identifying these uncertainties, helps managers appreciate to what degree of confidence they can have in the risk assessment while helping in the prioritization of future data collection efforts (Hope 2006).

Limitations to Predicted Species Densities and Noise Levels Risk Assessment: The NOAA ONR (2016) notes the uncertainty associated with both ***Predicted species densities*** and ***noise levels*** that were used in the risk assessment— insinuating, the uncertainty related to the predicted species densities, for instance, arose primarily from the '*inter-annual variability*[18]' of species distributions (Redfern et al. 2013). They suggest the uncertainty could be reduced with (1) extended data time series, (2) the use of finer-resolution habitat data, and (3) the incorporation of prey data. They also suggest the need for seasonality examination of the risk estimates, citing Southern California, for example, tend to host fin whale's presence all year round while some blue and humpback whales might have arrived before or remained after the data collection period. Therefore, their final risk assessment conducted uses the maxima or minima of the predicted noise levels from August to November.

Limitations to Co-Occurrence Risk Assessment on Habitat and Noise Estimation: current risk assessments identify co-occurrence areas between whale habitat and commercial ships noise, whereas metrics are essential, and needed in estimating the consequences for this co-occurrence. According to NOAA ONR (2016), previous studies estimated the potential losses in communication opportunities among individual species (e.g., Clark et al. 2009, Hatch et al. 2012) towards quantifying chronic noise influence on more massive whales. Again, locally degraded acoustic environment's fitness implications can also be determined using population viability models that may include other environmental determinants pliable to foraging and mating success, and that which account for trends in those variables (e.g., climate change). The final item considered is the stress hormone levels amidst other health and demographic indicators compared, could be among populations, subspecies, or sister species occurring in areas associated with the difference in long-term noise conditions (NOAA ONR, 2016).

Regulations and Management Approach Towards Addressing the Chronic Noise Problem: currently, U.S. regulation for noise related to the Endangered Species Act and Marine Mammal Protection Act made no room for chronic noise impacts associated with commercial shipping, thus according to NOAA ONR (2016). Consequently, suggesting, the need for a new and different type of management approach to addressing low-frequency ocean noises. Therefore, Hatch & Fristrup's (2009) noted that a place-based management approach did focuses on specific ecosystems and range of activities impacting the system. The NOAA ONR (2016) also notes how it relates to their risk

[18] Interannual variability' is the simple environmental variances caused by changes within oceanographic conditions on annual (e.g., the El Niño Southern Oscillation), decadal (e.g., the Pacific Decadal Oscillation), and longer time scales (e.g., climate change) (Redfern et al. 2013; NOAA ONR, 2016).

assessment. Thus by highlighting how several place-based management techniques influenced the shipping noise. The techniques include the use of the National Marine Sanctuary, an IMO designated Area to be Avoided, and the IMO traffic separation scheme (TSS). Haren's (2007) previous evaluations confirm the obstacles faced in directly managing low-frequency noises and addressing the influence of shipping noise beyond sanctuary boundaries. However, this is in contrast with NOAA ONR (2016) risk assessment findings which suggest the designated CINMS as an ATBA by IMO's has resulted in lower noise in most of the zonal areas of the sanctuary, compared to the totality of southern California waters. Consequently, therefore, international management tools of various forms are more broadly focused on reducing spatial overlap between co-occurrence of human activities and vulnerable marine areas as a means of noise management (NOAA ONR, 2016).

It is important to note that Traffic Separation Schemes ordinarily concentrate shipping traffic and noise, and as such, where TSS occurs within CINMS, these living resources –are exposed to high levels of low-frequency noise resulting in gaps within the sanctuary's placed-based protection. Therefore, the NOAA ONR recommends, designating these areas as Particularly Sensitive Sea Areas (highlighting their need for 'special' protection) for which noise occurrence heavily impact these BIAs while implementing management measures requiring or recommending ships operate in a manner with reduces noise levels.

Henceforth, across the world's oceans, there are strategies employed to reducing ship-strike risk which includes the moving or creating TSS, the moving or creating voluntary shipping routes, and the compulsory reduction in ship speeds. These strategies if well implemented, may also reduce shipping noise. Thus, hence suggesting, the need for consideration of the consequences of low-frequency noise in line with ship strikes in cumulative risk assessments and marine spatial planning. Therefore, several placed-based management strategies mostly appear static in space and time. There is also a considerable need for dynamic management strategies as a response to spatial and temporal variability inherent within marine mammal distributions and the use patterns of humans (NOAA ONR, 2016). Concluding this review in line with other obstructionist stressor identified as strike impediment hazards and under this study, the Redfern et al.'s (2013) study subsequently reviewed is in the next section (Sec. 3.3).

2.2.3 Ship Strikes, Impact on Marine Life and Environment

The review takes a look at Calambokidis et al.'s (2019), Nichol et al. (2017)'s and Redfern et al.'s (2013) study. The individual works sort at addressing spatial planning, *potential biological removal*[19]. It also sorts to maintain *optimal sustainable populations*[20] of the marine mammals in their various study regions. The review attempts at deriving beneficial knowledge needed in appreciating the scenario within the Gulf of Guinea region.

2.2.3.1 Introduction

Calambokidis et al. (2019) reiterated the growing concern of ship strikes of the whales in many areas around the world (Panigada et al., 2006; Williams and O'Hara, 2010; Silber et al., 2012b) while emphasizing the acuteness of the concern along the US West Coast after several periods with elevated ship strikes were reported. At least, four fin whale suffered ship strikes (Douglas et al., 2008), so documented within Pacific Northwest in 2002 and another four-set of blue whales; were documented to have been struck by ships off southern California during Fall of 2007 (Berman-Kowalewski et al., 2009). Others include blue, fin, and humpback whales that are often feeding in coastal waters (Calambokidis and Barlow, 2004; Calambokidis et al., 2004, 2015; Redfern et al., 2013; Douglas et al., 2014; Dransfield et al., 2014; Rockwood et al., 2017). Although several ship strikes have been reported as of concern, these according to Williams et al., 2011; Rockwood et al., 2017, and Calambokidis et al. (2019) likely underrepresent the actual number of ship strikes occurring due to the low proportion of strikes documented or carcasses recovered. West Africa and Ghana for that matter are not exempted. There remains a problem for years though changes in shipping lanes have successfully reduced overlaps between areas of high shipping traffic and whale concentrations for the major shipping lanes off the US West Coast (Segee, 2010; Redfern et al., 2013). Vessel speed restrictions is another measure at reducing the lethality of strikes of ships (Conn and Silber, 2013). Other strategies include voluntary ship

[19] U.S. Marine Mammal Protection Act requires calculation of potential biological removal, which it defined as "the maximum number of animals that may be removed annually by anthropogenic causes while allowing the population to reach or maintain its optimum sustainable population."

[20] The U.S. Marine Mammal Protection Act refers to the phrase *Optimum Sustainable Population* which it defined as "the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element" (16 U.S.C. 1362[3][9]).

slowdowns as referred to by McKenna et al., (2012) and the use of acoustic alarms according to Nowacek et al., (2004) have been ineffective or of limited use.

Therefore, scientific data on whale behaviour and distribution are essential in evaluating strategies for reducing ship strikes. Thus, it is without limitations. Thus, whale distribution data including habitat models within most regions especially, in the US West Coast come primarily from sightings data based on surveys (Redfern et al., 2013; Becker et al., 2014; Calambokidis et al., 2015) limited to daytime sighting data only. Some of the strategies could help reduce ship strikes only possible in daylight (thus, avoidance based on visual sightings, for example). Hence, the vulnerability of whales during the day and the night is critical to understanding and evaluating the mitigation strategies. The situation, therefore, is the reason for the data from tags –thus, attached to whales to provide detailed information on whale behaviour, distribution and movements. It also includes implications for ship strike risk (Irvine et al., 2014; Abrahms et al., 2019; Calambokidis et al., 2008; Johnson et al., 2009; Goldbogen et al., 2013a, 2014; Cade et al., 2016); insights into diel differences in feeding behaviour (Friedlaender et al., 2009); and warnings of whale behaviour on close approach (McKenna et al., 2015). The use of alarm sounds alert the whales of ships' approach (Nowacek et al., 2004) or that of anthropogenic sounds such as Navy sonar (Southall et al., 2012, 2019; Goldbogen et al., 2013b). However, tag position and movement data face some fundamental limitations. Thus, due to bandwidth limitations in uploading data, longer-term satellite tags do not provide very frequent or accurate positions from satellite observation. The Archival tags, on the other hand, records more frequently high-quality GPS positions, however, are limited with short durations. The situation is due to the need for recovery tags and attachment limitations (Szesciorka et al., 2016). According to Calambokidis et al. (2019), a combination of high-resolution, long-duration position information, and detailed dive behaviour relating to time near-surface or reaction to ships, remains crucial in assessing their vulnerability to ship strikes. Hence, they deployments both longer duration archival tags that helped fully sample the day and night periods while examining the differences in day and night diving and ordinary movement for three baleen whale species within the eastern North Pacific and evaluating these differences in the context of risk of ship strikes. On another breath, Nichol et al. (2017), in understanding the relative risk of lethal collisions between ships and whales off the Vancouver Island, Canada, performed their first spatially explicit analysis estimations by calculating strike risk for two (2) most frequently observed species of baleen whales within British Columbia (BC), thus on the humpback and fin whales. They predicted whale densities across their study region employing systematic aerial surveys over a period between 2012 and 2015. Redfern JV et al. then overlaid these population densities with marine traffic dataset (2013) obtained through the automatic ship tracking information via the Automatic Identification System (AIS). The essence was to calculate and determine the relative risk of both vessel strikes and collision lethality. Redfern JV et al. (2013) however, carried out a spatially explicit assessment of ships striking risk (hereafter, ship-strike risk) on humpback, blue, and fin whales. This assessment was also off the coast of Southern California, via modelling of the whale habitat, while quantifying co-occurrence of whales and shipping traffic. Thus their study also goes to suggest the growing level of interest in the area with recent studies (Vanderlaan et al. 2009; Williams & O'Hara 2010). The growing interest among scientist is, however, not the case for the west coast of Africa faced with various environmental challenges.

2.2.3.2 Material and Methods Review

1.0 Data Collection

According to Redfern et al. (2013), their data gathering process made use of whale sightings alongside oceanographic data collected by the National Marine Fisheries Service's Southwest Fisheries Science Centre primarily between August through November for the years, 1991, 1993, 1996, 2001, 2005, 2008, and 2009. However, the surveys they conducted between1991to 2008, had regions of broad coverage of the U.S. West Coast, except for the 2009 survey which focused primarily on Southern California – representing approximately 40% of their total efforts forming the high proportion of whale sightings (Supporting Information). Essentially, all the surveys conducted made use of line-transect methods for collecting marine mammal data during daylight hours.

Their survey method certainly varies from the survey conducted by Calambokidis et al. (2019). Calambokidis et al. (2019) made use of tag deployments within eastern North Pacific along the US West Coast on the habitats of the blue, fin, and humpback whales. Thus, they used a variety of archival tags with 20 continuous hours of dive data, and high-quality positions detection from an onboard GPS to sample both day and night behaviour. However, Nichol et al.'s (2017) cetacean survey sightings conducted was from a De Havilland DHC-8-102 Dash-8 aircraft—coordinated to fly along systematically placed transects at an altitude of 305 m (1000 ft), with a nominal speed of 278 km h-1 (150 knots). The transects were northeast to southwest with roughly, a perpendicular dimension to the west coast of Vancouver Island at periodic intervals of approx. 16 km. There were two designated observers positioned at unique large observation windows aft of the cockpit (left and right), who reported all whale sightings a data recorder. For this study, the focus of the review will be, had on Redfern et al. (2013), and Nichol et al.'s (2017) approaches. Redfern et al.'s (2013) use of approximately 9300 km survey effort collected under the Beaufort Sea states scale of 5 or lower, also consisted of 2 observers using pedestal-mounted 25 × 150 binoculars in search for marine mammals from the ship's bridge; while having a third observer search by eye or with 7× (magnification) handheld binoculars. They recorded both the sightings and the survey conditions and where they needed to essentially identify and estimate the species group size upon detecting marine mammals, the vessel would approach the group. Observers, therefore, independently recorded their best estimates (both high and low) of group size for each sighting. Where mixed-species sightings were encountered, observers estimated percentages of each species in the group. To obtain a single estimate of each group size during sighting; the averages of best estimate by each observer, or best of the estimate was multiplied by the percentage of each species. Where none of the observers gave no best estimate, averaged low estimates was deduced (Redfern et al. 2013).

Oceanographic Sampling: Redfern et al. also systematically conducted oceanographic sampling during each survey, using a thermosalinograph in measuring sea surface temperature (SST) and salinity in 2 minutes' interval or more frequently. Other measurements included Surface chlorophyll concentration and *mixed-layer depth*[21] at approximately 55-km or shorter intervals.

2.0 Whale Distribution Modelling

Therefore, Redfern et al. (2013) indicated that the availability of habitat data predetermined the shape of their study area. Hence, a divide of transects into approximately 5 km with continuous-effort segments was used. Thus –also described by Becker et al. (2010), however, relied on generalized additive models (GAMs) to relate the number of individuals of each species in each segment of the following using habitat variables such as sea surface temperature and salinity, log-transformed surface chlorophyll concentration, mixed-layer depth, and distance to the 200-m isobaths. Thus, this *isobaths* represented a vital habitat feature for many species of large whales along continental shelf break zones for many areas of the coast of California (Fiedler et al. 1998; Becker et al. 2010). Several correlations observed were between surface chlorophyll concentration and SST (–0.71), mixed-layer depth and SST (–0.44), and mixed-layer depth and the 200-m distance isobaths (0.55). The 200-m isobaths utilized in waters shallower than 200m to differentiate shelf from slope waters derived was from ETOPO1 (Amante & Eakins 2009), one arc-minute global-relief model on the negative value scale while interpolation of oceanographic variables throughout the study area was by kriging— whereas, bilinear interpolation aided the extraction of values from the Kriged grids at the midpoint of the transect segments.

[21] Mixed-layer depth: Redfern et al. (2013) defined as the depths at which temperature was 0.5◦C less than SST. This mixed-layer depth estimates is obtained from expendable bathythermograph drops and conductivity, temperature, and depth casts.

The distance travelled on effort in each segment of the study area was an offset in the models because the amount of effort varied among segments. Survey year was a linear term in the model for each species to account for long-term changes in whale abundance (Calambokidis & Barlow 2004; Moore & Barlow 2011).

A Poisson GAMs, where over-dispersion corrected was with the quasi-likelihood model –using the software package S+ (Version 8.1 for Windows, Tibco Software, Somerville, Massachusetts) was fitted (Redfern et al., 2013) and used models developed to predict the number of whales in each cell of a (2 × 2 km) grid of the study area. However, average predictions did not account for with-in-year variation in species distributions; but rather, represented expected long-term patterns within humpback, blue, and fin whale population distributions for the periods of August and November (Redfern et al., 2013). They also argued that agreeing with Dormann (2007) that spatial autocorrelation of species distributions had a limiting effect on the interpretation of habitat relationships while restricting the transferability of habitat models in space and time.

3.0 Strike Risk Determination

In terms of risk of strikes, Redfern et al., (2013) used Automatic Identification System (AIS) data collected in the periods of September 15 and November 20 of 2008 and 2009 (McKenna et al. 2012) which upon analysis gave a more unambiguous indication of traffic patterns for commercial ships with LOA at least 100 m. Essentially, linear ship transits created, were joining successive position reports with same ship identifiers that occurred no more than 1 hour apart with less than a 30-degree heading difference in between. These criteria employed helped minimize inaccuracies in transits caused by the uncertainty of ship locations. Though the transit analyses did not account for seasonal variations in traffic; it mostly represented traffic patterns observed that coincided with whale surveys periods.

According to Redfern et al. (2013), all shipping routes particularly, the TSS composed of the inbound lane, an outbound lane, and a middle traffic separation zone, under the TSS conventions for the Santa Barbara Channel. Hence, they assumed that for all routes, no ships travelled in or through the traffic-separation zone. They proceeded to overlay the number of predicted whales' distribution developed by the models within the (2 × 2 km) grid cells on maps of each shipping route. Therefore, the predicted number of whales for the inbound and outbound lanes were then summed to derive for each route the total number of whales, respectively. With the assumption that all vessel traffic was occurring within a lane of a route, ship density determined was as one for all routes except those of the Central Fan route which accounted for lower ship density expectation. This value they deduced by calculating ship density as a ratio of the area in the Central route that occurred within the fan to the general area of the fan (Redfern et al., 2013). The predicted number of whales to each route was then multiplied by ship density to obtain estimates of possible ship-strike (*ship-strike risk*[22]*)*. They then proceeded to summarize results by deducing the statistically weighted average and standard error for the annual risk estimates of periods studied. Therefore, the weights derived were as the proportion of survey efforts estimates of the study area each year, while defining '*relative risk'* for each route as "the difference between the average route risk and the average Channel route risk divided is by the average Channel route risk" (Redfern et al., 2013: 297). Another issue they analysed was the route use-overlap predetermine by other active users beside commercial shipping traffics of which the military, fishing were central factors of concern besides the natural overlap of routes in the marine sanctuary zones. Other elements also impacted on their analysis while the evaluated risk in distributions considered –assuming traffics occurred evenly within both channels. Therefore, Redfern et al. (2013) were conscious of the fact that habitat-modelling studies which suggested annual predictions of species distributions may be susceptible to substantial error, yet, remained hopeful average predictions could provide accurate summaries for expected long-term patterns in species distributions as illustrated by Barlow et al., (2009).

2.2.3.3 Results and Discussions Review

According to Redfern et al. (2013), the final models of each species did differ with either variable selected or shape of the relations (Supporting Information), and hence, aided the predicted distinctions of high- density areas for each species. Habitat relations were similar for all species observed during fine-scale surveys off Southern California –comparative to Fiedler et al. (1998); along the entire West Coast (Becker et al. 2010).

Distribution Occurrences of Humpback, Blue and Fin whales: In productive coastal waters in the northernmost portion of the study area with cold temperatures, low salinities, and high chlorophyll

[22] Ship-Strike Risk is defined as "a measure of the co-occurrence of whales and shipping traffic"(Redfern et al., 2013 pp297).

concentrations characterization, humpback whale habitats did occur). Again, they assert that, though predictions of humpback whale numbers across each year understudy were accurate, annual ratios of *'observed to predicted number of whales'* indicated inaccurate determination of individual years' whale numbers (Supporting Information). Nonetheless, the humpback whales' occurrence across the distances considered (0–50 km) were observed to have spatial autocorrelation significantly positive (Moran is I 0.010–0.043), with Blue and fin whales more broadly distributed). Habitat modelling for these species, however, showed lower deviance percentages (14.9% for blue whales and 17% for fin whales) comparative to 31.2% of the humpback whales. However, annual ratios of *'observed to the predicted number of whales'* for both species indicated greater accuracy compared to humpback whale model. Again, in waters that had intermediate mixed-layer depths and high concentrations of surface chlorophyll along the 200m isobaths (Supporting Information), high densities of blue whales occurred; close to shore and extended somewhat northward into the Santa Barbara Channel, and also farther south within offshore waters. Spatial autocorrelation of Blue whales at 5 km (Moran is I 0.066) was significantly positive, whereas Fin whales' spatial autocorrelation were significantly positive at 45 km (Moran is I 0.016). The Fin whale habitat occurrence was in offshore waters, characterized by intermediate concentrations of surface chlorophyll, cold surface temperatures and intermediate mixed-layer depths (Redfern et al., 2013).

Ship Strike Risk Assessment: Under the assumption of all traffic occurring in the Channel route, the risk was higher for humpback whales (risk = 3.58) whereas recording lower (risk 0.93) under assumptions of all traffic occurrence within the Southern route (Redfern et al. 2013). They also observed these opposite patterns for fin whales with risk at 6.39 in Channel route and 13.70 in the Southern route respectively. According to Redfern et al., implementation of the fuel rule in the area (thus, approximated from the multi-route traffic pattern observed in 2009), showed a differentiated decrease in risk at 0.91 for humpback whales and an increase from 1.56 for fin whales, with the change attributable to the higher proportion of ships altering travelling route to the south of the northern Channel Islands, away from using the TSS in the Santa Barbara Channel. The area also predicted high densities of blue whales with similar risk estimates among all routes. The *fuel rule* implementation had little change on a risk assessed. Again, because of inter-annual variability in distribution and availability of habitat, the variance in risk was high for all species. Therefore, Redfern et al., (2013) deduced the potential for conflict due to overlap between areas used for other purposes and the shipping routes— thus, having Channel route with least military ranges overlap, and remaining the only route also overlap with the National Marine Sanctuary and other marine protected areas. The Channel route was also ducted with the highest fishing areas overlap; however, to determine how much fishing occurs within the TSS, better fishing data are needed (Redfern et al. 2013). Redfern et al. (2013) insisted that because of the large area traversed by ships which also host military ranges before entering the Central Fan route, the route recorded the most extensive overlap with military ranges.

In summary, Redfern et al.'s (2013) findings go to suggest that increased traffic correlates with risks of strikes, and regulatory arrangements influence these risks. To this regard, since vessel traffic never changes but only diverted, their impact is transferred, and the danger is never eliminated. Nichol et al., (2017) however, in their study of ship strike risk based on spatial analysis models of whale densities, suggested a practical approach for identifying regions of conservation concerns. They were particular of areas (e.g. offshore) where actual mortality rates quantification from carcass evidence or eye-witness reports are naturally obscured. Their evidence of humpback and fin whales' habitat partitioning showed higher densities on the continental shelf (particularly over the shelf break) for humpback whales, whereas the distribution of fin whales was with somewhat lower densities in deeper waters offshore. Their findings also suggested that whales in any location where distributions overlapped with marine traffic had the potential to be struck by ships. They observed ship speeds within the offshore area of the west coast of Vancouver Island at sufficiently high levels (>12 knots). Hence, collisions risk with whales were more likely than not (>50%) to result in lethal injuries. Therefore, the delimitation of their models developed for predicting the spatial distribution of whale population vulnerability was useful in advising mariners of high-risk collision locations. Ultimately, they suggested speed restriction zones, areas to be avoided, or PAM-linked mariner notification systems (or a combination of these strategies) as part of mitigation efforts to reduce the impact of ship strikes. Also, they suggested additional survey effort of the area could help further to refine the whale density models and ship-strike risk estimates while highlighting the need for seasonal or annual trends analysis, or predictions of species (e.g. blue whales) less-frequently encountered (Nichol et al., 2017). Nichol et al. (2017) and Redfern et al. (2013)

and many more others all agree there is more that needs to be done if marine wildlife is to be better appreciated and protected wherever in the world's ocean serves their dwelling.

2.2.4 Vessel Lightening and Impact on Marine Lives

According to Davies et al., (2015), one of the extreme pressures these marine ecosystems are subjected to, is the night-time lighting, which over the years have remained unstudied. While arguing that light remains a vital cue guiding settlements of invertebrate larvae, its gradual effect is spearheading the alteration of natural regimes of nocturnal illumination and hence, with the potential of modifying patterns of recruitment amongst sessile epifauna. They proceeded to present the first evidence of night-time lighting effect of change in the composition of temperate epifaunal marine invertebrate communities. They emphasized that illuminating surfaces of settlement with white light-emitting diode lighting at night, to current levels experienced in these communities locally, inhibited and encourages colonization of taxa. Davies TW, Coleman M, Griffith KM, Jenkins SR. (2015), indicate therefore that ecological light pollution whether from coastal developments, shipping and offshore infrastructure, is a potential conduit for change in the composition of marine epifaunal communities. These communities also remain the epicentre of the marine live food web and therefore changing impacts tend to influence the BIAs of marine mammals. Hence, this study finds the need to review the lighting impact study by Davies et al., (2016) as essential to building a more robust understanding of the BIAs architecture and hence proceeds as follows.

2.2.4.1 Introduction

The sessile marine benthic invertebrates' assemblages are described as acting as engineers in supporting the most diverse ecosystems in some parts of the world, which further sustain local fisheries while providing coastal protection and serving as tourism attraction [Coleman FC, Williams SL. (2002)]. The benefits notwithstanding, many such natural assemblages are under threat globally with multiple anthropogenic pressures –encompassing bottom fishing, hypoxia, coral bleaching and ocean acidification. Again, Davies TW, Coleman M, Griffith KM, Jenkins SR. (2015) also reiterated the concern suggesting –the use of night-time artificial light as yet another unexamined anthropogenic disturbance. That probably is altering the composition of sessile invertebrate assemblages as far as the continuous experience of interferences tends to impact on patterns of reproduction and recruitment among their constituent species [Davies TW, Duffy JP, Bennie J, Gaston KJ. (2014)]. The impacts observed underscores the relevance in ensuring a safeguard of the BIAs. It also asserts that the intensity, spectral composition and periodicity of natural light can be described as necessary cues both for synchronizing the timing of broadcast spawning events [Naylor E. 1999; Harrison PL. 2011]. They also serve in the guiding of larval recruitment into suitable habitats for both post-settlement survival and reproduction [Thorson G. 1964; Mundy CN, Babcock RC. 1998]. Of the totality of the world's coastal regions [Davies TW, Duffy JP, Bennie J, Gaston KJ. (2014)] (excluding Antarctica), 22 per cent are estimated to be experiencing artificial light effects at night from a variety of sources. This sources, according to Davies et al. (2014), includes coastal towns, harbours, offshore infrastructure installations for oil, gas and renewable energy, shipping and light fisheries. Whereas these artificial lightings are illuminating shallow benthic communities, they are likely leading to a range of unanticipated effects that includes a selection of sub-optimal settlement site and the consequent increase in post-settlement mortality. They also extend the time buffer where light is available to guide the settlement process.

To this effect, Davies et al. (2015) investigated the effect of nocturnal illumination by white light-emitting diodes (LEDs), influencing the colonization of sessile and mobile temperate invertebrates within newly available habitats. The LEDs was particularly important a technology forecast to dominate the lighting industry by 2020, according to [McKinsey & Company. 2012; Davies et al., 2015].

2.2.4.2 Review of Material and methods

Davies TW, Coleman M, Griffith KM, Jenkins SR. (2015), quantified the colonization of 36 previously, bare 10 × 10 cm roughened grey PVC settlement panels over 12 weeks experimental deployment commencing July 1, 2013. The experiment was done on a floating raft in the Menai Strait, UK (on latitude 53.2295078; and longitude – 4.1532278). The panels deployed were at a vertical depth of 20 cm in pairs on 18 separate wooden boards. Each pair of panels was considered as one treatment replicate during the analysis to avoid pseudo-replication. Therefore, each treatment pair was either not control lit, or lit to either the 19 lux or 30 lux (measuring using ATP DT-1300 LUX meter) on the water's surface using cool white LEDs (thus, with the n ¼ 6 replicate boards per treatment). These lux levels described are, as comparable to those found on water's surfaces adjacent nearby assemblages of epifaunal invertebrates exposed to night-time lighting (with lux between 5 – 21.6 measuring). The make and model of white LED strips spectral power distribution used is provided in Bennie J, Davies TW, Cruse D, Inger R, Gaston K J., (2015). All lights powered were via 12 V battery trickle charger using a solar panel (Sunware 24 W). The panel was switched on at dawn and off at dusk using the Cell Optick 12V photocell. The boards vertically deployed were in order to simulate substrates both suitable for colonization by temperate epifauna while exposed to artificial lighting (for example pier pilings, vertical rock faces, sea defence walls, floating pontoons), and random allocation designed across two rows of nine slots. Across treatments, light trespass was avoided by facing panel-fronted boards in the same direction so that rather than any stray light illuminating the experimental face of the neighbouring boards). It illuminated the back face. A separate grey PVC sheet used was in guiding light down the experimental face of each board, thereby minimizing any light trespass onto adjacent boards. The colonization period ended with panels been brought back into the laboratory and then preserved under 4% formalin pending detailed analysis. An abundance of the individual taxon was then identified to the lowest possible resolution before quantification either as the number of individuals, or their percentage cover towards colonial mat-forming taxa. Hence, the composition from resulting communities compared separately for both numerical abundance data and percentage cover data, thus, employing the multivariate analysis of variance model (MANOVA, CRAN: Vegan) carried out on Bray–Curtis dissimilarity matrices calculated respectively from the square root- and log (x þ 1)-transformed data. The differences within the numerical abundance and percentage cover were then tested individually for each taxon. The percentage cover data analysis performed on fourth root-transformed data employed either a Gaussian generalized linear model (GLM) or a quasi-binomial GLM on raw data where the transformation data failed to satisfy the linear modelling assumptions.

Therefore, their numerical abundance data had the fittings of Poisson and negative binomial GLMs, zero-adjusted Poisson (ZAP) as well as negative binomial (ZANB) regression models (CRAN: psc l). Among which the most parsimonious model –thus, displaying the lowest AIC, is being selected. Essentially, individual tests were not carried out on species that recorded in less than half replicates as were so, deemed to have occurred too infrequently; hence, could result in drawing unreliable conclusions per any of the approaches above. The paired panels for each replicate treatment board summed up were for numerical abundance data, and percentage cover data average before analysis (Davies et al., 2015).

2.2.4.3 Review of Results

According to Davies et al., 2015, forty-seven (47) taxa –representing seven phyla were observed and identified on the settlement panels. Each community under the artificial light colony significantly were observed to be dissimilar to those taxa colonized under control conditions, quantified using percentage cover (MANOVA: $F_{2,\ 15} = 2.85$, $p = 0.005$) data. Light treatment has no impact on community composition (MANOVA: $F_{2}, _{15} = 1.21$, $p = 0.252$) for the taxa quantified using numerical abundance, although driven by the influence of one outlying data point. The data point was unusual with low species richness and thus, exerting leverage on the analysis. However, when there was an omission of this data point, the light treatment had a significant impact on the numerically enumerated taxa composition (MANOVA: $F_{2,\ 14} = 1.79$, $p = 0.018$). That was supported with individual taxa independent performance tests performed. Hence, 13 out of the 47 taxa identified, were present in sufficient abundance towards obtaining reliable estimates of LED lighting impact on abundance made. Out of these, where the abundance of three sessile (immobile) and two mobile taxa which significantly were affected by light treatment shown in Table 8. The colonization by *Colonial Ascidian*[23], Botrylloides Leachii appeared suppressed significantly under both light treatments. An abundance of tube-building polychaete worm Spirobranchus lamarcki significantly observed was to be higher on panels colonized under artificial light treatments, which suggested white LED lighting bolstered its colonization (Davies et al., 2015). According to Davies et al. (2015), significant results indicated, treatment with light explained significantly more variation in taxon abundance compared to null intercept only model. Let n denotes data quantified as numerical abundance. % is Data quantified as % cover. Species, where colonization was significantly affected, are in bold.

[23] *Colonial Ascidian:* is a colony of animals (or zooids), where it is hard to distinguish separate animals.

*Table SEQ Table * ARABIC 8: Effects of LED lighting on colonization by sessile and mobile benthic species.*

higher classification	taxon	mobility	abundance	χ^2 or F	p-value
Arthropoda					
Amphipoda	***Corophium* sp.**[c]	mobile	*n*	8.46	0.015
Cirripedia	*Balanus balanus*[d]	sessile	*n*	0.83	0.661
Copepoda	*Laophonte setosa*[d]	mobile	*n*	0.73	0.695
	Metis ignea[d]	mobile	*n*	6.10	0.047
Ostracoda	*Leptocythere pellucida*[c]	mobile	*n*	3.21	0.200
Bryozoa					
Cheilostomatida	*Electra* sp.[b]	sessile	%	2.50	0.115
Chordata					
Ascidiacea	***Botrylloides leachii***[a]	sessile	%	8.79	0.003
	Molgula sp.[d]	sessile	*n*	3.01	0.222
Cnidaria					
Hydrozoa	*Kirchenpaueria pinnata*[d]	sessile	*n*	0.27	0.875
	Plumularia setacea[b]	sessile	%	3.68	0.050
	Ectopleura larynx[f]	sessile	*n*	5.13	0.275
Mollusca					
Bivalvia	*Anomia ephippium*[c]	sessile	*n*	3.26	0.196
Polychaeta					
Serpulidae	***Spirobranchus lamarcki***[d]	sessile	*n*	19.45	$<$0.001

[a]Gaussian GLM on fourth root-transformed data.
[b]Quasi-binomial GLM on raw data.
[c]Poisson GLM.
[d]Negative binomial GLM.
[e]ZAP.
[f]ZANB.

** Table reproduced from Davies et al., (2015)*

2.2.4.4 Review of the Discussion

Davies et al. (2015) observed that artificial lights at night changed organism behaviour in agreement with Stone EL, Jones G, Harris S. (2012) and Kempenaers B, Borgstro¨m P, Loe¨s P, Schlicht E, Valcu M. (2010). It also restructured their native communities [Davies TW, Bennie J, Gaston KJ. (2012)] while altering the trophic interactions [Bennie J, Davies TW, Cruse D, Inger R, Gaston KJ. (2015)] for those within terrestrial ecosystems. They admitted that although night-time lighting is perceived to generally disrupt navigation among others of marine animals including birds, turtles and fish [12 – 14], thus, increasing their mortality while altering spatial and temporal activity patterns. Per their knowledge, the results gathered remains the first-hand evidence of impact on the composition of marine communities regardless of the limited number of species influenced in the study. In drawing reliable conclusions of the impact of LED lighting on recruitment success, Davies et al. (2015) however, conceded that large proportions making 72% of the taxa, colonizing their tiles were present in insufficient abundance to this aim. 39% of the taxa tested had LED lighting significantly affect colonization. According to them, this far-suggest the potential for far-reaching impacts on epifaunal marine invertebrates and associated mobile species.

According to Davies et al. (2015), though the study is novel, results, however, were unsurprising, given light's essential role in guiding recruitment to sessile invertebrate assemblages [Thorson G. 1964; Mundy CN, Babcock RC. 1998], as well as the optimizing role of post-settlement survival mechanism. Therefore, they assert, the light remains a key structuring factor for shallow marine benthic ecosystems, thus, vertically and horizontally [Vermeij MJA, Bak RPM. (2002); Miller RJ, Etter RJ. (2008)]. According to them, a plethora of studies documented for larval movement, orientation and recruitment over the twentieth century classically highlights its importance.

They further reiterated that the much recent global surge in LED lighting increasingly illuminating and eliminating portions ecological night-time environments with white light. While these holds the potential of reducing financial expenditures and CO_2 emissions, they contend the overall spectral output compared to traditional sodium-based technologies rather encompasses a 'greater' range of wavelengths. The condition is useful to a variety of light-guided behaviours that may be sensitive [Davies T W, Bennie J, Inger R, de Ibarra N H, Gaston KJ. (2013)], such as larval recruitment. The forecast market of LEDs as predominant light source worldwide points to a growing dominance by 2020 [McKinsey & Company, (2012)], in industrial, commercial, residential and architectural lighting applications, though they remain increasingly popular within shipping as well as the oil and gas industries. As such, Davies et al. (2015) in concluding, emphasised that the recruitment altering effect of lights as critical for sessile marine invertebrates. The recolonization, in effect, is changing the composition of the epifaunal communities –suggesting, the consequences of night-time lighting over a broad range of marine ecosystems and services provided remaining unknown. Hence, to reiterates Davies et al. (2015) findings, "the breeding of marine species is an important ecological factor that hinges on sunlight. The role played is by guiding the broadcast of spawning, recruitment, diel vertical migration, communication, navigation and the predator-prey interactions [Davies et al. (2014)]. Thus, do also suggest a widespread impact at already play from artificial light (pseudo lighting) on marine ecosystems structure.

Linking Ecosystem Processes to Community Responses: Food Webs under ALAN impacts on individuals-to-communities play out via its change of food webs and energy flow on the ecosystem scale. Flows of energy by which nutrients, organic matter, and prey –are transferred across and within ecosystem boundaries (e.g., aquatic-terrestrial) by abiotic (e.g., fluvial and tidal flow) and biotic (e.g., movement of consumers) vectors shapes the ecosystem processes (Zapata, M.J., Sullivan, S.M.P. & Gray, S.M. (2019)). Link et al. (2005) indicated that food webs as trophic networks, primarily reflect energy pathways, biodiversity, ecosystem productivity and species interactions. It does so, according to Thompson et al. (2012), by integrating individual, species, and the very responses these communities to environmental change. Therefore, quantitative measure of the food-web structure— encompassing food-chain length (FCL), the strength of interactions, and connectome, best describes the trophic networks' topology and their functional ecosystem properties (Thompson et al. 2012). To this effect, they cited the example of energy transfers from basal organisms to apex predator (i.e., FCL) interaction to affect secondary production and biomass accumulation of biodiverse ecosystem. The case of seagrass communities of the York River estuary, according to Duffy et al. (2005), predators tend to regulate the grazer community –thereby promoting algal production; as such Saint-Béat, et al. (2015) and Hooper et al. (2012) iterated that where there may be ALAN-induced changes in biodiversity and trophic networks, a destabilization of coastal ecosystems or declines of ecosystem functions.

ALAN, notably LED white lights to affect primary producer biomass and community composition of freshwater systems (Grubisic 2018); therefore, bottom-up food-web effects are expected in estuaries. Again, phytoplankton productivity typically is said to vary along estuarine gradients, where lighting limitation are often linked turbidity (Harding et al. 1986, Cloern, 1987). In such situations, ALAN tends to induce differential impacts on phytoplankton carbon assimilation across an estuary.

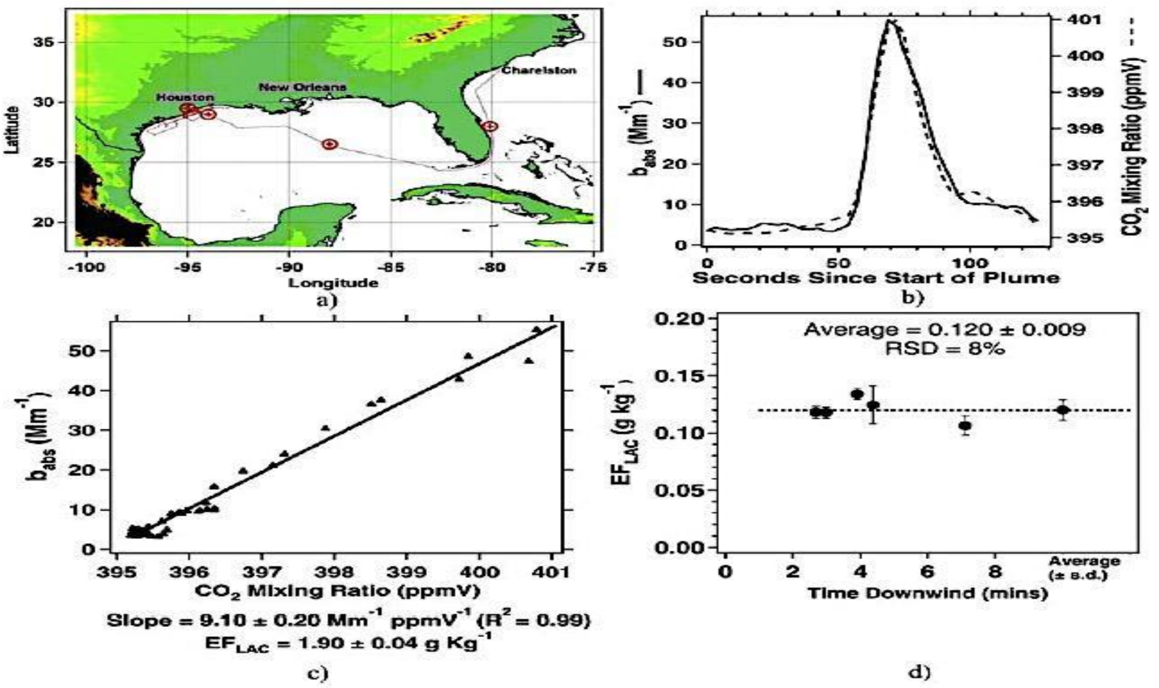
ALAN, however, is expected to be advantageous to taxa that utilize light as a resource in locating prey, while hampering those who seek darkness for protection from prey or predators (Davies et al. 2012, Gaston et al. 2013). Such taxon-specific responses elicit a top-down trophic impact on the community structure (refer to Bennie et al.'s (2015a) review). Therefore, beyond its potential indirect effects for consumers, exposures of terrestrial and aquatic consumers to ALAN, which is markedly distinct in spectral and temporal patterns of light. The situation directly influences interactions mediating aquatic-terrestrial trophic linkages of consumers. Davies et al. (2016) concluded their review proposing key research avenues, as the basis for the development of a cohesive research framework: thus, (1) Characterizing natural diel and seasonal light changes in habitats (Sensu Veilleux and Cummings, 2012), (2) developing an understanding of Biological responses on the duration, magnitude, frequency, and predictability of exposure to ALAN, (3) developing the connections delimiting known effects of natural and artificial light on animal physiology and community ecology (Zapata et al. (2019)), and (4) linking ALAN-responses across levels of biological organizations. There is, therefore, no doubt that ALAN is an environmental stressor prevalent throughout urban and developing coastal areas which include Marine Protected Areas (MPAs) in the Gulf of Mexico and Caribbean, East coast of South America, Atlantic Mediterranean, and Australia – all subject to extensive ALAN (Davies et al., 2016). A growing link between coastal development and light intensity trends has been reported (Davies et al. 2014), yet, there are opportunities of implementing policies and technologies capable of minimizing the ecological impacts (Gaston et al. 2012). Therefore, to adequately manage issues of rising sea level, changing the salinity regime, freshwater inputs, there is the need to be able to anticipate changes to ecosystem functionality associated with ALAN. Davies et al. (2016) emphasised that despite MPAs experiencing the presence of ALAN in the early 1990s, research is only beginning to hone the understanding of the scale of the environmental stressor along with its consequences on ecological processes in coastal ecosystems *(Zapata, M.J., Sullivan, S.M.P. & Gray, S.M. (2019))*.

2.2.5 The issue of Air Emission from Vessel Operations Amidst Climate Change

This section takes a look at marine vessel operations, its contribution to climate change and the overall impact on the ecosystem. This, it does by reviewing Lack et al.'s (2008) study of *'Light absorbing carbon emissions from commercial shipping'* featured in Geophysical Research Letters, Vol. 35, L13815, and in conjunction with Heneghan, Hatton and Galbraith's (2019), review article titled, *'Climate change impacts on marine ecosystems through the lens of the size spectrum'* that appeared in Emerging Topics in Life Science (2019) Volume 3, Issue 2: 233-243.

2.2.5.1 Introduction

The IMO (2000) estimates that the total installed main engine power of ships in the world fleet in general consists of 63% slow speed diesel, 31% medium-speed diesel and 6% representing others, e.g. gas and steam turbines. Though CO_2 and SO_2, for example, are fuel dependant, NO_X is not and primarily a resultant element of combusting process (i.e., dependent on engine type). Nitrogen oxide is, therefore, chemical formations related to high pressures and temperatures during combustion rather than to the nitrogen content, if any, of the fuel (AP-42, Vol. I, 3.4). Other pollutants, such as HC, CO, and smoke, are instead primarily as a result of incomplete combustion ("US EPA, OAR, Office of Air Quality Planning and Standards", 2011), whereas in this case, white, blue, and black smoke may be emitted from IC engines (AP-42, Vol. I, 3.4). The black smoke primarily is constituted of agglomerated carbon particles (soot). Usually, these liquid particulates appear as white smoke in the exhaust during a cold engine start, idling, or low load operation. It is imperative to assert here that, the ship has generally consumed varieties of fuel classed in terms of viscosity (thus, from distillates through to heavy residual oils (RO)). Heneghan, Hatton and Galbraith (2019), when considering impact, explained that climate change as we know is a complex global issue today driving countless shifts within the structure and function of marine ecosystems. To better understand these shifts, they suggest many processes need to be considered, away from the approach which far too often appears to have incompatible perspectives. They, therefore, proposed a relatively simple, integrated perspective: '***the abundance-size spectrum'*** by admitting that with the given the millions of marine species inhabiting the world's oceans, their diverse life strategies and inter-relationships, coupled with the multi-dimensional anthropogenic stressors, it is incredibly challenging to gain an understanding of the overall impact of climate change on marine ecosystems. However, Lack et al., (2008) looked at ship's contribution referred to black carbon (BC) aerosol produced in the combustion of the fossil at 'strong' source regions as considered by Koch and Hansen, (2005). Comparative to radioactively forced contributions of CO_2 (+1.56 Wm^{-2}), the Intergovernmental Panel on Climate Change (IPCC), (2007) estimated BC to contribute +0.44 Wm^{-2} –thus, occurring in environmentally sensitive regions like the Arctic. Flanner et al., (2007); IPCC, (2007) also noted anthropogenic BC as decreasing albedo of snow and ice surfaces. Additionally, BC (as an aerosol emission) leads to visibility reduction, adverse health effects, and eventual premature mortality [Park et al., 2003; Corbett et al., 2007a]. Bond et al., (2004) and Lack et al. (2008) agree that uncertainty in global inventories is partly the reason for the large uncertainties of BC contribution to climate effect. Whereas globally, one-third of BC emissions is of fossil fuel, estimates of emission from shipping according to Sinha et al., 2003; Bond et al., 2004; Eyring et al., 2005a; Wang et al., 2008; T. C. Bond, personal communication, 2007; vary from 19 –132 Gg $yr.^{-1}$ (or ~0.2% to ~5% of anthropogenic emissions). The intensity of emissions is relative to near landfall [Corbett and Fishbeck, 1997] where emissions quickly spiral into cloud condensation nuclei altering cloud properties within pristine marine environments [Ferek et al., 1998; Schreier et al., 2007; Lack et al., 2008]. The phenomena, also pre-suggested that similar intensity patterns around heavily patronized offshore installations, bearing in mind rising fuel consumptions [Eyring et al., 2005b; Corbett et al., 2007b] with expected growth at 2%–6% $yr.^{-1}$ and spatial changes in ship routes. In light of this, Lack et al. referred to the only two distinct studies of BC direct emission from three ships published [Sinha et al., 2003; Petzold et al., 2008] as a guide to their study area (see Figure 39 (a)) to develop an extensive set of measurements of light-absorbing carbon aerosol (thus, with quantity functionally similar to BC) emissions from commercial vessels by NOAA research vessel Ronald H. Brown (RHB) per 2006 Texas Air Quality Study/Gulf of Mexico Atmospheric Composition and Climate Study (Tex-AQS/GoMACCS). The study area encompassing the Gulf of Mexico to Port of Houston (host of 10th total cargo tonnage) [Port of Houston Authority, 2008], RHB track and areas where most vessels –were encountered. Lack et al. indicated they applied measured emission factors in estimating global burden



while investigating the impacts on BC surface concentrations using MOZART global model framework [Horowitz et al., 2003; L. K. Emmons, personal communication, 2008].

2.2.5.2 Measurement of Light Absorbing Carbon Emission Factors

Lack et al., (2008 pp1) used a photoacoustic technique [Lack et al., 2006] to measure "***aerosol light absorption*** (b_{abs}) (<1 mm, relative humidity < 30%, 532 nm) seconds to minutes downwind of ship plumes". BC and 'brown carbon' measurement achieved are via optical absorption [Andreae and Gelencser, 2006], which combined, Lack et al. referred to as ***Light Absorbing Carbon*** (LAC). For new emissions, BC forms the central part of absorption. However, LAC is a more appropriate definition when using a light absorption technique (2008). A 532 nm gas-phase optical absorption interference measured, was with cavity rings down spectrometer [Baynard et al., 2007] (on average, a 15% correction to b_{abs}), thereby allowing Lack et al., determine the LAC emission factors (EF_{LAC}: grams of LAC per kilogram of fuel burnt) using the equation (1) below.

$$EF_{LAC}\left(\mathrm{g\,kg^{-1}}\right) = \frac{b_{abs}\left(\mathrm{Mm^{-1}}\,at\;STP\right)}{CO_2(\mathrm{ppmV})} \times \frac{1}{MAC(\mathrm{m^2\,g^{-1}})} \times f_{fuel} \quad (1)$$

Given that the ratio of b_{abs} to CO_2 normalizes b_{abs} to plume dilution shown in Figures 35 (b) and 35 (c), where it is then divided by the mass absorption coefficient (MAC) to produce the EF_{LAC}. The optical absorption per unit mass of LAC, MACs are measured by absorbing aerosol at ranges of fuel types to combustion efficiency. MACs for

LAC and BC were reviewed by Bond and Bergstrom (2006), reviewing MACs for LAC and BC reported MAC for fresh fossil-fuel combustion aerosol at 7.5 ± 1.2 m^2 g^{-1} at 550 nm (thus to say, 7.75 m^2 g^{-1} used here, spared MAC's convert to 532 nm using λ^{-1} based on Kirchstetter et al., (2004) estimation. Therefore, fuel conversion factor, $_{fuel}$ (given as 1.62 x 106 m^3 ppmV kg^{-1}) is defined to include (i) fuel fraction of carbon (0.865 by weight) per Lloyd's Register, (1995), and (ii) CO_2 mixing ratio to the concentration of carbon conversion, whereas 101 ships' plumes are analyzed using average b_{abs} /CO_2 R^2 at 0.93 ± 0.05. E. Williams et al., described in the 'Emissions of NO_X, SO_2 and CO from commercial marine shipping', (2008) is the basis of the Gas-phase measurement used by Lack et al. (2008).

Lack et al. (2008) noted precision measurement of EF_{LAC} was determined applying repeated encounters with a vessel (Patriot tanker ship) anchored to a location at night under constant wind speed conditions (~ 7 ms^{-1}) with plume transit time for closest and farthest encounters at (~2) and (~7) minutes respectively. They subsequently assumed MT Patriot operated under stable conditions towards attributing EF_{LAC} variability to imprecisions within calculation uncertainties of b_{abs} and CO_2, and aerosol processing during plume transit. The Standard Deviation (SD) per the measurements was 8% while the propagation of uncertainties in EF_{LAC} resulted in EF_{LAC} at ±20%, subdued by the MAC uncertainty (at 15.5%). However, the average SD in b_{abs} /CO_2 was 10% with precision in EF_{LAC} at 8%. The uncertainty in fuel carbon content stood at 1% with total carbon conversion to CO_2 at 2% (Lack et al., 2008). The automated identification system (AIS) used was in the vessel, speed and unique plumes identification, with the awareness of collision avoidance transmission requirements for vessels exceeding 300 metric tons (Lack et al., 2008).

2.2.5.3 Results Review

In the open ocean, transit channels and ports, Lack, et al. (2008) observed 101 vessel encounters and presented EF_{LAC} data estimates which include; tanker, container, cargo and bulk carriers with slow speed diesel (SSD) engines; medium speed diesel (MSD) engine tugboats and large fishing fleets; and high-speed diesel (HSD) engine passenger vessels (e.g. ferries, pilot boats. By a factor of approx. Two on an average, MSD vessels emitted more LAC aerosol per unit fuel consumed than other vessels. Importantly, tug boats, operating in busy ports near populated areas, emit the most LAC aerosol per unit fuel consumed, and as such, contributing to air quality issues. In estimating engine loads, the ratio of vessel speed from AIS to vessel service speed [Corbett et al., 2006; Lloyd's Register, 2006] was used. According to Lack et al., (2008), the EF_{LAC} within the dataset appear independent of engine load, hence, inconsistent with Petzold et al. (2004) of an inverse relationship subject to low speeds inefficient combustions producing more LAC. Whereas aerosol emissions studies per engine load showed large variability (Lloyd's Register, 1995), in their data and of vessels types, LAC remained present: thus, linking engine load to individual vessels, hence, according to Lack et al. suggest a need for further research exploring LAC emissions to engine load of the international fleet vessels in capturing the variability of global vessel emissions. The emission factors for some gas-phase species (EF_{CO}, EF_{SO2} and EF_{NOY}) were compared with EF_{LAC}, allowing for the association of LAC production to primary gas production phase pollutants, in order to suggest LAC emission control strategies. For MSD engines, Lack et al. (2008) observed a direct relationship between EF_{LAC} and EF_{CO} at [$R^2 = 0.6$] (not for SSD). That indicated MSD vessel LAC emissions are as a result of inefficient combustion (thus attributed to, e.g., ageing or low maintenance) (MAN B&W Diesel, 2007). In comparison, the tug fleet recorded large variability in quality, which did not suggest statistically significant links between EF_{SO2} or EF_{NOY} and EF_{LAC} compared to MSD or SSD engines. For SSD vessels, they determined an average EF_{LAC} of 0.41 (±0.27) g kg^{-1}, with 0.97 (±0.66) g kg^{-1} and 0.36 (±0.23) g kg^{-1} for MSD and HSD vessels respectively. SSD vessels at the dock (4 vessels) had average EF_{LAC} of 0.52 (±0.28) g kg^{-1}, implying EF_{LAC} for vessels at the dock not necessarily less compared to SSD average, and thus, a critical consideration requiring docked vessels change unto clean energy (Kay and Caeser, 2007). Sinha et al. (2003) and Petzold et al. (2008) in their studies measuring EF_{LAC} (or BC) for shipping exhaust plumes, used a light absorption technique with an assumed MAC in calculating EF_{LAC} of 0.18 (±0.02) g kg^{-1} on sampling large tanker and a container ship exhaust (both SSD engines) in the open ocean. Petzold et al. (2008) considered a container ship at 85% maximum power to derive EF_{LAC} at 0.17 (±0.04) g kg^{-1} of 10 plume passes. Lack et al. (2008) contend these results as lower compared to those determined for SSD by a factor of two herein. Bond et al.'s (2004) inventory relied on an indirect emission factor for ship BC of 1.02 g kg^{-1}. Lack et al. (2008) proceeded to make a global assessment of shipping LAC emission based on Eyring et al., (2005a) fuel consumption data (for 2001), in close agreement with

Wang et al.'s (2008) inventory. The results of their combined emission factors matching global vessel type and fuel usage distributions of Eyring et al. [2005a]. Therefore, they estimated total LAC emission from shipping as 133(±27) Gg $yr.^{-1}$ (2001) compared to Eyring et al.'s [2005a] estimate of 50 Gg $yr.^{-1}$ (2001 fuel usage, EF_{LAC} of Sinha et al. [2003]), Wang et al.'s [2008] estimate at 71.4 Gg $yr^{-1}$and Bond et al. [2004] and T. C. Bond's (personal communication, 2007) value of 132 Gg $yr.^{-1}$ to BC for shipping (1996). The single assumption that the apparent independence of EF_{LAC} derived represented average engine load of all vessels was at the core of all inventories, of which a wide range of engine loads sampled, gave EF_{LAC} they supposedly felt represented the fleet average (Lack et al., 2008).

Improved quantification of global LAC emissions has several implications. Such is of the spatial distribution of LAC from shipping (for January) routes modelled using the MOZART chemical transport model referred to by Horowitz et al., (2003). According to L. K. Emmons' communication, (2008)— he applied the same model parameters detailed by Granier et al. (2006), Bond et al. (2004) for LAC inventory, and Endresen et al.'s (2003) for the spatial distribution of emissions while scaling LAC intensity for shipping to 133 Gg yr^{-1}[Lack et al. (2008)].

Lack et al. recognized the introduction of some uncertainty applying the spatial distributions used by Endresen et al. (2003) (Automated Mutual-assistance Vessel Rescue) in comparison to Wang et al. (2008) (International Comphensive Ocean-Atmosphere DataSet) suggestion. In investigating surface concentrations of the LAC (with and without shipping emissions) in MOZART model, showed there could be significant absolute increases in atmospheric concentrations due to shipping activity (20–100 ng m^{-3}). Again, the most dramatic increases in concentrations (up to 40%) were in cleaner regions. The east coasts of North America and China did not show significant relative changes, presumably due to terrestrial sources dominance of LAC [Lack et al. (2008)].

2.2.5.4 Review of Summary

For light-absorbing carbon, Lack et al., (2008) determined mass-based emission factors (EF_{LAC}) of 0.41 (±0.27) g kg^{-1}, 0.97 (±0.66) g kg^{-1} and 0.36 (±0.23) g kg^{-1} for 96 unique vessels of slow (SSD), medium (MSD) and high-speed diesel (HSD) powered engines respectively, during 101 encounters of within the Gulf of Mexico, with 20% uncertainty in each EF_{LAC} due to contributing uncertainties. The EF_{LAC} also remained independent of engine load proxy— not consistent with previous data [Petzold et al., 2004]. However, EF_{LAC} and EF_{CO} correlated for MSD vessels suggesting LAC emission corresponded to engine efficiency. MSD (mostly tug boats) saw the doubling of EF_{LAC} compared to other class ships; and a significant impact for local air quality in busy ports and vessel traffic lanes. For SSD vessels, EF_{LAC} more than double compared to limits of previous estimates [Sinha et al., 2003; Petzold et al., 2008], hence, difference and variability echoing the difficulty with applying single emission factor to all shipping. With the use of shipping fuel consumption data of Eyring et al. [2005a] and EF_{LAC} derived, they calculated global LAC contribution on shipping routes to 133(±27) Gg $yr.^{-1}$, or ~ 1.7 % for total LAC in 2001, which favourably compares to the previous estimate used on many global models [Bond et al., 2004]. Although with a contribution ~1.7% Lack et al. reiterated that shipping mostly concentrated in trade routes and ports near populated areas. The concentration evidenced is by the large absolutes (20– 50 ng m^{-3}) and the relative LAC (up to 40%) increases. They predict future emission increases in sensitive areas, such as the Arctic might relay substantial local effects in climate feedback mechanisms. Thus, imply any small fraction of LAC emitted globally by the shipping is capable of local and regional scale masking of considerable climate significance, air quality, and health [Lack et al. (2008)].

2.2.6 The Issue of Marine Oil Pollution and Operations Offshore in the Gulf of Guinea

Pollution stressors in the maritime environment over the years have taken a very complex form, and hence, have become very difficult to deal with especially in light of coastal nations expanding the economic value of those regions. According to Ansari and Matondkar (2014), the issue of providing accurate scientific assessments of the environmental ramifications of human activities have long lingered on the hearts and minds of ecologists and environmental scientists –regardless the uncertainty of consequence on marine habitats. Herewith, assessment of anthropogenic impacts remains highly essential as Mann and Lazier (1991) contend of its management on biodiversity and marine ecology. Therefore, pollution in this study is reviewed focusing on Lamptey, and Sackey, (2017) study of risks of pollution, particularly of oil spillage amidst offshore operations and how to detect and monitor its impact. However, the case of waste management in general by these ships, is critically examined.

2.2.6.1 Introduction

Lamptey and Sackey, (2017) the pollution challenges faced in Ghana's maritime boundary highlighted some marine vessel accidents that resulted in oil spillage incidents in the year 1991, off the coast of Angola, involving MT ABT Summer (Farzaneh, 2010), holding 260,000 tons of crude, in an explosion 900 miles away, burning for three days before sinking. Oil spillage in this regard; be it small or in large quantity, leads to degradation of ocean environment which leaves many marine species vulnerable (thus, in protection, body heat lost) (Figure 40). They emphasized that a significant contending issue is with operational discharges, despite legislations against them. Coastal habitats' recovery from lethal levels of oil exposure in a sense may take several decades (Levy and Gao, 2008; Lamptey and Sackey, 2017) as in the case of the Niger delta spillages by Shell or in many recent times BP 2010 spill incident on the Gulf of Mexico.

Lamptey and Sackey, (2017) also referred to Rodrigues, (2009) categorization of spill into four types based on variation in the physical and chemical properties of the petroleum product. Assertive of its definition in, UNCLOS 1982, Article 1(4)[24] for vessels as pollution, Lamptey and Sackey, (2017), (2017) identifies seeping oil from tectonic faults is another significant environmental hazard. The consequences of all these are the destruction of the natural marine habitats and the eventual extinction of marine and human lives. There are spillages (operation discharges and crude cargo) concerns along with the supply and consumption chain, continually due to dispositional issues of production source to market – (thus, transportation of crude). Therefore, Lamptey and Sackey, (2017) in the study, sort to

[24] UNCLOS 82 article 1(4) states; "pollution of the marine environment" means the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities"

suggest ways at addressing issues of illegal spillages probable along the Ghanaian coast with oil exploration and production field in mind, while advocating the adaptation of the most appropriate technology for detecting and monitoring oil spill by vessels calling on port and offshore facilities as well as those exercising rights of innocent passage. It is a crucial concern to highlight here that the global economic routes of marine vessels through Africa have increased with the growing successes of hydrocarbon find and production, hence, exploring deterrent by detection and tracking technological methods currently employed by Ghana, and investigating pollution prevention structures implemented to promote safety in the waters. These findings are also relevant to neighbouring West African countries making use of the Gulf of Guinea, as data will highlight challenges ahead in monitoring, controlling and maintaining a safe maritime environment. The study was developed based on a case study approach, allowing for exploration of largely qualitative & quantitative data from the Jubilee field, Tema and Takoradi ports [Lamptey and Sackey, (2017)]

2.2.6.2 Review of Detection and Monitoring of Oil Spillage

Remote sensing technologies are being used (governments and organizations) for surveillance: thus, with early detection and continuous monitoring of oil slick. Sensors classification are based on the surveillance crafts, ranging from aircraft, marine vessels, tracking buoys and space satellites. According to Liew (2001), visible, infrared, ultraviolet, fluorescent laser, synthetic aperture radar (SAR) and microwave sensors are the most popular operating on the principles of the electromagnetic spectrum, with a wide range of electromagnetic wave frequencies –travelling at a speed of 2.99792458 x 10^8 m/s. Electromagnetic wave frequency, therefore, depends on the source of propagation, as such, oil is a sound emitter of these waves. Waves are of low frequency (LF) as in electric transmission lines to very high frequency (VHF) in gamma radiations from atomic nuclei in the electromagnetic spectrum. Wadsworth (1992) and Maya et al. (2008) note the best and effective means of tracking oil slicks as direct field observation by trained observers using surveillance platforms. In comparison, Benjamin and Sackey, (2017 pp64) note that no one method has accurate documentation of “location, shape, size, thickness, coverage, state of weathering, and trajectory of a slick than the other,” aircraft are the most common (Discharge Tracking on Water Journal, 2006). For marine vessels, the Discharge Tracking on

Water Journal, (2006) explains that an observer aboard can have better sampling and assessment of oil per its consistency and thickness with no likelihood of misidentifying with naturally-occurring sheen. Therefore, correlating aerial and marine observations taken at the same time and place is useful, whereas indirect methods, such as infrared technology or tracking buoys, may be used at times where slick cannot be directly observed, non-availability of aircraft or vessels, or in limited visibility, or remoteness. An infrared camera (handheld or fixed/mounted devices on marine vessels or aboard an aircraft) detects differences in an oil slick and surrounding water temperatures. Thus, the spreading of slick results in oil cooling to ambient temperature, and infrared technology, therefore, becomes less effective. Tracking buoys, however, are floating radio devices, broadcasting signals and, are useful to remotely locating buoys. Some have a GPS device installed for exact position identification. Others transmit to portable radio receivers whereas some transmit to satellites. Relocating oil spill is greatly simplified if the tracking buoy remains within the slick; unfortunately, experience has proven otherwise. Notably, tracking buoys are not determining thickness, area, coverage, or consistency of slick (Discharge Tracking on Water Journal, 2006). Airborne surveillance mostly is limited by high operational costs, in as much as it been less efficient in comprehensive-area surveillance; hence, space-borne Synthetic Aperture Radar (SAR) usage in a first warning. Besides the use of SAR, other space-borne remote sensing devices with the potential for oil spill monitoring such as the Moderate Resolution Imaging Spectroradiometer (MODIS), is in use. These are carried onboard the NASA satellites Terra and Aqua –and thus have moderate-resolution bands of 250m and 500m for wide spectral ranges. It is capable of providing images of daylight-reflected solar radiation and day/night time thermal emissions. Though initially designed for land imaging, its medium-resolution showed potential for daily monitoring of coastal zones in search for oil spills. It is also mainly noted that cloud cover and lack of sunlight limits the use of satellite optical sensors as well as the need also to distinguish slicks produced by algal blooms from oil spills. In order to discriminate between various patterns of satellite images, visual analysis variations in current patterns may be required. The Hyperspectral sensors slick monitoring is a recent technology with potential for detailed identification and better estimation of abundance –thus, providing over 200 wavelengths from which spectral signature of oil is exploited in distinguishing the various oil types (Lamptey and Sackey, 2017; Friedman et al., 2002) while efficiently eliminating false alarm rate due to ocean features (with colour and appearance as oil). Lamptey and Sackey, (2017) assert, the signature matching method based on airborne hyperspectral imaging (looking at chemical composition), where analysis relies on visual interpretation of oils colour and appearance in satellite images, was more accurate (Salem and Kafatos, 2001) than the conventional techniques. They cite NASA EO-1 Hyperion hyperspectral sensor – space-borne technology with a small swath width of 7.5-100km, as an example launched in 2000. Detection of oil spills in visible images can only be achieved under conditions of favourable illumination and sea state. Therefore, positive imaging from satellite data, do not guarantee occurrence, rather a reasonable probability, often before the scrambling of a remote sensing aircraft for verification. Also, SAR equipped satellites like Canadian Radarsat 1 and 2, European ERS- 2 and Envisat are currently in use by CleanSeaNet— an example of the satellite service provider providing an oil monitoring (EMSA 2007; Lamptey and Sackey, 2017).

2.2.6.3 Research Method

2.0 Structure of the Study

The study commences with acquisition before the processing of data in ideas (Lamptey and Sackey, 2017). According to Lamptey and Sackey, these ideas as information base had two primary sources; thus, matters of relevance and mode of data acquisition. Well-enhanced tools such as structured, unstructured interviews and field visits, were employed –bearing in mind restrictions of access to strategic infrastructures, under the operational jurisdiction of both state and multinational corporations. Henceforth, visits and interviews planning took above-stated reasoning into account beside available resource to the researchers. Other data source made use of Internet searches, electronic books, leaflets, articles, news reports and lecture materials. The second phase was the correlation and integration of literature review information with primary information, a sum of which knowledge, was gradually built –to appropriate the proper understanding on the nature of issues, for informed analysis and conclusions (Lamptey and Sackey, 2017).

2.2.6.4 Analysis and Results

Benjamin and Sackey utilize mainly qualitative analysis method, based on Björklund (2003); Radriguez (2009), though slightly varied. Their method employed comparative arguments, focused on relating findings to study objectives. At this early stage, it began with; information sorting; then identification and characterization of relevant aspects to integrating into the satellite surveillance idea while finding a functional relationship of it with results information; and then, relationship obtained used. They also intended to compute any records of Quantitative data obtained relating to the incidence of oil discharges or spillage on our waters –helping make inferences about likely tendencies of oil spills. The results representation was in two phases, the first phase focusing on data defining, describing, and identifying relative function or usefulness of the waters for the socioeconomic and cultural life of Ghanaians. In contrast, the second discusses data concerning oil spillage tendencies, policy and regulatory frameworks, amidst its successes and challenges. This data is a compilation interview of resourced persons, and site observation visits information at the Marine Operations Department of Tema and Takoradi Ports (of GPHA), Ghana Naval Headquarters and Ghana EPA, obtained between January and March 2012 (Lamptey and Sackey, 2017).

1.0 Economic Benefits

Benjamin and Sackey note transportation of goods is one significant economic benefit for Ghana Ports and Harbour Authority (GPHA) operators of the two seaports, with an annual estimate of 120 oil tanker vessels calls on the Tema Port alone, not to mention the container terminals with a 24hr turnaround time receiving massive influx container vessels. Others include general bulk, fishing, reefers, chemical, RO-RO, gas carriers, offshore installations, and the thousands of average canoes with outboard motors taking shelter. Fish meal is also noted as a significant protein source feed for the nation, swelled with 50 fishing communities stretching from Keta (East Coast) through to Half Assini (West Coast). The energy uses derived from lake Akosombo and Bui Dam's estuaries to the ocean, whereas serving as housing for the West Africa gas pipeline from Nigeria, the Sankofa and Jubilee Gas pipelines to the Ghana Gas plant in the Western Region and hosting critical hydrocarbon assets. Employment uses vary among the uneducated and educated ranging from peasant fishing, fishmongers, through to navigators, e-commerce and associated sea trade labours. Revenue generations are primarily accounted for by the use of the ports, exploitation of hydrocarbon resource where Jubilee field alone accrued 3billion dollars for the first 3years (Myjoyonline.com, 2016; Lamptey and Sackey, 2017).

2.0 Policy for oil spillage prevention and Effectiveness

Benjamin and Sackey indicated that Ghana Maritime Authority (GMA), was resourced in carrying out port State control (PSC) inspections on vessels calling on ports and offshore facilities for the various antipollution certificates such as International Oil Pollution Prevention Certificate (IOPPC), International Sewage Pollution Prevention Certificate (ISPPC) and International Air Pollution Prevention Certificate (IAPPC). In contrast, any suspicions of vessels violating despite carrying certificates could result in detention aided by Navy. Vessels, exercising the right of innocent passage exempted from PSC. In recognition of this, the Navy conducts regular patrols. The PSC is said to be most effective for oil tanker compliance, especially calls at Jubilee oil field, however, not so with Offshore Support Vessels (OSV). Hence, concerning detection and monitoring, they contend the EPA deem as moderately effective, relying on random commuter vessels, aircraft and fishing canoes informants. The GMA and GN felt there is need for improvement [Lamptey and Sackey, (2017)].

3.0 The Penalties, Detection and Monitoring

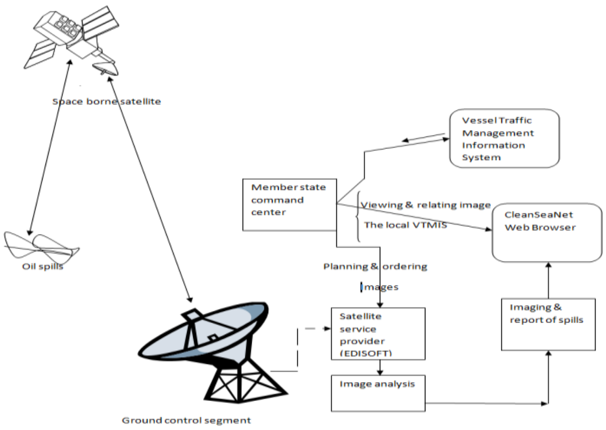
Lamptey and Sackey quoted the GMA as saying, "penalties are there for defaulters, but this varies with circumstances leading to the spillage," (2017 pp70) which establishes the Polluter Pays Principle (PPP) based on MARPOL 73/78. Annex II of the convention, for instance, subject failure in submitting spill report to liable 1,000 penalty units, which Ghana laws est5imates to GHC12,000 equivalent penalty units. The GMA however, is not charged with the responsibility to monitor oil spillages, but rather the duty to respond based on the existing National Oil Spill Contingency Plan (NOSCP), reviewed annually. Ghana Navy regular patrol services vigilant lookout for spills by facility operators is the primary means of monitoring. All facilities are dully fitted with response kits in emergencies. Detection or monitoring are mostly visual observation, as there is no extra surveillance maintained at the port facilities. The EPA's use of hired aircraft patrols on the seas is somewhat irregular. As such, the GMA's installed, Vessel Traffic Management Information System (VTMIS) off the entire coast— providing radar identification of vessels position traversing her waters remain critical means of monitoring the waters. The command centre of the VTMIS is at GMA premises in Accra, where coordination data from sub-centres are achieved. These actions further supplemented are by the establishment of the Maritime Organization of West and Central Africa (MOWCA) whose role is to provide coast guard functionality into national maritime security scheme of each West African nation in a collaborative effort on emergency response along the West and Central African coasts [Lamptey and Sackey, (2017)].

2.2.6.5 Discussions

Although the maritime environment continues to play an essential role in the nation's development, little investment made is to protect it for the benefit of society (Lamptey and Sackey, 2017). Growing exploitations of petroleum basins, according to Lamptey and Sackey, has led to demarcations for fishing sites away field installation, despite schools of fishes attracted to the massive use of white lights deployed on installations. To them, this might be a reason to the issues of unemployment and poverty in these fishing communities, perhaps the reason these local fishermen fail to comply with safety zone regulations (Sakey and Lamptey, 2019). It also requires that all vessels stay clear of traversing restricted areas. The regulation thus increases the vessels' turnaround time margins. The exploitations inshore and offshore now even make a case for heightened caution against oil spillage to avoid loss of marine lives, employment, recreational activities at the coast, foreign exchange earnings, property or human lives. Besides, there is a high cost of surveillance and response to spillage. The GMA, therefore, addresses issues of operational or accidental spillages with the enforcement of PSC inspections, while collaborating with the EPA and GN on the operationalization of the NOSCP and monitoring with the VTMIS identifying vessels and their positions respectively. In line with coast guard functionality in the shared protection and safety of MOWCA member states, GMA, is expected to provide security and emergency response assigned to probable situations. The PSC inspection as a deterrent measure has effectively catered for vessels calling on ports and offshore facilities whereas it surveillance reliance is to 'goodwill' of commuters reporting, periodic patrol by the Navy, and random use of hired aircraft. Benjamin and Sackey submit the findings suggest this is limited and inadequate as reports have never recorded any apprehension of possible suspects. The reason, Benjamin and Sackey suggest these probable spillers are vessels exercising their right of innocent passage exempted from PSC inspections. In summary, they indicate there is currently no measure in place to prevent oil pollution from vessels exercising rights of innocent passage, which the GMA hopes the VTMIS will forestall, even as they consider deterrent as preventive measures. They proceed to highlight several methods and equipment used for detection and monitoring today— citing satellite surveillance and aerial surveillance systems, of which merits and demerits considered were per sensor technology applied (***Visible, Infrared, Ultraviolet, Laser fluorosensor, Radar,*** and ***Microwave,*** on aircraft). The locations, shape, size, thickness, coverage, state of weathering, and trajectory of slick remain primary to accurate documentation which aircraft sensors fail to give in overall sea coverage and of continuous coverage capable of deterring recalcitrant vessels. Additionally, with its high operational cost, its very effective use is for follow-up or reinforced surveillance after detection of slick. Satellite surveillance, however, employs sensors (such as ***synthetic aperture radar*** (**SAR**), among others), capable of long and short-term response while providing total area and 24hr period sea coverage. However, positive image readings are far from guaranteeing oil (spillage) discharge occurrence, yet, it does present a reasonable probability. Therefore, the first warning is its domain (Lamptey and Sackey, 2017).

2.2.6.6 Conclusion

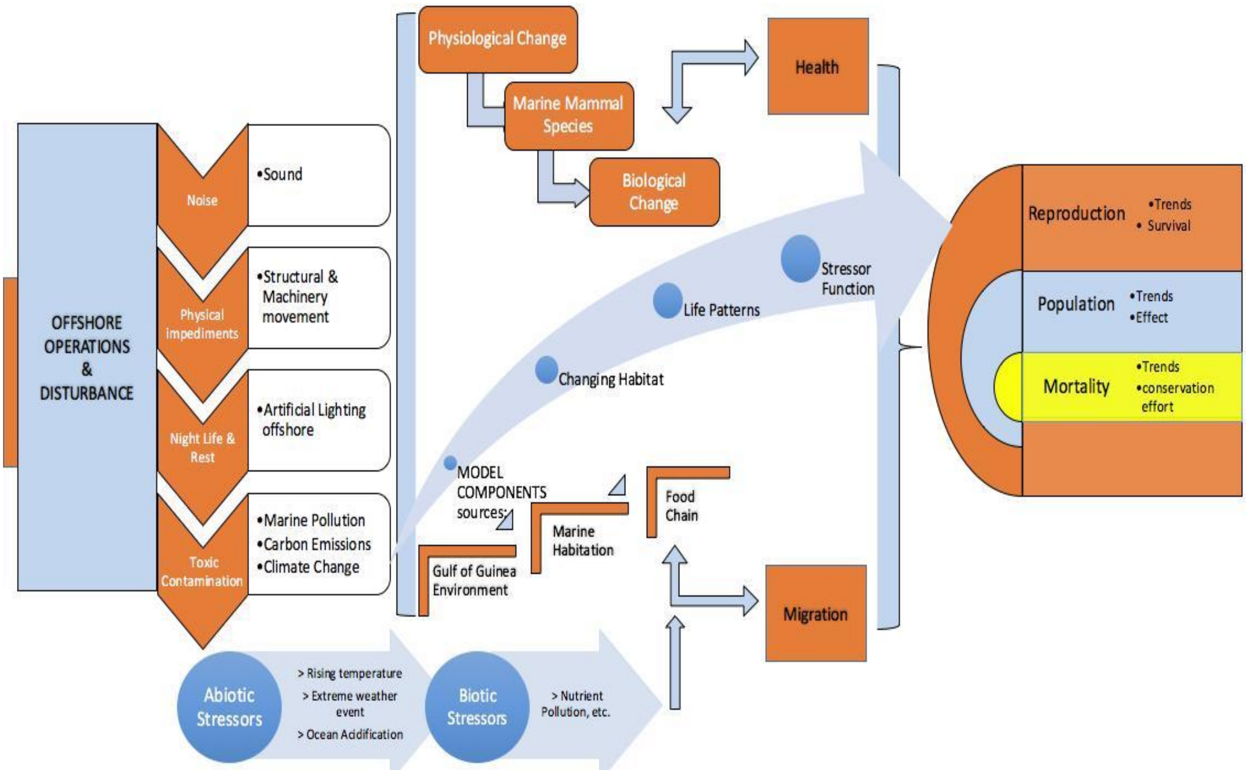
Lamptey and Sackey conclude by alluding that satellite or space-borne detection when subscribed to, is a suitable measure for the integrated superimposition of the VTMIS as shown in Figure 41, where benefits enhance sea scope and 24hour time surveillance coverage of oil spill supported by vessel tracking data, granting an opportunity to rework slip and perpetrator trajectory to identify culprits. If MOWCA member states are to adopt satellite surveillance subscription, the cost of such service will be relatively lower; thus, with members installing VTMIS though not a requirement. Yearly random patrols of navies and hired aircraft will be limited if not eliminated while aiding emergency responds capabilities. There are several satellite services for oil spill today; notable among them is EMSA CleanSeaNet under the operational command of EDISOFT used herein the illustration. Therefore, as illustrated by the schematic diagram in Figure 36, the operational surveillance of satellite service can be integrated with VTMIS data records. Thus, any possible detected slick picked up by space satellite, is relayed to the ground segment where initial analysis carried out is to determine the region. Herein, the satellites images will be passed on to the country of incidence (e.g., Ghana) through a web portal for detailed analysis— in conjunction with VTMIS data records. Ocean tides, current and weather, factored into the analysis should help limit possible suspects to be questioned whereas the area mapped out is for field monitoring. That makes the navy more purposeful in protecting the waters (Lamptey and Sackey, 2017).



2.3 THEORETICAL FRAMEWORK

2.3.1 Development of the Theoretical Concept of the Study

The theoretical framework for this study is hinged partly on Simon's theory of '*bounded-rationality' concerning the implication of* decisions made by stakeholders within the oil and gas industry. In contrast, Roger's diffusion theory is related to discussing the changes in terms of technological advancement that have over the years, driven hydrocarbon exploratory discoveries and production from inland sources farther down into deeper areas of the Atlantic oceans (Nutley and Davies, 2000; Neels and Kris, 2005). That indeed subjects the area to potential environmental disturbances termed as PCoD. The Potential Consequences of Disturbance (PCoD) to allow for the consideration of more data gathering, using specific obstructionist stressor types as surrogates for noise pollution, subsea physical impediment, nighttime artificial lighting as colonizing factor, marine pollution particularly oil spills and climate change are chosen for a case by case investigation in this study respectively. That purpose is at developing an understanding as to how human-induced behavioural changes are emerging as population-level (NRC, 2005) effect catalysts on cetaceans in the Gulf of Guinea. The study's



theoretical framework is a slightly modified theory from New et al.'s (2014); Douglas et al., 2016;

ONR, 2016). Thus, outline developing the relationships linking the consequential disturbances to changes in animal behaviour and physiology. Its effect on health, vital rates, and population dynamics while examining linkages relevant to mammalian habitation, food chain, migration and mortality. The New et al.'s (2014) model was also consequential to the modification by NOAA Ocean Noise Strategy Roadmap (ONR) (2009) concerning the U.S. National Research Council's (NRC 2005) model of Potential Consequences of Acoustic Disturbance (PCAD), with an effort between the periods of 2009-2015. The PCoD is as shown in Figure 42 above.

While this effort specifically targets marine mammals, the conceptual model has broader applicability in illustrating the potential pathways from individual anthropogenic disturbances on population-level impacts to other various taxa (NOAA ONR, 2016). As depicted in the flow diagram, each existing relation is not in isolation. Therefore, it forms the bases of inquiry undertakings within the Gulf of Guinea region in the North Atlantic Ocean. The essential fact that the growing deep-sea oil and gas exploitation within the Gulf of Guinea, of which Ghana and her West African neighbours are active participants, essentially appears to be an irreversible pursuit for economic wealth by participating countries, tagged as *'third world'*. To these nations and their managers, deep-sea exploration remains the best solution as they fight the challenge of youthful population outburst, consequential to the massive unemployment, large scale illiteracy and poverty. Others urgent needs include infrastructure underdevelopment, inadequate health care standards, insecurity and instability in some cases, among others. These nations, therefore, do see the influx of investment from multinational oil producing companies seeking to exploit their hydrocarbon resources as a form of 'heavenly manna'. Indeed, rightly so in terms of the direct foreign exchange earnings and the quota of local labour required. However, the activities associated with these investments leading to the production of the hydrocarbon products are altering the cause of the natural marine ecological environment for these living mammals, in various behavioural forms, population shapes and distribution of the animals.

The contextualized framework (shown in Figure 42), chosen is consequent to the hypothetical insinuations. Thus:

H1* *if the increasing quantum of offshore surf operations concentrated within certain areas of the Gulf of Guinea region, does act in tandem with the ordinary physical natural ocean features (forces)— in* *determining the impact of any sustained variations within the ocean environment. That of its effect on behavioural changes of identified marine mammals, as well as within the very integrity of the Mammal's habitable zones.*

H2* *If the impact of the identified actual independent pressures (stresses) exerted on the marine mammal habitation –from anthropogenic obstructionist activities and their interrelated factors; does result in assumed stressful risk complications and eventual premature deaths.*

The hypothesis suggests therefore that, one needs to come to an understanding of the mechanisms capable of driving the population to the brink of a potential consequence of disturbance (PCoD) (Christiansen & Lusseau, 2015; New et al., 2014; NRC, 2005, 2016). Also see Figure 42 below – depicting relationships between anthropogenic, biotic and abiotic stressors in the marine environment. The initial framework of the PCoD primarily though focused on potential consequences of acoustic disturbance (PCAD) model, before the formal generalisation framework, PCoD model (King et al., 2015; Schick et al., 2013; NOAA ONR, 2016). The concept of the PCoD framework is that a source of disturbance affects the vital rates (e.g. survival and reproduction rates), which can ultimately lead to population effects (population dynamics) through a series of transfer functions (NRC, 2005; NOAA ONR 2016). According to NOAA ONR, since its introduction (2016) nearly a decade ago, further developments at improving our understanding of PCoD, both theoretically and empirically have been made (Christiansen & Lusseau, 2015; Nabe-Nielsen, Sibly, Tougaard, Teilmann, & Sveegaard, 2014; New et al., 2013, 2014; Pirotta, New, Harwood, & Lusseau, 2014; Schick et al., 2013).

The fact that not much is understood about the Atlantic Ocean, and specifically, the Gulf of Guinea; per composition and the nature of impact these exploitative activities are having on the entire ecosystem, leaves stakeholders to rely on making entirely rational decisions only to the best of their understanding. In other words, decisions made are based on feeling, which is simply not good enough for a reasonable outcome to ensure generational sustenance.

2.3.2 Understanding the Linking of Behaviour Changes to Population Viability

To evaluate the effects of anthropogenic disturbances, Bejder, Samuels, Whitehead, Finn, & Allen, (2009); Gill, Norris, & Sutherland, 2001; Nisbet, (2000) noted that evidence of wildlife response intricacies to human activities today characterises traditional behavioural sampling approaches as inadequate. Regardless, traditional behavioural sampling methods (J. Altmann, 1974) have been used successfully in some cetacean studies to inform and implement conservational measures (e.g. Tyne, Johnston, Rankin, Loneragan, & Bejder, 2015). That notwithstanding, improving our ability to measure behaviour accurately is a continuous drive (NOAA ONR, 2016).

The threats identified are to include; (i) vessel radiated noises (International Towing Tank Conference, ITTC. 2017; NOAA ONR, 2016; Jensen et al., 2009; Lesage, Barrette, Kingsley, & Sjare, 1999); (ii) whale or animal strikes from vessel movement [Nichol et al., (2017); Calambokidis et al. (2019); Redfern et al. (2013)]; (iii) the intensive nocturnal lighting (Davies et al., 2014:2015); (iv) marine pollution [Benjamin and Sackey, 2017; Mearns et al. (2019)]; and (v) the compound effect of the climate change menace (Lack et al. 2008; Heneghan et al., 2019). However, the behavioural response in all these studies related to various unique ocean ecologies and biodiversity across the globe, relating their findings to the ecological and biodiversity make-up in the Gulf of Guinea in the West African sub-region was primarily critical, as the area broadly lucked literature in terms of species populations estimates and behavioural patterns at the onset of the deep-water hydrocarbon production. The study has essentially reviewed relevant literature— attempts to depict the linkage of the various relationships in Figure 42. The area is home to various marine mammal species such as the small cetaceans, beaked whales (see Chapter 2.1). Assessing their areas of predominance and general behaviour in line with actions within BIA of individual cetaceans at sea is challenging, although non-invasive methodologies to assess body condition are improving, (Miller et al., 2012) and aerial photogrammetry techniques (Durban et al., 2015; Miller, Best, Perryman, Baumgartner, & Moore, 2012; Christiansen and Lusseau, 2015).

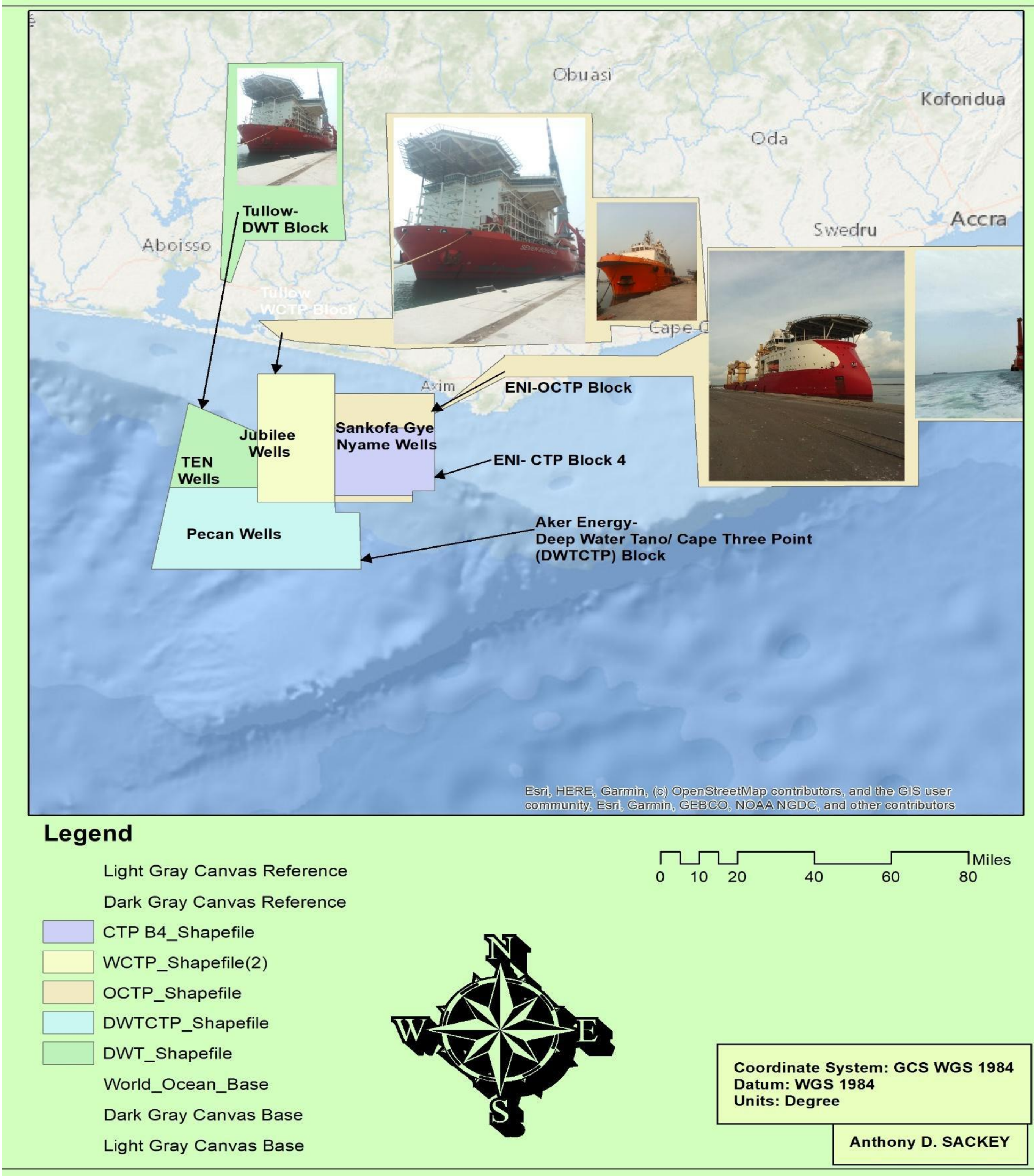
CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1.1 Description of the Study Site

The study site covers the entire active hydrocarbon production fields in the western basin of Ghana's marine waters at the Cape Three Point enclave (shown in Figure 41 and Figure 42 respectively) towards the seaports and beaches of Takoradi as well as the entire coast of western regions. This area is well placed in the Gulf of Guinea near the Ivorian maritime boundary also under exploitation. The area is saturated with several fishing communities as fishing remains the main occupation for the local folks. Hence, a significant number of local fishing boats fitted with outboard motors are a regular feature on the construction development and production fields (Sackey and Lamptey, 2019).

This vast area also accounts for the traffic of vessels operating offshore routinely making transit to port for project cargos before subsea installations operations. However, the marine vessels which served as platforms for the various direct site study include; time spent onboard Heavy-lift and Pipe-lay vessel. The Seven Borealis Nassau of the subsea seven fleets in the last quarter of the year 2015 during the Tullow and partners TEN project development before gas production from FPSO Attah Mill and the jubilee field during flowline mitigation project in last quarter 2018, and also the Cum Buoy mitigation project of FPSO Kwame Nkrumah in the first quarter of 2020, the over a year-long time spent onboard Light Construction Vessel (OCV) Polar Onyx on time charter, the Offshore Construction Vessel (OCV) Lewek Constellations, and the Seven Arctic by EMAS CHIYODA SUBSEA/Subsea 7 UK ltd., for the ENI Spa and Partners OCTP-Sankofa Gye Nyame development project between the years 2017 and 2018, the time spent onboard (thus these marine vessels serving as study platforms illustrated are in Figure 44). While aboard the various vessels, the researcher served as a competent member of the construction crew with his versatile background in both marine navigation and heavy-lift rigging technician. That was paramount to the understanding of the construction field operations and procedures and how its impact related to the marine environment at stages.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Anthony D. SACKEY

3.1.2 Research Approach

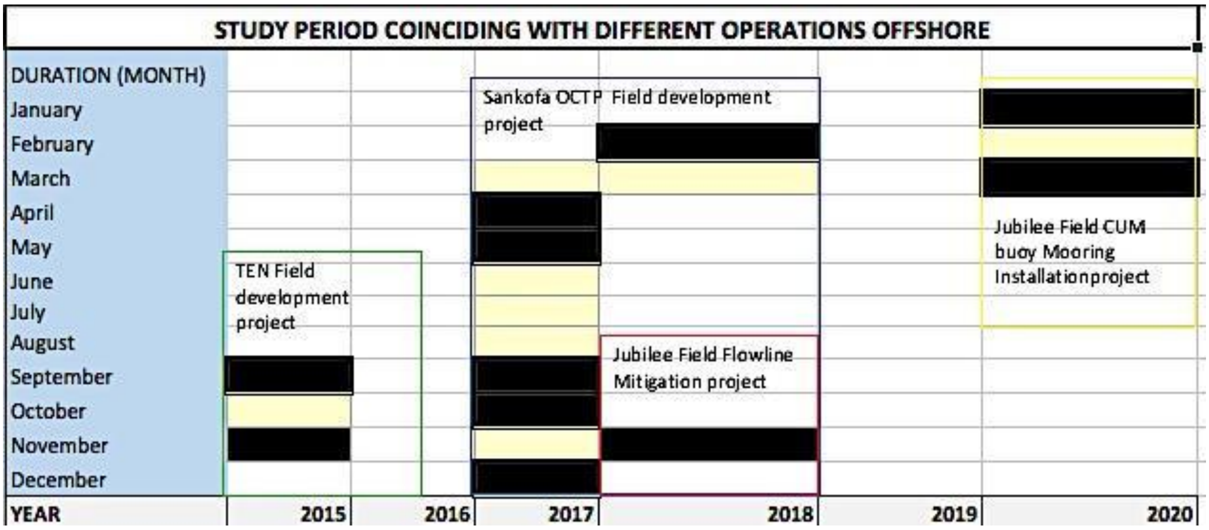
As a case study within Gulf of Guinea region where hydrocarbon exploration is currently ongoing, the focus was had on all production and development sites of shallow to deep and ultra-deep-water areas, however, due to limitation of resources to the researcher, not the entire oil fields stretching from Gabon to Liberia could be covered. Therefore, offshore operational sites within the western basin of Ghana's maritime boundary –host to growing deep-water (Jubilee, TEN, and Sankofa Gye Nyame fields) exploitations and ultra-deep-water (Pecan fields among others) in West Africa considered was for the data-gathering efforts. See each case study in Chapter Four for designated maps. That is because the area's hydrocarbon mining history is only a few decades old in terms of development and production compared to other areas. Overall, the region characterized is with similar features of geologically, oceanographically, ecological and atmospheric conditions. Thus likewise, the socio-economic and cultural nature despite the few local political differences –an aspect that drives the political, economic and financial decisions of the individual nations within the ECOWAS block.

The study, therefore, spans several periods of field observations on each of the three significant oil field developments at opportune times on various study platforms (shown in Table 9) between 2015 and 2020. The progress schedule observed is shown in Table 10. However, it situates in the context leading to first oil production at the stage, EIA carried out was towards the peak of development.

Table 9: Offshore Sites under the Study and their periods of developments in Ghana (2010 - 2018)

OFFSHORE CAPE THREE-POINT SITES	LEAD OPERATOR	FIELD DEVELOPMENT PERIOD	STUDY PLATFORMS (Marine Vessels)
Jubilee Fields	Tullow	2010 – 2013 2018 – Present towards Greater Jubilee	1) Seven Borealis Nassau, 2) Seven Adaba Lagos,
TEN Field	Tullow	2015 2018 – Now towards Greater Jubilee Dev	1) Seven Borealis Nassau, 2) Polar Onyx Bergen
Sankofa Gye Nyame Field	ENI	2017- 2018	1) Polar Onyx Bergen, 2) Lewek Constellation Panama, 3) Seven Arctic Bahamas

*Table SEQ Table * ARABIC 10: Offshore project timelines subject to the study within Ghana's Oil and Gas fields.*



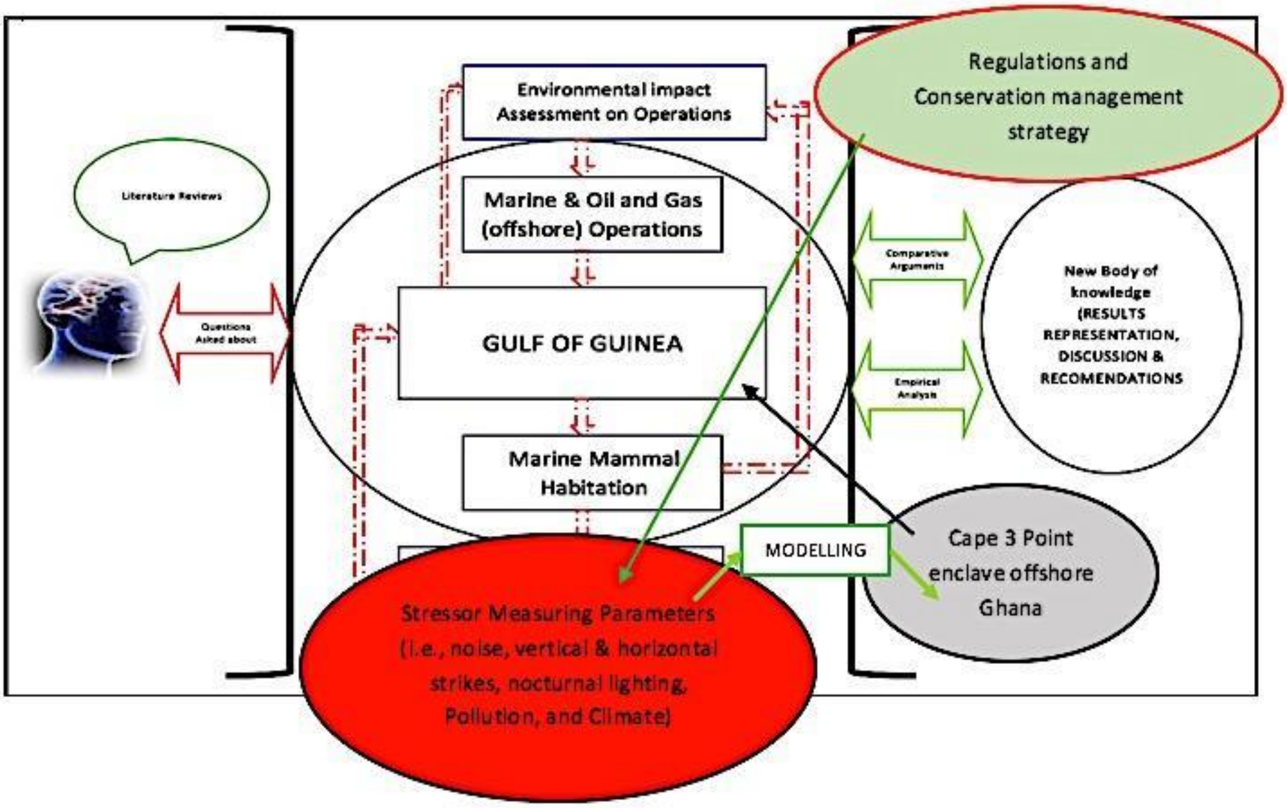
3.1.3 Structure of the Study

The study takes into account varying degrees of time spent by researcher onboard various marine vessels while contracted in various working roles including working as an Offshore Rigging Technician and Deck Cadet Training Officer with Subsea Seven UK ltd., undertaking various forms of subsea operations on various field development locations within the Cape Three Point enclave, just adjacent the Ivorian eastern maritime boundary in the Gulf of Guinea. As described in chapter one of this same study, the exploratory phase sort of combining qualitative and quantitative data gathering technique before the analysis of data, aimed at describing the specific direct impact of the stressor parameters measured, thus, insofar as simulating the consequence of the marine and subsea operations towards a modelled response within Ghana's waters and the Gulf of Guinea in general.

Gathering of Primary Data: given that the study employed a mixed-method approach, various datasets gathered used various scientifically accepted instruments. These processes were carried out in phases to limit any form of conflict that may arise within the process or the outcomes sort. Another reason for this was because direct site observation in the field data gathering was accessible only at various points in time of these study areas which occurred concurrently with their development. Therefore, these tasks of data gathering were carried out over a five-year duration at various points in time (as in Table 10), measuring different elements in line with the studies objective. Parameters measured as a source of obstructions included Nocturnal lighting, Ship Vibrated Noises, Ship operations, subsea structure and machinery movements, pollution and food waste discharges and Black carbon emissions. Therefore, ships forming part of the study targeted were for data on specific parameters. Thus, depending on overall perceived performance for impact on the environment. The frequency of their visit to the area and nature of their operations was also quantified. For the marine mammals, sight observations were possible through the use of binoculars and the use of remotely operated vehicles (ROVs). Other primary data relied on included environmental conditions recorded by sensors on the ROVs and weather buoys deployed at locations. Environmental procedure documents of these companies were also in reference. These tools implemented are detailed in each case study.

Gathering of secondary data: several works of literature on the subject matter considered were during the development of the literature review. That was particularly important to establishing the conceptualization of the study, the theoretical framework based on which the ideas deduced, were reshaped to inform the fundamental analysis. This data gathering relied on scientific journal publications, lesson notes and lectures contained on electronic media such as pdfs, websites, online news articles, news reports on radio and television and e-books. Other materials found were from printed textbooks, books, news reports, and pamphlets, among others.

Data Analysis Process: the analysis process, which combines both qualitative and quantitative data gathered, is structured to correlate the understanding of offshore operations and the marine



environmental conservational (sustainability) needs. The analysis of the study is as depicted in a schematic diagram shown below (Figure 40).

Per the modified Ellinor's (2013); Lamptey and Sackey (2017), analysis structure utilized in the general analysis, perceptions of expert opinion examined the levels of *'obstructionist stresses'* to be defined, with the later examined using Osgood semantic differential scale on opinions of the expert respondent (Osgood; May and Miron, 1975). The interest here is to compare the results on the various delimited anthropogenic stressors identified in the study, based on accurate understanding through reviewed literature on minimum prevailing stress levels acceptable for marine mammal adaptability –and thus, making reasonable inferences best fit to the aim of the study upon conclusion. The outcomes shall be deduced through modelling using Phil Dyke's (2016) modelling coastal and marine process, to ascertain the effect of the identified parameters on the marine environmental variables. The discussion, therefore, is expected to follow an argumentative pattern and will be supported with graphical stats analysis on empirical cases of all quantitative environmental data gathered per variables examined, respectively. Computer-based analytical tools such as Distance 7, ArcGIS, Lake Environment, among others; was utilized in this regard towards numerical and spatial analysis.

CHAPTER 4

PRESENTATION OF CASE STUDIES, RESULTS AND ANALYSIS

Chapter 4.1 Outlining the Offshore Marine Environment and Mammal Habitation with the Changing Climate: the case of Ghana's waters.

4.1.1 Introduction

World over, there is a genuine concern for the environment –stemming from several decades of work undertaken by several scientists and environmental activist, who believe there is a clear proof that the environment is changing and changing for the worse. Efforts at addressing these concerns, however, have become more political and emotional than the use of standard scientific application and technology aimed at reversing predicted trends. Therefore, for the past two decades, very little progress has been made. Nevertheless, there is no doubt that a changing environment does beset with naturally devastation consequences. Hence, in Ghana, critical in reflection to issues within her maritime environment is the recent rise of carcasses of dead whales found along the beaches of coastal communities, thus fostering Ghana EPA's concerns –predicting many more deaths to come (Korateng K., 2017), with the cause still to be determined. There is also the concern of sea-level rise encroaching and inundating coastal communities, increasing coastal erosions, lost in coastal eco biodiversity, the depleting fish stocks in the adjacent ocean. Many have attributed these changes occurring in the natural environment to human activities (National Geographic Society, 2020). It is far too common to find plastic pollution across major coastlines of Ghana (Plastic Punch, 2020) today, despite the enormous humanitarian efforts by environmentalist and NGOs (e.g. the Plastic Punch organisation based in Accra) in beach cleanup exercises.

In summary, the current concerns range from pollution, over-exploitation of natural resources, coastal or offshore marine developments, erosion. Therefore, grounding the concerns for biodiversity, environment distraction and the desire for wildlife conservations, will be the need to understand Ghana's marine environment better. Thus the marine environment of Ghana forms part of the Gulf of Guinea bay and is today actively utilised for socio-economic, cultural and political gains. The importance of conserving marine and notable coastal eco biodiversity areas (such as Amansuri Wetlands; and Domini Lagoon within Ghana, and internationally, Grand-Bassam Ramsar; N'Ganda N'Ganda Ramsar; and Iles Ehotilé-Essouman Ramsar of a neighbouring country, Ivory Coast (ERM/TGL, 2014)) cannot be overemphasised particularly with the rising record of infrastructure developments springing up near shore and offshore areas along the gulf stretch. These changes include development on new hydrocarbon license blocks, massive port expansions covering several square kilometres of sea and landmass (such as the Tema and Takoradi port expansion projects, and the pecan oil field development offshore). In coastal areas, the commencement of expansion works to port facilities appear inevitable as seen with the two commercial seaports in Tema and Takoradi. This development was to shore-up capacity directed at hosting dedicated offshore-onshore terminals for the oil and gas industry [Ghana National Chamber of Commerce and Industry, GNCCI (2017)]. These developments are in tandem with observations from countries bound to the south Atlantic, according to David Rogers' article (Global Construction Review, 2017). Some of the developments happening beside the various port expansions along with West Africa, includes subsea oil and gas pipelines from offshore areas to onshore receptacles, offshore FPSO unit installations, subsea installations, oil refinery plants.

The effect of all these projects on the natural environment is no way hidden. Therefore, specific queries explored in this section of study are as follows. What is the nature of the marine and coastal environment? What type of marine and coastal habitations contribute to the biodiversity found in the area? Is there a visible threat to the various natural habitats? What are the actions taking by authorities to ensure eco biodiversity sustenance? The study in resolving these questions will investigate the baseline knowledge of the marine and coastal biodiversity and ocean environment. The study will also proceed to identify vulnerabilities found in the natural environment while evaluating regulations and measures in place to ensure the destructive impact are minimized. Therefore the study herewith, asserts that results obtained will fill the gap of knowledge relevant to the dynamics of the meteorological-oceanic environment, biodiversity, and eco sustenance within the Gulf of Guinea bay.

4.1.2 Materials and Method

4.1.2.1 Study Area

Though the entire Gulf of Guinea bay remains the subject of the study, the focus was on specific locations within the western basin (Tano Cape Three Point) of Ghana's hydrocarbon reserves (see Figure 46 of Chapter Three and Figure 41 of Sec 4.1.3). This area was particularly, crucial locations because they together present a profile of the met-ocean environment of the regions currently undergoing anthropogenic changes. It also forms the mammal habitation to be estimated for population abundance. At the Jubilee area, according to ERM-TGL, (2009), wind direction and speed characterising the offshore area are relatively constant annually. The Jubilee field, which lies in Deep Water Tano and West Cape Three Points license blocks located 60km away from the southern coast of Ghana. The location of Ghana places it within the Inter-Tropical Convergence Zone (ITCZ) characterised by low-pressure wind (maritime air mass) migrating from south to north and vice versa, hence influencing seasonal patterns (ERM-TGL, 2009). Thus, ERM-TGL, (2009) reiterated that between November and April, the ITCZ usually bounded south, during which desert (air mass) winds from the Sahara regions drive-in down south over the African continent. A reverse is seen between May and October when the ITCZ is bounded north. At this period the yearly southwest trade (maritime air mass) winds appear to gain a more southeasterly direction. This change is mainly as a result of Coriolis force acting on the Earth surface (ERM-TGL, 2009; Rui Xin Huang, 2017, 2015).). The area also has water depths as deep as 1400meters (see Figure 46). Adjacent the DWT/WCTP license block is the OCTP license block stretching northward near the coast with water depths under 1000meters. This area is more within the continental shelf reach and towards the coast. To the south and east of WCTP and OCTP Blocks areas respectively, lies the Pecan oil fields discoveries situated within the DWT/CTP block (on the continental slope area), and the Afina-1 Well discovery within WCTP Block 2 license area. Same meteorological features broadly characterise all these areas.

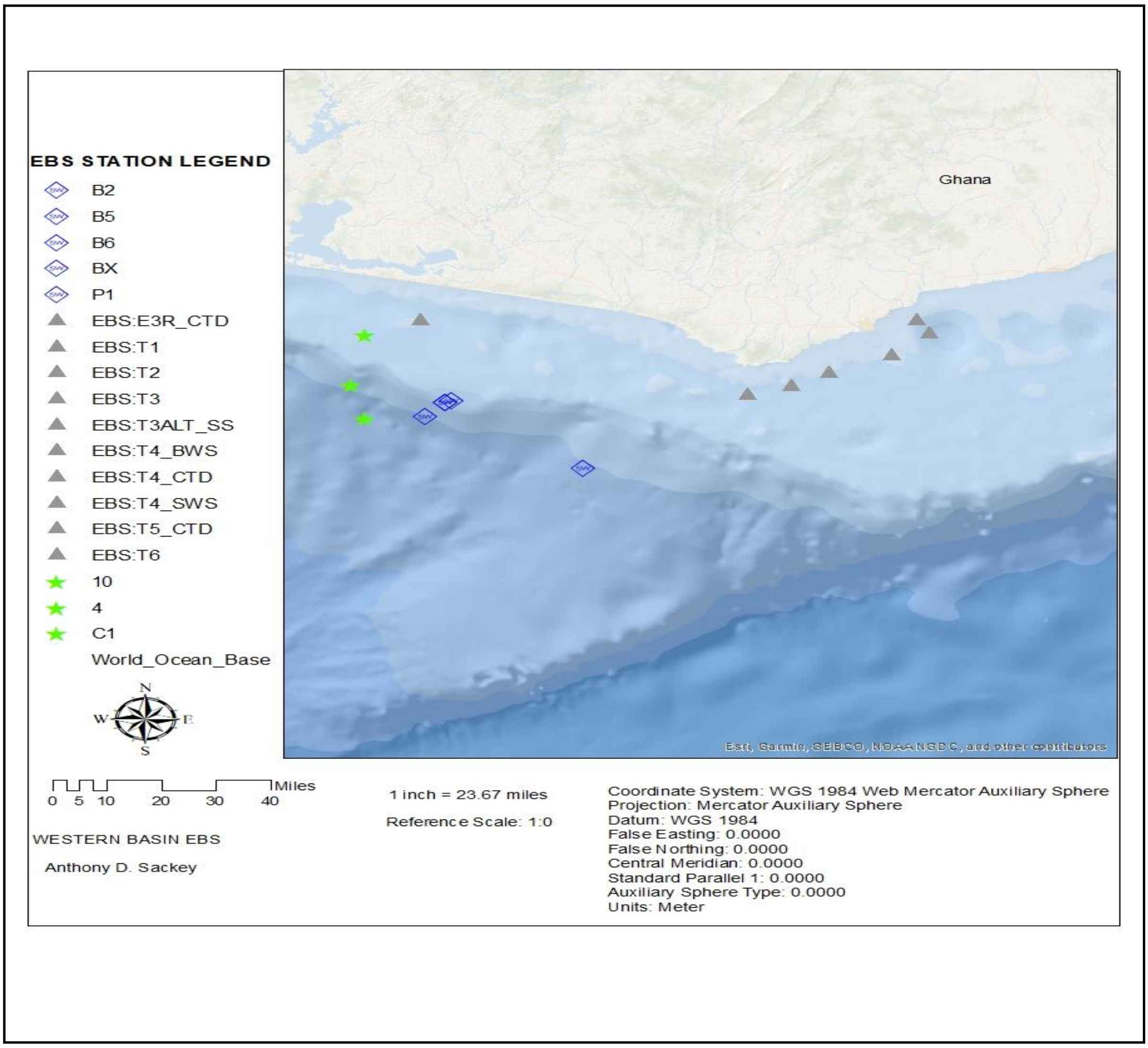
4.1.2.2 Methodology

The study here largely remained descriptive –relying on both qualitative and quantitative data obtained through various means of hydrographic, oceanographic and meteorological measurements. This approach relied on a series of field measurements achieve through the use of marine vessels, and specialised pieces of equipment, operated by vessel staff. The study also made use of combined qualitative and quantitative data gathering techniques over the 2020 four-month-period field undertakings. The parameters tested in line with the natural marine environment include; (a) metrological, and (b) oceanographic samples, thus, providing an outlook of the area against the specie habitats forming part of the broad ecosystem of the region.

4.1.3 Data Sources and Analysis

4.1.3.1 Survey Design

The survey design was planned to incorporate previous EBS studies during the analysis stage as the fundamental description of the area. Meteorological data covered daily recordings taken at all vessel locations while at the site in the year 2020. In brief, ocean data gathered for EBS analysis included a sampling of locations selected during the 2020 surf operations on the Jubilee field [see Figure 47]. Both night time and daytime data were gathered. This new sampling data will be juxtaposed to a 2008 and 2011 EBS studies from the DWT and WCTP blocks conducted over water column sample. Thus samples from near-surface to 100-m water depths at Station 4 (profiled on the 26th of March at 1,500meter water depth) and 10 (profiled on the 27th of March at 1000meter water depth), and that sample along the gas export line from near-surface and near-bottom (<5m to the seabed) at station C1 (profiled the 28th of March at 77meter water depth)). A comparison of EBS hydrographic data to the findings of this study's data in subsequent paragraphs. Though the entire region is the focus in this study, due to limited access and resource at researcher's disposal at the time of the study, the hydrographical profiling aspect of the environment was relatively limited to locations within the Jubilee Field compared to meteorological data and are therefore in Figure 42 (b) below. In summary, Figure 42 (c) contains previous EBS within the study location from EIA, as well as this study's survey locations forming the baseline information. In summary, during the WCTP EBS EIA surveys, about 80 sample locations selected though less that number were sampled overall due to insufficient data recovery at specific locations and inaccessibility as a result of extreme shallow depths, however, this study highlights 14 of the locations in the above map from which a sample of graphical analysis would evaluate in comparison. (Refer to Appendix and supplementary material for the samples data).



4.1.3.2 Field Methods

Data Gathering process: was defined by the nature and type of data parameter sort and utilised in the analysis process. Qualitative data, in this regard, was obtained through interviews, references to internal documents, and site observation. Quantitative data, however, which refers to the primary parameters of the study involved the deployment of remotely operated vehicles, position beacons and access to data from a stationed weather buoy installed and operated by a third-party institution. Environmental variables considered are; Conductivity, Ocean Current, Visibility, Waves, Wind, Temperature, Density, Dissolved Oxygen, Water Depths, Salinity and Velocity. Each of these variables uniquely helps define the environment. Sight observations conducted were also for the animal presence and visibility levels. An instrument used in gathering data on salinity, temperature, water depth was Subsea 7 ACV09 SCU. Handheld binoculars as well as bridge equipment such as GPS, Gyro was also used.

4.1.4 Description of Data Analysis

The data analysis process though follows the general design described in earlier chapters of this very study, based on mixed data gathering approach, analysis of each type of data is described in detail as follow.

Climate and Meteorological Data: data of this included wind, atmosphere pressure, visibility (fog/ midst), atmospheric temperature and ocean surface (wave height and direction) conditions observed and recorded. Analysis of wind conditions makes use of the Lakes Environmental Software Version 7.0.0., (1998-2011) in Windows 10 OS. The study modelled for a viable wind rose and wind class frequency distributions over the data gathered for the period of the 10th of January to the 28th of March, 2020— taking into account wind speed and direction over an hourly interval. Atmospheric pressure, temperature, visibility, and ocean surface conditions, however, were analysed using Microsoft Excel (2013); in deducing graphical information of the various data obtained. The Ocean's Hydrographical Data and Modelling: took into account key conditions (Water depth, Ocean temperature, Salinity or Conductivity and Density) measured and recorded over a selected number of locations. Densities computed were by UNESCO Equation of State of Seawater (EOS-80) Formula, and in some cases, Salinity computed was based on Weiss (1970) set of equations (Benson and Krause, 1980 and 1984) from specific conductivity readings. One of the crucial element to the marine ecosystem is the presence of dissolved oxygen (D.O.). Numerically, following Benson and Krause (1980; 1984; U.S. Geological Survey (USGS), 2011) preceded by Weiss theoretical formulas, estimates of D.O. derived was at 100% saturation along with water depth. The general relationships given are below;

The analysis concludes deducing a graphical relationship between D.O., Ocean temperature (degree Celcius), Salinity [Practical Salinity Unit (psu)] or Conductivity (micro siemens per centimetre), Density (kg/m^3) and the various Water depths of the selected study locations.

$$[DO] = DO_o * F_s * F_p, \text{-------------------------------} (1)$$

…. (2)

Where, dissolved oxygen (DO) concentration in mg/L represented describes a baseline concentration in freshwater (DOo) multiplied by salinity (F_S) and pressure correction factor (F_P). Additionally, the salinity and the pressure correction factor are a function of salinity and barometric pressure respectively. The U.S. Geological Survey (USGS) (2011) reiterated that all three terms are a function of water temperature. Benson and Krause equation of DO is in equation (2) below;

OR

Where T is the water temperature in Kelvin (T = t(°C) + 273.15). The Benson and Krause salinity factor is:

Where S is salinity in parts per thousands (%$_0$), T is temperature in Kelvin. Salinity estimated, however, is based on its relationship with specific electric conductivity given as;

Where SC is specific conductances in measured in microsiemens per centimeter (µS/cm) over a wide range of temperature (0-40 °C) and specific conductance (0-67,000 µS/cm). Refer to USGS (2011) *Office of Water Quality Technical Memorandum 2011.03: Change to Solubility Equations for Oxygen in Water,* for the entire equations applicable for the rest of elements applied in equation (1).

4.1.5 Results and Discussion

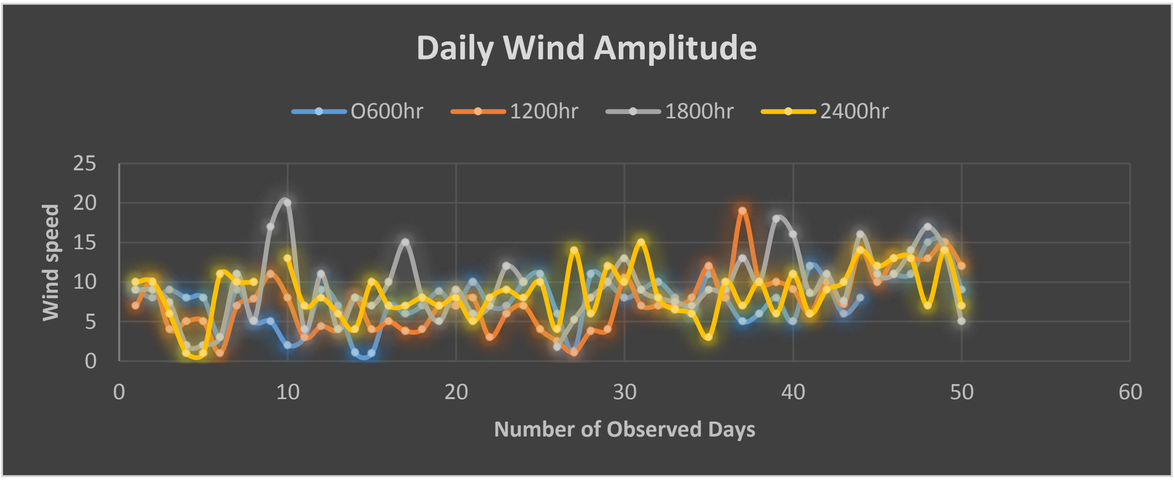
The results presented in this section are categorised into two-phase –describing the marine environment. Thus, namely (i), the first employs qualitative and quantitative findings characterising the atmospheric surroundings of offshore Ghana, delimiting its meteorological value, characterising the ocean environment of the offshore study areas. (ii) The second concludes with analysis and discussion profiling the METOCEAN information descriptive of the marine environment suiting the specific mammal habitations found within. Henceforth, findings on the nature of the marine environment of the area essentially are compared to environmental baseline studies conducted during EIA on the various field driving the analysis. The study's data gathering process also took into account the challenges brought about by the coronavirus restrictions and subsequent impact on the maritime industry after its declaration as a global pandemic by the WHO on March 11 2020 (Verdict Media Limited, 2020). The situation adversely impacted on the period of study –limiting the amount of data needed for a comprehensive study. Details results, therefore, are in proceeding paragraphs.

4.1.4.1 The Atmospheric Conditions of the Marine and Coastal Environment

Robert H. Stewart (2008 pp39) noted that because the atmosphere drives the ocean, while the ocean drives the atmosphere, it is imperative to consider the ocean and atmosphere as a *'coupled dynamic system'.* This principle laid the foundation on which the study develops. The climate of the area examined is in regards to primary meteorological conditions observed for patterns and occurrences. This conditions included wind activity, atmosphere pressure, visibility (fog/ mist), and atmospheric temperature –with findings presented in proceeding paragraphs. Consideration is for the ocean surface condition as well. This ocean surface condition precedes the understanding into the ocean and the marine environment. Hitherto, the METOCEAN environment defining the area is as described below.

4.1.4.1.1 Climate and Meteorological Information

Observation of Wind Patterns: In general, the atmospheric characteristics underlining the coastal and marine environment of Ghana have minimal variations, thus according to earlier EIA baseline studies conducted by ERM/TGL (2009) and ESL Consulting/ENI S.p.A (2015). The ERM/TGL (2009), asserts for example that, primarily, observed winds generated are of the southwest quadrant –and thus having a maximum non-squall attribute of 10m/s wind speed. Figure 48 also shows results compiled of daily wind from the study region during the study. Again, the assertion from ERM/TGL (2009) and ESL Consulting/ENI S.p.A (2015) is in agreement with the findings of the study depicted in Figure 48 and 49, which showed an intense wind activity directed within the southwest quadrant of the wind rose, with maldistribution within the northwest. Again, 41.8 per cent wind speed recorded between the 10th of January and the 28th of March 2020 study period, fell within the frequency range of 7-11knots. ERM/TGL (2009) notes that this wind characteristics accordingly, besets the fairly consistent year-round wind patterns of the region. Squall[25] events observed, however, have been attributed to thunderstorm generating extreme wind conditions. Thus, approximately 15 – 30 squall events are expected yearly though with a short duration. Implicitly, over the ocean, they end up with weaker surface current and low wave heights (ERM/TGL, 2009).



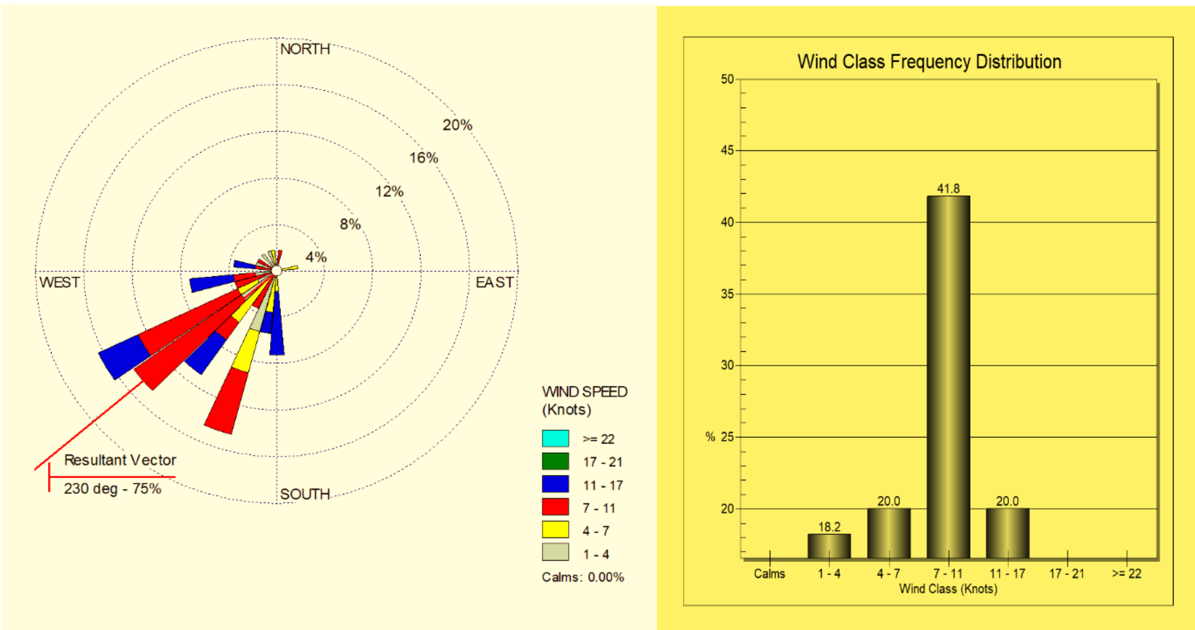


Figure 49: left: Wind Rose and right: Speed Frequency

[25] Squall is a sudden violent gust of wind or localized storm, especially one bringing rain, snow, or sleet.

Observed Atmospheric (Barometric) Pressure: the period of January to March 2020 for which the study carried out before the covid-19 pandemic, showed relatively, a minimum and maximum sea-level pressure (MSLP) range of 1000mbar and 1010mbar (shown in Figure 50)— thus, below the standard average sea-level pressure of 1013.325mbar (101.325kPa; 29.92 inches of mercury; 760.00mmHg per the International Standard Atmosphere (ISA). The GCNS (2009); Stewart (2008) noted that pressure distribution around the earth surface results from the heating sun (insolation) which varies with latitude.

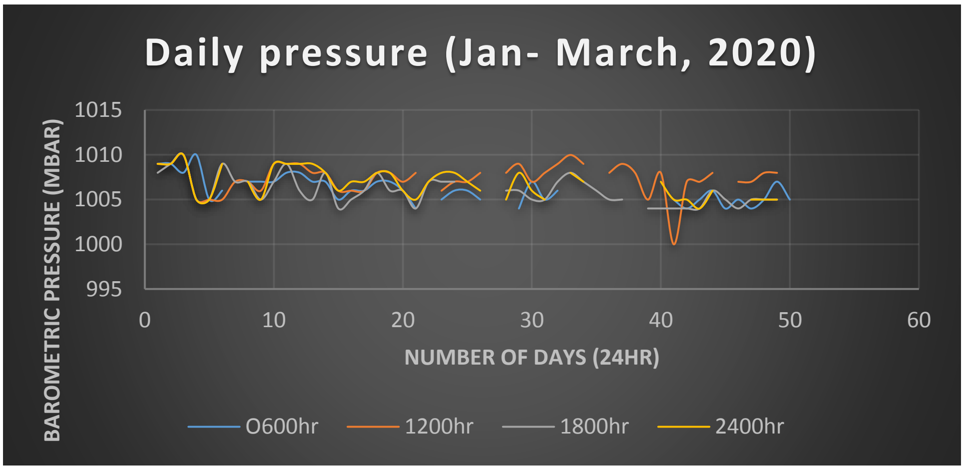


Figure 50: The 24hr Atmospheric Pressure

From the graph, the least sea-level pressure of 1000mbar recorded was by the noon hour (GMT) midday. Pressures recorded remained reasonably low –influencing atmospheric activities (such as cloud and winds resulting in the occasional rainfalls observed over the study period). The 6:00 am, 12:00 am and 12:00 pm periods recorded as high as 1010mbar of barometric pressure— with a Mean (average) at 1006.578947mbar. The region under study lies near the equatorial latitude, and hence, tends to benefit from the massive influx of sun's thermal insulation –resulting in surface heating. The area, therefore, lies within the 'Equatorial Low' (GCNS, 2009).

Observed Conditions of Visibility: in navigational terms, visibility means the extent to which an individual either on the navigational bridge or deck watch-keeping can maintain a visual lookout for an object over distances on ocean up to horizon form a marine vessel or platform. Richard B. P. Brown (Ed) and Nigel Brown (Ed), (2016) explains this as the "term used in describing the transparency of the atmosphere, and defined by the maximum distance at which a suitable object is seen." Conditions such as fog, sea smoke and massive rainstorm are a few atmospheric processes that contribute to reducing visibility during the day. Implicitly, the knowledge of the level of visibility on the ocean at any particular time is paramount in ensuring the safety of life, property and environment during navigation. Figure 51 below is a graph indicating visibility pattern over the study region for the study period.

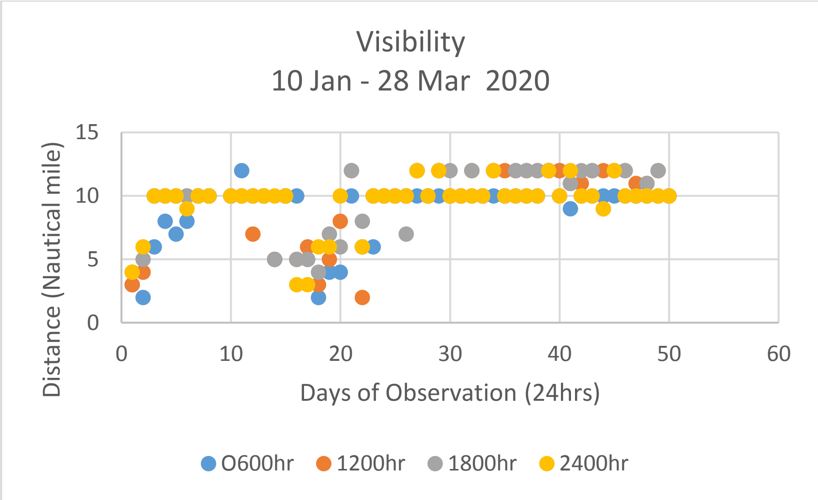


Figure 51: Observed Visibility over 24hr period

Though visibility recorded was relatively good (mostly) with a median of 10nm, the minimum visibility recorded over the period was under 2nm in January and February. The reduced visibility recorded can be attributed to both radiation and advection fog activity. The radiation fog influenced visibility of vessel at the Takoradi port location from the 10 through to the 12th (during the *P.O.* vessel mobilisation). Unlike the radiation fog formation occurring at the coast of Ghana, the remoteness of the condition's location over 60kilometers offshore, suggested an advection fog formation (Richard B. P. Brown (Ed) and Nigel Brown, 2016) –thus, consistent with the low visibility through the first and second weeks of February heading into March (marking the summer cold sea temperatures). This condition, therefore, put animals; surfacing on the water in the region, at risk of strikes from speeding marine vessels. Maximum visibility was as high as 12nm, though did vary over 10nm for the study period. The period under study also marked the upwelling season characterising the feeding behaviour of marine mammals in the area –suggesting the imminence of animal surfacing behaviour (thus detailed in Chapter 4 Section 4.2).

Atmospheric temperature: which is the measure of the degree of hotness or coldness of an object or place, was primarily crucial in this study in order to understand the level of thermal energy transfer occurring above the ocean surface within the study location. Stewart R. H. (2008) in fact, asserted that only a fifth of the solar energy released by the sun is absorbed directly into the atmosphere as either evaporation or infrared wave energy. Therefore, the temperature seen in Figure 52 is a recorded function of these two primary atmospheric energy delineating the atmospheric dynamics of the study region within the subtropical area.

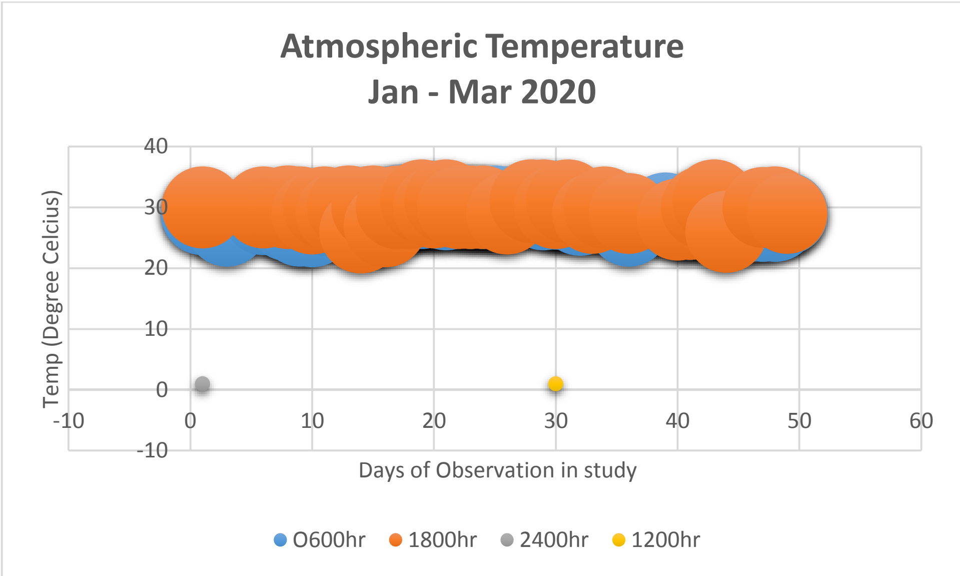
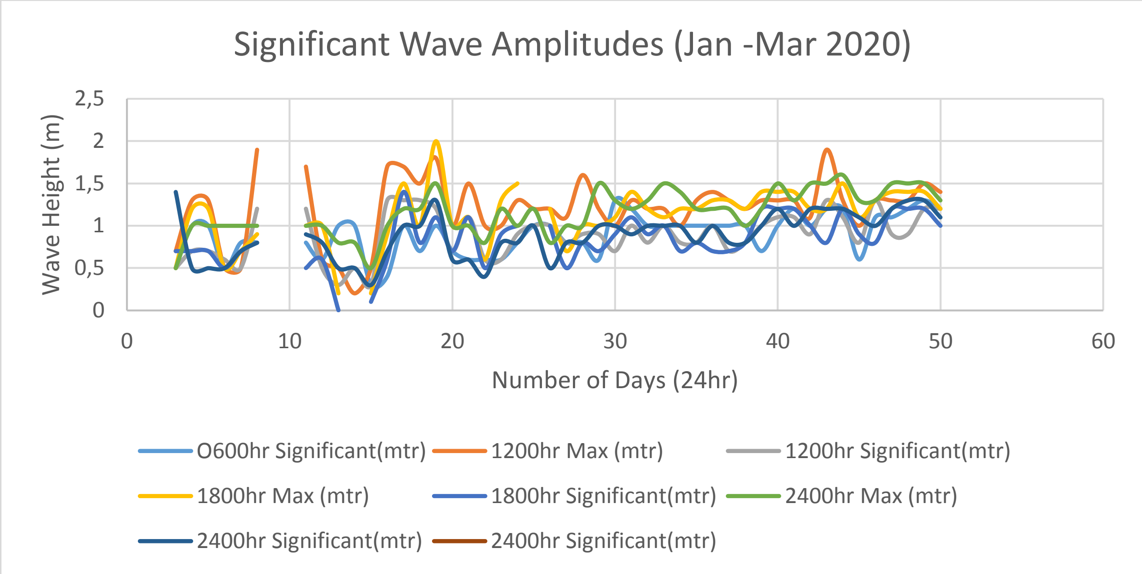


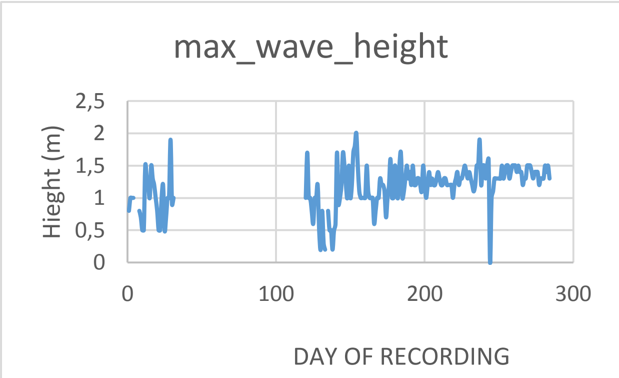
Figure 52: Atmospheric Temperature over 24hr period

From the graph, temperatures from 10th of January and 28th of March at 0600 am (hr) range between 27^0C and 30^0C with a Median 29^0C. Similarly, the 1200pm (hr), 1800pm (hr), and 0000am (hr) recorded minimum and maximum temperatures of 26^0C – 32^0C (a median of 30^0C); 26^0C – 31^0C (a median of 30^0C); and 28^0C – 30^0C (a median of 29.5^0C), respectively. These results are fairly consistent with subtropic temperatures readings –suggesting some levels of active humidity.

4.1.4.1.2 The Ocean Surface Conditions

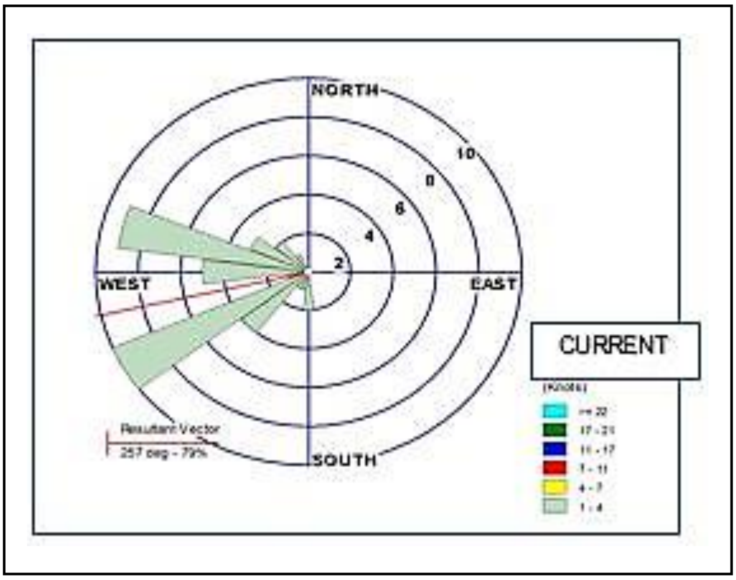
Observed Wave Activity: waves were driven by surface wind interactions – generating significant wave heights up to 1.4meters. Waves with a median of 0.9meters. These are in Figure 53 below.





The maximum recorded wave was over 2meters in height for January through to March 2020. These waves characterised were within the southwestern quadrant –same pattern as with winds. However, wave periods over time are subject to *dynamic instability* in which stable ocean waves become unstable due to velocity shear.

Observed Ocean Current: activities of ocean current observed was of both surface and water current conditions, primarily referred to as *Guinea Surface Current and Guinea Underwater Current*. The surface current measured was from the 0meter ocean depth at the surface to a depth of 40 meters. Figure 54 shows both the amplitude and direction of the water surface current. The direction of the surface current showed a powerful feature within the southwest and northwest quadrants. According to GCNS (2009), surface currents are mainly wind-driven (see also Figure 54) –a conduit of surface friction at a right angle due to the Coriolis Effect. He was thus explaining the current in the westerly direction. The patterns observed compared favourably with ERM/TGL (2009) findings as well as the depiction from GCNS (2009) global current map layout shown in Figure 55 is of concern. Again, Stewart (2008 pp51) notes that tropical ocean currents, particularly of the Atlantic, play a vital role in the unsteady transportation of thermal energy (solar energy stored in the ocean) from summer to winter during the amelioration of the earth's climate. This reason is also critical to understanding climate change.



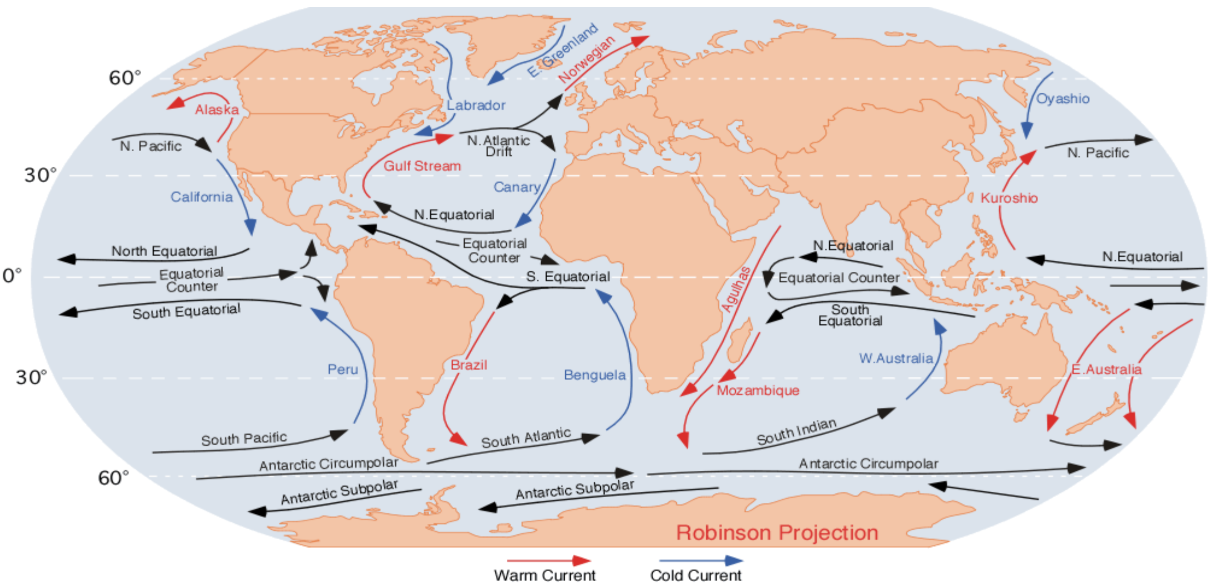


Figure 55: Surface Ocean Currents. Modelled image courtesy, GCNS (2009)

The dynamics between the current and waves observed in the earlier graphs was paramount to understanding ocean stability. Hitherto, Stewart (2008 pp129) stressed that because oceans appear strongly stratified with weaker currents, turbulent mixing remains intermittent and are rare. This situation generates a period of stable and unstable ocean surface from frequent wave formations and breaks.

4.1.4.2 The Ocean Makeup and Marine Ecosystem

The ocean is a natural supporter of various life forms –with capabilities to thrive in its unique environment. However, life support of most living mammal or organisms relies on fundamental environmental conditions that include Oxygen, lamination (Sunlight), water, favourable shelter and food sources. The ocean, unlike rivers and streams that are freshwater sources for animals within, living organism in the ocean, are forced to contend with a high concentration of salts. The study primarily examined the relationship of salinity concentration (psu), dissolved oxygen (D.O.) concentration (mg/L at 100% saturation level), Density (D) and temperature variations (synonymous to radiated heated energy from sunlight) over water depth as characteristic supportive of marine lifeforms in terms of feeding, habitat, and procreation.

4.1.4.2.1 Water Column and Hydrographical Data

While previous environmental baseline surveys (EBS) conducted in EIA over the region on the various oil fields and surrounding areas have determined to some level the baseline conditions of the environment. Thus on biological, chemical and physical importance before field developments, it also identifies ecosystem parameters sensitive to impending changes; thus, all as part of meeting environmental impact assessment requirement, the EBS sampling locations were selected by the oil field license operators in their EIA EBS. The scientists factored in; daily water column profiling, and seafloor sediment sampling (CSA International, Inc. /TGL, 2011).

The summary hydrographic results of the 2011 EBS on the DWT block by CSA International, Inc. /TGL, (2011) which is also within the field demarcation of this study, have been presented in detail alongside the findings of sample location selected in this study, to enable comparative analysis. The sample data accompany graphical analysis. The other samples were from the WCTP license block, Jubilee oil field area, which also forms part of the study location. The *EIA* EBS carried out was conducted by TDI-Brooks International aboard *R/V JW Powell* between 09th through to the 13th of September 2008. The study at this point does not make available previous tabular data on parameters for the DWT and WCTP used in EIA EBS sampling in this comparison analysis but does make available graphical data in this regard for reanalysis as presented in Figure 56. The two graphs of TEN-EBS Station-4 and Jub-EBS0003 attempts to illustrate the relationship between Salinity, temperature and oxygen of the sampled location. Juxtaposing the below graphs (Figure 56) of March 2011 and June 2008 site data recordings Figure 57, which are sample analysis graphically produced based on data gathered on-site study, the assertions in the proceeding paragraphs can be made. Therefore recordings of tabular data obtained at various station identified, earmarked and surveyed can be found in Appendix A for detailed inferences.

The graphs (in Figure 56), represent parameter data obtained at varying timelines, thus, EBS Station -4 on the 26th march 2011 and sample station EBS003 on the 12th of June 2008 – marking a three-year interval of data timelines. Both locations fell within a 1400 and 1500meter water depth zone. Temperatures observed varied between 24.8^0 C to 4.2^0 C (at Jub EBS 003) and 21.05^0 C to 4.15^0 C (EBS Station 4) respectively –and in both cases decreasing along with the water depth. Comparing CSA Int. Inc. / TGL (2011*)* results to results of this study per the sampled stations presented in Figures 57, a real sense and level of variations can be determined.

The Jubilee P1 Manifold location (Figure 57 on the right: data taking within February 2020) had maximum water depth range of 1235meters (with a median water-depth of *621.5*, and standard error *(S.E.) of 10.12011199*), from which various hydrographical data was as obtained. At a minimum of 8meter water depth, sea surface temperature (SST) was 29.99-degree Celsius (*S.E. = 0.147263907, and a median temp. of 6.31degree Celsius, Sample Variance =26.63121632*). A minimum temperature of 4.54-degree Celsius recorded was also at the maximum water depths of 1235meters. Salinity readings also did vary between a maximum and minimum of 35.27psu and 33.74psu (with a *Median = 34.42, S.E. = 0.007588667*), whereas max., and min., densities (D) are 33.2522 and 20.8852 kg/m^3 (with a *Standard Error = 0.071268403,* and a *Median = 29.75945*). Dissolved Oxygen (D.O.) estimated over the area showed a median value of 8.934279203mg/L (*S.E. = 0.01663382*) with Minimum of 6.267872443mg/L and Maximum of 9.169776741mg/L at a 100% saturation value under 1009.6mbar of atmospheric pressure. Similar patterns observed are of the Jubilee FPSO location (Figure 58) area with a 1002meter water-depth, a minimum temperature of 4.8-degrees Celsius and maximum of 30.2-degree Celsius. A 34.12psu and 35.39psu as well as 21.0411 and 31.9387 kg/m^3 are the minimum and maximum Salinity, and density values recorded respectively across the water depth— with estimated D.O. ranging between 6.240481615mg/L and 9.173744832mg/L of 100% saturation under 1005mbar of atmospheric pressure. Additionally, slight variations observed, are in Jubilee-field locations KP0.000 (in Figure 58: data taking in March 2020), and KP48.808 (in Figure 59: data taking in September 2020) over the study period. Again, profiling for chemical and physical parameters in the *EIA* survey by CSA International, Inc. /TGL, (2011), revealed in total that nitrogen and phosphorous were present in all samples though with minor differences among samples. Differences were also evident in chemical composition for samples collected at deeper depth compared to shallow areas. Thus, the sample from deeper depth (i.e., at 100m or near the bottom) regardless the sample stations, recorded <0.24 to 0.40 and 0.0335 to 0.0545 mg/L total nitrogen (N) and phosphorous (P) concentrations respectively compared to <0.15 to 0.22 and 0.0141 to 0.0161mg/L of N and P. Hence, there were no viable differences in chlorophyll and pheophytin concentrations compared to nutrients near the surface and at depth— a subject of productivity and organic mineralisation (CSA International, Inc. /TGL, 2011). The lack of difference according to CSA International, Inc. /TGL, (2011) suggest the near-surface water column as beset with the same water mass. Therefore, CSA International, Inc. /TGL, (2011) also stated that, given that the hydrographical parameters were consistent with measured water quality parameters from the various EBS, it was indicative of the general open ocean conditions underpinned by low levels of chlorophyll, suspended solids and nutrients in general. Comparatively, the rest of the selected stations for reanalyses are present in Figure 60, and Figure 61, which covers surveys conducted in 2008. The data also did concur with the findings of this study in terms of Salinity, DO, Temperature.

The Sound Velocity Gradients: for the sample locations in the 2020 Jubilee study, the researcher also found that the sound velocities showed similar patterns of graduation summarised in Table 11 and Table 12 with graphs presented in Appendix.

Table 11: Sound Velocities computed for three stations between February and March 2020.

Descriptive Statistics Terms	JUBILEE STATION IDENTIFICATION					
	P1 (10 Feb 2020)		B5 (15 Feb 2020)		B6 (15 Mar 2020)	
	Depth(m)	Velocity(m/s)	Depth(m)	Velocity(m/s)	Depth(m)	Velocity(m/s)
Mean	505	1507.677709	505	1495.922824	493	1495.33529
Standard Error	9.110434	0.343496926	9.110434	0.433606446	9	0.41149073
Median	505	1504.71	505	1490.7	493	1489.38
Mode	#N/A	1526.42	#N/A	1485.37	#N/A	1485.13
Standard Deviation	287.3761	10.83513671	287.3761	13.67751722	280.4479	12.8224105
Sample Variance	82585	117.4001875	82585	187.0744774	78651	164.41421
Kurtosis	-1.2	-0.368146391	-1.2	1.464434072	-1.2	1.52001305
Skewness	8.95E-19	0.805357118	8.95E-19	1.377590478	-6.2E-17	1.42319639
Range	994	39.77	994	61.23	970	58.36
Minimum	8	1494.97	8	1484.01	8	1484.84
Maximum	1002	1534.74	1002	1545.24	978	1543.2
Sum	502475	1500139.32	502475	1488443.21	478703	1451970.57
Count	995	995	995	995	971	971

Table 12: Sound Velocities computed for two stations in September 2020.

Descriptive Statistics Terms	JUBILEE STATION IDENTIFICATION			
	B2 (05 Sep 2020)		BX (22 Sep 2020)	
	Depth(m)	Velocity(m/s)	Depth(m)	Velocity(m/s)
Mean	377	1498.476762	360.5	1509.539088
Standard Error	7.46101	0.409135915	7.653975	0.264031256
Median	377	1495.25	360.5	1508.67
Mode	#N/A	1486.94	#N/A	1521.39
Standard Deviation	192.6906	10.56648452	202.7942	6.995582733
Sample Variance	37129.67	111.6505952	41125.5	48.93817777
Kurtosis	-1.2	-1.274934095	-1.2	-1.33726051
Skewness	-6E-17	0.490753374	-4.1E-17	0.168369103
Range	666	31.85	701	22.3
Minimum	44	1486.68	10	1499.09
Maximum	710	1518.53	711	1521.39
Sum	251459	999484	253071	1059696.44
Count	667	667	702	702

The study found the median sound velocity range of 1489.38 m/s and 1508.67m/s over varying water depths ranging from 8meters to 1002meter depth of the various sample locations. The findings are in agreement with previous data which categorises sound velocity at 1500m/s –allowing animals using sound to detect target prey (echolocation), achieved their goal with wavelength 4 or 5 times to length of target prey (Project Oceanography, 2000). It is also useful in animal navigations, feeding and breeding.

4.1.4.2.2 Habitat Found in the Region and Vulnerability Concerns

The nature of habitat observed was based on animal sightings that took place throughout the study. This period refers to the January to March 2020, and the September 2020 field observations. Other observations of species made include the periods of March 2017 to March 2018 on the offshore Sankofa Gye Nyame oil and gas field; and the September to November 2015 on the TEN oil and gas fields. Among some of the animals observed of interest include, sharks, Short-finned Pilot whales, Bottlenose Dolphins, Humpback Whales, Marine Turtle, and Mantra. (*See section 4.2 for details of marine animals study*). Bottom dwellers also observed included worms and pink coloured jellyfishes at locations as deep as 700meters on the Sankofa Gye Nyame field. Again, observation of offshore subsea construction operations over the period did appear to have risk implications in terms of sound (underwater noises), movement, night-time lightings, flaring and pollution. Table 13 here list some of the essential animals observed. Seabirds were a continuous presence through the period of September on feed hunting routs. Several sighting of Mantra seen in Figure 62 occurred at about a 100meter water depth.

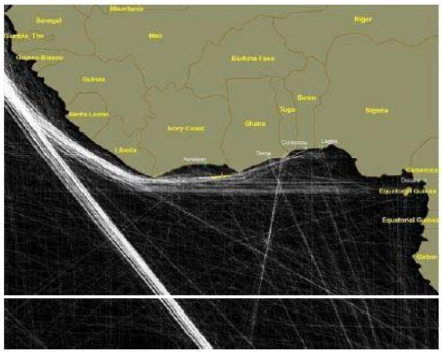
Table 13: Some Observed Animals

Month of Observation	Animals Sighted
January	Bottlenose Dolphins
January, February, March, September	Short-finned Pilot Whales
February	unidentified cetacean
September	Seagull
February, September	Mantra
March September	Marine Turtle
June, July, August	unidentified dolphins

February	Sharks
All months during the survey	Variety of Fishes

Source: field survey

Given that the area lies directly in the heart of the West African shipping lane as depicted in Figure 63 (http://www.nceas.ucsb.edu/GlobalMarine/impacts, 2009; ERM, 2009), there are real vulnerabilities if measures are not adequately designed to cater for the growing changes.



Refer to Chapter Five for the conclusion of this case study.

(*See Section 4.3 for the study on anthropogenic challenges*).

Chapter 4.2 An Assessment of the Marine Mammal Abundance and Population Density within the Ghanaian Offshore Construction Areas.

4.2.1 Introduction

Marine biodiversity is increasingly an important subject area to the marine scientists who perceive their sustenance as consequential to human existence. Inland, coastal and marine waters underlining the world's oceans, rivers and lakes, all serve to ensure biodiversity regardless of the increasing anthropogenic concerns. Understanding the nature of the biodiversity has remained the subject of research survey undertakings. The interest pool spanned species' behaviour, migration patterns, population size, trends, as well as their spatial and seasonal distributions across the ocean. The west coast of Africa is not exempted from the rising inquisition interest, according to Van Waerebeek et al. (2015). Tullow Ghana Limited (TGL, 2009) also suggested the mammalian ecological significance of Ghana's coast waters has only recent times gain prominence among scientist in a bid to explain the unknown history and lacking data on animal abundance and density estimates. For this study, marine mammals, particularly the small and large cetaceans and their habitation found within the Ghanaian water component of the Gulf of Guinea at remote offshore oil and gas location are the centres of focus. Rhetorically, how much is known and documented on Cetaceans in the Area? According to Valdés and Déniz- González, (2015), compared to the entire West African sub-region, there are modest levels of information concerning cetacean biodiversity in Northwest Africa (NWA), primarily derived from incidental stranding, sighting accounts and of much recent limited direct monitoring of stranding and by- catches (Hazevoet et al., 2010; Perrin and Van Waerebeek, 2012; Mullié et al., 2013). The assertion is also true for the entire coast of West Africa (Van Waerebeek (2014). Van Waerebeek (2014) asserted that, based on obtained data through vessel- based surveys— sponsored by Japan (Diallo et al., 2002, 2004), have provided distributional insights. Again, from several geophysical seismic surveys that remain buried in unpublished internal reports, among others, like the incomplete record in the CCLME region (Van Waerebeek (2014). These suggest that a simple observer effort from platforms- of- opportunity vessels significantly, contribute to the understanding of the marine mammal biodiversity; and their spatial and seasonal distribution in the Region (Valdés, and Déniz- González, 2015). Van

Waerebeek, Ofori-Danson, and Debrah (2009) proceeded to provide an inventory list of eighteen (18) cetaceans' specimens evident in Ghana. Undertakings of this nature are particularly important considering the current developmental changes being witnessed within the marine and coastal environment across the world at large. Getting to understand the general behaviour of these mammals peculiar to these areas will help in assessing the impact of the level of changes, thus if there are any behavioural changes in the marine animals, we can easily assess how much is attributable to, for example, vibration noise stressors. Di Iorio Lucia and Clark Christopher W. (2009) in their study' *Exposure to Seismic Survey Alters Blue Whale Acoustic Communication'*, illustrated for example that blue whales changed their calling behaviour in response to relatively low source-level sounds from the seismic survey, and thus calling more during periods without seismic noise. This study, therefore, will attempt to address the following questions directed at the issue. Questions such as; what cetacean species are identifiable to the region? What is the population estimate of these animals found within offshore construction fields at a point in time? Are they evenly distributed thus spatially and seasonally? What are some of the observed behaviours per their interaction with operations offshore? Are there any observed vulnerabilities in the region? What are these risks, and how are they be mitigated? Animal density estimations in West Africa is particularly now of essence in other to understand how these animals are lured into construction sites. Riding on the back of Platform-of-Opportunity (PO) vessels for direct sightings, the focus of this study was further narrowed to areas offshore within periods of massive subsea construction operation undertakings. Thus, offshore marine operations increasingly, have become a feature within the marine and coastal areas of the Gulf of Guinea, whereas Ghana's deep-sea oil and gas development is a recent development example in the Area. This region, found along the equator belt of the South Atlantic Ocean has therefore seen growth in not only traditional commercial shipping routes. It traffics in and out of the various national port facilities in West Africa, but also an expansion to newer offshore zones within the EEZ, new transit routes and rampant vessel traffics from offshore-to-port bases. This spike is in tandem with every new exploratory discovery undergoing development and production. Ghana's growing examples of activities from the Jubilee, TEN and Sankofa Gye Nyame fields after 2010, 2015 and 2017 respectively –helps interested parties envisage the potential spikes with every possible discovery in the region across nations with regards to; rise in traffic upon commencement of development towards oil production, future developments among subsequent discoveries, and further or redevelopment of producing fields. Suffice to add; it is essential to recognize that the coastline waters stretching from shore into deeper waters, thus above the continental shelf down the continental slope towards the ocean floor is home to the many unique marine species including the cetaceans. This areas of their dwelling have become the subject of a geological query in an economic bid for hydrocarbon resources. To this effect, surrounding marine environments and living resources within, have had to bear the brand of the destructive changes to their ecological dwellings, migration patterns, food-chain, and social interactions. With limited data forming the level of knowledge about the living mammals in the Area, little to nothing done is fully to protect the endangered species among them. The study when concluded significantly will provide a deeper understanding to the cetacean population and distribution by developing animal estimation within Ghana's offshore construction sites in the time frame of field development while emphasizing the effects of these operations on behaviours of marine mammals and habitats. Therefore, this study seeking to provide useful information and a better understanding of marine mammal population offshore construction fields in West Africa will help in conservation efforts, develop the economic relationship between environmental sustenance and potential destruction, and serve as a supplement to the much-needed literature on the subject matter. In other words, answers to these questions will fill the gap of knowledge relevant to seeking a perfect balance in offshore operations, ecosystem sustenance and the conservation of marine mammal life forms.

4.2.2 Materials and Method

4.2.2.1 Study Area

The study is centrally focusing on offshore deep-water enclaves of Ghana as in Figure 64. It provides a typical outlook into the much recent continuous changes within the marine environment forming part of the habitable zone of marine mammals, thus particularly of the cetacean family. Ghana, as a growing oil and gas producing country, does boast of several proven identified oil reservoir blocks. These mostly are found in the western sedimentary basin off her west coast. The west coast commences from the east maritime boundary of Ivory Coast and stretches more than halfway (Sackey and Lamptey, (2019)) –

again, from her east maritime boundary with Togo. This water resource, as one of the single most important natural asset found within the maritime boundaries of Ghana, is not peculiar to her alone, as

neighbouring countries also within the Gulf of Guinea, have made similar significant discoveries. This discoveries fundamentally goes to suggest the gulf of guinea, as one characterized by a general unique oceanographic, geographical, geological and atmospheric conditions— one which cuts across the region's nation-states bounded to her north regardless of national borders. They also went ahead to list; the guinea surface and underwater currents, the zones of coastal upwelling and presence of warmth (with high-pressure gradient), and the low levels of salinity in waters as some of the common oceanographic phenomena. Sackey and Lamptey (2019) proceeded to establish that offshore construction operation carefully is orchestrated with these unique conditions in mind. The conditions may also very well inform the behaviour and interactions of living mammals found in the region*)*. The study conducted was on the Jubilee, Tweeneboa Enyenra Ntomme and Sankofa Gye Nyame fields, respectively. *(For further readings on the offshore environment, refer to Chapter 4.1*).

However, the particular focus had was on the Jubilee field.

4.2.2.2 Methodology

The study sites which encapsulate current oil and gas production fields in Ghana's offshore industry examined were during the time frame of field redevelopment, thus before first oil and gas offtakes, and at periods of field maintenance, and again, where further or redevelopments projects eminently were pursued. This time frames expected were to show high levels of anthropogenic activities via marine vessel operations, which underlines the growing changes exerted in the marine environment and the mammal habitation by external forces.

As described in chapter one of this same study, the study is explorative and combined qualitative and quantitative data gathering and analysis techniques. It aims at describing the marine mammal population phenomenon on construction fields thus, insofar as simulating the consequence of the marine and subsea operations towards a modelled response within Ghana's waters and the Gulf of Guinea at large, was of concern., thus with the later discussed into detail in proceeding chapters.

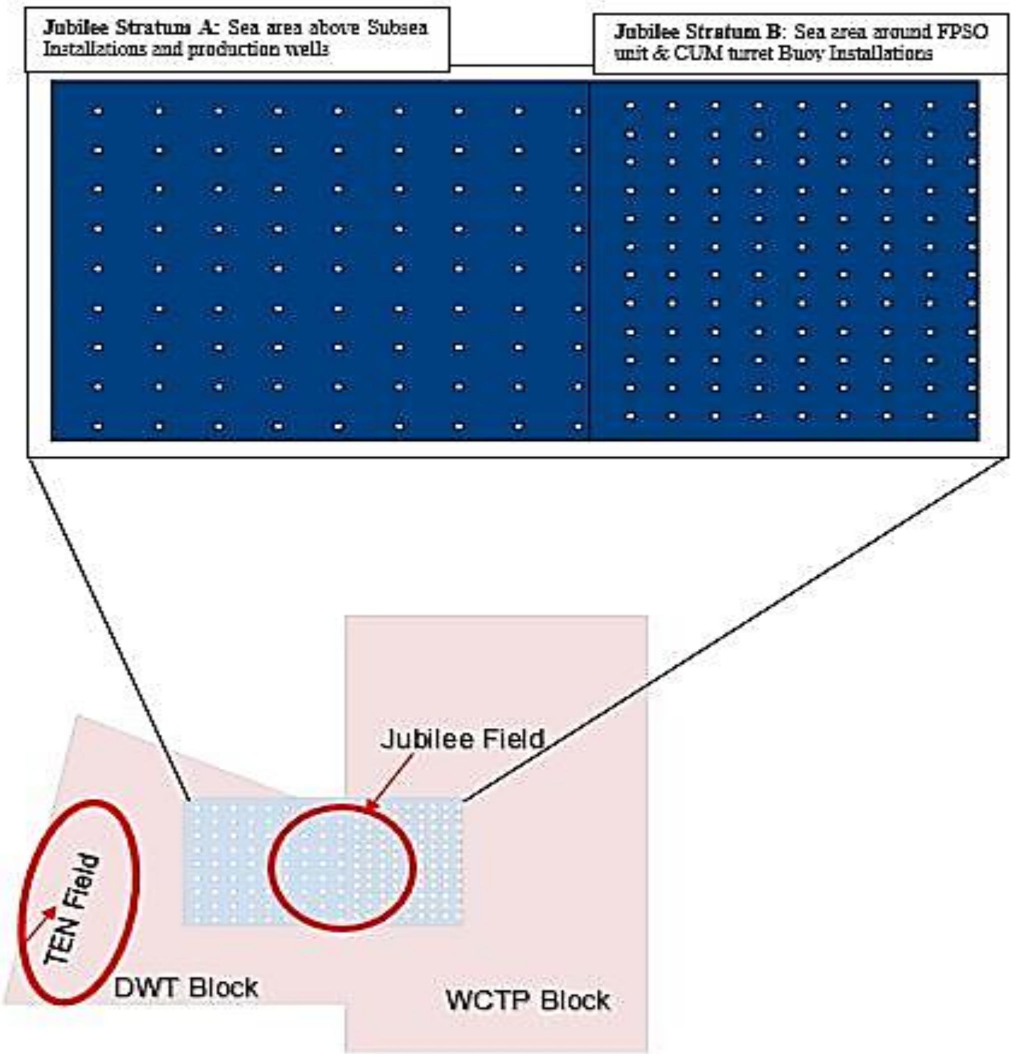
4.2.3 Data Sources and Analysis

4.2.3.1 Survey Design

The areas shown in Figure 64, were examined following the ecological distance sampling methods used in population studies. Given that, activities on offshore construction fields are periodic over limited sea scope and achieved mainly with vessel virtually in stationary positions, thus under dynamic positioning operation. Ultimately, it accounts for longer hours of a vessel restricted in ability to manoeuvre, and relatively the dead-slow speed of vessels. This phenomenon is particularly important in the survey design choices for the population estimates within the construction site. Therefore, under the distance method, a point transect design technique for sampling survey was employed during animal sightings –focused on the time frame of subsea construction works to which encounters of these mammals are of concern to operations. The Jubilee study site under observation captured in Figure 64 is subsequently stratified into Jubilee Strat-A and Jubilee Strat-B for easy sampling. The JubStrat-A area referred to sea areas surrounding Jubilee subsea oil and gas wells, risers, flowline and subsea manifolds tied to FPSO, while JubStrat-B referred to sea areas surrounding CUM Moor Buoy located 1nauticalmile away from FPSO unit. See Figure 59, for details. The stratification, therefore, made use of the boundary coordinates between the DWT and WCTP blocks. The approach depicted in Figure 64, 65 and 66, relied on the principle that animal observed had a random pattern, according to Krebs (2017). Due to limited resources and accessibility, the Researcher, the mammal sightings for population estimation focused on the Jubilee field, between January and March, and also September of the year 2020.

The survey areas demarcated are by the boundary strip covering a total area of 521.089 square kilometres. The individual stratum showed in Figure 65 and 66, catered for outliers and the census zone

–thus hosting the simple sets of random points generated for the study with the aid of Distance Software version 7.3.



This encounter was paramount to understanding the perceived changes influencing the mammal behaviour in the Area over time. The Point Transect sampling technique was a systematic design and in agreement with the determined PO vessel position, which was less random. Thus as described by Buckland et al. (2001) and Buckland et al. (2004: 2006) for sampling, these animals who naturally expected are to occur randomly showing a surfacing behaviour (Matt Villano, 2007) in the study area in the data gathering process.

The systemic sampler points to the study area were to be achieved at random via the dynamic manoeuvres at dead slow speed and positioning of the Platform-of-Opportunity (PO) vessel (shown in Figure 67) on a predetermined location at any particular point in time during subsea construction

operations. Thus, we assumed that all position achieved by the *PO* vessel was strictly at sampler locations, and this included those recorded vessel positions slightly away from sampler points. The time spent at each point was averagely $1^1/_2$ hour period— suitable for the Point Transect Distance method deployed.

4.2.3.2 Field Methods

The one hundred twenty sampler points developed for animal sighting locations had a 500meter imaginary radius –equivalent to the 500-meter zone UNCLOS 82 (article 60) requirement around installations. In this case, it was an extension from the *PO* vessel centreline, (thus for Seven Borealis under restricted manoeuvrability during observations). The two stratum estimates animal observer efforts at 45 and 55 per cent respectively; thus cumulating into a total sampler of 120 within a grid area coverage of approximately 1km x 1km (see Figure 65). On the field, the data gathering process made

use primarily of direct (naked) 'eye' sightings of the animals and only resorted to the handheld marine 10x50 T Carl Zeiss Binocular (Fig. 68) with a suitable focal range beyond 3.3ft found on the bridge. It helped in identifying the specie and features of the animal. Distance estimations were by 'eye' per Taylor's (2014) SWFSC marine mammal research ship cruises. Three volunteer observers offered to undertake partial observation to aid the Researcher, though not much emphasis placed was on their effort. Due to the *PO* vessel's share size, multiple deck layers beside the main deck and the uneven distribution of high rising deck machinery (such as the 5000metric tonnes crane and J-lay tower) creating blind spots, observers were placed at vintage locations at any given time across the decks. The bridge wings another of observer locations also stood at a height approximately about 46meters above sea level allowing for a projected view all-round the vessel except in blind spot areas at the stern and starboard side-amidships. Sightings were taking only during the day time between the hours of 0600gmt and 1800gmt accounting for 720 minutes per day and 5,040 minutes per week depending on the entire duration on study sight.

The observations took into account, the number of animals occurring in clusters or singularly. Also were animal species identification and behaviour. Computational data such as range estimates (taking as the radial distances) and bearing were of animals from the vessel. Other data recorded include weather, time, vessel heading and nature of operations. Primarily, the latter part of data, such as weather records, vessel heading, and position, were obtained from vessel bridge records. Again, qualitative data obtained was also through series of interviews with experienced subsea construction personnel aboard (See Table 14), and of the critical marine scientists at the shore, one from the University of Ghana and doubles as resource fellow for the EPA of Ghana on marine science issues (See Table 15).

Table 14: Onboard Resource Persons interviewed

(1) 7 Borealis Chief Engineer	(5) 7 Adaba Chief Engineer
(2) Subsea Surveyor of 7B	(6) Project Shift Supervisor
(3) Project Deck Foreman & ADFs of 7B	(7) 7 Borealis Vessel Captain

(4) Project Engineers of 7B	(8) 7 Adaba Electro/Technical Officer (ETO)

Table 15: Shore-based Resource Persons Interviewed

(5) Marine Scientist & HOD Marine Science Department, University of Ghana
(6) Assist. Marine Scientist, Ghana Wildlife Society of
(7) Communications Officer, Ghana Wildlife Society

4.2.4 Data Modelling & Analysis

Data analysis achieved was in three stages with the use of various statistics and geostatistical tool, that is (1) Geographical data obtained were put through Geospatial analysis and projected to provide visualization of outcomes. The tools utilized in this exercise included ArcGIS 10.8 Software; (2) Statistical estimation of population densities evolved from the use of point transect distance methods via Distance Software version 7.3 on quantitative data gathered, and thus, driving assumptions and nature test to perform in the analysis. Other supporting tools in this regard are Microsoft excel, R and python statistical environments; and finally (3) the use of comparative arguments was optimized to evaluate qualitative data supporting the observed, consequences. The conventional distance sampling method used is in the analysis process of the population density estimation – favoured by Fewster and Buckland (2004); S. T. Buckland, C. S. Oedekoven, and D. L. Borchers (2015). They asserted that conventional distance sampling usually adopted hybrid approaches, thus for detection process –by using model-based methods and relying on design-based methods in estimating animal abundance of the study region, whereas estimated probabilities of detection.

Population Density and Abundance Estimations: The objective of the modelled-based conventional distance sampling deployed was to estimate mean animal density in the Jubilee strata study area based on a survey conducted of animal sightings along with a set of sampler points, distributed in a stratified layer based on a typical systematic random sample design (Buckland et al., 2016). Essentially, certain assumptions were made before data gathering and during the analysis in regards to sightings, which were of two parts— mainly designed-based thus; (a) Offshore subsea construction works were taking place in fixed locations with floating platforms affixed to the ocean floor at those locations at all times during encounters which occurred randomly. (b) Animals sighted invading these construction sites were residence/ inhabitance of those areas at all time and were not moving. These animals were also uniformly distributed across the fields. (c) All observations over the period could not have taken place more than once at any random point. Parameter estimations in this regard cover various extrapolation including; Encounter rate in individual stratum and of the global Region, Detection probability modelled by stratum (and global region), Expected cluster size by stratum (and global region), Density and Abundance by stratum (and global region).

Given that several approaches to modelling population abundance estimations proposed over the years are with greater accuracy, this study uses the model described by Borchers et al.'s (2002). The ***binomial model*** examines the number of animals' *n*, detected out of a population of *N* size. It is subsequently multiplied with resulting point transect likelihood, arising from the detection function based on *Conventional Distance Sampling (CDS)* survey model.

In summary, the analysis was slightly based mainly on the below theories of estimations concepts by the University of St Andrews, Centre for Research into Ecological and Environmental Modelling (2018); Borchers and Burnham (2004); and Buckland et al. (2016), who assumed animal cluster detections were luring as in point transect sightings.

<table>
<tr>
<td>Abundance Estimator:
Generally, animal abundance given is by the expression; $\widehat{N} = \frac{nA}{2wLP_a}$
where ; $\widehat{N}$ is population estimate, n is the number of observations, A is the study area,</td>
<td>Density Estimator:
The expression gives animal abundance; $\widehat{D} = \frac{n}{2wLP_a}$
where; $\widehat{D}$ is the density estimate, w is the point transect width or radius
Note: the rest of the terms defined are in subsequent paragraphs.</td>
</tr>
</table>

Model Selection Criterion: parameter estimates for data examined on individual stratum under the selection of CDS analysis model, was dependent on the likelihood assessment of the critical functions used in delimiting the estimated parameter. Another model fitness test also performed was to evaluate how well it performed on the data. This test included Chi-sq GOF test. Plot charts, such as plot probability density (Pdf) function also used was to evaluate the point transect data- thus by superimposing a density curve over radial distances measured. Qq-plot was another graphical evaluation used in checking model fitness. Notwithstanding, the model selection, in general, was achieved using the likelihood assessment statistical estimator described below. The likelihood assessment was essential to understanding the probabilities of observing animals over certain distances.

Given that likelihood is denote by $L_{n,y}$ and expressed as the product of two likelihoods, i.e.,

$\boldsymbol{L_n}$ = likelihood of obtaining sample size n,

$\boldsymbol{L_y}$ = likelihood of detections in distances y.

Then according to Borchers and Burnham (2004), these can be expressed separately as in equation. (1) and (3);

$$L_y = \prod_{i=1}^{n} f_y(yi) = \prod_{i=1}^{n} \frac{g(yi)\pi_y(yi)}{P_a}$$

eqn (1)Thus given us the likelihood of any animal detection at any distance

Where $\boldsymbol{f_y(y)}$ is the probability density function of distance y,

The function $\boldsymbol{g(y)}$ is the probability that an animal at a distance y from the point is detected,

Whereas $\boldsymbol{\pi_y (y)}$**:** refers to the distribution distances of animals from the point. Thus irrespective of detection or not.

$\boldsymbol{P_a}$ is the probability that an animal on the plot is detected, unconditional on its distance y. Therefore;

For the sample size model, the natural model used is the binomial distribution likelihood for animals, given as:

$$L_n = \binom{N}{n} (\gamma_c P_a)^n (1 - \gamma_c P_a)^{N-n} \qquad eqn\ (3)$$

Where *N:* is the number of animals in the study region and

$\boldsymbol{\gamma_c}$ is the Probability of an animal within the study region found is on one of the surveyed plots.

Therefore, the overall likelihood formulation as a covariate is thus given by Borchers et al. (2002) as;

$$L_{n,y} = L_n \times L_y$$

$$= \binom{N}{n} (\gamma_c P_a)^n (1 - \gamma_c P_a)^{N-n} \times \prod_{i=1}^{n} \frac{g(yi)\pi_y(yi)}{P_a}$$

$$L_{n,y} = \binom{N}{n} (\gamma_c)^n (1 - \gamma_c P_a)^{N-n} \prod_{i=1}^{n} g(yi)\pi_y(yi)$$

eqn (4)

Determining the Probability of detection $\boldsymbol{P_a}$ is also given as in Eqn (2);

$$P_a = \int_0^w g(y)\pi_y(y)dy \qquad eqn\ (2)$$

Thus, a normalizing constant in Eqn (1) –ensuring $f_y(y)$ remain a valid probability density function. Again, since the plots are randomly placed systematically, $\pi_y(y) = 2y/(w^2)$.

A *Hazard Rate* key function, therefore, was deployed in determining the model fitness to empirical distribution function. The *Hazard Rate* key function given is:

$$k(y) = 1 - Exp\ (-y/A(1))^\wedge - A(2)) \text{ -------- Eqn (5)}$$

However, convergence was not achieved with 14 functional evaluations, having Final Ln (likelihood) value = -274.70964, Akaike information criterion, AIC = 553.41931 and Bayesian information criterion = 556.84644. Therefore an adjustment with a simple polynomial order of 4, 6 and 8 was implemented in three separate models— all achieving a convergence with 10 (*Final Ln value = -258.34734, AIC= 522.69470*), 174 (*Final Ln value = -250.27944, AIC= 508.55887)* and 35 (*Final Ln value = -227.78479, AIC= 465*.56958) functional evaluations respectively.

The Likelihood ratio test performed selected the final model with a likelihood ratio test value of 44.9893 based on minimum AIC value. The same Likelihood assessment conducted in stratum B with Hazard Rate key function (Eqn. (5)), showed a result of convergence in the first model on 44 functional evaluations with a Final Ln (likelihood) value = -314.73040 and AIC value of 633.46082. a second model assessment performed with a simple polynomial adjustment of the order of 4 also achieved convergence with 12 functional evaluations –producing a Final Ln(likelihood) value = -314.69515 and an AIC of 635.39032. Subsequently, a likelihood ratio test conducted between the two models resulted in a test value of 0.0705. Therefore, model one selected was over two for minimal AIC value. These models implemented were into obtaining the various parameter estimates such as h (0), *Pa (or p)* and *EDR.*

4.2.4.1 CDS Model Goodness of Fit Test to Be Performed

Three individual tests determined as appropriate and run on the model, upon which two main tests carried out, was on the detection function probability distribution in each survey area. A Kolmogorov-Smirnov (*K-S test*) test performed in stratum A and B. The upper tail probability, *p-value* = 0.4385 in relation to n = 41 observation, from sighting efforts. The test yielded a cumulative Dn = 0.1356. The test indicated a convergence correlation between the cumulative distribution function (cdf with ascending index $i=1$, n, $F(x)$) and empirical distribution function (edf, $S(x)$) smaller difference – showing the goodness of fit. The same test performed on stratum B with n= 56 observation given an upper tail probability, p-value = 0.6375, a Dn value of 0.0994— suggesting a strong positive correlation between cdf and edf functions. According to Gibbons (1971, pp81; Distance 7.3 User Guide (2020)), this test performed is suitably accurate in practical applications with sample sizes greater or equal to 35. The second test performed was the Cramer-von Mises (Cv-M) family tests that focused on the sum of squared differences between *cdf* and *edf*. A Cramer-von Mises test with uniform weighting function also carried out examined the goodness of fit of the probability detection function values evaluated through the relationships;

$$Q = n\int_{-\infty}^{\infty} [F(x) - S(x)]^2 \varphi(x) dF(x)$$

Where φ is a weighting function allowing for the weighting of different parts of the distribution.

In given all observations the same weight, a standard Cv-M obtained statistically as;

$$W^2 = \frac{1}{12n} + \sum_{i=1}^{n} [\hat{F}(x_i) - \frac{i - 0.5}{n}]$$

The tail probabilities of W^2, always relies on sample size (5 – 1000) of α-levels ($\alpha_1 < p < \alpha_h$). If simulated bases on the equation, it obtains sets of critical values on the sample size, for W^2, where $\alpha_{1 \text{ and }} \alpha_h$ are the bounding critical values

Again Cramer-von Mises test with cosine weighting function though similar to the above test is performed for observations with distances closer to zero (0 distances). In this case, the weighting function utilized is;

$$cos\ cos\ (\pi\ x_i/2w)\ ,$$

Where $x_i$the radial is the distance of observation, and w is the given truncation distance.

$$C^2 = \frac{-16n}{\pi^3} + \frac{2}{\pi}\sum_{i-1}^{n} \left[\left(2\hat{F}(x_i) - \frac{2i-1}{n}\right) sin\left(\frac{\pi}{2}\hat{F}(x)\right) + \frac{4}{\pi} cos\left(\frac{\pi}{2}\hat{F}(x_i)\right)\right]$$

note: tail probability calculated and presented the same as W^2

This test is, as discussed by Buckland et al. (2004)[26].

In summary, the data obtained herewith modelled using Distance Software version 7.3, primarily relying on Buckland et al. (1993, 2001) CDS methods. Probability of detection function was modelled as a function of observed radial distances from sampler points while making use of robust, semi-parametric methods, in randomizing the outcome, where there were repeat counts at specific locations, the temporal correlation initiated by using random-effects (Oedekovenet al. 2013, 2014).

4.2.5 Results and Discussions

4.2.5.1 Preamble

The results presented in this section are categorized in two forms, mainly, (a) the qualitative findings which form the base knowledge driving the study with questions and queries, (b) the quantitative findings used in the estimations and predictions, and finally, (c) qualitative findings addressing issues on estimations and findings per regulations and procedures. Due to the number of parameters and the considerable size of data gathered, the results, are discussed simultaneously with analysis with expectations that such build-up of knowledge may birth ideas useful to profitable conclusions (Sackey and Lamptey, 2019). Details of results are in preceding paragraphs.

The study generally took into account time spent onboard Platform-of-Opportunity vessels within the year 2015 on the TEN field, the year 2017 to 2018 while on the Sankofa as well as Jubilee field, and the year 2020 –back on the Jubilee field in growing understanding of the offshore marine mammal

[26]Further reading on the model employed, S. T. Buckland (B), C. S. Oedekoven and D. L. Borchers Centre for Research into Ecological and Environmental Modelling, The Observatory, Buchanan Gardens, University of St Andrews, St Andrews KY16 9LZ, Scotland, UK (E-mail: steve@st-andrews.ac.uk), (2015). This article is with open access at Springerlink.com. Journal of Agricultural, Biological, and Environmental Statistics, Volume 21, Number 1, Pages 58–75. DOI: 10.1007/s13253-015-0220-7.

habitations beyond the west coast of Ghana. However, when developing the population density estimates and abundance, the study specifically focused on Jubilee Strata, over the last three-month (January- March) time spent by Researcher onboard two marine vessels, namely; MPSV Seven Borealis (central observer platform) and AHST Seven Adaba, in a bid to identify and populate marine mammal interactions during the entire duration of the construction project undertaking by Subsea 7 Engineering UK ltd., on behalf of Tullow Ghana Plc and partners. The following are a representation of outcomes.

4.2.5.2 Survey Effort Estimates

As mentioned in earlier paragraphs, the CDS statistical modelling technique implemented, determined the population density and abundance estimation based on fundamental parametric values on data obtained between January and March 2020 over 73 days on the study, Jubilee offshore strata area within the Greater jubilee enclave of Deep Water Tano and West Cape3 Point oil blocks. The Jubilee strata further divided into the Jubilee Strat-A & Strat-B saw a slightly varied survey effort respectively per design, with the latter as high as 55 per cent (out of 100%) effort rate. Survey efforts spread over a 118 out of 120 systematically designed sampler locations visited between January and March 2020. The design percentage effort rate did not account for coverage areas; instead, areas of much direct active subsea installation operations compared to the relatively low activity area. The Jubilee Substratum-A: represented sea areas of 308.765 sq. kilometres above and surrounding oil and gas wells and subsea installation locations, while the Jubilee Substratum-B: represented sea areas of 212.324 sq. kilometres beneath and surrounding surface installations of the FPSO KNK and the newly installed CUM Turret buoy mooring station (as shown in Figure 65 and Table 16).

Table 16: Total Area covered and surveyed on effort per daytime sightings on the Jubilee strata area

Study Region *(Jubilee oil field)*	**Total coverage Area in Sq.km**	**Days on Survey**	**Survey effort per daytime in**		**Total Area covered on effort in Sq.km**
			Km	**Hr./min**	
Substratum A	308.765	32	24.00	348/23,040	25.971 (2.5078)
Substratum B	212.324	41	35.00	492/29,520	37.329 (5.0042)

Total of Plot-A:					
Jubilee Strata	521.089	73	59.00	876/52,560	56.88 (7.5120)

The biasness in the design skewed towards Jubilee substratum B was essential if we were to develop an understanding of installation operations as one of the luring factors influencing encounter rates, or otherwise. Hence, from Table 16, a total coverage area of 56.88sq. Km (representing 10.92 per cent out of 521.089 sq. km) received direct survey efforts per observations made within an *EDR* area to a total of 7.1235sq. Kilometres. Importantly, understanding the marine environment of the Area of observations made is herewith essential identifying the peculiarities of the habitat hosting the animals of interest and is as discussed in the proceeding paragraphs.

4.2.5.3 The Nature of the Marine Environment on Construction Field

The offshore marine environments of the sub-Sahara Africa regions within the Gulf of Guinea, located along the nearest proximities of the Greenwich Meridian— thus, east and west above the equator at latitude 4 degree heading west and slightly below equator belt to the far-east of West Africa with oil-producing countries like Nigeria, Cameroon. The Jubilee offshore enclave found within the West Cape 3 Point block, straddles the Deep Water Tano oil block, and forms part of the broader Atlantic Ocean environment howbeit, found within the western corridors of the Gulf of Guinea along the southern coast boundaries of West African nations. The entire region beset with both surface and underwater Guinea currents (Sackey and Lamptey, 2019; Roy, 1995; Binet and Marchal, 1993) that vary in direction and speed depending on the seasonal parametric conditions delimiting these variations. The condition, therefore, naturally created the favourable seasonal upwelling fostering the sustenance of marine mammals and the varying fish stock in the Gulf of Guinea region (TGL, 2009). The Jubilee strata of ocean environment as alluded to in Section 4.1 of this very study, is inherent of tropical nature with average *Sea Surface Temperatures (SST)* ranging from 29.97-degree Celcius (^{0}C) average at about 8 meters water depths dropping steadily, declining to an average of 16.76-degree Celcius (^{0} C) at 100 meters water depths. The declining pattern observed, is in terms of *Salinity* concentrations at same depths, thus with a 33.84 average at 8 meters depth and 35.11 at 100 meters water depths for lat. 4.5550

Northing and long. 2.9378 Easting location, for instance with a total water depth of 1,235 meters. *Atmospheric Pressure* of the Region ranges on the averages between 1000 and 1010hpa (mbar). Water densities are also at an average of 1.0209 at the surface and rising steadily at water depths. This ocean environment briefly described above, generally forms the marine mammal habitation for the offshore biodiversity along the west coast of Ghana. (*Refer to Chapter 4.1 for further reading*).

4.2.5.4 The Identified Marine Mammals within the region

In developing the understanding of the various marine mammal species (particularly, of the cetacean species) identifiable within the region, a review of the limited literature on the topic, was the sort of forming the basis of field inquiries and interviews. Generally, the biodiversity of the West African and Macaronesia ocean environments do boost of over one-third of the world's known species on small cetaceans regardless of the unknown conservation status of these animals in contrast to other areas around the world (UNEP Convention on Migratory Species, 2008). UNEP CMS (2008), Van Waerebeek et al., (2009) asserted the validation of identifiably 18 different cetacean species (17 odontocetes, and one mysticete) found in west Africa subtropic fauna (UNEP CMS section C 10, 2001; Notwithstanding this known fact, only 11, are listed). This identified mammals included; Atlantic (Van Waerebeek et al. 2004; Djiba et al., 2015) humpback dolphin (*Souza Tuezii*), Long-beaked Common Dolphin (*Delphinus Capensis*), Harbour Porpoises. The *PO* vessel departed the port of Takoradi on the 10th of January and arrived at the Jubilee oil field under 12 hours travelling at an average speed of 4.8kn. Direct field observations aboard *PO* vessels revealed the well-known fact of the various observable individual marine mammal species within the region. Species identifications were incredibly challenging for species sighted surfacing once at farther distances and in some cases of those sightings generally made at greater distances beyond 350meters away from the observer. Such subsequently, were classified as 'unidentified cetaceans'. Relatively, captured videos and pictures of some of these animals that were nearer were subsequently shared with the study's resource persons to confirm these species. Animals were identified based on the various unique features associated with the body form, colour, behaviours and markings where necessary based on internationally acceptable guidelines among other such as that documented by Boucher and Boaz, for the National Marine Laboratory (NML), Northwest & Alaska Fisheries Center (NAFC), National Marine Fisheries Service (NMFS), the NOAA, and AMMPA standardized information: Bottlenose Dolphin. Professor Ofori Danso is well equipped in this regard and aided the process. The following is Table 17, showing the list of both identified and unidentified but suspected cetaceans howbeit among other animal species recorded over the survey period.

Table 17: Observed species of cetaceans in the Marine mammal survey on Jubilee Construction Field

Period of Observation (in months)	**Length of Tracking (in Days)**	**Identified Cetacean Species, (spp.)**	**Remarks base on Suspicion or Possible Specie identity**
Jan	1	Bottlenose Dolphin (*Tursiops truncatus*)	Identified & unconfirmed
Jan-June-July-Aug	1	Unidentified Dolphin	Suspected Atlantic Humpback Dolphin (*Sousa Teuzii*), unconfirmed
Jan-Feb-Mar	59	Short-fin Pilot Whales (*Globicephala macrorhynchus*)	Identified and confirmed
Feb	2	Shark	Unknown species
Mar, Sept	3	Sea Turtle	
Mar, Sept	6	Mantra	Identified & Observed subsea via ROV

These observed species of animals in the table of the list goes to suggest that the Area under study affirms the assertion by UNEP CMS (2008) of the vibrant biodiversity inherent in the offshore ocean environment of the Gulf of Guinea. The sightings of the study also confirmed the presence of three main cetacean species of the order ***Odontocetes*** (i.e., Short-fin pilot whales- shown in Figure 69, Bottlenose Dolphins and Atlantic humpback dolphins. TGL (2009) aware of animal presence generally, reiterated that monitoring of landings over a few years had demonstrated the presence of 17 different species of dolphins and small whales in the entire region. Whereas the first identified, is confirmed, Researcher identified the second but unconfirmed by the Resource Persons.

Figure 69: Image short-fin pilot whales captured within the Jubilee oil production field

The latter was unidentified and is only a suspected species per the observed behaviour). The inability to confirm the latter two species was because direct imaging was not possible due to distances sustained between animal and Researcher on *PO vessel.* Agreeably, though the adjacent field in DWT block designated in this study (thus the TEN field) could not be studied for mammal estimation. According to TGL (2014), in the *EIA* report, sightings of ten different species of marine animals were recorded with a majority 43 per cent consisting of dolphins. TGL also asserted that the most commonly identified species was the short-finned pilot whales, which is in agreement with the study's findings. TGL, however, recommended that a dedicated survey by experienced marine scientist to carried out subsequently to present the accurate estimation of marine mammals and turtle species of the Area. The other study site thus of the Sankofa Gye Nyame fields did not cover animal estimation at this time, however, had no information on marine mammals within the field per the EIA report (Eni S.p.A. Exploration & Production Division ESHIA, 2017). To better understand the extent of the biodiversity, a population density and abundance estimation subsequently, is carried out on both identified and unidentified cetacean species within the Jubilee field. These detailed results are, as shown in the following paragraphs.

4.2.5.4 Population Density and Abundance Estimations

The survey efforts on the entire jubilee strata were biased towards Jubilee Substratum B which was seeing the direct offshore installation operations compared to the adjacent substratum A, thus having 45% search effort committed to Jubilee Substratum-A and a 55% effort rate to Jubilee substratum-B.

This effort did account for the various encounter rates observed during the survey even though some survey locations were visited more than twice.

(a) Animal Encounter Rates and Probability Estimates

Estimation of animal encounter rate was particularly critical in determining the animal abundance and cluster sizes since the animals encountered were mostly in groups spread over undetermined distances per every survey location, (sampler points, k = 118 out 120 designed samplers). Table 18 below presents the details of the encounter rate estimates per survey efforts.

Table 18: Encounter Rates within Substratums of the Jubilee Oil Field Study Area

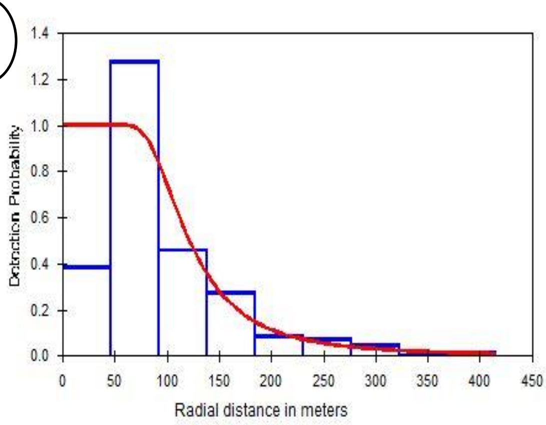
Stratum Name	Survey parameters	Estimated Value	%CV	df	@ 95% Confidence Interval	
Substratum A	n	41.000				
	k	48.000				
	K	24000.				
	n/K	0.17083E-02	6.96	47.00	0.14853E-02	0.19649E-02
	Left	0.0000				
	Width	415.00				
Substratum B	n	56.000				
	k	70.000				
	K	35000.				
	n/K	0.16000E-02	6.02	69.00	0.14191E-02	0.18039E-02
	Left	0.0000				
	Width	415.00				

In total, 97.000 animals (n) encounters were of cetaceans belonging to the order *Odonteces* (thus predominantly of *Globicephala macrorhynchus spp.*) over the period for the offshore shipboard survey area. This findings, correlated Leatherwood and Reeves' (1983); (2008) findings; suggesting *Globicephala macrorhynchus* were widely distributed across the world's ocean within tropical waters to warm temperate waters. 56 animal encounters out the total sum observations, were made within the Jubilee Substratum-B coverage area at 35 survey point locations— projecting an encounter rate (n/K)

of 0.16000E-02 (*CV = 0.0602 certainty*). Subsequently, an encounter rate of 0.17083E-02 determined, regards, n = 41 animals encountered within Jubilee Substratum-A at 24 (out of 48) sampler location. In summary, the rates of the encounter on both strata were fairly even regardless of the uneven distribution of survey efforts— and thus suggesting a slight variance in animals' detection probability, p estimates.

E

F



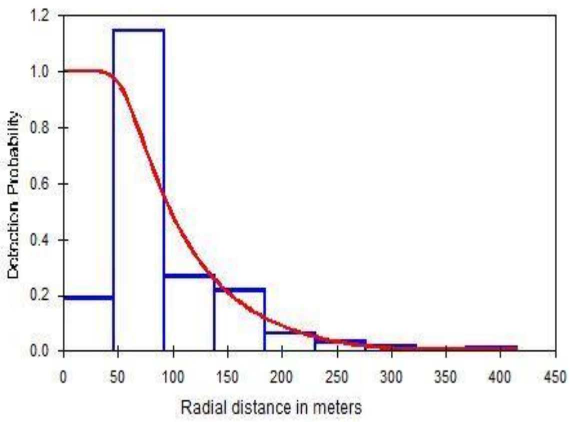


Figure 70: Depicts statistical graphs of; (E) Area sustained between the probability function three superimposed on the histogram of radial distances measured for Jubilee Substratum A; (F) Area sustained between the probability function three superimposed on the histogram of radial distances measured for Jubilee Substratum B

For substratum-A, the Probability of detection, p was estimated at 0.96564E-01 (while relying on as high as five parameters, (m = 5) to improve fitness with minimal high variance) — projecting high levels of detectability ranging over a 95% confidence interval of 0.33116E-01 to 0.28157, based on Akaike information criterion (*AIC = 465.57*) value (See Fig. 70). This value demonstrates that more animals are in areas under Effective Detection Radius distances (where *EDR* = 128.96 meters, 95% *C.I* of 73.403meter < *EDR* < 226.57meter), upon encounter on survey effort while also suggesting that more were less likely to be detected at longer *EDR* distances on a 95% confidence interval. The *p-value had a high CV = 0.5666* indicating reduced certainty in detectability of animals in the Area.

In Jubilee substratum-B (with an estimate of *p* = 0.13213), a probability of detection, *p* derived based on three-parameter (*m* = 2) was selected for model fitness (shape criterion and robustness), which is a relative sense had an *AIC* value of 633.46, suggesting minimal variance and biasedness compared to stratum A, hence, the less *CV* value (*CV = 0.*2096). Given a 95% confidence interval of *p* at 0.87182E-01 and 0.20025, animal detectability upon encounter under areas of Effective Detection Radius, (*EDR* = 150.36 meter) was relatively high at farther *EDR* distance not exceeding 186.02 meters. In other words, observed detectability rate *p* of 0.13213 for example, short-fin pilot whales sighted within the study subregion stratum-B were more likely to be detected along farther *EDR* distances approaching between 122.33meters and 186.02 meters to a 95% confidence interval compared to, *p* of 0.96564E-01 approaching distances of 73.403 meters and 226.57 meters within Jubilee Substratum A study locations. Conclusively, the above-discussed conditions give a 95% confidence level in the data obtained for animal detectability except for the slight uncertainty shown in Jubilee substratum-A study area. This observation is with no regards to any other unquantifiable factors of uncertainties introduced, during survey effort reshaping outcomes. The animal detection conditions are an influence on the density and abundance estimates derived on the survey data. These density estimates are in proceeding paragraphs.

(a) Density and Abundance

Given that, the total animal population of the entire Gulf of Guinea, in general, remains unknown, and that is to suggest that among the identified cetacean *spp.,* across the study area remain unknown. Again, according to the expert respondent, Prof Ofori-Danso, he suggested, lack of interest and high cost involved over the years, as being the predicate delimiting the common scientific queries. Prof Ofori-Danso and a colleague in 2017, on a World Bank-funded marine mammal survey, buttressed this assertion in a brief discussion with the Researcher while onboard *LCV Polar Onyx Bergen* within offshore OCTP Ghana –explaining the limitations and suggesting a national consciousness and effort is required to help in this effort. It is in light of this present challenge that the final population estimates from the study on the Jubilee oil field construction area presented are in Table 19. The model estimates design to cater for animals occurring singularly and in clusters to delimit population abundance or densities. An average cluster size of 17.950 (*with hazard rate adjustment estimate as 19.712, and 95% C.I of 15.537 and 25.009*) determined for animals observed within Jubilee substratum A (*CV= 0.1002*) with a 95% confidence interval range along 14.666 and 21.970. Jubilee substratum B, however, had the shared animal cluster size observation of 8.9643 (*CV= 0.1198*) over a 95% confidence interval ranging between 7.0575 and 11.386 animal cluster sizes. These cluster sizes are depicted in the regression plots shown in Figure 71 and Figure 72 for each stratum, respectively.

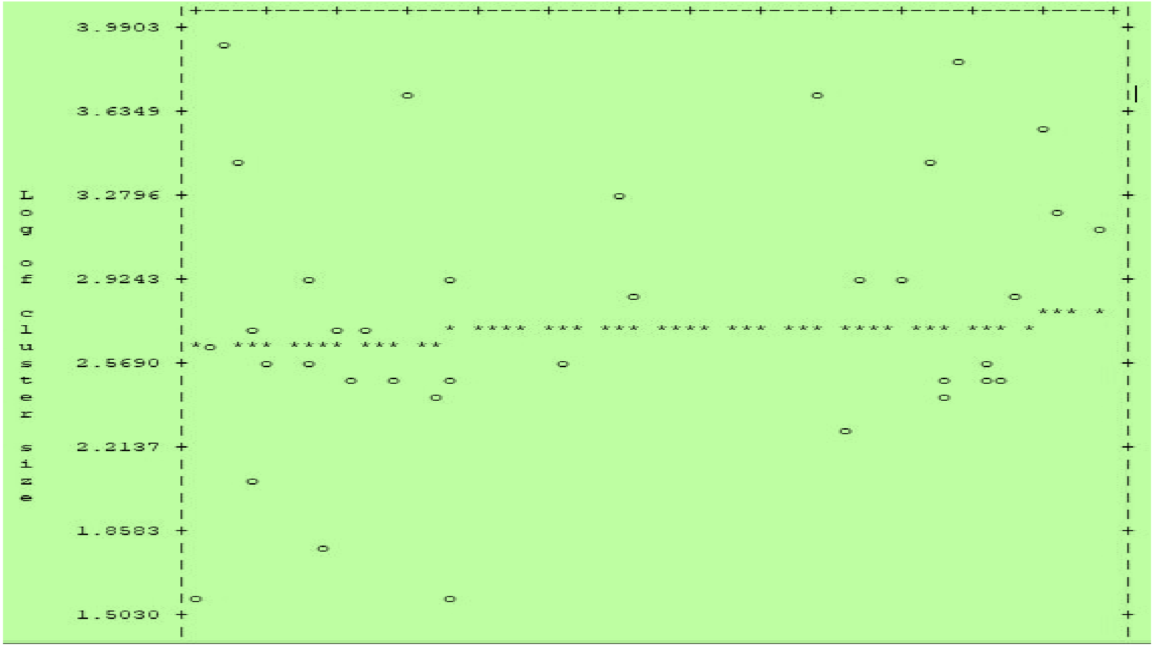


Figure 71: Regression Plot Chart depicting cluster size distribution within Jubilee substratum-A

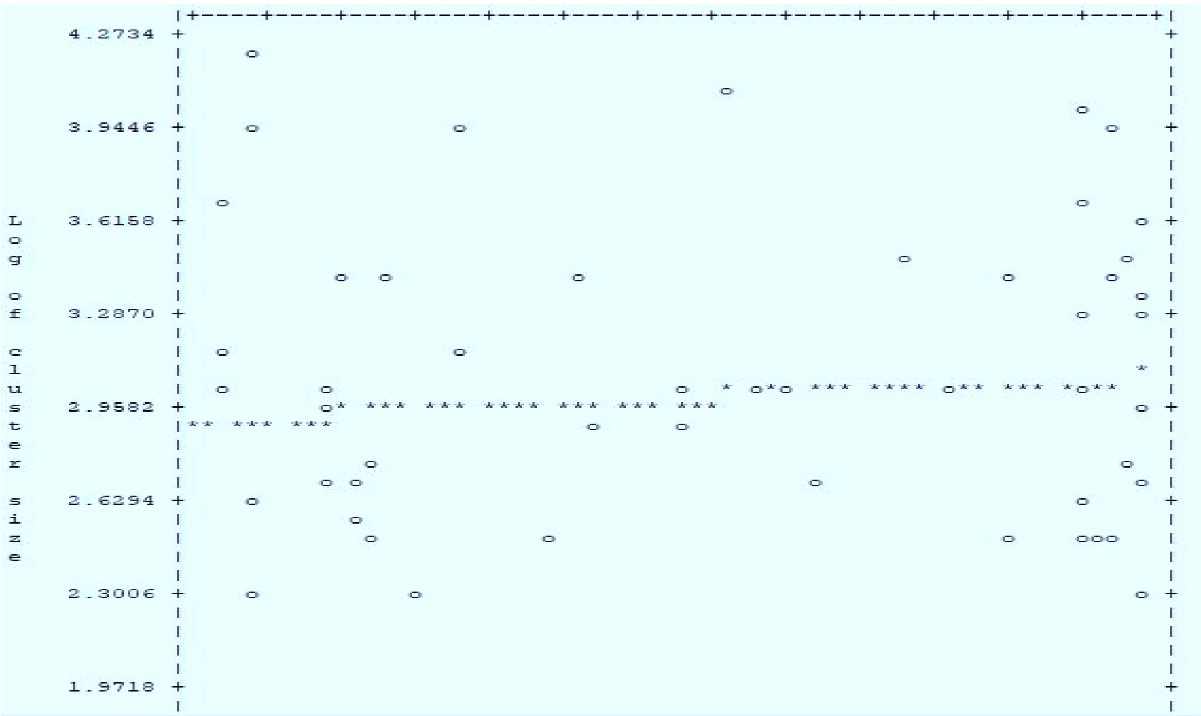


Figure 72: Regression Chart depicting cluster size distribution within Jubilee substratum-B

Table 19: Density and Abundance estimates within Jubilee offshore oil construction strata

Stratum Name	Density & Abundance parameters	Estimated Value	%CV	df	@ 95% Confidence Interval	
Substratum: A	DS	0.16349E-01	57.09	37.09	0.55737E-02	0.47954E-01
	D	0.32226	58.30	40.25	0.10803	0.96132
	N	100.00	58.30	40.25	33.000	297.00
Substratum: B	DS	0.11190E-01	21.81	62.94	0.72734E-02	0.17216E-01
	D	0.28601	23.52	82.51	0.18029	0.45374
	N	61.000	23.52	82.51	38.000	96.000
Entire offshore Jubilee Strata study area	DS	0.14247E-01	39.44	39.50	0.66044E-02	0.30733E-01
	D	0.30749	37.28	45.20	0.14870	0.63586
	N	160.00	37.28	45.20	77.000	331.00

From the table above, one observes that for animals occurring in clusters, their observed mean population cluster per sea area coverage was 0.14247E-01 cluster size per sq. kilometres. However, the overall animal density estimated for the 104 (*CV= 0.3728*) population of animals observed was 0.30749 (*CV= 0.3728*) animal per sq. km. In concluding, this estimate goes to suggest that animal abundance within the offshore construction sites averaged at 33.67 per cent, which is slightly above one-third of the mean population observed. This data overall is not a comprehensive estimate on the entire offshore constructions fields in Ghana and Researcher herewith recommend further studies in this regard.

4.2.5.5 Understanding the Spatial Pattern Concerns of Animal Distribution

In developing an understanding of the spatial distribution of the animals studied in the region, concerns focused on both temporal and seasonal distributions. However, due to the coronavirus outbreak becoming a global pandemic in mid-march, 2020, construction projects0 on the jubilee field was subsequently halted and suspended to a later date. Therefore, this phase of the study could not proceed further on the limited data per time required to understand the seasonal patterns. Research, therefore, has planned further studies in the nearest future to provide a global understanding of the spatial patterns.

4.2.5.6 Observed Animal Interactive Behaviour with Operations

Animals were observed for established associated behaviours well documented. However, the focus was had on curious intrusive interactive behaviour on the field as this had a direct impact on the life-threatening risk they may face during operations. Two observed scenarios illustrate this behaviour demonstrated in the field. These states as follows;

(a) The animal approach of installations or vessels: animals showed a sense of curiosity though it remains unclear to what level their movement towards installations or vessels influenced by the abnormally occurring in their natural habitable zones. Operations naturally were without the radiated noises, structural and machinery movements through water columns, general navigation and effect of nighttime lighting. This behaviour suggests some level of intrusive behaviour in the animals that is worth investigating within offshore construction sites.

(b) Animal cycling of installations or vessels: again animals were observed cycling platforms before continuing in their path. This observed behaviour was not peculiar to single individuals of animals observe but the animal in small cluster sizes of individuals. The phenomenon observed suggest a curious behaviour on the part of the animals that need to be studied in other to understand how animals interact with a changing habitation.

In concluding, it is unclear, however, as to whether the behavioural actions observed amounted to animals' pursuit of feed source, a natural intrusive behaviour or just out of curious expeditions. One or two or all may apply to these animals and therefore, the need for further studies.

4.2.5.7 Predictable Vulnerabilities and Possible Mitigations

There were apparent vulnerabilities observed, especially when animals out intrusive curiosity came very close to platforms and vessels in the field, thus according to subsea construction personnel interviewed. As to whether such concerns have ended fatal to animals, they were confident it rarely happens in the industry, and most were yet to encounter such incidence in their offshore work experience. In an unrelated incident, two respondent, however, recounted an incidence where they observed several in meters water-depth from ROV cameras, a shark hitting on the subsea ROV. To them, this was frightening yet an intriguing sight captured by Subsea Seven 7 Borealis ROV and survey team. As to what might have contributed to this situation, ROV lights, among other reasons lie noise of thrusters appears to have drawn-out this behaviour. With this said, they affirmed by an extension the vulnerability of the observed animals and suggested operations naturally took every necessary caution to mitigate such threat posed to endangered mammals. They identified general navigation, DP manoeuvring, subsea machinery and infrastructural movement, pollution especially of plastic, and oil spillage as a possible life-threatening risk when in the oil field. They, however, believe plastic debris was relatively dangerous due to the time it took to decompose if ingested. Hence, poly plants used in operations among other pollutant are disposed on under strict environmental management policy by subsea seven engineering limited. In effect, there were nine actively operating vessels engaged in the field, which is a multiplying factor of the level of dangerous under various aggregation. These are in Table 20. These were vessels with unique capabilities and strength in terms of engine horsepower, machinery and tonnages.

Table 20: List of vessels and installations sighted and the risk they posed

Vessel/ Installation Name	Vessel Type	Nature of Operations and Risks
Seven Borealis Nassau	Heavylift and Pipelay vessel	Subsea construction works such as pipeline production and heavy lift installations *–risking (Noise, collision during Navigation/ DP manoeuvring, Subsea Machinery and structure movement)*
AHTS Skandi Skansen	Anchor Handling and piling vessel	Subsea installations work such as installation anchors by piling –risking *(Noise, collision during Navigation/ DP manoeuvring, Subsea Machinery and structure movement)*
AHTS Seven Adaba	Offshore Support vessel	We are providing tow, security, bunkering and logistical support. –risking *(Noise, collision during Navigation/ DP manoeuvring, Subsea Machinery and structure movement, and pollution)*
Pacific Purpose	offshore support & rescue vessel	Providing towing support for the offtake shuttle tankers –risking *(Noise, collision during Navigation/ DP manoeuvring, Subsea Machinery and structure movement, and pollution)*
Maersk Voyager	MODU	Engaged in drilling operations

		–risking *(Noise, collision during Navigation/ DP manoeuvring, Subsea Machinery movement, and pollution)*
FPSO Kwame Nkrumah (KNK)	FPSO	Serves as oil production and storage platform –risking *(Noise and Pollution)*
OSV Bear	OSV	Providing tow, security, and logistical support –risking *(Noise, collision during Navigation/ DP manoeuvring, and pollution)*
MV Zodiac	support tug	Providing security and rescue logistical support –risking *(Noise, collision during navigation, and pollution)*
Lancelot	Accomodation barge	Providing floating hotel accommodation and logistical support —risking *(Noise, collision during Navigation/ DP manoeuvring, Subsea Machinery and structure movement, and pollution)*
CUM Turret Buoy	Not under command installation	Serves as turret offloading mooring unit for loading tankers –risking *(Noise and Pollution)*

**Refer to section 4.3 for further reading*

As listed in the table, and observed on the field, these vessels by operation posed life-threatening concerns for these animals. Discussion of these threats are in Sections 4.3, and 4.4 Chapter 4.0 as case studies of anthropogenic stressors to marine life on the construction field. There were also other concerns referred to by the consulting scientists. About addressing the lack of state-sponsored mammal monitoring and surveillance, they decried the situation and asserted that there is a need for urgent attention in addressing the situation. They believe this situation did not demonstrate a commitment to mammal conservation. Hitherto, they referred to a rise in dolphin harvesting as a growing challenge amongst local artisanal fisher folks, which needed redress by the state. It is unclear if these are generally incidental by-catch or deliberate dolphin harvesting. Currently, scientist relies mostly on local informants within the fishing communities for information as a result of the limited resources allocated to monitoring. Through this approach, a non-governmental body, thus Ghana wildlife society recently obtained a video of a harvested common bottlenose dolphin (*Tursiops truncatus*) onboard a local fishing boat (LFB) being mishandled by the crew at one of the landing beaches along Ghana's western coast. Image of incidence is in Figure 73. Though this image is not directly related to the study, the presence of this LFBs is a frequent future within offshore operational sites in the EEZ (Sackey and Lamptey, 2019) and their actions influence mammals within the region. In a rare moment while on the Sankofa Gye Nyame oil field the year 2017, the Researcher was occasioned to have observed an unidentified whale (i.e. animal length approx.. 8 and 12 meters precisely the size of most of the LFBs with outboard motors) tracking the movement of an LFB on its course within proximity of roughly 20 -30 meters. Intriguingly, at every turn of the LFB as it navigated the field, the whale followed making the same turn. Perhaps, this interpreted as the whale had mistaken the fishing boat for a fellow whale or animal of interest. The situation concern also does project the vulnerability of the animals in light of both large and small marine vessels operated. On the issue of sponsored surveillance, Professor Ofori-Danso commended the World Bank Group for making regular mammal monitoring on the Sankofa Gye Nyame oil field a prioritized requirement in the financial arrangement with the offshore operator, ENI and partners. This arrangement though was to ensure the oil-producing company fully met the initial Ghana EPA *EIA* requirement on mammal species survey prior the development; this at least ensures continuous regular monitoring of the animals throughout the life span of the oil-producing field. The issue of regular monitoring is, however, not the case for the Jubilee oil field which had been in operation since 2010.

Again, on the concerns of vulnerability, Prof Ofori-Danson and others have made extensive calls for the creation of a marine sanctuary zone. They believe it will help limit encroachment on the mammal habitation while providing a haven for their survival, procreation and feeding. Refer to Chapter Five for conclusions and recommendations.

Figure 73: Image captured Dolphin on LFBs in Ghana’s waters courtesy Wildlife Society of Ghana (2020)

Chapter 4.3 Offshore Marine Habitation in Ghana: A case study of Impact of Subsea Installations, ROV, Crane and Vessels Movements.

4.3.1 Introduction

All across the world, there are countless efforts placed on engineering systems (Knight and Westwood, 2004). The marine offshore oil and gas upstream sector is classically a masterpiece of engineering undertakings within the harshest environment of nature. It includes those also set within remote offshore hydrocarbon locations to assist in meeting the ever-growing energy demand –stack at 80 per cent per IEA report [Oseghale Lucas Okohue (2015)]— while highlighting its importance to energy stability of the world. Thus, an idea that set forth wellheads and production equipment directly on the seabed and only allows hydrocarbon flow out into a processing receptacle either placed on land or at sea afloat (Oseghale Lucas Okohue, 2015). This development, as can be seen, today, comes at a substantial financial cost, and also in terms of the skilled workforce (or competency training) and the technological capabilities. Furthermore, thus, hydrocarbon fields within the exclusive economic zones (EEZs) have merged with the habitations of marine wildlife. Consequentially, the situation is altering the standards of life of these living mammals whose territories are encroached. With the latest subsea production system engineering, high-value assets ships have become ever more sophisticated and daring in operational design platforms— treading subsea developments. For any new field, the subsea development will include; *Subsea completed well(s), Seabed wellhead(s), Subsea production tree, Subsea tie-in to flowline system, Subsea equipment (i.e. jumpers, spool, PLEM, PLAT, among others.) installations.* It is easy to dismiss these concerns of anthropogenic developments on the back of arguments –suggesting the ocean space (making up roughly 70 per cent of earth surface) are as vast enough (International YOTO, 1998; US NOAA, 2020) to accommodate every marine animal within. Furthermore, because total offshore developments across the world will still account for very little use of ocean space, such developments yielding unintended consequences no doubt alter the lives of these animals in many different ways unimaginable. Concerns of Consequential disturbance being the direct physical impact *ship lethal strikes* of marine animals studied by Calambokidis J. et al. (2019), Nichol M. L., et al. (2017) and Redfern J. V., et al. (2013) –are just few mention challenges. Félix and Van

Waerebeek, (2005); Van Waerebeek et al., (2007) made the same assertion concerning the growing traffic in the West Africa subregion. Subsea structures incidentally influence benthos and demersal fish relative to habitat loss or the disruption to defined areas of the seabed. TGL (2009) estimated the distracted area out of the 1,090,000m^2 Jubilee unit area on the field to be approximately 23,096 m^2 – representing 2% of transformed seabed. There is also concerns with under-reporting (or no records) where such incidences are believed to have occurred. William et al. (2011), Rockwood et al., (2017) and Calambokidis J., et al. (2019), suggested these incidences largely are underreported or go undocumented, and therefore, accurate statistics may certainly be higher. Daily ship operation is noted to induce surface and underwater noises which include radiated noise from thrust vibration, engine and machinery operations (Redfern et al., 2013). Another noise source identified is from direct survey operations undertaking with seismic sounding (operational) noises) (ONR NOAA, 2019). Apparently, "being able to produce and detect sound is critically important to many marine species, so changes to the natural ambient soundscape may have effects on ecosystem health than previously thought," thus according to US NOAA Fisheries Biologist, Jason Gedamke (2019). Again, the heavy reliance on saturated nighttime lighting for nocturnal operations during offshore developments is a growing challenge for coastal marine organisms (Davies et al. 2019). This situation concerns the colonising effect of light within a nocturnal ecology (Davies et al., 2015). Another of the most critical concern raised is the issue of pollution which today have taken many various forms within the ocean water body and adjoining atmosphere. Dr Marcus Erikson in visualising the state of plastic pollution using the given rough estimate of 5.25 trillion pieces, explained that it could compare to Two-liter plastic bottles stacked together end-to-end forming a column to the moon and back twice as reported by ourworld.unu.edu. These plastics have become a mistaken source of feed for many marine animals (ourworld.unu.edu, 2014). Other pollution contenders of primary interest to this study are oil spillages from operational discharges or potential blowouts and emissions (including black carbon) from marine vessels operating within offshore sites. Lamptey and Sackey, (2017), affirmed in their study that oil spillages from operational discharges, in general, are a constant feature in Ghana's maritime waters though are in less significant quantities. However, little thus far is known of the relationship between the unintended consequential disturbances and the current state of marine mammal conservation in Ghana and the entire west coast of Africa. Today in Ghana and across the entire West African sub-region, marine mammal carcasses are regularly spotted within coastal communities (JoyNews Report, 2015; Korateng Kwabena, 2017). Nevertheless, not much known about the cause of these deaths amidst the growing offshore developments. Henceforth, specific questions like; are these pollutants identified in offshore operation in Ghana? What are the most common and what form do they take? What potential risks do they pose to marine organisms and environment? What specific operations contribute to them in offshore Ghana? How much of a combined effect do these pollutants have on mammals and changing climate? How are these currently managed? Are these recommended for continuous monitoring in the Environmental Impact Assessment (EIA)? What regulations are in force? How are regulations and policies protecting mammals in this regard?

Hitherto, the study will attempt to examine the risks of physical collisions and traumas associated with growing traffics resulting from offshore operations in Ghana, and also of the risks subtended of the vertical movement through water columns by ship machinery and subsea structures during construction operations. The study will also proceed to explore the issues of ship radiated noises and night-time lighting concerning subsea construction operations. The study will finally conclude examining the nature and levels of pollution and seek to provide the best framework in advancing a co-effort led operations for animal conservation amidst economic development. A successful outcome of the targeted objectives should help design operations with a model response implementable in Ghana's waters and the Gulf of Guinea at large, capable of ensuring coexistence of marine animals and operational safety. The significance of this undertaking is because currently there has been no independent studies over this concerns within the offshore environment of Ghana, which is seeing a rapid rise in upstream activities due to recent exploration licensing rounds and discoveries. The upstream activity surge has become a common denominator of the entire West African coast. This rising activity implies challenges faced in the upstream sector will be binomial across nation-states bound to the Gulf of Guinea; hence, knowledge generated in this section of the study will serve this common interest. It will also provide the needed insight into the subject for academia and researcher alike while helping resolve the concerns of marine mammal death on the rise in Ghana and West Africa as a whole. The case study, therefore, does assert that answers to queries will fill the gap of knowledge-seeking a balance in the conservation of biodiversity and offshore developments for marine life forms and human activity within the Gulf of Guinea bay.

4.3.2 Materials and Method

4.3.2.1 Study Area

The study site covers the entire active hydrocarbon production sites of the Jubilee, the Twenneboa Enyenra Ntomme (TEN), and the OCTP-Sankofa Gye Nyame oil and gas field in the western basin reservoir blocks of Ghana's marine waters at Cape Three Point described in earlier sections of this study (see Figure 46 of Section 4.1 and Figure 64 of Section 4.2).

4.3.2.2 Methodology

The study covered various field developments, maintenance and production stages beyond exploration operations. The first leg of the field study covered three months spent onboard Seven Borealis on the Tullow TEN field in the last quarter of 2015. The second was on the ENI Sankofa Gye Nyame field over a year-long within 2017 and 2018. The third phase of site attendance was on the Tullow Jubilee field during the last quarter of 2018, and the first and third quarter of the year 2020. These engagements involved the boarding of several Platform-of-Opportunity vessels *(PO)* involved with the various phases of construction operations (see Figure 39). Seven PO vessels including two unmanned platforms (thus FPSO unit and CUM Mooring Turret Buoy unit) were embarked on during the offshore field construction operation study. The study takes into account the time spent by researcher onboard the various marine vessels during the entire duration of the construction project by Subsea 7 UK ltd on the various fields on behalf of the operators. The study was explorative, combining qualitative and quantitative gathering and analysis techniques for the respective data. Where observations were of concern, relatively good access was given to a researcher in that regard. Visual observation for spills, emissions, strikes, and the effect night-time light usage was a continuous process throughout the study. Witnessing the nature of operations nearby was also critical in the assessment.

4.3.3 Data Sources and Analysis

4.3.3.1 Field Methods

Data obtained was by the field survey and also from remote sensing equipment deployed by major institutions noted for providing meteorological and oceanographic information (e.g., Fugro metocean buoy services, NASA satellite station). A hybrid approached was implemented in the data gathering process. Various qualitative and quantitative data obtained included the use of interviews with resource person onboard concerning various variable per their expertise and experiences. Vessel internal reports, as well as log records of operations, were made available to the researcher. Confidential records were therefore not accessible at the time of field study. These resource personalities from Subsea 7 engineering ltd., are identified as in Table 21.

Table 21: Resource Persons Interviewed

(8) Subsea Engineers	(9) Subsea Surveyors
(10) Deck Foremen	(11) Tech Superintending Supervisor
(12) Ship Chief Engineer	(13) Ship Electro-Technical Officer
(14) Deck Officers	(16) Ship Engine Officers
(15) Health and Safety Officers	

4.3.4 Description of Data Analysis:

The analysis made use of the mixed dataset – taking into consideration the ongoing operations being observed, explanations from interviewees, ship operations record log, and internal reports (in both statistics and essay formats). The focus was on; strike risk assessment, the co-occurrence of radiated ship noises to animal sightings; the night-time lighting colonizing effect, marine plastic pollution concerns, air emission estimates, and oil spillages. Also, predicted trajectories amounting to changing climate on some of the concerns herewith was analysed and discussed in based on the following.

4.3.4.1 Model Distribution of Animals

Using the density and abundance estimates obtained in Chapter 4 Sec 4.2 developed based on the CDS modelling method as the basis for animal encounters in predicting strike risks on the various fields, the animal behaviour (described in Sec 4.2) was subsequently measured statistically for curiosity and feeding to animal presence upon surfacing. The time of observation, thus ‘stay’ duration (presence) and frequency of animal occurrence were recorded and analysed against surf operations parameters. The animal model distribution formed the basis of this study and therefore, was developed in two phases and measured for various frequencies.

4.3.4.2 Strike (Collision) Risk Determination

The strike risk determination is in two phases. The first phase was of vessel movements predetermined by the planned surf operations per the subsea engineering design established for the various oil and gas sites forming the study region. As Redfern et al. (2013) explained, all shipping routes, particularly of any TSS, consisted of both an inbound lane and outbound lane, the offshore installations were with similar features encapsulating the 500meter zone (expanded to 1nautical mile by Government of Ghana around installations) EEZ regulation, which permitted vessel entry and exit off the field. This imaginary boundaries, therefore, formed the borders between a safe animal haven and operational sites—the number of vessels to the frequency of transiting between offshore installations and port marked against their sizes. The vessel density was determined for the Jubilee field in the study, with specificity to the various specialise vessels engage in various capacity at the time. There have been various approaches at deriving ship density, which have resulted in many difficulties, thus according to the European Marine Observation and Data Network (EMODnet), (2019). The study derived the vessel density by obtaining mass displacement (kg) from vessel deadweights at particular points in time acting under gravity 9.8 m/s^2 to determine the level of force exerted or acting as a function of the acceleration of the given body of mass. The deadweights act as an added force in this case. Where data on deadweight of ships were not available gross tonnage (volume displacement) was used. The vessel mass is multiplied with time to obtain vessel mass-time usage (kg. hr) for each vessel before subsequently being summed. The coverage area was then divided by the vessel mass to time used to obtain the shipping density in sq. km per kilogram hour for the period.

Based on Redfern et al. (2013) concept, the predicted number of whales (animal) sightings within the study site was classified per route of DP manoeuvring and then multiplied by ship density to obtain estimates of possible ship-strike (*ship-strike risk*[27]*)*. The study then proceeded to summarise results by deducing the statistically weighted average and standard error for the annual risk estimates of periods

[27] Ship-Strike Risk is defined as "a measure of the co-occurrence of whales and shipping traffic" (Redfern et al., 2013 pp297).

studied, howbeit utilising data from a single field observed. Therefore, with operations mostly consisting of DP manoeuvring, the weights were derived as the proportion of survey efforts per the field estimates of the study area. The study defined '***Relative risk'*** for each route as the difference between the ***average DP manoeuvring route*** risk and the ***average Field route*** risk divided by the average Field route risk which is a slightly modified form of Redfern et al., (2013: 297) approach. The second phase concerned movement through the water column by crane, ROV and subsea installation, making way to the seafloor under load as observed from vessels and of vessels engaged in surf operations. The estimation of the risk followed a similar approach making use of subsea load weight to diameter and gravity. In other words, the above computational approach was slightly varied and used in predicting ***strikes risks*** within water columns of animals further away from the sea surface and ROV, Crane and Subsea Structures moving through water column unto the seabed.

4.3.4.3 Surf Operations' Air Emission Estimates Modelling

Ship emission inventory was taking for only 2018 & 2020 surf operations which was the centre of focus of this study. Data in this regard were from internal reports kept by vessels and the leading licensed oil and gas operators, Tullow Ghana Limited (TGL). The estimates derived relied on updated US AP42 emission factor, EF standards produced by NASA, EPA and the Lloyds register. This emission factors were the same used for Tullow Jubilee field EIA (annexe Environmental Release Summary Document e27) (TGL, 2009) air emission estimations before the hydrocarbon production. These factors are in Table 1-23 of Appendix based on US EPA AP-42 Standards. Therefore, standard emission estimates according to AP-42 is given per the relationship;

$$E = A * EF * (1 - \frac{ER}{100})$$

Where:

$E =$ Refers to Emissions estimated for either SOX, COX, VOC, PM10, NOX, and CH_4 air discharges in tonnage from the burning of fuel, and gases. Unit is tonnes or metric tonnes.

$A =$ Activity rate given is as a function of time. The activity rate over a long period of emission estimation accounts for both times of upset and routine activity process for the ships examined.

$EF =$ Refers to emission factor— an expected representative value associated with the release of that pollutant from ships that attempts to relate the quantity of a pollutant released to the atmosphere with activity. These expressed weights of pollutant are in terms of division by unit weight, volume, distance or duration. Unit of measurement is tonnes/hr or kg/day; and

$ER =$ Overall emission reduction efficiency, is given as a percentage, %. Thus, a product of a control device for emission destruction or removal efficiency. It also represents the capture efficiency of the control system. (for example, a newly build ship produces fewer emissions due to efficient working parts compared to an older ship with much wear and tire in the system)

The AP-42, published since 1972 is a compilation of Air Pollutant Emissions Factors, as a primary compilation of EPA's emissions factor information. Besides emissions factors, the document holds process information for more than 200 air pollution source categories. Our study limits its focus on primary emittance from fossil energy resources.

4.3.4.3.1 Basic Assumptions Considered

Before estimations, several assumptions made in term of ER are that most of the vessel deployed were relatively under one decade old, and hence, fitted with emission control devices per design. This assumption was in line with previous assumptions made by TGL in order to have estimates conform to trends. It, therefore, assumed that only 2% of S content in fuel converted to SO_2. It also assumed, the marine gas oil (MGO) was equivalent to number 2 fuel oil made from distillates only emissions data that are available for vessels “at sea” or “manoeuvring”, hence the categorisation of all vessels was into one of these scenarios. Medium speed emissions were assumed for all vessels manoeuvring, or at sea regardless. The final estimates were then compared to climate change conditions to ascertain the level of impact and what form they take relative to environmental changes occurring in the region. The distillates were further classified, into subdivisions of marine gas oils (MGO) and marine diesel oils (MDO) (EC, 2002). Herewith, relying on ISO (ISO, 1996b) and EC measurement of viscosity, RO fuels (measured at 50^0C) is 55-810 cst, 5.5-50 cst for MDO and 1-5.5 cst for MGO, thereby allowing the marine vessels in the study region identified by the fuel types with the emission factors implemented in estimating the levels of emissions in the field. The emission factor (EF) chosen was EC’s proposed EF (in kg/tonne fuel), which are about US EPA (1985), NMTRI (1990), Lloyds Register (1995). The

European Commission's (EC) (2002) assertion that rather than the size of engines, ME and AE engines characteristics were typically sub-divided according to their engine speeds at crankshafts, thus: *high speed, medium speed* and *slow speed*. The classification was necessary for the vessels on the field studied in order to quantify the various emission estimates. Slow speed, in this case, is defined as "engine speed at the crankshaft in terms of the number of revolutions per minute (rpm)" (EC, 2002pp21). The study, therefore, relies on EC's assigned classes, thus, given that "slow speed has been assigned to engines with speeds between 60 - 300 rpm, medium speed as 300 - 1000 rpm and high speed as 1000 - 3000 rpm, in some cases, high and medium-speed diesel engines are combined collectively and termed simply medium-speed diesel engines" (EC, 2002pp21).

Moreover, emissions from slow and medium-speed engines were estimated to be abundant relative to high-speed engines for main engines. The AP42 itemises the primary pollutants from internal combustion engines as oxides of nitrogen (NOx), hydrocarbons and other organic compounds, carbon monoxide (CO), and particulates. They suggested the emissions make of both visible (smoke) and nonvisible matter but their effect on the environment are never in doubt.

4.3.4.3.2 The Climate Change Contribution Estimate

A global warming potential, *GWP* shall be deduced for carbon equivalent of all the air emission pollutant estimated. Thus given a sense of greenhouse contribution coming from the construction operations offshore Ghana.

4.3.4.4 Spill Modelling

The spill trajectory model simulation was also to be developed based on various scenario identified in the investigative studies. However, the simulation is on a few scenarios—the characteristics of oil such as density and viscosity with temperature. A stochastic prediction model via NOAA's GNOME and DHI MIKE software in Windows OS help develops the spill spreading models.

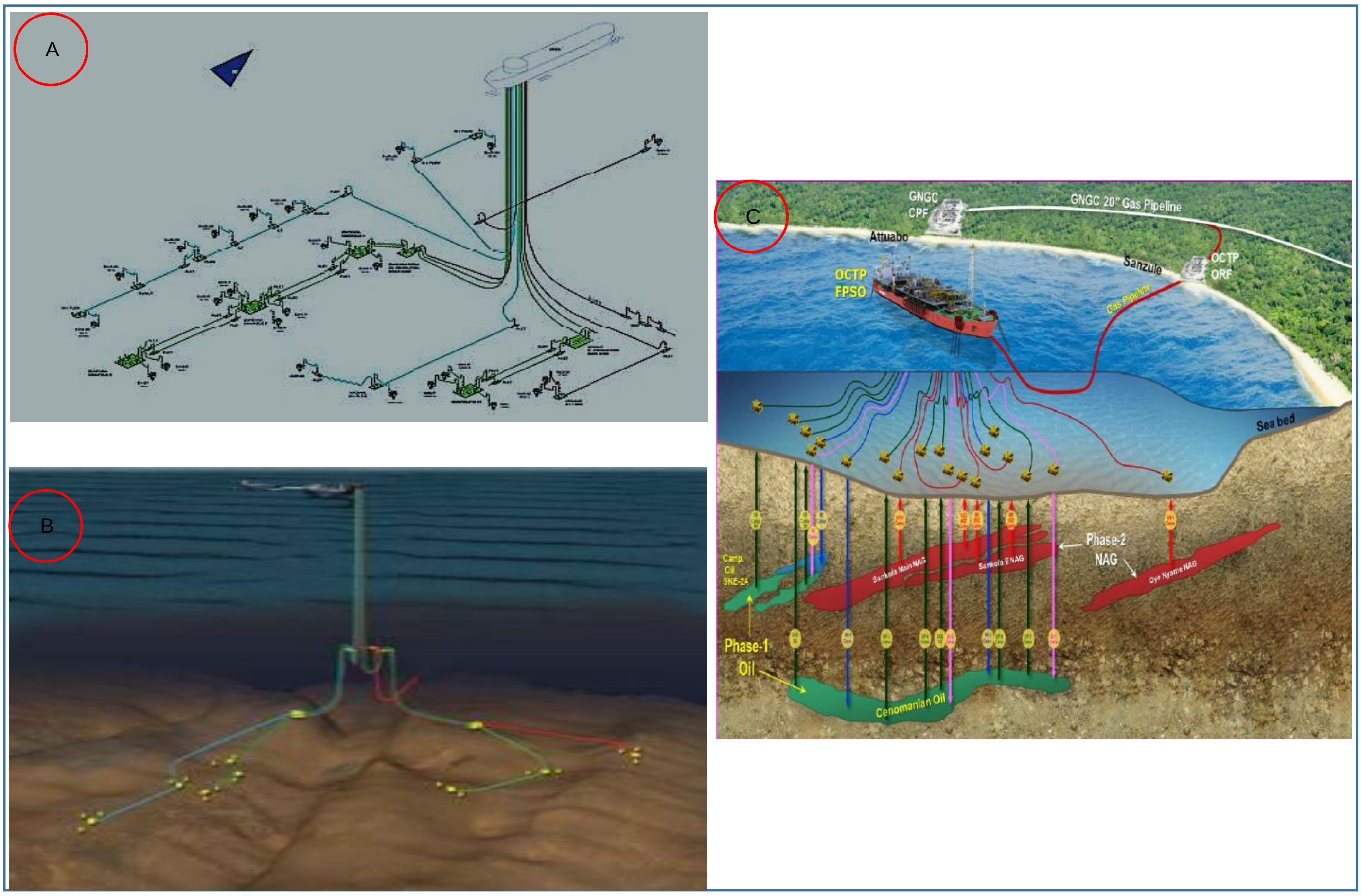
4.3.5 Results and Discussion

The results and discussion presented in this section of the study makes use of reviewed *EIA* material published by TGL and ENI and submitted to the Government of Ghana in meeting EPA regulations before offshore field developments alongside site observations, interviews and internal reports.

However, not all issues appear within the reviewed *EIAs* reproduced in order to meet the primary objectives of the paper. As characterised in Chapter 4 section 4.2, the area enjoins the unique characteristics of the Guinea surface and underwater currents driving the upwelling season. It is also known to be a mammalian marine habitation (particularly of short-finned pilot whales and various species of dolphins) per abundance and density estimations from (January – March 2020) observations made by the researcher early in the study. The upwelling tends to suggest an area of biological importance (BIA) for feeding animals. As alluded to, there were visible vulnerabilities faced by these animals which showed a curious otherwise intent, moving closer to ships and platforms stationary, manoeuvring or undertaking subsea engineering works. The nature of operations varies from project to project. Hence, the following paragraphs highlight some of the critical operations that continue to take place while examining the various anthropogenic pressures; these events turned to risk on both the lives of marine animals in the habitation and the general climate of the met-ocean environment.

4.3.5.1 Nature of Marine Operations Offshore taking place within Offshore Ghana

The offshore marine development within Ghana as observed remains a continuous evolving subsea to surface (SURF) engineering progress, set up within one of the world's most challenging environments in nature. Incidentally, the bargain follows a series of phased developments on hydrocarbon discovery wells, drilled after 2009 on the Jubilee field –continuing well into 2011 within joint Deepwater Tano (DWT) and West Cape 3 Point (WCTP) license blocks. The Phase 1 Jubilee development saw 17 wells (9 Oil producers, five water injectors, and three gas injectors) drilled from a deep-water marine environment, relatively of 1200meters depths inching to 1530meters water depth. The Tweneboa Enyenra and Ntomme fields combined, forming the TEN development also located within the DWT license block (fall along the continental slope, approximately 50 and 70 km from the south of the west coast.), had two essential wells drilled at 1330 m and 1990 m water depths.


A
B
C
GNGC
CPF
GNGC 20" Gas Pipeline
Attuabo
Sanzule
OCTP
ORF
OCTP
FPSO
Gas Pipeline
Sea bed
Camp.
Oil
SKE-2A
Sankofa Main NAG
Sankofa E NAG
Phase-2
NAG
Gye Nyame NAG
Phase-1
Oil
Cenomanian Oil

The TEN development (with proved oil, gas and condensates), also like the Jubilee field, witnessed the drilling of 17 different wells after the year 2015 (ERM/TGL, 2014). The nature of engineering development in all active oil-producing sites in offshore Ghana, though appear similar, they do vary in content and context as can be seen in the schematic outline of Figure 74.

As shown in Figure 75, several structures designed to withstand the harshness of the subsea environment were transported from shore-based facilities via specialised marine vessels to these remote locations offshore, installed on the seafloor. During site study in the final quarter of the year 2015, the researcher observed onboard from the *PO* vessel, MPSV Seven Borealis the off-boarding installations of several manifolds, anchor pile, and the flowline pipeline production executed by Subsea 7 Engineering Limited on the TEN field. Seven Borealis was aided sister-vessel, Seven Esperanza. In the year 2017 through to 2018, the researcher witnessed from onboard *PO* vessel LCV Polar Onyx, OCV Lewek Constellation, and Seven Arctic the off-boarding of several structures including Mudmats, Jumpers, FLETs/ AFLETs, Christmas tree, Risers, Flowline, Manifolds, Suction Pile (see Figure 76). Furthermore, as at the end of 2018, oil and gas have been successfully transported from the all the three oil and gas production site offshore to both the foreign and domestic energy markets via shuttle tankers and gas pipeline completed well ahead of schedule. Mostly, surf construction operations of this very nature make use of two distinct engineering interfaces; thus (1) connection and testing preparatory works at the water surface, where the installation is of concern, and (2) subsea connections and testing at the sea bottom (see Figure 76). The first interface involves a human interface where the rigging engineering plans are carried out by project deck crew in support with project engineers. Issues of testing, asset integrity, safe execution and approach verified before off-boarding of structures. The 2017-2018 OCTP-Sankofa Gye Nyame project, the short term 2018 and 2020 Tullow Jubilee Flowline Remediation and Catenary Turret Buoy Remediation projects respectively, are also other examples of operations observed by researcher demonstrating the engineering process. Images of these operations, as shown in Figure 75, 76 and 77. The images shown depict some of the various complex operations and installations carried out on the surface of the water. The special-purpose catenary moor turret buoy is one such floating installation, and according to Tullow Ghana Limited, the first of its kind to be designed and implemented in the world. The mooring buoy's platform forming the mooring master station is rotatable through a 360-

degree angle and has a mooring shed to the bow from which offtake tankers may be moored and loaded one nautical mile away from Jubilee FPSO KNK.

Subsea works such as the anchor piling that held the chains firm –keeping the buoy in position was achieved with the help ROVs operated by AHTS Skandi Skansen (see Figure 75). This operation was after MPSV Seven Borealis vessel had off-boarded all anchor piles. The project though initially scheduled for completion in the first quarter of 2020, was faced with the challenge of strong underwater current during the pipe-lay. The global declaration of COVID-19 later exacerbated the situation as a pandemic. The project suffered a setback as operations suspended to a later date. During subsea construction development projects, as many as ten marine vessels engaged in various capacities along

*Figure SEQ Figure * ARABIC 75: Images on the left depicting operations prior to subsea development offshore; thus image of FLETs onboard by Polar Onyx crane in Takoradi Port prior to departure for Sankofa field in 2017, and Lewek Constellation with flex pipelay unspooling from aft rail heading over TLS tower amidships and down the Moonpool to subsea on the Sankofa field ; and Images on the right shows the 2020 Jubilee turret buoy installation being anchored to the seabed with the aid of AHTS Skandi Skansen), tug, Seven Adaba and Bear*

various stages of the development. All these operations involved the use of special machinery (assets) and equipment which have physical implications for the environment and marine lives. Ordinarily, the second phase of subsea hydrocarbon field construction involves the underwater tie-in connections of subsea structures, the supply of power and the ability to maintain control remotely, through systems designed and installed on the FPSO units. Specialised technicians piloted ROVs (as can be seen in

Figure 77) onboard the construction and survey vessels. The ROVs make this operational tie-in connection and testing of equipment subsea possible. Among some of the essential functions of subsea ROV includes; direct seafloor and equipment survey, removing riggings, screwing and unscrewing bolts and nuts. All such operations involved a tremendous amount of movements in predetermined directions, the use of subsea lighting and constant transfer of loads. For the Jubilee mooring buoy project observed, ROVs deployed helped with the connections of Anchor Chains to Piles and the connection of the (Oil Offloading Line) OOL pipeline production. Due to unforeseen circumstances, the second OOL could not be delivered in due time and hence rescheduled for a later time.

4.3.5.2 Distribution of Animals and Animal Behaviour

The results presented in Chapter 4 sec 4.2 of this study asserts the existence of marine mammal habitation offshore to include areas in and around

the Jubilee, and TEN fields of the DWT and WCTP license blocks, the study concluded with an observation of both small cetacean and whale species. The estimate of population abundance was 160.00 (*CV* = 0.3728) animals with a density of 0.30749 (*CV= 0.*3728) animals per square kilometre over the entire study region. An average cluster size of 17.950 and 23.482 was observed within respective stratum— projecting a pooled cluster density of 0.14247E-01. Short-fined pilot whales were among the commonly sighted animals which exhibited a curious behaviour coming closer and cycling the construction vessels. This phenomenon was both witnessed at day and night times. Another animal species largely sighted throughout the study were a marine bird, seagull. These birds regularly were seen swooping over the water surface in a bid to find food (e.g. fish) –suggesting the area as a BI for their species. This sighting is at the core of the concerns raised in these paragraphs as it discusses anthropogenic events of the area their effect on marine life and environment.

4.3.5.3 Strike Risks Assessment

During offshore construction works from the surface to subsea operations, animal ‘strike risk’ can take place in two identified forms, thus according to resource persons, they indicated there could be a head-on collision of the vessel with an animal during manoeuvrings, and also where subsea movement through the water column is of concern. Thus, there is that danger as well at water depth where cranes carrying load fly blind to their destination. These assertions confirm the initial conception raised in the study. As indicated earlier, several vessels were engaging in the various project tasks. Resource persons also indicated that this levels of traffic presented a multiple fold strike risk in the environment, had it not been that the general operational manoeuvrings of this vessel are relatively slow mostly during DP, suggesting an ample time for any animal in the way of the vessel to escape. Perhaps, the dead slow DP manoeuvrings do also give a pseudo indication of a vessel being stationary relative to animal's motion observed; hence, curious animals tend to move closer to operations and spiralling the danger they may face.

For Subsea structures, machinery assets and equipment destined subsea, there are considerable physical strike risk concerns for marine animals navigating the waters at water depths. This risk is buttressed by an earlier observation onboard the Polar Onyx, where the research observed ROV tool basket carried subsea return onboard vessel's deck trapping live fishes, turtle, jellyfish. The turtle was subsequently released back into the sea. The researcher also recounts the event of a shark physically attacking an ROV working subsea. The video captured by the Seven Borealis survey team of the incident –though unrelated to the study area, depicted a good predatory animal behaviour that had the potential of leading to extreme vulnerabilities for the animal involved. In determining the sustained risk-weighted distributions forming the force of impact over time of vessel usage considered against animal presence per their distribution. Therefore, the following statistics (in Table 22) were compiled of peak surf operations during the Jubilee Turret buoy installation projects offshore Ghana and did illustrate the density of vessel strike force to the risk vulnerabilities for marine animals of all life forms. The data represent the number of days vessels have served on the jubilee field.

Table 22: Vessel weight distribution over time spent on the Jubilee Field as at the time of Survey

Vessel Observed	Type	Deadweight (DWT)	days	hours	Total hrs.	Weight in time usage ton. hrs
Skandi Skansen	AHTS	4982	89	24	2136	10641552
Seven Adaba	AHTS/ Towing vessel	2131	89	24	2136	4551816
Maersk Voyager	MODU	59285	89	24	2136	126632760
Maersk Venturer	MODU	59557	89	24	2136	127213752
Seven Borealis	Pipelay/ HeavyliftVessel	49735	89	24	2136	106233960
Lewek Scarlet	SupplyVessel	2316	909	24	21816	50525856

Maersk Forza	Survey Vessel	6601	89	24	2136	14099736
Polar Onyx	Light Construction Vessel	8194	909	24	21816	178760304
KNK	FPSO KNK	240550	909	24	21816	5247838800
Pacific Porpoise	SupplyVessel	1529	260	24	6240	9540960
Pacific Valhalla	SupplyVessel	2485	909	24	21816	54212760
Long Xiang 601	Fishing Vessel	0	89	24	2136	0
Bear	Tow Vesel	2854	788	24	18912	53974848
Elizabeth Knutsen	Shuttle Tanker	124758	248	24	5952	742559616
EMAR John Ernest Aiddoo	tug boat		89	24	2136	0
	Security Boat		260	24	6240	0
Pacific Goldfinch	SupplyVessel	4054	21	24	504	2043216
SUM of Weighted Usage in hours (@ 2 years 46 days)			**=**			**6,728,829,936 tons hr**

Source: Field survey 2020

From the table above, one observes that some ships had zero estimates though there are sighting on the field. This feature is because these ships had no rated deadweight due to vessel share size, weight (which is under 100tonnes) and operations per international maritime organisation standards. The sum weighted usage in hours estimated here refer to the impact force acting on the specific water column (area) at the particular time. This estimate is as presented in Table 23.

Table 23: Final Ship density estimates and animals @ risk strikes in the region

SUM OF WEIGHT USAGE IN TIME	6728829936 tons hr
AREA OF JUBILEE STUDY STRATA	521.089 sq. km
TOTAL REGION(DWT & WCTP)	3120.4 sq. km
SHIP DENSITY IN Jubilee STUDY AREA	12913014.74tons. hrs./ km^2
SHIP DENSITY IN REGION	2156399.8tons. hrs./ km^2
RELATIVE DENSITY (RD)	0.166994296
ANIMAL ABUNDANCE ESTIMATE (*N*)	160
STRIKE RISK (*N*/RD)=	**26.7190873 Animals @ risk**

Source: Field survey 2020

Ship density, therefore, is estimated for the Jubilee strata coverage area at 0.00000007744112 sq km per tons hr and also estimated for the entire DWT & WCTP block area at 0.00000046376 sq km per tons hr. An estimated relative density of weighted ships in both the global and regional study area given as 5.988228498. Therefore, it deduced that approximately 27 animals from the entire population stand the risk of been stroke by marine vessels manoeuvres in the study region over the two years (2 years 49 days) offshore project development by TGL. This slow to dead speed levels reduces the potential of ship collision 'strike risks' (Redfern et al., 2013) by giving the animals' ample time to move away from the impending danger. In other words, near-miss scenarios are therefore more likely on the field, which in effect also induces psychological trauma compared to transits between offshore locations and port facilities.

Again, collision or strike risk, also examine for subsea structures, and subsea machinery movement through water column was based on data gathered over the same period and have been presented as follows in Table 24.

Table 24: Water column strike Risk from Machinery and Subsea Equipment

Vessel Machinery	Average Daily use in hrs	Average Use Duration in min	Number of days Deploy ment	Total time usage subsea in hrs	Max Subsea Load usage in tons	Tonna ge Hour usage(ton hr)
7B-MainCrane	4	112.5	6	11.25	120	1350
7B-AuxillaryCrane	2	37.5	5	3.125	12	37.5
POX-CRANE	6	195	250	812.5	70	56875
SKANDI SKANSEN-CRANE]	6	137.5	17	38.95833	12	467.5
MAERSKFORZA-CRANE	3	45	5	3.75	12	45
SUM OF TONNAGE INTIME USAGE (tons hrs)				**=**	**58775**	

SUM TONNAGE TIME USAGE IN AREA	58775
JUBILEE STRATA AREA	521.089
TOTAL AREA OF DWT & WCTP	3120.4
DENSITY IN STUDY AREA	0.008865827
DENSITY IN REGION	0.0530906
RELATIVE DENSITY (RD)	5.988228498
ESTIMATED ANIMAL POPULATION, *N*	160
STRIKE RISK (N/RD)	**26.71909 animals**

Source: Field survey 2020

From the above statistical description, deduced the strike risk from ship manoeuvring and machinery movement in the water column under load, or ROV manoeuvring subsea risked striking roughly 27 animals over the two years and forty-six days period of subsea maintenance and construction. In other words, the risk permeated both depth and surface of the waters though relatively reduced by the chances of vessels mostly stationary for hours. Rhetorically, how does this risk relate to other concerns for the animals? It is, however, unclear how much of this risk directly translates into real-time incidences either observable or unobservable.

4.3.5.4 Concerns of Radiated Noise and High Concentrations of Nocturnal Lighting Pressures

The concerns of radiated noises from operation as well as the use of nocturnal lighting were observations made on all construction sites throughout the study. The study of night-time lighting along the radiated noises was essential in understanding the external conditions that allowed for the changes in BI (Biological Importance) gradient of the area. Marine vessel radiated noises observed were of both high and low frequencies— stemming from the various machinery assets and were not limited to vessel main engines, and propulsion systems. It is empirical to note here that not all source-level radiated noises from vessels and machinery spaces could be studies statistically due to asset restrictions. Onboard the *PO vessel Seven Adaba,* the source levels radiated noise observed as a concern to the marine environment was relative to the condition of the main engine and propulsion system. The engineers on board *MV Adaba* asserted that controllable pitch propeller (CPP) for the DP propulsion, required the raising of the rotary shaft at a constant revolution of 400rpm to 600rpm in order to generate the needed thrust. This additional load intensifies the vibration noises which were large of low-frequency levels. Observations from the main *PO vessel, Seven Borealis* was not any different except there were more source-level noises from secondary machinery and equipment. Besides the source level noise from the six main engines and thrusters sources, there were two hydraulic power units (1000kW J-Lay HPU, 2,400kW Main HPU) and two electronic power units (8MWaH main EPU, 7,200kW J-Lay EPU) machinery affixed to the vessel's deck for pipe-laying (Table 25).

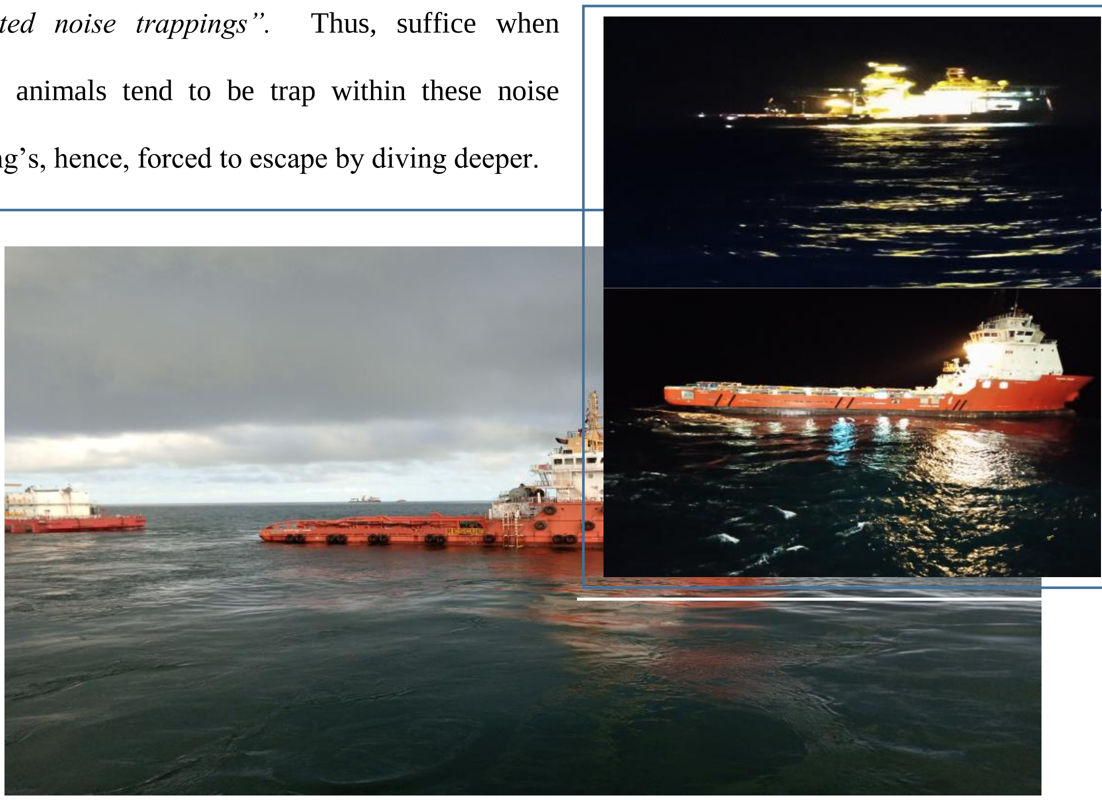
Hence, questions relayed to resource persons upon direct and indirect observations, found that these concerns of ship vibrated noises were known, and systems were therefore in place to remedy the situation to an extent. The superintendent tech engineer indicated there are currently no specific readings of noise levels from the systems as mentioned above, except that of the ship machinery spaces in general. According to the tech superintendent, the average source vibration noises from machinery space ranged between (73.5db- 108db) and (91.6db -123.5db) (see Table 25). These were significantly high levels of noise that did not only risk impact human but animals as well regardless of transmission losses through vessel hull and water. For hum, an impact, they did indicate the company has ear protection policies implemented on-board. There are also soft earplugs available everywhere on deck and engine rooms where the noise was imminent. He further suggested that currently, there is no regular monitoring except for the periodic third-party testing undertaken (with results given above). Resource persons further suggested that internationally acceptable noise levels and general knowledge on noise relative to water in terms of transmission losses, travel distance and speed, the *Seven Borealis* for instance, was designed to have engine room thruster flanks (which is one primary source of engine room source noise) extrude unto the main deck. This design prevented direct transmission from the engine room into the ocean but the atmosphere. Statistically, the number of source-level noise is critical to evaluating the noise pressure faced by the animals who more often than not, use sound in all aspect of their activity. Direct readings and recordings of underwater radiated noise from installations and ships, could not place at the time of study due to access restrictions. Therefore, the study compiled the number of identified sources for the radiated noises, from which a picture of the (ship) radiated noise network easily transformed— into imaging the spread layout on the field at a given time. Table 25 is the list of identified source noise of the vessel on the jubilee field on producing the cumulative effect of noise pressure.

Table 25: Main Identified Noise Level Sources on the Jubilee Field at the time of study

Marine vessels	Noise Sources	Measured Contributions
Seven Borealis	J-Lay Main HPU J-Lay Main EPU Main HPU Main EPU 6 Main Engine	 73.5 – 108dB 91.6- 123.5
Seven Adaba	Main Engine Propulsion System (variable CPP)	unknown
FPSO KNK	Pressurised Gas Flaring	>84 Db

Source: field survey data 2020

The list so far is limited to PO vessel Seven Borealis, Seven Adaba, and Polar Onyx (POX) radiated noise source. Figure 78 shows a clear example of vessel distribution at a point in time. This radiated noises forming a network noise web enclosures on construction site is what the study does term as *“radiated noise trappings”.* Thus, suffice when marine animals tend to be trap within these noise masking’s, hence, forced to escape by diving deeper.



The nocturnal lighting observed were continuous and from every single vessel on the field. Deck lighting at night did cast an extended shadow on the ocean (see Figure 79) that drew both small and large schools of fishes, including fingerlings into the vessel’s vicinity (see Figure 80). Ship officers, therefore, suggested night-time lighting as a challenge to the marine habitat though could not specify to what extent this was affecting the natural marine environment. Another noise and nocturnal lighting concern observed on the field was the ongoing flaring on FPSO and MODU units. On the Jubilee field flaring on FPSO KNK by TGL upon approval by the Government of Ghana in February 2020, also commenced a series of high and low frequencies noises from the flare tower sending vibrations noises through FPSO hall into the marine environment –detrimental to animals directly in the surrounding or at water depth beneath the FPSO KNK. This situation is as a result of the pressurised gas blowing through the high exhaust. The noise levels occasionally are observed to intensify from time to time during the flaring cycle. Flaring noise level recorded from Borealis deck 50 meters away felt within 41db and 85db on one occasion. At night time, the ball of fire (as shown in Figure 81) glowing on the flare tower cast very long lighting shadow on the surface (more than 500meter away as observed), creating a false impression of 'sunlight' condition for surface animals.

The compound effect of noises transmitted through vessel hulls and machinery into the water may be impeding the communication among these animals, thus according to another resource person. He indicated that when noise transmitted does remain for a more extended period; the detrimental effect easily seen with earthiness injuries and the eventual death of the animal, particularly amongst young cetacean calves. Perhaps, being the reason for the many carcasses found in the last decade along the west coast of Africa. This phenomenon suggested that younger mammals were at greater risk of noise pressure injuries. Others also suggested echolocation in the upwelling season over February and March (thus during construction periods) were influenced by anthropogenic activities indirectly. This influence they referred to, citing of the swamp or schools of fish that were continually aggregating around vessels due to the effect of nocturnal lightings. Observations on the field attribute the phenomena primarily, night-time lighting and also the discharge of treated food waste into surrounding waters. The degree of influence by both light and food, however, did vary and is difficult to refer to one as a single particular reason. Schools of fishes were drawn to vessels daily by day and night. Since environmental policies of subsea 7's Borealis vessel did not permit the discharge of food waste at the time of the study, the night-time swamping of fish schools can be best explains as the colonisation effect of the night time lighting. It estimated that above 75kg of food waste enclosed in a mud skip disposed of ashore regularly. On the Polar Onyx, however, waste food was treated and discharge after midnight. This environment created a feeding frenzy for marine animals within its vicinity. Though the DWT and WCTP offshore areas were relative over 60 kilometres away from the coast, surface insect from time to time observed around the vessel in a relatively low number. Like insects, the light extended by the vessels into the water tends to draw these schools of fishes, which are natural prey for the odontocetes. This observation, therefore,

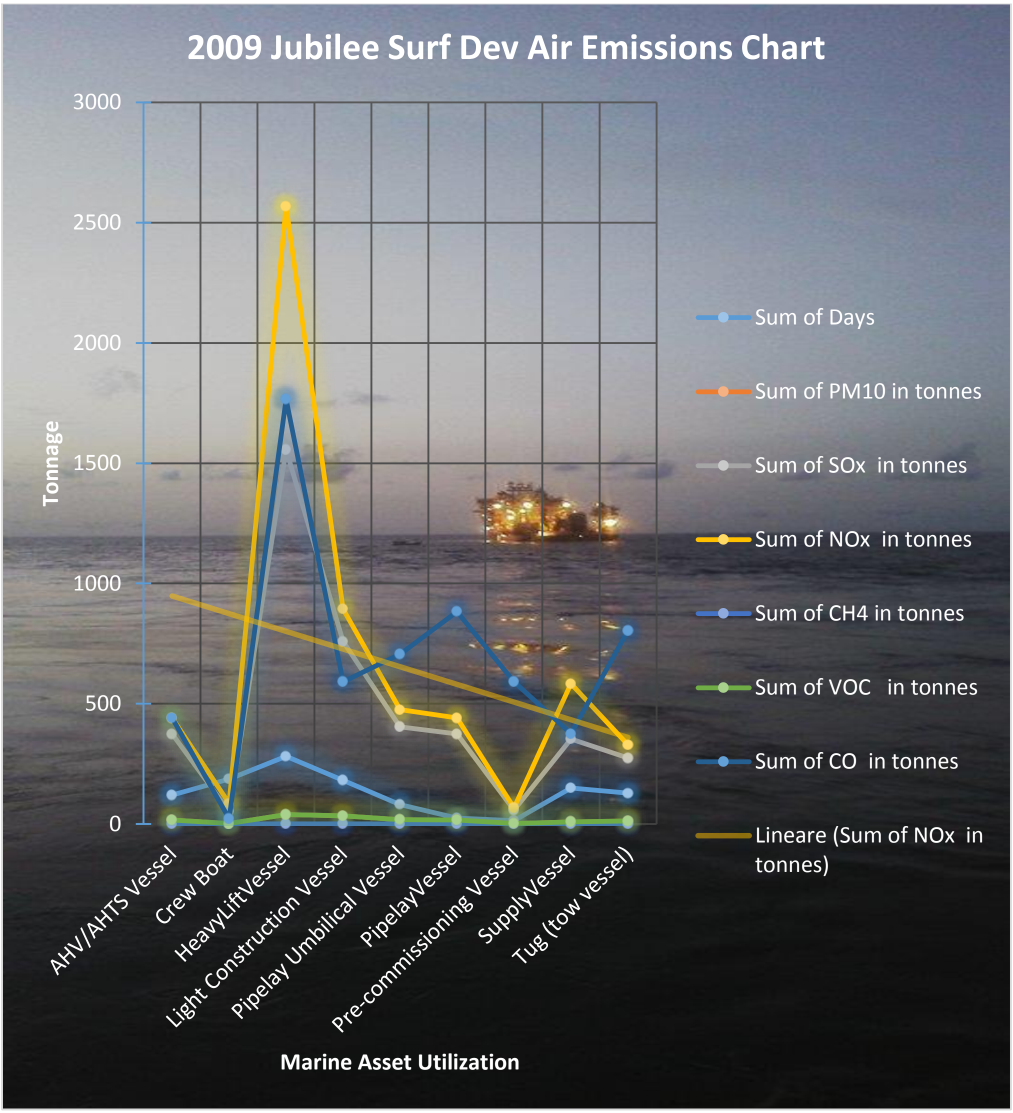
could explain the night time sightings of animals cycling the vessel at a point. The combined effect of light and radiated noises can be said to have a gradual change in the BIA. For short-term projects, these conditions may not have a long time altering effect ignored. However, where the frequency of projects increases and at longer durations, there could be permanent phenomena of behavioural changes which stand the chance of increasing the risk of survival of these animals. This risk, however, needs to be studied further if we are ever going to be able to identify the source of death of these animals in the Gulf of Guinea.

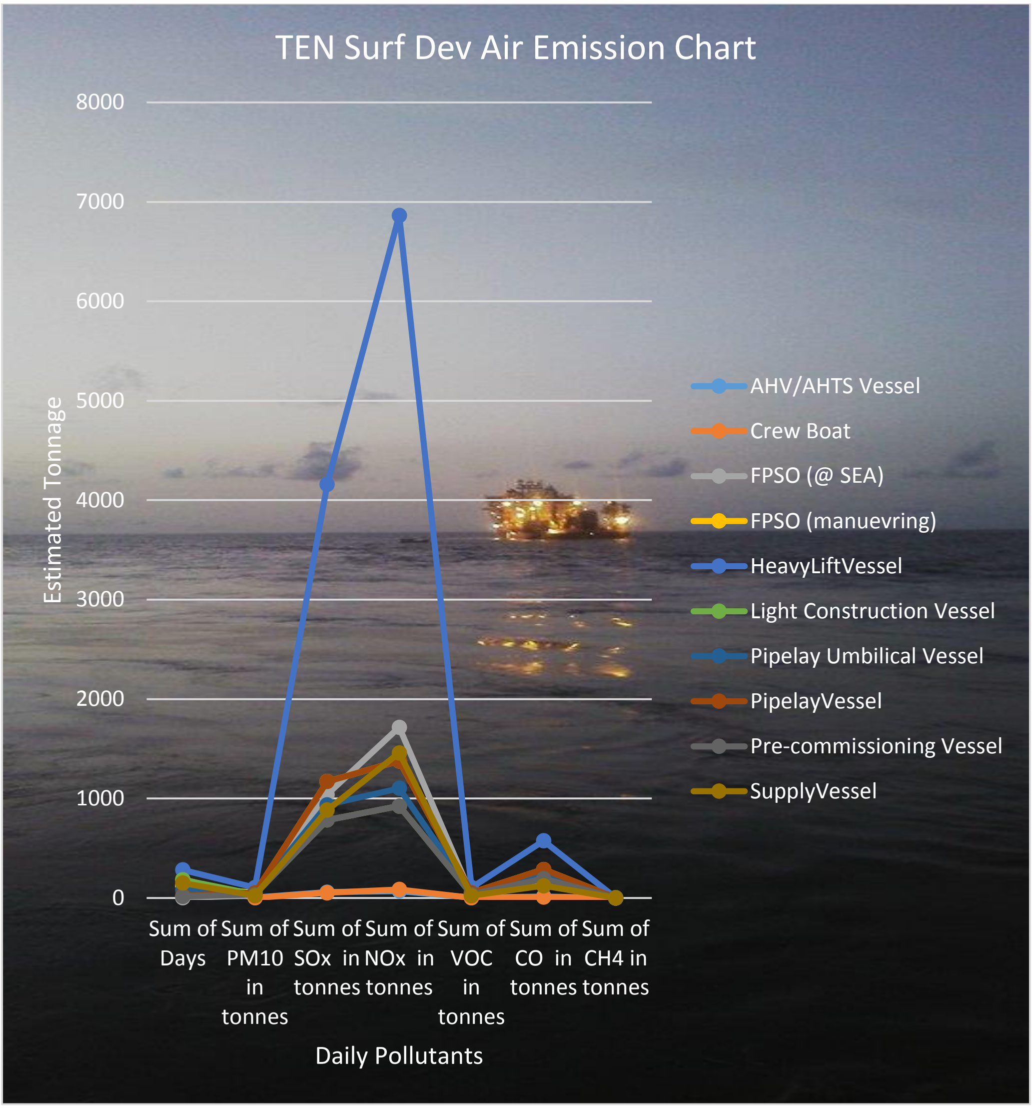
4.3.5.5 Pollutions and climatic Change Concerns of the Area

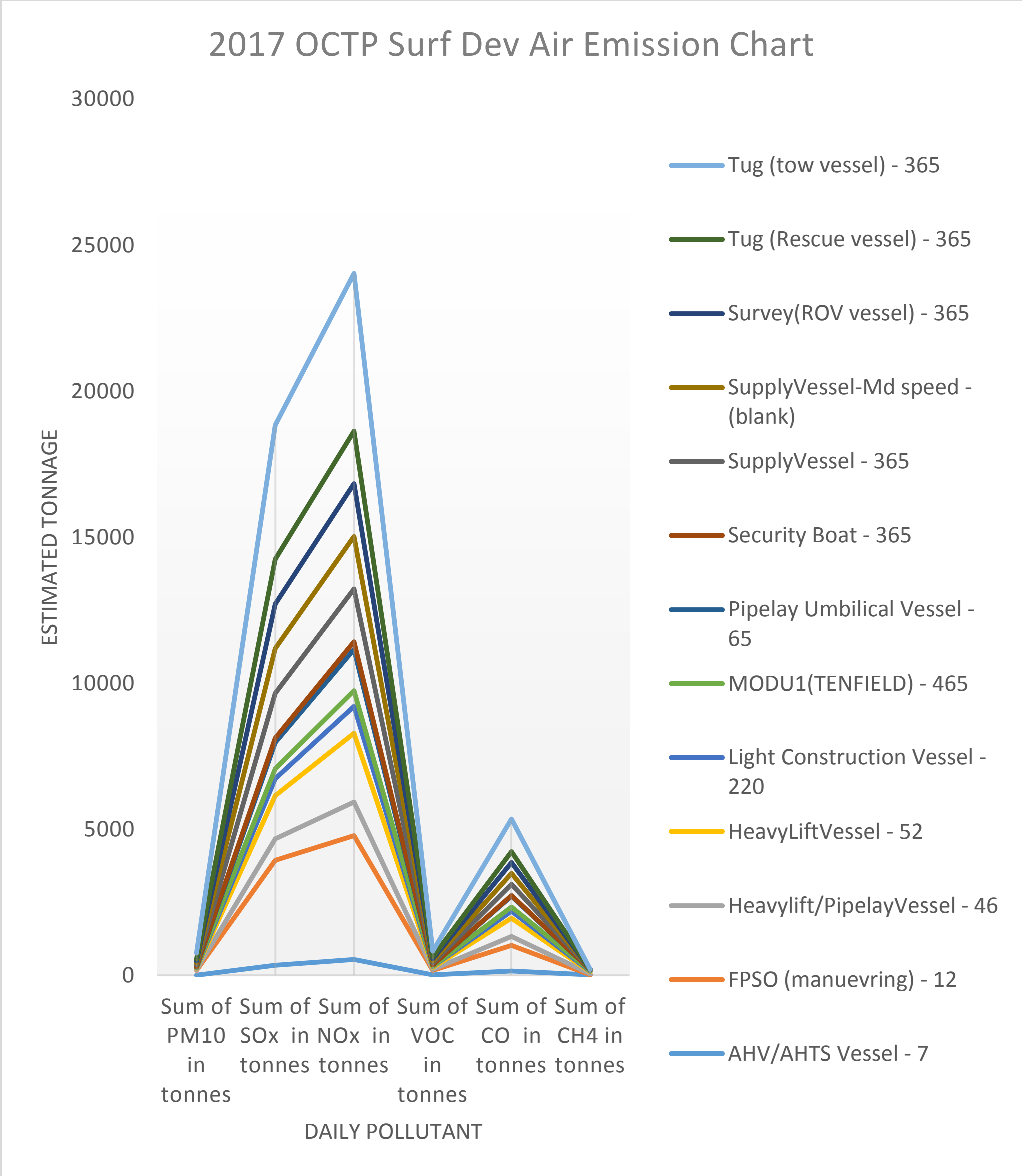
The pollution observed on the field were of three state (i.e., solids, liquid and gas) –a conduit of the self-sufficiency of ships in terms of power regardless of the number of auxiliary power-driven machinery appended to propulsion systems in meeting work demand. According to resource persons, oil and plastic pollution was the most significant challenge faced by marine animals and the environment, while suggesting chemical, air and noise pollution ranked third on the list. Several measures currently are in place to deal with the issue of plastic; thus, according to resource persons, who further iterated logistical concerns with disposing of garbage was a primary issue in the industry. Whereas alluding to the fact that some clients do not allow garbage incineration hazardous waste disposal, he explained that general waste (paper, cardboard) and plastics during the project ranging from [(200kg - 400kg) and (100kg – 200kg)] respectively, were incinerated daily. Concerning the magnitude of emissions from combustive systems, the European Commission (2002) indicate that *Main (ME)* and *Auxiliary (AE) diesel engines* lead by far, and only seconded by vessel turbine machinery (steam and gas turbines). They further explained that emissions from boilers, emergency diesel engines and waste incinerators relatively were in minimal quantities and could mostly be considered negligible (excluded hereafter) in estimating emissions. This statement was true as observed during operations offshore on both the MPSV Seven Borealis and AHTS Seven Adaba. To better under the trends of emissions and oil spillages, the study derived statistical estimates, and modelling simulations respectively, relying on data obtained from direct observations and internal documents made available to the researcher.

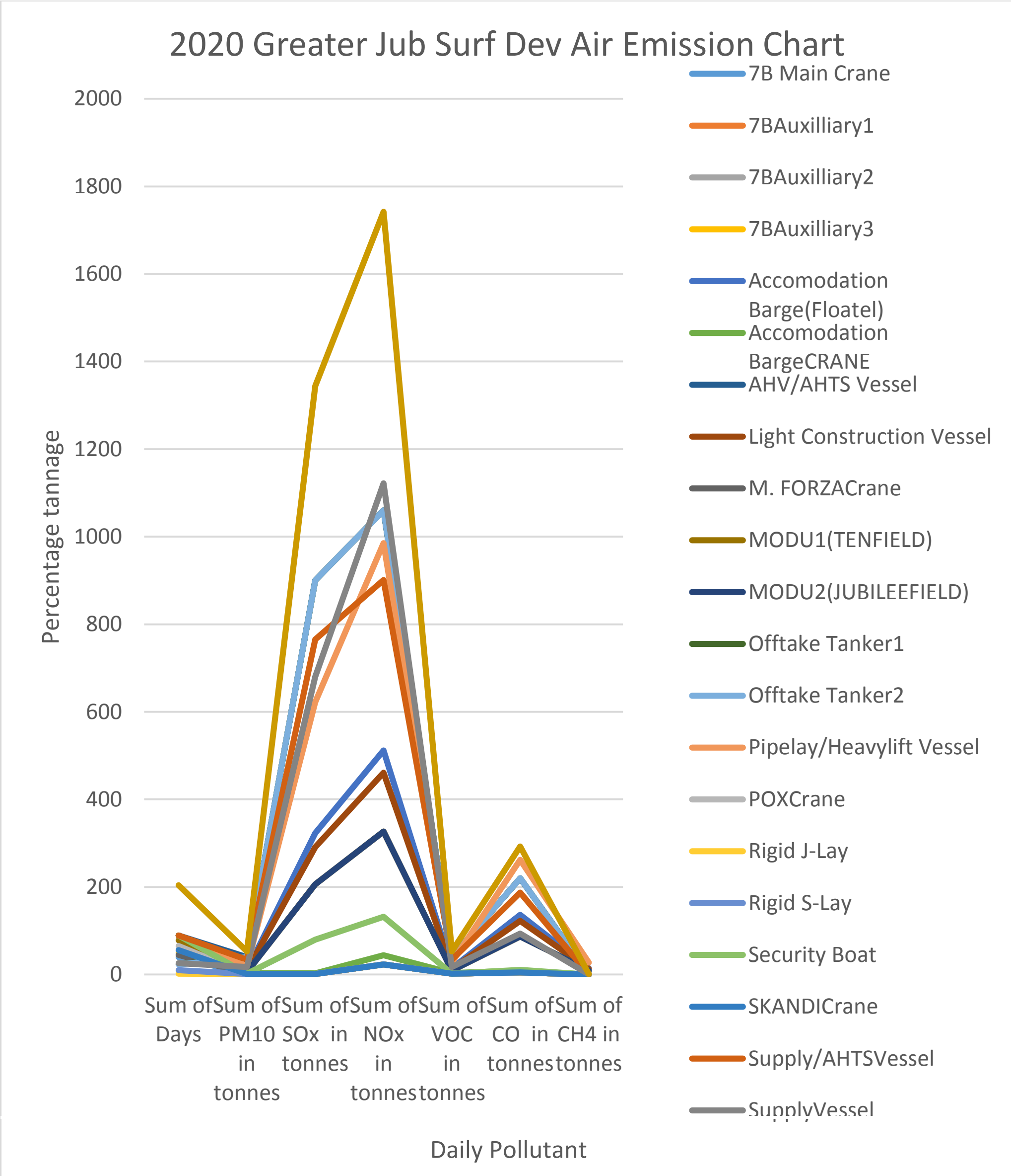
(a) Gaseous Air Pollutants and Estimates: Air emissions (like that seen in Figure 82 during gas flaring) taking into account for the estimation included Particulate Matter (PM) 10, NOx, SOx, CO, CO_2, CH_4 and VOC. However, CO_2 contribution is isolated in each operation and used in developing the final analysis. The following Figures 75, 76, 77 AND 78 are a graphical representation of emission estimate derived over the primary notable surf operations witnessed within offshore Ghana. This estimates did not include exploratory drilling phase emissions or emissions from the production unit operations. The EIA might have covered comprehensive estimates overall for the various phases of operations for the various individual projects. From Figure 83 below, the study observed that nine (9) marine vessels were actively engaged on the field for the subsea-to-surface installation operations during the 2009 Jubilee development phase before first oil production offtake— and thus, contributing to the various levels of air emissions into the atmosphere. The heavy-lift, light construction, umbilical and pipe-lay vessels, in this case, were large contributors to NOx (i.e., approximately 2500tonnes) (linked mainly to the efficiency of ship's engine), SOx (approx. 1500tonnes) and CO (1700tonnes) productions. These estimates were commensurate with the number of days spent by marine vessels on the field in active operations. From the 2015 TEN field surf installation development, emission estimate shown in Figure 75, similar trends were observed compared to the Jubilee. However, it differs hugely in NOx to a range estimate of up to 4,000tonnes and 7,000tonnes for Heavylift and AHTS vessels. The SOx and CO were sharply estimated to be under 2,000tonnes throughout installations. The 2017 OCTP-

Sankofa Gye Nyame oil field, surf operations pollution estimates (are in Figure 84), had contributory emissions from slow manoeuvring tugs engaged in

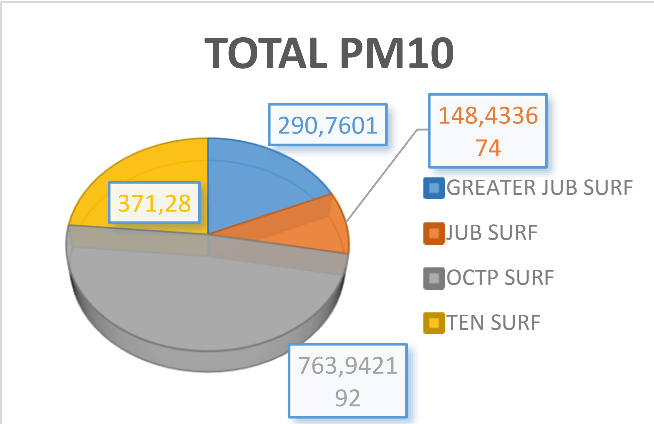

2009 Jubilee Surf Dev Air Emissions Chart
Tonnage
3000
2500
2000
1500
1000
500
0
AHV/AHTS Vessel
Crew Boat
HeavyLiftVessel
Light Construction Vessel
Pipelay Umbilical Vessel
PipelayVessel
Pre-commissioning Vessel
SupplyVessel
Tug (tow vessel)
Marine Asset Utilization
Sum of Days
Sum of PM10 in tonnes
Sum of SOx in tonnes
Sum of NOx in tonnes
Sum of CH4 in tonnes
Sum of VOC in tonnes
Sum of CO in tonnes
Lineare (Sum of NOx in tonnes)


TEN Surf Dev Air Emission Chart
Estimated Tonnage
8000
7000
6000
5000
4000
3000
2000
1000
0
Sum of Days
Sum of PM10 in tonnes
Sum of SOx in tonnes
Sum of NOx in tonnes
Sum of VOC in tonnes
Sum of CO in tonnes
Sum of CH4 in tonnes
Daily Pollutants
AHV/AHTS Vessel
Crew Boat
FPSO (@ SEA)
FPSO (manuevring)
HeavyLiftVessel
Light Construction Vessel
Pipelay Umbilical Vessel
PipelayVessel
Pre-commissioning Vessel
SupplyVessel


2017 OCTP Surf Dev Air Emission Chart
30000
25000
20000
15000
10000
5000
0
ESTIMATED TONNAGE
Sum of PM10 in tonnes
Sum of SOx in tonnes
Sum of NOx in tonnes
Sum of VOC in tonnes
Sum of CO in tonnes
Sum of CH4 in tonnes
DAILY POLLUTANT
Tug (tow vessel) - 365
Tug (Rescue vessel) - 365
Survey(ROV vessel) - 365
SupplyVessel-Md speed - (blank)
SupplyVessel - 365
Security Boat - 365
Pipelay Umbilical Vessel - 65
MODU1(TENFIELD) - 465
Light Construction Vessel - 220
HeavyLiftVessel - 52
Heavylift/PipelayVessel - 46
FPSO (manuevring) - 12
AHV/AHTS Vessel - 7


2020 Greater Jub Surf Dev Air Emission Chart
Percentage tannage
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Sum of Days
Sum of PM10 in tonnes
Sum of SOx in tonnes
Sum of NOx in tonnes
Sum of VOC in tonnes
Sum of CO in tonnes
Sum of CH4 in tonnes
Daily Pollutant
7B Main Crane
7BAuxilliary1
7BAuxilliary2
7BAuxilliary3
Accomodation Barge(Floatel)
Accomodation BargeCRANE
AHV/AHTS Vessel
Light Construction Vessel
M. FORZACrane
MODU1(TENFIELD)
MODU2(JUBILEEFIELD)
Offtake Tanker1
Offtake Tanker2
Pipelay/Heavylift Vessel
POXCrane
Rigid J-Lay
Rigid S-Lay
Security Boat
SKANDICrane
Supply/AHTSVessel
SupplyVessel

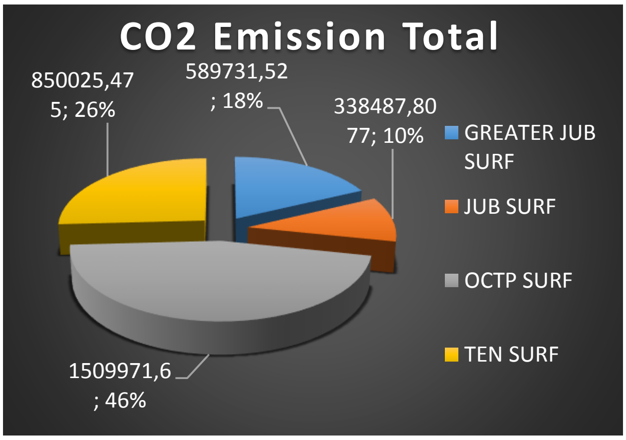
Several tow operations. The OCTP surf operations which lasted for over a one and half year period, in general, saw high-level operation from various vessels that contributed to NOx, SOx, and CO emissions greater than 8,000tonnes and under 20,000tonnes. NOx from Tugs were as high as over 24,000tonnes. The Greater Jubilee project of 2020, which encompasses both the Jubilee and TEN production field development, also showed similar trends in regards to air emission pollution estimates throughout the study. As seen in Figure 85, emissions estimated for the eighty-nine (89) days period were relatively low compared to other operational periods under the study. This estimates, however, reflected the general trend relative to vessel types in operation. Again, from the chart, it can be observed that ship machinery estimates were also derived, but emission data obtained were relatively low in concentration (thus under 600tonnes for all the categories of air pollutant examined).



Overall, PM10 (shown in Figure 85) from the source was also significantly high, especially of the concentration from combustion, thus Black Carbon aerosol (Lack et al., 2008; Koch and Hansen, 2005) emissions which has a high affinity to forming Cloud Condensate Nuclei capable of influencing the rainfall patterns of the region. It is, however, unclear if this is currently the case of emissions for ships operated over the years since there have been no baseline studies for such comparison of the current weather trends. As observed in the study, there is no doubt that these anthropogenic emissions from ship funnels, including *PO* vessels, are reshaping the natural environment. Again, as witnessed in Figure 82 (on the previous page), plumes of gas flared by the Jubilee FPSO KNK rose steadily into the atmosphere to form a thick white cloud over some time. This observation suggested an unnatural cloud activity –such as cloud condensate nuclei, capable of contributing to rainfall patterns of the area which needs studying into detail. Also, given that general visibility in the region was relatively high (10nm - 12nm) with occasional lows under 3 to 4 nautical miles. There were intermittent rainfalls all year round with the barest minimum cloud activity. The situations compound with the flaring of natural hydrocarbon gas from the production installations. The flaring necessitated following low productivity challenge suffered by Tullow reinjecting the gas back into the wells as a result of a failure in being able to supply it to the domestic market. There was also the fear of it destabilising the wells with excess pressure according to the engineers. The Government of Ghana, therefore, consented to a flaring arrangement which commenced February 2020. Thus the dichotomy of having to take decisions risking emission impact, which is only an environmental concern over possible Well blowout with both economic and environmental concerns was a challenge on environmental regulations implemented by the state. Other oil and gas fields FPSO units did only flared the generally associated gases such as SO2 (Sackey and Lamptey, 2019). Again, continuous flaring appeared to influence the immediate atmospheric temperature gradient within its immediate surrounding. This dynamics as to what extent the effect is shaping the atmospheric pressure and general humidity also remains unknown statistically. Further studies in regard will provide more in-depth insight.

The Global Warming Potential

CO_2 concentration during the various surf operations and its contribution to GHG emissions (+1.56 Wm^{-2}) as a radiative force contribution to emissions were high than all other GHG CO_2 equivalent (CO_2e) pollutants. As can be seen in Figure 86, 46 per cent of the 3,288,216.403tonnes GHG CO_2 (*GWP=1*) emissions estimated at 1,509,971.6 tonnes was released during the OCTP-Sankofa Gye Nyame oil and gas field development in the year 2017-2018 surf operations alone, within the western basin offshore Ghana. This estimate is in sharp contrast with ESL-ENI Spa (2017) EIA CO2 emission estimate of 88,352,125.19 kg (88,352.12519tonnes) which focused on limited pollutants such as *drilling unit, supply vessels, gas flared in production testing, and oil burned in production testing*. Overall, a GWP value of 88,477,288.75kg CO_2 equivalent estimated for the period of OCTP emission observation (ESL-ENI Spa, 2017). The study estimate 1,509,971.6 tonnes represent 46 per cent of total emissions on surf operations offshore Ghana.



Again, from the chart, the remaining estimates of CO_2 emissions thus was 26 per cent representing 850,025.475tonnes and 18 per cent representing 589,731.52tonnes. The rest being 10 (33,847.8077tonnes) per cent were emissions resulting from the other surf operations observed in the study region. In a related development concerning GHG emissions, IFC report (2019) also referenced TGL activities resulting in an annual estimated total of 1,160,511 tonnes of CO2 equivalent (tC02eq) in 2018, compared to a 2017 GHG emission estimated at approximately 1,494,870 tC02 eq. The slight difference attributed to the drop in flaring from the TEN and Jubilee fields. Their estimates factored in: the Well Engineering Operations Jubilee and TEN Fields for a Total tCO2eq; the Production Operations - Jubilee and TEN FPSOs' for a Total tCO2 eq; and the Aviation and Marine Transport for the Total tCO2 eq. Similarly, employing the same empirical formula based on IPPC (2006) CO_2 conversion factors, GWP for the other GHG emissions are presented in Table 26 below.

Table 26: The Global Warming Potential (GWP) of GHG emissions over the four surf operations

Pollution	NOx in tonnes	VOC in tonnes	CO in tonnes	CO2 in tonnes	CH4 in tonnes	TOTAL GWP in tonnes CO2 equivalent
Estimated Tonnes	55761.81341	1674.702074	15580.5674	3,288,216.403	295.9737256	
Individual GWP values in metric tonnes CO2 equivalent	15,074,707	37,982	51,826	2,983,020	6,713	**18,154,248**

Source compilation: EIA of TGL (2009:2015), 2015, 2017 and 2020 Field surveys data

In summary, a total of 18,154,248 metric tonne CO_2 equivalent (20,011,634 tCO_2e) discharged into the atmosphere span 2009, 2015, 2017 and 2020 surf operations period within the DWT, WCTP, and OCTP oil and gas licensing blocks of Tullow and ENI. This GHG emissions metric is a significant contribution having a direct impact on the climate of the area, though it is unclear how much of an effect experienced. This effect needs examining going forward as offshore operations in the region are continually growing.

(b) Oil spills as Liquid Pollutant Concerns for marine life and environment: The 2020 first quarter (Q1 89day) eighty-nine-day period surf operations aboard the PO vessels offered the researcher the opportunity to observe closely the nature of operations that were potentially at risk of producing operational oil spill discharges. The final quarter help with reconciling observation of first-hand knowledge on the possibility of accidental oil spillage resulting from the hydrocarbon storage facility (FPSO) offshore. Observations of patterns in the weather and ocean environment were also to aid in developing an understanding of useful spills upon occurrences. This pattern was particularly crucial to determining any oil spill trajectory. As mentioned, the risks identified were of two folds, the third identified here is subject to Well stability and are all explained as follows;

i) ***Oil spillage occurring through operational Discharges***— operations on the field for all vessels took place at a continuous 24hr period nonstop. These operations meant a continuous usage of fuel in powering machinery systems throughout operations. The fuel relatively was a finite resource that required the need for refilling using pumps and horses connected to another marine vessel (see Table 27).

Several bunkering operations of this nature (also known as bunkering) observed on the field appear in the table below.

Table 27: Bunkering operations recorded between Jan-Mar, 2020

Ship Type	Fuel Type	Time Duration of Transfer in hours	Number of Bunkering Ops	Estimated Quantities of Fuel Received in Metric Tonnes
Heavylift / Pipelay	MDO	5	3	1,000.00
Acomodation Barge/ Floatel	MDO	4	3	1,000.00
FPSO Unit	MGO	4	2	unknown amount

Source: Field survey 2020

ii) ***Oil spillage occurring during and after oil offtake operations***— such situational spills were not a common future at the time of study due to the stringent measures put in place to limit its occurrences. This operation primarily differed from bunkering operations that periodically witnessed on the field. The operations involved the connection of the FPSO KNK unit with the shuttle tanker positioned at a distance (see Figure 87). A floatable connection hose used to achieve this operation. The operation did require the oil tanker vessels coming alongside and receiving the supply hose with the aid of a support tug boat.

Due to the critical nature of the operation, two standby support vessels are engaged in the process to ensure the danger of collision also was eliminated. After oil offtake pumping is completed, the supply hose is blown through with air to ensure there is no residual oil before it is wet-stored on the sea (as can be seen in Figure 88).

Oil spillage from such operations may result from many varying situational incidences for that matter. Over the period only two small incidental spills sheen were sighted on the Jubilee field. This observed spill is shown in Figure 81. The oil slick observed is a small amount of oil that might have resulted from accidental discharge. Several incidental oil slick and mud discharges were also sighted on the Sankofa Gye Nyame oil field during the 2017 development period.

iii) ***Accidents or Possible Blowouts***— though accidents commonly future in the workplace environment, and offshore operations world over, have had a fair share of accidental disasters right through 1964, 1982, 1988, 2005 and 2010 (Verdict Media Limited, 2019; also *for stats refer to Bureau of Safety and Environmental Enforcement US Department of the Interior, 2o19 at https://www.bsee.gov/stats-facts/offshore-incident-statistics*), Ghana's offshore is yet to experience such misfortune. A case in point being the BP oil spill of 2010 in the Gulf of Mexico by an oil rig blowout.

Other accidental spillages have resulted from carrier tankers either running aground or in a collision course –with the most recent recorded case off the coast of Mauritius. MV Wakashio on July 25 carrying 4,000metric tonne of oil grounded on a coral reef –leaking fuel oil into the Indian Ocean polluting the reef and surrounding beaches (NASA, 2020). Concerning such spill potentials, several measures were in place to limit the risk on the field. Such measures included the use of support tugs during offtake operations within the 500-meter zone. Again, all vessels were required to maintain the 500-meter zone safety during their operations while on the field. The vessel, in this case, were only allowed into the 500meter zone upon meeting permit entry requirement. One such requirement for vessels when entering the FPSO unit area is the avoidance of all hot works on deck, including the nonsmoking requirement of the crew in the open.

Where Well blowout is of concern, the stability of Wells continuously monitored through the control systems for pressure variabilities, does according to TGL resource person. Because operational calls are a constant feature around offshore installations, especially for tanker off-loading operations, a significant step at reducing the risk of accidental spill according to TGL was the installation of the turret mooring buoy one nautical mile away from the FPSO unit from which offtake tankers loaded before sail away. All these are bold measures sort to limit the risk of accidental spillages.

Nonetheless, the entire risks not eliminated with every single operation that occurs in the area –hence the reason for oil spill emergency response plans to be a secondary requirement by operators and government. Well, blowout fundamentally is as it stands, difficult to predict given all the safety measures deployed in Well developments, and therefore contingency measures towards responding to such situations are the only option available to stakeholders. Over the years, blowouts have resulted due to many varied reasons, including equipment failure, poor calibration, and excessive Well pressure. For this reason, given that new wells, as well as old production, remain in active service offshore Ghana, continuous monitoring of these Wells is part of the production process according to engineers. They recognised that such incidences are likely to result in large oil spills, possible explosions and fires and eventual distraction of living, property and environment. Hence, understanding the trajectory of a massive oil spill in the area will help develop a better understanding of situational controls. There were no simulations for spill trajectory as intended at this stage due to some technicalities; it, however, is the focus of the next paper with the aid of MIKE ocean modelling software on the subject of adequate regulations, conservation and oil spill contingency plans and response.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The chapter discussed is of each case study examining the ocean environment and the level of biodiversity when the Gulf of Guinea sub-region; attempting an estimation of the marine mammal population at the given time, and determining the impact of anthropogenic concerns arising out of the growing oil and gas development. The chapter thus projects a summary, conclusions and recommendations from the various studies. Details are as presented in the proceeding paragraphs.

5.1.1 Fundamentals of the Marine Environment

The region under the study appeared to have rich biodiversity –fostering the presence of various marine animals clustered along with the various web of the food chain. The tropical nature of the region meant high radiation influx from the sun— leading to the thermal insulation of the Area. The temperature recordings taking were a direct function of the solar energy absorbed into the atmosphere, delimiting humidity infrared wave outputs. The dynamic also is critical to the ocean and atmospheric relationship— thus, driving both wind and ocean current circulations. Winds observed were within southwestern quadrants, similar to ocean surface currents. The ocean sampled showed consistency with underlining EBS studies. Thus, from all the locations sampled in this study with results presented in Section 4.1.4.2, density remained relatively constant and in agreement with Boussinesq Approximation (Bastiaan Willink (2008); Joseph Boussinesq, 1842-1929) principles and assumptions, except where gravity was of concern. In this case, the study looks into marine animals' navigations and marine assets movement within water columns of the offshore marine environment. Sea temperatures also showed a pattern of declination along with the water depth (pressure) from the ocean surface to the bottom (seafloor). Variation in salinity in some cases was relatively small. These two conditions have a direct impact on sound travel in the ocean, though the latter (salinity recordings) in this case is negligible. The velocity at which sound travels in the ocean environment is primary to the marine animals' interactions of the region (NOAA, (2016: 63-64); Stewart, 2008). This velocity was also imperative in understanding the adverse effect of the anthropogenic noises generated by marine assets. Sound velocity from the study region recorded is found in the Appendix. According to Stewart (2008), typical ocean conditions, project speed within the range of 1450m/s to 1550m/s. The study's findings of 1493.5m/s and 1534.74m/s (summarized in Table 28) for station P1 (Jubilee P1 Manifold) Location agree with this typical ocean speed limits determined. Profiles of velocities for the various locations graphically have been given in the Appendix.

Table 28: Summary of Sound Velocity Estimate from Jubilee P1 Manifold Location

Water Depth	Statistical Summary	Velocity	Statistical Summary
Mean	621.5m	Mean	1505.104m/s
Standard Error	10.12011	Standard Error	0.317054
Median	621.5m	Median	1501.335m/s
Mode	#N/A	Mode	1493.72
Standard Deviation	354.6374	Standard Deviation	11.11048
Sample Variance	125767.7	Sample Variance	123.4428
Kurtosis	-1.2	Kurtosis	-0.07645
Skewness	-8.4E-17	Skewness	0.966338
Range	1227	Range	41.24
Minimum	8m	Minimum	1493.5m/s
Maximum	1235m	Maximum	1534.74m/s
Sum	763202	Sum	1848268
Count	1228	Count	1228

**Source: Field data. Velocities calculated based on MacKenzie, (1981); Munk et al. (1995 pp33). Refer to Appendix and supplementary material for detailed analysis of all the locations sampled.*

Another ocean condition that delineates the habitable nature of the offshore region was about the amount of dissolved oxygen mix in the water. Dissolved oxygen is a necessity to many lifeforms, and that includes fish, invertebrates, bacteria and plants (Fondriest Environmental, Inc., 2013). Fondriest Environmental, Inc., (2013) reiterated that organisms within the marine environment use this oxygen for respiration; thus, in similar ways to living organisms found on land. They described the respiration process in fish and crustaceans as one that occurred through the use of gills. They also emphasised that dissolved oxygen for respiration only took place in plant life and phytoplankton, during periods of unavailable sunlight for photosynthesis –and thus, suggesting the amount of dissolved oxygen needed by organisms varied. This assertion is true as the samples from the study showed D.O. levels relatively lower near sea surface compared to the ocean bottom dwellers. The dissolved oxygen structure along with the water depth also did suggest the nature of habitat stratification at each location— with regions of less D.O. indicating areas of dense marine habitats. In other words, more animals inhabited are near the ocean surface. Fondriest Environmental, Inc., (2013) cites organisms (sea bottom feeders) such as crabs, oysters and worms as those requiring minimal oxygen of 1-6 mg/L, compared to shallow water fish –requiring higher levels of 4-15 mg/L [Osmond, D.L., D.E. Line, J.A. Gale, R.W. Gannon, C.B. Knott, K.A. Bartenhagen, M.H. Turner, S.W. Coffey, J. Spooner, J. Wells, J.C. Walker, L.L. Hargrove, M.A. Foster, P.D. Robillard, and D.W. Lehning. (1995)]. Therefore, marine mammals of the order *Odoncetes* such as pilot whales, bottlenose dolphins, and predator fish like sharks sighted, find the area as a conducive feeding ground. The above discussed, therefore, are the underlining condition of the marine environment of the area favourable to living mammals. (Refer to section 4.2 to read about the population of animals inhabiting the area)

5.1.2 Understanding the Marine Population

The study surveyed cetacean populations within the offshore Jubilee oil field construction site to develop an understanding of the population of animals in the Area and how they interacted with construction operations. The study sort expert opinions on relevant concerns and undertook and shipboard survey within January to March, and September when due to covid-19 concerns the study proceeded to an abrupt end amidst the suspension of the pipeline production project by seven Borealis. Overall weather was good, with an irregular pattern of rainfalls occurring at various points in time. The average Visibility was 6 to 8 nautical mile (see section 4.1), allowing observers to carry out sighting watches within areas of the designed sampler radial distances. Virtually, all sighting occurred during the day with fewer mention of night time sightings which discussed concerns of nocturnal animal behaviour.

In summary, the animal population abundance at 160.00 (CV = 0.3728) animals with an estimated density of 0.30749 (CV= *0*.3728) over the entire study region. An average cluster size of 17.950 and 23.482 was observed within respective status— projecting a pooled cluster density of 0.14247E-01. Animals showed a curious and intrusive behaviour on the field coming in at close as within 36 meters from construction (*PO*) vessel while cycling vessel for a period before moving on. Vessel operators were aware of the situations and to mitigative measures to the best of their abilities, where they deem the danger posed was inevitable. Where state's mandate was of concern, it notes the little progress made, thus with no long-term biodiversity conservation policy for these living marine mammals.

5.1.3 The Growing Anthropogenic Challenges

The issue of pollution is an environmental condition that seems never to go away as long as human beings are of concern. This challenges embattles of life forms across every natural life-supporting medium, be it the oceans, atmosphere or land. In the ocean environment, though the quantum of this impacts remains mostly under quantified, rough estimates of ocean plastics alone –according to Ourworld (2014), amounts to 5.25 trillion pieces whereas the rest remains unknown. They identified that two mechanisms are accelerating the plastic phenomenon; gyres, pulverise plastic, and ocean currents do the transportation of the plastic across the length and breadth of the world. Researcher, Dr Marcus Erikson in visualising it, explained that it could compare to Two-liter plastic bottles stacked together end-to-end forming a column to the moon and back twice as reported by our world (ourworld.unu.edu, 2014). They further suggested micro-plastics— numbering 100 times less than expected as the most toxic and chemically lethal form of the plastic pollutants. The right sizes of this plastic debris are often mistaking as food by hungry fishes among other filter-feeding marine lives, thereby congesting them to their very deaths (ourworld.unu.edu, 2014). This situation, therefore, presents a most significant challenge to the food chains environment of the ocean biodiversity despite the global consented efforts directed at minimising if not eliminate the problem.

Other pollution contenders of primary interest to this study are oil spillages or operational discharges and carbon emissions from marine vessels at sea. Lamptey and Sackey, (2017), affirmed in their study that operational discharges and oil spillages, in general, are a constant feature in Ghana's maritime waters. Moreover, thus with the challenge been the need for adequate surveillance detection and monitoring where both recalcitrant vessels undertaking the right of innocent passage and those calling or after calling on nations port and offshore facilities are a concern. They highlighted the spillage incident off the coast of Angola by motto tanker vessel ABT Summer (Farzaneh, 2010) and the 2010 BP well blowout incident the Gulf of Mexico spilling several millions of gallons of crude oil to the devastation of marine live and coastal and marine environments stretching mile and mile towards shore (myjoyonline, 2010). Concerning monitoring, Lamptey B. L., and Sackey A. D., (2017), in considering the potential devastation if such situation occurs in Ghana's coast and offshore environment; decried the sole reliance on local fishers as informants, random patrols, one-off hire of aircraft patrols which never fully helped with apprehending the culprits while suggesting the combined use of the Vessel Traffic Management Information System (VTMIS) and satellite monitoring for early warning and vessel tracking. According to them factoring these measures alongside the strict reliance on state functionalities like Port state control inspections and provision of shore receptacles for waste management towards the implementation of the Marpol 78 conventions will ensure the sustenance of the environment. The next concern is with carbon emissions into the atmosphere. This study focusing on marine oil and gas offshore operations takes a closer look into the operations of highly specialised vessels with capabilities beyond the average vessel operation requirements. Subject to the long hours of DP manoeuvrings and the environmental conditions, there are growing concerns about black carbon emissions.

In contrast, current studies have related plumes concentrations for vessel activity –remarkably, within a port environment where according to Lack et al., (2008) remains high, they suggest it remains high also amongst offshore support vessels and vessels proceeding at slow speed within port areas. This assertion goes to the root of offshore operations, which is characterised mainly by dynamic (stationary) position (DP) keeping, dead-slow manoeuvring speeds, harsher environment and massive power-consuming pieces of machinery. This DP operation affects the fuel consumption rates and the need for bunkering operations offshore. This situation, therefore, is a potential for oil spillage and reason for a thorough examination of the risks.

5.2 Conclusions

The study's findings have highlighted several concerns within the marine environment with considerable challenges as offshore operations continue to expand in the Gulf of Guinea of West and Central Africa. The area naturally is beset with rich marine and coastal eco biodiversity that require some protection and development. Again, the Cape Three Point enclave suggest the possible presence of coral reefs along the stretch of the west coast due to the long term effects of wind and ocean current dynamics of the area. Researcher suggests some of these reefs are identified but remain unexplored. Marine wildlife conservatory monitoring has not been prioritised in Africa regardless of the economic benefits local economies stand to gain (e.g. tourism). Ghana's situation is no different in this regard. Anthropogenic activities near coast and offshore therefore risk the destruction of these biodiversities if no proper and stringent effort is put in place to ensure its sustenance. The situation also does have health implications for human life and animals in general. It concludes by alluding to the single fact that environmental safety is only expensive and properly value only after the fact of an incident had occurred. Going by this approach with the *'wait and see'* attitude in environmental governance is not a sound and prudent management practice anywhere in the world. These animals have economic benefit in terms of tourism if properly managed, especially during the breeding season and winter season when they deck around our coast. After these findings, the study, therefore, concludes by making a few recommendations.

5.3 Recommendations

The recommendations directed are towards policymakers, and stakeholders of the maritime industry and well as academia (see Figure 90).

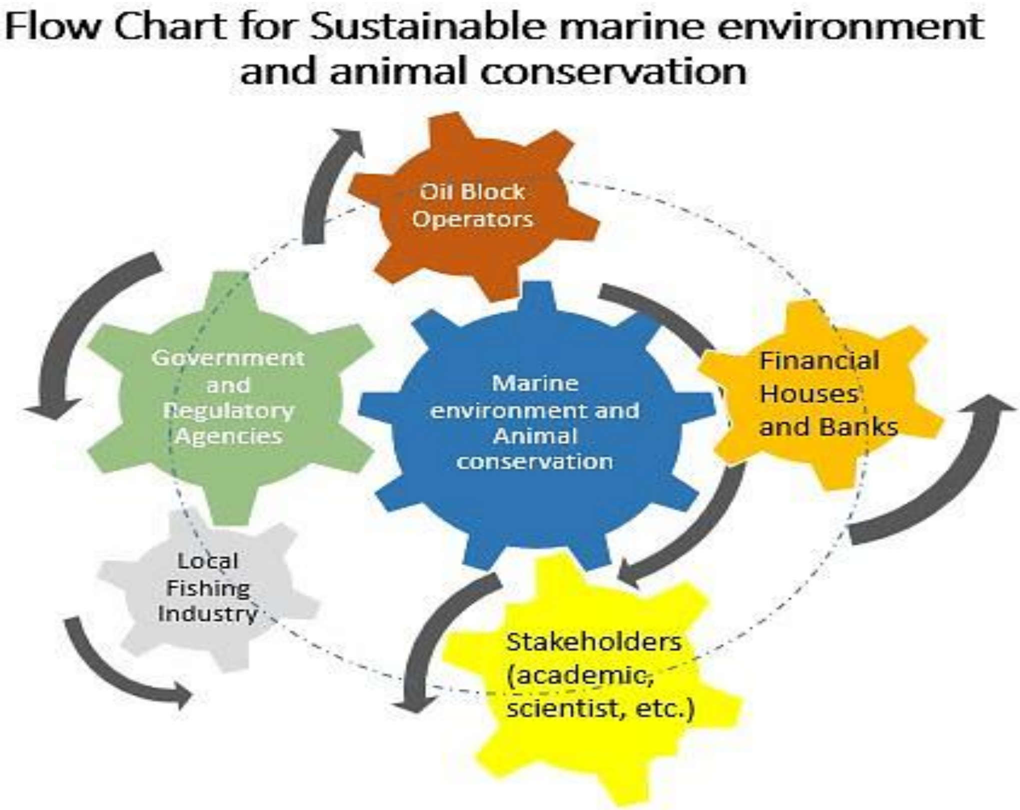


Figure 90: Recommended collaborator for effort marine live and environment sustenance

This stated schematic flow chart is explained as follows.

5.3.1 Recommended obligation for Government

a) Though environmental concerns appear prioritised to be within the upstream sector per contracting or licensing regulations expressed in agreements between the state and interested parties therein, in practice, there is very little done to ensure long-term sustainable environmental outcomes by the state. The EIA, which is the foundational document produced by oil and gas operators before and during exploration and development in meeting environment requirement, is not enough in ensuring long-term sustainable environmental outcomes for marine biodiversity. As offshore operations grow, it has become more critical, that the state delineate the region via mapping of the mammal habitation in an effort geared towards establishing sanctuary zone within the EEZ aimed at promoting marine biodiversity.

b) The failure of government institutions mandated to ensure marine conservation has seen little to no redress or prioritisation despite the clear-cut evidence of marine mammal mortality occurring along the coast. Not much reported is on the current state of affairs, except perhaps concerns of carcasses found on the shores of coastal communities from time to time. This situation notwithstanding, it is imperative that animals within offshore exploration, development and production areas are monitored to ensure any changes in behaviour and population trends are recorded and used in decision making. The failure or Lack thereof stems from the high cost involved in such surveys and monitoring, equipment and training. This financial predicament can be augmented if Government on award and acceptance of any plan of development (*PoD*) in any offshore block, elect mammal surveys and monitoring as an expressed prerequisite requirement before accepting any *PoD.* Such an effort should be separate from the general EIA requirement developed before exploration and development. Effectively, this will help grow the capacity of staff while making the needed tools available.

c) The current challenge of not knowing whether dolphins have deliberately been harvested and used as bait for sharks or a mere case of by-catch remains unacceptable. This situation, according to communications spokesperson at the Ghana wildlife society –suggest a rising mortality rate beyond simple concerns of by-catch. At least, the video evidence they obtained remains hard to prove the current trend. It is therefore imperative for Government to liaise with private institutions among other stakeholders, in this efforts and support conservation effort with a legislative instrument, instituting a ban on dolphin harvesting.

d) Enforcement of conservatory laws requires punitive measures, which can only be actualised if crimes are detected or reported and punished. This application of the law can only mean efficient monitoring or surveillance. Therefore, besides public education for the fisher folks, setting up a coastal community marine mammal watchdog or policing team within all landing beaches would be required to serve as a deterrent in ending the harvesting of dolphins.

5.3.2 Recommended Obligation to Financial Institutions

e) The World Bank's apparent motivation referred to in earlier paragraphs, can constitute a useful model for financial houses involved in the upstream industry in implementing local conservatory monitoring along meeting the financing required to Oil field operators. This policy will help developing nations in the offshore oil and gas industry to meet local conservatory requirements where states institutions have been ineffective. Due to the many conditions such as inadequate funds, promoting foreign investment, and reducing unemployment, states are unable to ensure complete marine environmental sustenance for both the local fishery industry and maritime. Again, Ghana's Government should demand, as either part of organisations' corporate social responsibility, or requirement in oil block licensing agreement, to have onboard an appointed marine scientist or marine environmental scientist as a third-party monitor throughout the various operational phases. Thus the marine conservation clause should be part of agreements negotiated with the client before sponsorship.

5.3.3 Recommended Obligation to Marine Researchers and Academic Institutions

f) Currently, there is a single active marine scientist in Ghana. Ten (10) years is by far a good enough time for anyone seeking to develop an interest in the oil and gas industry to ever do so, however, due to restrictive nature of the industry as a result of high capital assets and skilled competencies required such interest in relatively on the low in Africa, and Ghana in particular. Many students are unsure which career choices are there in the offshore industry. With many taking up courses in oil and gas and remaining redundant long after completion, the Researcher believe the interest of student can be kindled in marine conservationism to help grown data in the sector in order to help drive environmental development. Academic institutions are in an excellent position to lead the charge and liaise with industry to help whip up student interest.

g) Again, research has shown that there is currently limited knowledge on marine mammal population estimations along the entire west coast of Africa. This limitation leaves a depth of knowledge gap –needful of filling if we compared the Area to other parts of the world. The petroleum commission of Ghana in a 2019 July capacity building conference for local and indigenous companies for which Researcher was privileged to have attended, highlighted the problem of luck in data while recommending local firms in the upstream sector to take up the challenge of developing a service package in this regard. Indeed, the challenge comes with the opportunity to academia, a marine scientist and marine environmental researchers within the west coast of Africa in filling the gap. Without the needed research, efforts seen in marine animal conservations will continue to below. Thus to say there will be little to no adequate attention given to concerns by state actors during decision making.

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APPENDIX

Tables

Table 29: Emission Factor implemented in air emission estimates based on AP-42, Lloyd register and European Union Commission data

Source	PM10	SOX	NOX	VOC	CO	CO2	CH4
AP42-TABLE 3.4	0.0573	1.01S	3.2	0.09	0.85	165	0.09
AP42-TABLE 3.3	0.31	0.29	4.41	0.36	0.95	164	0.00247
AP42-TABLE 3.1	6.60E-03	0.94S	0.003	0.0021	0.082	110	8.60E-03
Vessels Manuevers	0.4	9	10.6	0.4	2.2	717	0.008
Vessels at sea	0.2	8	13.2	0.2	1.1	652	0.004

Table 30: Table of Estimated Air Emissions from the main survey fields

PROJECT	PM10 in tones	SOx in tonnes	NOx in tonnes	VOC in tonnes	CO in tonnes	CO2 in tonnes	CH4 in tonnes
JUB SURF	148.433674	4203.37458	5882.799112	148.433674	6180.804	338487.8077	2.968673
TEN SURF	371.28	11038.3	15898.22	371.28	2048.9209	850025.475	7.4256
OCTP SURF	763.942192	18839.3408	24039.728	834.6736	5358.584	1509971.6	207.4736
GREATER JUB SURF	290.7601	7233.9747	9941.0663	320.3148	1992.2585	589731.52	78.10585
SUM TOTAL	**1574.415966**	**41314.99008**	**55761.81341**	**1674.702074**	**15580.5674**	**3288216.403**	**295.9737**

Table 31: Estimated Global Warming Potential

Pollution	NOx in tonnes	VOC in tonnes	CO in tonnes	CO2 in tonnes	CH4 in tonnes	TOTAL GWP in tonnes CO2 equivalent
tonnes	55761.81341	1674.702074	15580.5674	3288216.403	295.9737256	
Individual GWP in metric tonnes CO2 equivalent	15,074,707	37,982	51,826	2,983,020	6,713	18,154,248

GRAPHS

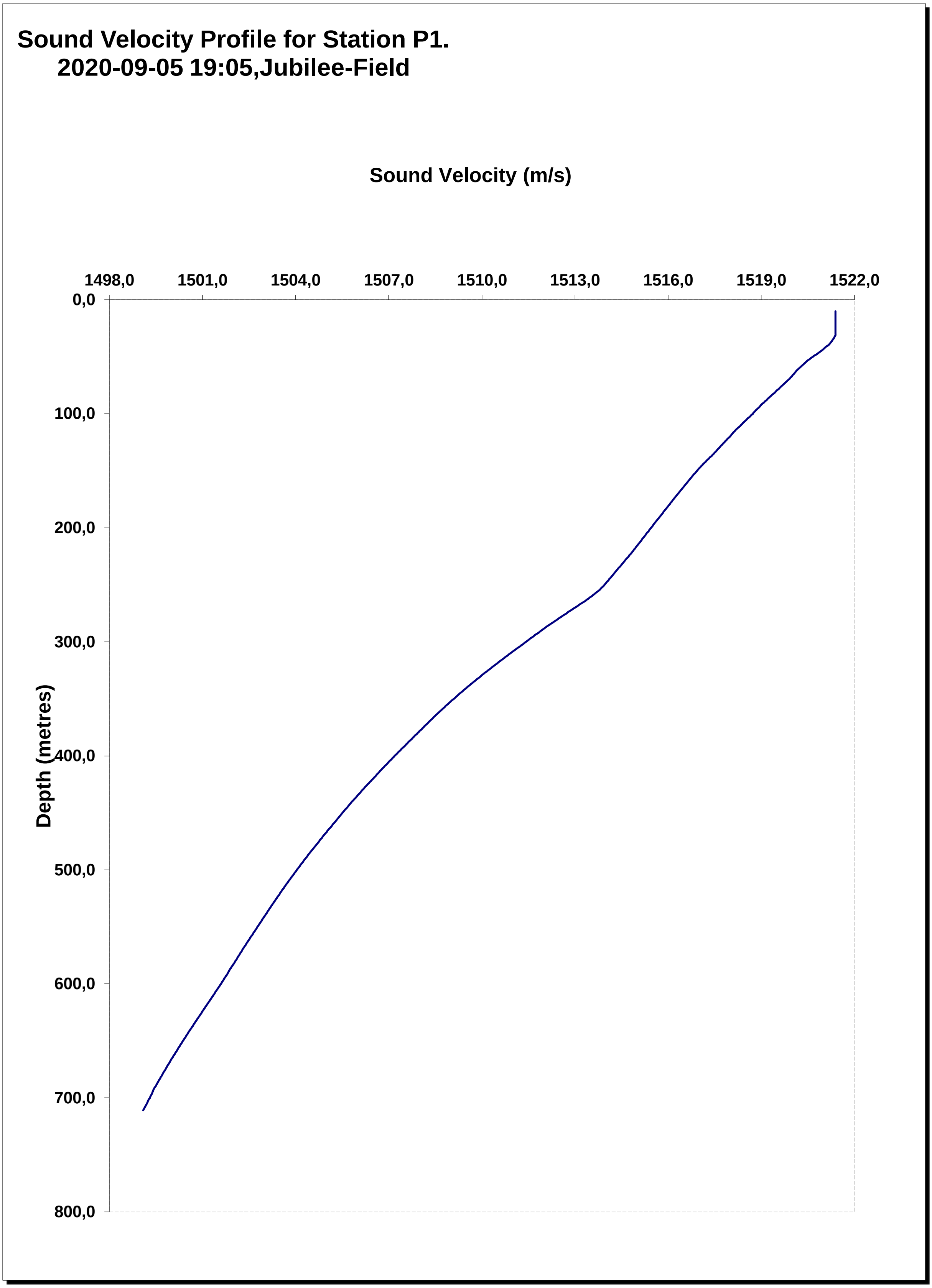

Figure 91: STATION P1 VELOCITY READING

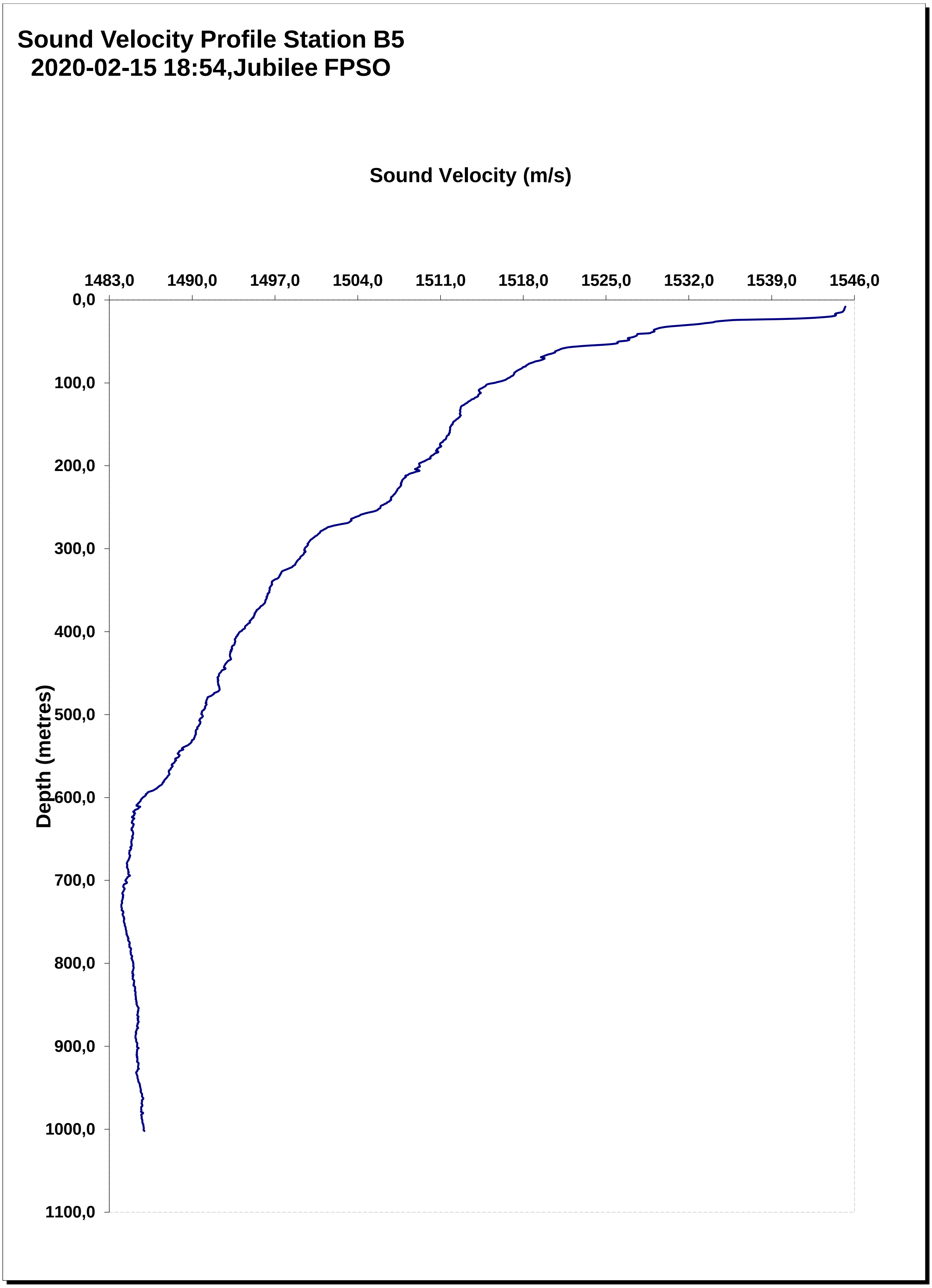

Figure 92: STATION B5 VELOCITY READINGS AT JUBILEE FIELD

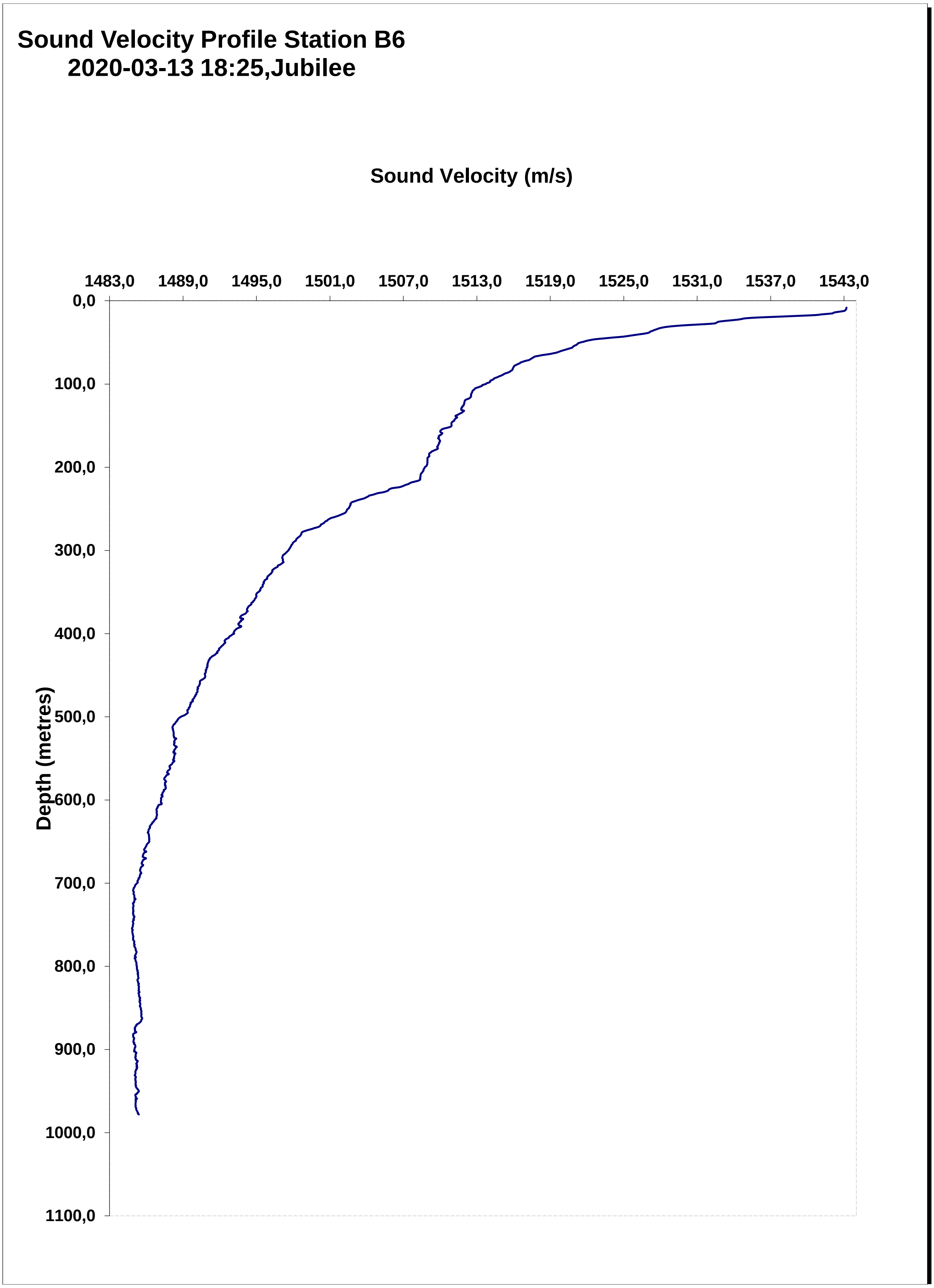

Figure 93: STATION B6 VELOCITY READING AT JUBILEE FIELD LOCATION

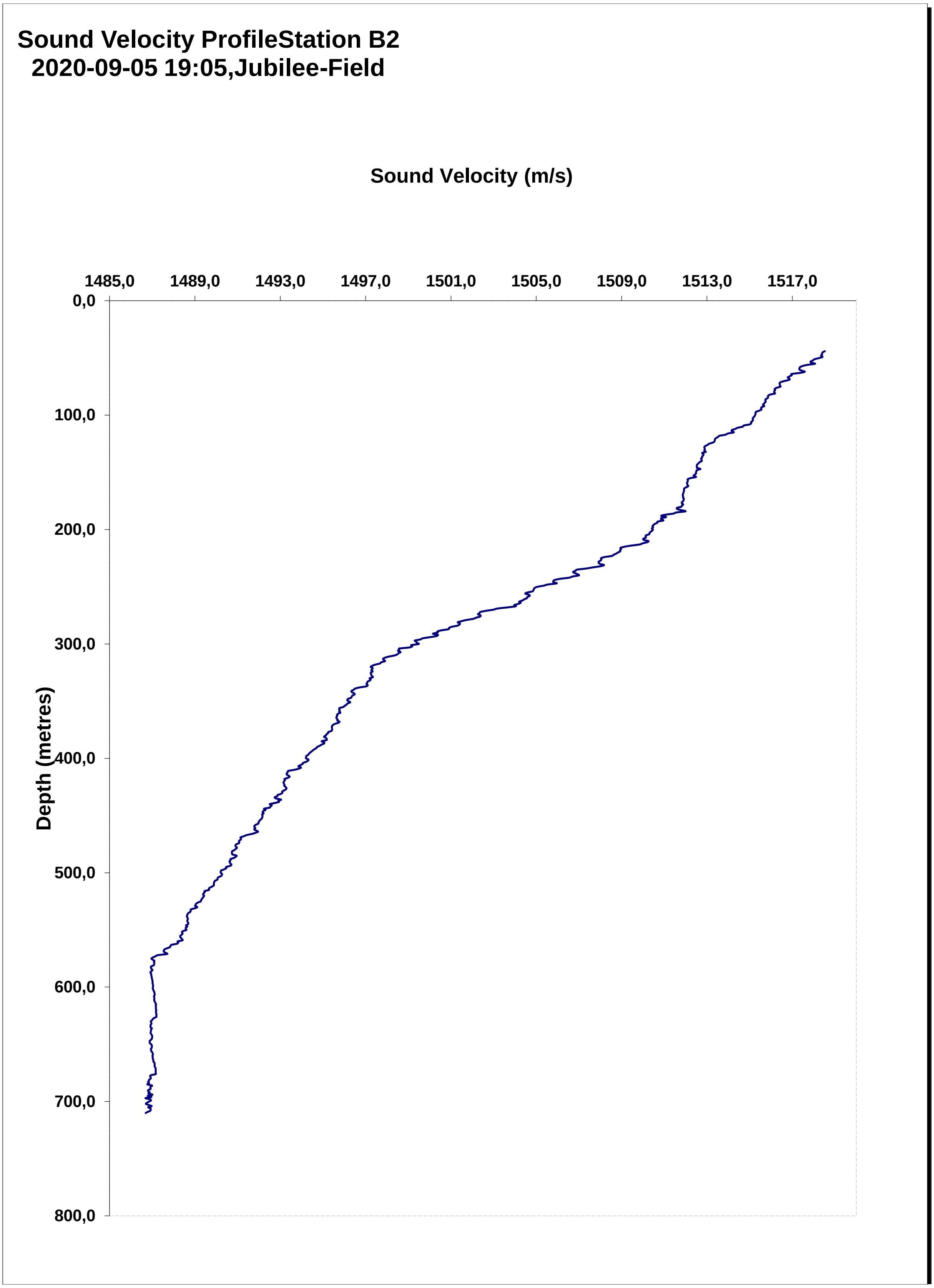

Figure 94: STATION B2 SOUND VELOCITY