UNIVERSITY OF CAPE COAST

ASSESSMENT OF THE IMPACT OF LIGHT EMITTING DIODE (LED)-FITTED GILL NETS ON SEA TURTLE AND FISH CATCH IN THE COASTAL WATERS OF MANKOADZE, GHANA

BY

ANDREWS AGYEKUMHENE

JANUARY 2020

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THESIS SUBMITTED TO THE DEPARTMENT OF FISHERIES AND AQUATIC SCIENCES, SCHOOL OF BIOLOGICAL SCIENCES, COLLEGE OF AGRICULTURAL AND NATURAL SCIENCES, UNIVERSITY OF CAPE COAST IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY DEGREE IN INTEGRATED COASTAL ZONE MANAGEMENT

JANUARY 2020

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature... Date...............................

Name: Andrews Agyekumhene

Supervisors' declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature: ……………………..……... Date ....

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Co – Supervisor's Signature: ……………………………… Date ……………………

Name: Prof. Edward A. Obodai

ABSTRACT

This study investigated the impact of light emitting diode (LED)-fitted gill nets on sea turtle and fish catch in the coastal waters of Mankoadze, Ghana. The study also assessed the artisanal fishery of the area and quantified the annual rate of sea turtle by-catch in the artisanal fishery. The methods used included interviews, analysis of fish landing data from Fisheries Commission and field data collection. The results indicated that set net was the most dominant fishing gear used in the coastal waters of Gomoa and Effutu, and comprised 35.6% of the total gears. Data from Fisheries Commission indicated that a total of 74 fish species belonging to 37 families were caught between 2001 and 2015 in the artisanal fishery. There was an increase in the number of artisanal fishermen and canoes in the study area by 13.0% and 27.5% respectively from 2001 to 2013, resulting in continuous decline in fish catches from 29,697.89 tonnes in 2001 to 7,213.66 tonnes in 2013. Catches of the common fish species (*Sardinella* spp., *Engraulis encrasicolus* and *Euthynnus alletteratus*) were highest during the months of July to October. The results also indicated that, irrespective of species, sea turtles were captured as by-catch in artisanal fishing gears at an average rate of 4 turtles per canoe per year. The leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*) and the olive ridley (*Lepidochelys olivacea*) were the three main species captured. Deployment of LED lights on fishing nets resulted in a significantly lower ($t=3.65$, $p<0.05$) turtle by-catch in nets using the LED lights (4.6±1.2 turtle/100 m net/12 hrs) than in the nets without LED lights (6.5±2.1 turtle/100 m net/12 hrs), but did not significantly ($t= 2.14$, $P>0.05$) influence the fish catch. It was concluded from the study that LED light is an effective turtle by-catch reduction device. A recommendation for further studies on behavioural adaptation of sea turtles to LED light has been made.

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DEDICATION

I wholly dedicate this work to my wife Rebecca Osafo Agyekumhene and my two sons, Brendan Nana Yaw Kusi Agyekumhene and Aiden Kwabena Agyekumhene.

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CHAPTER ONE

INTRODUCTION AND BACKGROUND

Marine fishery

Global capture fisheries play important role in the global ecosystem, economy and human diets. Of the 93.4 million tonnes landed in 2014, 81.5 million tonnes was from marine waters and 11.9 million tonnes from inland waters (FAO, 2016b). Global fishery production from the marine waters has recorded increases over the years. For instance the world's fish catch rose from an estimated 74.9 million tonnes in 2011 (FAO, 2012) to 81.5 million tonnes in 2014 (FAO, 2016b). This huge production coupled with increase in consumption of fish increased the intake of animal protein by 20% and subsequently enhanced consumers' diets globally through several nutrient-rich foods (Bennett et al., 2018).

About 28.5 million people are directly employed by the marine fishing sector (both industrial and artisanal) across the globe with tens of millions more (many of them women involved in fish processing) indirectly employed. Of these figures, artisanal or small-scale fishing comprises 90% of all fishing jobs worldwide, represents approximately 45% of the world's fisheries, and produces nearly a quarter of the world catch (Schoor, 2005).

The involvement of international trade in fisheries has played an important role in establishing several beneficial opportunities such as employment creation, food and nutrition security, and income generation, thereby contributing to the overall boosting of the economic profile and development growth of countries involved in major fishing activities (FAO, 2016b). The employment status for fisheries was boosted by 36%, 23% and 40% for fishers engaged in it full-time, part-time and occasional fishing respectively with about 19% of the total workforce in the sector being women who are mainly into fish processing and trading (FAO, 2016a).

The fishery resources of the marine ecosystem are vitally important and highly depended upon. These resources were previously considered unlimited and renewable, but with increased human knowledge and the improved technology developed by man to exploit these resources, the marine resources now appear to be exhaustible (World Bank and United Nations Department of Economic and Social Affairs, 2017). This increasing fishing effort on marine stocks has major impacts on the short-term dynamics and sustainability of the fish populations (Bakun, 1993). Overfishing and environmental degradation in most fishing countries continue to present huge challenges to the resource (FAO, 2012).

The decline in fish stock globally is mostly attributed to heavy commercial fishing (Nunoo et al., 2014; FAO, 2016b; Lazar et al., 2018). The use of improved technology and methods, driven by increased demand for fish food and rigorous government intervention to develop fishing sector, has resulted in widespread decline of fish stock around the globe from overfishing. Over-fishing has proven to cause changes in composition and population of both targeted and non-targeted fish species and causes an unpredictable change in marine ecosystems (Maureaud et al., 2017), with its negative impacts spreading to all oceans and seas worldwide (Schoor, 2005).

By-catch from commercial source is also an issue confronting marine fishery as some fishes caught are not used at all for any purpose but discarded. Endangered and protected species are at high risk as it reduces their already low and threatened numbers globally when harvested and discarded. The harvesting of smaller sized, though desirable species which is also associated with by-catch have over the years affected the fishery of many countries. In some instances, though the species is desirable, they are often discarded as the size influences the value of the fish on the commercial market (Wallace & Fletcher, 2001).

Marine fisheries in Ghana

The fishery sector of Ghana plays a significant role in contributing to the national socio-economic development relative to employment, livelihood, foreign exchange earnings, food security and poverty reduction. Ghana's fishery sector contributes 4.5% to the national GDP and accounts for 5% of Agricultural GDP. The sector continues to be a significant source of non-traditional export since 1984 (Quaatey, 1996). In 2010 and 2011 alone, fish and fishery products accounted for approximately 62 million US dollars and 254.4 million dollars respectively (FSSD, 2016). Fish is a preferred source of animal protein and with 75% of all domestic fish production consumed locally, fish and fish foods represents 60% of animal protein intake domestically (FAO, 2016b; FSSD, 2016). With aquaculture activities still yet to attain a sound stability, and the inland fisheries constituting only 16% of the total annual production, the marine fishery has become the mainstay of Ghana's fishery, contributing about 80% of the total fish supply.

According to FAO (2016a), the sector produces an average catch of about 300,000 metric tonnes annually. The marine fishing sector in Ghana also contributes both directly and indirectly to employment creation along the entire coastal stretch. According to FAO (2016a), many poor and vulnerable Ghanaians depend on fisheries either directly or indirectly for their livelihoods with numerous post-harvest opportunities existing in the sector to gainfully engage the needy Ghanaian on either full-time or part-time basis. As many as 2.6 million Ghanaians, representing 10% of the population, are dependent on the fisheries sector for their livelihoods. Nearly 11,583 wooden canoes operated in the marine sector in 186 fishing communities at 292 coastal landing beaches (FSSD, 2016). The marine sub-sector is also significant in supporting gender balance in its provision of labour. While the men undertake the direct fish harvesting, the women are the key players in on-shore post-harvest activities such as fish processing, storage and marketing.

Despite the fact that Ghana's commercial fishery emerged only in the 1900s, the sector is facing numerous challenges which are causing the resources to dwindle over the years. For example, the production from marine fisheries has been declining from almost 420,000 tonnes in 1999 to about 202,000 tonnes in 2014. Total fish exports also declined sharply from its peak value of USD 120 million in 2003 to USD 44 million in 2014. The major cause of the decline has been attributed to the poor governance, open-access structure of the fishery, and increasing number of fishermen which has resulted in overfishing and overcapacity of the fishing fleet (Minta, 2003; Lazar et al., 2018).

The use of bigger and more efficient fishing gear and technologies is also a cause of the drastic decline in landings (Lazar et al., 2018). Currently, the marine fisheries resource is exploited mostly by small-scale fleet of over 11,000 dugout canoes with more than half of the number motorized. The average purse seine has increased in size from about 275 m in the 1970s to about 800 m in recent times. The gross tonnage and capacity of canoes have also increased from 2 to 5 tons. With more fishing canoes moving into the industry (Koranteng et al., 1987), there is the tendency for an over-burdening situation for the marine fisheries. Between 2001 and 2013, the number of canoes in the artisanal fishery increased from 9,981 canoes to 12,728 canoes representing a 27.5% increase in artisanal fishing canoes (FSSD, 2016). Insufficient infrastructure (such as modern landing sites, leading to high postharvest losses), inappropriate and technologically-limited fishing craft and gear, inadequate fish processing and storage facilities; poor enforcement of the regulatory framework; and insufficient monitoring and surveillance of Ghana's waters are also challenges facing the marine fishery sector (FAO, 2016a). Without effective monitoring and management startegies, the sector is going to experience more and more vessels emerging into sector which will eventually result in overfishing (Nunoo & Berchie, 2013).

The drilling of oil in Ghana, has brought other challenges to the marine fishery and the industry is also greatly being affected by oil exploration activities. The oil exploration has presented fishing restriction of about 500 m exclusion zone around the oil rigs for fishermen. This restriction has compelled fishermen to travel much further from inshores shallow waters into the deep sea for fishing activities, which directly increases the cost of fishing (through increased usage of premix fuel) and reducing profit and income eventually (Egyir, 2012). The operations of the oil explorations drilling such as the use of explosives from seismic surveys affect fishing by causing fish migration farther away from familiar fishing grounds. This is creating competition among fishers leading to other related conflicts from fishing communities (Bannett et al., 2001).

Declining Ghana's marine fishery production

Increasing national population over the past two to three decades, especially in the coastal communities, has led to increasing fishing effort and a subsequent decrease in yield.

There is a general assumption by fishermen in the fishery sector that the fish stocks are inexhaustible, free and not restricted in terms of usage, and this has resulted in a negative impact on the sector, as growing population contributes to overcapacity of the fishery sector leading to overfishing and a reduction of fish population. Assessment of the fishing effort for the main fleet (canoe) show a considerable increase in the number of fishing canoes over time (FAO, 2016a; FSSD, 2016; Lazar et al., 2018). For example, the canoes frame survey by the Fisheries Scientific Survey Division (FSSD) reported an increase in the number of canoes from 3775 canoes in 2001 to 4450 in 2004 in the central region of Ghana (FSSD, 2016). The introduction and development of motorized vessels and more specialized fishing gears, coupled with the increased number of fishermen and longer fishing duration at sea has resulted in increased pressure on the fishery resources of the country (Minta, 2003).

The fishery in Ghana has exhibited high fluctuations over the years, especially the small pelagic resources, that constitutes over 70% of the annual landings from the marine sector in Ghana (FAO, 2016a; FSSD, 2016), and whose quantity and availability seem to determine the annual production of the fishery. There are corresponding yearly fluctuations in catch and catch per unit effort (CPUE). Unusually high catches were recorded in 1972 due to availability of the fish. However, poor landing was recorded in the ensuing years attributed mainly to overfishing and anomalous climatic conditions (Koranteng, 1991).

Generally, the small pelagics, like most other species in Ghanaian waters, are considered to be overexploited in spite of the recorded increases in landings during certain years (Mensah & Quaatey, 2002). Lazar et al. (2018) argue that the small pelagic resources, especially sardinella, are on the brink of collapse. The increase in fishing efforts has resulted in a decline in the annual landings for over a decade because of overfishing resulting from increase in fishing fleets. The open access system of Ghana's fishery has also resulted in increased fishing pressure from artisanal fleets who employ bigger and more efficient fishing gear and technologies. There has been an incessant sharp decline in the total fish catch since 2000 with landings reaching their lowest of 19,608 tonnes in the year 2016 (Lazar et al., 2018). This decline in catch has resulted in over 25% of fishermen returning to landing beaches with zero catch in 2017 (Lazar et al., 2018).

The rapid decline of small pelagic landings suggests that biomass has declined as a result of overfishing. This is corroborated by a noticeable decline in CPUEs and by the presence of small fish sizes in the catch recorded in almost every landing site. The decline is also evident from the reduction in the contribution of fisheries to the GDP, from about 6% in 1993 to the present level of 4.5% (FAO, 2016a). The lack of fish in nearshore areas has transformed the operations of the artisanal fisheries using bigger nets, with large number of fishermen on board bigger canoes. This change in the fishery affected the associated catch rates (landings/trip) which are no longer comparable to the early years.

Fishing Fleets

Four main fleets exploit Ghana's marine fishery and these are small-scale or artisanal/canoe fishery, semi-industrial or inshore, industrial or offshore, and tuna fleets (Table 1). The semi-industrial sector, the industrial sector and the tuna fleets constitutes the large-scale fisheries while the artisanal sector represents the small-scale fishery (Nunoo et al., 2014). Of these the artisanal fishery is the most important due to its huge contribution to fish production and local supply of fish (FSSD, 2016).

Table 1. Fleets exploiting the coastal fishery in Ghana (Anakwah and Santos, 2002; Nunoo et al., 2014)

Fleet	Vessel Type and Size	Target Species	Gear Type
Artisanal	Canoe, up to 8 m	Anchovy, Sardinella, Mackerels, Guinea Shrimp, Burrito.	Drift Nets, Purse Seine
Semi - Industrial	Small Boats, 8-37 m	Anchovy, Sardinella, Mackerels, Burrito, Other Demersals.	Purse Seine, Trawls
Industrial: Large Trawlers	Large Steel Vessels over 35 m	Sardinella, Chub Mackerel, Horse Mackerel, Shrimp, Cephalopods.	Trawls
Tuna fleet	Large Steel Vessels over 35 m	Yellowfin tuna, Skipjack tuna and Bigeye tuna	Purse Seine, Pole and Line.

The small-scale (or artisanal) fishery

The artisanal fisheries sector has long been a very important economic sector in Ghana, the activities of which have been passed on from generation to generation (Matthew, 2001), with fathers teaching the trade to their sons. Artisanal fishing activities however vary depending on the environmental, social, economic and historical contexts in which fishers live, but the underlying factor has always been to sustain livelihood and food security (Matthew, 2001).

Ghana's fishing sector began as an artisanal fishery with just very simple and mostly inefficient gears and methods operating at close coastal waters, lagoons, estuaries and rivers. Artisanal fishers in Ghana utilize dugout canoes built from wawa (*Triplochiton scleroxylon*) and employ many gears including beach seine, set net, hook and line, drift gill net, '*ali*', '*poli*' and '*watsa*' nets for fishing in near-shore, coastal waters (Nunoo et al., 2014; FSSD, 2016). For statistical purposes, the '*ali*', '*poli*' and '*watsa*' nets are usually reported together resulting essentially in the use of five main gears in the artisanal sector (Nunoo et al., 2014). Each boat typically carries a crew of up to 25 individuals that operate the net, and two or three individuals to drive and select the fishing locations. Antwi (as cited in Samey, 2015) reported that the industry serves domestic demands within cities and towns and conducts very limited export activities.

The artisanal fishery sector in Ghana is very important because it provides major employment, food, livelihood support and socio-economic benefit to Ghana's economy (Nunoo et al., 2014). The sector is the most significant in marine fisheries in terms of volume of output and contribution to production and local fish supply (Koranteng & Nmashie 1987; Koranteng, 1998; Quaatey et al., 1997; Bannerman & Cowx, 2002). The artisanal sector contributes about 70% to 80% of the total fish production from the marine sector (FSSD, 2016). The sector is a major source of employment for women who are actively involved in the trade as much as their male counterparts, employing over 60% of the total women population involved in the fishery value chain (FAO, 2016a). The men actively go on fishing expeditions, whiles women manage the processing aspects, emphasising the complementary gender specific roles played (Nunoo & Berchie, 2013). In a study conducted by FAO (2016b), it was also revealed that fish-trading, processing and retailing were fishing activities entirely meant for women from all ages ranging from 20-90 years. These traders have much influence on estimating cost of fish to be sold and supplied and provide general information for prices of all fish species sold within the supply and demand chain.

The number of artisanal canoes operating actively in Ghana's marine waters in the last two decades has been estimated at various times as between 6,000 and 8,000 units (Koranteng, 1996), but keep increasing over the years except between 2013 and 2016 when the number of canoes as well as the fishermen in the artisanal sector was reported to have decreased by 9.0% and 22.7% respectively (FSSD, 2016) (see Appendix A). For example while Amador and other in 2006 reported over 12,000 artisanal canoes with about 200,000 fishers operating from 334 landing beaches in 195 fishing villages located along the coast, the Fisheries Scientific Survey Division, in 2016, reported 11,586 canoes with 107,518 fishermen operating from 186 fishing villages and 292 landing beaches.

The size of canoes used in the artisanal fishery sector however has increased over the years. While Koranteng (1996) and Doyi (1984) respectively reported the length and width of artisanal canoes to be 3 - 8 m long and 0.5 - 1.8 m wide, recent surveys by Ghana's Fisheries Commission (2016) recorded the size of artisanal canoes along the coast to be about 7.0-19.5m long and 1.2-2.4m wide. Currently, some purse seines operate from canoes ranging between 10 to 20 meters in length (Lazar et al., 2018). About a half of the canoes involved in the artisanal fishery are propelled by outboard engines of up to 40 hp (Nunoo et al., 2014).

The nature of Ghana's artisanal sector has changed over time with major changes including (i) introduction of outboard motors (ii) introduction of the purse seine net and (iii) change from use of natural to synthetic netting materials. Assessing the catch and fishing effort for the artisanal sector has been difficult to achieve over the years due to the multiplicity of gears and the problem of migration of fishers that characterise the artisanal fleet.

The artisanal sector despite its immense contribution to the nation's economic growth, is poorly managed resulting in intense dependence and pressure on the fishery (Shester & Micheli, 2011), and all these benefits derived from small-scale artisanal fishery is under threat (FAO, 2006b). The fisheries have been managed basically as an unregulated common pool resource bringing about overcapitalized biological overfishing and hence a decline in catch per unit effort. Existing regulations (Fisheries Regulation, 2010) restrict the use of light aggregation devices which involves shining of light source in the ocean when the moon is out fully, to attract fish and increase catch. The regulations also put a ban on the use of mesh sizes smaller than an inch when stretched diagonally, and the use of explosives such as dynamite in fishing. These regulations, as outlined by Ghana's Ministry of Fisheries aim at limiting fishing efforts in an attempt to revive the stocks.

Following several consultations with relevant stakeholders in the fishing industry such as the Ghana Canoe Fishermen Council, Chief Fishermen, traditional rulers and fish mongers from across the country, the Ministry of Fisheries introduced and implemented the "closed season" in 2019. The closed season, which is in accordance with sections 76 (3) and 84 of the Fisheries Act 2002 (Act 625) was aimed at helping to reduce excessive pressure and overexploitation of fish stock to address the dwindling stock of fishes in

Ghana's marine waters. The Ministry declared May 15 to June 15 of each year as the "closed season" period for artisanal fisheries while August 1 to September 30, and January 1 to February 28 were also closed for industrial fishers and Tuna fleets respectively.

Despite the challenges associated with the sector, artisanal fishing is still very promising. To obtain full benefits of Ghana's artisanal fishery resources however, the actual resource birth must be kept in a healthier, functional and improved management atmosphere to enhance full production (Nunoo et al., 2014). Fishing is a very profitable venture despite certain identified challenges. However, policies need to be enforced and complied with in order for the sector to be more sustainable for the future (Polet & Depestele, 2010).

The semi-industrial (or inshore) sector

The inshore or semi-industrial sector comprises of locally-built, wooden hulled vessels measuring between 8 and 37 m long (Anakwah & Santos, 2002). There are also a few steel-hulled foreign-built vessels being used in the semi-industrial sector. For statistical purposes, the Fisheries Commission of Ghana has put these vessels into two categories, namely those with lengths between 8 and 12 m which undertake daily fishing trips and those over 12 m which are capable of staying at sea for up to 7 days. Vessels in the semi-industrial sector are powered by inboard engines of between 90 and 400 hp (Koranteng, 1998; FSSD, 2016). The inshore fleet developed rapidly from 2 vessels in 1948 to over 260 operational ones in 1984 (Mensah & Koranteng 1988; Koranteng 1996). In the last decade, the inshore fleet has declined in importance as most of the vessels are old and hardly seaworthy; only 165 inshore vessels operated in 1996.

The inshore fleets exploit both pelagic and demersal fishes and the vessels use bottom trawl nets or purse seines depending on the season (Nunoo et al., 2014). The purse seine gear is used mainly during the upwelling season when sardinellas are the target species. During the rest of the year, the vessels that have strong engines switch to bottom trawling. Presently, the inshore vessels operate mainly from bigger coastal landing centres, such as Tema in the Greater Accra Region, Winneba, Apam, Mumford and Elmina in the Central Region and Sekondi, Takoradi and Axim in the Western Region (Koranteng, 1998). The operation of these vessels, especially those measuring only up to 12 m, was severely affected by the disappearance of the triggerfish from this ecosystem towards the end of the last few decades (Koranteng, 1998).

The industrial sector

Large, steel-hulled foreign-built trawlers, shrimpers and tuna bait boats are used in the industrial sector. These vessels operate only from Tema and Takoradi where there are suitable berthing facilities. The first industrial vessels were acquired about four decades ago principally for fishing in more productive distant waters, mainly off Angola and Mauritania. From mid 1970s, when countries claimed the 200 nautical miles of exclusive economic zone, the industrial vessels started fishing in home waters in accordance with provisions of the third United Nations Conference on the Law of the Sea (UNCLOS III).

Between 1969 and 1975, a shrimp fishery operated mainly in the Anyanui estuary and adjacent sea in the Volta Region of Ghana (Anon, 1990). And by 1970, as many as 18 shrimp vessels were into shrimp fishery causing the collapse of the fishery for various reasons including over-exploitation and the impact of the Volta dam at Akosombo on the hydrology of Anyanui estuary and the Keta lagoon. In 1986 however, commercial shrimping was resumed with two vessels. The number of vessels increased rapidly thereafter and by 1995, as many as 17 industrial vessels were in the fishery.

Tuna Fishery

Commercial tuna fishery in Ghana commenced in 1960 when a survey established, among others, that tuna species abound in the Gulf of Guinea (Nunoo et al., 2014). The commercial tuna fleet in Ghana initially consisted primarily of Japan-registered vessels but later comprised Japan- and Korean-registered vessels. In 1973, as many as 40 of these foreign fleets operated in Ghanaian waters which represented the peak of foreign fleet domination of the industry (Kwei, 1988). In compliance with requirements of the Fisheries Act 625 of 2002, most tuna vessels fishing in Ghanaian waters are operated on joint-venture basis, with Ghanaian owners having at least 50% of the shares.

The tuna fishing vessels catch mainly yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*) and bigeye tuna (*Thunnus obesus*). Atlantic black skipjack (*Euthynnus alleteratus*) Atlantic bonito (*Sarda sarda*), frigate mackerel (*Auxis thazard*), Atlantic sailfish (*Istiophorus albicans*) and Broadbill swordfish (*Xiphias gladius)* are other tuna and tuna-like species usually exploited (Nunoo et al., 2014).

Environmental damages resulting from fishing practices

The fishing industry involves catching, processing, and marketing fish and seafood for either recreational or commercial purposes. Globally, more than 500 million people depend on the fishing industry for survival (Cochran et al., 2009). Because of its direct involvement in marine habitats, the fishing industry has a significant environmental impact (Garcia, Zerbi, Aliaume et al., 2003). The world's ocean is thus predicted by Roach (2006) to have no fish by 2048 due to these environmental impacts resulting from unmonitored and irresponsible fishing which are extremely detrimental to the aquatic environment and the fishery. This is because not only does the fishing industry directly damage these marine habitats, but it also removes unsustainable numbers of reproductively mature fish from their habitat. The amount of degradation caused by the fishing industry depends on the specific technique utilized to catch fish and other seafood.

Light Fishing

It is a very common practice to fish during the daytime for most countries and communities, but unfortunately most fish species tend to be more active during the night time with the greatest migration activities taking place at this time (Hammerschlag et al., 2016). Light used to fish has been in existence for many years ever since man discovered that fish species were attracted to light source. The first light used for night fishing was pressurized kerosene lanterns and were later replaced with Compact Florescent Light 9CFL) which had enough brightness, easily accessible, affordable and easy to use (Susanto et al., 2017).

Fishes, like most organisms, have the ability to alter their activities based on the length of day or night through a phenomenon called Photoperiodism (Bradshaw & Holzapfel, 2007). Photoperiodism influences seasonal activities such as growth, development, reproduction, migration, and dormancy that make a direct contribution to survivorship and reproductive success (Vera et al., 2007). Fishes have the ability to adapt themselves to a wide range external stimuli, including light, that influence their seasonal breeding activities and migrations. Some fish species, although capable of breeding all the year round, show an increase in reproductive activity with the increasing day-lengths of the spring (Pyle, 1969) hence their abundance is influence by light conditions of the environment.

According to Marchesan (2005), the reactions to changes in light conditions are often species-specific. Most likely, there exists a relationship between behavioural response to artificial light source and visual behaviour in natural light conditions. Differences in visual behaviour patterns may be related both to phylogenetic and ecological factors established.

Artificial source of light attracts general fish species and sizes, and this method has been used to improve catch of fishes. The use of light in fishing causes great harm to most fish species by altering their normal periods of attraction to light. This activity also affects their reproductive cycles and feeding patterns (Longcore & Rich, 2004). Constant exposure to artificial night lighting or the excessive use of light for fishing can affect nocturnal fish species accustomed to navigating during the night for their activities and in some cases, can lead to blindness, as stated by Longcore & Rich (2014). The use of light for night fishing has resulted in a negative impact as more juvenile and immature fishes tend to be caught by the excessive energy from the lamp. These have necessitated the need to address light fishing through proper measures and regulations to help reduce the excessive catch of juvenile fishes and also provide a more environmentally friendly equipment and technology.

Bottom Trawl

Bottom trawl nets are employed to catch shrimp and fish living on the seafloor from shallow coastal waters to extreme depths of 2000m (Morgan & Chuenpagdee, 2003). In addition to the target fish and shrimp, many other organisms, including undersized fish, are captured and discarded, (Clucas, 1997; Kelleher, 2005). Bottom trawling is one of the fishing methods with most destructive impact of fishery and is reported to account for up to 95% of global ocean damage (Kelleher, 2005). It is the type of fishing in which a net is dragged along the ocean bed to catch bottom-dwelling fish. The activities of bottom trawls disturb the seabed and cause a significant amount of sediment to suspend which could impact fish by clogging their gills and impede feeding.

Bottom trawling decreases the biomass and production of benthic species. The practice also destroys corals, oysters and sponges that form productive marine habitats. Coral is important in promoting the health of the ocean ecosystem because they provide shelter to a number of deep sea-dwelling species. Suspended sediment creates murky waters, blocking sunlight from reaching underwater plants and creating dead zones of oxygen deficiency. Additionally, many of the organic pollutants that have settled into the sediment are stirred back up and reintroduced to the food chain, beginning with plankton and moving up to humans. These impacts can cause widespread die-offs of marine life.

Dredging

Dredging is a practice commonly used to harvest clams and employs a large metal scoop that drags along the seafloor to pick them up. Dredging causes sediments to re-suspend along the seafloor and water column, thereby decreasing water quality (Thrush &

Dayton, 2002). The practice can also dig up and destroy burrowing worms from the sediments. These animals are important because their burrows increase contact between sediments and the water and help returns nutrients to the water, where they are used by microorganisms in nutrient cycling. Without these burrowing animals, waters along the seafloor can become depleted of oxygen and uninhabitable (Coleman & Williams, 2002).

Blast fishing

Blasting in carried out by lighting sticks of dynamite and throwing them into the water. The explosion stuns the fish, rapture the swim bladders and cause them to float to the surface for easy capture. The practice destroys productive coral reef habitat that serve as nurseries for many fishes (Njoroge, 2014). This causes stocks of many species of fish to rapidly decline.

Purse seine fishing

A purse seine is a large wall of netting deployed around an entire area or school of fish. Purse seines can reach more than 6,500 ft (2,000 m) in length and 650 ft (200 m) in depth, varying in size according to the vessel, mesh size, and target species (FAO, 2016a). Purse seining is a non-selective fishing method that captures almost everything that it surrounds, including protected species. Sea turtles can be captured by a purse seine as it is set and then become entangled in the net mesh as it is hauled in. Entangled turtles may sustain injuries to their flippers and shells due to the force of the net as it is hauled. In a large catch, turtles risk being crushed under the sheer weight of the tow. Purse seines can also encircle marine mammals along with target species as the net is set. Once the netting has been set, encircled marine mammals cannot escape and can become entangled, injured, or stressed. Even with quick retrieval, marine mammals' sensitive bodies and internal organs cannot usually withstand the weight of the catch or the impact of being placed on the vessel.

Due to its characteristics there is no impact on the bottom habitat. The only known impact occurs in cases where the water depth is less than the height of the seine during the fishing operations causing the lower edge of the gear to wipe the sea bottom. The increasingly used practice of encircling floating objects, including man-made Fish Aggregating Devices (FADs) increases the capture of small sized and immature aggregating around such devices.

Gill-net fishing

Gillnets are widely used in artisanal fisheries because it is a cost-effective means of fishing for a target species and offer fishermen the opportunity for low-energy fishing (FAO, 2016a). Their design allows gill nets to be used to fish in surface layers, in mid water or at the bottom. Gillnets have high degree of selectivity with regards to fish size. An advantage of gill net fishing therefore is its ability to preserve younger or undersized fish. This ensures the continued presence of the target species in the fishing waters.

Though gill nets are size selective (Heikinheimo & Mikkola, 2004) and allow non-target fish smaller than the desired species to swim through the mesh unharmed, there are some concerns about the effects of gill net fishing on the environment. Incidental catch of non-target species such as turtles and sharks in gill nets are a matter of growing concern. In some areas also, the entangling of seabirds, especially ducks, is a major problem associated with gillnet fishing.

"Ghost" fishing by lost gears (ghost nets) is one of the major problems in the gillnet fishery and gill nets have been reported to form a greater composition of ghost nets. A ghost net is a fishing net that has loosened and floated away. This may be due to a storm or pollution when a damaged gill net is disposed off by throwing it overboard. Although no longer in active use for commercial fishing, the net still has the potential to entrap fish and other marine life. The synthetic fibres used for gillnets do not easily degrade and the gear may fish for a long time. Sea turtles and dolphins are non-targeted species usually entangled in ghost nets. Since these nets are unmonitored, the animals may not be able to disentangle themselves, and gradually either starve to death, become easy prey for other species or suffocate from a lack of oxygen. The extra weight imposed on the turtles and dolphins by the net leads to dissipation of energy and fast exhaustion which could also lead to drowning.

Long line fishing

Longline fishing involves stringing out baited hooks on enormous lengths of line to catch large fish and other marine creatures. Each line consists of a main horizontal line about 250 to 800 m long with 4 to 15 branch-lines, each with a wire leader and a hook. Longline fishing is designed to attract a particular target fish, but other species also get attracted to the bait. When unregulated or poorly practiced, longlines can have significant environmental effects, particularly in terms of incidental catch of non-target species or juvenile and endangered species such as sharks, turtles and seabirds, especially albatrosses and petrels (FAO, 2010).

Though fishermen practicing longline often attempt to reduce by-catch by using specialized hooks and attempt to return ensnared endangered animals to the water, often too much damage would have already been done by the time the animal is rescued from the hook and the animal dies. Also when sea birds, turtles and marine mammals that happen to be near the long fishing lines can get unintentionally ensnared, the hooks can tear or even tear off fins, wings and other body parts, killing the victims.

Influence of some climatic conditions on coastal fisheries

Environmental conditions can influence demographic rates of marine fish populations through several environmental pathways (Drinkwater et al., 2010; Ottersen et al., 2010). This is a result of changes in atmospheric and physical conditions of the ocean influencing higher-trophic-level species via bottom-up forcing that is facilitated by vertical ocean transport (Ottersen et al., 2010; Di Lorenzo et al., 2013a; Malick et al., 2015a). The variability in coastal climate has been reported to influence the abundance and availability of pelagic stocks by many authors including Mensah & Koranteng (1988), Mensah (1991), FAO (1997), Koster et al. (2003) and Drinkwater et al. (2010). The high variability in recruitment in the population of most marine fish is due to the variability on environmental conditions (Fiechter et al, 2015).

Climatic and oceanographic conditions of the marine environment have been argued to influence the recruitment variability and early survival rates of many fish species (Aebischer et al., 1990; Ware & Thomson, 2005). The growth and maturity rates of marine fish are also impacted by variability in both the abiotic (e.g., temperature) and biotic (e.g., availability of food) factors of the fish's environment (Brander, 1995; Godø, 2003). Long-term increases in temperature, changes in wind patterns, changes in freshwater runoff, and acidification of the ocean are all as a result of changes in the climatic conditions of the environment (Intergovernmental Panel on Climate Change [IPCC], 2007b; Doney et al., 2009). These changes in environmental conditions have great direct (e.g., temperature effects on growth) and indirect (e.g., changes in ocean productivity) influence on the abundance, distribution, and productivity of fish species (Stenseth et al., 2002; Perry et al., 2005). Enhanced growth of fish has been reported to be as a result of environmental variability (Richardson & Schoeman, 2004) and associated changes in food web dynamics occurring in the post-smolt nursery (Beaugrand & Reid, 2003; Friedland et al., 2009a).

Among the most influential climatic conditions affecting the fisheries of an area are upwelling, temperature, wind speed and direction, rainfall and salinity. Figure 1 below summarises the interactions between the climate and the biotic and abiotic environments of fish as described by Glantz (1992). Atmospheric temperature presents the most influence on the abundance, distribution and productivity of fish in the marine ecosystem, acting directly on the fish or indirectly through influencing other factors such as salinity and ocean current.

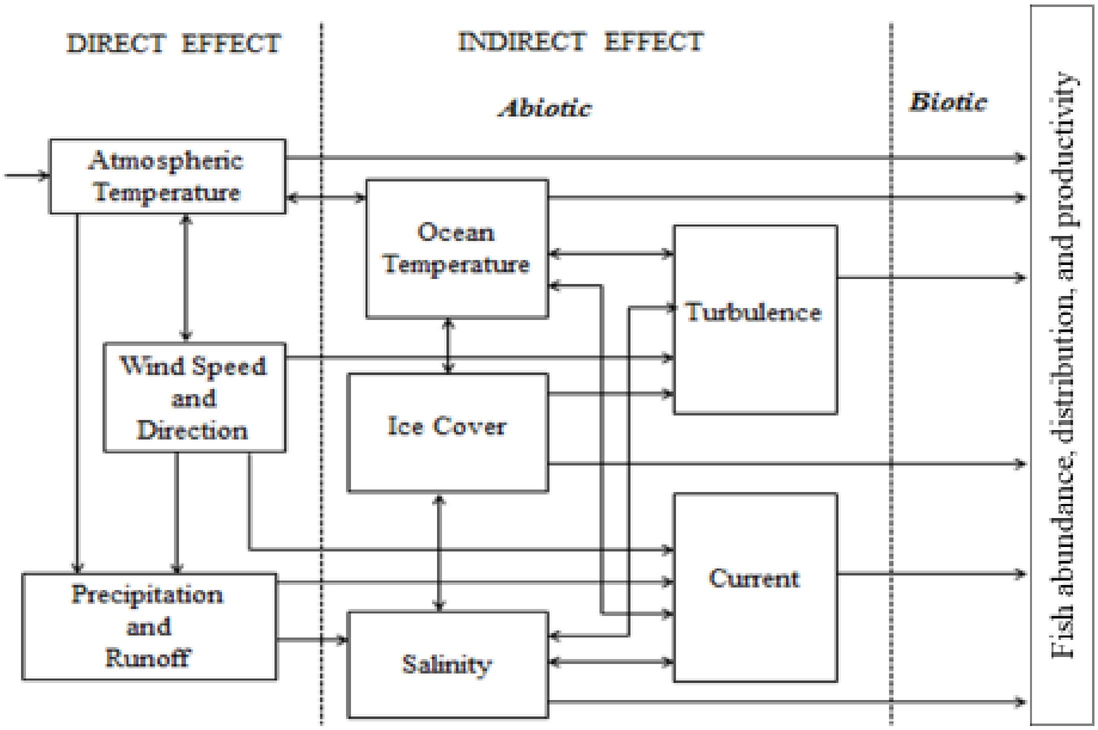


Figure 1. Schematic representation of the major climatic factors affecting the abiotic environment of fish (Adapted from Glantz, 1992).

Upwelling

Upwelling occurs twice in the coastal waters of Ghana and exhibits seasonality (Quaatey, 1996; Nunoo et al., 2014). The two seasons are characterised by decreases in Sea Surface Temperature (SST), increases in salinity and decrease in dissolved oxygen. Upwelling of cold waters with temperatures between 22-25°C occurs in late June-July to September-early October, otherwise, sea surface temperatures typically vary between 27-29°C (Minta, 2003; Nunoo et al., 2014). While the major upwelling typically lasts for about three months, the minor upwelling lasts for three weeks and occurs in January, February or March (Minta, 2003; Nunoo et al., 2014). The only exception to this trend was in 1986 when the minor upwelling lasted for 10 weeks (Minta, 2003).

Ghana's continental shelf experiences two seasonal upwelling events. There is a major upwelling that occurs from late June/early July to September/early October, and a minor upwelling that occur mainly in January or February and lasts up to a month (Nunoo et al., 2014). During each upwelling event, water temperatures typically drop below 25^{o}C to 17°C and the mixing of cold nutrient rich lower layers with water from surface layers enhances productivity. The resulting increased population of phytoplankton and zooplankton leads to increased production of higher taxa, particularly fish (Minta, 2003). Upwelling-induced plankton production help maintain large stocks of pelagic fishes. These fishes presumably take advantage of the peak in production associated with the onset of coastal upwelling (Quinn, 2005; Fiechter et al., 2015). The timing, intensity, and duration of upwelling events therefore have great influence on the feeding conditions of juvenile Chinook salmon (Fiechter et al., 2015). These climatic conditions subsequently determine the abundance of fish species (Beamish & Mahnken, 2001; Wells et al., 2012).

Coastal upwelling in Ghana is reported to be the most influential factor affecting the pelagic species, besides fishing efforts. This because variations in upwelling events results in fluctuations in biological production in coastal ecosystems by enhancing spawning and recruitment (Minta, 2003). For examples the increase in catches of the round sardinella (*Sardinella aurita*) in Ghana during the last decade and the spatial and seasonal distribution of the stock has been attributed to upwelling events (Pezennec & Bard, 1992; Binet & Servain, 1993). In the work by Koranteng (1991), the use of models that took into consideration both the period and intensity of upwelling revealed that years of higher upwelling indices coincided with those of high Sardinella yield in Ghana. Similarly, the models by Cury and Roy (1987) which analysed the annual fluctuations in the CPUE of La

Côte d'Ivoire indicated that the fishing effort accounts for 18% of the CPUE variability while the upwelling indices accounted for 40% of the catch. This is attributed to the ability of the seasonal coastal upwelling to periodically modify the physicochemical parameters of the water masses and control the biology of the subsystem. Mensah (1991) reported a correlation between zooplankton production and rainfall pattern, river discharge and sediment transportation**.** This rainfall patterns was found to always precede the major upwelling, which produces outbursts of fish yield. According to Roy (1996), the upwelling provides favourable habitat and occurs spontaneously with fish spawning especially around Cape Three Points of Ghana.

Though the dynamics of upwelling systems seem to be different and not clearly defined, wind stress is believed to be an important factor. Binet (1997) found that Sardinella catches are related to along-shore wind stress of the year except during the early months of larval life. Increased wind stress induces enrichment favourable for larval survival except immediately after hatching when turbulence and offshore advection induce adverse effects. It would therefore be expected that warmer years with higher sea surface temperatures would be characterised by increased number of eddies along the coast. The enlarged turbulent structures would enable the survival of a large number of larvae in regions where spawning occurs.

Upwelling events have also been linked to mean sea level and dynamic height of the sea (Verstraete et al, 1983). A simultaneous drop in mean sea level and dynamic height is recorded just before the start of a major upwelling. Roy (1993) postulates that the changes in the Sardinella populations in the last decade could have been induced by long-term environmental fluctuations in upwelling. According to Bakun (1993) also, the dramatic changes in the pelagic fish yield in the Gulf of Guinea could either be as a result of global scale climatic effects that could lead to intensification of coastal upwelling, or of teleconnections to the Pacific El Nino Southern Oscillation (ENSO) system.

Temperature

Ghana lies in the tropical equatorial belt and experiences high temperatures of between 25 and 35 °C with minimum variation throughout the year (Koranteng, 1998; Mensah et al., 2006). The average daily maximum temperature across the sub-region can however vary between 27-29°C in August–September and 31-33°C in February-March. Temperatures are generally high across the entire nation ranging from 18 ^{o}C to 40^{o}C in the North and 24 ^{o}C to 30^{o}C in the South. These changes in temperature conditions are due mainly to the amount and distribution of rainfall (Biney, 1990). With the coastal climate being equatorial, there is a considerable difference in the amount and seasonal distribution of precipitation (Minta, 2003).

The oceans represent an integral component of the climate system and exhibit important physical and biogeochemical interaction with the climate. There is a continuous process of storage and exchange of energy in the form of heat and moisture between the atmosphere and the ocean. With the oceans being the largest reservoir of moisture, they are more effective at heat absorption than land and ice surfaces and hence better heat reservoirs than land. The increase in the concentration of greenhouse gases (carbon dioxide, water vapour, methane, nitrous oxide and chlorofluorocarbons) and associated global warming could therefore increase sea surface temperatures (Kawasaki, 1992). It could also intensify wind stress on the sea with a resultant acceleration in coastal upwelling. These climatic factors would affect the biotic and abiotic elements that influence the abundance and spatial distribution of most fish species (ICES, 2017). The abiotic elements include water temperature, salinity, nutrients, sea level and current conditions while biotic factors include food availability and presence and species composition of predators and competitors.

Water temperatures has been reported to directly affect spawning and survival of juveniles as well as fish growth (Kurita, Fujinami & Amano, 2011) hence will have great influence on the abundance of fish. Sea surface temperature (SST) has been reported to also affect the spatial distribution of marine species (ICES, 2017). Long-term spatio-temporal progressions of SST have been used to estimate the annual abundance of fishes and also determine the impact of climate changes on the spatial distribution of pelagic fishes (ICES, 2017). Sea temperature also affects the biological production rate and, hence, food availability in the ocean, which is a powerful regulator of fish abundance and distribution (IPCC, 2001). Coastal SST measurements have shown that, twice in every year, there is a moderate, then a great decrease of the SST between January and March and between July and September along the coasts of Ghana.

Wind and ocean current

Ghana experiences the Guinea current which flows offshore from the west to the east as a continuation of the Equatorial counter current. The dominant wind in Ghana is the south-westerly monsoon modified by land and sea breezes in the coastal area. This is a relatively weak wind reaching a maximum speed of only 5 m s^{-1} during boreal summer (Roy 1996). This monsoon reinforces the Guinea current, which is also modified by the harmattan. There is spatial variation in the Monsoon with respect to diurnal and annual ranges due to distances from the modifying effect of the sea breeze.

Changes in ocean current patterns, have been found to influence the production of higher-trophic-level species through altering their foraging conditions. For example, the feeding conditions and growth rates of the Pacific salmon (*Oncorhynchus* spp.), during their early marine life stage is reported to have strong influence on stock productivity (i.e., the number of adult recruits produced per spawner) (McGurk, 1996; Farley et al., 2007; Duffy & Beauchamp, 2011; Malick et al., 2011). Since the diets of juvenile salmon during this stage are largely composed of zooplankton and other weakly-swimming or passive drifters (Beauchamp et al., 2007), changes in ocean currents and subsequent advection of potential prey into coastal areas may strongly influence the distribution and availability of prey items for juvenile the salmon.

Water current is found to affect the movement of zooplankton communities. While the large-bodied lipid-rich zooplankton community is associated with alongshore movement of cooler water from northern areas into the region, the small-bodied lipid-poor zooplankton community is influenced by the movement of warmer water from southern and offshore areas into the region (Bi et al., 2011a; Keister et al., 2011). In the study by Bi et al. (2011), lipid-rich northern zooplankton community was found to be associated with higher coho salmon (*Oncorhynchus kisutch*) survival in the Northern California Current region, suggesting that horizontal transport may be important for salmon productivity in other regions. Brodeur et al. (2007a) also reported that horizontal transport may be important for other salmon species, especially pink (*O. gorbuscha*), chum (*O. keta*) and sockeye (*O. nerka*) salmon, which tend to feed at a lower trophic level than coho salmon.

Rainfall

Ghana experiences two main rainfall regimes namely the major wet season and the minor wet season (Asante & Amuakwa-Mensah, 2015). There is thus a double maxima with peaks from May to August and September to October in Southern parts of the country including the coastal zone; and there is a single maximum from May to October with a long dry season from November to May which exclude the coast but encompasses the major rivers which drain into the sea. Rainfall is highest in the south and decreases towards the North. Annual rainfall averages between 82 mm in the southeast and 215 mm in the southwest (Biney, 1990).

The rainfall patterns are reported by Allersma & Tilman (as cited in Minta, 2003) to be strongly related to the pattern of river flow and sediment transport into the sea. The volume of freshwater reaching the sea from rivers and streams increases greatly during the rainy seasons. Though the coastal current is weak, the amount of freshwater from rivers meeting the saline seawater gives rise to currents. The run-offs from rain-fed rivers replenish organic nutrients and elements consumed in the sea during photosynthesis which help sustain productivity of the coastal ecosystems (Mensah, 1991). The salinity of the surface waters in the Gulf of Guinea also decreases as a result of the increases freshwater input form the rains through rivers (Binet & Servain, 1993).

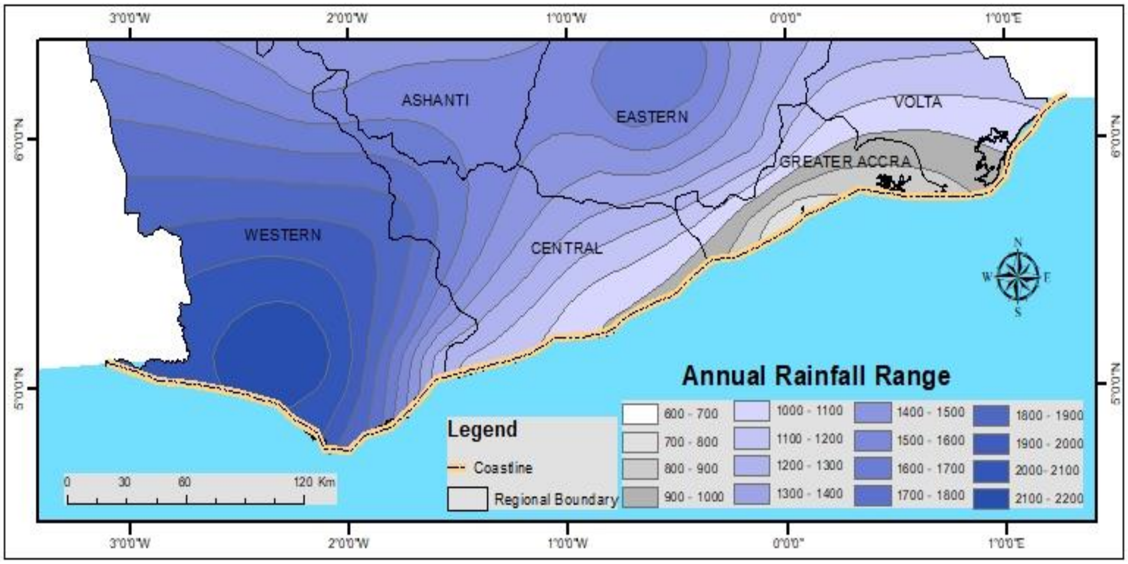


Figure 2. Rainfall distribution along the coast of Ghana showing the rainfall range for the Central coast.

Sea Turtles

Turtles are an ancient group of air-breathing reptiles. They once lived together with the dinosaurs and have survived the giant Plesiosaurus and the Ichthyosaurus (Márquez, 1990). Records of turtle fossil extends back at least 120 million years (Cadena & Parham, 2015; Lindsay, 2015). Known to be one of the only two surviving sea-water-adapted reptiles together with the marine snakes and iguanas, they inhabit tropical and subtropical seas throughout the world (Márquez, 1990) and play significantly important roles in the marine ecosystem as well as the terrestrial systems.

There are over 360 species of living turtles in the world, but only seven of them live in the ocean (Kiprop, 2018). These species are those previously documented by most scientists which includes the Leatherback, *Dermochelys coriacea*; Green, *Chelonia mydas*; Olive Ridley, *Lepidochelys olivacea*; Loggerhead, *Caretta caretta*; Hawksbill, *Eretmochelys imbricata*; Kemp's Ridley, *Lepidochelys kempii*; and Flatback, *Natator depressus*. These seven species fall into two main sub-groups; the unique family *Dermochelyidae*, which consists of a single species, the leatherback; and the family *Cheloniidae*, which comprises the six hard-shelled sea turtle species (Eckert et al., 1999).

Sea turtles of the world

Although sea turtles are circumtropical in terms of their distribution, sea turtle species exhibit wide variations in their seasonal cycles, geographical ranges and behaviour (Márquez, 1990), with even populations of same species showing considerable differences in distribution.

Sea turtles are found in warm and temperate seas throughout the world. The members of the superfamily have a general worldwide distribution. They have been found in all oceans around the world, except for the Polar Regions. Some species also travel between oceans (Dutton et al., 2013). With the exception of the flatback and Kemp's Ridley which have restricted distribution, most of the species of sea turtles surviving presently have uneven distribution in all the three tropical oceans. Flatback (*Natator depressus)* is found in Northern Australia while the Kemp's ridley (*Lepidochelys kempii)* is found in the Gulf of Mexico (Amiteye, 2000).

Sea turtles of African waters

Sea turtles are among the most wide ranging creatures on earth, and have been reported in Africa since the early Jurassic period (60 million years ago) as reported by Gaffney and others (as cited in Agyekumhene, 2009). Five of the world's seven sea turtle species (leatherback, green, olive ridley, hawksbills, and loggerhead) inhabit the coastal waters of Africa, nest on its 26,000 km shores, and spend most or all of their life cycles within the borders of the continent from Mauritania south to Angola on Africa's Atlantic coast, and from South Africa north to Somalia on the Indian Ocean coast, and also on archipelagos (Agyekumhene et al., 2017).

Although these five aforementioned species are the species reported to forage and nest in Africa, there are some sea turtles that nest outside Africa but spend time in African waters as well. The Kemp's ridley turtle for instance is endemic to the North and the Gulf of Mexico but occasionally wanders into the waters of Africa, making the Australian flatback turtle the only species completely out of Africa (Agyekumhene et al., 2017). Whereas individuals in Africa only stay on the continent, others may migrate to other areas and oceans. Turtles hatched on West African beaches have been reported throughout the Atlantic and Caribbean whereas Green and Loggerheads from the beaches of the Indian Ocean migrate through the north of Arabian Peninsula (Agyekumhene et al, 2017). Leatherbacks that nest in South Africa and nearby Mozambique migrate through the cold waters around the Cape of Good Hope to forage off Namibia. Ghana's leatherbacks are reported to form part of a wide-ranging population that possibly extends throughout the South Atlantic Ocean (Dutton et al., 2013).

Sea turtles in Ghana's coastal waters

All five species of sea turtle reported in Africa have also been confirmed in West Africa and in Ghana. The Leatherback (*Dermochelys coriacea*), Green (*Chelonia mydas*), Olive ridley (*Lepidochelys olivacea*), Loggerhead (*Caretta caretta*), Hawksbill (*Eretmochelys imbricata*) sea turtles have been reported to have nested on sandy beaches along the coast in the past (Irvin, 1947; Toth & Toth, 1974). However, more recent studies have documented the Leatherback (*Dermochelys coriacea*), Green (*Chelonia mydas*) and Olive Ridley (*Lepidochelys olivacea*) as the only species nesting along the coast of Ghana (Amiteye, 2000; Beyer, Ekau & Blay, 2002; Agyekumhene, 2009). Of these three species, the Olive Ridley has been found to nest in appreciable numbers along the coast of Ghana in recent time (Amiteye, 2000; Agyekumhene, 2009; Agyekumhene et al., 2010). These nesting activities in Ghana are concentrated on the 80 km stretch of beach between Prampram and Ada-Foah in the Greater Accra region (Amiteye, 2000). However, substantial nesting activities also occur along the entire coast. Generally, nesting activity by the three species that utilize Ghana's sandy beaches for nesting habitat increases from the Western coast to the Eastern coast (Amiteye, 2000).

The olive ridley is known to show the highest relative abundance among the three species nesting currently in Ghana (Agyekumhene et al., 2010). Anecdotal nesting activities have been reported for hawksbill and loggerhead in some parts of Ghana's coast. A nesting loggerhead was documented in eastern coast around Ningo-Prampram in 2014 (Allman et al., 2015).

Ecological importance of sea turtles

Sea turtles are critically important and perform many ecological services in both the marine ecosystem and terrestrial environment. Turtles also have socio-cultural values which vary among countries and also, locally within countries. In parts of the globe, turtles are utilised for their dietary, medicinal, cultural, economic, and religious values (Amiteye, 2000; Agyekumhene, 2009). Sea turtles occupy a unique position within the food web by consuming diverse forms of prey, including jellyfish, crustaceans, sponges, tunicates, sea grasses, and algae. Most species of turtles increase fish stocks through feeding on jelly fish which, when in large numbers, are considered a threat to fisheries (Mckeown, Okoh & Owusu, 2003). Several terrestrial animals such as crabs, dogs, and birds are common predators of turtle eggs and hatchlings emerging from the nest (Agyekumhene, 2009; Wilson et al., 2010). In the sea, neonate turtles are eaten by predators such as sharks. Nel, Le Gouvello, Harris and Bezuidenhout (2017) reported ghost crabs to feed on the eggs and hatchlings of sea turtles with some amount of turtles also found in the diet of snails and other scavengers that live within the beach sand. These organisms however do not feed exclusively on sea turtles but also on other prey items (Nel et al., 2017).

Sea turtles have been found to promote the growth and development of reefs and sea grasses. Propagates of these coral reef and sea grasses settle on the carapace of the sea turtle or get attached to its skin and as the turtle travel long distances, these propagates may fall at different areas within the sea (Wilson et al., 2010). The carapace of sea turtles provides habitat or substrate for sessile marine invertebrates.

The hawksbill sea turtle is also utilized in the fashion industry where the shells are used for decorative ornament, with the scutes from the shells used in making jewellery, combs and eyeglass frames. In the cosmetic industry, the oil obtained from its carcass is used as skin lotion additives.

Sea turtles play a critical role as nutrient transporters from the ocean to the intertidal areas of beach ecosystems. By coming ashore to nest, turtles transport nutrients from highly productive marine habitats such as sea-grass beds to energy-poor habitats like sandy beaches (Bouchard & Bjorndal, 2000). This process enhances growth of vegetation along the beaches and help stabilizes the beaches against erosion. Recent studies show that the value of nutrients sea turtles bring to the sandy beach ecosystems play a vital role in the development of beaches and dunes (Nel et al., 2017). Through the decomposition of unhatched turtle eggs, shells from hatched eggs and unmerged hatchlings, nesting activity of sea turtles produce a great amount of nutrient pulse into the otherwise nutrient-poor beach ecosystems.

Since sea turtles feed their entire life at sea and only come to lay eggs on the beach, all the nutrient converted into developing the eggs are from the marine environment. And because turtles consume little food during the migration and nesting period, the energy and nutrient invested in reproduction originate from the marine feeding grounds and are transported to the nesting beaches via the eggs that fail to hatch successfully (Nel et al., 2017). This helps to reverse the unidirectional flow of nutrient from land to sea. These nutrients enhance vegetation growth at the beach and this helps to stabilize the beach by reducing erosion. By introducing these nutrients into beach ecosystems, sea turtles may also help maintain stable dune systems that are critical to their reproductive success (Bouchard & Bjorndal, 2000) and support a host of meiofauna living in the sand such as nematode worms (Nel et al., 2017).

On most turtle beaches where plants or algae are absent, the intertidal ecosystems have been found to be supported solely by nutrient inputs from outside sources such as those brought in by sea turtles which are usually rich in carbon and nitrogen. By feeding on the eggs and hatchling below and above the high tide line, beach fauna ensure that nutrients are widely distributed from above the high tide line where turtles typically deposit their eggs to other areas of the sandy beach (Nel et al., 2017).

Biomedical importance of sea turtles

Traditionally, sea turtles help in promoting the health of humans. The oil from sea turtles is also believed to be of medicinal value and has been used as cure for several ailments like asthma in children (Amiteye, 2000). In some local communities in the Volta region of Ghana, oil from sea turtle is mixed with honey to treat convulsion in children, as stated by Amiteye.

Sea turtle species identification

The species of sea turtles are identified using features such as the type of shell, number and arrangement of scutes on the shell (Figure 3), and tracks left on sandy beaches. True turtles (Family: Cheloniidae) have hard shells with scutes. These are differentiated from each other using the number and arrangement of scutes on the hard shell (Márquez, 1990; Shanker, Choudhury & Andrews, 2003). Other morphological features for identification include number and arrangement of scales on the head, and shape of carapace. However, leatherbacks (Family: Dermochelyidae) are identified by their uniquely soft leathery carapace with dorsal ridges running along the body length and without scutes (Shanker et al., 2003).

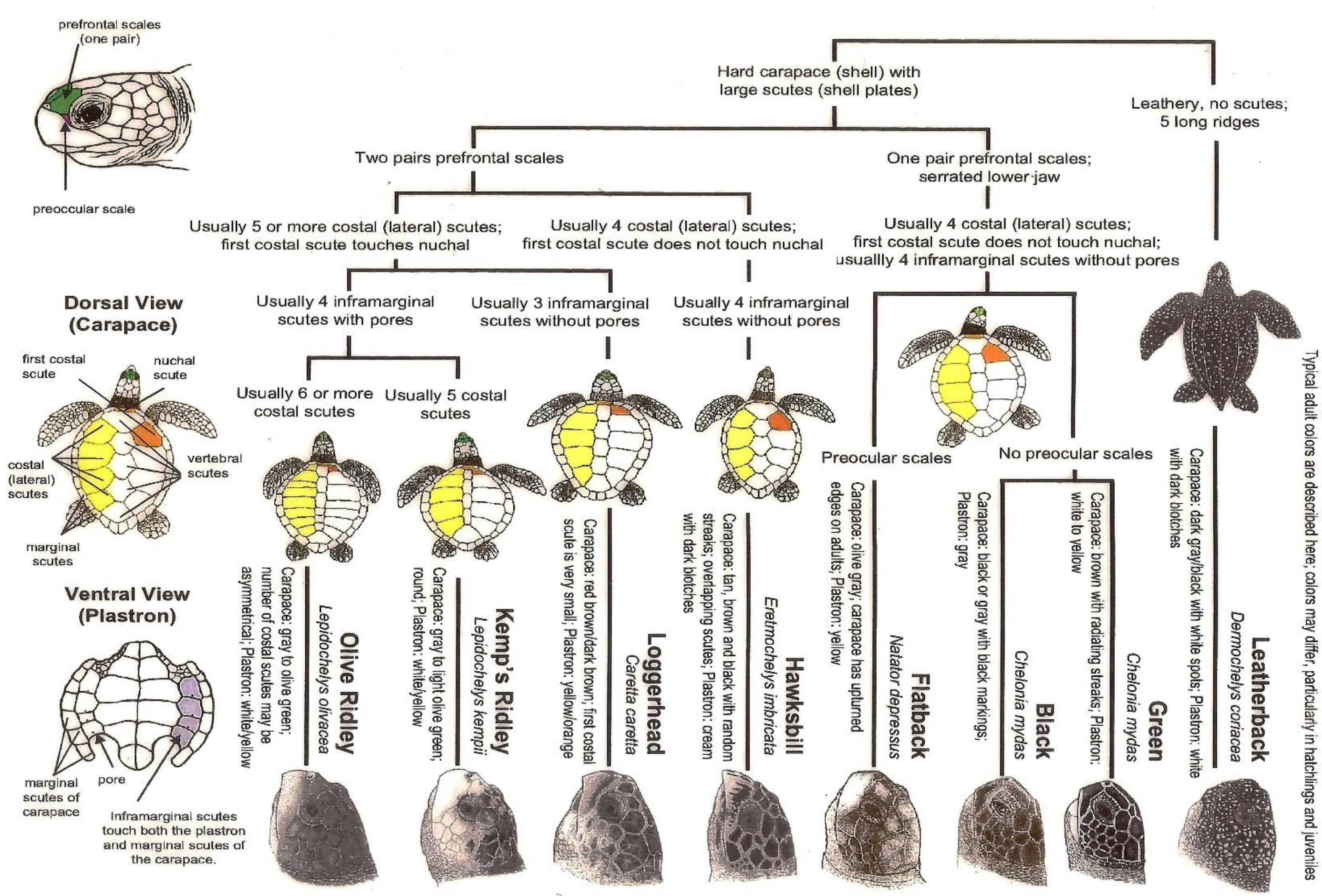


Figure 3. Identification key showing the observable morphological features of the various species of sea turtles (Sources: Pritchard & Mortimer, 1999; Marine Turtle Specialist Group, 2005).

Species identification using morphological features

Leatherback

The leatherback *(Dermochelys coriacea)* is the world's largest living species of sea turtle measuring up to 907.2 kg in weight and 180 cm in straight carapace length (Eckert et al., 1999). They have the most extensive size-range of any reptile and are surpassed in size only by some species of crocodiles. Adults are easily distinguished from all other species of sea turtles by their spindle shaped huge bodies and their leathery, unscaled (scuteless), keeled carapaces (Eckert et al., 1999) (see Plate 1). Thousands of tiny bones, embedded in cartilage, support their leathery skin. The head of the adult leatherback is small, round and scaleless, and equals 17 to 22.3% of the carapace length. It has a feeble beak with a sharp edge well adapted for grabbing sluggish pelagic food. When the mouth is closed, it gives the appearance of a 'W' in front view.

Leatherbacks do not have a hard shell like other sea turtles (Eckert et al., 1999). Their barrel-shaped bodies are divided by keels (ridges) into sections. There are 7 dorsal and 5 ventral longitudinal keels on the plastron to increase hydrodynamics. The dorsal keels (already present in hatchlings) converge posteriorly in a blunt end, much above the tail. The flippers are large and paddle-shaped. In adults, the fore flippers usually equal or exceed half the carapace length and thus are relatively longer than in other sea turtles while in the hatchlings, they look enormous and are clearly as long as the carapace. The rear flippers are connected by a membrane with the tail. Claws may be visible in hatchlings, but disappear in sub-adults and adults.

Adults show certain variability in colour pattern. The dorsal side is essentially black, with scattered white blotches that are usually arranged along the keels, becoming more numerous laterally and very dense beneath the body and flippers, so that the ventral side is predominantly whitish. There are pinkish blotches on neck, shoulders and groin. Theses blotches become more intense when the turtle is out of the water, possibly by blood congestion in the skin vessels. Hatchlings and juveniles have more distinct white blotches which are clearly arranged along the keels. The density of the spots and also their spot sizes are highly variable among populations, but apparently show certain constancy within each population. Males are distinguished from females mainly by their longer tail; they also seem to have a narrower and less deep body. Apart from their short tail, females have a pink area on the crown of their head.

Plate 1. Photograph of Leatherback turtle showing morphological features.

Olive ridley

The Olive ridley *(Lepidochelys olivacea)* is the smallest species of sea turtles. The adult ridley may weigh, on average, between 35 to 50 kg with a straight carapace length of 72 cm long (Eckert et al., 1999). The olive ridley turtle has a slightly deeper body. The carapace is nearly round to heart-shaped in adults, upturned on the lateral margins and flat on top (see Plate 2). Its width is about 90% of its length (SCL). The head is sub-triangular, moderate-sized, averaging about 22.4% of its straight carapace length (SCL). The lateral scutes are often five or more pairs, with the first pair always in touch with the precentral scute (Eckert et al., 1999; IUCN-Marine Turtle Specialist Group, 2005). Each of the four limbs has two visible claws (Eckert et al., 1999). As in other turtle species, males have larger and more strongly curved claws, as well as a longer tail. The distinguishing feature between male and female turtles is that the male's tail extends past the carapace assisting in mating, while the female's does not. Hatchlings have relatively bigger heads (39% SCL) and longer carapaces (width 78% SCL), and also the flippers are comparatively bigger than in adults.

In terms of colouration, the adults are plain olive-grey above and creamy or whitish; with pale grey margins underneath. Newborn hatchlings, when wet, are almost completely black, sometimes with greenish sides, and in general become dark grey after drying. With growth, they change to grey dorsally and white underneath.

Plate 2. Photograph of Olive ridley turtle showing morphological features.

Green Turtle

Of the three native Hawaiian species, the most common is the green sea turtle *(Chelonia mydas)*. This is the largest of the hard-shelled turtles weighing up to 200 kg and measuring up to 1.2 m. The body is depressed in adults, carapace oval in dorsal view, with its carapace width about 88% of its length (see Plate 3). The head is relatively small, blunt, and about 20% of the carapace length. The dorsal side has 4 pairs of lateral scutes, 5 central scutes, and usually 12 pairs of marginal scutes (Eckert et al., 1999). The lateral scutes do not make contact with the precentral scute (IUCN-Marine Turtle Specialist Group, 2005). The dorsal side of the juveniles is low keeled lacking a median keel in subadults and adults. On the underside, the scutes are also smooth and rather thin and comprise 4 pairs of inframarginal, 12 pairs of central plastral, usually one intergular and sometimes one interanal scute. Each flipper has a single visible claw.

Unlike other sea turtle species, all of which have two pairs of scales in front of their eyes, green sea turtles have just a single pair.

On the upper side, the general appearance varies from pale to very dark and from plain colour to combinations of yellow, brown and greenish tones, forming radiated stripes, or abundantly splattered with dark blotches. In juveniles, the scales of the head and upper sides of the flippers are fringed by a narrow, clear, yellowish margin that is lost with age. Underneath, the Atlantic forms are plain white, dirty white or yellowish white whilst the Pacific forms are a dark grey bluish – green. The newborn hatchlings are dark brown or nearly black on the upper side, the carapace and the rear edges of the flippers with a white margin. Underneath, they are white.

Plate 3. Photograph of Green turtle showing morphological features.

Species identification using tracks

The tracks of different species can be difficult to tell apart. The use of turtle tracks (type and width) in identifying a species therefore involves the careful observation of important diagnostic features such as track width, body pit depth (deep or shallow), and whether the diagonal marks made by the front flippers are symmetrical or asymmetrical (Shanker et al., 2003). However, the use of tracks to identify the species is very important especially when the animal is not directly observed in the field. There are two main track types that would be left on the beach by sea turtles during any emergence; Symmetrical and Asymmetrical (Eckert et al., 1999). If the track is fresh and the sand crisp, an exact measurement of maximum track width can also provide yet another clue as to species that visited the beach.

A symmetrical track (Figure 4) is formed when the front flippers move together synchronously to pull the turtle over the surface of the sand, literally dragging species above the high-tide line. This results in a track in which the right and left halves are almost mirror images (Shanker et al., 2003). Hind flippers create matching parallel mounds in the middle of the track. Both species tend to drag their tails, leaving behind either solid or broken lines with accentuated points. The leatherback and green sea turtles leave symmetrical tracks (Eckert et al., 1999). The track sizes of these turtles differ noticeably; the track of the leatherback is much larger and can only be potentially confused only in the case of a very large green turtle or a very small leatherback turtle ascending the beach.

Leatherbacks leave a track of width 150-230 cm wide, deep and broad, with symmetrical diagonal marks made by the fore flippers, usually with a deep median groove from the tail. A green turtle track will be 100-130 cm wide, deep with symmetrical diagonal marks made by the forelimbs, with tail drag solid or broken lines (Shanker et al., 2003; Agyekumhene, 2009).

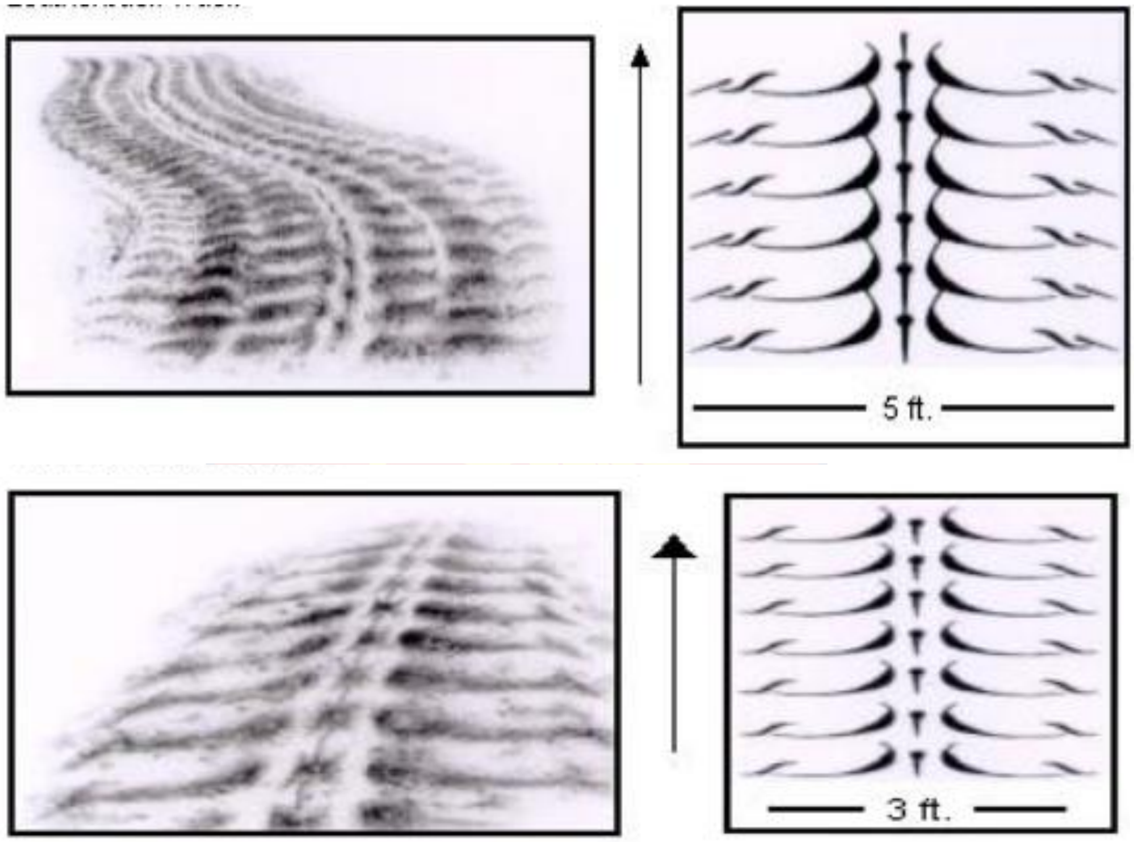


Figure 4. Schematic representation of a symmetrical track of leatherback (top) and green turtle (bottom). Arrows indicate direction of movement of the turtle (Source: Sea Turtle Conservation Guidelines of Florida Fish and Wildlife Conservation Commission, 2007).

An asymmetrical track (Figure 5) is formed when the front flippers move alternately (right, left, right, left, etc.) to carry the turtle forward (Shanker et al., 2003). This is sometimes referred to as or alternating tracks or “zipper crawls” and three species of sea turtle (olive ridley, loggerhead and hawksbill) leave asymmetrical or alternating tracks on the beach.

An olive ridley leaves a track of 70-80 cm wide on the beach; light with asymmetrical, oblique marks made by forelimbs; tail drag marks may be lacking or inconspicuous. Olive ridley tracks are often hard to distinguish from that of the hawksbill but since the two species nest in very different beach types, the tracks can be identified using the type of beach. Whereas the ridley prefers a wider beach with sand dunes at a river mouth, the Hawksbill prefers a narrow beach on islands or mainland shores (Shanker et al., 2003). But the olive ridley is the most likely to have their tracks on most beaches in Ghana since the hawksbill has not been reported to nest in Ghana for over decades.

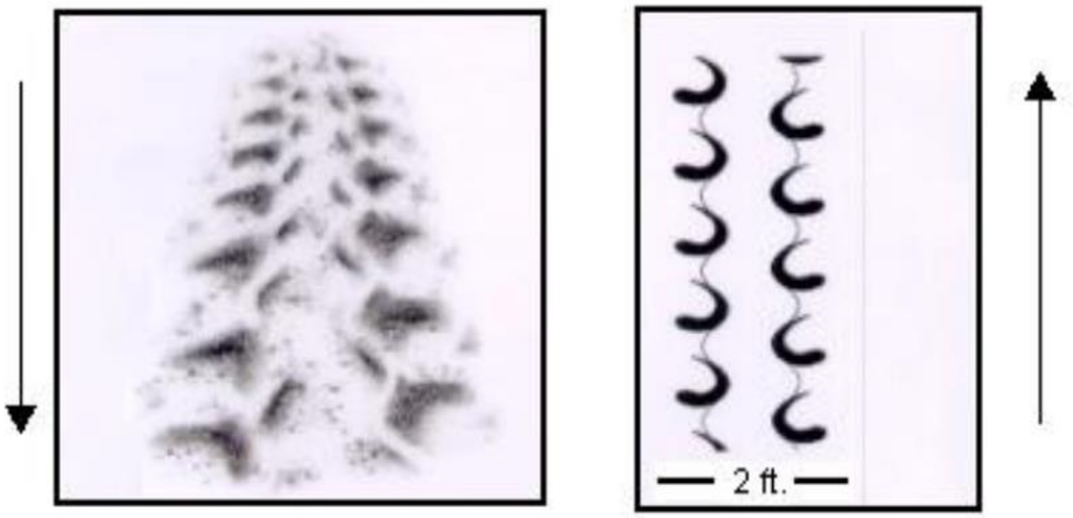


Figure 5. Schematic representation of asymmetrical track of sea turtles. Arrows indicate direction of movement of the turtle (Source: Sea Turtle Conservation Guidelines of Florida Fish and Wildlife Conservation Commission, 2007).

The state and threats of sea turtles

Globally, sea turtles face many and diverse forms of threats emanating from both the terrestrial (beach) and aquatic environment (Ocean). However, the primary threats to sea turtle populations are mostly anthropogenic (Amiteye, 2000; Agyekumhene, 2009; Tanner, 2014). Harvesting of eggs on the nesting beaches, poaching and killing of nesting female turtles on beaches (Amiteye, 2000; Agyekumhene, 2009; Tanner, 2014), sand mining and its associated erosion of nesting beaches, beachfront development, accumulation of debris on the beach and presence of beach front lightening are among the threats sea turtles face on land (Amiteye, 2000; Agyekumhene, 2009).

Despite the many laws that protect sea turtles, poaching and killing of adult turtles remains a threat to the sea turtles especially on nesting on beaches (Troëng, 2002). Sea turtles are usually harvested and sold live or killed and their meat used for food or sold for income due to the low income levels of most coastal communities (Agyekumhene et al., 2014). Sea turtle harvesting threatens turtle populations along nesting beaches by reducing the number of eggs available for hatching leading to low hatching production and reduced recruitment (Ndamba & Fretey, 2014). In Ghana, harvesting of nesting female turtle have been known to occur before the turtle could deposit her eggs and complete the nesting cycle (Agyekumhene, 2009). In other parts of Africa such as on the Rufiji Delta of Central Tanzania, poaching of turtles by local fishers have resulted in lack of successful hatchings (West & Hoza, 2014).

Nest predation is one factor that affects the hatching success of sea turtles on a sandy beach. It also affects the recruitment by reducing the number of individuals entering the population. Past surveys conducted along parts of Ghana's nesting beaches reported major predation on turtle eggs by dogs and pigs (Amiteye, 2000; Agyekumhene, 2009). Members of coastal communities also visit nesting beaches in the night for the turtle eggs and the nesting female turtles. While the humans usually collect eggs right after deposition, eggs can be predated by dogs and pigs at any time during egg development. Most of the eggs are however predated soon after the nests are laid since the dogs are always on the beach scavenging for eggs (Agyekumhene, 2009). These dogs are usually seen moving on the beach at night and during the day.

The morphology of sandy beaches has significant impacts on the nesting activities of sea turtles (Agyekumhene, 2009). Beach morphology and profile may change not only over centuries or decades, but also in a matter of hours depending on the types and intensity of the forces such as waves acting on the beach. In most areas of the world, such as the eastern coast of Ghana, from Prampram to the Volta estuary, sandy beaches are being eroded more than accreted (Wellens-Mensah et al., 2002). This continuous loss of beach area has negative impact on nesting habitat and has put sea turtles in great danger. Sea turtles have a high affinity for their nesting sites (Eckert et al., 1999), and as such, the loss or reduction of even a single nesting beach can have a much greater effect on the sea turtles' nesting activity and threaten sea turtle populations. Nesting sites are destroyed in many other ways such as, beach armouring, beach nourishment, and sand winning.

Destruction of nesting habitats through global warming and its associated sea level rise (Troëng, 2002) also poses great threats to sea turtles. Higher sand and nest temperature can be generated by global warming which would result in a mass feminization of hatchlings since sex determination in the turtles is temperature-dependent (Lutz & Musick, 1997). This has impact on recruitment and ultimately results in population declines.

Of great impact on sea turtle population declines are the threats to sea turtles in the aquatic environment (Mancini, Seminoff, & Madon, 2012) which include pollution (mainly from plastic), ingestion of plastic materials, entanglement in fishing gears or their drowning in trawl-fishing and development of offshore oil fields. Significant among the risks to the survival of sea turtles in the marine environment emanate from their regular entanglement or capture in commercial and artisanal fisheries (FAO, 2010; Lewison et al., 2013; Tanner, 2014). Although commercial fisheries such as the pelagic long-line has been stated as a key threat to sea turtle survival (Agyekumhene et al., 2014; Alexander et al., 2017), the risk of entanglement and by-catch of marine megafauna in small-scale coastal net fisheries such as the fixed fishing gear in the pelagic and shelf waters might approach or even surpass the by-catch rate in some industrial fisheries (Jaramillo-Legorreta, Rojas-Bracho & Brownell, 2007; Peckham et al., 2007a, 2008; Alfaro-Shigueto et al., 2011; Mancini et al., 2012).

Conservation status of sea turtle

Sea turtle populations all over the world have been declining at an alarming rate in recent times. Sea turtles have come under threat of extinction due to increasing human activities that impact the species negatively. This decline in the populations of marine turtles in recent times has led to the International Union for the Conservation of Nature (IUCN) classifying all species of sea turtles as either Vulnerable (Leatherback *Dermochelys coriacea*, Olive ridley *Lepidochelys olivacea* and loggerhead *Caretta caretta*), Endangered (Green turtles *Chelonia mydas*) or Critically Endangered (Hawksbill *Eretmochelys imbricata* and Kepm's ridley *Lepidochelys kempii*); with the exception of the Flatback (*Natator depressus*) which is the only species listed as Data Deficient under the IUCN Red List of Threatened Species (Márquez, 1990).

The International Union for the Conservation of Nature (IUCN) Red List provide objective and scientifically-based information on the current conservation status of sea turtles as well as information on their distribution which lays the foundation for making informed decisions about conserving the species at national and international levels. On the list, the relative risk of extinction of all sea turtles is determined and those species facing higher risk of global extinction is highlighted and given prominence by categorizing them as Critically Endangered, Endangered and Vulnerable (see Appendix B). Species whose status cannot be evaluated because of insufficient information are categorized as Data Deficient.

The Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora is an international agreement between governments of contracting parties to ensure that international trade in specimens of wild animals and plants does not threaten their survival in the wild. Currently, there are high levels of exploitation of some animal and plant species, which together with other factors, such as habitat loss, could greatly deplete the populations of these species and consequently result in the extinction of the species or bring them close to extinction. Though many traded wildlife species are not endangered, the existence of an agreement to ensure the sustainability of their trade is important in order to safeguard these resources for posterity. Since CITES does not replace any existing national laws but rather provides a framework to be respected by each Party, each Party then has to adopt its own domestic legislation for implementing CITES at the national level.

Under the CITES, all species are categorized into three appendices depending on how threatened they are by international trade. Each of Appendices I, II and III of the Convention afforded different levels of protection from over-exploitation (The CITES Appendices, 2019). Appendix I species include all those threatened with extinction which are or may be affected by trade. Trade in specimens of these species requires extremely strict regulation so as to not endanger further their survival and must only be authorized in exceptional circumstances. Appendix II shall include species which although are not currently threatened with extinction, have the tendency to become extinct unless trade in their specimens is subject to strict regulation in order to avoid utilization that threatens their survival. Appendix III also include all species which any Party identifies as being subject to regulation within its jurisdiction for the purpose of preventing or restricting exploitation, and as needing the co-operation of other Parties in the control of trade. Trade in specimens of species included in Appendices I, II and III is not allowed by the Parties except when in accordance with the provisions of the present Convention.

All sea turtles are also listed in Appendix I of the Convention on International Trade in Endangered Species (The CITES Appendices, 2019). CITES affords international protection for sea turtles by placing a ban on the trade in sea turtles and their products on the international market. Although signing on to CITES is voluntary, it is still binding on contracting parties of CITES. The international trade in sea turtles and their products is therefore not allowed by all Parties except when the purpose of the import is not commercial, for instance for scientific research. In such exceptional instances, trade may be allowed to take place but with authorization through the granting of both an import permit and an export permit.

The United Nations Convention on Biological Diversity (CBD) also exists to provide protection and conservation for sea turtles and their habitats globally. As an international and legally-binding treaty, CBD has as its goals to ensure conservation and sustainable use of biodiversity which includes sea turtles. Countries which are parties to the convention have to, among others, identify and monitor processes and activities which have or are likely to have significant negative impacts on the conservation and sustainable use of biological diversity; promote the protection of ecosystems and natural habitats of endangered species like sea turtles; maintain viable populations of species in natural habitats; and promote the recovery of threatened species through ecosystem rehabilitation, restoration, and implementation of relevant plan and management strategies. Countries are further required to develop or maintain legislation and/or other regulatory provisions for the protection of threatened species and populations.

The Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention or CMS adopted in Bonn on June 23, 1979) provides a global platform for the conservation and sustainable use of migratory animals, their habitats and their migratory routes. All the sea turtles species, with the exception of the Flatback (*Natator depressus*), are listed under Appendix I of the convention. Being one of the species listed under Appendix I of the convention, contracting parties are enjoined to protect both sea turtles and their habitats and ensure free and safe migration of the species due to the existence of reliable evidence, including best available scientific evidence that the species is endangered. Parties are required to prohibit the taking of sea turtles except for scientific purposes, for enhancing the propagation of sea turtles or for accommodating traditional subsistence; provided the taking does not negatively impact sea turtles.

The African Convention on the Conservation of Nature and Natural Resources (adopted in Algeria on September 15, 1968 and signed by Ghana on October 9, 1969) also have sections that are applicable to the conservation of fauna including sea turtles.

In some countries, there are statutory measures which seek to protect sea turtles and their nesting beaches. In the United States of America, for instance, several Regulations and Acts exist to protect the sea turtles. Among these acts are the Endangered Species Act (ESA) of 1973 which protects six of the seven sea turtle species (the green *Chelonia mydas*, hawksbill *Erythmochelys imbricata*, Kemp's ridley L*epidochelys kempii*, leatherback *Dermochelys coriocea*, loggerhead *Caretta caretta*, and olive ridley, *Lepidochelys olivacea*). The Florida Endangered and Threatened Species Act of 1977 (FETSA) was also established to conserve and sustainably manage its resources, especially endangered and threatened species. The Marine Turtle Protection Act (MTPA) of 1995, also offers protection for the green (*Chelonia mydas*), leatherback (*Dermochelys coriocea*), hawksbill (*Erythmochelys imbricata*), Kemp's ridley (L*epidochelys kempii*), and loggerhead (*Caretta caretta*) sea turtles. The Coastal Zone Protection Act of 1985 (CZPA), was designed to manage sensitive coastal areas by minimizing damage to the environment, private property, and life whereas the Beach and Shore Preservation Act (BSPA) regulates coastal construction and beach preservation projects such as beach restoration and nourishment, navigation inlet improvement, and erosion control projects.

In Ghana, all sea turtle species are protected through the Wildlife Conservation Regulations, 1971 L.I. 685, the Wildlife Conservation (Amendment) Regulation 1983 L.I. 1284 and the Fisheries Regulation of 2010. The Wildlife Conservation Regulations, 1971 L.I. 685 and the Wildlife Conservation (Amendment) Regulation 1983 L.I. 1284, categorize all wildlife in Ghana under Schedules: from 1 to 3 with animals in Schedule 1 having the highest level of protection while Schedule 3 animals have the least. Sea turtle are listed under the Schedule I of these regulations and are therefore completely protected. With sea turtles being listed as completely protected, the hunting, capturing or destroying of sea turtles and their products is absolutely prohibited at all times by any person. The Wildlife Conservation Regulations, 1971 L.I. 685 also require that all activities involving sea turtles be permitted by the Executive Director of the Wildlife Division or his representative. The Wetlands Management (Ramsar Sites) Regulation of 1999 L.I. 1659, protects the nesting habitats of sea turtles by prohibiting degrading activities such as sand winning on the beach, and ocean dumping, and pollution of water bodies (e.g. the sea). The Fisheries Regulation of 2010 prohibits the use of shrimp nets without Turtle Excluder Device and require that all turtles accidentally caught in fishing nets during a fishing operation be released into the sea.

Traditional beliefs and taboos have also helped in the conservation of wildlife species and their habitats in many African countries including Ghana (Ostrom, 1990; Hulme & Murphree, 1999; Roe et al., 2009; Alexander et al, 2017). For example, in Madagascar, Tengo and others (as cited in Alenxander et al., 2017) reported that the taboo against despoliation of sacred forest has worked to maintain to ecological integrity of the forest area. In Indonesia also, the presence of a taboo against killing of certain wildlife have provided special protection for these species even though some of the species like the monkeys destroy farm crops of the To Lindu people (Riley, 2010). This spiritual, historical and cultural beliefs of some clans, tribes, families and ethnic groups were exploited to conserve, preserve and protect terrestrial and aquatic wildlife species and their habitats by many communities before the introduction of Western conservation methods to Africa (Ostrom, 1990; Hulme & Murphree, 1999; Roe et al., 2009).

In Ghana traditional beliefs and taboos exist among some clans to protect sea turtles in some coastal fishing communities (Agyekumhene, 2009; Agyekumhene et al., 2012; Alexander et al., 2017; Allman & Agyekumhene, 2017). In Ada-Foah for instance, members of the clans Adibiaweh, Lomobiaweh, Tekpebiaweh, Kponor and Dangmebiaweh hold the turtles sacred and do not eat the sea turtles or their eggs (Agyekumhene, 2009). These clans learned through oral history that the turtles are believed to have saved their ancestors when they were drowning at sea after their canoes were capsize by a heavy storm. Another story also is told of sea turtles helping the Dangbe people of eastern Ghana in the past to defeat their local enemies, the Ashanti warriors, at war fought by the mouth of the Volta River (Allman & Agyekumhene, 2017). Some of these clans also get good omens through the turtles while others have spiritual revelations through the directions of the turtles. Because of these traditional systems of taboos and beliefs, sea turtles are not hunted, captured, killed or eaten by these clan members; sea turtles are released from fishing nets when accidentally captured at sea; sea turtles whether in part or whole are never sent to or cooked in the house of the clan members and sea turtles are buried when found dead at the beach by any clan member.

With the advent of Christianity and Islam among Ghanaian communities, the traditional structure in which these taboos and beliefs are imbedded are rapidly eroding because of the spread of secularism (Allman & Agyekumhene, 2017). Many of the customs and beliefs associated with traditional practices are now relegated to festivals and the tourism sector. Transmigration also plays a bigger role in the breakdown of those nature protecting taboos (Allman & Agyekumhene, 2017). Many of today's coastal fishermen moved from inland communities, where hunting and agriculture have become increasingly difficult. Those fishermen do not adhere to the traditional stories of the coastal ethnic groups and, as a result, are routinely seen breaking traditional codes that date back hundreds of years. Although there are several other factors that militate against the effectiveness of traditional beliefs, the belief is still held among many clans and is passed on by some clan members from generation to generation (Agyekumhene et al., 2012).

Threats of fisheries to sea turtles

Sea turtles are highly vulnerable to fishing nets, particularly gillnets and driftnets, in the marine environment, because with the exception of the leatherback, they are known to spend most of their lives in shallow coastal waters (Eckert et al., 1999). This easily exposes them to the excesses in activities by humans who still present the largest oceanic threat to sea turtles (Barkan, 2010).

By-catch, the capture of unintended species in fishing gears during fishing operations, remains a major threat and has been a great source of concern for many fisheries managers because it presents a serious threat to many marine animals (Komoroske & Lewison, 2015). Species which have been recorded as subject to by-catch (especially from gillnet and driftnets) are numerous and they are from a wide range of taxa including fish, birds, pinnipeds, cetaceans and sea turtles (Wallace, Kot, Dimatteo et al., 2013). By-catch has resulted in the decline in several megafauna exerting surging and widespread ecological impacts (Komoroske & Lewison, 2015). For populations of some already depleted species such as the aquita *(Phocoena sinus),* Amsterdam albatross (*Diomedea amsterdamensis*), leatherback sea turtle (*Dermochelys coriacea*), and dugong (*Dugong dugon*), by-catch remains the largest threat to their risk of extinction (D'Agrosa et al., 2000; Marsh et al., 2002; Read, 2008; Rivalan et al., 2010; Wallace et al., 2013).

Fisheries by-catch has threatened the continued survival of several sea turtle species, which have experienced population declines over the past several decades. Over 70% of sea turtle interaction in fisheries results in capture with less than 30% not resulting in turtle by-catch, and this presents a major source of sea turtle mortality around the globe (Soykan et al, 2008; Peckham et al., 2007a, 2007b). For example, in the 1990s, an estimated 44,000 sea turtles were killed annually by the US shrimp trawl fleet (Magnuson et al., 1990) alone. Also an estimated 71,000 annual deaths of turtle resulting from an annual estimated mean of 346,500 turtle interactions, was reported to have occurred in general fisheries of the US (Finkbeiner et al., 2011). Large numbers of turtles have also been reported to be lost to shrimp fishing operations in Ghanaian waters by Nunoo and Evans (as cited in Agyekumhene, 2009). It is reported that deaths through all sources of human activities combined do not match the deaths caused by incidental catches in shrimp trawls (National Research Council, 1990). Wang et al (2013) also reported high turtle mortalities from fishery by-catch which makes it difficult to achieve any recovery of sea turtle population from just increasing the hatchling production alone.

Incidental capture in purse seine, gill nets, and various types of unattended fishing gear are also responsible for a larger number of sea turtles kills around the globe (Soykan, 2008; Peckham et al., 2007a, 2007b; Wang, Barkan, Fisler, Godinez-Reyes, & Swimmer, 2013). Entanglements also result from lobster and crab pots, as well as long-line fishing. These gears often snare the turtles, and frequently are not pulled soon enough to free the turtles before they are mutilated, debilitated, and drowned. Although turtles can remain underwater for long periods, they need to breathe atmospheric oxygen. A trapped turtle will struggle, significantly reducing its oxygen supply and shortening the time it has before it needs to reach air. The long struggles by these trapped turtles cause death through sea water infiltration into the lungs of the turtles.

Although sea turtle by-catch keeps increasing over the years, the true amount of global by-catch is not well documented as a result of lack of observers and inaccurate catch reports (Barkan, 2010). By-catch is often discarded back to the sea, dead and unused, because the by-catch species is either protected by regulatory policies or commercially valueless, and most of these discards are not reported due to absence of observers. By-catch is however accidental since it is a problem for fishermen because it damages their fishing gear, takes time to remove from gear, and can result in reduction of target catch (Barkan, 2010: Agyekumhene et al., 2014).

Although several efforts have been made in the past to protect sea turtles, the incidental capture in pelagic long-line, trawl, and gillnet fisheries still threaten the survival of the species. Mortalities result from the animal either drowning after becoming hooked or entangled, or suffering fatal injuries on-board the vessel from swallowing the hook. Because net entanglement can reduce swimming abilities, sea turtles caught in gillnets and trawls face a higher chance of mortality from drowning than those captured on a long-line hook.

By-catch reduction devices

Given the threats to marine species populations from incidental capture by fishing gear, several methods have been developed to reduce by-catch. These methods include fisheries time and area closures and introduction of catch limits aimed at reducing fishing pressure which will likely reduce by-catch. The political processes associated with fisheries policies enactment and management decisions, as reported by Barkan (2010) may be too long to save some critically endangered by-catch species. The expedition of fisheries closures, especially in artisanal fisheries, is likely to encounter political obstructions in some countries (Barkan, 2010), as fishermen perceive the process as an attempt to reduce their catch and hence their income. Several devices have therefore been developed to help reduce by-catch of megafauna in marine fisheries.

Turtle excluder devices

Turtle excluder devices (TEDs) are implements designed to reduce sea turtle by-catch in shrimpers and other trawl fisheries. A turtle excluder device (TED) is made up of a metal grid of bars built into the net that open to allow sea turtles out of the net through a trap door while allowing shrimp to pass through the bars into the back of the net. Federal regulations of most countries require trawlers to install turtle excluder devices (TEDs) on the fishing gears. The Fisheries Regulation 2010 of Ghana for example requires that all shrimp trawlers fix TEDs on their gears and also report any capture of sea turtles from their fishing operations. The introduction of TEDs in shrimp trawl fishery was with the expectation of reducing incidental capture of sea turtles by 97%. The device was effective at reducing by-catch rate by ensuring that sea turtles exited from fishing gears in a healthy and injury-free state (Lewison et al., 2013). However, TEDs were efficient at decreasing stranding rate of loggerhead and Kemp's ridley in the first three years after which the stranding rate increased possibly due to improper use of TEDs, inadequate size of TED openings, and poor TED use compliance, as reported by Lewison and others.

Studies have suggested that the adult size used to establish the mandatory proportions of TEDs is smaller and unable to allow exit of loggerhead sea turtles which are currently larger than they were in 1992 when TEDs were first introduced (Barkan 2010). It is therefore imperative to expand the size of TEDs to bring about less mortality of loggerhead sea turtles in shrimp trawls, as reported by Barkan. The huge size and heaviness of TEDs could also be possible cause of the device not utilised in countries like Ghana. TEDs have been reported to interfere with the setting and hauling of fishing gears and are also heavy to convey on fishing expeditions.

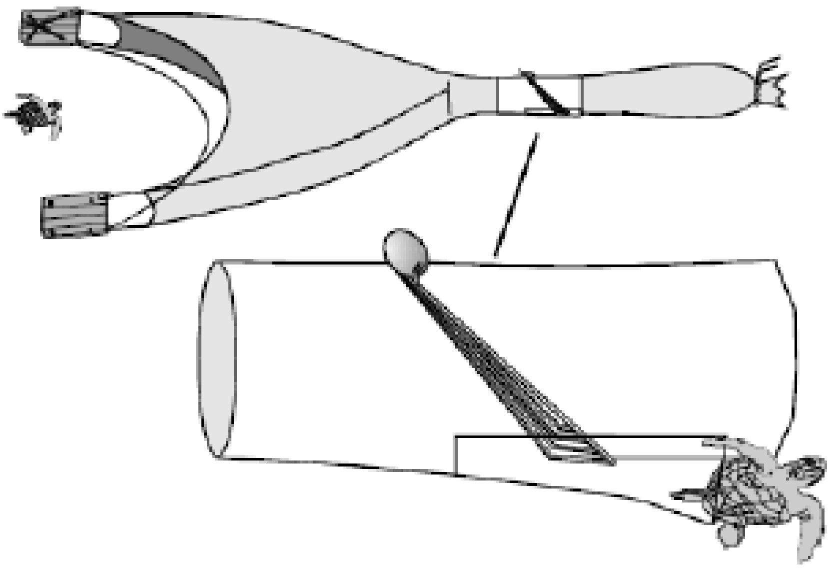


Plate 4. Turtle Excluder Device (TED) used in trawl net fisheries (Source: Barkan, 2010).

Circle hooks

Long-lines, sometimes extending as long as 100 km, are used at or near the sea surface to catch large pelagic fish such as tunas and swordfish. Long-lines are more selective than nets but still result in significant by-catch of species like seabirds and sea turtles that prey on the bait attached to the hooks (Barkan, 2010). Circle hooks have been used as alternatives to the traditional J-shaped hooks in long-line fisheries as another gear modification technique aimed at reducing sea turtle mortality. Circle hooks have been effective at reducing loggerhead sea turtle by-catch in long-line by 90% in some fishery (Barkan, 2010). The main difference between a J-hook and a circle hook is that the tip of a circle hook curves to point back toward the hook shaft, resulting in a wider hook with a smaller gap between the shaft and the tip. The hooks reduce sea turtle mortality by hooking the turtle in the mouth rather than deeper in the throat or stomach. This allows fishermen and turtle conservationists to unhook the turtles without causing serious injury or mortality. Circle hooks are however only effective in shallow-set long-line fisheries because in deep-set fisheries, a turtle hooked in the mouth will still drown and die. Circle hooks are also gear specific and work only in long-line fishery.

Plate 5. Circle hook (left) and J-hook (right) used in the pelagic longline fisheries (Source: Barkan, 2010).

Shark shapes

The use of shark shape has also been adopted as sensory cues manipulation method to reduce sea turtle capture in fishing gears. Black shark silhouette shapes are suspended in front of the net along the float line which served as visual deterrent to reduce sea turtle by-catch (Wang et al., 2010, 2013). The use of shark shapes has demonstrated a significant reduction of green sea turtle interactions with nets by 54%. Shark shapes used in artisanal demersal gillnet fishery also resulted in significant reduction in catch per unit effort (CPUE) of non-target species by 45% and mean catch value by 47.4% (Barkan, 2010). Notwithstanding, shark shapes have received relatively minimal usage due to the huge size of the shark silhouette shapes which present a great interference to the fishing process; setting and hauling of nets.

Plate 6. Shark shape used in the gill net fishery (Photo credit: Ocean Discovery Institute).

Acoustic Pingers

Acoustic pingers have been employed as a method to reduce marine mammal and turtle by-catch (Piniak et al., *in manuscript*). The pingers are installed on gill nets along the float line from where they continuously emit noises at specified frequencies that deter marine mammals from approaching the gear. Fitting active pingers on gill nets that emitted a 300 ms pulse every four seconds has the tendency to reduce marine mammal by-catch by 90% (Campbell and Cornwell, 2008). In California, the use of pingers has been successful at reducing marine mammal capture by a third of what nets without pingers capture. Though pingers have been successful at reducing marine mammals in fishery, it has received lower patronage and usage from fishermen due to factors such as high cost, required periodic maintenance, and the huge size of the device which interferes with setting and hauling of fishing gear (Campbell and Cornwell, 2008). Coupled with these concerns from fishermen is the weak compliance of regulations on the pingers. In the Gulf of Maine for instance, compliance ranges from 38% to 91% due to lack of required logistics for the enforcement agency (Coast Guard) to haul nets and check for the presence of pingers when nets are set (Campbell and Cornwell, 2008).

Plate 7. Acoustic pinger (Photo credit: Ocean Discovery Institute)

Buoyless nets

The viability of buoyless nets for reducing sea turtle by-catch in fishing operations has been investigated using bottom set nets (Peckham et al., 2015) in Baja, California. The experiment was set up on the premise that reducing the vertical profile of fishing nets which resulted in reduced sea turtle by-catch. The buoyancy of the fishing was therefore reduced by increasing the distance between the buoys from 1.7 m interval on control nets to 8.7 m interval on experimental nets (buoyless nets). The experiment reported a 68% reduction in mean loggerhead turtle by-catch but also lowered the market value of fish catch significantly by 29% due to lowered catch in the buoyless nets. This presents an important source of concern by local fishermen accepting to use the technique.

Light emitting diodes

Sensory cue manipulation to repel species from hooks or nets have been utilised to facilitate new methods for preventing incidental capture in fishing gears. Studies have thoroughly examined the visual properties of sea turtles to discover the role visual cues play in sea turtle by-catch reduction. Juvenile loggerhead sea turtles are known to be attracted by glowing green, blue, and yellow chemical lightsticks, as well as orange light-emitting diodes (LEDs) (Wang et al., 2013). Also loggerhead and green sea turtles are able to detect ultraviolet light, while pelagic fishes cannot due to the presence of different types of visual pigments in the photoreceptors of pelagic fishes. This is suggestive of colour sensitivity by the different species and has been exploited to reduce by-catch of megafauna, although the extent of colour sensitivity is dependent on the depth of the foraging habitat.

In spite of the fact that sea turtles and fish occupy the same marine habitat, there is enough variation in the sensory abilities as a result of the different lifestyles. Studies conducted to compare the visual ecology of sea turtles and fish revealed that turtles were more sensitive to UV light than the fish (Wang et al., 2013). Gear modifications technologies have employed these variations to allow fishing gears catch targeted species while reducing the rate at which endangered sea turtles are ensnared. Ultraviolet

(UV) light emitting diodes (LEDs), have in recent times been a potential by-catch reduction technology (BRT). These are diode that emits ultraviolet (UV) light detectable by sea turtles, but not by many of the most commercially valuable fish species (Wang et al., 2013). A fishing gear fitted with these lights traps significantly fewer turtles, while continuing to capture normal amounts of target fish.

Plate 8. Green light emitting diode (LED) light used in gill net fishery (Photo credit: Ocean Discovery Institute).

Light emitting diode as a by-catch reduction device

Incidental capture of sea turtles in commercial fishing gear is an issue of growing concern for fishers and fisheries managers (Southwood et al., 2008). In recent times, fishing gear designed to capture pelagic fish species has become a source of high mortality for sea turtles around the globe (Wang et al., 2013). Most efforts at reducing sea turtle by-catch in fisheries, such as seasonal and fishery closure, turtle excluder device (TED), acoustic pingers, shark shapes and circle hooks have exhibited limitations including loss of fish, loss of revenue, major modification to fishing gear, and high cost of device maintenance. This rendered these by-catch reduction efforts less desirable by fishermen who do not want to compromise profits from the livelihoods. This has made the usefulness of these approaches for reducing sea turtle by-catch limited. There has therefore been a growing interest in identifying economic and practical fishing techniques that minimize by-catch without impacting target species catch rates.

A broad range of by-catch reduction techniques that employ mechanical, behavioural and physiological approaches have been explored to address the varied challenges associated with the different fishery. Prominent among these methods is the use of sensory techniques. Although the factors attracting sea turtles and fish to fishing gears are poorly researched (Southwood et al., 2008), multiples sensory cues are believed to play a key role in the process. This emanates from the realization that sea turtles and fishes are evolutionary diverse and therefore have different sensory biology that possibly affects the way they interact with objects in their environment such as fishing gears (Southwood et al., 2008). This difference in sensory capabilities of sea turtles and fish and how it influences their attraction or repellent to objects has been the underlying principle for developing by-catch reduction technologies that specifically target desired species and help reduce by-catch of sea turtles.

Chemoreception, the ability for an organism to sense chemical cues in its environment by taste (gustation) or smell (olfaction), have been reported for most species of animals. Numerous studies have shown that fish use chemical cues to detect and locate prey, to navigate during short- and long-distance migrations, and for intraspecific communication related to reproduction and predator avoidance (Doving & Stabell, 2003).

Chemical cues play a role in food detection and search behavior in fish such as tuna that are reported to rely on chemical cues for initiating prey search behaviour. The work by Shamchuk et al (2018) also showed that sharks are able to detect and track minute concentrations of prey in the environment using chemicals cues. Southwood (2008) in their field experiments of different bait types, also found that altering the chemical signature of longline bait have significant effect on catch rates of target species, implying that different species use different chemical cue to detect baits.

In sea turtles, like in fish species, chemical cues play vital roles by influencing important processes such as feeding, navigation, migration, and natal homing for these species (Constantino & Salmon, 2003). Turtles are able to use their chemosensory abilities to detect a variety of underwater chemicals including those emanating from pray item during feeding (Constantino & Salmon, 2003; Piovano et al., 2004). Sea turtle orientation to breeding site is also influenced by chemical cues which allow hatchlings to imprint on their natal beach and migrate back to these beaches in subsequent years to breed (Grassman, Owen & McVay, 1984).

Even though chemical cues influence feeding behaviour in sea turtles (Constantino & Salmon, 2003), there is growing evidence to suggest that turtles primarily use visual cues in locating prey (Constantino & Salmon, 2003). In the presence of visual and chemical cues associated with jellyfish, leatherback turtles move towards the visual stimuli created by the jelly fish ignoring the chemical stimuli which suggest that visual cues play much greater role in prey finding than chemical cues (Constantino & Salmon, 2003). Visual cues in sea turtles have also been reported to induce a stronger feeding response in turtles than chemical cues by Constantino and

Salmon (2003). These studies suggest that though there is the tendency for both visual and chemical cues to attract sea turtles to a fishing gear, visual cues have a relatively higher influence on sea turtles getting attracted to a fishing gear than chemical cue (Southwood et al., 2008). The use of visual modification techniques to make fishing gear less attractive to sea turtles or easy for turtles to see and avoid has therefore been appealing from an economic and conservation perspective than chemical cues.

The use of visual cue alteration as a by-catch reduction technique in marine mega fauna emanates from the fact that different organisms exhibit different preference to different wavelengths of light due to differences in photoreceptor anatomy and visual pigments. Surface-feeding striped marlin, for example, are most sensitive at spectral wavelengths of violet-blue (436 nm), blue (488 nm), and green (531 nm) (Fritsches et al., 2003a) while adult yellowfin tuna, also surface layer feeder, exhibit optimal sensitivity to light in the violet-blue (426 nm) and blue (483 nm) range (Loew et al., 2002). Swordfish and bigeye tuna are deeper water feeders that hunt during the daylight hours, and their photoreceptor anatomy and visual pigments are sensitive solely to the dominant blue wavelength (Southwood et al., 2008). The lenses of the tuna and billfish species are able to effectively block ultraviolet (UV) light making it impossible for their visual range to get into the UV spectrum (Fritsches et al., 2000). However, many of the shark species possess lenses with pigments that filter UV lights and this help to increase long-distance sight for improved prey detection. Sea turtles also have lenses and other optical media which transmit light to 320 nm, and have the capacity to detect light in the UV range (Mäthger et al., 2007).

Sea turtles and pelagic fishes are highly visual predators, and visual cues play an important role in attracting both groups of animals to fishing gear (Southwood et al., 2008). Although sea turtles and fish occupy the same marine habitat, their lifestyles are different enough that the two groups tend to vary in their sensory abilities. There are great differences in the visual sensitivity between and within these species (Loew et al., 2002; Fritsches et al., 2003a; Southwood et al., 2008). Modifications to fishing gear that exploit these differences in visual capabilities to modify the behaviour of sea turtles and pelagic fish in relation to gill nets could therefore be effective mechanism for reducing by-catch rates of sea turtles (Southwood et al., 2008).

Problem statement

By-catch in fisheries has been reported as a major and significant source of sea turtle mortality around the globe. The interaction of small scale coastal gill net fisheries with sea turtles is reported to equal or in some cases exceed sea turtle interactions with industrial scale pelagic fisheries. A greater percentage of sea turtle interaction with fishery results in capture and this presents significant source of mortality for sea turtles. This growing evidence of high by-catch rate threatens turtle species in artisanal fishery (Peckham et al., 2007b). Field surveys have indicated growing agitations between fishermen wanting to sustain their livelihoods and sea turtle conservationists who seek to protect the endangered species. There is therefore the need for measures that will help protect the threatened wildlife in their habitats while ensuring that the fishermen still make a living from fishing activities.

Justification of study

Sea turtle mortality around the globe as a result of high by-catch in fishery (Soykan et al., 2008; FAO, 2010) is causing declines in populations of the species worldwide (D'Agrosa et al., 2000; Tasker et al., 2000; Read, Drinker & Northridge, 2006; Peckham et al., 2007b, 2008; Alfaro-Shigueto et al., 2011; Casale, 2011; Crowder

& Heppell, 2011; Wallace et al., 2013). By-catch during fishing operations, has been the focus of research over the past two decades (Soykan et al., 2008). These by-catch research has however targeted only industrial fishing vessels and not artisanal fishery because it is much easier to study few large ships than many smaller boats (Soykan et al., 2008).

The lack of by-catch research on artisanal fisheries is as a result of the fact that these fisheries, especially in developing countries, are rarely regulated, making it difficult to apply the data collection methods employed for industrial fisheries. Also, unlike industrial scale fisheries, small-scale fisheries are often faced with the challenge of inadequate resources and infrastructure limiting the ability to assess and effectively regulate their by-catch rate and impacts (Shester & Micheli, 2011). There is therefore still the lack of comprehensive understanding of by-catch rates not only across species but also fisheries and ocean basins (Soykan et al., 2008). Due to the immense economic and nutritional importance that small-scale fisheries possess, especially in developing countries like Ghana, there is the need for innovative approaches as opposed to limiting or banning the use of driftnets (Wetherall et al., 1993; D'Agrosa et al., 2000) to reduce the by-catch of marine megafauna such as sea turtles while maintaining the fisheries. Again, though the artisanal and other small-scale fisheries represent a particularly data-poor sector, it makes up a large majority of the world's fishers (Béné, 2006; Pauly, 2006) and can have significant negative impacts on marine megafauna (D'Agrosa et al., 2000; Peckham et al., 2007b; Mangel et al., 2010).

In Ghana, although the Wildlife Conservation Regulations of 1971, L.I. 685 makes it an offence, punishable by fines, imprisonment or both to capture, kill or sell part or the whole of sea turtles, there are still high incidences of accidental capture in fishing gears among many coastal communities. A substantial number of Vulnerable leatherback sea turtles, Endangered green sea turtles, and Vulnerable olive ridley sea turtles are killed each year from the purse seine and gill net fisheries in Ghana (Tanner, 2014). In 2013 for instance, over two hundred and seventy-three mortalities reported to be associated with fishery interaction were recorded in three coastal fishing communities (Ghana Wildlife Division, *unpublished data*). The capture of sea turtle in fishing nets coupled with the threat they face on their nesting beaches such as eroding beaches and collection of nesting female (Agyekumhene, 2009; Wellens-Mensah et al., 2002; Armah et al., 1997) have contributed to the decline in their population along most sandy beaches of Ghana.

For proper management and conservation goals to be achieved, a better understanding of the ecology and threats both in the water and on their nesting beaches are needed. Although several studies exist in Ghana on sea turtles, all of these studies have concentrated on nesting beaches to count nesting turtles (Armah et al., 1997; Amiteye, 2000; Allman & Armah, 2008; Agyekumhene, 2009; Agyekumhene et al., 2010; Alexander et al., 2012, 2017) or in fishing communities to assess the influence of local knowledge on sea turtle conservation (Agyekumhene et al., 2010; Alexander et al., 2012, 2017).

For instance, the first sea turtle work in Ghana was carried out by Irvine (1947) and Toth & Toth (1971) was along coast where he documented five species of sea turtle (leathetback *Dermochelys coriacea*, green *Chelonia mydas*, olive ridley *Lepidochelys olicacea*, loggerhead *Caretta caretta*, and hawksbill *Eryhtmochelys imbricarta*) to be nesting along Ghana’s sandy beaches. In 1997, Armah and other workers also conducted sea turtle conservation work in fishing communities in Ningo and Prampram where they reported collection of female, egg predation by dogs and pigs, and entanglement in fishing nets as the main threats facing sea turtles in Ghana. Amiteye

(2000) also worked on sea turtle abundance and distribution along the coast of Ghana and found that nesting by sea turtle occur along the entire coast of Ghana where there are sandy beaches and nesting intensity increases from west to east with areas from Ningo-Prampram to Ada receiving the most nesting activities. Beyer, Wkau and Blay in 2002 also worked on nesting beaches in Old Ningo to determine the effect of predation on hatching success of olive ridley (*Lepidochelys olivacea*) and reported 67% of nests were predated by dogs preventing 61.3% of eggs deposited from hatching. Agyekumhene in 2009 conducted sea turtle population studies in Ada Foah looking at the factors influencing nesting and hatching success of sea turtles and concluded that sand particle size and beach morphology affects the nesting of sea turtles while predation impact on the hatching success of turtles.

More recent sea turtle studies have also further concentrated on the species protection on their nesting habitats. Allman and Armah (2008) also established the first sea turtle tagging program to determine population trends on the beaches of Ada Foah and reported three species (leathetback *Dermochelys coriacea*, green *Chelonia mydas* and olive ridley *Lepidochelys olicacea*) to actively nest on Ghana's beaches in recent times. Alexander, Agyekumhene and Allman (2017) also examined the role of taboos in protection and recovery of sea turtles and reported that traditional practices make fishing communities more receptive to sea turtle conservation and more willing to follow government regulations and that fishers in the communities that are aware of the taboo are also more willing to adjust fishing methods to better protect sea turtles. Allman and Agyekumhene (2017) in the paper "*Traditional Taboos help save Ghana's sea turtles*" recounted the various stories that exist on how turtles were in the past revered by some fishing communities but due to the infiltration of migrant communities and religion (Christianity and Islam), these taboos to erode over time putting sea turtles in danger of being killed for food and for sale by fishermen.

In spite of these and many more studies on sea turtles, no study has been conducted in Ghana on the in-water threats to the species. Currently, gear modification using illumination method has also not been tried in West Africa or Ghana. Only one study exists around the globe by Wang et al. (2010) which revealed that illuminating fishing nets with green LED lights significantly reduced rate of sea turtle capture by 40% with no significant impact on targeted fish catch. The other study on gear illumination, also by Wang et al. (2013), explored the effect of ultraviolet (UV) LED lights on reducing turtle catch in gill nets. These studies however were both focused on the impact of the LED light on green turtles and therefore impacts of the green LED lights on other species like leatherback and olive ridleys which nest in appreciable number along Ghana’s coast were not reported.

Also, the study by Wang et al. (2010, 2013) was carried out in Mexico where oceanographic conditions may be different from those existing in Ghanaian waters. The efficacy of gear illumination methods could be influenced by factors associated with oceanographic conditions within specific fisheries, such as turbidity, water transparency, level of pollution, and the visual characteristics and capabilities of the local fish species.

The studies by Wang et al (2010, 2013) using UV and green LED lights each tested the impact of the light on sea turtle and fish catch at two different locations. It is possible that the fishery and also the localised oceanographic conditions in the area where the experiment on turtles were conducted may be different from those of the areas where the fish catch experiment was conducted and this can affect the results (National Marine Fisheries Service & Atlantic States Marine Fisheries Commission, 2013). This could affect the efficiency of the LED lights. There is therefore the need to perform additional study that combines the two experiments in one location to eliminate the potential impact of oceanographic condition.

In both experiments by Wang et al. (2010, 2013), the two groups of nets (nets using LED light and nets without LED lights) were paired to fish in the same areas at the same time. This does not mimic the natural fishing process of fishermen and could therefore impact the acceptability of the technique by local Ghanaian fishermen. This will reduce any possible impact that the experiment may have on conservation of sea turtles since fishermen do not fish in pairs and may not use the light.

No study in Ghana has comprehensively assessed sea turtle-fishery interactions and quantified the rate of sea turtle by-catch in Ghana's fishery. This paucity in data and information on in-water threast to sea turtles further compound the problem of sea turtle mortality. While the study by Wang et al (2013) examined the impact of LED light on fish catch (volume in kg) and market value of fish catch, the study did not examine the impact of the LED light on species diversity and size of fish caught as well as the sex. These are critical parameters since light has been reported to serve as fish aggregating device attracting smaller sizes of fish (Beverly et al., 2012). According to Marchesan (2005), the reactions to changes in artificial light conditions are often species-specific hence the need to look at the impact of LED lights on species diversity of fish catch which the work by Wang et al (2013) did not report on. These form the underlying justification of this study which is the first of its kind in the country and in West Africa.

The study when completed will add on to existing knowledge about sea turtles in Ghana, West Africa and around the globe. The study will also serve as a basis for conservation and management programs, not only in the Central Region, but also in other fishing communities in Ghana and Africa. Recent genetic analyses indicate Ghana's leatherbacks are part of a wide-ranging population that possibly extend throughout the Atlantic Ocean (Dutton et al., 2013). Clearly, protecting Ghana's sea turtles is extremely important for the global recovery of the species.

Research objectives

The primary goal of this research is to identify alternative fishing methods/techniques that reduce sea turtle by-catch without reducing target fish catch rates. The research investigates the impacts of light emitting diode-fitted nets on sea turtle and fish catch.

The specific objectives of the study are:

i. To assess the artisanal fish catch of the study area.
ii. To quantify annual sea turtle capture in gill net fisheries in the study area.
iii. To assess sea turtle by-catch in gill nets with and without LED lights.
iv. To asses fish catch in gill nets with and without LED lights.

Hypothesis

The following hypotheses are made by the study and will be tested to achieve the above objectives:

1. Adding light emitting diodes to gill nets will not reduce sea turtle by-catch.
2. Adding light emitting diodes to gill nets will not impact target fish catch.
3. Adding LED light will not impact market price of target fish species.

CHAPTER TWO

MATERIALS AND METHODS

Study Area

The study was conducted in the coastal waters of the Gomoa District and Effutu Municipality (Figure 6) in the Central Region of Ghana (0^{o} 37′ and 0^{o} 42′ W, and 05^{o} 19′ and 05^{o} 17′ N). The area was chosen for the study because of the presence of a known sea turtle nesting beach (Agyekumhene et al., 2014; Alenxander et al., 2017) and evidence of increasing sea turtle-fishery interaction. The Muni-Pomadze Ramsar Site, a 9,461.12 ha coastal wetland is located between Mankoadze, a small fishing town where the study on turtles was conducted, and Winneba in the Effutu Municipal area. Since 2010, Ghana Wildlife Division (GWD) officers and the Ghana Turtle Conservation Project (GTCP) have conducted routine sea turtle education, ecotourism promotion and law enforcement activities in the area. Fisheries officers also routinely engage fishermen in best fishing practices.

The annual sea surface temperature of the study area ranges between 20°C and 35°C, and sea surface salinities between 32 $^{o}/_{oo}$ and 38 $^{o}/_{oo}$ (FSSD, *unpublished*). The area is characterised by a major rainy season in May-June and minor rains in August-September. Annual average rainfall has been reported as 38 mm to 221 mm during the major wet season, and 25 mm to 58 mm during the minor wet season (Meoweather, 2013).

Fishing and fish mongering constitute the main economic activity of the people in the area (Ntiamoah-Baidu & Gordon, 1991; Koranteng, 1995; Ghana Statistical Services, 2014). The fishery of the area is primarily artisanal involving the use of dugout canoes made from “Wawa” (*Triplochiton scleroxylon*) and “Onyina” (*Ceiba pentandra*). Fishing is carried out each day of the week except on Tuesdays and during periods of full moon. Gillnetting and beach seining are the most common methods of fishing with hook-line fishing periodically employed (Agyekumhene, Akwoviah & Allman, 2014). The type of fishing gear used however varies along the 10 landing sites in the study area. The dominance of a particular gear in a fishing area is influenced by the target species.

There are an estimated 1,827 fishing canoes operating in the study area, of which 987 are registered (FSSD, 2016). Of these, 818 are motorized while the remaining 169 use paddles and sails. The canoes measure 2.5 m to 26 m in length. The crew size varies from 2 to about 21 individuals depending on the fishing method and the size of canoe. There are, however, a few one-man canoes operating in the area. The crew comprised of men from the same family or members from the community hired by the canoe owner (Alenxander et al., 2017). Most of the canoes (83%) are powered by 5 hp to 40 hp outboard engines while a small proportion (17%) use sails and paddles. About 15% of the canoes store fish on ice at sea allowing fishing to last for up to three days.

The catch is usually shared among the crew in proportion that is negotiated prior to a fishing trip. A larger proportion of the catch is however sold to women from the community who sell the fish in local markets, and a small amount is kept for home consumption.

Some fishermen engage in construction or farming as an alternative livelihood during the lean fishing season, October to June, and resume fishing during the major season, July to September.

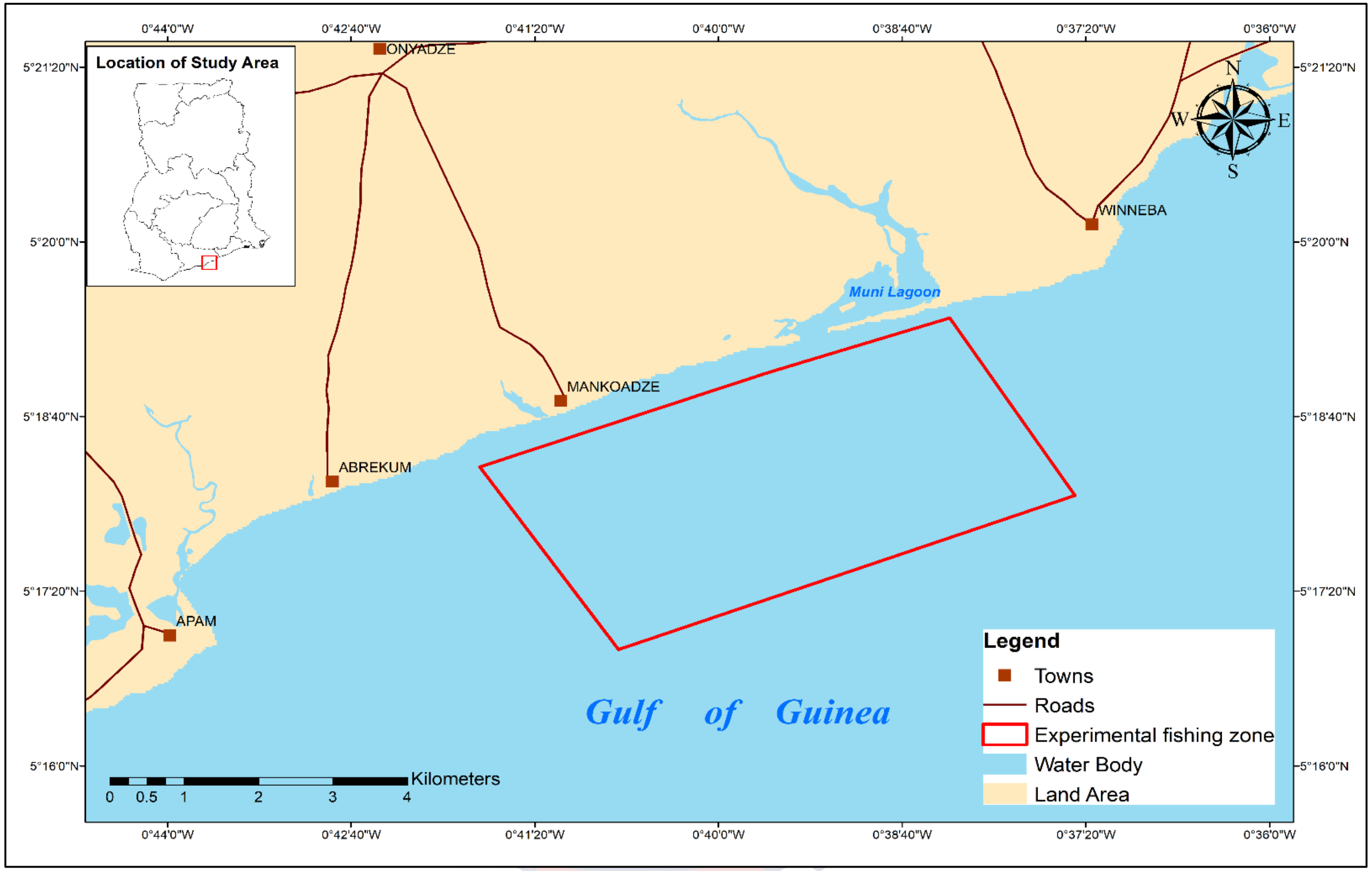


Figure 6. Map showing the study area within the coastal waters of Gomoa and Effutu Districts, Ghana. Red rectangle indicates the approximate fishing zone within which the experimental gill nets were deployed.

Data Collection

Sea Surface Temperature and Salinity

Daily sea surface temperature and salinity records of the study area were by courtesy obtained from the Fisheries Scientific Survey Division (FSSD) of the Fisheries Commission at Tema and used to assess the monthly variation and influence on fish catch of the area.

Data collection from the commercial artisanal fish catch

Fish catch and effort from the canoe fishery of the Effutu Municipality and Gomoa District from 2001 to 2015 were obtained from the FSSD in Tema.

Experimental sampling design

Gillnets commonly used in the local fishery were employed in the experimental sampling. The nets measured 82 m to 144 m in length and 7 m deep with a 2.5 cm stretched mesh size. Fifteen canoes were used to assess the rate of sea turtle by-catch in fishing nets from January 2015 to December 2015 to determine whether there was substantial turtle catch by the gill nets to make the fishery require a by-catch reduction method. Twenty canoes were used to assess the impact of LED green lights on sea turtle and fish catch from January 2016 to March 2017 to determine if the LED lights were effective at reducing turtle by-catch in the fishery. Ten of the canoes used nets with LEDs and ten used nets without LEDs. The LED lights were fixed at 10 m intervals on the head rope. Nets were set in the evening and retrieved before morning. A trained observer on each canoe recorded data on sea turtle by-catch. Each of the 20 fishing nets was checked every 90 minutes and any turtle caught removed, identified and the sex determined. Sex of the turtle was determined by physically observing the length of the tail. While the female turtles have a short and skinny tail, the males have long and thick tail with their vent (cloaca) positioned closer to the end of the tail. Turtle species were identified using keys developed by the State of the World's Sea Turtles Scientific Advisory Board (SWOTSAB, 2011). The carapace length (CL) and the carapace width (CW) were measured before releasing it back into the sea. The carapace length (CL) and carapace width (CW) of turtles were measured to the nearest 1.0 cm using flexible tape measure.

On each sampling occasion, fish samples were taken from the two groups of fishing canoes after landing using a standard bowl. Weights of fish samples were taken at the landing beach using a top pan balance. The total fish catch from each canoe was determined in kilograms. The average value of catch per basket was determined for each canoe from sales on the landing beach. The total number of baskets from the catch was then multiplied by the average value per basket to obtain the total monetary value of the catch per canoe.

Fish samples from canoe with LED and non-LED nets were stored in labelled transparent plastic bag with observer's name and sampling date. Samples were kept on ice and transported to the field station at Mankoadze for further examination. Fish were sorted separately and identified to their family and species using identification manual by Kwei and Ofori-Adu (2005) and FAO fish identification guides by Psomadakis et al. (2015). Fish was measured for total length (TL) using measuring board, and body weight (BW) with a 10 kg capacity scale.

Interviews on sea turtles

A semi-structured questionnaire (Appendix H) was used to gather information on the demography of the study area and fishermen's knowledge of sea turtles and their conservation using interviews with eighty-two fishermen from Mankoadze in June 2015. The ability of respondents to identify turtle species presented from photography was ascertained.

Data Analysis

Composition of sea turtles and fish

The percentage numeric composition of turtle and fish species was determined as the ratio of the number of turtle or fish species to the total number of turtles or fish caught multiplied by 100, and given by the equation:

$$\text{Numeric composition } (\%) = \frac{\text{Number of turtles or fish species}}{\text{Total number of turtles or fish caught}} \text{ x } 100$$

For the artisanal fish catch data obtained from FSSD, all the species caught from 2001 to 2015 were grouped into their respective families and their weights determined. The percentage composition of each family was determined as the ratio of the weight of fish of a family to the weight of the total catch multiplied by 100, and was given by the equation:

$$\text{Composition } (\%) = \frac{\text{Weight of fish of a family (kg)}}{\text{Weight of total catch}} \text{ x } 100$$

Species diversity of fish

The diversity of fish caught by the LED and non-LED nets was determined using the Shannon-Wiener index (H'), given as $H' = -\sum_{i=1}^{s} Pi(lnPi)$, where *s* is the number of species in the community and P_i is the proportion of individuals belonging to the species in the community (Shannon & Weaver, 1963). Evenness (J') of the fish species caught in the two groups of nets was estimated from Pielou's index calculated as $J' = H'/H_{max}$, where $H_{max} = \ln s$ (Jost, 2010). Changes in composition of fish caught in LED and non-LED nets was determined using Margalef index (*d*) given as $\frac{(s-1)}{\ln N}$ where *s* is the number of species in the community, and *N* is the number of individuals in the community (Margalef, 1958).

Catch and Value Per Unit Effort

Turtle and fish Catch per Unit Effort (CPUE) of the experimental nets was computed using equation of Wang et al. (2013) as follows:

$$\text{CPUE} = \frac{\text{Number of sea turtles caught or weight (kg) of fish caught}}{(\text{Length of net}/100\text{ m}) \times (\text{net submersion time}/12\text{h})}$$

The market value of fish caught per unit effort (VPUE) of LED and non-LED nets was calculated from Wang et al. (2013):

Value-per-Unit-Effort (VPUE) for fish catch was calculated for each set of nets as:

$$\text{VPUE} = \frac{\text{Cost of fish catch}}{([\text{Length of net}/100\text{ m}]) \times ([\text{net submersion time}/12\text{h}])}$$

Catch per Unit Effort values for sea turtles and fish in LED and non-LED nets were compared using the students' t-test. A similar test was performed on fish VPUE for LED and non-LED nets.

Analysis of length-frequency distribution of fish and turtles

Length-frequency distributions for the commonest turtle and fish species from gill nets were analysed at 1 cm class intervals. Length-frequency distribution of sea turtle was carried out using only length data from olive ridleys due to the low numbers of leatherback and green turtles captured in the study.

Analysis of length-weight relationship of turtles

Weights of all turtles captured were estimated directly from length and weight values recorded by Eckert et al. (1999), and used to generate a length-weight relationship for the turtles.

Fluctuations in temperature, salinity and fish catch

Monthly means of sea surface temperature and salinity were computed and related to the monthly means of the fish catch. A regression analysis was used to establish the relationship between fish landings and temperature, and fish landings and salinity. Five fish species with relatively high percentage compositions were used for this analysis.

CHAPTER THREE

RESULTS

Ownership and sharing of benefit of catch

There are three main canoe ownership schemes in the area namely individual ownership, family ownership and joint ownership. Of the 987 registered canoes, 96% are owned by individuals, 3% are owned by families and 1% has joint ownership. For all the canoes, irrespective of the type of ownership, crew members are usually hired and paid with some of the catch for the day. The daily catch is usually shared according to an agreed ratio where 50 percent goes to the fishermen on one side and the remaining 50% to the owner of the canoe, net and outboard motor on another. In a situation where the canoe, net and outboard motor belongs to different individuals, the catch is divided in the proportion of 50% to the fishermen, 10% to the canoe, 20% to the net and 20% to the outboard motor. For family-owned canoes, a member of the family is usually detailed to oversee the operation at sea and manage the catch.

Composition of fishing gear

Canoes are classified on the basis of the type of gear used. Six different gears are employed in the area namely purse seine (poli/watsa), beach seine, drift gill net, ali net, set net and hook and line. Gears recorded in the area, and their percentage representations are shown in Figure 7. Set net was the most common comprising 35.6% of the gears followed by purse seine, hook and line, and ali nets with compositions of 24.0%, 22.3% and 11.0% respectively. Beach seines and drift gill nets were lowly represented and respectively made up 4.9% and 2.1% of the total gears in the area. The purse seine and '*ali*' nets are usually considered together as Ali-Poly-Watsa (APW) resulting essentially in the use of five main gears (Nunoo et al., 2014). Though each canoe in the study area has one gear type which is most often used, one canoe can be used to operate more than one gear.

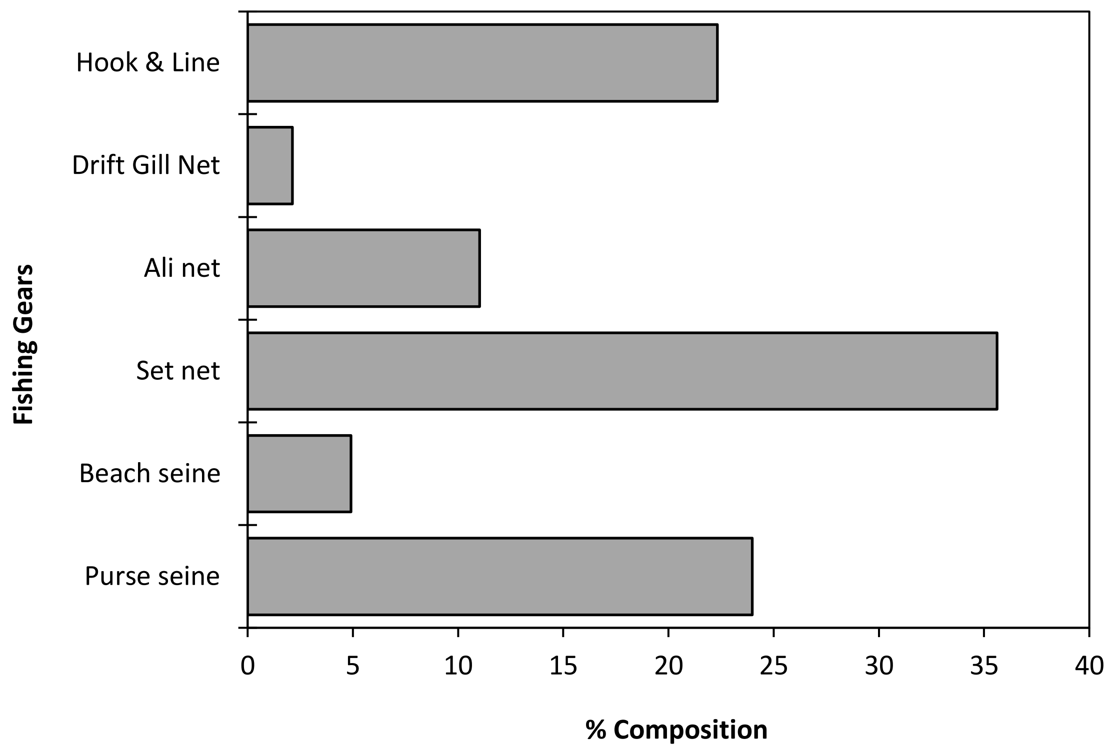


Figure 7. Composition of gears used in the fishery of Gomoa and Effutu coastal waters (Source: Fisheries Scientific Survey Division, 2016)

Characteristics of the fishing gears

The various fishing gear encountered in the study area and their characteristics are presented in Table 2. Among the gears are Ali-Poli-Watsa (APW), Beach seine, set net, drift gill nets, hook and line.

Table 2. Characteristic of gear types encountered in the study area.

Fishing gear	Characteristics	Key fish species landed
Ali-Poli-Watsa (APW)	Three hundred and sixty-one purse seine nets (Poly/Watsa) and 166 ali nets were counted in the study area. Mesh size of the poli nest used in the area are 3.18, 6.35, 31.75 and 44.45 millimetres while those of watsa are 6.4, 25.0, 31.8, 38.1 and 50.1 millimetres. The length of canoes operating with these nets in the area ranges from 12.0 m to 19.5 m and 1.2 m to 2.4 m wide. The APW canoes are usually propelled by outboard motors with capacity of 25 hp to 40 hp. Some of the canoes use Global Positioning System (GPS) to locate fish in the sea. Fishing by the APW is carried out from dawn through the day except during the major fishing season (July to September) when fishing is done in the night.	Round sardinella (*Sardinella aurita*), flat sardinella, (*Sardinella maderensis*), anchovy (*Engraulis encrasicolus*), chub mackerel (*Scomber colias*) and kingfish (*Scomberomorus cavalla*).
Beach seine	During the field survey, 74 beach seine canoes were recorded. The size of the canoes ranged from 8.5 m to 11.5 m long. Beach seine	Beach seine nets are noted for the multi-species nature of landed catch.

Fishing gear	Characteristics	Key fish species landed
	canoes are mostly propelled by paddles but outboard motors are also used on some canoes. Fishing is done usually during the day. The fishing net is usually left in the water for about 2-3 hours after deploying before hauling to the beach.	
Set net	The survey recorded 536 set net canoes in the study area. Mesh sizes of the set nets in the area are 50.8 and 563.88 millimetres. The set net canoes operate small nets rigged to fish at the bottom or in midwater depending on the strength of the float line (FSSD, 2016). Set nets are operated on a daily basis and canoes are propelled by paddles, sails or outboard motors. Set net canoes ranged from 7.0 m to 9.5 m in length.	Atlantic bonito (*Sarda sarda*) while also trapping a variety of crustaceans.
Drift Gill Net	Thirty-two drift gill nets (DGN) were counted during the survey. Their size ranged from 12.0 m to 19.5 m long and 1.2 m to 2.4 m deep with mesh sizes of 31.8 and 635 millimeters.	Yellowfin tuna (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*), big-eye (*Thunnus obesus*), sword fish

Fishing gear	Characteristics	Key fish species landed
		(*Xiphias gladius*) and Atlantic sailfish (*Istiophorus albicans*).
Hook and Line	About 336 hook and line operators fish in the study area. The lines measured 12.0 m and 18.5 m in length with varied thickness of 203, 279 and 457 millimeters. The sizes of the hooks used in the study area ranges from 279 to 457 millimeters. Canoes with this gear have ice chests to preserve the fish at sea so fishing trips last 3 to 4 days.	Demersal species from rocky bottoms including sparids such as Congo Dentex (*Dentex congoensis*) and Angola Dentex (*Dentex angolensis*) (Nunoo et al., 2014), snappers and groupers (FSSD, 2016).

Fish catch in the study area

Catch composition

Figure 8 shows the family composition of fish caught by the artisanal fishermen in the study area from 2001 to 2015 (data obtained from the Fisheries Scientific Survey Division of the Fisheries Commission). Seventy-four fish species belonging to 40 families were caught during the period. Fish of the family Scombridae were the most abundant representing 23.7% of the catch. These were followed by Clupeidae and Engraulidae with compositions of 21.5% and 16.9% respectively. Carangidae, Haemulidae and Sparidae were fairly represented in the catch with compositions of 12.1%, 6.8% and 6.6% respectively. All other families were lowly represented in the catches and together made up 12.4%.

The family Scombridae was dominated by the Atlantic little tuna (*Euthynnus alletteratus*), Skipjack tuna (*Katsuwonus pelamis*), and Chub mackerel (*Scomber colias*) while the round sardinella (*Sardinella aurita*) and flat sardinella (*Sardinella maderensis*) were the most dominant species of the family Clupeidae. Anchovy (*Engraulis encrasicolus*) dominated the family Engraulidae while the Horse mackerel (*Trachurus trachurus*), bumper (*Chloroscombrus chrysurus*) and African threadfish (*Alectis alexandrinnus*) were the most common species from the Carangidae family, with seabream (*Dentex canariensis*) and red pandora (*Pagellus bellotti*) dominating the Sparidae family. Burrito (*Brachydeuterus auritus*) was the only species from the family Haemulidae. While some families had only one species, others had as many as nine fish species though their percentage compositions by weight were relatively low.

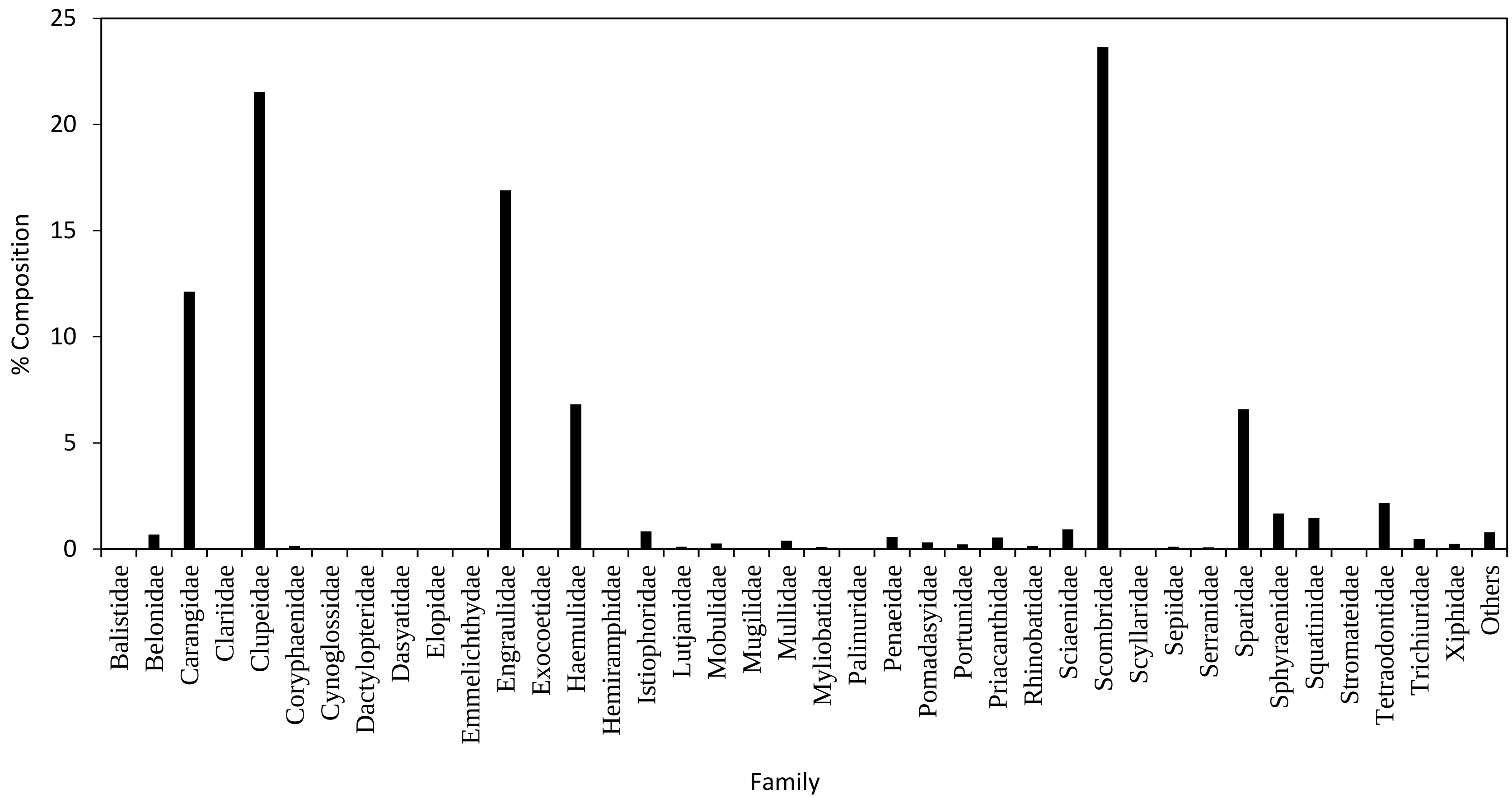


Figure 8. Family composition of fish caught in the artisanal fishery of Gomoa and Effutu coastal waters from 2001 to 2015 (Source: Fisheries Scientific Survey Division).

Annual fluctuations in fish catch

The annual fish catch by artisanal fishery in the study area from 2001 to 2015 is illustrated in Figure 9. Annual fish catch was highest in the year 2001 (29,697.89 tonnes) and lowest in 2015 (3,685.20 tonnes). A general decrease in fish catch was observed over the period.

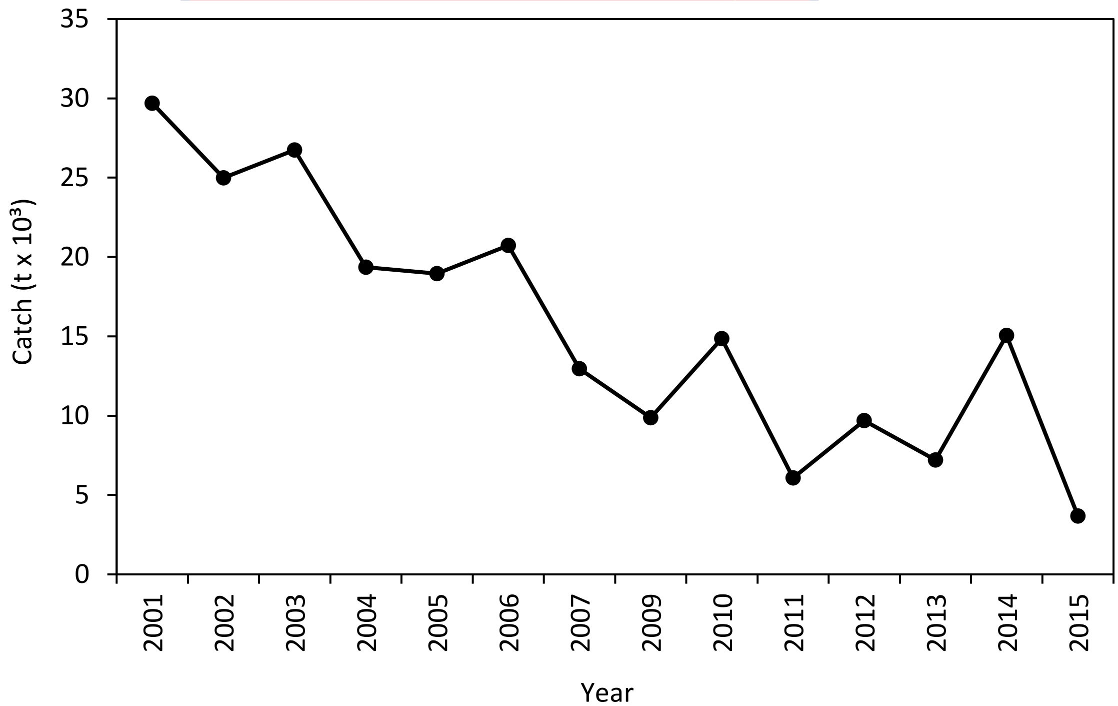


Figure 9. Fluctuations in the annual fish catch in artisanal fishery of Gomoa and Effutu coastal waters from 2001 to 2015 (Source: Fisheries Scientific Survey Division).

Fishing effort

Figure 10 shows the annual mean fishing efforts in days for the study area from 2001 to 2015. The highest effort was recorded in 2001 (810,655 days) while the least effort was recorded in the year 2015 (77,754 days). Generally, effort declined over the years except during 2005, 2006 and 2007 when an increase in effort was recorded.

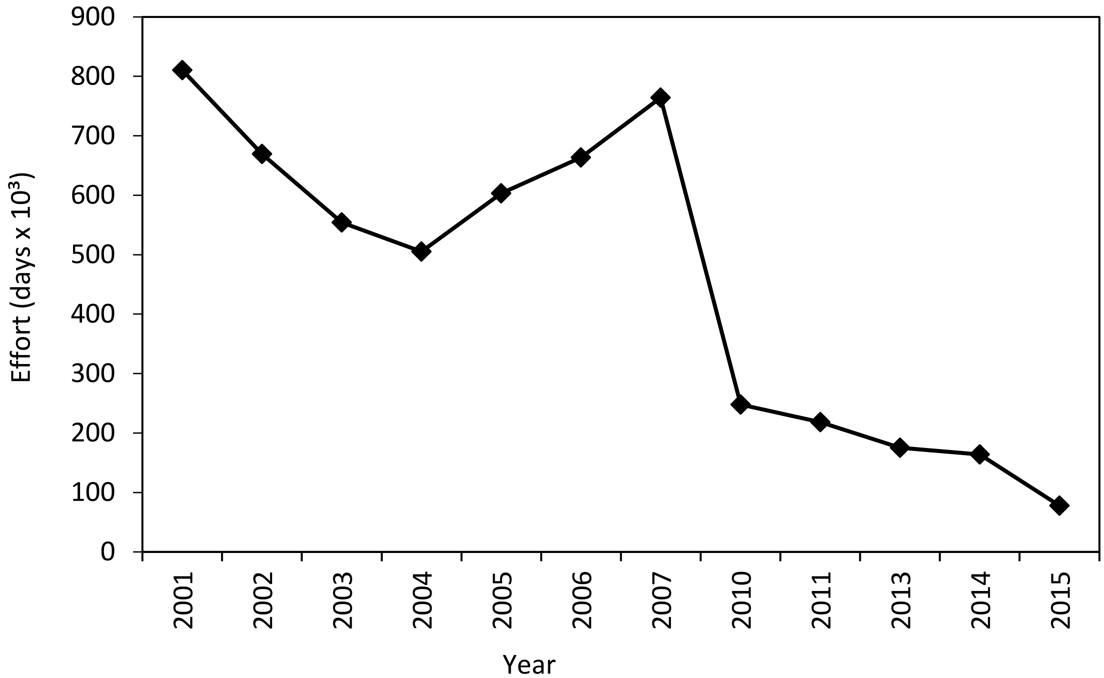


Figure 10. Annual fishing effort in days in Gomoa and Effutu coastal waters from 2001 to 2015 (Source: Fisheries Scientific Survey Division).

Annual catch per unit effort

The catch per unit effort (CPUE) in metric tons per day from 2001 to 2015 is shown in Figure 11. The highest and least CPUEs were recorded in 2014 (0.09 $t \cdot day^{-1}$) and 2015 (0.02 $t \cdot day^{-1}$) respectively. Generally, CPUE increased over the years.

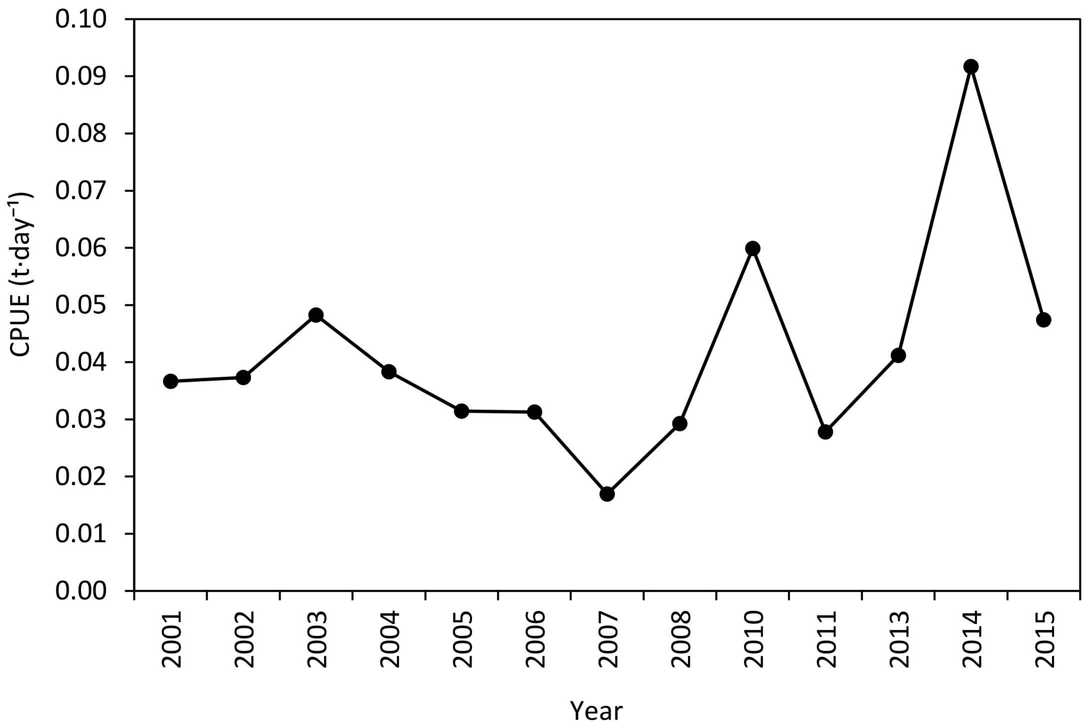


Figure 11. Annual mean catch per unit effort from 2001 to 2015 for artisanal fishery in the study area (Source: Fisheries Scientific Survey Division).

Annual fluctuations in catch of common fish species

Sardinellas

Figure 12 shows the annual catch trend for the *Sardinella* species *(Sardinella aurita* and *Sardinella maderensis)* in the artisanal fishery of Gomoa and Effutu coastal waters. The highest landing was recorded in 2003 (11,113.4 tonnes) and the lowest catches (800.82 tonnes to 1,105.80 tonnes) recorded in the years 2009, 2010, 2011 and 2015.

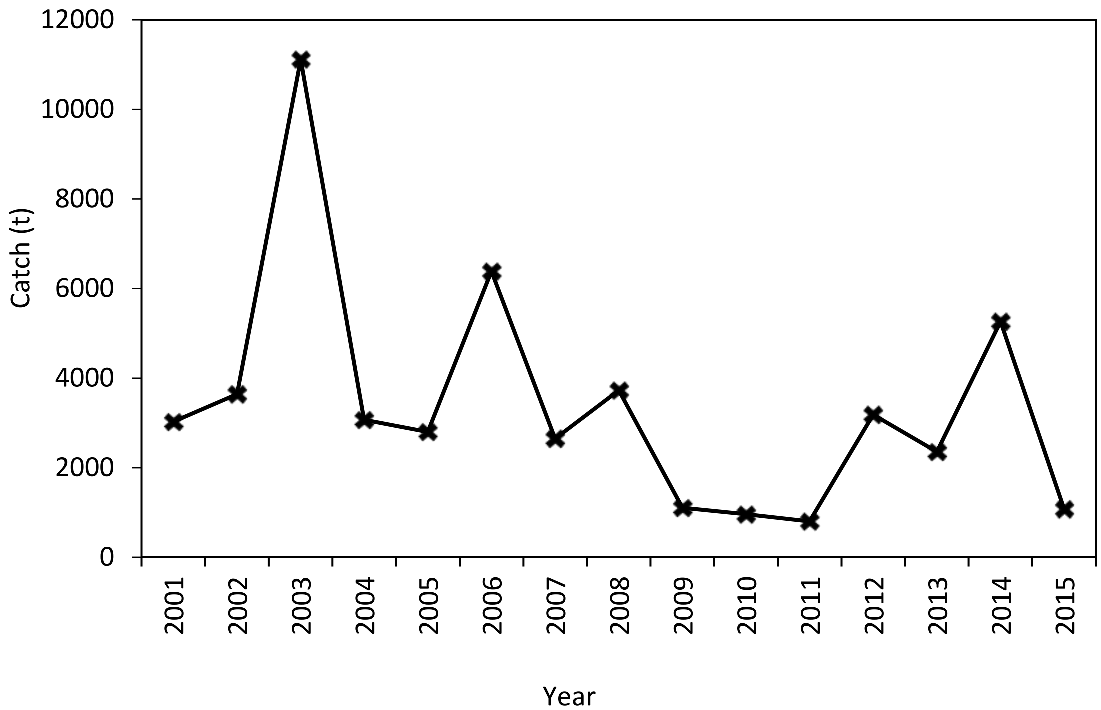


Figure 12. Annual catch of *Sardinella* spp. in artisanal fishery of Gomoa and Effutu coastal waters (Source: Fisheries Scientific Survey Division).

Anchovy

Figure 13 shows the annual catch trend for the anchovy (*Engraulis encrasicolus*) in the fishery of the area. There was a general decline in catch from 12,574.1 tonnes in 2001 to zero catch in 2015.

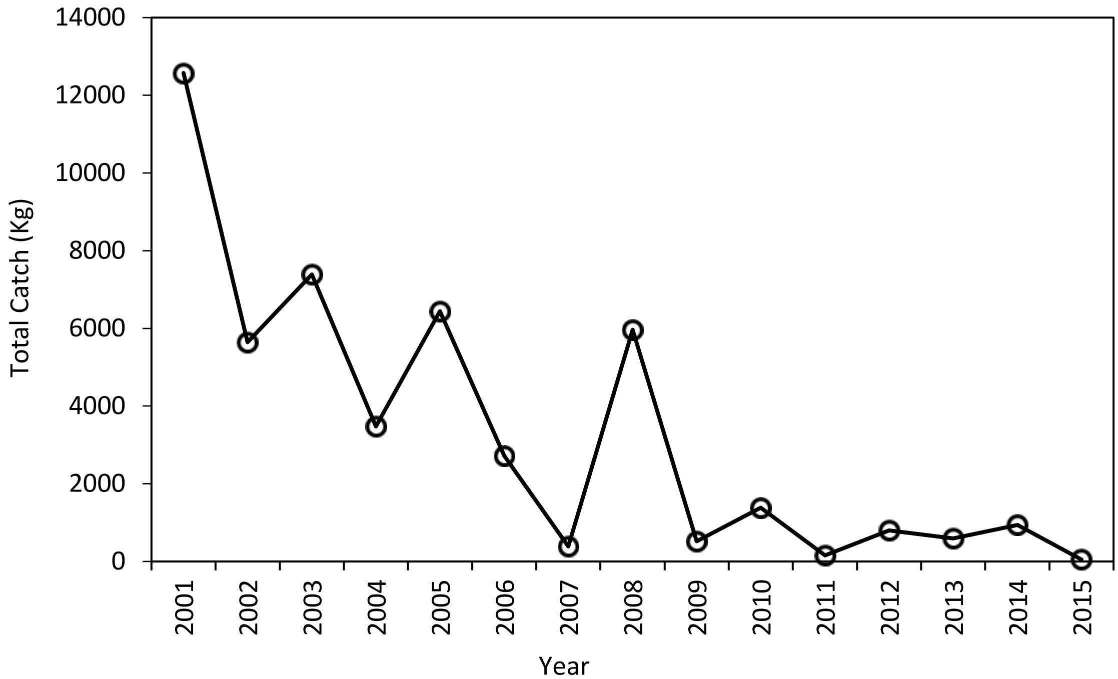


Figure 13. Annual catch for *Engraulis encrasicolus* in artisanal fishery of Gomoa and Effutu coastal waters (Source: Fisheries Scientific Survey Division).

Atlantic little tuna

The annual catch of Atlantic little tuna (*Euthynnus alletteratus*) is shown in Figure 14. Following the highest landings in 2001 and 2002 (1,162.27 tonnes and 1,593.94 tonnes respectively), catches decreased progressively over the remaining 13 years.

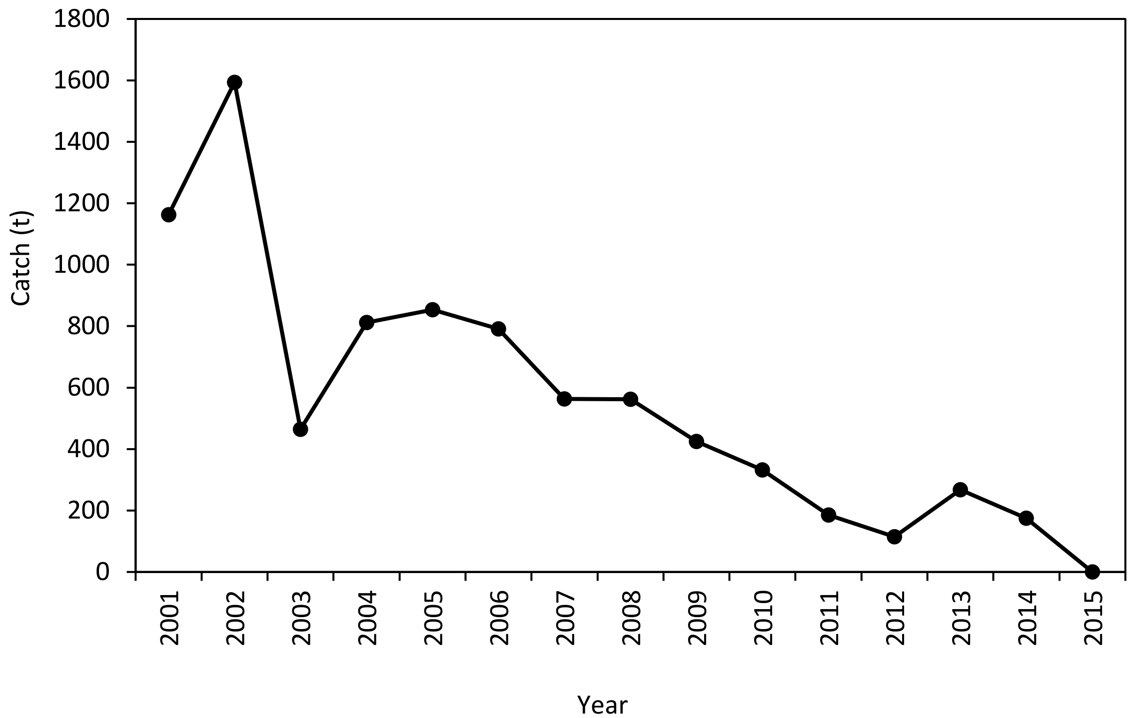


Figure 14. Annual catch for *Euthynnus alletteratus* in artisanal fishery of Gomoa and Effutu coastal waters (Source: Fisheries Scientific Survey Division).

Monthly variation in catches of commonest fish species

Figure 15 shows the monthly catch of Sardinellas (*Sardinella aurita* and *Sardinella madarensis*), anchovy (*Engraulis encrasicolus*), and Atlantic little tuna (*Euthynnus alletteratus*), in the coastal waters of Gomoa and Effutu from 2001 to 2015.

The highest catch for sardinellas for the 15 years period was recorded in August (10,248.3 tonnes) while the lowest catch was recorded in February (1,940.7 tonnes). The highest catch for *E. encrasicolus* was recorded in September (8,481.15 tonnes) and the lowest in February (2,092.17 tonnes) and July (1,385.72 tonnes). The highest landing for *E. alletteratus* was recorded in August (9,306.2 tonnes) and lowest catch (350.32 tonnes to 1,189.71 tonnes) in the months from January to June and November.

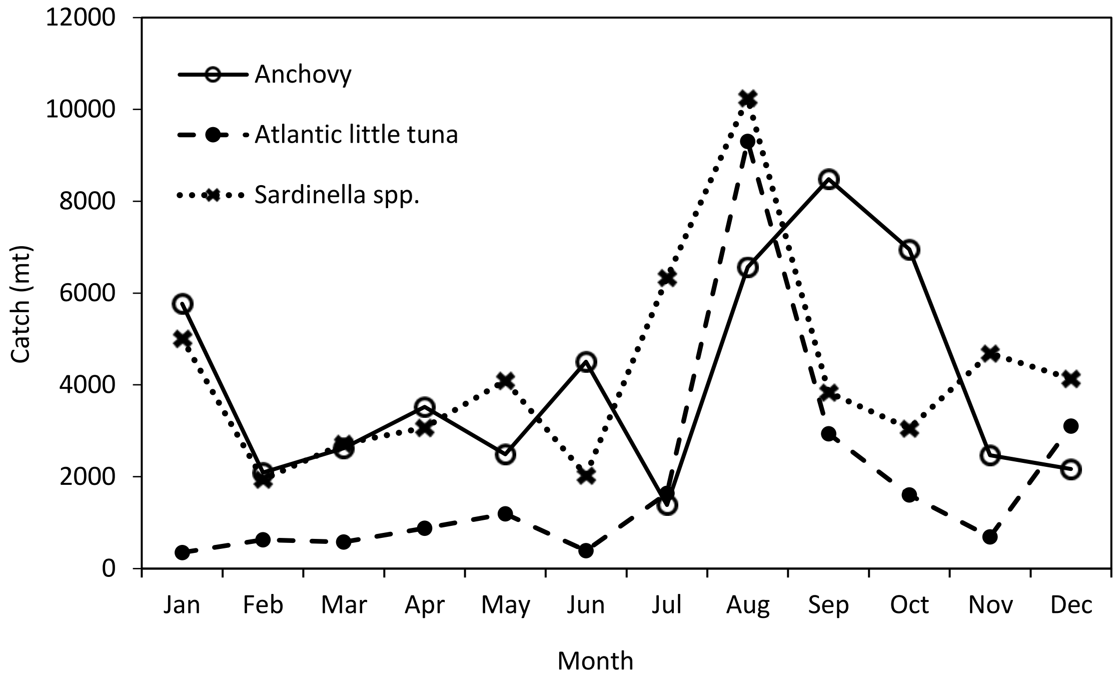


Figure 15. Monthly variation in Anchovy, Atlantic little tuna and Sardinella spp. catch in Gomos and Effutu coastal waters from 2001 to 2015 (Source: Fisheries Scientific Survey Division).

Temperature and salinity of the coastal waters

Figure 16 shows the mean monthly sea surface temperature and salinity for the study area. Mean monthly water temperature ranged from 22.0±1.1 °C to 27.8 ± 0.6 °C. Temperature was relatively high from October (27.0±0.7 °C) to June (26.2±0.7 °C) and low temperatures from July (23.9±1.8 °C) to September (24.6±1.6 °C). Salinity values ranged from 34.7±1.1 $^{o}/_{oo}$ and 35.5±0.3 $^{o}/_{oo}$ over the period. Highest mean salinity for the period was recorded in August (35.5±0.3 $^{o}/_{oo}$) while October recorded the least mean salinity (34.7±1.1 $^{o}/_{oo}$). A strong positive correlation existed between the temperature and the salinity (Appendix J) with a significant difference between the two parameters ($r = 0.64$, $p<0.05$).

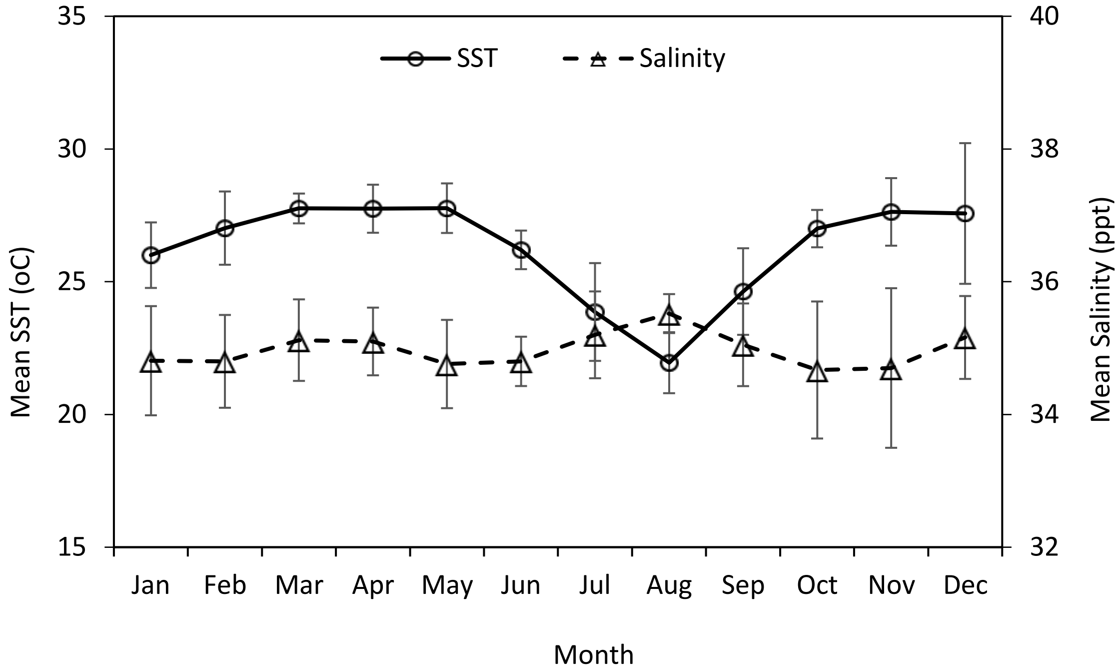


Figure 16. Mean monthly variation in temperature and salinity in the Gomoa and Effutu coastal waters from 2001 to 2015.

Fluctuations in temperature, salinity and fish catch

Figure 17 shows changes in the mean monthly temperature and catch of sardinellas, anchovy and Atlantic little tuna. Higher landings was recorded in July, August and September when temperature was lowest. Mean monthly temperature correlated negatively with catches of the three fish species (See Appendix K for the regression graph showing the relationship between temperature and the three dominant fish species). The correlation was stronger for sadinellas and Atlantic little tuna than anchovy.

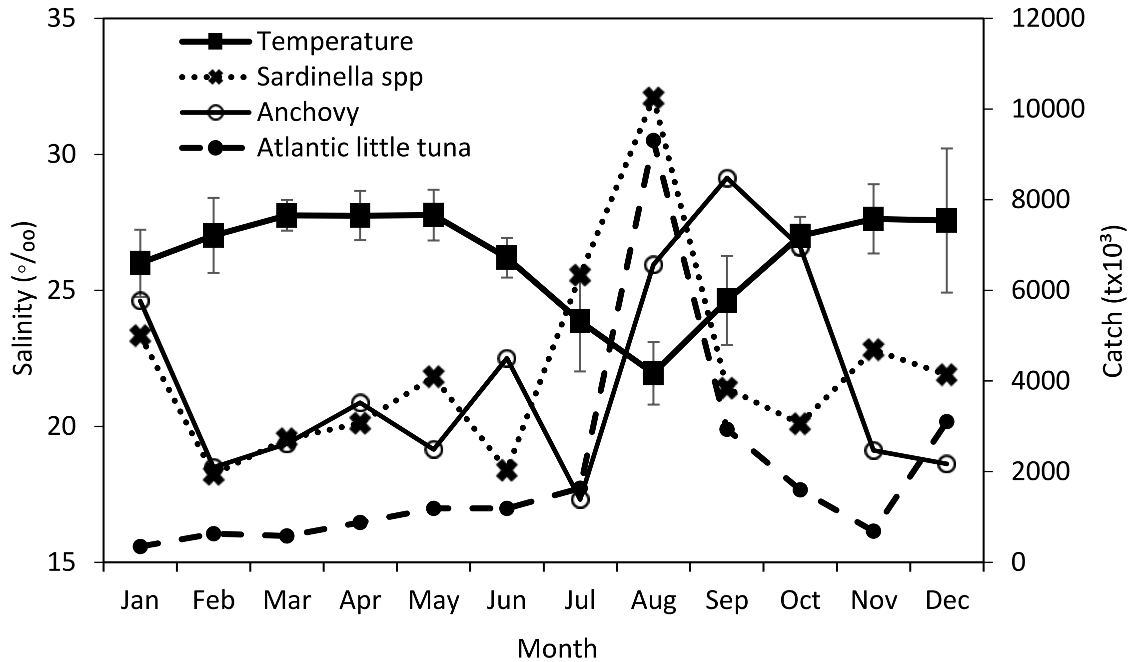


Figure 17. Variation mean monthly sea surface temperature and catch for Sardinella spp., Anchovy and Atlantic little tuna in Gomoa and Effutu coastal waters from 2001 to 2015.

Figure 18 shows changes in the mean monthly salinity with catch of sardinellas, anchovy and Atlantic little tuna. Values of salinity was highest in July, August and September when fish catch was high. Mean monthly salinity correlated positively with catches of sardinellas and Atlantic little tuna but no clear correlation was observed with anchovy catch (See graph showing the relationship between salinity and catch for the three dominant fish species in Appendix L). The correlation was slightly stronger for Atlantic little tuna than sadinellas.

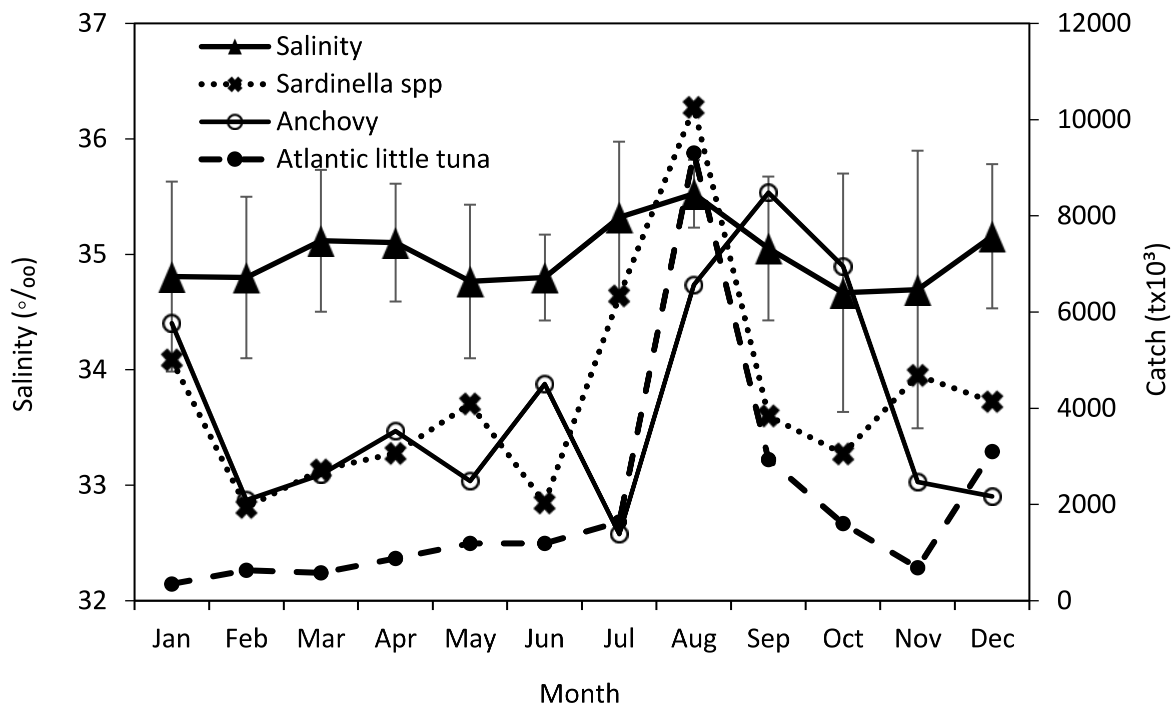


Figure 18. Variation mean monthly sea surface salinity and catch for Sardinella spp., Anchovy and Atlantic little tuna in Gomoa and Effutu coastal waters from 2001 to 2015.

Sea Turtle interaction in artisanal fishery

Encounters of fishermen with sea turtles

The 82 fishermen interviewed demonstrated good knowledge about sea turtles, with 23% having encountered turtles either at sea or at the beach (77%). All respondents were able to distinguish between sea turtles and hinged back tortoise from photographs. The hinged back tortoise is a forest species and has been reported (Raxworthy & Attuquayefio, 2000) to occur in the Yenku forest reserve close to the study area. All respondents classified leatherbacks as "large turtle" and all other species of turtles as "small turtles". The leatherback is called as "*efu*" and the other species "*epuhuru*" in the local Efuttu and Fante languages.

Table 3 shows the responses of fishermen on the importance of sea turtles. Turtles were reported by fishermen as a food source (18%), providing income (7%), protecting fish (5%), serving as indicators of fish presence (12%), and feeding and clearing sea grass from fishing areas (5%). They were also reported to be of cultural significance (1%). According to the respondents, turtles are considered as deities in some fishing communities where they are revered with the belief that turtles saved ancestors of fishermen from drowning (5%).

While 53% of respondents recognized sea turtles as important in the ocean, 47% of respondents reported sea turtles as having negative impacts. One individual recounted how a net he had tied to his canoe offshore trapped a leatherback turtle which nearly capsized the canoe.

Table 3: Responses of fishers to questions on the importance of sea turtles

Importance of sea turtles	Percentage response
Positive Impact	
Fish protection	5
As a food source	18
Indicators of fish presence	12
Source of income	7
Cultural value	1
Clearing sea grass from fishing areas	5
Rescue drowning fishermen	5
Negative Impact	
Destruction of Fishing nets	46
Capsizing canoes	1

Figure 19 illustrates the frequency of fishermen's encounters with sea turtle species in the area. All 82 respondents reported encountering five species of turtles namely leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*), olive ridley (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*) and hawksbill (*Eretmochelys imbricata*). Olive ridleys, green turtles and leatherbacks were the species most sighted and captured in the area with incidence rates of 32%, 21% and 18% respectively. Thirteen and 16 percent of respondents, respectively, indicated capturing loggerheads and hawksbills in their fishing nets.

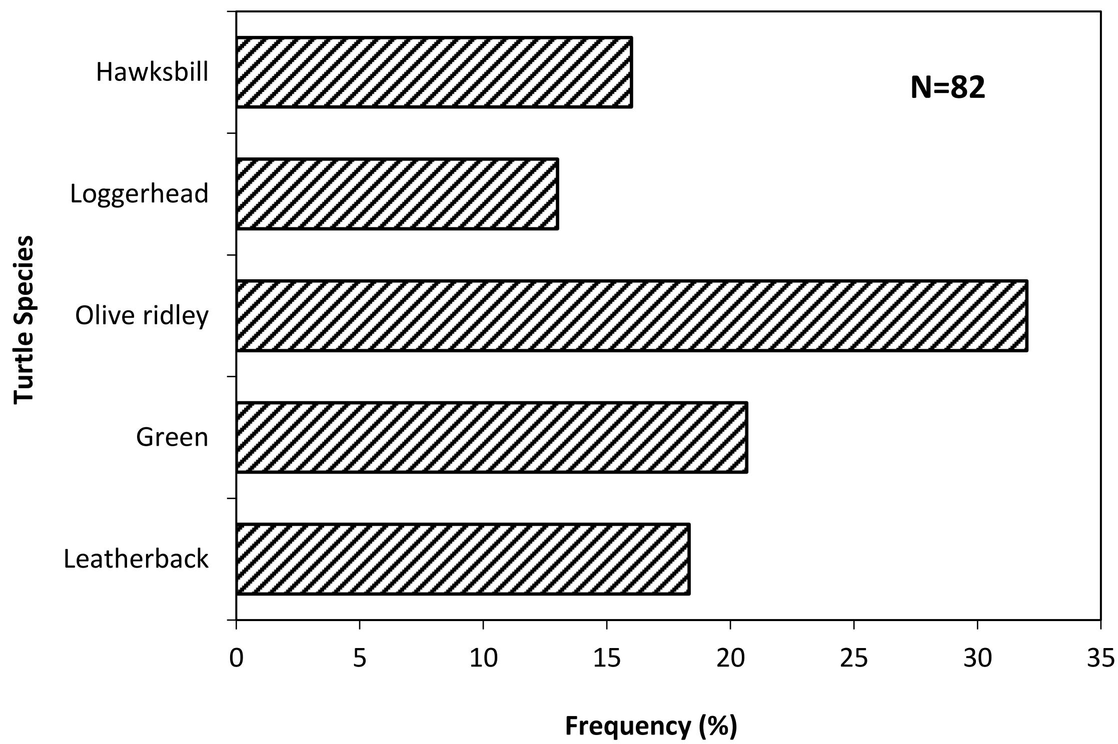


Figure 19. Frequency of occurrence of sea turtle species in fishing nets (N= number of respondents).

Figure 20 indicates the number of turtles encountered by fishermen in a year. Forty-five percent of the fishermen caught up to 5 turtles within a year with 37% of the respondents catching between 6 and 10 turtles annually. Fourteen percent of the fishermen interviewed encountered between 11 and 30 turtles each year while 4% caught more than 30 turtles every year in their fishing operations.

Figure 21 shows the proportion of fishermen who caught turtles in each month of the year. The results indicate most captures in November-December and least capture in March. While 11% of the fishermen reported that they did not target sea turtles because it is illegal to catch them, 63% did not target turtles in order to prevent their nets from being damaged by turtles. Twenty-six percent of the respondent did not target turtles for reasons of both avoiding the law and also protecting their fishing nets.

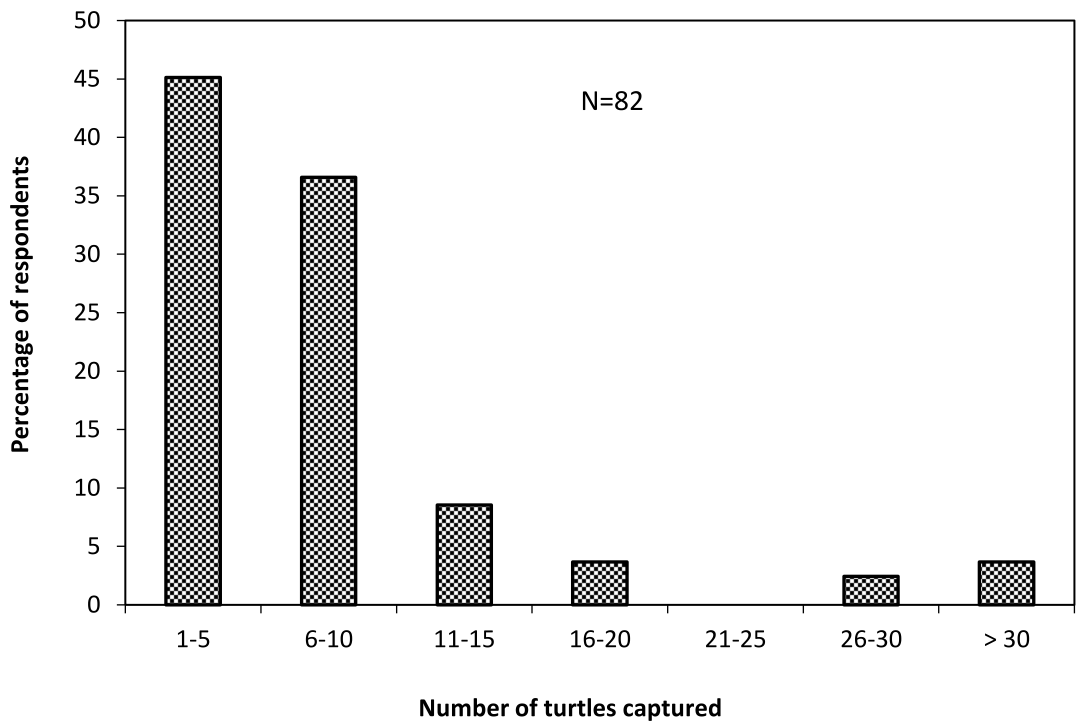


Figure 20. Number of sea turtles caught in gill nets per year by respondents (N= number of respondents).

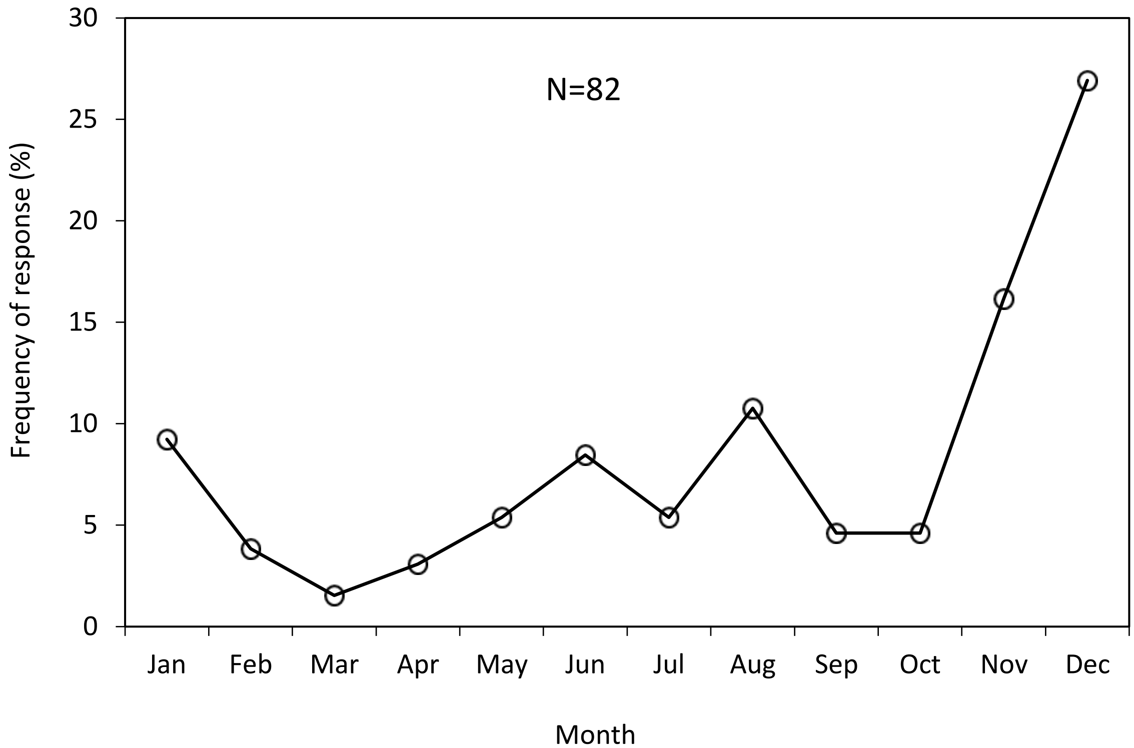


Figure 21. Percentage of respondents' capturing sea turtles in the study area (N= number of respondents).

As shown in Table 4, 61% of the 82 fishermen interviewed reported that sea turtle captured were usually alive and active when removed from fishing nets while 37% mentioned that the turtles were usually dead before releasing them into the sea. Two percent of the fishermen also reported that turtles captured were always unconscious. Interviewee reported that turtles captured alive in fishing nets were either killed for food (25%), sold for money (57%) or released (18%).

Table 4. Respondents assessment of condition of captured turtles

Condition of turtle	Percentage response
Alive and active	61
Alive and Unconscious	2
Dead	37

Survey of sea turtle by-catch in gill nets

Species composition

Sixty-four turtles of three species, leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*) and olive ridley (*Lepidochelys olivacea*), were captured during the 12-month survey from January 2015 to December 2015. Of these, 51 were olive ridley, 6 were leatherbacks and 7 were green turtles, representing 80%, 9% and 11%, respectively of the total captures. All turtles captured were females.

Size distribution

The sizes of sea turtles captured in survey nets are presented in Table 5. Average lengths of 131.7±11.2 cm, 55.0±20.5 cm and 64.4±4.2 cm were recorded for leatherback, green, and olive ridleys with estimated weights of 364.1±31.1 kg, 140.7±52.4 kg and 44.7±2.9 respectively.

Table 5. Size of sea turtles captured in survey nets in 2015

		Carapace length (cm)		Carapace width (cm)		Estimated Body Weight (kg)	
Species	**N**	Min - Max	Mean ± SD	Min -Max	Mean ± SD	Min -Max	Mean ± SD
Leatherback	6	112.5 - 147.0	131.7±11.2	95.5 - 108.0	106.0±6.1	312.5 - 408.3	364.1±31.1
Green turtles	7	29.7 - 83.0	55.0±20.5	27.2 - 80.5	51.9±20.5	76.0 - 212.5	140.7±52.4
Olive ridley	51	52.6 - 71.0	64.4±4.2	53.0 -70.8	64.5±4.5	36.5 - 49.3	44.7±2.9

Length-frequency distribution of turtles

Figure 22 shows the length frequency distribution of olive ridley sea turtles caught in gill nets without LED during 2015 survey. The carapace length of turtles fell within the size class of 52.0 - 72.9 cm. The modal class size was 64.0-65.9 cm.

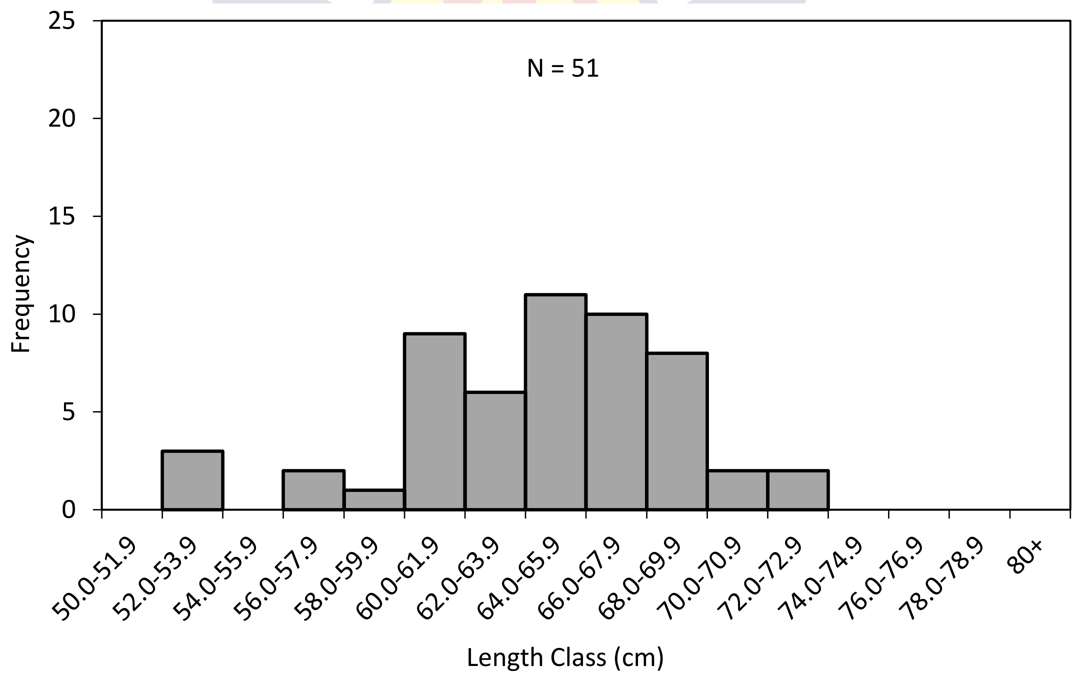


Figure 22. Length-frequency distribution of olive ridleys caught in gill nets during 2015 survey.

Monthly variation in abundance

Changes in number of turtles caught in survey nets from January 2015 to December 2015 are illustrated in Figure 23. Leatherbacks were caught from October to January, while green were caught in June, October and December. Olive ridleys were caught in nine months of the study period except in January, April and May.

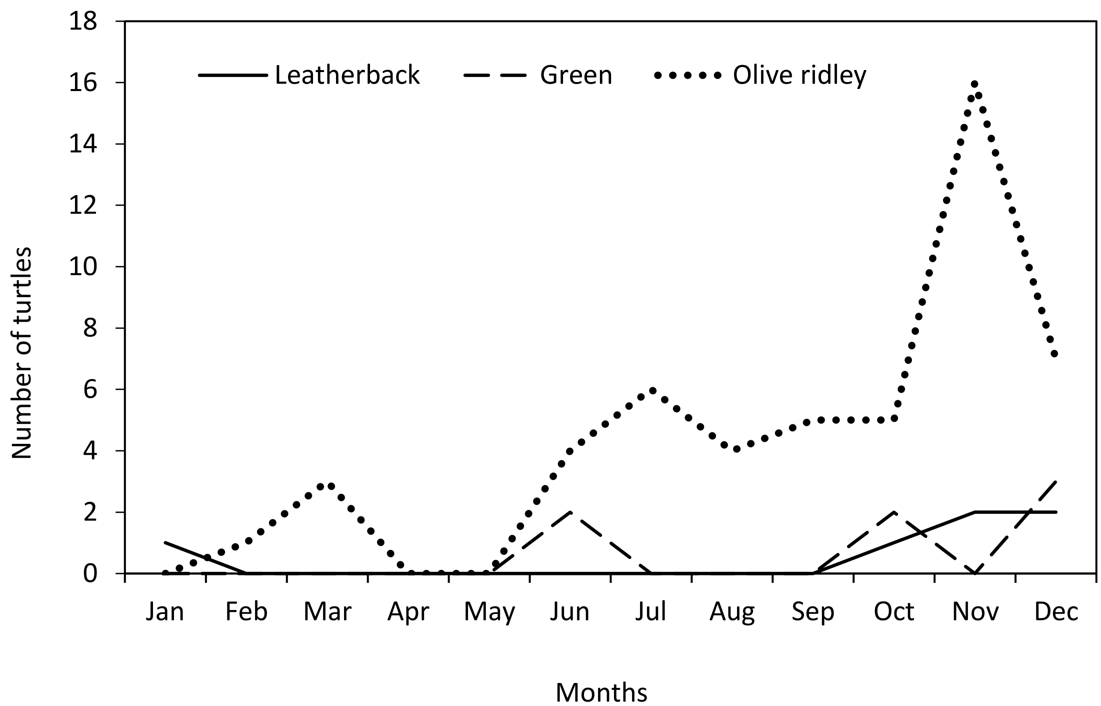


Figure 23. Monthly number of sea turtles sea turtles captured in survey nets during January to December 2015.

Turtles caught in non-LED gill nets

Species composition

Sixty-seven turtles from three species, namely leatherback (*Dermochelys coriacea*), green (*Chelonia mydas*) and olive ridley (*Lepidochelys olivacea*), were captured from January 2016 to March 2017 by the 10 canoes without LED lights. They comprised 7 leatherback, 6 green and 54 olive ridley; i.e. 10%, 9% and 81% respectively of the turtles caught. All turtles captured were females except one green turtle that was a male.

Size distribution

The sizes of sea turtles captured in non-LED nets are shown in Table 6. Average lengths of 148.3±7.0 cm, 83.0±19.3 cm and 68.6±3.0 cm were recorded for leatherback, green, and olive ridleys with estimated weights of 411.8±19.3 kg, 152.7±35.5 kg and 47.6±2.1 respectively.

Table 6. Mean size of sea turtles captured in gill nets without LED from January 2016 to March 2017.

		Carapace Length (cm)		Carapace Width (cm)		Estimated Body Weight (kg)	
Species	**N**	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Min - Max	Mean ± SD
Leatherback	7	137.1 – 161.0	148.3±7.0	96.5 - 112.0	105.7±5.4	380.8– 447.2	411.8±19.3
Green turtles	6	62.0 – 101.0	83.0±19.3	59.0 - 90.0	76.4±15.2	114.8 – 185.8	152.7±35.5
Olive ridley	54	62.0 - 78.0	68.6±3.0	61.0 - 76.0	68.4±3.3	43.1 – 54.2	47.6±2.1

Length-frequency distribution of turtles

Figure 24 shows the length frequency distribution of olive ridley sea turtles caught in gill nets without LED during 2016-2017 survey. The carapace length of turtles ranged between the size class of 62.0 - 79.9 cm respectively. The modal class size was 68.0-69.9 cm.

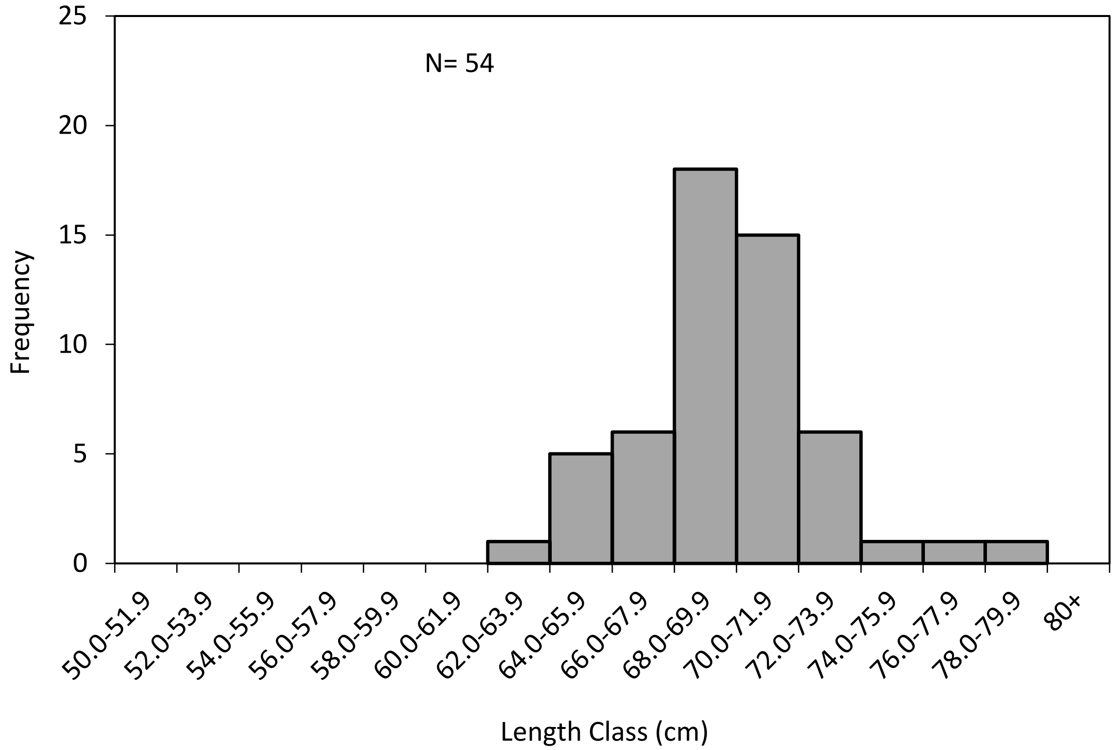


Figure 24. Length-frequency distribution of olive ridleys caught in non-LED nets from January 2016 to March 2017.

Monthly variation in abundance

Monthly variations in the number of turtles caught from January 2016 to March 2017 are shown in Figure 25. Sea turtles were captured in all the months, except March, April and May in 2016 and January and February in 2017. Peak numbers were captured in October for leatherback, January for green and November for olive ridley. The only turtle captured in 2017 was during the month of March.

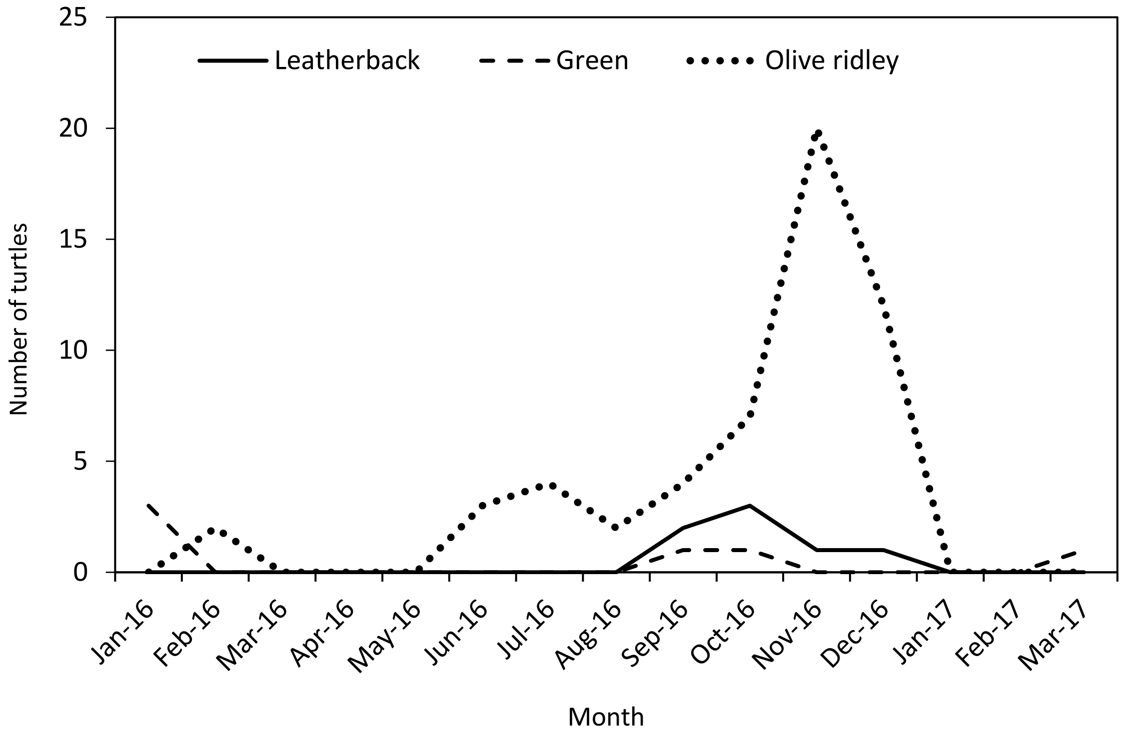


Figure 25. Monthly number of sea turtles captured in gill nets without LED from January 2016 to March 2017.

Turtle species and number caught in LED gill nets

Species composition

Eighteen turtles were caught in nets fitted with LEDs which comprised one leatherback, (*Dermochelys coriacea*) and 17 olive ridleys (*Lepidochelys olivacea*). All turtles captured were females.

Size distribution

The sizes of sea turtles captured in nets fitted with LEDs are presented in Table 7. The olive ridleys measured 62.0 cm to 71.1 cm in carapace length and 61.0 cm to 71.1 cm in carapace width.

Table 7. Mean size of sea turtles captured in gill nets with LED in 2016

		Carapace Length (cm)		Carapace Width (cm)		Body Weight (kg)	
Species	**N**	Min - Max	Mean ± SD	Min -Max	Mean ± SD	Min -Max	Mean ± SD
Leatherback	1	137.1	-	96.5	-	380.8	380.8
Olive ridley	17	62.0 - 71.1	66.3±2.4	61.0 – 71.1	67.3±2.8	43.1 – 49.4	46.1±1.7

Length-frequency distribution of turtles

Figure 26 shows the length-frequency distribution of olive ridley sea turtles caught in gill nets fitted with LED during 2016 and 2017. The carapace length of turtles ranged between the size class of 62.0 cm - 71.9 cm. The length distribution was bi-modal with modal class sizes of 60.0-67.9 and 68.0-69.9 cm.

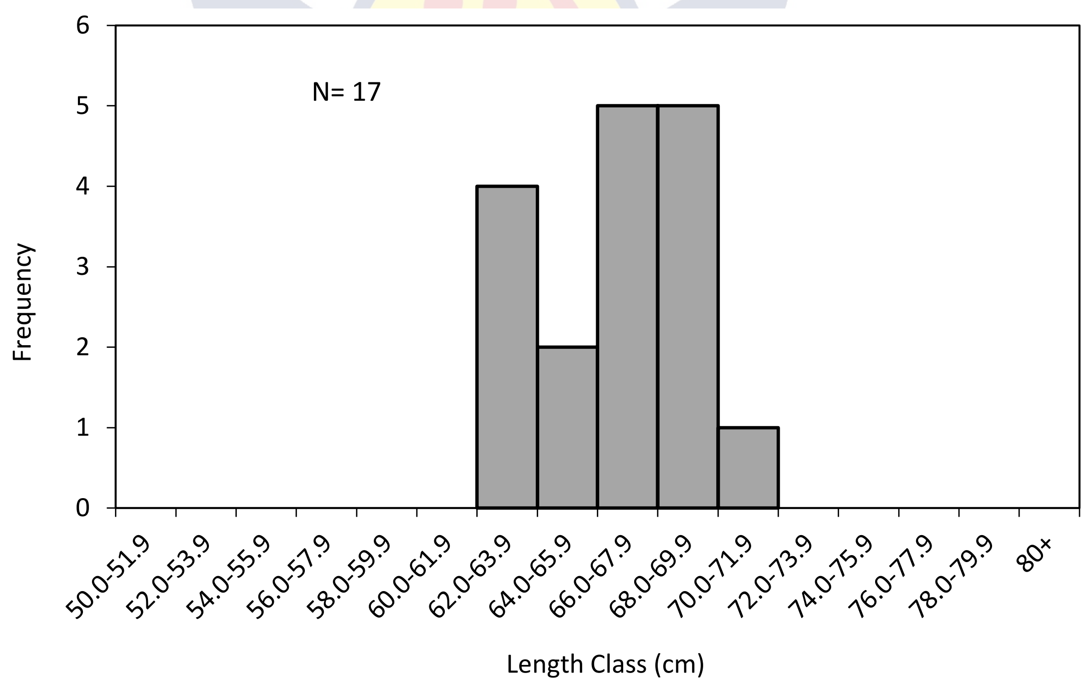


Figure 26. Length-frequency distribution of olive ridleys caught in LED nets from January 2016 to March 2017.

Monthly variation in abundance

Changes in number of turtles caught in LED gill nets from January 2016 to March 2017 are illustrated in Figure 27. Olive ridleys were caught during February, June, August, October, November and December of the year 2016, while leatherback was caught only in December of the same year. The highest number of sea turtle captures (n=8) was recorded in November representing 44% of the total number of sea turtles caught over the period while the least number (n=1) was recorded in August and December. No turtle was caught in LED nets in 2017. Generally, sea turtles capture during the months was sporadic.

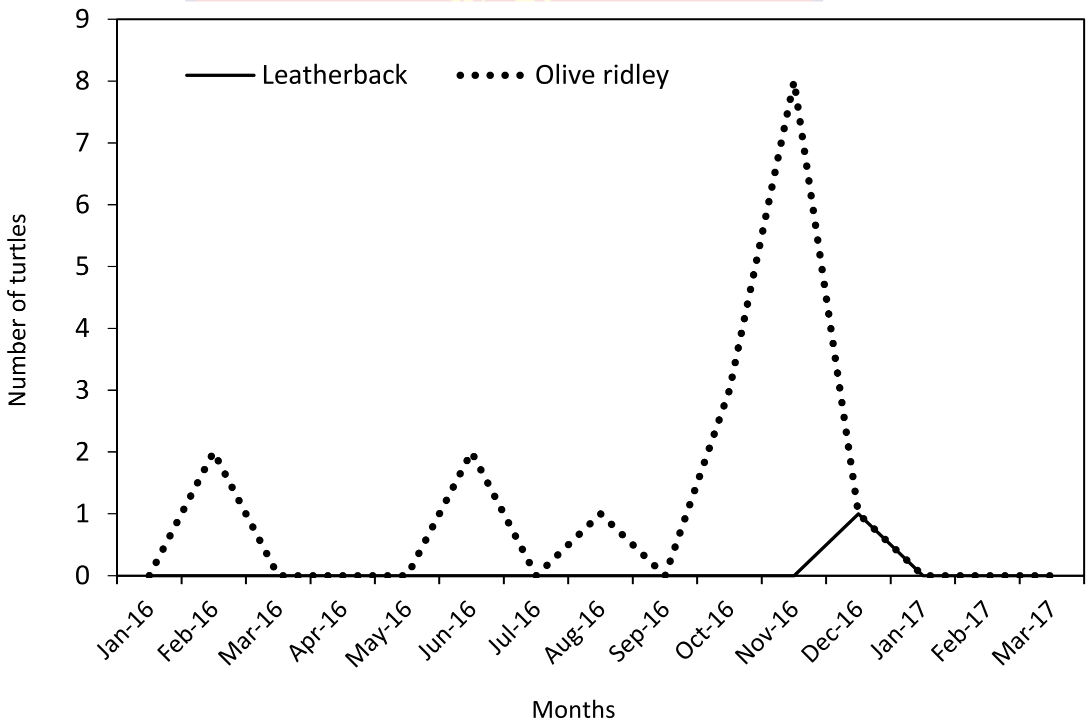


Figure 27. Monthly number of sea turtle species captured in LED nets from January 2016 to March 2017.

Length-weight relationship of the sea turtles

The length-weight relationship of leatherback, olive ridley and green turtles captured during the study, from January 2016 to March 2017, is shown in Figure 28. Weight of each turtle was estimated from Eckert et al. (1999). Carapace length correlated positively with body weight for leatherback (y = 2.7778x + 9E-12), green turtle (y = 1.84x + 2E-13) and olive ridley (y = 0.6953x - 0.0516). A perfect correlation existed between lengths and weights of leatherback and green turtle due to the estimations of the weight.

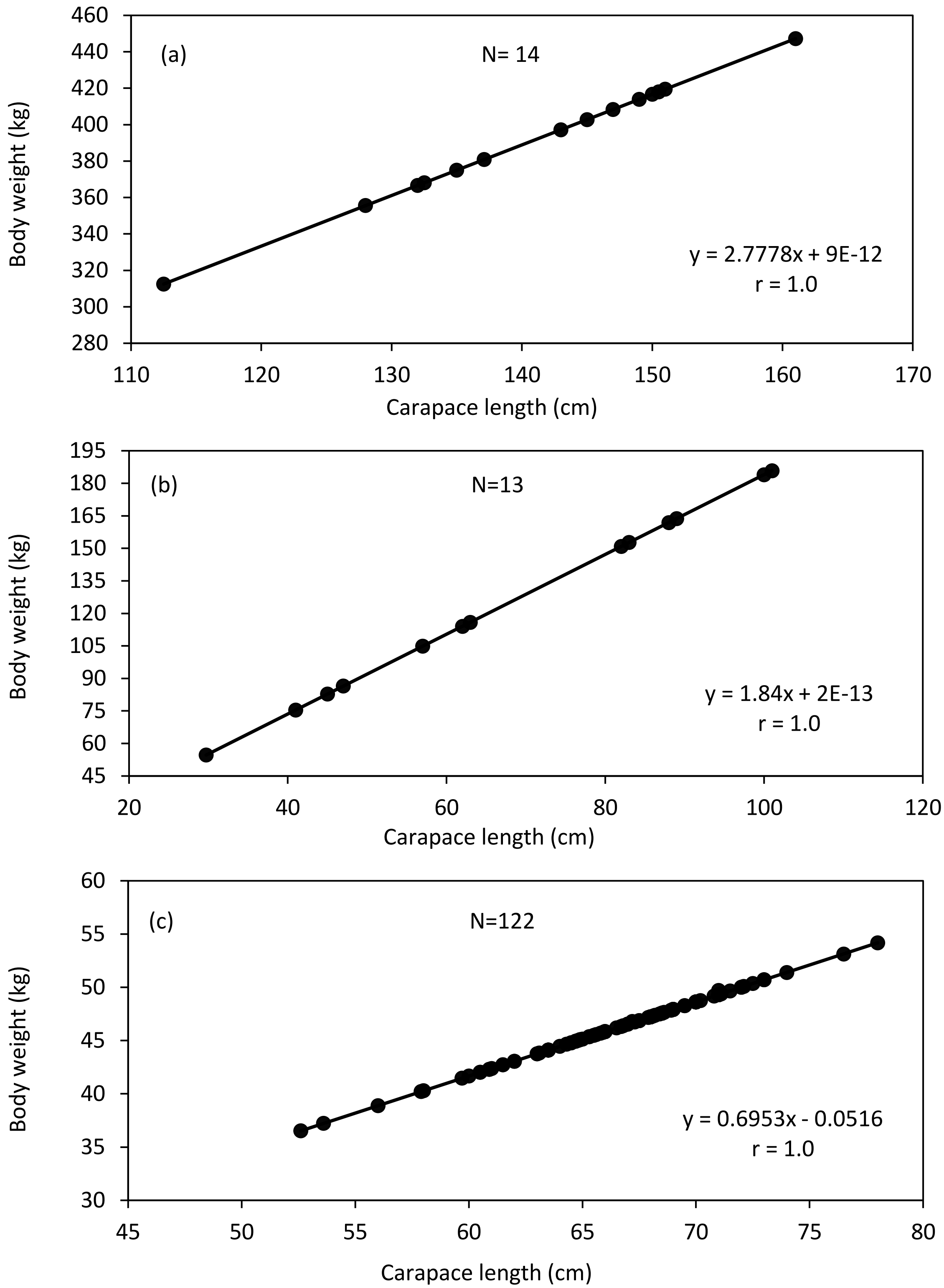


Figure 28. Length-weight relationship for (a) leatharback, (b) green and (c) olive ridley turtles captured in gill nets from Januray 2015 to march 2017.

Fluctuations in turtle catch per unit effort in the experimental nets

Figure 29 shows the monthly mean sea turtle catch per unit effort (CPUE) during the experimental period, January 2016 to March 2017. Non-LED nets caught turtles in 10 of the 15 months studied while LED nets trapped the species in 6 months during the same period. The CPUE in non-LED nets varied from 3.69 to 12.90 turtle per 100 m net per 12 hours of fishing, and LED nets from 3.08 to 8.26 turtle per 100m net per 12 hours of fishing. Analysis of the pooled data from the two sets of nets gave mean CPUE values of 6.50 ± 0.27 and 4.58 ± 0.29 turtle per 100m net per 12 hours of fishing for non-LED nets and LED nets respectively, further indicating a significant difference between the two groups of net ($t=3.65$, $p<0.05$).

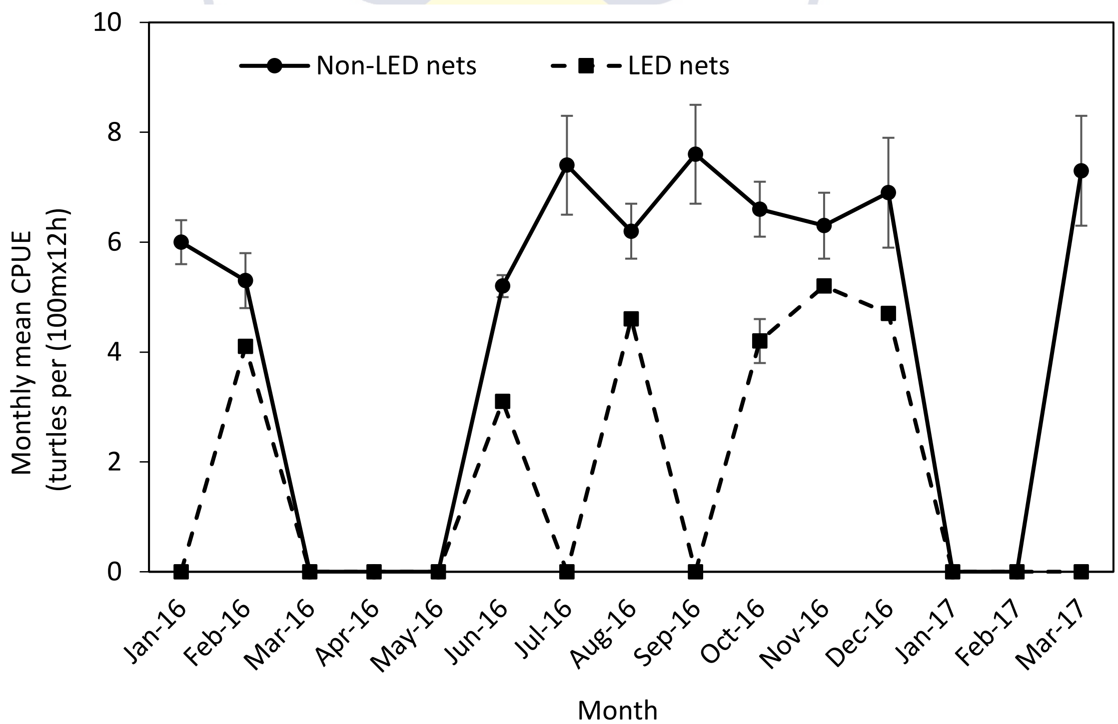


Figure 29. Monthly mean CPUE of sea turtles caught in LED and non-LED gill nets from January 2016 to March 2017. Bars represent standard errors.

Fish species composition and diversity in the experimental nets

The corresponding fish species caught in the non-LED and LED fitted nets between January 2016 and March 2017 is presented in Table 8. The non-LED nets caught 31 fish species belonging to 16 families, while the LED nets caught 32 species belonging to 13 families.

Figure 30 shows the percentage composition of fish species caught by nets without LED and nets with LED. *Ethmalosa fimbriata* was the most abundant with composition of 59.6% and 51.6% of the total catch from non-LED nets and LED nets, respectively. *Chloroscombrus chrysurus* had the second highest composition forming 19.9% of the total catch in non-LED and 21.8% of the total catch in LED nets. All other species were lowly represented in the catches with compositions less than 7% for non-LED nets and LED nets.

Table 8. Fish species encountered during experimental fishing with gill nets with and without LED lights from January 2016 to March 2017. '+' and '-' indicate species present and absent respectively.

FISH FAMILY	SPECIES	COMMON NAME	Non-LED nets	LED nets
Acanthuridae	*Acanthurus monroviae*	Monrovia doctorfish	+	+
Balistidae	*Balistes punctatus*	Bluespotted triggerfish	-	+
Carangidae	*Alectis alexandrina*	Alexandria pompano	-	+
	Caranx crysos	Blue runner	+	+
	Caranx hippos	Crevalle jack	+	+
	Chloroscombrus chrysurus	Atlantic bumper	+	+
	Elagatis bipinnulata	Rainbow runner	+	+
	Lichia amia	Leerfish	+	+
	Selene dorsalis	African moonfish	+	+
	Trachurus trachurus	Atlantic horse mackerel	-	+
	Urapsis secunda	Cottonmouth jack	+	-
Clupeidae	*Ethmalosa fimbriata*	Bonga shad	+	+
	Sardinella aurita	Round sardinella	+	+
	Sardinella maderensis	Flat sardinella	+	+
	Ilisha africana	West African ilisha	+	+
Cynoglossidae	*Cynoglossus senegalensis*	Senegalese tonguesole	+	-
Drepaneidae	*Drepane Africana*	African sicklefish	+	-
Elopidae	*Elops crysos*	Lady fish	-	+
	Elops lacerta	West African ladyfish	+	+
Exocoetidae	*Fodiator acutus*	Sharpchin flyingfish	+	+
Haemulidae	*Brachydeuterus auritus*	Bigeye grunt	+	+
	Pomadasys incisus	Bastard grunt	-	+
	Pomadasys jubelini	Sompat grunt	+	+
Lutjanidae	*Apsilus fuscus*	African forktail snapper	+	+
Mullidae	*Pseudupeneus prayensis*	West African goatfish	+	-
Polynemidae	*Galeoides decadactylus*	Lesser African threadfin	+	+
	Pentanemus quinquarius	Royal threadfin	+	+
	Polydactylus quadrifilis	Giant African threadfin	+	+
Sciaenidae	*Pseudotolithus typus*	Longneck croaker	+	+
	Pseudotolithus senegallus	Law croaker	+	+
	Pseudotolithus senegalensis	Cassava croaker	+	+
	Pteroscion peli	Boe drum	+	+
Scombridae	*Orcynopsis unicolor*	Plain bonito	+	+
	Scomberomorus tritor	West African Spanish mackerel	+	+
Sphyraenidae	*Sphyraena sphyraena*	European barracuda	+	+
Tetraodontidae	*Lagocephalus lagocephalus*	Smooth puffer	+	+
Total species present			**31**	**32**

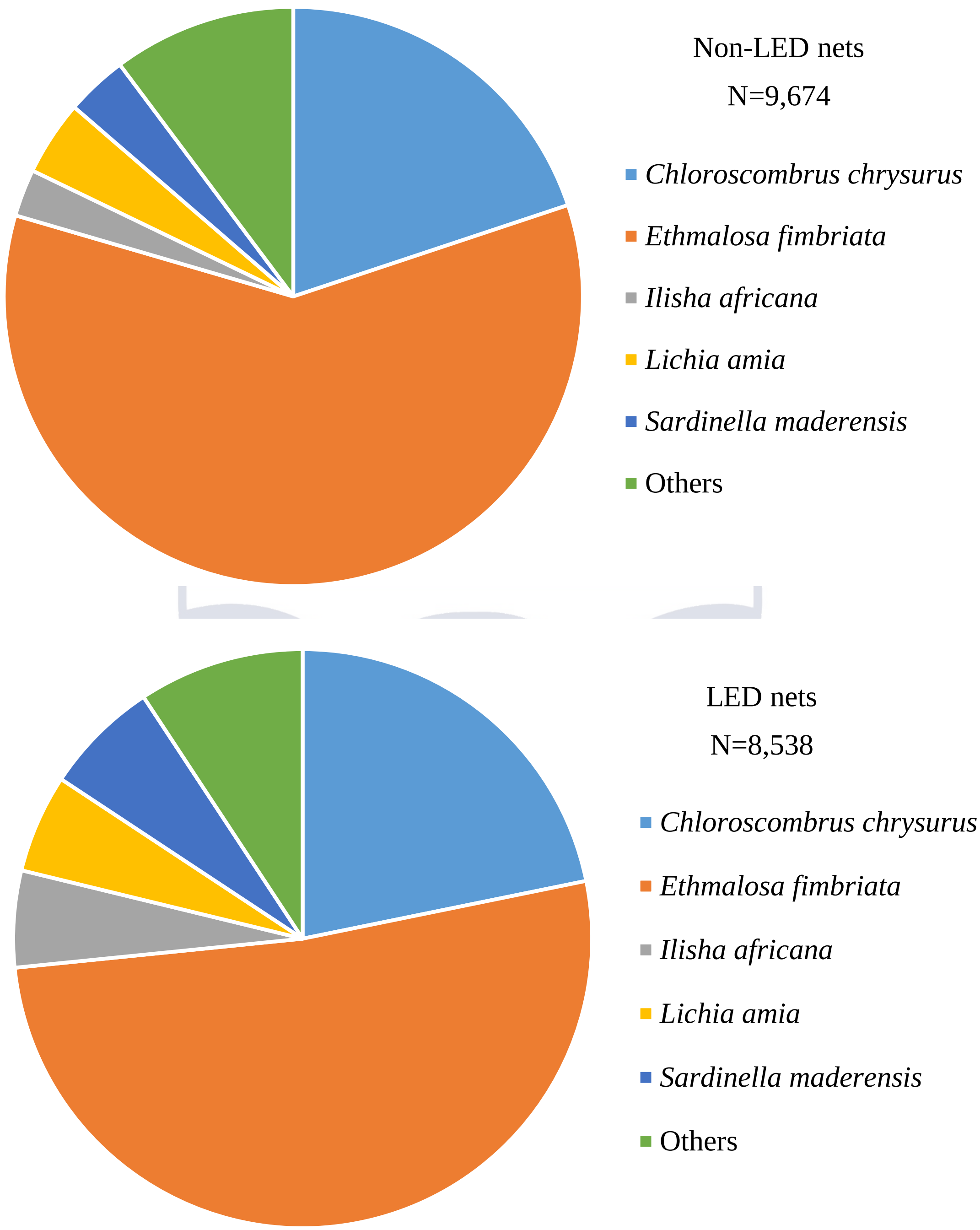


Figure 30. Percentage composition of fish species caught by non-LED nets and LED nets.

Table 9 provides information on the diversity indices of fish caught in the two groups of nets. It was observed from the values that there are no significant difference in the diversity of fish caught in the non-LED and LED nets.

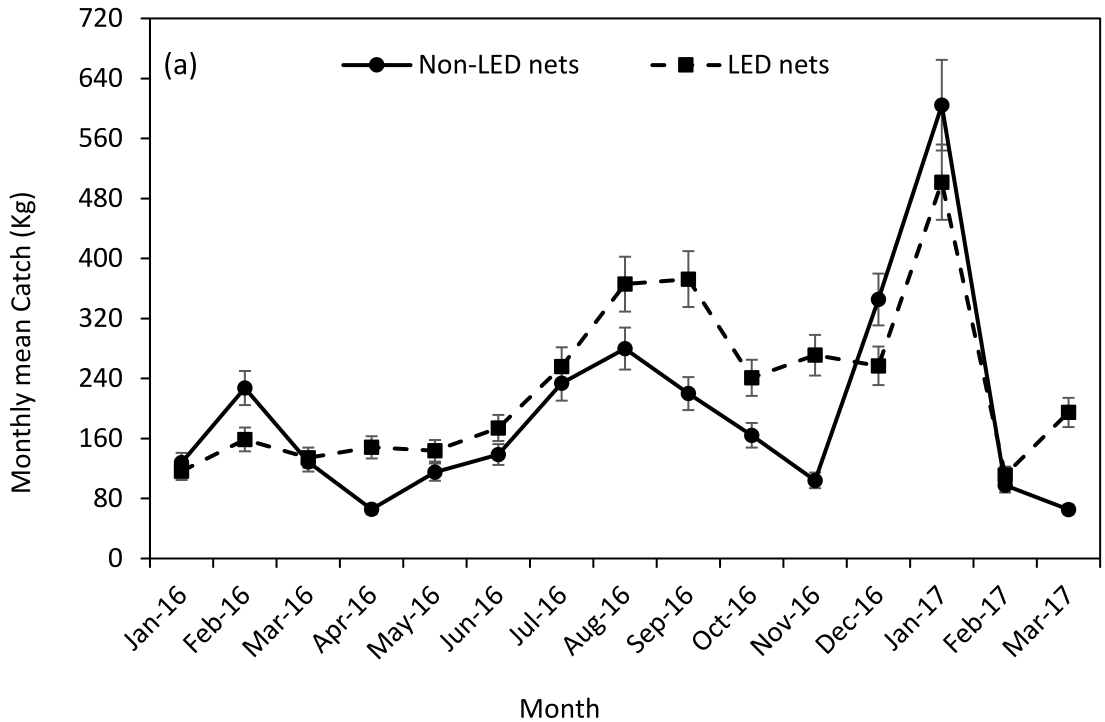
Table 9. Diversity of fish species caught by non-LED nets and LED nets

	Number		Richness	Diversity	Evenness
Treatment	**Families**	**Species (*s*)**	**(*d*)**	**(*H'*)**	**(*J'*)**
Non-LED nets	16	31	3.18	1.50	0.44
LED nets	13	32	3.09	1.61	0.48

Fish catch in the experimental nets

Monthly variations in fish catch and CPUE in non-LED and LED nets are illustrated in Figure 31. Monthly fish catch for non-LED nets was highest in January 2017 (604.3±7.0 kg) and lowest in March 2017 (65.3±2.4 kg). The highest catch for the LED nets was recorded in January 2017 (501.7±8.7 kg) and the lowest catch recorded in February 2017 (111.4±4.9 kg). Higher catches, dominated by bonga chad (*Ethmalosa fimbriata*), tended to occur in LED nets for most months of the study period except in January, February and December 2016 and January 2017. The combined data for the study period showed no significant difference between fish catches of non-LED and LED nets ($t=0.12$, $p>0.05$).

Peak CPUE for LED nets occurred in July-September 2016 and January 2017, and for non-LED nets in February, August and December 2016. No significant difference ($t= 0.28$, $p>0.05$) was however found between the pooled CPUE data for the two groups of nets.



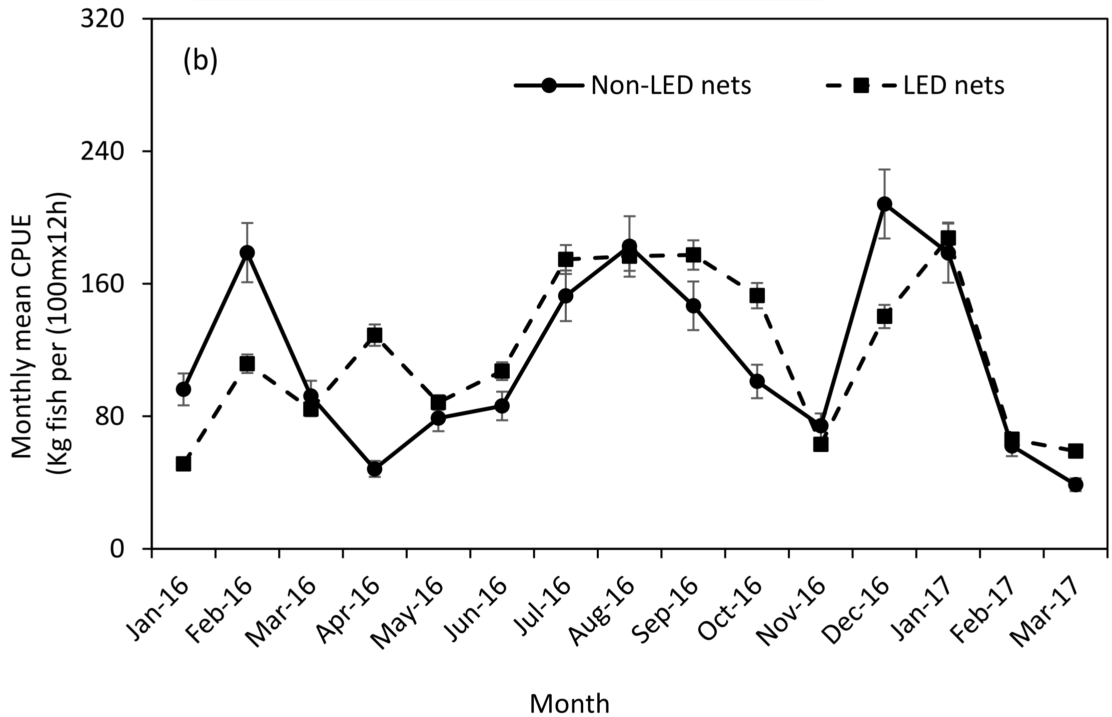


Figure 31. Variations in (a) mean monthly fish catch and (b) mean monthly CPUE in the gill net fishery of Gomoa and Effutu coastal waters. Bars indicate standard deviations.

Length-frequency distribution of the common fishes

The length-frequency distributions of the five common fish species caught in the nets with and without LED lights are presented in Table 10. The pooled data for fish caught from January 2016 and March 2017 showed a similar modal class for *Ethmalosa fimbriata*, *Chloroscombrus chrysurus, Sardinella maderensis* and *Lichia amia*. The size range in centimetres was also similar for *Sardinella maderensis* over the period.

Table 10. Length-frequency distribution for common fish species caught from January 2016 to March 2017.

Species	Size range (TL)(cm)		Modal length (cm)		Remarks
	Non-LED	LED	Non-LED	LED	
Ethmalosa fimbriata	8.0 - 23.0	8.0 - 22.0	16.0 - 16.9	16.0 - 16.9	Similar modal length
Chloroscombrus chrysurus	4.0 - 20.0	6.0 - 20.0	12.0 - 12.9	12.0 - 12.9	Similar modal length
Sardinella maderensis	10.0 - 24.0	10.0 - 24.0	14.0 - 14.9	14.0 - 14.9	Similar modal length
Lichia amia	11.0 - 26.0	9.0 - 24.0	17.0 - 17.9	17.0 - 17.9	Similar modal length
Ilisha africana	10.0 - 21.0	10.0 - 20.0	16.0 - 16.9	14.0 - 14.9	

Monthly length-frequency distribution of common fish species

Ethmalosa fimbriata

Figure 32 illustrates the monthly length-frequency distribution of the bonga shad, *Ethmalosa fimbriata* samples in non-LED nets during the fifteen month experimental study period. The distributions were unimodal with modal length ranging from 14.0-14.9 cm in

March 2016 and 17.0-17.9 cm in December 2016 with no clear pattern in shifts in the modes.

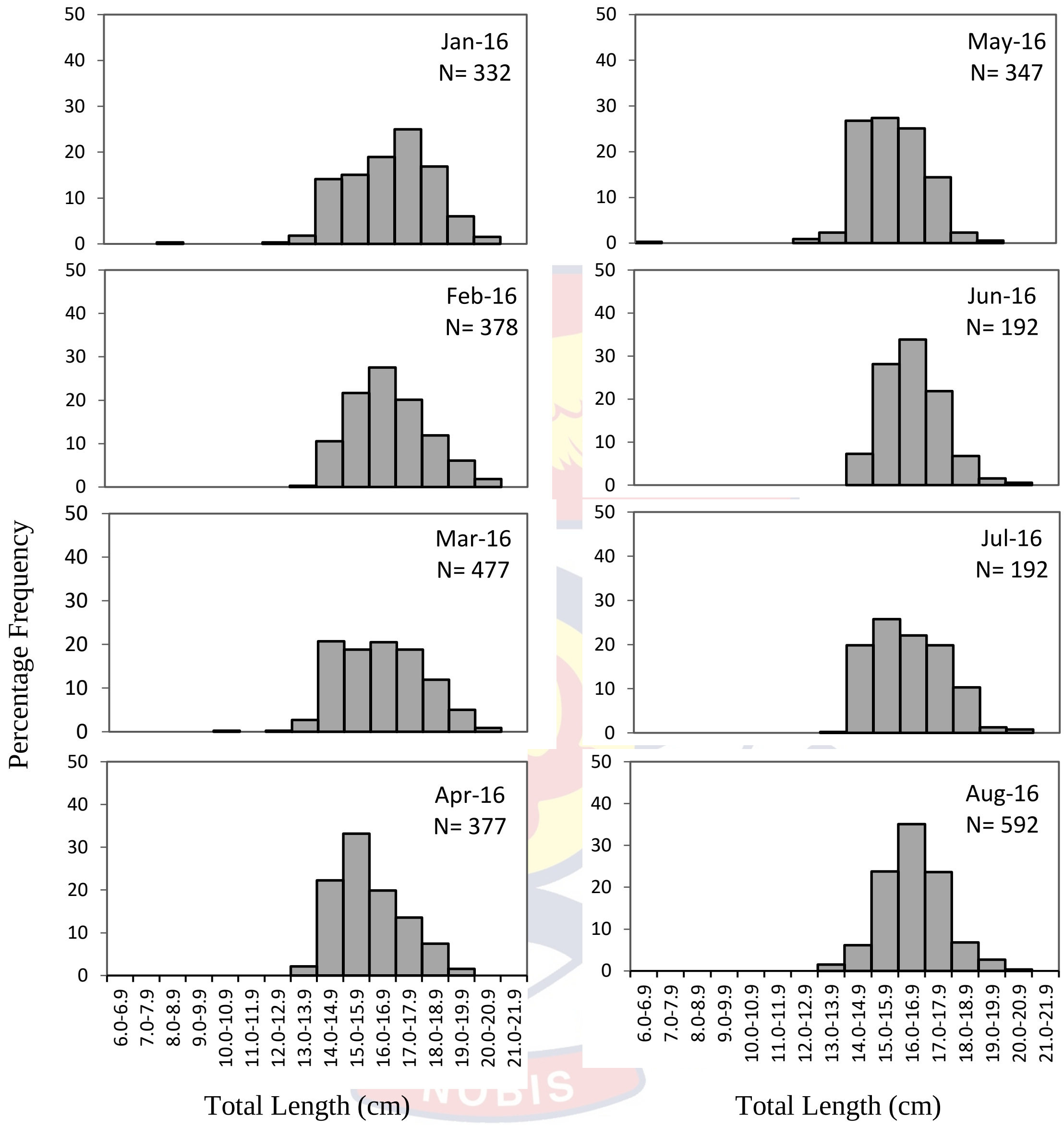


Figure 32. Monthly length-frequency distribution for *Ethmalosa fimbriata* caught in nets without LED.

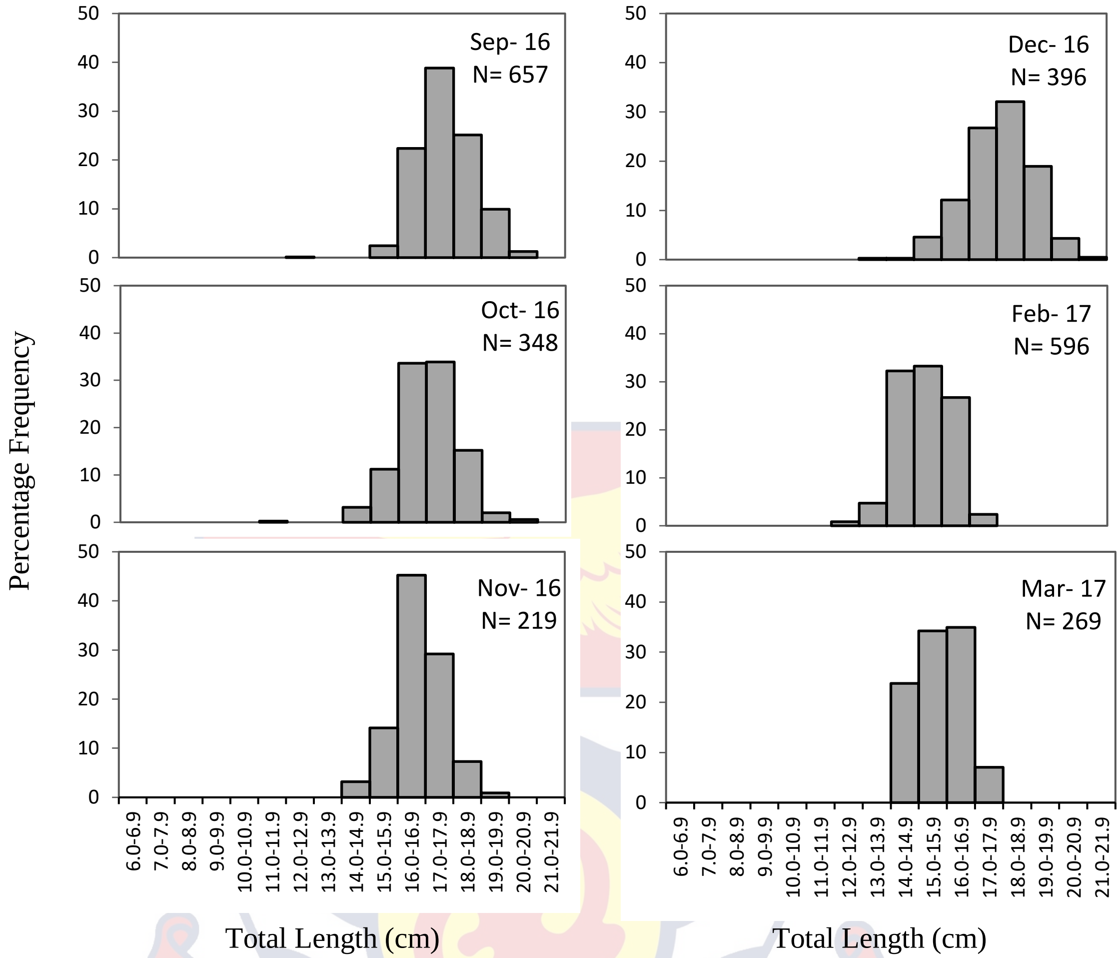


Figure 32 continued. Monthly length-frequency distribution for *Ethmalosa fimbriata* caught in nets without LED from January 2016 to March 2017

Figure 33 shows the monthly length-frequency distribution of the bonga shad, *E. fimbriata*, samples caught in nets with LED during the fifteen month period. Similarly, the distribution is unimodal with modal lengths ranging from 14.0-14.9 cm in March 2016 and 17.0-17.9 cm in December 2016. No catch was recorded in January 2017 for the species. Again the shifts in modal length was irregular.

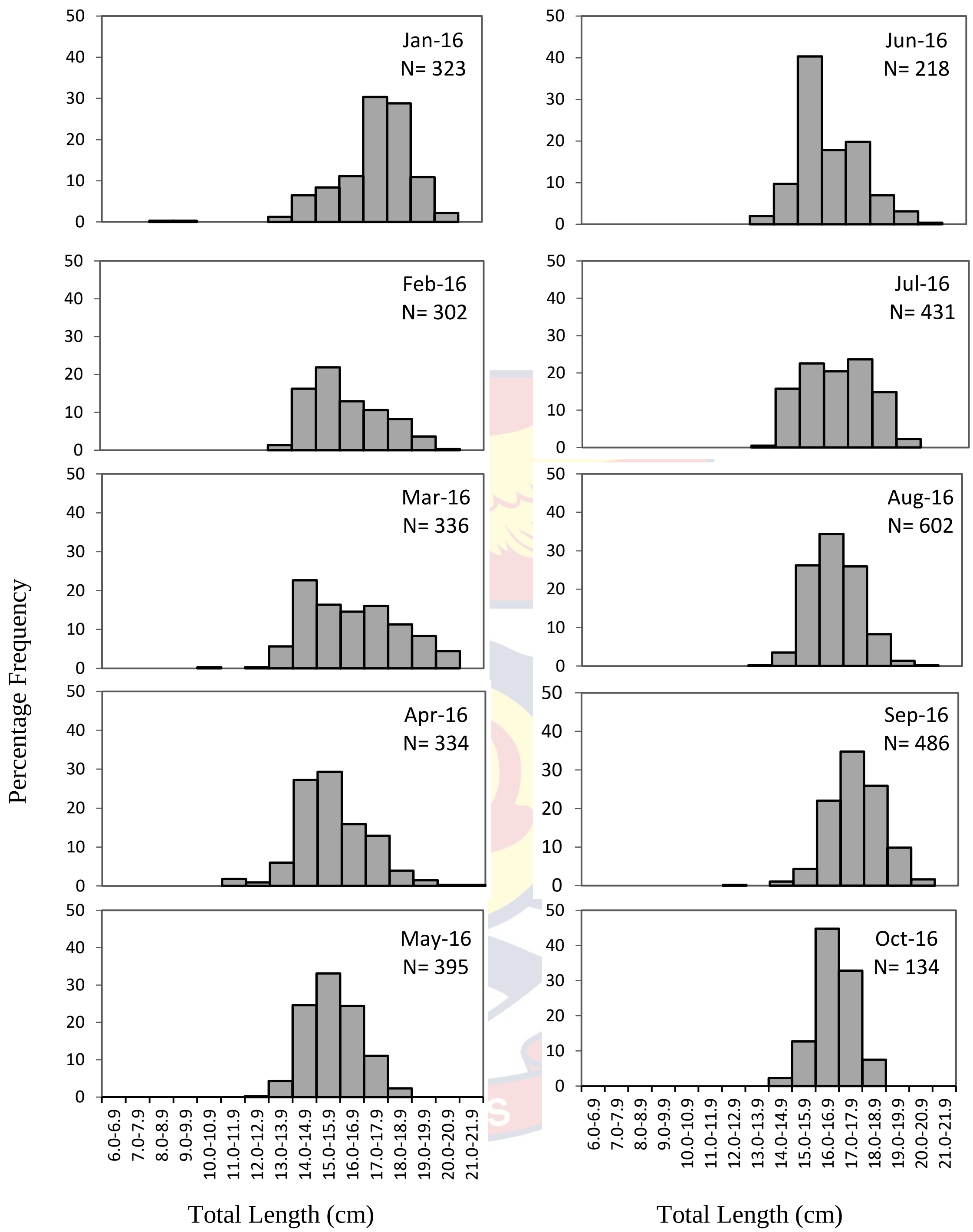


Figure 33. Monthly length-frequency distribution for *Ethmalosa fimbriata* caught in nets with LED.

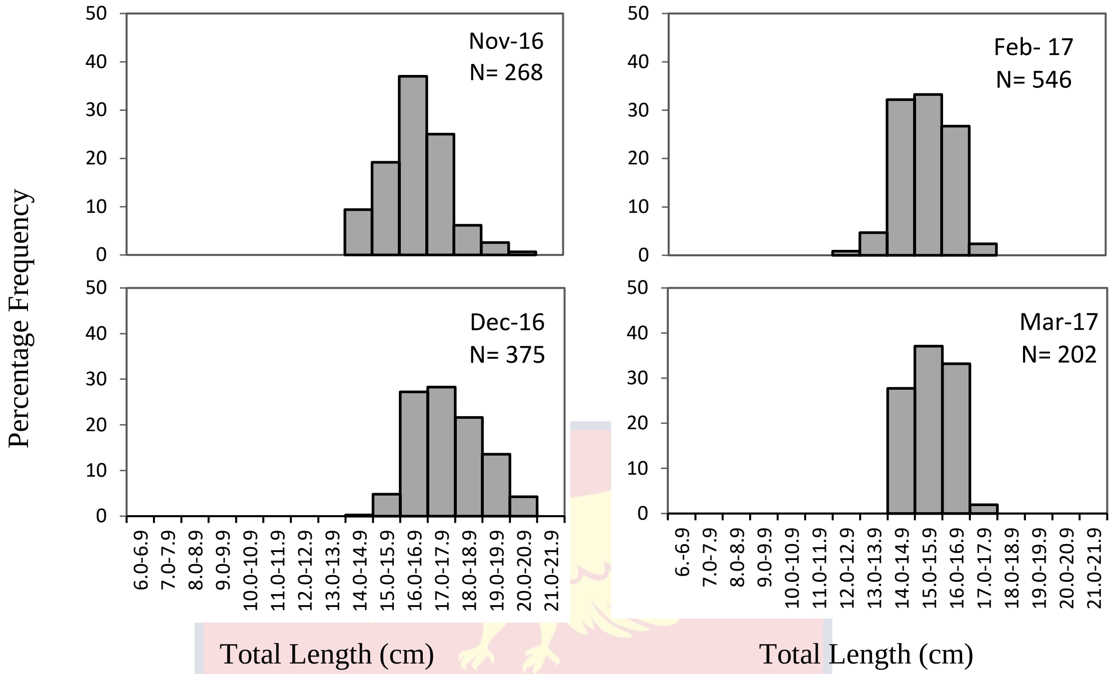


Figure 33 continued. Monthly length-frequency distribution for *Ethmalosa fimbriata* caught in nets with LED.

Chloroscombrus chrysurus

The monthly length-frequency distribution of the Atlantic bumper, *C. chrysurus*, specimens caught in non-LED nets during the fifteen month period is shown in Figure 34. The distribution is unimodal with modal lengths ranging from 11.0-11.9 cm in February 2016 to 15.0-15.9 cm in August 2016. The shift in modal length was irregular. No catch was recorded in September 2016, February 2017 and March 2017 for the species.

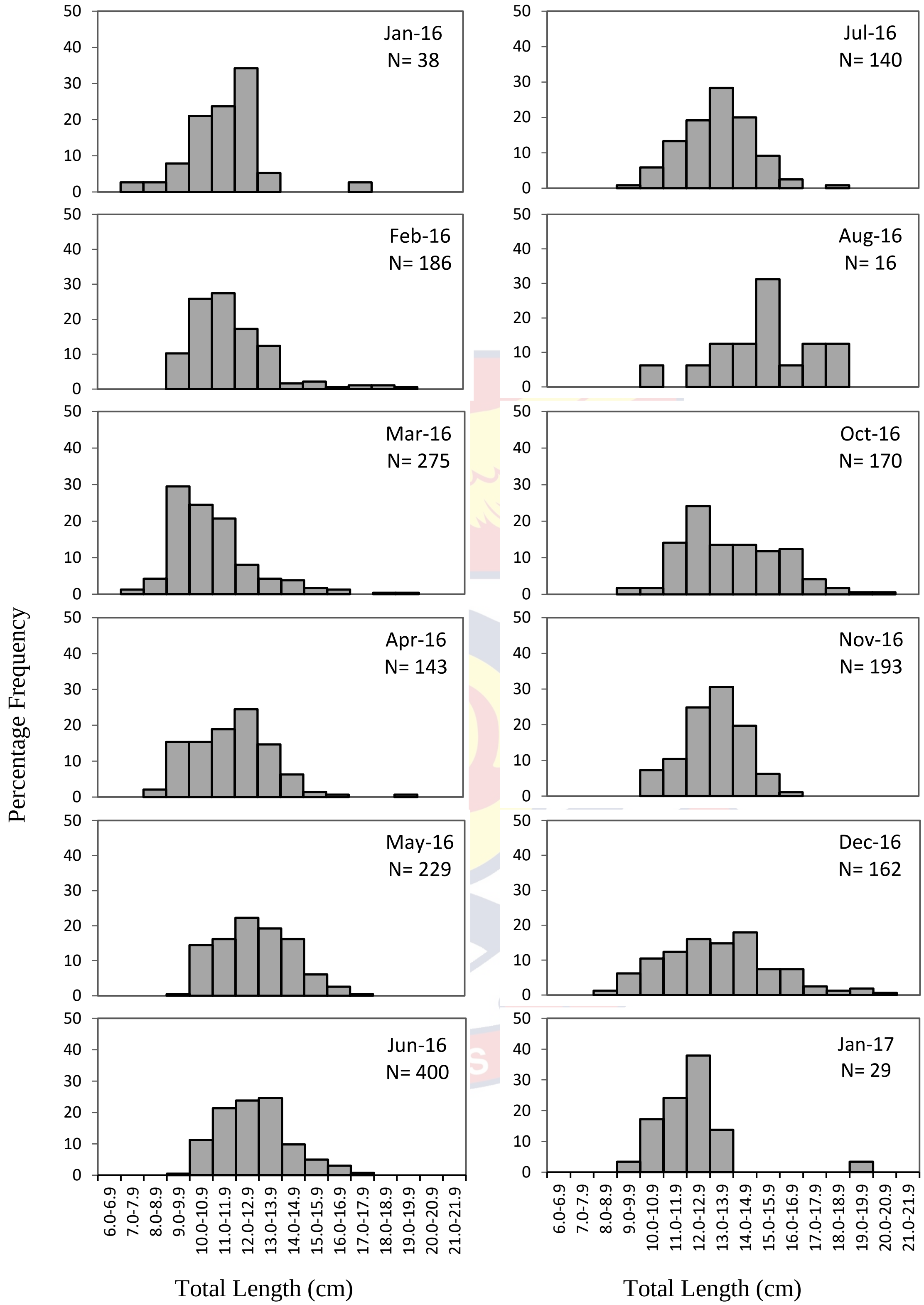


Figure 34. Monthly length-frequency distribution for *Chloroscombrus chrysurus* caught in non-LED nets from January 2016 to March 2017

Figure 35 shows the monthly length-frequency distribution of the Atlantic bumper, *C. chrysurus*, samples caught in nets with LED during the fifteen month period. The distribution was unimodal in all months except January 2016 when a polymodal distribution occurred. Modal lengths ranged from 9.0-9.9 cm in March 2016 to 14.0-14.9 cm in October 2016 with an irregular shift in modal class. No catches were recorded in September 2016 and February 2017 for the species. Modal length ranged between the 9.0-9.9 cm and 14.0-14.9 cm size classes.

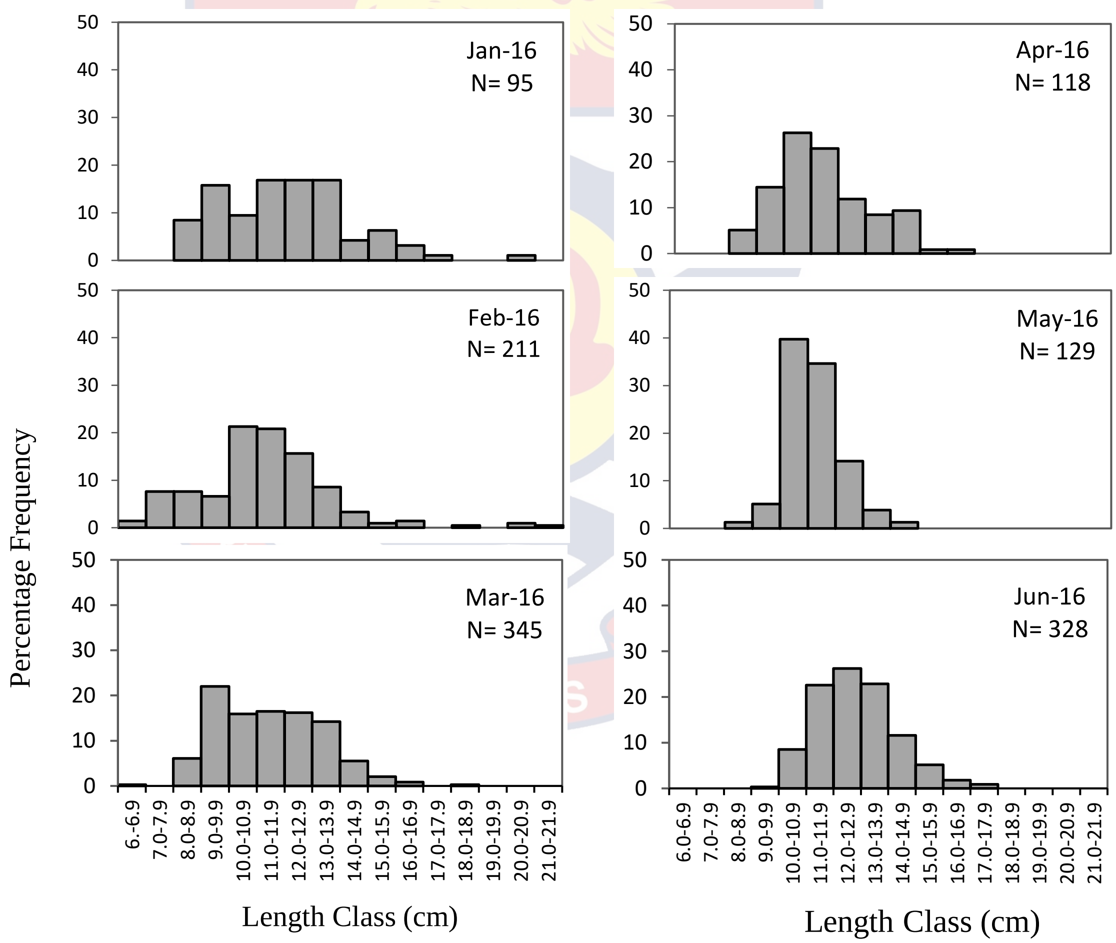


Figure 35. Monthly length-frequency distribution for *Chloroscombrus chrysurus* caught in LED nets.

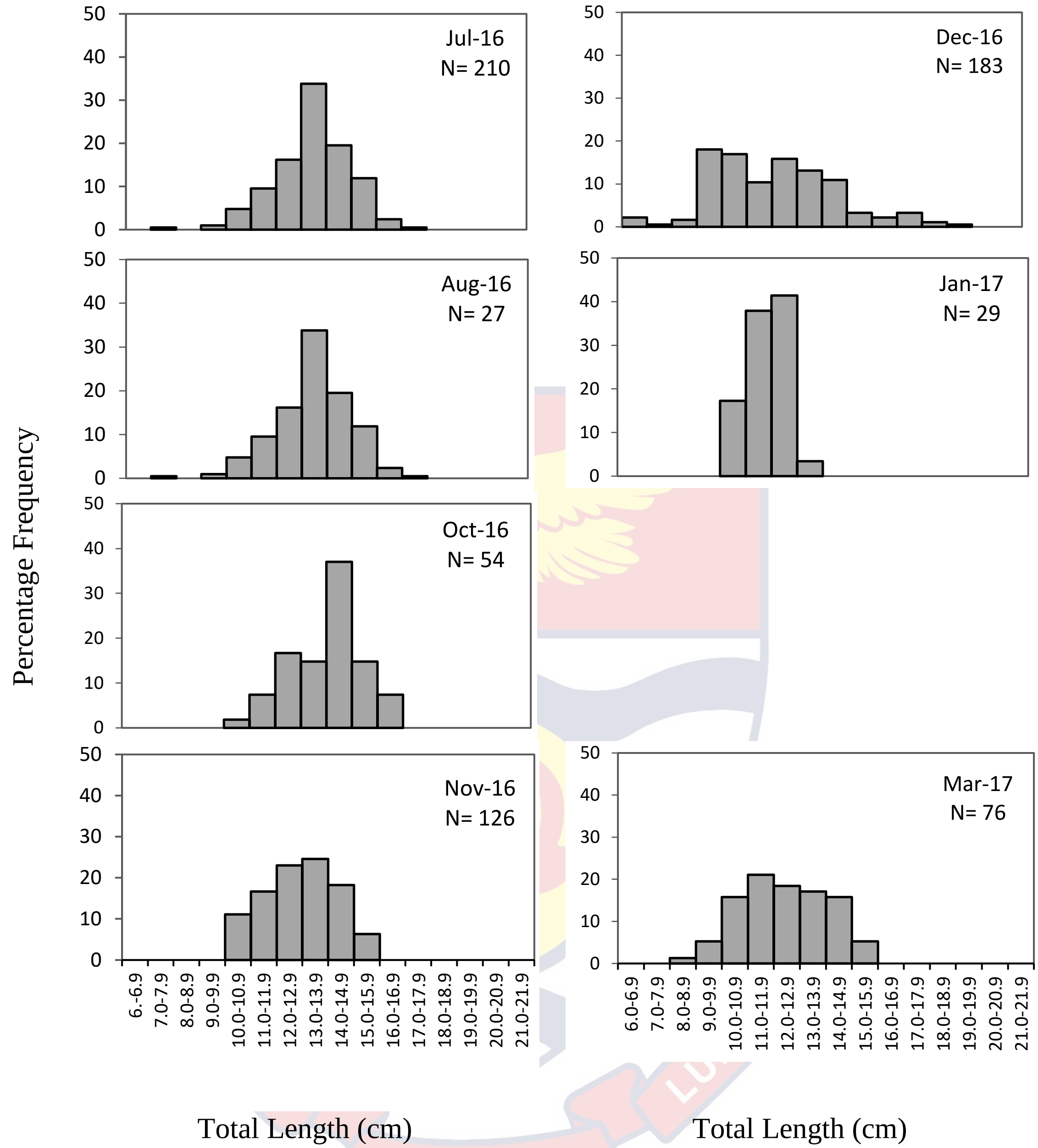


Figure 35 continued. Monthly length-frequency distribution for *Chloroscombrus chrysurus* caught in LED nets.

Sardinella maderensis

Figure 36 illustrates the monthly length-frequency distribution of the flat sardinella, *S. maderensis*, caught in non-LED nets during the fifteen month study period. Catches for the species were recorded in 6 months of the study period namely January, April, May, July, October and November 2016. The distributions were unimodal with modal length ranging from 15.0-15.9 cm in April 2016 to 20.0-20.9 cm in November 2016 with no clear pattern in shifts in the modes.

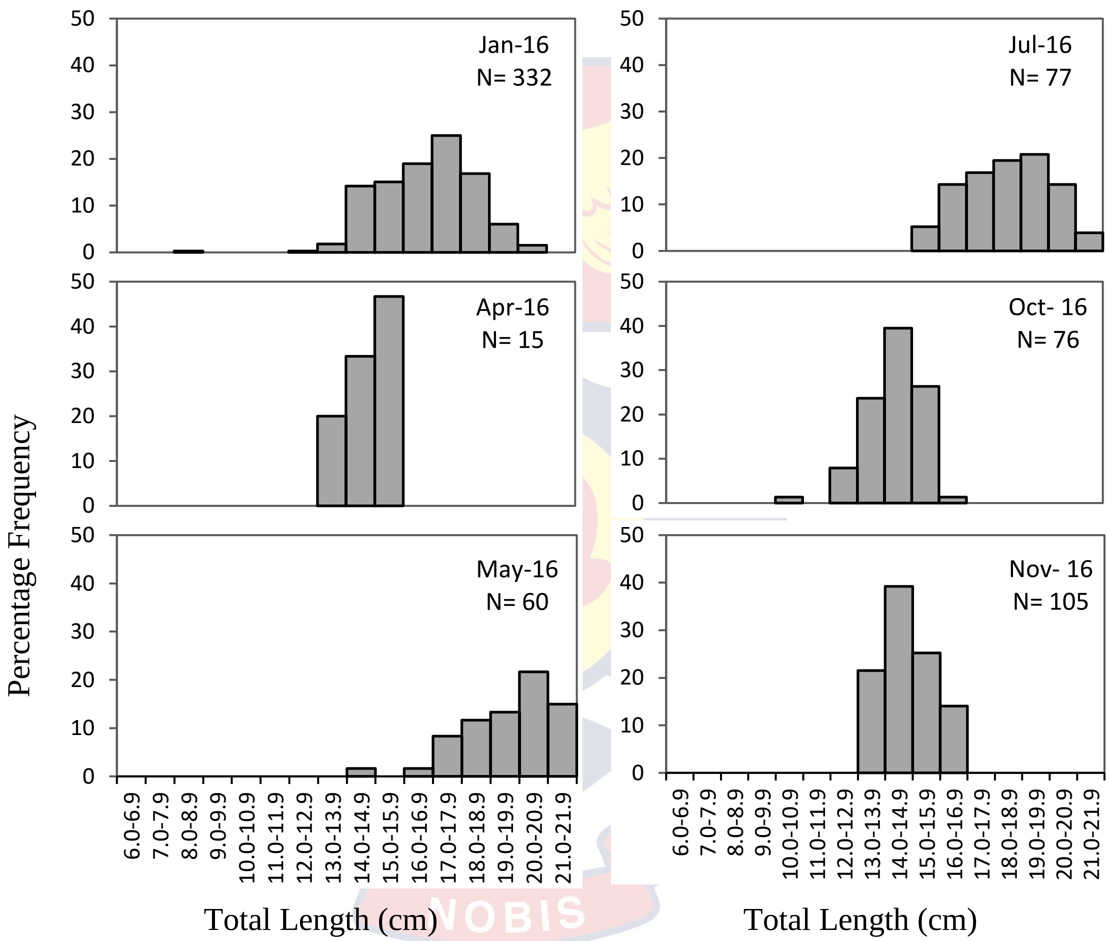


Figure 36. Monthly length-frequency distribution for *S. maderensis* caught in nets without LED.

The monthly length-frequency distribution of the flat sardinella, *S. maderensis*, specimens caught in LED nets during the fifteen month period is shown in Figure 37. The distribution is unimodal in all the month that recorded sardinella except in May 2016 where a bimodal distribution occurred. Modal lengths ranged from 11.0-11.9 cm in March 2016 to 19.0-19.9 cm in July 2016. The shift in modal length was irregular. Catches for the species were recorded in 6 months of the study period namely March, April, May, July, October and November 2016.

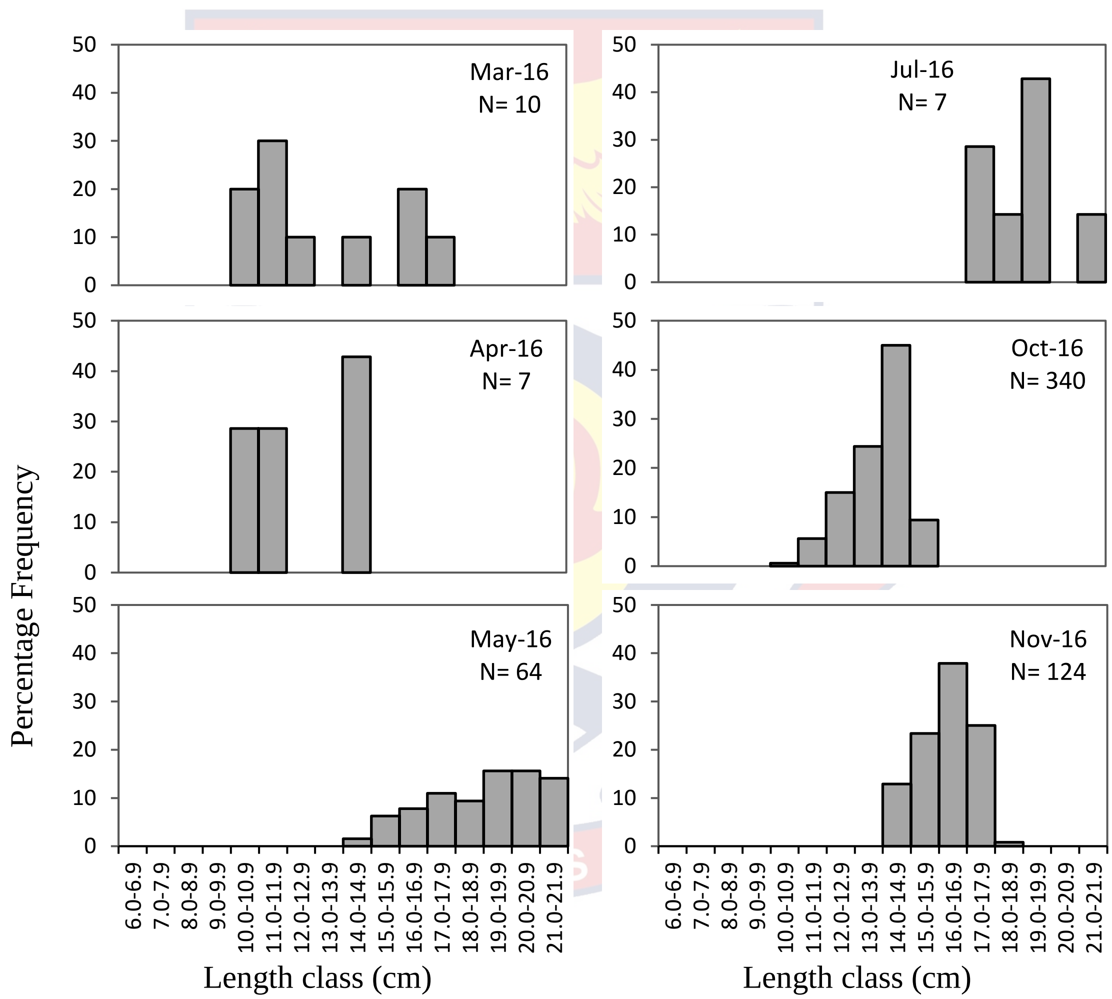


Figure 37. Monthly length-frequency distribution for *S. maderensis* caught in nets with LED.

Lichia amia

The monthly length-frequency distribution of *Lichia amia* specimens caught in non-LED nets during the study is shown in Figure 38. The distribution is unimodal in the month that recorded *L. amia* except in November 2016 where a bimodal distribution occurred. Modal lengths ranged from 14.0-14.9 cm in April 2016 to 19.0-19.9 cm in November 2016. The shift in modal length was irregular. Catches for the species were recorded in January to June, then November and December of 2016.

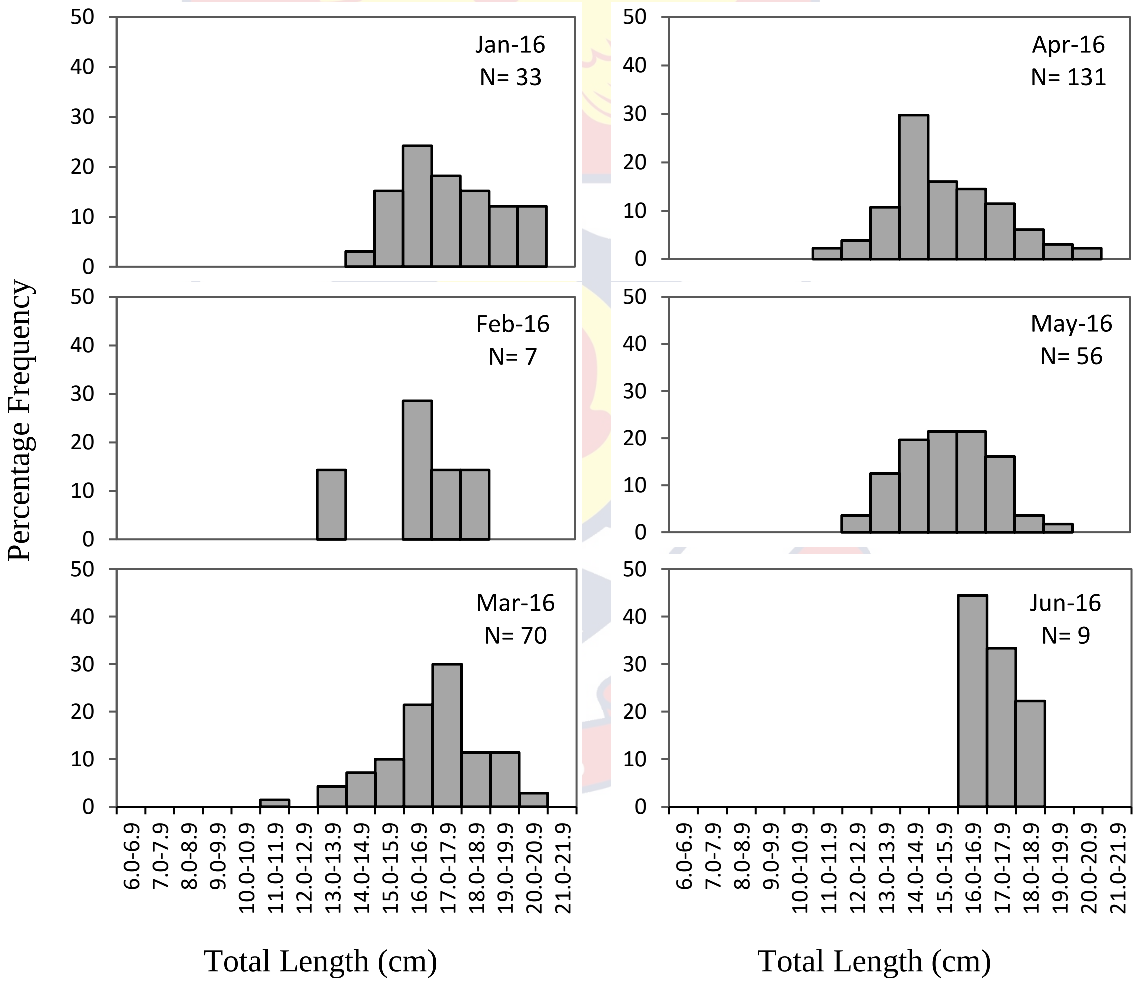


Figure 38. Monthly length-frequency distribution for *Lichia amia* samples in nets without LED from January 2016 to March 2017.

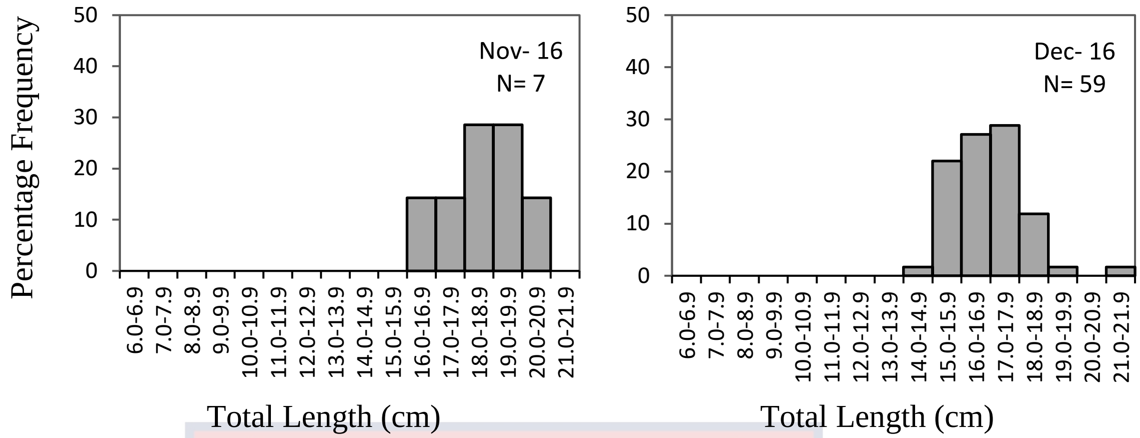


Figure 38 continued. Monthly length-frequency distribution for *Lichia amia* samples in nets without LED from January 2016 to March 2017.

Figure 39 illustrates the monthly length-frequency distribution of the *Lichia amia* caught in LED nets during the fifteen month study period. Catch for the species was recorded in 9 months of the study period. A unimodal distribution was observed in the length classes with no clear pattern in shifts in the modes. The modal length ranged from 14.0-13.9 cm in January and March 2016 to 19.0-19.9 cm in September 2016.

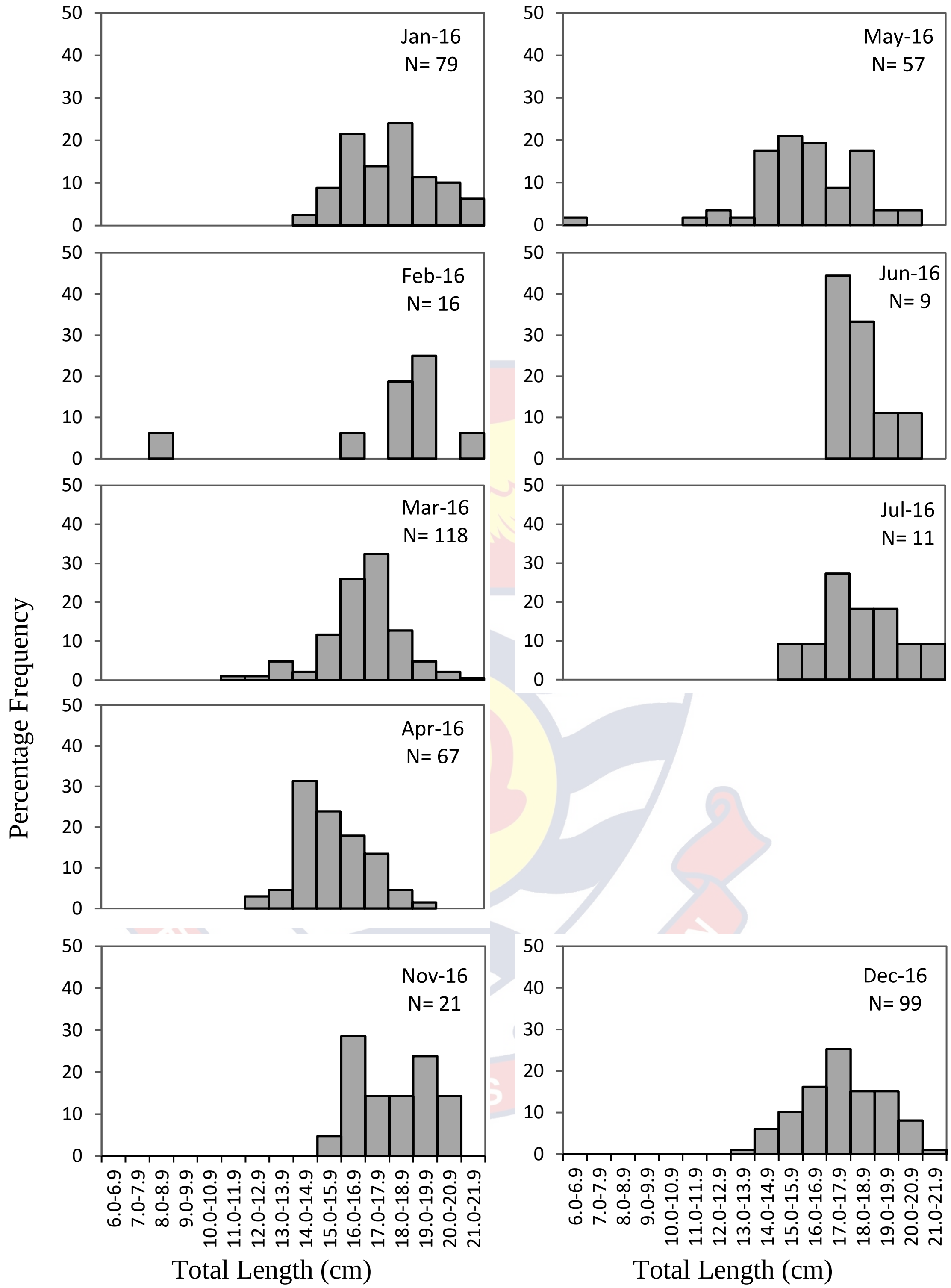


Figure 39. Monthly length-frequency distribution for *Lichia amia* samples in nets with LED from January 2016 to March 2017.

Ilisha africana

Figure 40 illustrates the monthly length-frequency distribution of the *Ilisha africana* caught in non-LED nets during the fifteen month study period. Catch for the species was recorded in 10 months of the study period. A unimodal distribution was observed in the length classes except in September 2016 where a polymodal distribution occurred. The modal length ranged from 13.0-13.9 cm in January and March 2016 to 19.0-19.9 cm in September 2016 with no clear pattern in shifts in the modes.

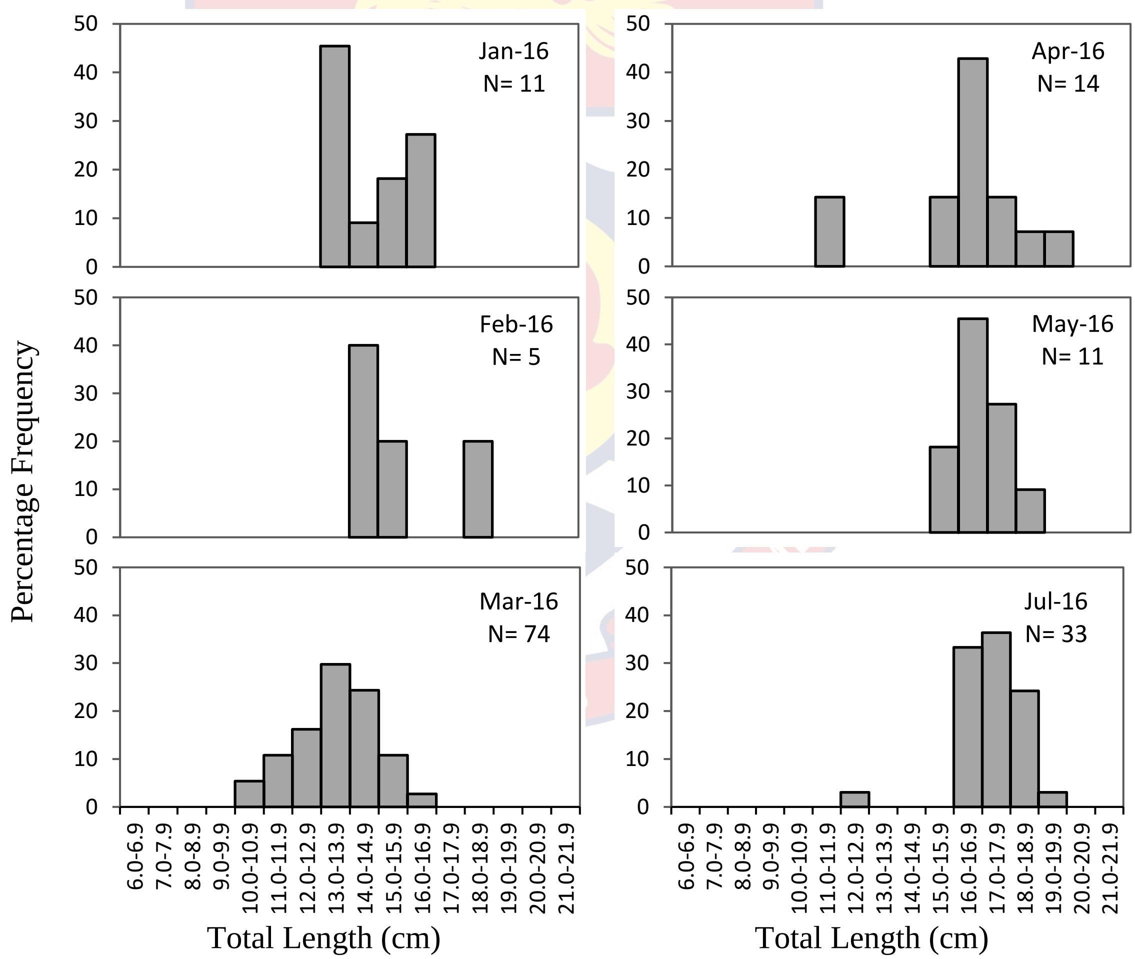


Figure 40. Monthly length-frequency distribution for *Ilisha africana* caught in nets without LED.

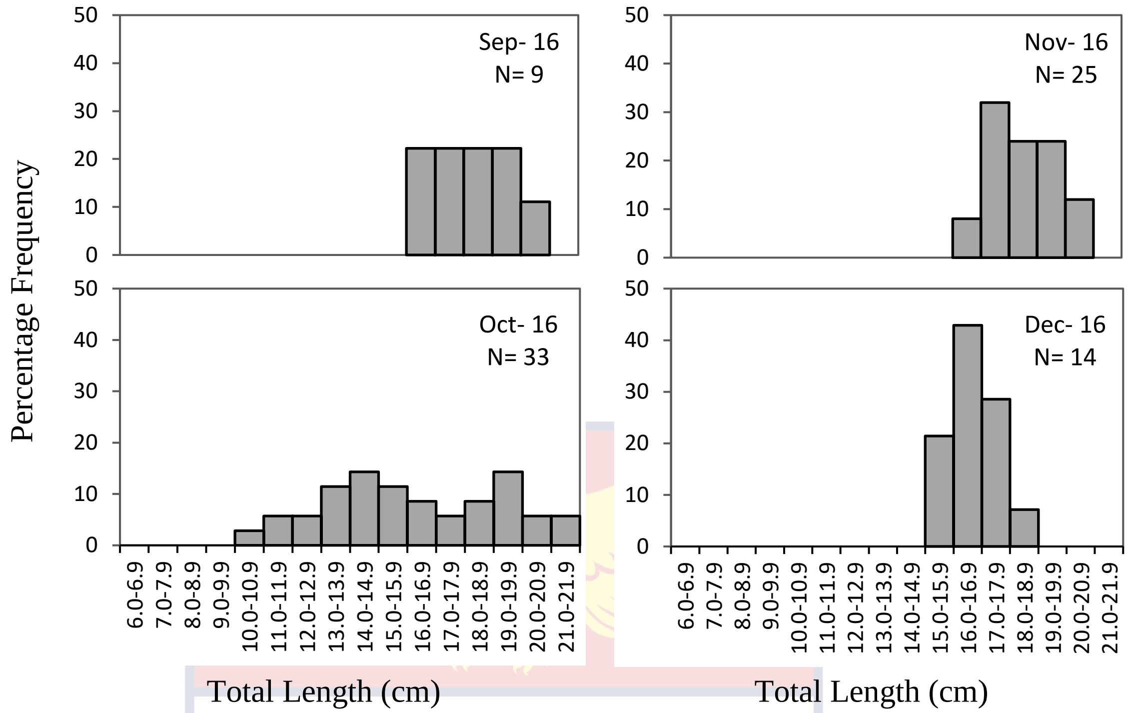


Figure 40 continued. Monthly length-frequency distribution for *Ilisha africana* caught in nets without LED.

Figure 41 shows the monthly length-frequency distribution of the *Ilisha africana* samples caught in nets with LED during the study. The distribution is unimodal with modal lengths ranging from 12.0-12.9 cm in April 2016 and 18.0-18.9 cm in February 2016. Again the shifts in modal length was irregular.

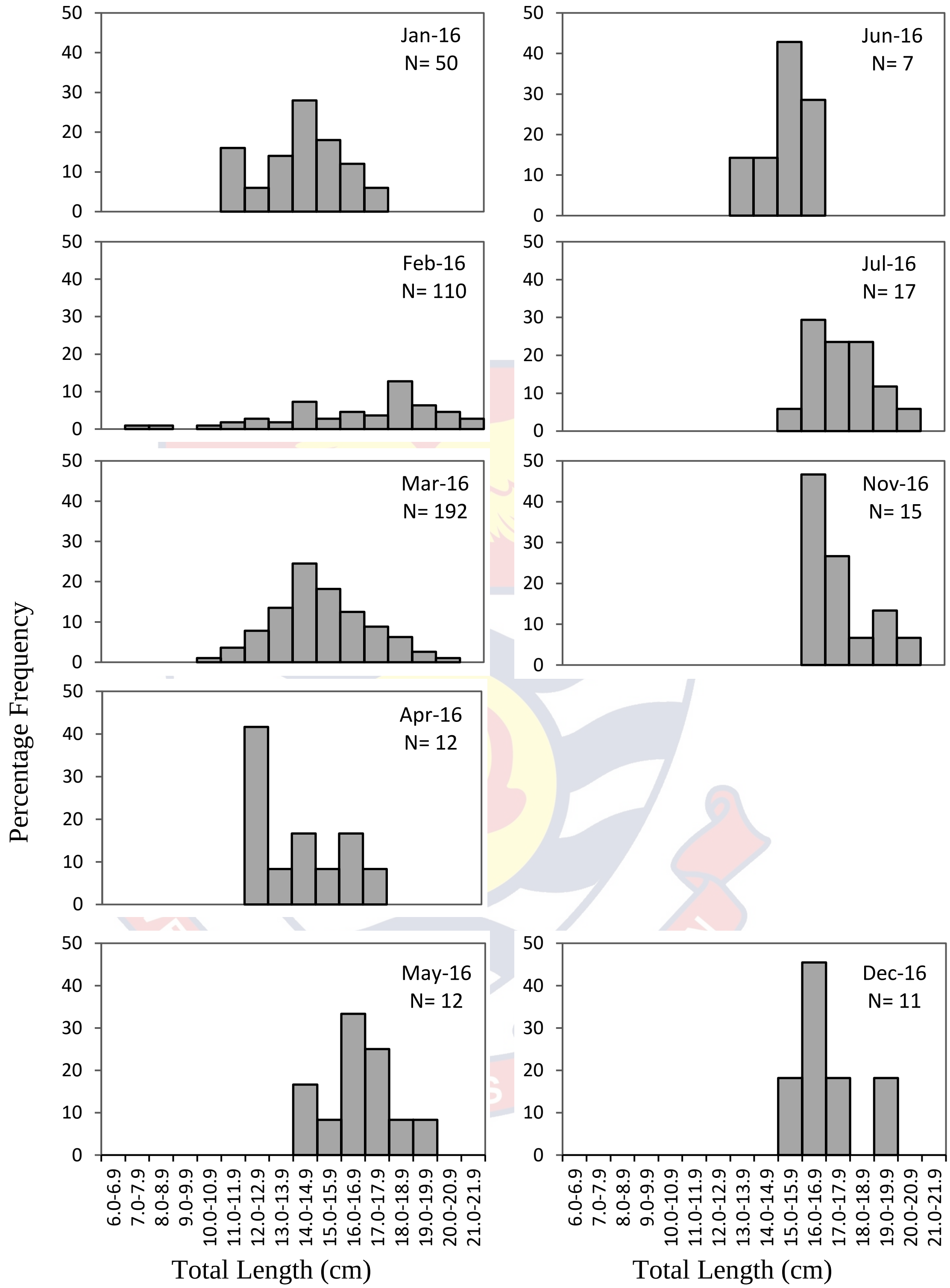


Figure 41. Monthly length-frequency distribution for *Ilisha africana* caught in nets with LED.

CHAPTER FOUR

DISCUSSION

The section discusses the results as related to the trends and variations in artisanal fish catch and species composition observed in this study, the factors that influence fish catch in the area, rate of sea turtle by-catch in fishing nets and the impact of light emitting diode (LED) on turtle and fish catch in artisanal fishery of the area.

Artisanal fishery of the study area

The increase in the number of artisanal fishermen and canoes in the study area by 13.0% and 27.5% respectively between 2001 and 2013 (see Appendix A) is in line with those made by Koranteng et al. (1987; 1992) who reported a general annual increasing trend in the number of canoes in the artisanal fishery in Ghana's coastal communities. Lazar et al. (2018) also reported that the fishing effort in the artisanal sector of the country has been increasing for over a decade, which is corroborated by this study. The findings of this study are however, contrary to that made by Quaatey et al. (1997) who reported a decrease in the number of canoes in the artisanal fishery. The general increase in the number of fishermen and canoes in the study area could be due to the increased population in the area resulting in more people going into the artisanal fishing industry. The Food and Agriculture Organization, FAO (2016b) reported that population growth in Africa has resulted in an increase in the number of people engaged in capture fishing.

Also, the population of Effutu, one of the districts in the study was reported to have increased by 24.4% between 2000 and 2010 (Ghana Statistical Service, 2014) representing a growth rate of 2.4% per annum. With each artisanal fisherman estimated to have between one and five wives (Koranteng et al., 1992), and 74% of the fishermen also having four or more children (FSSD, 2016), it is likely that the population growth in the study area is higher in the fishing communities than the non-fishing communities of the district. Over 73% of children belonging to fish processors and traders in the Central region are reported to have no level of education (FSSD, 2016). These children tend to join the trade of the parents as was reported during interviews in the communities, leading to an increase in the population of fishermen in the study area.

The higher number of registered (987) than unregistered (840) canoes was due to an informal agreement between the Fisheries Commission office in the area and the local distributors of pre-mix fuel whereby canoes that are not registered and embossed were not allowed to access pre-mix fuel. Majority of the canoes that still do not have license and embossment were those canoes that mainly use oars and sails during fishing.

The number of fish species and family reported in the present study area is higher than those reported by Okyere (2015) who sampled forty-seven fish species belonging to thirty-two families from the marine ecosystem at Anlo beach, in the Western Region of Ghana. The difference in number of species and families observed in the two studies could be attributed to the geographical differences and variabilities in environmental conditions as well as the different fishing methods used. Climatic and oceanographic conditions of the marine environment have been argued to influence the recruitment variability and early survival rates of many fish species in an area (Aebischer et al., 1990; Ware & Thomson, 2005). These changes in environmental conditions have great direct and indirect influence on the abundance, distribution, and productivity of fishery species (Stenseth et al., 2002; Perry et al., 2005). Okyere (2015) speculated that salinity was the principal physicochemical factor that dictated the variations in the fish community of the aquatic ecosystem in the Western Region of Ghana. Bruno et al. (2013) also reported temperature, wind speed, rainfall and salinity to be the influential factors on fish abundance and distribution patterns. Segbefia et al. (2013) has also recounted temperature and salinity as the main influential factors that determine abundance in Ghana's Volta River while Hossain, Das, Sarker and Rahaman (2012) also reported temperature and rainfall as the main controlling factor of fish abundance and distribution in the Meghna river estuary in Bangladesh. Work done by Chowdhury, Hossain, Das, and Barua (2010) found salinity and turbidity as the main parameters controlling the occurrence and distribution of fish in the Naaf Estuary in Bangladesh, while Nitrate concentration, depth, dissolved oxygen and temperature were found to be the most important influential factors of fish diversity in the Tagus estuary, Portugal (Gutie´rrez-Estrada, Vasconcelos & Costa, 2008).

The annual declining catch in the area could be attributed to the declining stocks of small pelagics which represent the bulk of the catch in artisanal fishery (Nunoo et al., 2014). This observed decline in small pelagic stocks have been reported by other authors as well. Lazar et al. (2018) recounted a rapid decline in the small pelagic landings between 2000 and 2016 and remarked that the small pelagic resources, particularly sardinellas, are on the verge of collapse.

Decline in landings of small pelagics in Ghana has been attributed to many factors. The FAO (2016a) and Lazar et al. (2018) attributed the drastic decline in the trend of fish catch mainly to overfishing and overcapacity of fishing fleets as well as the use of smaller mesh size in fishing. Alexander et al. (2017) attributed the decline in fishery resource of the study area to increased fishing efforts and the illegal use of light when night fishing.

Over-fishing causes changes in species composition and abundance of both targeted and non-targeted fish and causes an unpredictable change in marine ecosystems (Okyere, 2015).

The poor governance and open-access system of the fishery have been cited as another cause of overfishing in Ghana (Minta, 2003; Lazar, 2018). Improvement in the efficiency of fishing gears and technology has reduced search time and increased pressure on the fishery, leading to declining stock. Other contributing factors are poor enforcement of the regulatory frameworks and insufficient monitoring and surveillance of Ghana's coastal waters which have resulted in more vessels entering the fishery with the tendency of over-burdening the situation in the marine fishery sector (FAO, 2016).

Contrary to reported increases in fishing effort by canoes (Nunoo et al., 2014; Lazar et al., 2018), a decline in fishing efforts by number of days spent at sea (810,655 days in 2001 and 77,754 days in 2015) was recorded in the study area. This translated into a general increasing CPUE for the area from 2001 to 2015. The fewer days spent at sea by fishermen is mainly as a result of the low fish catch being experienced in the artisanal fishery of the area, as also observed by Lazar et al. (2018) in fishing communities around Tema. The lack (high cost and unavailability) of fishing inputs such as nets, outboard motors and pre-mix fuel, could also a contributing factor to the low number of fishing days recorded for fishermen in the study area.

Fluctuations in the catch of common fish species

The fish species recorded in the study area were dominantly small pelagics, namely the sardinellas (*Sardinella aurita* and *Sardinella maderensis*) which formed 35.7% of the total catch by weight, anchovy (*Engraulis encrasicolus*) constituting 34.2% and Atlantic little tuna (*Euthynnus alletteratus*) constituting 16.3% of the total catch landed between 2001 and 2015. Other species recorded low catches over the same period. Small pelagics such as round sardinella (*Sardinella aurita),* flat sardinella (*Sardinella maderensis*), anchovies (*Engraulis encrasicolus*), mackerel (*Scomber colias)* and other Clupeidae have been reported to be the dominant and most important pelagic fish species exploited in the Ghanaian coastal fisheries (Nunoo et al., 2014; Lazar et al., 2018).

Catches of sardinella, anchovy and Atlantic little tuna generally decreased over the years from 2001 till they reached their least catches in 2015. The declining catch of these small pelagics recorded in the study is similar to findings made by Nunoo et al. (2014) and Lazar et al. (2018). Nunoo et al. (2014), in reconstructing Ghana's fish catch reported the catches of sardinella to have experienced a drastic decline in the early 1970s and mid-1990s. Catches of anchovy were also reported to be experiencing continuous decline since the mid-1990s (Nunoo et al., 2014).

The highest catch of sardinella and Atlantic little tuna coincided with the lowest temperature of 22.0^{o}C in August. The high catches recorded for both sardinella and tuna in August could be as a result of temperature-induced upwelling in the coastal waters of the area, as supported by works done by Glantz (2002) and Bruno et al. (2013). Koranteng (1996) also asserted that the small pelagic fishes, such as sardines, anchovies and others, are the main stocks that form the backbone of Ghana's inshore artisanal fishery, and their abundance is strongly dependent on the intensity of the upwelling season. Upwelling is a major process that drives productivity in the marine waters of Ghana and Ivory Coast (Nunoo et al., 2014).

During upwelling event, higher taxa such as fishes take advantage of the peak plankton production and become abundant in the surface water (Quinn, 2005; Fiechter et al., 2015). While sea water temperature of 25°C is reported as the maximum threshold for upwelling in the Gulf of Guinea (Bakun, 1993), sea surface temperatures between 22°C and 19°C in Ghanaian waters reportedly coincided with higher upwelling intensity. The colder conditions reported in the study area in August (temperature decreased to 22^{o}C) likely enhanced the upwelling process, resulting in high catches of sardinella and tuna. The sardinella season is reported to begin with the fall in the sea surface temperatures when the sardinellas initiate their spawning migration (Nunoo et al., 2014).

Catches of sardinella and anchovy were again high in January from 2001 to 2015. This high catch recorded could be due to the minor upwelling which also occurs in the coastal waters of Ghana from January to April, with a weaker intensity (Okyere, 2015). Though the major upwelling was, in the past, considered to be more important than the minor upwelling, works done by Koranteng (1998) and Pezennec and Bard (1992) reported the minor upwelling to be as important as the major upwelling contributing to the recruitment of sardinella in the Ivorian and Ghanaian marine ecosystems.

The highest landing for Anchovy (*Engraulis encrasicolus*) was recorded in September. This observation was probably as a result of the fact that temperatures were still below 25^{o}C which could have triggered mixing of bottom nutrient-rich water with surface waters (Bakun, 1978; Minta, 2003). The temperature of 24.6±1.6^{o}C recorded in September could therefore mean that the upwelling event was still occurring hence high water productivity which influenced the abundance of anchovy in the system. This is confirmed by Minta (2003) who reported the major upwelling to last for about three months, starting late June or early July to late September or early October. Similarly, Nunoo et al. (2014) reported the major upwelling to occur from late June or early July to September or early October, during which the sea surface temperature drops from 25°C to 17°C or below.

Incidence of sea turtles in the artisanal fishery

According to the fishermen, Olive ridley, leatherback and green turtles were the species most sighted and captured in fishing nets (Figure 19). The loggerhead and hawksbill were rarely captured. The relatively high occurrence of these three species (32 Olive ridley, 18 leatherback and 21 green turtles) reported by fishermen could be due to the fact that these are the species that nest on our beaches while the loggerhead and hawksbill only utilise the waters of Ghana for feeding and occasionally nesting (Beyer et al., 2002; Allman & Armah, 2008; Agyekumhene, 2009; Agyekumhene et al., 2010; Alexander et al., 2017).

Capture of sea turtles in fishing nets was accidental, as reported by all the interviewees. Other similar studies have also reported fishermen acknowledging that the capture of sea turtle in their fishing nets was accidental (Agyekumhene et al., 2014; Alexander, et al., 2017). Fishermen have on many occasion 'beat' their canoes with the paddle and oars upon sighting a turtle swim towards their nets, to create noise that causes the turtles to dive deeper and away from the fishing nets. Such noise from fishermen could probably mimic those from acoustic pingers by emitting sounds to scare the turtles. The acoustic pinger is a device that prevents marine mega fauna such as sea turtles, sharks and dolphins from interacting with, and getting caught in fishing nets (Barkan, 2010).

Fishermen do not target sea turtle during fishing operations for many reasons but they mainly avoid catching sea turtle to protect their nets. The capture and entanglement of sea turtles in fishing gillnets destroy the net and allow the fish to escape causing financial loss to the fisherman (Agyekumhene et al., 2014; Alexander et al., 2017). Some fishermen also avoid turtle in their nets for reasons such as avoiding punishment from the law, as also reported by Agyekumhene et al. (2014) and Alexander et al. (2017). In Ghana, the Wildlife Conservation Regulation of 1999 (L.I. 680) prohibits hunting, capture and killing of sea turtles. Fishermen found in breach of this regulation are punished by a fine or a term of imprisonment, and this deters most fishermen from harming sea turtles in fishing communities in Ghana (Agyekumhene et al., 2014; Alexander et al., 2017). The role of sea turtles in improving fish stock and health of the ocean, by enhancing seagrass communities, makes them a non-target species for fishermen. Through the routine conservation education in and around the study area by the Wildlife Division of Forestry Commission and Fisheries Commission, fishermen are now aware and understand the role sea turtles play in helping sustain their livelihood and recognize that it is beneficial to have sea turtles in the oceans. The work done by Agyekumhene (2009) in the Greater Accra Region, as well as Agyekumhene et al. (2014) in the Central Region of Ghana, revealed and recommended that conservation education is key and important in conserving natural resource in local communities.

Another reason why sea turtles are not target species in fishing is probably the existence of community-based systems constituted by the Ghana Turtle Conservation Project (GTCP), a local non-governmental organization that operates in the study area. GTCP has instituted several interventions in the area that ensure that local communities are actively involved in the conservation of the sea turtles. The organization undertakes research, education and ecotourism using local community members as tour guides. Community-based initiatives have been demonstrated to be a powerful tool for effective conservation (Peckham & Maldonado-Diaz, 2012). These initiatives improve communication and knowledge sharing among conservationists and resource users such as fishers, and create an environment where both groups actively contribute to the development and implementation of mitigation strategies. There is improved understanding among fishermen concerning the rational underlying the management regulations and mitigation measures. Local knowledge and community needs are also incorporated into developing sustainable management solutions. In communities where top-down management approach and enforcement is difficult as a result of inadequate resources, such community-based systems have proven to be successful since they create a sense of ownership in the process and ensure community buy-in which makes compliance and sustainability successful (Campbell & Cornwell, 2008; Alfaro-Shigueto et al., 2010; Peckham & Maldonado-Diaz, 2012; Piovano et al., 2012).

To some of the fishermen, sea turtles have cultural values and have to be protected for that reason. Turtles were reported to protect fishermen at sea during events when canoes capsize. Agyekumhene et al. (2014), Alexander et al (2012, 2017), and Allman and Agyekumhene (2017) reported the existence of an oral history in some fishing communities along Ghana's coast where fishermen recount their ancestors whose canoes wrecked at sea but were rescued by sea turtles which carried them on their backs to shore. Another folklore is how sea turtles helped the Dangme people of the Greater Accra Region to defeat the Ashanti warriors in a battle by forming a bridge to allow the Dangme people cross the

Volta River while retreating from the Ashanti warriors (Allman & Agyekumhene, 2017). For these reasons, members of the clan protect sea turtles and do not harm them. The capture of a turtle by a fishing net belonging to a member of these clans was considered a taboo for which the punishment was poor fish catch from the gods. Any individual from these clans who harms a turtle is also punished with skin rashes by the gods. In times past, a turtle that died and was washed to the shore was given a burial after a ritual has been performed. These cultural restrictions afforded turtles protection from fishermen in the study communities.

According to Campbell (2003), conservation efforts around sea turtles and coastal habitats have aimed to include communities by acknowledging the traditions and beliefs that link them and the turtles. Fishermen who uphold the belief and taboos willingly release turtles caught at sea by their fishing nets without intervention from the statutory enforcement body. According to these fishermen, their traditional belief was the main reason for releasing turtles caught in their nets though they were aware of the national regulations that forbid harming turtles. A similar finding was reported by Alexander et al. (2017) as well as Westerman and Gardner (2013) that in communities where both national and traditional regulations (taboos) existed, the traditional regulations afforded the most protection to sea turtles.

Fishermen however reported the diminishing effect of taboos in the community due to several reasons such as religion (Christianity), intermarriage with people from other tribes who do not share the belief, and migration of fishermen from other communities into the area. A similar finding was made by Allman and Agyekumhene (2017) in other coastal fishing communities in Ghana where they found that taboos against killing of sea turtles is waning. Similarly, Etiendem et al. (as cited in Alexander et al. 2017) reported that the traditional protection offered by taboos against the hunting of Cross River gorilla (*Gorilla gorilla diehli)* in Cameroon is eroding and disappearing over time. Likewise, Anoliefo, Isikhuemhen, and Ochije (2003) found that urbanization and the adoption of Christianity had adverse effects on the adherence to taboos that protected sacred groves in certain communities in Nigeria. Again in Nigeria, Jimoh et al. (2012) found several eroding social taboos which support the assertion that biodiversity conservation are under attack from the effects of colonization.

Captured sea turtles, when alive, are eaten as food, sold for money or released back to sea. Fishermen however, do not consider selling or eating turtles for food as a priority hence the relatively fewer number of fishermen reporting that they sell turtles for money or eat them. The fishermen who sold sea turtles did so to raise money to defray some of the cost of repairing their fishing nets (Agyekumhene et al., 2010, 2014). With most families in Ghana's coastal fishing communities living on an annual income below the national average of $210.38 USD (Ghana Statistical Service, 2008), such damage to fishing nets can be a huge source of financial burden to a fisherman. Turtles are therefore sold to compensate for the loss. Another reason turtles were sold by fishermen was the declining fish stocks which has greatly increased the pressure on turtle meat as an alternative income and food source.

With each turtle entanglement, the canoe risks capsizing. This is usually the case with leatherback sea turtles which, because of its huge size, is able to shake the canoes in an attempt to free itself from the net. For this reason, there is a notion among fishermen that sea turtles can cause death and should not be protected, as mentioned by respondent during the interviews. The possibility of drowning from capsized canoe makes most fishermen fear the presence of turtles in their nets. This disturbance of fishing nets and rocking of canoe by turtles caught have however helped to notice captured turtles in a timely manner for their release before the turtle drowned.

Whereas most fishermen claim they release live turtles into the sea, dead turtles are mostly eaten or sold with few dead turtles being discarded at sea. Fishermen who ate dead turtles gave the reason as dead turtles not being able to perform any function again in the ocean so releasing them was a waste. For those fishermen that released the dead turtle into the sea, they did so simply because they did not know the cause of death. These fishermen recounted seeing turtle with 'boils' on their bodies which indicated that the turtles were infected with diseases hence unsafe to eat.

Green turtles have been reported to be affected by Fibriopapiloma (FP) tumours (see Appendix G) manifested on the soft body parts as lumps which may cause them to not feed well and hence die as a result (FAO, 2010; Work & Balaz, 2013; Hama & Fretey, 2014). FP tumours are forms of cancer which almost exclusively affects green turtles and, to a lesser extent, other species such as olive ridleys and loggerheads (Duffy et al., 2018). The tumour incapacitates sea turtles through a variety of other mechanisms. Severe form of FP tumours can suppress the immune systems of the turtle leaving it susceptible to other disease with low likelihood of survival (Work, Rameyer, Balazs et al., 2001).

Another factor that discouraged fishermen in the area from selling sea turtle was the low revenue from the sale of sea turtles. The selling price of sea turtles has been on the decline over the years and it is unable to fully compensate for the damage to their fishing gear and loss of fish. With the frequent education and law enforcement by the Ghana

Wildlife Division in the area, many turtle buyers have also abandoned the trade further reducing the chances of getting a good price for a turtle. In spite of the destruction sea turtles cause to the nets of fishermen and the economic loss associated, e.g. loss of fish and nets, fishermen still perceive sea turtles as important.

Sea turtle capture rate in fishing nets

The three species of sea turtles (leatherback, green and olive ridley) encountered in this study is similar to what has been reported by other authors in other areas along the coast of Ghana (Armah et al., 1997, 1998; Amiteye, 2000; Beyer et al., 2002; Allman & Armah, 2008; Agyekumhene, 2009; Armah et al., 2010; Agyekumhene et al., 2014; Alexander et al., 2017). The relatively higher numbers of olive ridley encountered in this study (Figures 23, 25 and 27) suggest that they are the commonest species in Ghana's coastal waters. This finding corroborates those of Armah et al. (1997), Amiteye (2000) and Agyekumhene (2009).

All species combined, the mean capture rate of four turtles per canoe per year recorded by the 15 canoes in the January to December 2015 survey was similar to numbers reported by fishermen in the interviews in which 45% claimed to catch up to 5 turtles in a year. Although the annual sea turtle by-catch per fisherman appears to be low, the cumulative impact of these captures in the entire fishery of the area could be huge since the gillnet fishery accounted for about 37.7% of the fishing methods in the area and also along the coast of Ghana (FSSD, 2016). A similar finding was made by the National Research Council (as cited in Agyekumhene, 2009) that the individual fishermen in the Gulf of Mexico catch few sea turtles in a year but the magnitude of the fishery makes the overall impact of the capture significant. With over 568 gillnets used in the area (FSSD, 2016), the capture of sea turtle is estimated to be over 150 turtles per year, and this could have huge impact on the population of the species. Also with over 11,000 gill nets operated along the coast of Ghana (FSSD, 2016), over 2,933 sea turtles are estimated to be captured in Ghana's gill net fishery per year.

All 64 turtles captured were females. The absence of male turtles in gillnets during 2015 is probably due to the fact that only females swim closer to the shore and tend to aggregate in near-shore areas, especially during inter-nesting periods. Female turtles carrying eggs are reported to usually occupy inshore waters during the inter-nesting season and only migrate into oceanic waters outside of this period (Alvarro & Murphy, 1999). In sea turtles, both courtship and mating occur in offshore breeding grounds. Soon after mating, the male leaves the breeding grounds and return to their foraging areas, while the female approaches the nesting beaches to find a suitable nesting spot where they emerge from the sea and crawls to the back beach to lay their eggs (Limpus, 1993; Allard et al., 1994).

Olive ridleys have been reported to nest year round in Ghana (Armah et al., 1997; Amiteye, 2000; Agyekumhene, 2009; Agyekumhene et al., 2014) which could be the reason for their capture in all the months, except May and April, while leatherback and green turtles were captured primarily from October to December. The higher number of sea turtle captures in November and December could be due to the fact that in Ghana, nesting by all the three species are reported to peak in November-December (Armah et al., 1997; Amiteye, 2000; Beyer et al., 2002; Agyekumhene, 2009). Sea turtles are known to mostly spend their time in the near-shore areas during inter-nesting migrations and this could make them vulnerable to capture by the fishermen hence the high number of turtles captured during the major nesting months when inter-nesting migration occurs most. The findings made from this study on species of turtle present in the area, and the months in which they are mostly captured, were similar for both the field observations and the responses given by the fishermen during interviews.

The smaller sizes of olive ridleys captured in 2015 (52.6 cm to 71.0 cm) than in 2016 (62.0 cm to 78.0) could be the result of nesting of different populations with the varied size at maturity (Hirth, 1971; Hirth, 1980; Witzell, 1983; Limpus, Fleay, & Baker, 1984; Dodd, 1988). The mean carapace lengths recorded for olive ridley sea turtles captured in gillnets (64.4±4.2 cm in 2015 and 68.6±3.0 cm in 2016) were respectively lower and higher than mean length of 66.6±8.3 cm recorded by Agyekumhene (2009) for olive ridley turtles nesting on beaches in Ghana. The study did not however, find a significant difference between the body sizes of the turtles captured in gillnets at offshore areas and the turtles nesting on Ghana's beaches ($t=-4.77$, $p>0.05$). According to Limpus (1992), sexual maturity is positively correlated with carapace size, whereby sexually matured females tend to have bigger carapace size than immature females. The absence of a significant difference between carapace sizes of nesting turtles and captured turtles could mean that the turtles caught in gillnets were within the reported size range of 60.6 to 73.0 cm at reproductive maturity, and were matured females that may possibly be carrying eggs. Sea turtle by-catch in fishery therefore has the potential to reduce future recruitment into the population. Limpus (1992) has also reported green sea turtles to reach a sexual maturity at body length of between 69 and 79 cm which is similar to the 57 to 83 cm size recorded by this study, suggesting that the green turtles captured were within the size of reproductive maturity.

Sea turtle capture in experimental nets

No green turtle was captured in any of the LED nets. The absence of green turtles in the LED nets could be due to the relatively lower numbers of green turtles encountered in Ghanaian coastal waters (Amiteye, 2002; Agyekumhene, 2009; Beyer et al., 2002). Even though the non-LED nets caught green turtles, the numbers were relatively fewer than the other species affirming the observation that green turtles have the least abundance among the species that currently nest and forage in Ghana, as also reported by Amiteye (2000). The absence of green turtles in the nets with LED could also be attributed to the species being more reactive to the LED light than leatherback and olive ridley. Differences in spectral sensitivities of different species of sea turtles have been reported (Southwood et al., 2008; Crognale et al., 2008).

The olive ridley was the dominant species trapped in both the non-LED and LED nets which is similar to findings made by other studies on nesting ecology of turtles along beaches in Ghana, which reported that of all the sea turtles species in Ghana, the olive ridley is the most abundant (Armah et al., 1997; Amiteye, 2000; Beyer et al., 2002; Agyekumhene, 2009; Agyekumhene et al., 2010, 2014). The number of turtles caught in the experimental net in 2016 was lower than the numbers caught in 2015 and this could be due to the fact that different individuals and populations nesting during different years. While male turtles may mate every year, female turtles do not reproduce every year (Hirth, 1971, 1980; Limpus et al., 1984). The number of years taken for female turtles to nest again after a successful nesting season varies among the species and it is dependent on the quality and quantity of food available for energy accumulation, deposition, reorganisation and utilisation (Bjorndal, 1980b).

Most of the turtles captured in nets with and without LED occurred between October and December with the peak capture occurring in November 2016. This is probably due to the fact that turtles nest on Ghana's beaches primarily between October and November (Armah et al., 1997; Amiteye, 2000; Beyer et al., 2002; Agyekumhene, 2009; Agyekumhene et al., 2010, 2014) and mostly migrate through the coastal waters during this period.

The CPUE for sea turtle capture was significantly lower ($t=3.65$, $p<0.05$) in nets using the LED lights (4.6±1.2 turtle/100 m net/12 hrs) than in the nets without LED lights (6.5±2.1 turtle/100 m net/12 hrs). This supports the observation by other authors that the use of green LED light is effective at reducing sea turtle capture in gillnet fishing. A similar study conducted in Baja California, Mexico by Wang et al. (2010) also revealed that green LED lights reduced sea turtle capture in gill nets by 39.7%. The use of by-catch reduction technologies has been shown by many authors and researchers to be effective at reducing sea turtle capture in most fisheries and it is becoming a growing method of interest (Melvin, Parrish & Conquest, 1999; Sato, Ochi & Yokawa, 2012).

Fish species composition and abundance in the experimental nets

The number of species (36) and families (16) recorded in the experimental nets is less than those reported by other authors such as Okyere (2015). The difference in sampling location, period, duration and the effort between the two studies could account for the difference in species observed for the marine system in the two areas. The difference could also be ascribed to the geographical variabilities in environmental conditions such as temperature, salinity, rainfall, turbidity, nitrate, water depth and dissolve oxygen (Gutie´rrez-Estrada et al., 2008; Chowdhury et al., 2010; Hossain et al., 2012; Segbefia et al., 2013). Bruno et al. (2013) attributes the structure and fish assemblage distribution to factors such as food availability, dissolved oxygen and turbidity or biological interactions (group behavior, competition and predation).

Five fish species were dominant (*Ethmalosa fimbriata* > *Chloroscombrus chrysurus* > *Sardinella maderensis* > *Lichia amia* > *Ilisha Africana*) in both the non-LED and LED nets. These species are the most common in Ghanaian artisanal marine fishery as also reported by other authors. Okyere (2015) reported the bonga shad (*Ethmalosa fimbriata)* as one of the commonly occurring marine fish species which was similar to the findings made in this study. Majority of the species and families were similar between the non-LED nets and LED nets. The difference in diversity and evenness of fish catch between non-LED and LED nets was also low.

The absence of a significant difference in species composition of fish caught by the non-LED and LED nets could also imply that the LED light had no influence on fish composition though the LED light appeared to influence the behaviour of turtles by causing the turtles to avoid the fishing gear. This is supported by the studies of Wang et al. (2010, 2013) which concluded that using LED lights on gillnets to reduce sea turtle capture did not have any impact on the target fish catch. The ability of the LED to reduce sea turtle capture and not affect target fish was reported by Crognale et al. (2008) who suggested that though different species may have common photopigments, the visual capacities may differ as a result of differences in retinal photoreceptor complements and associated spectral sensitivity, as observed in both marine and terrestrial species (Jacobs, Neitz, & Krogh, 1996; Fritsches et al., 2003a; Levenson et al., 2004). The LED light may be warning only the turtles of the presence of the net, thereby deterring them from entering, but the visual capacity of the fish may not allow them to perceive the nets hence get captured. Although sea turtles and fish occupy the same marine habitat, their behaviours are different enough to produce responses that vary in their sensory perceptions. There are differences in the visual sensitivity between and within these species (Loew et al., 2002; Fritsches et al., 2003a; Southwood et al., 2008).

There was no significant difference ($t=2.14$, $p>0.05$) between the total weight of fish caught by the non-LED and LED nets over the study period. This finding is in line with those of Wang et al. (2010, 2013) who found out that illuminating fishing nets with LED lights did not result in a significant decrease in the volume of target species. This suggests that the LED light does not influence fish catch and therefore does not function as a fish aggregating device.

The similarity in the modal class for the dominant fish species caught (Table 10) in the area could be further indicative that the LED light did not influence the sizes of fish catch. The use of light has been reported as a major threat that results in fishery declines in most areas bringing several losses to fishermen (Nunoo & Berchie, 2013; Alexander et al., 2017).

The mean value per unit effort (VPUE) of fish caught in the experimental net was higher in the non-LED nets than the LED nets. There was however no significant difference ($t=0.74$, $P>0.05$) between the VPUE of fish caught by the two groups of nets. This further indicates the LED may not be aggregating fish hence not performing light fishing. Wang et al (2013), in a similar study, found no significant difference in the VPUE of gears using LED light and gear with no LED lights and concluded that fitting LED lights on fishing nets does not affect the market value of the target fish.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The study revealed that the fishing effort in the study area was increasing by 27.5% while the number of landing sites remained the same between 2001 and 2013. The increasing fishing effort is as a result of population increase in the fishing communities. Artisanal fishermen in the area operated different fishing gear from wooden canoe powered by 5 hp to 40 hp outboard motors or sail. The set net was the dominant gear type in the area.

A total of 74 fish species belonging to 37 families were sampled from artisanal fishery of the study area from 2001 to 2015. The dominant fish species recorded in the artisanal fishery of the study area between 2001 and 2015 were the small pelagic types.

There was a downward trend in catches of small pelagics by the artisanal fisheries of the area as a result of overfishing, overcapacity and increased number of fishermen and fishing canoes in the area. Catches of sardinellas, anchovy and Atlantic little tuna formed the bulk of the artisanal produce. Most fishermen did not go to sea as often as they used to due to the low and sometimes zero catch, which has resulted in reduced number of fishing days in the area, from 810,655 days in 2001 to 77,754 days in 2015.

The catches of turtles in non-LED and LED nets were similar. Although five species of sea turtles utilize the coastal waters of the study area for foraging habitat, only three (leatherback *Dermochelys coriacea*, green *Chelonia mydas* and Olive ridley *Lepidochelys olivacea*) were captured in fishing nets during the study. Of the total captures, the Olive ridley (80.0%) was the most dominant in term of capture rate in fishing nets followed by the Leatherback (9.0%) and then Green turtles (11.0%).

Capture of sea turtles occurred in the area at a rate of 4 turtles per canoe per year. Though Olive ridley was caught in gillnets year round, sea turtle capture in fishing nets occurred mainly from October to March peaking in November-December. This number and their body size caught in fishing nets varied between years as a result of the different populations that nest during the different years.

Sea turtle capture was low in fishing nets using LED lights (18 turtles) but high in nets without the LED lights (67 turtles). CPUE for sea turtle capture was significantly lower in nets using the LED lights than in nets without LED lights. Using the LED lights on gillnets for fishing therefore resulted in a reduction in sea turtle by-catch. No green turtles were caught in the nest using LED lights.

The use of LED light was not found to influence the total quantity of fish catch in gillnets. Species and families of fish caught in gillnets were similar between the non-LED nets and LED nets.

The use of LED light did not significantly affect the value of fish caught in the two groups of gillnets. The VPUE of fish catch were similar between the non-LED nets and LED nets.

Sea turtle capture in gill nets during fishing operation is considered to be a by-catch. Both national and traditional (taboos) regulations were found to be in place to protect sea turtle from harm. Fishermen reported the traditional regulation to afford turtle more protection than the national regulation

The study underscored the need to reduce sea turtle by-catch in fishery and avoid economic loss to fishermen. Any device that reduces sea turtle by-catch should be easy to deploy and must not present huge modification to fishing gears such that it interferes with deployment and retrieval of fishing nets. The device should not impact the quantity of fish catch, as reported by fishermen.

This study establishes that illuminating gillnets with LED light reduces sea turtle capture rates and has no apparent effect on total catch rates and value of the target fish. Light emitting diode may be potentially useful as a by-catch reduction device in coastal artisanal fishery.

Recommendations

A sensitisation and awareness programme should be intensified by the Fisheries Commission to educate the fishermen on good fishing practices, national fisheries laws and district and local by-laws. The existing punishments for non-compliance with these regulation should also be highlighted in the fishing communities. The use of small mesh size and light for fishing are some harmful fishing practices that the education program should target since these were identified as major causes of the declining fish stocks.

The fisheries laws of Ghana, as well as the by-laws set by the Effutu Municipal Assembly for responsible fishing in the area should be implemented and enforced to prevent illegal fishing activities in the area and help in the management of the fishery.

There is the need to have sub-committees on fisheries at the various Metropolitan, Municipal and District Assemblies (MMDAs) where fishing is a major economic activity.

This will ensure that issues relating to fishing are given enough attention and resources for challenges to be addressed in a timely and effective manner.

Fishing effort should be gradually reduced to help stabilise the increasing pressure on the fishery. This could be through several means such as through instituting fishing quota for artisanal fishers, specifying fishing days for the canoes, and each canoe reducing the net and canoe sizes for a period. The close season implemented in 2019 should also be sustained to help reduce fishing pressure.

The study endorses income-generating alternative livelihoods to be introduced in the area. These will provide other sources of income aside fishing and help reduce the pressure on the fishery by reducing the efforts.

The marine and coastal environment should be conserved and the primary obligations should be on coastal communities to adopt proper environmental management and conservation measures to ensure that fishery resources are maintained and not endangered by pollution. The measure should address sanitation issues in the area such as improper dumping of waste, especially plastics, in the sea, at the beach, in the lagoon, and river bodies, and open defecation. Proper environmental stewardship could help address the issue.

A taskforce should be formed to ensure that fishermen do not land marine megafauna including sea turtles that are protected by the existing national laws. This will ensure that marine biodiversity is not threatened by fishing operations.

The Fisheries Scientific Survey Division of the Fisheries Commission should include comprehensive sea turtle by-catch information gathering in their routine field data collections. This should be stored in a repository to afford easy access of annual by-catch rate in Ghana's fishery, and allow for comparison between year, locations and fisheries.

Enforcement of traditional laws should be side by side with the national laws. The Wildlife Division of the Forestry Commission and Fisheries Commission of Ghana should amend their respective regulations to include the use of LED lights on fishing gears, especially the gillnets and driftnets, as a requirement to reduce sea turtle by-catch. The regulation should be enforced to ensure compliance to make the maximum impact.

The Fisheries Commission should have in its laws a clause that requires a turtle caught in all kind of fishing gears to be released by fishermen. Currently, the only law existing to protect sea turtles in fishing operations is the Fisheries Regulation 2010, LI 1968, which requires turtles captured in shrimp nets to be released. By interpretation, other fishing nets are not mandated to release turtles captured during their operations.

The Fisheries Commission should work with the Ghana Ports and Habour Authority (GPHA) to ban the importation of fishing nets with unapproved mesh size. The Commission should also ban the importation of monofilament nets. To make this effective, the Fisheries Commission should put measures in place to ensure compliance such as making available and affordable to fishermen the right fishing gears.

Further behavioural studies of turtles are recommended to explore the exact function of the LED to help improve the efficiency of the device. It is recommended to determine whether turtles are avoiding the LEDs as a device, or whether the light rays from the LED device help the turtles see the fishing nets better.

Further studies are recommended into the impact of environmental condition on the efficiency of the LED lights.

Future studies on the sea turtle taboo in Ghana should include analysis of adherence to it and any pressures that may drive its weakening. Further study of the continuity of the taboo and how those with current knowledge and adherence pass this on to the next generation, is also necessary. This is because of the realization from the study that taboos are gradually losing their respect, adoption and adherence in coastal communities.

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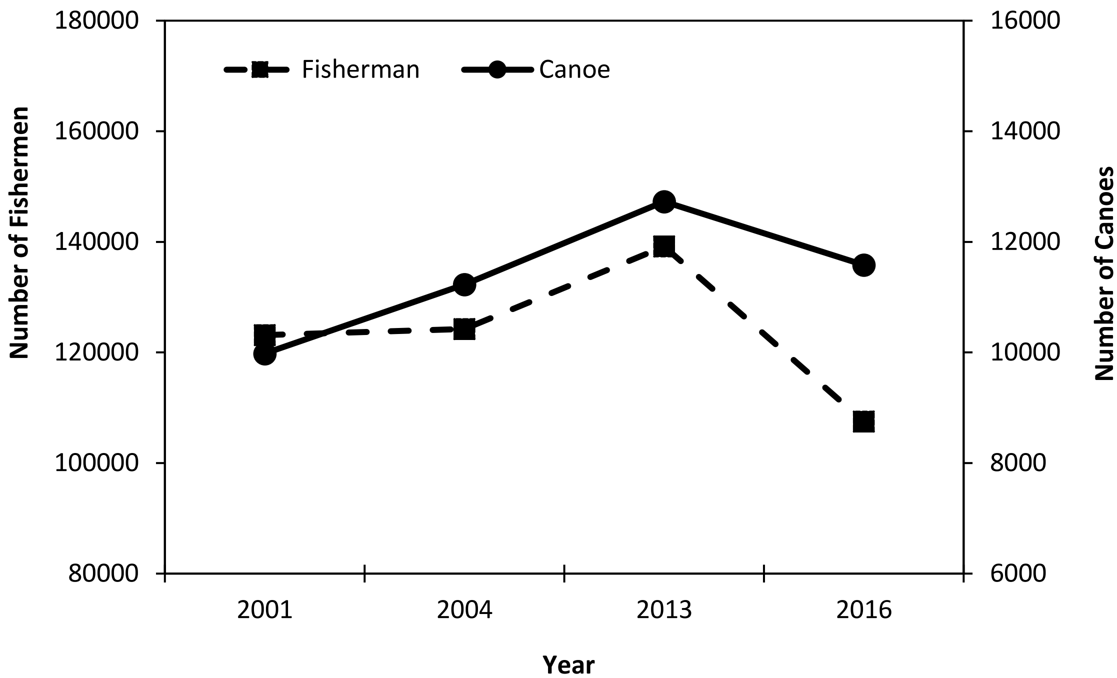
APPENDICES

Appendix A. Trends in number of fishermen and canoe in the artisanal fishery (Source: FSSD, 2016).



Appendix B. **Table of sea turtle species reported in Ghana's coastal waters and their international and national conversation status (IUCN- International Union for the Conservation of Nature; WCR- Wildlife Conservation Regulations of Ghana).**

SPECIES		CONSERVATION STATUS	
English Name	**Scientific Name**	**IUCN**	**WCR**
Leatherback	*Dermochelys coriacea*	Vulnerable	Completely Protected
Green turtle	*Chelonia mydas*	Endangered	Completely Protected
Olive ridley	*Lepidochelys olivacea*	Vulnerable	Completely Protected
Loggerhead	*Caretta caretta*	Vulnerable	Completely Protected
Hawksbill	*Eretmochelys imbricata*	Critically Endangered	Completely Protected

Definitions for conservation status

IUCN status:

Vulnerable (VU) - Species is likely to become endangered unless the circumstances that are threatening its survival and reproduction improve.

Endangered (EN) – Species has a very high risk of extinction in the wild.

Critically Endangered (CR) - species has an extremely high risk of extinction in the wild.

Wildlife Conservation Regulation

Completely Protected (CP) – Species has very low population which threatens its survival in the country.

Appendix C. GPS Coordinates for some fishing locations (in decimal degrees) of the two groups of fishing nets

LED nets		Non-LED nets	
Latitude	Longitude	Latitude	Longitude
5.30622	-0.65236	5.30634	-0.66131
5.30616	-0.65247	5.30762	-0.65272
5.30533	-0.65825	5.30764	-0.65224
5.30509	-0.65807	5.30771	-0.65215
5.30586	-0.66041	5.30775	-0.65197
5.30695	-0.66338	5.30961	-0.65123
5.30734	-0.66478	5.29715	-0.64572
5.30781	-0.66604	5.30519	-0.66433
5.30777	-0.65188	5.30730	-0.67018
5.30774	-0.65024	5.30960	-0.67615
5.30700	-0.6512	5.30960	-0.63709
5.29766	-0.64705	5.30960	-0.63687
5.30033	-0.65247		
5.30960	-0.67812		
5.30960	-0.63742		
5.30960	-0.63731		

Appendix D. Size range of fish species from net without LED (N- Number of fish; TL- Total Length; BW- body weight)

Family / Species	N	TL (cm)		BW (g)		Smallest Matured TL (cm)	% Matured (with ripe gonads)
		Min	Max	Min	Max		
Acanthuridae							
Acanthurus monroviae	1	11	-	24	-	-	-
Carangidae							
Caranx crysos	1	16	-	54		-	-
Caranx hippos	11	8	15	9	50	8	9
Chloroscombrus chrysurus	1981	4	20	1	68	10	6
Elagatis bipinnulata	4	11	17	11	29	11	25
Lichia amia	410	11	26	6	151	-	-
Selene dorsalis	17	9	14	14	49	-	-
Uraspis secunda	1	11	-	19	-	-	-
Clupeidae							
Ethmalosa fimbriata	5723	6	23	14	98	14	11
Ilisha africana	256	10	21	3	88	13	29
Sardinella aurita	311	11	19	16	60	14	20
Sardinella maderensis	332	10	24	19	114	17	6
Cynoglossidae							
Cynoglossus senegalensis	1	18	-	28		-	-
Drepaneidae							
Drepane africana	8	10	13	2	66	-	211
Elopidae							
Elops lacerta	4	24	33	66	211	-	-
Exocoetidae							
Fodiator acutus	14	12	14	10	23	-	-

Family / Species	N	TL (cm)		BW (g)		Smallest Matured TL (cm)	% Matured (with ripe gonads)
		Min	Max	Min	Max		
Haemulidae							
Brachydeuterus auritus	185	9	16	7	78	10	45
Pomadasys jubelini	26	6	22	4	148	-	-
Lutjanidae							
Apsilus fuscus	18	9	13	7	30	9	33
Mullidae							
Pseudupeneus prayensis	1	11	-	16	-	-	-
Polynemidae							
Galeoides decadactylus	222	11	24	20	155	-	-
Pentanemus quinquarius	1	14	-	24	-	-	-
Polydactylus quadrifilis	57	12	24	18	144	15	2
Sciaenidae							
Pseudotolithus typus	3	16	17	46	50	-	-
Pseudotolithus senegallus	2	20	20	64	67	-	-
Pseudotolithus senegalensis	12	12	24	26	188	13	17
Pteroscion peli	38	10	16	13	54	12	16
Scombridae							
Orcynopsis unicolor	40	13	26	13	112	-	-
Scomberomorus tritor	35	2	25	20	98	-	-
Sphyraenidae							
Sphyraena sphyraena	80	16	31	23	160	-	-
Tetraodontidae							
Lagocephalus lagocephalus	1	18	-	102	-	-	-

Appendix E. Size range of fish species from LED nets (N- Number of fish; TL- Total Length; BW- body weight)

Family / Species	N	TL (cm)		BW (cm)		Smallest Matured TL (cm)	% Matured (with ripe gonads)
		Min	Max	Min	Max		
Acanthuridae							
Acanthurus monroviae	1	17	-	17	-	-	-
Balistidae							
Balistes punctatus	1	14	-	67	-	-	-
Carangidae							
Alectis alexandrina	1	12	-	48	-	-	-
Caranx crysos	2	13	13	16	23	-	-
Caranx hippos	25	9	28	15	53	-	-
Chloroscombrus chrysurus	1931	6	20	2	70	-	7
Elagatis bipinnulata	2	14	22	31	70	-	-
Lichia amia	541	9	24	7	88	14	1
Selene dorsalis	52	6	14	3	37	-	-
Trachurus trachurus	2	6	22	23	80	-	-
Clupeidae							
Ethmalosa fimbriata	4952	8	22	11	99	13	12
Ilisha africana	442	10	20	7	79	10	42
Sardinella aurita	226	12	21	20	97	14	11
Sardinella maderensis	551	10	24	12	118	19	2
Elopidae							
Elops crysos	3	9	10	24	28	-	-
Elops lacerta	2	26	29	108	134	-	-
Exocoetidae							
Fodiator acutus	26	11	14	11	24	-	-

Family / Species	N	TL (cm) Min	TL (cm) Max	BW (cm) Min	BW (cm) Max	Smallest Matured TL (cm)	% Matured (with ripe gonads)
Haemulidae							
Brachydeuterus auritus	204	6	16	2	63	11	29
Pomadasys incisus	5	12	13	28	40	12	60
Pomadasys jubelini	24	6	32	11	122	-	0
Lutjanidae							
Apsilus fuscus	21	9	15	13	35	12	29
Polynemidae							
Galeoides decadactylus	118	12	17	25	61	17	17
Pentanemus quinquarius	1	19	-	54	-	-	-
Polydactylus quadrifilis	120	9	91	8	91	15	3
Sciaenidae							
Pseudotolithus typus	1	19	-	54	-	-	-
Pseudotolithus senegallus	4	13	20	31	66	13	50
Pseudotolithus senegalensis	11	10	21	23	169	10	-
Pteroscion peli	2	15	15	42	53	-	-
Scombridae							
Orcynopsis unicolor	8	17	26	48	125	-	-
Scomberomorus tritor	21	11	21	15	77	-	-
Sphyraenidae							
Sphyraena sphyraena	155	15	29	22	138	-	-
Tetraodontidae							
Lagocephalus lagocephalus	1	14	-	47	-	-	-

Appendix F. List of fish species showing monthly occurrence between nets without LED and nets with LED from January 2016 to March 2017, (L- nets with LED; N- Net without LED; '+' - species present; empty cell- species absent.

Family / Species	Jan-16		Feb-16		Mar-16		Apr-16		May-16		Jun-16		Jul-16		Aug-16		Sep-16		Oct-16		Nov-16		Dec-16		Jan-17		Feb-17		Mar-17	
	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N
Acanthuridae																														
Acanthurus monroviae								+																						
Balistidae																														
Balistes punctatus			+																											
Carangidae																														
Alectis alexandrines							+																							
Caranx crysos																								+						
Caranx hippos	+	+	+	+	+	+	+	+																						
Chloroscombrus chrysurus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				+	+	+			+	+			+	
Elagatis bipinnulata			+	+																										
Lichia amia	+	+	+	+	+	+	+	+	+	+	+	+	+	+							+	+								
Selene dorsalis	+		+	+	+	+	+	+			+	+																		
Trachurus trachurus			+																											
Urapsis secunda						+																								
Clupeidae																														
Ethmalosa fimbriata	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+					+	+	+	+
Ilisha africana	+	+	+	+	+	+	+	+	+	+	+	+	+	+				+		+	+	+								
Sardinella aurita			+		+	+														+	+	+								
Sardinella maderensis					+		+	+	+	+			+	+	+				+	+	+	+								
Cynoglossidae																														
Cynoglossus senegalensis						+																								
Drepaneidae																														
Drepane Africana																				+										

Family / Species	Jan-16		Feb-16		Mar-16		Apr-16		May-16		Jun-16		Jul-16		Aug-16		Sep-16		Oct-16		Nov-16		Dec-16		Jan-17		Feb-17		Mar-17	
	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N
Elopidae																														
Elops crysos																							+							
Elops lacerta													+	+																
Exocoetidae																														
Fodiator acutus	+	+			+	+																								
Haemulidae																														
Brachydeuterus auritus	+	+	+	+	+	+				+			+	+	+	+				+					+	+				
Pomadasys incisus	+	+																												
Pomadasys jubelini	+		+	+		+																								
Lutjanidae																														
Apsilus fuscus					+	+																								
Mullidae																														
Pseudupeneus prayensis				+																										
Polynemidae																														
Galeoides decadactylus	+	+			+	+														+					+	+				
Pentanemus quinquarius				+	+																									
Polydactylus quadrifilis			+	+																										
Sciaenidae																														
Pseudotolithus typus	+	+	+	+																										
Pseudotolithus senegallus			+																											
Pseudotolithus senegalensis				+	+	+																			+	+				
Pteroscion peli	+	+			+	+									+					+										

Family / Species	Jan-16		Feb-16		Mar-16		Apr-16		May-16		Jun-16		Jul-16		Aug-16		Sep-16		Oct-16		Nov-16		Dec-16		Jan-17		Feb-17		Mar-17	
	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N
Scombridae																														
Orcynopsis unicolor						+							+	+				+												
Scomberomorus tritor	+	+			+	+	+	+	+	+																				
Sphyraenidae																														
Sphyraena sphyraena		+	+	+		+							+	+																
Tetraodontidae																														
Lagocephalus lagocephalus	+													+																

Appendix G. Picture of a live Green turtle caught in gill nets from the study area in 2017 infected with Fibriopapiloma Tumour (red circles)

Fibropapiloma tumour on the eye impeding visual ability of sea turtle.

Appendix H. Sample questions used for gathering information from fishermen on sea turtles encounter, status and protection in the study area

Knowledge about Sea Turtle

1. Do you know about sea turtles? Yes [ ] No [ ]
2. What are sea turtles?
3. Have you seen sea turtles at sea before? Yes [ ] No [ ]

Ecological Knowledge

4. Do you know any importance of sea turtles?

   Yes [ ] No [ ]

   If yes, what are they
5. Are there any negative aspects of having sea turtles in the waters?

   Yes [ ] No [ ]

   If yes, what are they

Species Diversity and Abundance in the area

6. What of these sea turtles have you seen in this area? (Identify from pictures)

Leatherback [ ] Green turtle [ ] Olive ridley [ ] Loggerhead [ ]

Hawksbill [ ] Others.

7. Which of these species do you see often? Arrange in order of decreasing frequency of sighting.

   > > > > > >

8. How many turtles do you see in a month during fishing operations?
9. During what month(s) of the year do you see the sea turtles in abundance?

Sea Turtle-Fishery Interactions

10. Do you encountered sea turtles during your fishing operations? Yes [ ] No [ ]
11. If yes to question 10 above, what is the nature of the encounter?

    Observed swimming at sea [ ] Captured in fishing gear [ ]
12. Has your net captured a sea turtle before during fishing operation? Yes [ ] No [ ]
13. Do you intentionally catch sea turtles at sea? Yes [ ] No [ ]

If yes/no, why

14. What do you do to a live sea turtle that is encountered in your fishing net?

Killed for food [ ] Sold for money [ ] Released [ ]

Others (Please specify):

15. What do you do to a dead turtle encountered in your fishing net?

    Eaten as food [ ] Meat sold for money [ ] Released into the sea [ ]

    Others (Please specify):

    How much does a sea turtle cost?
16. What is the condition of sea turtles that you usually released at sea?

    Alive and conscious [ ] Alive but unconscious [ ] Dead [ ]

Knowledge of Threats to Sea Turtles in the Community

17. In your opinion, has there been any change in the number of sea turtles as compared to previous seasons in the past years? Yes [ ] No [ ]

If yes, have they increased or decreased?

18. In your opinion, what might be the reason for the increase/decrease in number?

19. Has there been the disappearance of any particular species in from this area?

Yes [ ] No [ ]

If yes, which species?

20. Does this community eat sea turtle meat or eggs? Yes [ ] No [ ]

If yes/no, why?

21. Do people of this community trade in sea turtle meat or eggs? Yes [ ] No [ ]

If yes/no, why?

Knowledge of Sea Turtle Conservation and Management Practices

22. Do you think sea turtles should be protected?

Yes [ ] No [ ]

If yes/no, why

23. Are there any laws protecting sea turtles in this area/ community? Yes [ ] No [ ]

If yes, what are they? National [ ] Traditional [ ]

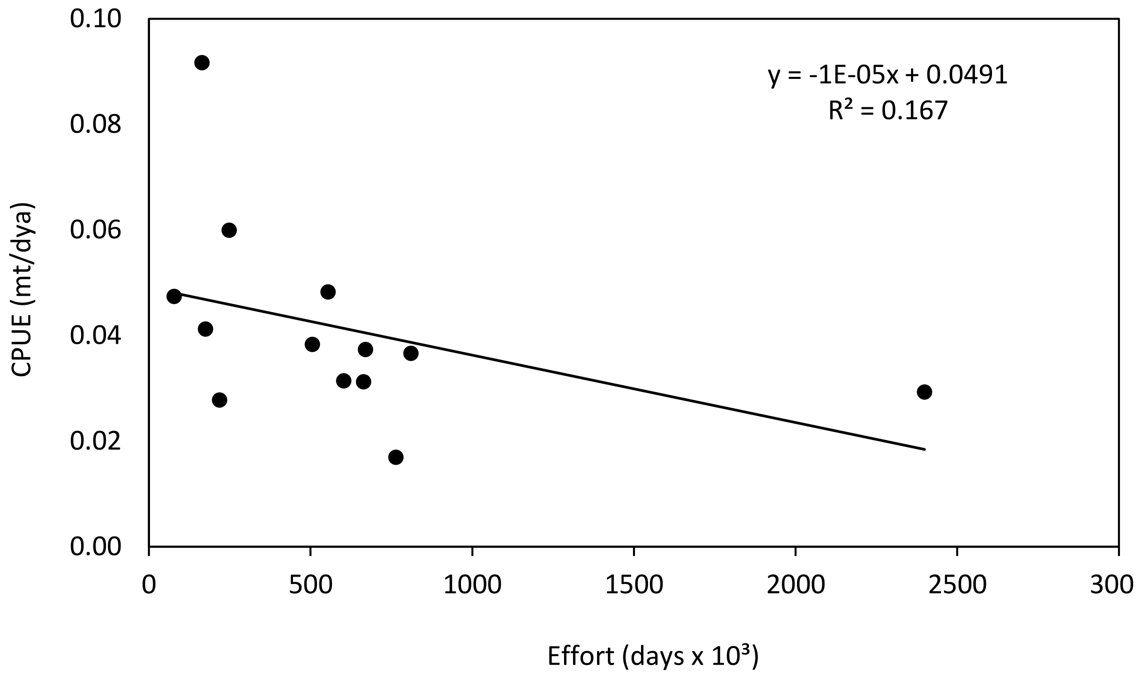
24. If there was a device that helps protect sea turtles from being captured in your nets, will you use it? Yes [ ] No [ ]

If yes/no, why?

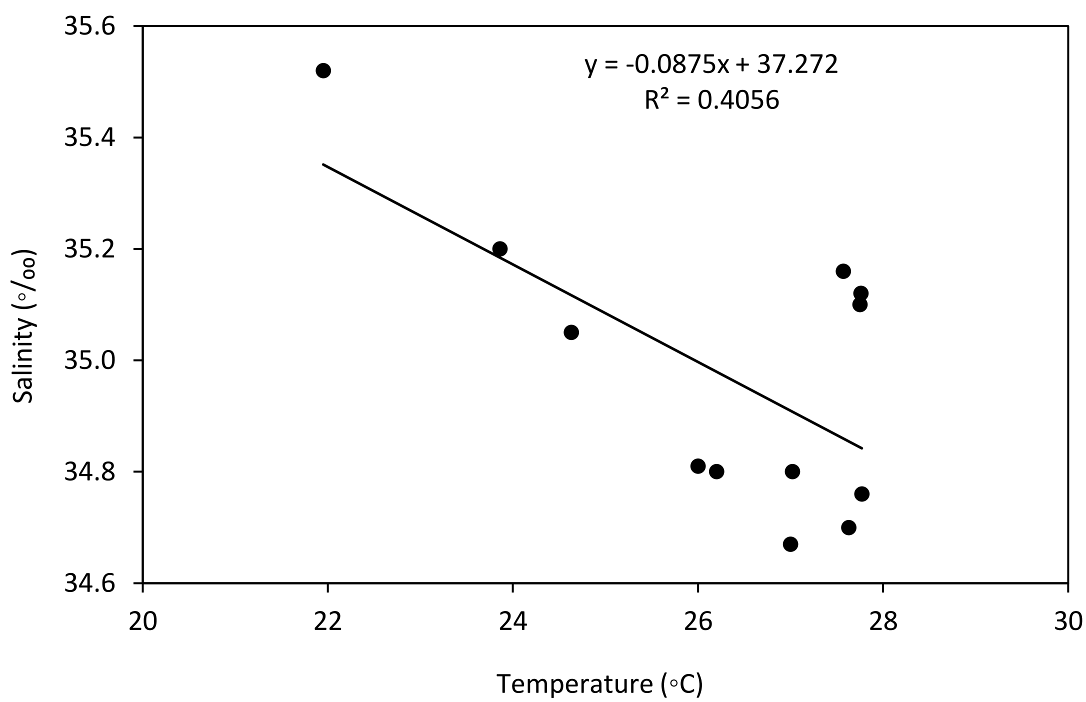
If there is a device mandated by law to be fixed on your fishing net to protect sea turtles, will you use it? Yes [ ] No [ ]

If yes/no, why?

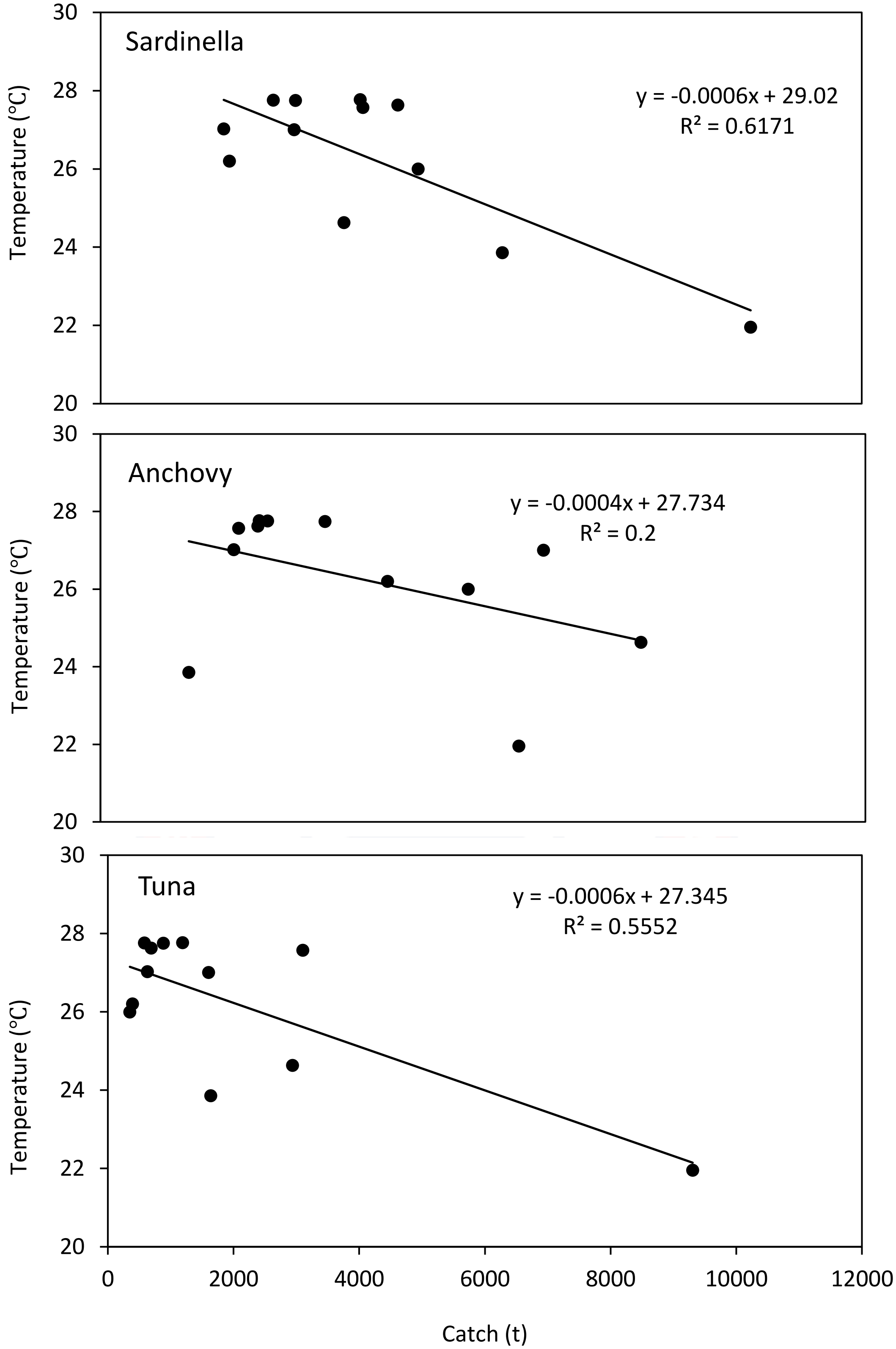
Appendix I. Graph of regression analysis for effort in relation to catch per unit effort in Gomoa and Effutu coastal waters



Appendix J. Graph of regression analysis for temperature in relation to salinity in Gomoa and Effutu coastal waters



Appendix K. Graph of regression analysis for temperature in relation to catch of the dominant fish species in Gomoa and Effutu coastal waters



Appendix L. Graph of regression analysis for salinity in relation to catch of the dominant fish species in Gomoa and Effutu coastal waters