UNIVERSITY OF CAPE COAST

UTILIZATION OF TWO BRACKISH WATER SYSTEMS NEAR CAPE COAST (GHANA) AS NURSERIES FOR JUVENILE MARINE FISHES

KEZIA BAIDOO

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BY

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Thesis submitted to the Department of Fisheries and Aquatic Sciences of the School of Biological Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy Degree in Zoology

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DECLARATION

Candidate's Declaration

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

Candidate Signature: ………………………………… Date: 25/10/2018…

Name: Kezia Baidoo

Principal Supervisor's and Co-Supervisor's Declaration

We hereby declare that the preparation of this thesis was supervised by us and that no part of it has been presented for another degree in this university or elsewhere.

Principal Supervisor Signature: ………………………… Date: 12/11/2018

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ABSTRACT

The results of a 6- month study of marine juvenile fish communities of two brackish water bodies (Kakum River Estuary and Benya Lagoon) in the Central Region of Ghana are presented. Fishes were sampled by using a 20 mm mesh cast-net from November 2016 to April 2017 over tidal and diel cycles. Twenty three marine fish species belonging to 15 families were from the Kakum River Estuary and Benya Lagoon which indicated low species richness compared to that reported in these same water bodies. Fishes of the family Mugilidae were dominant and the five species (*Mugil bananensis, Mugil curema, Mugil cephalu, Liza falcipinnis, Liza dumerillii*) sampled accounted for 54.63% of the fish from the estuary and 77.69% of the fish of the lagoon samples. The similarity indicators between the two communities (Index of similarity =0.89) during the study were similar and this reflected in the closeness of Shannon-Wiener index of diversity (H') values of 2.05 for the estuary and 1.55 for the lagoon marine communities. The two water bodies showed diel variation in catch rate which were out of phase with each other. There were fluctuations over the diel cycle in the number of species entering the brackish waters, number of individuals and their biomass. These fluctuations did not correlate with variation in temperature but they appeared to be influenced by salinity of the estuary and the lagoon.

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DEDICATION

This thesis is dedicated to my parents, Mr. Emmanuel Baidoo and Mrs. Mary Baidoo.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

A high level of biodiversity is necessary and also provides indications of relative good health status of the ecosystem. Therefore, maintaining biodiversity is necessary in order to assure the survival and productivity of ecosystems and livelihoods as a whole.

The Ghanaian waters, which form part of the Gulf of Guinea, are endowed with abundant fishery resource (Mensah & Quaatey, 2002; Mehl *et al.,* 2004, 2005). The most important pelagic fish species exploited in the Ghanaian coastal fisheries are the sardinellas, namely *Sardinella aurita* and *Sardinella maderensis,* which are important in the entire Gulf of Guinea (Bennerman & Cowx, 2002). Fish currently provides the greatest percentage of the world's protein consumption and, in Ghana, it accounts for about 60% of the animal protein intake (FAO, 2006).

However, the current global situation is likely to change soon as most fisheries are being fished at levels above their maximum sustainable yields, with many stocks having been overexploited (FAO, 2006). As a result, the health, economy, and livelihoods of several communities are under serious threat. The reason is that although fisheries resources are renewable, when over-exploited, they cannot be easily restored to their previous levels. In 2004 the fish requirement of Ghana was quoted at 700,000 metric tons while production was 300,000 metric tons leaving a deficit of 400,000 metric tons (Duffuor, 2005). In 2008, the Marine Fisheries Management Division (MFRD) of the Ministry of Agriculture reported the annual fish requirement as 880,000 metric tons but production averaged around 420,000 metric tons per annum, indicating a deficit of 460,000 metric tons per annum. Of the total amount of fish produced in the country about 84% comes from the marine fisheries with the remaining 16% coming from the Volta Lake, other inland waters and fish farms. Brackish water ecosystems (i.e. lagoons, estuaries and coastal marshlands) play a less significant role in fisheries production in Ghana at the moment although the FAO (1976) had estimated a production capacity of about 15000 metric tons per annum from these waters. Indirectly these brackish water bodies contribute to the fisheries by providing important nursery grounds for some fishes of economic importance.

In Ghana, lagoon and eastuarine fisheries are artisanal. They are prominent during the periods when catches from marine fishing are low and they play an important role in the economic lives of the induviduals living closer to them. For instance; Pauly (1976) investigated the biology, fishery and potential for aquaculture of *Tilapia melanotheron* in a small West African lagoon and recorded that the yield of Sakumo 2 lagoon near Tema, had been estimated at 50 kg of fish per day or 114 t/ year (Koranteng, 1995) which corresponds to recorded figures for the Muni lagoon (Winneba) and Densudelta were 75 t/ year and 2701 year respectively (Koranteng, 1995).

Coastal water bodies are considered among the most productive ecosystems and provide critical ecological services for a wide array of resident and migratory species. The essential services of lagoons and estuaries include provision of food, habitat complexity, filtration, buffering from extreme natural forces and refuge from predation, all of which enhance the estuarine nursery function for juvenile life stages of many commercially important species (Beck *et al.,* 2001; Nagelkerken *et al.,* 2013; Sheaves *et al.,* 2014). These have been exploited by small-scale fishermen settling along these coastal water bodies for generations to supports an informal workforce for better standard of living and proportion of the dietary resources of the human populations clustered around the various lagoons. Kapetsky (1981) in a comparative study of fishery yields from lagoons and other exploited marine and freshwater ecosystems concluded that coastal lagoons are more productive than the marine and freshwater ecosystems and this makes lagoons variable in terms of productivity. Much of the variability in yield among coastal systems is due to varying intensity of harvest (Kapetsky, 1981).

The structure of fish community depends on biotic and abiotic factors where salinity is the most important characteristic in coastal environments. Wide fluctuations in salinity may occur seasonally, annually or with the tide and may differ from the lower reaches nearest the sea to the riverine upper reaches. According to Whitfield (1990), temperature changes in coastal water bodies are noticeable in the temperate and polar latitudes and often affect fish population densities. The shifts in temperature from wet and dry periods strongly affect the rate at which vital nutrients such as nitrogen, phosphorus and silica enter the system from the surrounding watershed (Constanza *et al*, 1993). Domestic sewage and industrial waste could modify species composition and affect food chains by shortening them in estuarine systems (de Sylva, 1975).

Measures of relative quality of habitats include density, sutable environmental conditions, survivorship and growth rates of individuals and populations residing in alternative habitat types. There has been little effort to synthesize existing information and data to assess coastal water bodies patterns of nursery function, and threats to species of ecologic and economic importance that use Lagoons and estuaries for juvenile rearing. Because threats have been identified to be the main factor that may affect the entire coastal water bodies (Halpern *et al.*, 2009, Gleason *et al*., 2011, Merrifield *et al*., 2011, Greene *et al*., 2014), this lack of synthesis makes it difficult to identify strategies to strengthen fisheries production, or to alleviate threats to species and habitats of concern.

Coastal water bodies are often heavily impacted by the growing human population along the world's coasts that develops and adds stress to coastal environments and resources (Vitousek *et al.*, 1997). Threats to lagoons and estuaries and the organisms that rely on them come from a variety of sources, and can be either direct, such as excessive fishing (Jackson *et al.*, 2001) and habitat degradation and alteration (Lotze *et al.*, 2006), or indirect, such as climate change (Atrill and Power, 2002), eutrophication (Cloern, 2001; Rabalais *et al.*, 2002) and changes in community structure (Silliman *et al.*, 2005; Altieri, *et al.*, 2012; Hughes *et al*., 2013). Furthermore, these threats have been demonstrated to be widespread (Halpern *et al.*, 2009; Gleason *et al.*, 2011) and impacting populations of species of economic importance and conservation concern (Jackson *et al.*, 2001), while simultaneously reducing key functions of estuaries, including their nursery role (Beck *et al*., 2001; Kennish, 2002).

1.2 Statement of research problem and justification

Ghana Lagoons and estuaries have a countless impact on the well-being of socio-economic and health of the communities living closer and beyond to them. The small-scale labour-intensive characteristic of lagoon fisheries provides protein, employment, and income for people in tropical countries whilst the surplus catch contributes to the food supply of many areas (Kapetsky, 1981). The shellfish as well as their shells are an invaluable resource in the ceramic, animal feed and building industries.

Lagoons and estuaries are used as nursery ground by many junenile marine species (Whitfield, 1994). The increasing anthropogenic practices of these ecosystems such as exploitation of mangroves for fuel wood, exploitation of juvenile fish stock and pollution pose a severe danger to the biodiversity of these fish communities. Again urbanization along the coast and changes in land use and climate can affect both the availability of acceptable nursery habitat and the recruitment of young fish to populations of economically important species (Cloern *et al.,* 2007; Reum *et al.*, 2011; Hughes *et al.,* 2012). In Ghana, mangroves have been cleared in many areas to facilitate the manufacture of salt pans. These practices could lead to the damage of coastal environment, and recruitment of some species of commercial importants to the fishery. Additionally, eutrophication and resulting hypoxia from land-based nutrient sources, have been determined to occur along lagoons and estuaries (Hughes *et al.,* 2011), and threaten their nursery function by reducing biodiversity and available habitat (Hughes *et al.,* 2012, Hughes *et al.,* 2013). Habitat alteration (e.g., dredging, filling, diking, draining) and eutrophication caused by human activities have also caused widespread loss of essential vegetated estuarine habitats, such as salt marsh (Larson, 2001) and seagrass (Hughes *et al.,* 2013). These habitats support vital ecosystem functions associated with estuaries and serve as nursery habitat for many commercially important species, such as Dungeness crab, Pacific herring and several species of salmon.

Moreover, within the general framework of an Ecosystem Approach to Fishery Management (EAFM), considerable and increasing interest is being devoted to identify the distribution and habitat needs of species throughout their life cycle (Ward *et al.,* 2012). Lack of understanding of the structure of the population vis-à-vis species distribution, richness and abundance, as well as in-situ physico-chemical factors that support them and their periodicity could pose challenges to any kind of resource management regime in the future.

Day and night succession has a strong influence on the relative distribution of several species, changing the composition and richness of fish assemblages (Gaelzer & Zalmon, 2008). The distributions of fish species are mainly determined by a complex series of responses to both the physical and biological characteristics of their environment. These responses allow individual fish species to select those habitats that offer the best combination of a high potential for growth and reproductive output with the lowest risk of mortality. The requirements of theses individual changes, however, and a habitat that is suitable at one hunger state, time of day or stage in the life history may not be suitable at another. Consequently, many species move from one habitat to another at a variety of spatial and temporal scales. Moreover, habitats themselves do not remain constant but vary frequently on a daily and seasonal basis. Therfore several studies has been conducted on Félix-Hackradt *et al.*, (2010) studied diel and tidal variation in surf zone fish assemblages of a sheltered beach in southern Brazil. (Gomes *et al.,* 2003; Godefroid *et al*., 2004; Spach *et al.,* 2004) conducted a study generally related to spatial and temporal variations of the fish community structure, trophic ecology. Short-term changes in abundance occur mainly due to the tidal cycle, moon phase, and alternation of night and day (Oliveira-Neto *et al*., 2004). Many studies have found different patterns of fish habitat use, with greater daytime catches (Allen & DeMarttini, 1983; Nash and Santos, 1998; Rooker and Dennis, 1991) and higher number of species and diversity during the night (Livingston, 1976; Nash & Santos, 1998; Lin & Shao, 1999).

Knowledge on the ecological habit of juvenile marine fishes could provide fundamental importance for the effective management of the fishery but in Ghana there is a dearth of information.

Little information is documented on diversity of brackish water fisheries in Ghana. The species composition has however, been reported in few cases (Blay & Asabere-Ameyaw, 1993). In understanding the on-going change that occureed in environmental conditions and the continual utilization of brackish water resources in the country, periodic monitoring of the biodiversity of these ecosystems require to be vigorously pursued to assess their status. Bases on the result of the assessments, an adaptation of management strategies will be necessary. This present study describes the current status of species diversity, similarity, richness, and size distribution of marine fishes entering two contrasting brackishwater environments in the Central Region of Ghana and their possible relationship with some environmental factors.

1.3.0 Objectives of the study

1.3.1 Main objective

This study seeks to investigate the feeding ecology and diel variability of the structure of fish community in Benya lagoon and Kakum river estuary to improve the understanding of temporal structure of fish population and to highlight issues of ecological concern

1.3.2 Specific objectives

The specific objectives were to determine the species composition, richness and diversity of the marine finfish communities as well as the diel variation of the number of species, number of fish and biomass of marine species. Finally, the food habits of the species were also determined

1.4 Summary

In summery, understanding the on-going change occuring in environmental conditions and the continual utilization of brackish water resources in the country, periodic monitoring of the biodiversity of these ecosystems require to be vigorously pursued to assess their status.

CHAPTER TWO

LITERATURE REVIEW

2.1 Biodiversity and aquatic life of lagoons and estuaries

Biodiversity refers to the variability of living organisms from all sources including, *inter alia*- terrestrial, marine and other aquatic ecosystems and their ecological complexes of which they are part (Duarte *et al*., 2006).

The need for a better understanding of the role of biodiversity in the functioning of aquatic ecosystems has been raised by several authors (Duarte *et al.*, 2006; Ryan & Ntiamoa-Baidu, 2000; Scherer-Lorenzen, 2005; Neuman *et al*., 2015). Neuman *et al.* (2015) identified that the function of an ecosystem depends on several factors which include biodiversity and a multiplicity of interactions between the physical, chemical and biological determinants. Humbert and Dorigo (2005) have stated that ecosystem functioning depends on several factors such as biodiversity and a multiplicity of interactions between the physical, chemical and biological determinants.

Lévêque (1995) investigated the role and consequences of fish diversity in the functioning of African freshwater ecosystems and mentioned that several studies attribute ecosystem function largely to processes such as storage and transfer of matter and energy at different temporal and spatial scales. Scherer-Lorenzen (2005) studied Biodiversity and Ecosystem Functioning and also argues that the function of an ecosystem is highly dependent on the functional traits of the organisms involved as well as the abiotic environment. Teixeira-de Mello *et al.* (2009) reported that the higher densities of small fish, which tend to aggregate among the macrophytes, often exert a high predation pressure on the zooplankton and thus reduce grazing on phytoplankton, with implications for the clear water state of warm shallow lakes (Romo *et al.,* 2005; Meerhoff *et al.,* 2007). Jones and Sayer (2003) reported that, fish may also consume plant-associated macroinvertebrate grazers and indirectly enhance periphyton growth with cascading effects on plant growth and thus on water clarity, at least in temperate lakes.

However, there is little information on how the macroinvertebrate community responds to the potentially increased fish predation in warmer climates. Studies in subtropical shallow lakes (Meerhoff *et al.,* 2007) have shown lower taxon richness and significantly lower densities of plant-associated macroinvertebrates compared to similar temperate lakes, presumably as a result of the high densities of fish occurring within the macrophytes. Humbert and Dorigo (2005) investigated biodiversity and aquatic ecosystem functioning and pointed out that knowledge of the functional traits of biodiversity and ecological interaction between the biotic and abiotic environments is crucial for informed management decisions.

2.2 Importance of estuaries and lagoon ecosystems to fisheries

The ecological importance of estuaries and lagoons throughout the world is well recognized. Nagelkerken *et al.* (2013) identified that the high biological productive, scenic and physical diversity, abundant mineral resources as well as strategic location of coastal water bodies have gained great biologically and economic importance. Whitfield and Pattrick (2015) confirmed that these high productive ecosystems provide critical habitat and food for many organisms, including economically and ecologically important fish species. Barbier *et al.* (2011) studied the value of estuarine and coastal ecosystem services and identified that coastal areas with large estuaries, broad wetlands and large rivers support high fishery yield indicating that in general, coastal lagoons and estuaries with high proportion of salt marshes yield higher landings of fish. Garcia *et al.* (2001) investigated the dynamics of the shallow-water fish assemblage of the Patos Lagoon and estuary (Brazil) and reported that fish capture per unit area of estuaries was correlated with river discharge. Nixon (1995) discovered a relationship between aquatic primary production and fisheries yield which indicated that estuarine areas are more efficient in converting primary production into fish production than other water bodies. There have been various studies conducted on the abundance, distribution and diversity of larval and juvenile fishes in estuaries and lagoons due to their importance as nursery grounds in offering abundance of food and shelter for young fishes (Barletta *et al*., 2005).

Chesney *et al.* (2000) cited an estimate of approximately two-thirds of the catch of commercially important fishes in the United States are dependent on estuarine habitat for the growth of the younger fishes and to increase population of fish stocks in the open sea. According to Jackson *et al.* (2001) lagoon and estuarine fish communities are highly variable and often experience large temporal changes in species composition and abundance. Many individual populations of fish show predictable seasonal patterns of abundance within a given estuary or lagoon which affect both seasonal and annual estimates of diversity of fish species (Sosa-López *et al.,* 2007). These measures of species diversity, in association with other indices of community structure and species composition have been used to make long term comparisons of changes in estuarine and lagoon biological communities in relation to environmental quality (Yoklavich *et al.,* 1991). In recent years, the quest to increase food production for a growing population, among other reasons, has increased the importance of coastal fisheries. Brackish water fisheries provide the bulk of fish for semi-urban consumption. Nevertheless, these water bodies are currently under exploitation pressure (Hughes *et al*., 2014); already, and periodical oscillations of yield are visible in some species of economically important as a result of inappropriate exploitation strategies and unauthorized methods of fishing by fishermen, such resulting from the lack of understanding of the population and ecosystem structure of the lagoons and estuaries.

In Ghana, lagoons and estuaries provide fisheries resources to the local communities residing near them (Mensah, 1979; Ntiamoa-Baidu, 1991; Blay & Asabere-Ameyaw, 1993). These water bodies are maily dominated by the Blackchain Tilapia, (*Sarotherodon melanotheron*) which constitutes about 90% of the catches (Blay & Asabere-Ameyaw, 1993) and juneniles of some marine species of commercial importance. These resources are actively exploited and for their sustenance require some form of regulatory measures. The capture of large amounts of small, immature fish of commercial species in brackish systems is a serious problem that threatens the economic sustainability of fisheries and the renewability of resources (Ward *et al.*, 2012). Okyere *et al*. (2011) in a comparative study of ecological assessment of fish communities from coastal wetlands concluded that fish species composition, richness and diversity from the Essei lagoon generally recorded very low values and this observation could be attributed to intense artisanal fishing activities in these lagoons cannot be ruled out as a major impact on the lagoon fisheries. Such impacts have been reported elsewhere notably in South

Africa (Tomlin & Kyle, 1998) and the Gulf of Thailand (Simpson, 1982). Despite the adoption of several technical measures (gear and fishing operation) aimed at protecting juveniles, the problems related to the excessive removal of immature specimens are far from being solved (Carbonell, 1997; Stergiou *et al.,* 1998). Moreover, the classical regulation of fisheries has thus far been based on limitations of the fishing capacity (licences), minimum landing sizes, and net mesh sizes (Maggs *et al.,* 2013); together with temporary fishing closures, but the establishment of no-fishing zones, particularly within nursery areas (lagoons and estuaries), has been increasingly ignored as an additional component as a strategic management tool for the fishery.

Hence, assessing the biodiversity and interactions between the biotic communities and the abiotic factors of coastal water bodies would give a broader understanding of the functions and ecological value of these ecosystems (Quinn, 2004). The role and the taboos by the local traditional religious believe in this regards is well known. Notwithstanding, fisheries of the brackish systems, apart from playing the noble role of providing a relatively cheap source of animal protein, also provide employment and to some extent reduce the rural-urban drift. Documenting and quantifying the nursery value of juvenile rearing habitat is important in the context of effectively highlighting efforts to conserve and restore coastal ecosystems and support sustained populations of fish and invertebrates (Maggs *et al.,* 2013), Although these studies are conducted at a population level and focus on the fishery target species, they include habitat conservation concerns and attempt to explain the organization of juvenile fish species by investigating the biotic (benthic biocoenosis, availability of prey, presence of predators) and abiotic factors (temperature and salinity) that may affect them. Humbert and Dorigo (2005) have indicated that ecosystem functioning depends on several factors including biodiversity and a multiplicity of interactions between the physical, chemical and biological determinants. According to Lévêque (1995), several studies attribute ecosystem function largely to processes such as storage and transfer of matter and energy at different temporal and spatial scales. Scherer-Lorenzen (2005) also argues that the function of an ecosystem is highly dependent on the functional traits of the organisms involved as well as the abiotic environment. In agreement with Scherer-Lorenzen, (2005); Humbert and Dorigo, (2005), the functional traits of biodiversity and ecological interaction between the biotic and abiotic environments are crucial for informed management decisions.

2.3 Abundance and distribution of Juvenile fishes

The Indo-West Pacific region, stretching from the east coast of Africa through South and Southeast Asia to Australia and the Central Pacific, has the highest diversity of fishes in the world (at least 600 species in mangrove systems) (Selig *et al*., 2014). Selig *et al.* (2014) investigated global priorities for marine biodiversity conservation and recorded that the high diversity of the marine species decreases latitudinal away from the equatorial core area in Southeast Asia, but larger subtropical mangrove systems still contain at least 100 species. Clayton (1993) studied the ecology of the mudskippers and identified that many species of mudskippers occur throughout this region, while others are restricted to particular regions. According to Clayton (1993), a special group of fish species found in mangroves is the mudskippers (family

Periophthalmidae) which occupy a specialized niche in the intertidal zone. Kruitwagen *et al.* (2007) investigated the influence of morphology and amphibious life-style on the feeding ecology of the mudskipper (*Periophthalmus argentilineatus*). It was confirmed that mudskipper (*Periophthalmus argentilineatus*) are physiologically and morphologically adapted to an amphibious existence in this zone with highly variable environmental conditions. Ishimatsu and Maggs *et al.* (2013) investigated the roles of environmental cues for embryonic incubation and hatching in mudskippers and recorded that mudskippers are able to dwell on exposed mudflats when other fish species are forced to retreat to deeper waters with outgoing tides. According to Tittensor *et al*. (2010), in all regions of tropical West Atlantic region from the Gulf of Mexico to northern South America, except the Indo-West Pacific, Sciaenidae are one of the dominant families. In the Indo-West Pacific, sciaenids are important in the equatorial regions of Southeast Asia, but much less so elsewhere (Tittensor *et al*., 2010); this pattern may be connected with the amount of rainfall and the degree to which coastal waters approach estuarine conditions.

There are important differences in the relative proportions of freshwater species, both between and within regions. In East Africa and Australia, however, freshwater species are usually insignificant components of the mangrove fish fauna (Blaber and Blaber, 1980). Barletta *et al.*, (2005) investigated the role of salinity in structuring the fish assemblages in a tropical estuary and confirmed that, freshwater species make up more of the fish fauna in tropical Atlantic mangrove systems than in the Indo-West Pacific or East Pacific, particularly in South America where many of the very diverse fauna of siluriid catfishes are common in estuaries. Baran and Hambrey, (1999) identified that in West Africa various silurids and cichlids make a significant contribution to mangrove fish communities. According to Blaber and Cyrus (1981) the equatorial regions of Southeast Asia have somewhat more freshwater species than other areas of the Indo-West Pacific, (Kwak *et al.,* 2007) but despite the diversity of the freshwater fish faunas of Borneo and Sumatra relatively few live in estuaries. Acosta (1997) studied use of multi-mesh gillnets and trammels nets to estimate fish species composition in coral reef and mangroves in the southwest coast of Puerto Rico mentioned that throughout the islands of the Caribbean most mangroves are non-estuarine and small in size (fringing), and (Nagelkerken *et al.*, 2000b); typically contain marine species dominated by the families Gerreidae, Haemulidae, Lutjanidae and Scaridae

A broad understanding of the dynamics, nature, and history of the coastal water body is economically and scientifically significant. For instance, in a situation where coastal systems are utilized for waste disposal, there is the need to understand the physical and biological dynamics of these systems to avoid excessive pollution (Kwei, 1977). Welcomme (1975) investigated the fisheries ecology of African floodplains and identified an increase in salinity and conductivity of the pool waters during the study period which was attributed to the concentration of dissolved ions with decreasing water volume (Rosenberg *et al.,* 2001). Biney (1982) assessed the state of pollution of some lagoons and estuaries in Ghana, where twelve of those coastal systems were classified as polluted to various extents such that two, (the Korle and Chemu) were grossly polluted, and eight estuaries studied were generally clean or only slightly polluted. Odei *et al.* (1980) studyed the suitability of the Volta estuary for water sports, recommended that Ghana Tourist Authority need to ensure that sanitation in the area was upheld and that noxious effluents were not indiscriminately discharged into the Volta Estuary. A survey of the Volta estuary by Biney (1983) identified domestic plastics and oil originating from tanker traffic along the Gulf of Guinea as the main pollutants of the beach of the estuary. Physico-chemical studies conducted on estuaries by Biney (1982) and lagoons by Biney (1990) in Ghana also indicated that the quality of these waters is affected by the transfer of solutes from the ocean and the influx of fresh water.

2.4 Water Quality and aquatic life of lagoons and estuaries

Aquatic organisms are dependent on certain temperature ranges for optimal health. Temperature in aquatic environments is an important factor that influences the amount of oxygen that can be dissolved in the water, the rate of photosynthesis by algae and aquatic plants, the metabolic rate of organisms and the sensitivity of organisms to toxic waste, parasites, pollution and diseases (Hoover, 2007). According to Gilman *et al*. (2008), global climate change which is resulting into an increase of greenhouse gases in the atmosphere can be expected to alter significantly the temperatures and thermal structure of rivers, streams, lakes, oceans in association with the distribution and wellbeing of fish species, population and assemblages. Recent studies have shown that brackish water systems have substantially different trophic structure and dynamics (Meerhoff *et al*., 2007; Brucet et al., 2010).

According to Blanck and Lamouroux, (2007) and Jeppesen *et al.* (2010), the higher temperature at lower latitudes is connected with a shift to a fish community dominated by omnivorous fish, with higher specific metabolic and excretion rates, more frequent and earlier reproduction and smaller sizes than at higher latitudes. Some fish species can live in a water body with temperature smaller than 0.1^{o}C (Mereta, 2013) every fish species has its characteristic which help to acclimatize to optimum water temperature range and temperature tolerance limits which might change seasonally in a given stock and can be slightly different from one stock to another of the same species (Salin *et al.*, 2016).

According to Hester and Doyle (2011), the thermal niche of a fish can be describes as a range of preferred temperature 4^{o}C to 10^{o}C with a midpoint of about 10^{o}C to 15^{o}C for cold water fishes, 20^{o}C to 25^{o}C for cool-water fishes and 25^{o}C to 30^{o}C for warm water fisheries. Peterson *et al.* (1999) have demonstrated that there is the potential for fluctuations and spatial variability in salinity to cause significant variability in the short-term growth rates of at least one species in nursery areas. Temperature would have negative effects on the productivity in coastal water bodies such as the lagoons and estuaries where an increase in salinity may result in killing of young individuals (EPA, 2008). The change in climate contributing to high temperature predicted changes in the abundance, distribution and species composition of fish populations, as well as the collapse of other fish species, although expansion of others is also possible (IPCC, 2001). The perceived effects of high temperature resulting from climate change may increase in the future (IPCC, 2003), consequently the identity and organization of biological systems needs to be recognized. Salinity has been recognized as the main factor that influences the occurrence and the composition of species in the habitats of coastal water bodies in the tropics and subtropics (Little *et al.*, 1988; in Blay, 1997). This is because species differ in salinity tolerance. This factor might contribute to the presence or absence of some fish species in both the estuary and the lagoon despite the closeness of the two systems.

Blaber and Cyrus (1981) observed that in the coastal lake of South Africa, the changes in the fish fauna in response to gradual changes in salinity were a reduction in the diversity of marine species and an increase in numbers of individuals of a few freshwater species. Lugendo *et al.* (2007a) investigated the spatial and temporal variation in fish community structure of a marine embayment in Zanzibar, Tanzania and identified that Long-term salinity variations may also affect the distribution and occurrence of fish species in estuaries. Lugendo *et al.* (2006) found that fish species in mangrove coastal waters decreased during the rainy season which has decreased salinity, visibility and temperature. In various studies, catch rates of the most abundant species were most strongly correlated with long-term (months and years) salinity patterns (Barletta *et al.*, 2005). In the coastal lake Nhlange, part of the Kosi system of northern KwaZulu-Natal, South Africa, the changes in the fish fauna in response to gradual changes in salinity were a reduction in the diversity of marine species and an increase in numbers of individuals of a few freshwater species (Blaber & Cyrus, 1981). Nevertheless, even at salinities of 1 ppt or less the system still contained 23 estuarine or marine species. There is evidence that trophic structure changes along with salinity gradient (Burks *et al.*, 2002; Brucet *et al.*, 2009). Probably, eutrophic brackish water bodies resemble warm freshwater lakes in that they are often turbid and the biomass of zooplankton is lower than in cold freshwater lakes Burks *et al.*, 2002;

Jensen *et al.*, 2010). This has been accredited to a salinity-induced increase in the predation on large-bodied zooplankton and the loss of keystone species such as Dalphnia, leading to dominance of smaller and less efficient grazer species (Jeppesen *et al*., 2007; Schallenberg *et al.,* 2003).

The effects of salinity on the community structure of macroinvertebrates are, however, less clear. At salinity ranges from 1 to 3, macroinvertebrate assemblages exhibit reduced species richness and abundance and a change in species composition (Piscart *et al*., 2005; Boix *et al*., 2007). Some studies have shown that Crustacea are the most salinity tolerant of the major invertebrate taxon groups (Kefford *et al.*, 2003) whereas Ephemeroptera are among the least tolerant invertebrates (Williams *et al.*, 1990; Hart *et al.*, 1991). With climate warming, changes in the trophic structure and biodiversity of shallow lakes as a combined effect of increased temperature and salinity, the latter particularly in arid, semiarid and coastal areas (Brucet *et al.*, 2009). An increased strength of trophic interactions, not least predation, with warming has also been suggested (Brucet *et al*., 2010; Schemske *et al*., 2009).

2.5 Diel shifts of fish community

Fish living in coastal waters presents behavior patterns that are being ruled in particular by the day-night cycle (Potts, 1990), where the temperature and solar radiation changes influences feeding, and metabolic activities as well as behavioral responses which include protection from predators. These behaviors allow the species to be characterized as diurnal or nocturnal through observation of higher activity or rest periods searching for shelter (Hobson, 1965). Paterson and Whitfield (2000) investigated if shallow-water habitats function as refuge for juvenile fishes and identified that at night, fish leaves their shelters more frequently and this could explain the higher captures in shallow waters during this period, although the benefit of net avoidance in daylight by several species (Horn, 1980).

Many fish species also undergo daily migration either to their feeding or spawning grounds (Meyer & Koster, 2000); many studies have found higher densities of crustaceans in seagrass than in surrounding habitat. *H. clupeola* and *A. tricolor* were significantly more numerous during the day (Oliveira-Neto *et al.*, 2004). Probably, shoaling behaviour allowed them to occur in daylight since in this formation they are protected from visual predators, such as adult fish or shore birds (Nagelkerken, 2007) confirmed that Haemulidae and Lutjanidae species migrate to seagrass at night to feed on invertebrates. The lack of diel correspondence with species description agrees with other studies (Morrison *et al.*, 2002; Pessanha & Araújo, 2003), which showed no occurrence of strong changes in fish assemblage composition between daylight and night period. Gibson *et al.* (1996) investigated temporal changes in fish distribution and concluded that although significantly more species were caught at night overall the difference was slight and the major changes in assemblage structure observed were caused by the changing abundance of particular species rather than by their presence or absence. Verweij *et al.* (2006) found that *Haemulon flavolineatum* juveniles use coastal water bodies during the day for shelter.

Nagelkerken *et al.* (2000a) studied day-night shifts of fishes between shallow water biotopes of a Caribbean bay, with emphasis on the nocturnal feeding of Haemulidae and Lutjanidae and recorded that diurnally active species such as Acanthuridae, Sparidae, Scaridae and Pomacentridae feed during the day and migrate daily to shelter at night. Oliveira-Neto *et al.* (2004) identified that daily migration is most likely in response to food availability, prey activity and predation risk. Romer (1990) investigated Surf zone fish community and species response to a wave energy gradient and came to a similar conclusion for a surf zone fish community in South Africa. There was no evidence of a difference between the 2 months in this respect in contrast to the finding by Nash (1986); although some species were found only during the day or at night, with one exception (*Melanogrammus aeglefinus*) they were all rare and their absence at a particular time of day could be attributed to chances. Nash (1986) and Gibson, (1994) concluded that community structure variation is strongly influenced by the dominant species peculiarities and as a consequence, failed to find a clear periodic pattern. Diel variation in behavior of commercial fishes have received a little attention and is a well known problem in fishery assessment programmes (Gaelzer1 & Zalmon, 2008; Félix-Hackradt *et al.,* 2010). Again, differences between diurnal and nocturnal samples might also result from the higher visibility of the net during the day, a factor that could reduce its efficiency (Horn, 1980). Likewise, very translucent waters would decrease the efficiency of the capture nets because of their visibility to the fish (Hoese, 1973). For instance, species that occupy demersal environments are adapted to low light conditions, and this is a factor that may attribute why the occurrence of fish population in shallow environments usually occurs at night. To be able to reduce the variability in assessment caused by diel behavior patterns, there must be information on how to balance day and night catches (Pitt *et al*., 1981). Studies of fish assemblages in coastal water bodies can provide not only information of the temporal structure of populations on both seasonal and diel basis, but also of the life-history phases that occupy the habitats.

2.6 Food habits and trophic relationships of fish communities

According to Warburton and Blaber, (1992); Ley *et al.* (1999); Crabtree and Stevens, (1998) several studies have investigated trophic linkages in temperate estuarine systems, few have empirically examined these relationships in tropical and subtropical estuaries. Again Wallace and Fletcher (1996) mentioned that information on the food habits of the different age groups in a fish stock is vital for the assessment of the fish stock as it defines the trophic requirements of the various developmental stages. In order to interpret the function of an ecosystem habitat and to analyze food webs, it is necessary to consider prey availability since food type and its availability is of higher importance for the success of recruitment of fish species (Elliott *et al.*, 2002). It is also an important requirement for the ECOPATH model (Christensen & Pauly, 1992) used in elucidating aquatic ecosystem functioning and generating critical biological information for fisheries management (Mendoza, 1993; Silva *et al.*, 1993). Several studies on the food and feeding habits of grey mullet have been carried out by different inverstiggators Angell, (1973); Bruthet, (1975); Das, (1980); Zarka, (1970) and Ermen, (1961) on *Mugil curema, Mugil cephalus*, *Liza tade*, *Mugil saliens and Mugil chelo* respectively. Diatom is the favorite food of *Mugil cephalus*, which can be compared withthe observation shown by Bruthet (1975). Bruthet (1975) reported that the greatest abundance of diatoms were about 48% in all the stomachs examined. In Ghana, the food and feeding habits of some few marine species of economic importance have been studied. According to Blay (1995a and b) food and feeding habits of four species of juvenile mullets (*Liza falcipinnis, L. dumerilii, Mugil bananensis, and M. curema*) in the Elmina lagoon was assessed and observed that though all four species were diurnal feeders their feeding times differed. Blay and Eyeson (1982) studied the feeding activity and food habits of the shad *Ethmalosa fimbriata* in the coastal waters of Cape Coast. Rangaswamy (1973) who reported that in marine environment the gut content of *Mugil cephalus* contains 26.72% algae and 22.76% diatoms Food preference of two coastal marine fishes, *Galeoides decadactylus* (Polynemidae) and *Sphyraena sphyraena* (Sphyraenidae) off Cape Coast Ghana were assessed by Aggrey-fynn *et al.* (2013). The existing gaps between the studies cited basically force knowledge on the foraging ecology and population dynamics of juvenile marine fishes of the brackishwater systems in Ghana, which is a very relevant to inform, promote and to help shape lagoon and estuary management and for conservation purpose. Without knowledge for better understanding of dietary relationships among organisms, community structure and population interactions are difficult to deduce. Polis and Winemiller (1996) reported that, food web approach can be valuable in the study of natural communities. Since many tropical and subtropical estuaries are numerically dominated by juvenile fishes the trophic role of these life stages is especially important (Arrivillaga & Baltz, 1999). Currently, there have been few studies comparing the ecological status of fish communities in lagoons and estuaries in Ghana. Therefore the purpose of this study is to assess the diet and feeding habits of juvenile marine fishes as part of the process of gathering baseline information for a detailed investigation of the trophic structure of fish communities in the Gulf of Guinea ecosystem. The present study seeks to investigate the feeding pattern and the daily feeding cycle of the juvenile fishes of Kakum river estuaries and Benya lagoons in Ghana to highlight issues of ecological concern and also to encourage management interventions.

In lagoon and estuary ecosystems, density of juveniles has been intensively used for the assessment of recruitment, survival and mortality. This is because they serve as an important indicator of the nursery value of these habitats and again juveniles' response to changes in the aquatic ecosystem health. Assessment of feeding habit will be important for several convincing reasons. In order to interpret the function of an ecosystem habitat and to analyze food webs, it is necessary to consider prey availability since food type and its availability is of higher importance for the success of recruitment of fish species (Elliott *et al.,* 2002). In the marine ecosystem many juvenile fish species spend some time in shallow coastal waters to feed and grow to sub-adults stage before migrating into deeper waters. Recruitment of these juveniles into the fishery depends mostly on their rate of survival in the shallow coastal waters. Investigation on the feeding regime of fish may therefore help to identify habitats that serve as nursery ground and support the recruitment process of different fish species and stock. Information on the food habits of fish stock is essential for assessing the stock (Wallace & Fletcher, 1996) since it defines the trophic requirements of the various developmental stages of fish stock.

Investigating diets and feeding patterns of fish communities can contribute to an understanding of ecological interactions and community structure Nagelkerken *et al.,* (2006); Layman *et al.,* (2007). Dietary ecology and feeding habits can be explored by quantifying variation in resource use, feeding intensity and trophic niche breadth. Individuals are predicted to shift resource use in response to food availability in the environment (Barreiros *et al.,* 2002). Furthermore, Miracle *et al.* (2006) found that fish effect depends strongly on the diet of the species involved. As for zooplankton, the decrease in the abundance of plant-associated macroinvertebrate grazers at higher temperatures may have implications for the ecological status of lakes since it may enhance periphyton growth and indirectly promote the turbid water state by outshading macrophytes (Phillips *et al.,* 1978). In addition, potentially higher predation by small fish within the plants beds may influence the spatial distribution and diel movements of macroinvertebrates. Thus, zooplanktons have been shown to migrate to deeper layers or into submerged plants during the day as a result of the tradeoffs between predation risk, food availability and oxygen concentration (Burks *et al.,* 2002).

Optimal foraging theory predicts that dietary niche breadth of a population should expand as preferred food resources become scarce (Emlen, 1966; Schoener, 1971; Rodel *et al.,* 2004). Bolnick *et al.* (2002) conducted ecological studies by measuring individual-level of resource spercialization and recorded that topical advances in niche theory predict that the dietary niche breadth of a population can expand in differing ways. According to Araújo and Gonzaga, (2007) and Araújo *et al*. (2007) every individual in the population may use a broader array of resources or there can be greater individual specialization. Studies on the variety of taxa have found inter-individual diet variation, which has been shown in some cases to comprise the majority of the population's niche width (Hammerschlag *et al.,* 2010). Bolnick *et al.* (2003) Investigating diets and feeding patterns of fish communities can contribute to an understanding of ecological interactions and community structure. Tyler (1971) studied monthly changes in stomach contents of demersal fishes in Passamaquoddy Bay and mentioned that in fishes, feeding intensity is thought to decrease at lower temperatures due to lower metabolic demands. Hammerschlag *et al.* (2010) mentioned that dietary ecology and feeding habits can be explored by quantifying variation in resource use, feeding intensity and trophic niche breadth. Individuals are predicted to shift resource use in response to food availability in the environment (Nagelkerken *et al.,* 2006). Trophic niche breadth is influenced by a variety of factors, which includs food diversity and intraspecific competition (Svanback and Bolnick, 2005; Layman *et al.,* 2007). Intertidal areas of the coastal water bodies, fishes migrate at high tide purposely to feed (Sheaves & Molony, 2000; Lugendo *et al.,* 2006). Accordind to Nagelkerken *et al.,* (2000b) both the quantity and types of food may differ between coastal waters and adjacent waters; many of the foods available in sheltered coastal waters are rare or absent in offshore waters, particularly flora, microfauna and detritus as well as aquatic macrophytes and their epifauna and flora. Blaber and Blaber (1980) identified that the presence of mangroves in tropical estuaries increases the diversity and quantity of food available to juvenile fishes in coastal water bodies, and Robertson and Duke (1990a) have also shown highly significant differences in the densities of juvenile fishes between coastal waters and other nearshore habitats when they are immediately adjacent to each other. According to Nagelkerken *et al.* (2000a) fishes mainly shelter themselves in the coastal water bodies during daytime and feed on adjacent seagrass beds at night. Nevertheless, opportunistic feeding takes place while they shelter in mangroves during daytime (Nagelkerken & van der Velde, 2004b; Verweij *et al.*, 2006). Dankwa *et al*., (1999) reported the main constituents of the diet of *A. spilauchen* in the pools were debris, insect larvae and adult insects, with copepods representing a very small proportion of the food. Emmanuel *et al.* (2010) showed that *G. decadactylus* found off Nigerian coast feeds on a variety of crustaceans and molluscs. The food of *S. melanotheron* in the wetland did not differ from that of populations in the Sakumo Lagoon in Ghana (Ofori-Danson & Kumi, 2006) and Eleiyele reservoir (Ayoade and Ikulala, 2007) and Awba Reservoir (Ugwumba & Adebisi, 1992) in Nigeria, except that these populations fed on a wider range of algae and zooplankton. Gaughan and Mitchell (2000) mentioned the importance of "marine snow", with its organic content and associated microorganisms, has been noted in the diet of many pelagic species. Dankwa *et al*. (2005) similarly confirmed that the grey mullet *L. falcipinnis* in Benya lagoon in Ghana and River Pra and River Volta estuaries also in Ghana fed on similar food items. Carpenter and Nkem, (2001); Barreiros *et al.,* (2002); Porter and Motta, (2004); Hosseini *et al.,* (2009) reported that *S. sphyraena* feeds mainly consumed fish. Okyere *et al.* (2011b) stated that lagoon and estuarine populations ingested a broader spectrum of food items including red algae, molluscan larvae, polychaetes and nematodes, therefore, the relatively narrow spectrum of food eaten by the fish encountered suggests the unavailability of a number of their dietary items in the wetland. *T. zillii* preferably fed mainly on plant materials and debris which confirm their macrophagous food habits (Dankwa *et al.,* 1999) while *H. fasciatus* preyed on variety of items, from larvae and adult of insects to shrimps and fish fry, which confirms their minor-piscivorous feeding habit. Barreiros *et al.* (2002) discussed the feeding habit of *S. sphyraena* in Azores Island and found that the diet constituted 82.2% of Blue Jack mackerel, *Trachurus picturatus.* The preference of each grey mullet species examined in the estuary and the lagoon for a particular particle size was a way of partitioning the resource to avoid interspecific competition, thus ensuring their coexistence. This is in agreement with Nilson (1967), who reported that when two closely-related species coexist in one environment, various mechanisms may occur which permit this coexistence. Apart from detritus, an annual average of the diet composition shows the zooplankton–phytoplankton ratio in the food as 3: 2 (Stergiou & Karpouzi, 2002); similar feeding habits have been reported for round sardinella in northeastern Mediterranean. Hosseini *et al.* (2009) also found the main food of *S. sphyraena* in Bushehr Province waters to be two types of fishes, *Liza subviridis* and *Tenualoza illisia.* Comparatively, (Ugwumba & Adebisi, 1992) recorded that the food consumed by the populations of *H. fasciatus* in Tarkwa bay and the Lagos lagoon in Nigeria consisted principally of fish. Barreiros *et al*. (2002) on the diet composition and feeding habit of demersal fishes in Terengganu suggested that members of the genus *Sphyraena* are fish eaters. The differences in the variety of prey consumed by the wetland population and those in Nigeria could be related to the availability, abundance and diversity of potential prey in their respective environments. Fishes of the family Eleotridae and Gobiidae are generally known to be carnivores (Dankwa *et al*., 1999) and this predatory habit manifested in their diet in the wetland. Okyere *et al.* (2011a) reported that *K. kribensis* and *P. schlegelii* exploited copepods, oligochaetes and debris, chironomid larvae and fish scales.

Layman *et al.* (2007) and Svanback and Bolnick, (2005) identified that trophic niche breadth is influenced by a variety of factors, including food diversity and intraspecific competition. Tyler (1971) investigate monthly changes in stomach contents of demersal fishes in Passamaquoddy Bay and recorded that in fishes, feeding intensity is thought to decrease at lower temperatures due to lower metabolic demands. According to Bolnick *et al*., (2003) number of studies have investigated fish feeding patterns and trophic dynamics in tropical and subtropical marine environments. Most quantitative trophic studies involving fishes in which systems grouped diet data across seasons or did not investigate whether seasonal diet patterns existed (Nagelkerken & van der Velde, 2004; Nagelkerken *et al.,* 2006). However, studies from mostly temperate marine and tropical freshwater systems have shown that seasonal changes in resource availability and environmental conditions influence fish feeding patterns (Hammerschlag *et al.,* 2010). Bolnick *et al.* (2003) mentioned that, despite the few studies examining seasonal variation in the diets of fish populations inhabiting subtropical marine systems; little is known about between individual variations in resource use within populations. According to Bolnick *et al.* (2002, and 2003), this individual level variation is called individual specialization and refers to individuals whose dietary niche is significantly narrower than that of the population.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

The study was conducted in the Kakum River Estuary and Benya Lagoon (Fig. 1) in the Central Region of Ghana. The Kakum River Estuary (1° 19' W, 5° 05' N) is located near Elmina and about 5 km West of Cape Coast (the regional capital). The estuary is formed by a twin river system, the Kakum River and the Sweet River, fringed by a mangrove system which are pristine in some areas and highly degraded in other areas. The inhabitants of the fringing communities depend on the estuary and the lagoon as a source of fish and water for domestic use.

Benya lagoon is located at Elmina (1° 23' W, 5° 05' N), it is an open lagoon. The lagoon lies to the west of Cape Coast in the Central Region of Ghana and is approximately 3 km from the Kakum River Estuary.

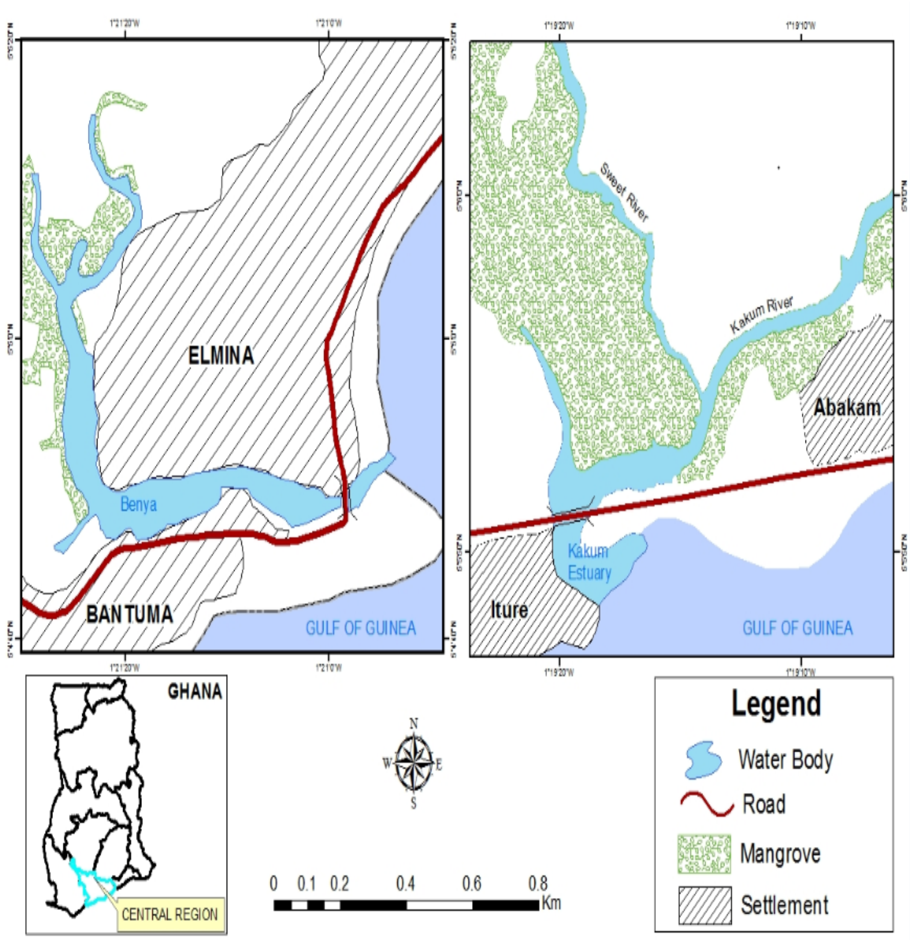

Figure 1: Map of Ghana and plate showing the location of Kakum River Estuary and Benya Lagoon

3.2 Diel measurements of temperature and salinity

Measurements of temperature and salinity were taken on each sampling date from November 2016 to April 2017 at 06:00, 10:00, 14:00, 18:00, 22:00, 02:00 and 06:00. Surface temperature and salinity were measured simultaneously using a HANNA multiparameter probe. Three replicates of each parameter were taken at different points of the water body during sampling and the average value was calculated.

3.3 Diel fish sampling and data collection

The fish from Kakum River Estuary and Benya Lagoon were sampled at the same time temperature and salinity were taken. Sampling was done within thirty (30) minutes on all sampling occasions. The fishes caught were preserved in 10% formalin immediately after capture to avoid post-mortem digestion of stomach contents. In the laboratory, fish were sorted into freshwater, brackish water and marine species and identified to their family and species level using fish identification manuals (Schneider, 1990; Kwei and Ofori-Adu, 2005). Individuals were measured for total length (TL, cm) and body weight (BW, g) to the nearest 0.1 cm and 0.01 g respectively. The biomass (wet weight), number of species and total number of marine fish caught during each sampling time were recorded to investigate their fluctuations. Stomach of each fish was examined and the various food items consumed were sorted and identified using (Newell and Newell 1963; Gibbons 1997).

3.4 Determination of length-weight relationship

The length of each species was obtained by pooling the six (6) months data. The length and weight of the species were plotted as scatter diagrams and a regression of the logarithmetic transformation data was carried out to obtain the regression equation. InBw = Ina+bInTL

All relationships were described by the equation:

$BW = aTL^b$

where BW is the weight (g), TL is the total length in cm, 'a' is the intercept and 'b' is the slope. The parameters a and b were estimated by:

$InBW = InBW + b\ InTL$

The 95% confidence limits for b (CL 95%) were calculated using the equation: CL= b ± (1.96 x SE) where SE is the standard error of b. Values of the exponent b provide biological information on kind/pattern of growth of fish. The growth is isometric if b = 3 and the growth is allometric if $b \neq 3$ (negatively allometric if $b < 3$ and positively allometric if $b > 3$). The Student's t-test was conducted as expressed by the equation according to Sokal and Rohlf (1987) to check if the value of b is significantly different from 3. The Student's t-test was calculated for the equation:

$t_s = (b-3) / SE$

All the statistical analyses were considered at significance level of 5%.

3.5 Determination of marine fish species composition

The percentage composition of each fish species was determined as the number of each species, divided by the total number of fish caught and the resulting value expressed as a percentage**.**

3.6 Calculation of ecological diversity indices

The composition and structure of each brackish water community were determined using the Shannon-Weiner function (Molles, 1999) calculated as follows:

$$H' = -\sum_{i=1}^{s} P_i \, (lnP_i)$$

where P_i is the proportion of individuals belonging to species i in the community.

The evenness component of diversity was calculated from Pielou's index (Pielou, 1966) as follows:

$$J' = \frac{H'}{H_{max}}$$

where H_{max} = ln*s*.

Margalef's richness index (Krebs, 1999) was estimated as:

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

where S is the number of species and N is the total number of individuals in the samples.

3.7 Determination of similarity between the fish communities

The degree of similarity between the marine fish communities in the Benya lagoon and Kakum estuary was determined by the Sorensen's coefficient (Southwood, 1978) given as:

$$C_s = \frac{2j}{a+b}$$

where C_s is Sorensen's index which ranges from 0 (dissimilar) to 1 (completely similar), *j* is the number of species common to the two water bodies, and *a* and *b* are the number of species occurring in either water body.

3.8 Stomach content analysis

Stomach contents were analysed by the frequency of occurrence method. The percentage frequency of a food item was determined as the number of stomachs containing the item expressed as a percentage of the total number of stomachs.

CHAPTER FOUR

RESULTS

4.1 Fish species occurrence in the two brackish waters

Fishes caught in the Kakum River Estuary and Benya Lagoon are listed in Table 1. In Kakum River Estuary, a total of 25 species belonging to 16 families were sampled while 24 species of fishes belonging to 16 families were sampled in Benya Lagoon.

While the brackish water species *Sarotherodon melanotheron* (Cichlidae) and *Aplocheilichthys spihauchen* (Cyprinodontidae) and the freshwater fish *T. zilli* (Cichlidae) occurred in both water bodies, the freshwater fish *P. leonensis* was found only in the Kakum River Estuary, and the remaining 23 species belonging to 15 families were of marine origin.

Table 1: Occurrence of marine and non marine species in Kakum River Estuary and Benya Lagoon (FW= fresh water, BW= brackish water), + present, - absent

FAMILY	SPECIES	KAKUM ESTUARY	BENYA LAGOON
Cichlidae	*Sarotherodon melanotheron* (BW)	+	+
	Tilapia zilli (FW)	+	+
Cyprinodontidae	*Aplocheilichthys spilauchen* (BW)	+	+
Clupeidae	*Pellonulla leonensis* (FW)	+	-
	Sardinella aurita	+	+
Bothidae	*Citharichthys stamflii*	+	+
Mugilidae	*Liza falcipinnis*	+	+
	Liza dumerillii	+	+
	Mugil bananensis	+	+
	Mugil curema	+	+
	Mugil cephalus	+	+
Lutjanidae	*Lutjanus fulgens*	+	+
	Lutjanus goreensis	+	+
	Lutjanus agennes	+	+
Gobiidae	*Bothygobius soporator*	+	+
	Porogobius schlegelii	+	+
Carangidae	*Caranx hippos*	+	+
Sciaenidae	*Pseudotolithus typus*	+	-
	Pseudotolithus senegalensis	-	+
Elopidae	*Elops lacerta*	+	+
Gerreidae	*Eucinostomus melanopterus*	+	+
Serranidae	*Epinephelus aeneus*	+	+
Ariidae	*Arius gigas*	+	+
Haemulidae	*Plectorhynchus macrolepis*	+	+
Acanthuridae	*Acanthurus monroviae*	+	+
Scombridae	*Scomberomorus tritor*	+	-
Cynoglossidae	*Cynoglossus canariensis*	-	+
Total number of Families sampled		16	16
Total number of species sampled		25	24

4.2 Percentage composition of marine species in the two water bodies

The composition of marine species in Kakum River Estuary and Benya Lagoon is represented in Figure 2. In Kakum River Estuary, the grey mullet *M. curema* was the most abundant fish with compositions of 18.50% while the other grey mullets *M. bananensis*, *L. dumerilli* and *L. falcipinnis* made up 12.95%, 13.10%, and 9.40%, respectively. *M. cephalus* was the least species representing 0.65% in the estuary. *Caranx hippos* were the third most common fish with compositions of 12.88%. The remaining species had composition of less than 10%.

In Benya lagoon, the grey mullet *M. bananensis* was the most abundant fish with a composition of 41.5% while the other grey mullets, *M. curema* and *Liza falcipinnis* made up to 21.10% and 12.06%, respectively. The remaining species had compositions of less than 10%.

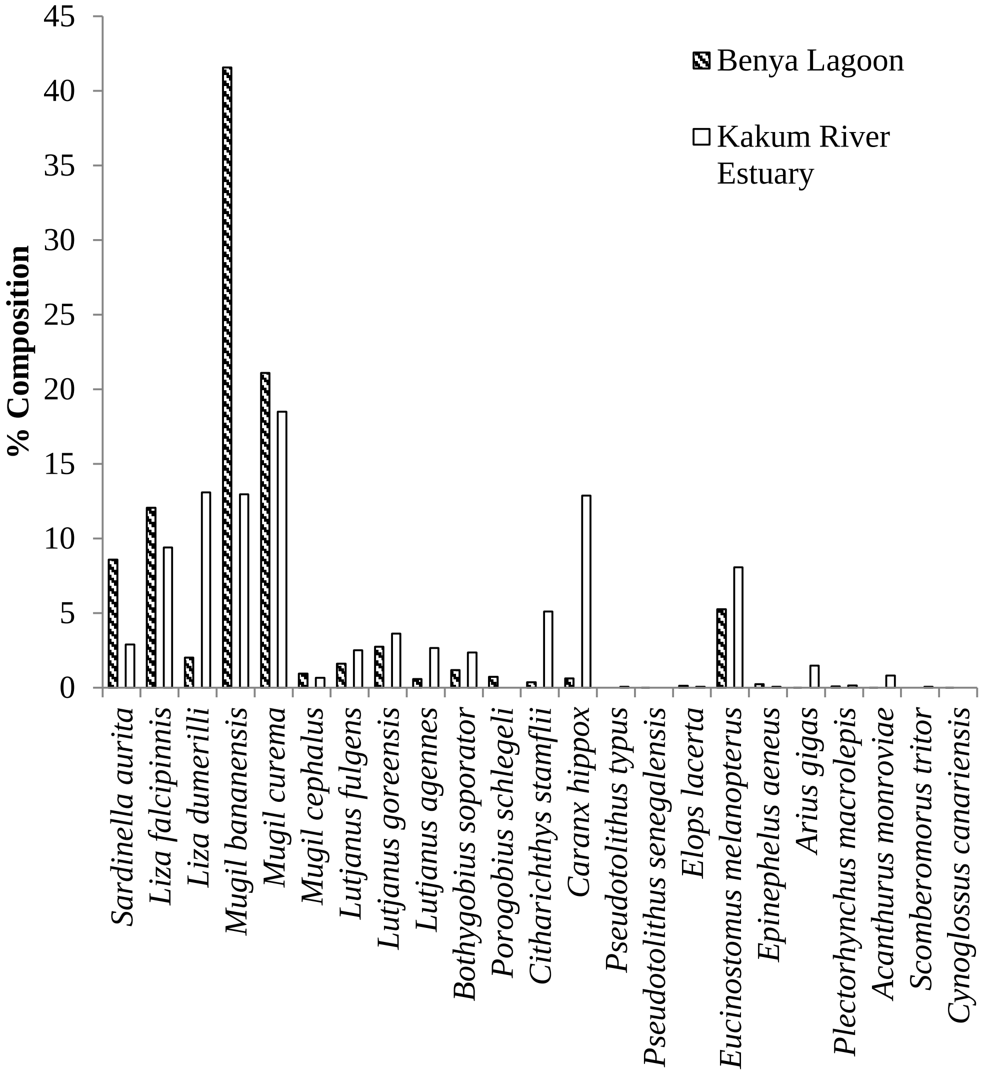

Figure 2: Percentage composition of marine fish species in Kakum River Estuary and Benya lagoon

4.3 Size range and modal size of marine fish species in the two water bodies

The size range and the modal class of the marine species in the estuary and the lagoon are presented in Table 2. A total of 1,327 fish were sampled from the estuary. The species in the estuasry measured 2.2 cm in *L. dumerilii* to 29.8 cm in *M. curema*. The modal length of the commonest species *L. falcipinnis*, *L. dumerilli*, *M. bananensis*, *M. curema*, *E. melanopterus* and *C. hippos* were 11-11.9, 8-8.9, 7-7.9, 8-8.9, 8-8.9 and 4-4.9 cm respectively.

A total of 2,226 fish were sampled from the lagoon. The species in the Lagoon measured 3.2 cm in *L. goreensis* to 22.4 cm in *M. bananensis*. The modal length of the commonest species *L. falcipinnis*, *M. bananensis*, *M. curema*, *E. melanopterus* and *S. aurita* were 10-10.9, 7-7.9, 7-7.9, 6-6.9 and 7-7.9 cm respectively.

Table 2: The size range of marine species in Benya lagoon and Kakum river estuary

FAMILY	SPECIES	Kakum River Estuary			Benya Lagoon		
		No.	Size Range (TL cm)	Modal Size (cm)	No.	Size range (TL cm)	Modal Size (cm)
Clupeidae	*Sardinella aurita*	39	7.1 - 17.6	8-8.9	191	5.9 - 10.5	7-7.9
Mugilidae	*Liza falcipinnis*	127	5.1 - 16.6	11-11.9	268	5.3 - 14.3	10-10.9
	Liza dumerilli	177	2.2 - 20.9	8-8.9	45	5.3 - 19.7	9-9.9
	Mugil bananensis	175	4.4 - 15.5	7-7.9	924	5.3 - 22.4	7-7.9
	Mugil curema	250	4 - 29.8	8-8.9	469	6.1 - 16.7	7-7.9
	Mugil cephalus	9	9.6 - 12.4	10-10.9	21	8.1 - 10.7	7-7.9
Lutjanidae	*Lutjanus fulgens*	34	5.1 - 16	6-6.9	36	4 - 9.4	8-8.9
	Lutjanus goreensis	49	5.1 - 15.8	5-5.9	61	3.2 - 10.5	5-5.9
	Lutjanus agennes	36	6.2 - 26.6	6-6.7	13	5.4 - 8.5	6-6.9
Gobiidae	*Bothygobius soporator*	32	4.1 - 12.4	7-7.9	26	6.5 - 13	10-10.9
	Porogobius schlegeli	-	-	-	16	7.9 - 12.8	10-10.9
Bothidae	*Citharichthys stampflii*	69	4.3 - 15.3	7-7.9	8	4.1 - 8.9	8-8.9
Carangidae	*Caranx hippos*	174	3.4 - 14.4	4-4.9	30	4 - 13.7	11-11.9
Sciaenidae	*Pseudotolithus typus*	1	9.3	-	-	-	-
	Pseudotolithus senegalensis	-	-	-	1	9.3	-
Elopidae	*Elops lacerta*	3	9 .6 – 10.2	9-9.9	1	9.8	-
Gerreidae	*Eucinostomus*	109	4.6 - 18.5	8-8.9	117	4.9 - 10.7	6-6.9

Table 2 contiuned

	melanopterus						
Serranidae	*Epinephelus aeneus*	1	8.4	-	5	6.9 - 8.2	7-7.9
Ariidae	*Arius gigas*	20	7.9 - 21.8	9-9.9	1	8.4	-
Haemulidae	*Plectorhynchus macrolepis*	2	4.9 - 7.6	-	2	4.5	-
Acanthuridae	*Acanthurus monroviae*	11	5.2 - 11.5	5-5.9	1	4.7	-
Scombridae	*Scomberomorus tritor*	1	5.0	-	-	-	-
Cynoglossidae	*Cynoglossus canariensis*	-	-	-	1	6.0	-
Total number of individuals		**1,321**			**2,237**		

4.4 Length-weight relationship of abundant species

Kakum River Estuary

A strong correlation (r = 0.84 to 0.97) was determined for the length-weight relationships of the nine species examined in the estuary (Table. 3). The regression coefficient *b* was significantly lower than the hypothetical value of 3.0 for the *L. dumerilli, C. hippos* and *M. bananensis* stock in the estuary indicating that the species exhibited negative allometric growth.

The coefficient *b* was significantly higher than 3.0 for *E. melanopterus and S. aurita* indicating that the species are growing isometrically but in *L. falcipinnis,* and *M. curema, L. fulgens, L. goreensis,* the regression coefficient *b* was significantly closer to the hypothetical value of 3.0 stock in the estuary indicating that the species are growing isometrically.

Table 3: The length-weight relationships of 9 abundant fish species collected from the Kakum River Estuary.

Fish species	**No**	***a***	***b***	**r**
Liza dumerilli	167	0.04	2.38±0.08	0.84
Liza falcipinnis	127	0.02	2.72±0.14	0.93
Mugil bananensis	175	0.03	2.48±0.14	0.92
Mugil curema	250	0.02	2.72±0.18	0.78
Sardinella aurita	39	0.01	3.07±0.21	0.96
Eucinostomus melanopterus	109	0.01	3.10±0.10	0.97
Lutjanus fulgens	34	0.02	2.97±0.20	0.96
Lutjanus goreensis	49	0.02	2.85±0.22	0.96
Caranx hippos	174	0.03	2.53±0.11	0.91

Note: *a, intercept; b, slope; r, Correlation coefficient*

Benya lagoon

The length-weight relationship for the commonest species in Benya lagoon (Table 4) showed strong correlations ranging from 0.78 to 0.97. The regression coefficient *b* was significantly higher to the hypothetical value of

3.0 for the *E. melanopterus* stock in the Benya Lagoon indicating that the species is growing isometrically. The regression coefficient *b* was significantly closer to the hypothetical value of 3.0 for the *L. fulgens, L. goreensis, L. dumerilli, L. falcipinnis, M. bananensis, M. curema, S. aurita, and C. hippos* stock in the Benya Lagoon indicating that the species are growing isometrically

Table 4: The length-weight relationships of 9 abundant fish species collected from the Benya Lagoon.

Fish species	No	*a*	*b*	r
Liza dumerilli	45	0.01	2.83±0.10	0.98
Liza falcipinnis	268	0.02	2.75±0.06	0.96
Mugil bananensis	924	0.02	2.69±0.06	0.93
Mugil curema	469	0.02	2.61±0.01	0.88
Sardinella aurita	191	0.01	2.95±0.12	0.92
Eucinostomus melanopterus	117	0.01	3.04±0.20	0.91
Lutjanus fulgens	36	0.02	2.76±0.17	0.98
Lutjanus goreensis	61	0.02	2.84±0.11	0.97
Caranx hippos	30	0.01	2.97±0.10	0.99

Note: *a, intercept; b, slope; r, Correlation coefficient*

4.5 Diversity of marine fish species

The diversity indices for Kakum River Estuary and Benya Lagoon are shown in Table 5. The values suggest higher species richness and diversity in Kakum River Estuary than Benya Lagoon. The distribution of the number of individuals among the various species was more even in Kakum River Estuary than Benya Lagoon.

Table 5: Richness diversity and evenness indices for the fish communities of the two water bodies

Water Body	No. of species	Richness (*d*)	Diversity (H')	Evenness (*j*)
Kakum River Estuary	25	3.34	2.05	0.65
Benya Lagoon	24	2.98	1.55	0.49

4.6 Similarity between the estuarine and lagoon marine fish communities

The Sorensen's index of similality (Cs) was calculated to be 0.89 which shows that the two communities of marine fish nursing in the estuary and the lagoon were very similar.

4.7 Diel fluctuations in number of marine species, abundance and biomass of fish

Kakum River Estuary

The number of species caught at different times from the estuary varied from 4 to 11 during the six (6) month study period (Fig. 3a). A diel cycle in number of species occurred on 16/11/2016 with low number of species during the day increasing to a peak at 22:00 hours. Two peaks in number of species were recorded at 14:00 and 02:00 on 10/12/2016 and at 10:00 and 22:00 on 12/01/2017. There were no clear patterns in the fluctuations on the remaning dates.

Fish abundance at the different sampling times (Fig. 3b) was clearly higher on 10/12/16 than the other sampling dates, ranging from a mean of 41 fishes to a mean of 90 fishes. Abundance was higher at 22:00 hours and 2:00 hours and lower at 6: 00 at the start of the sampling. On 10/11/16, fish numbers ranged from 14 at 6: 00 to a peak of 46 at 22: 00. On 15/02/2017, the peak fish number was recorded at 22:00. On 20/04/2017 the peak fish number was recorded at 14:00 hours.

The total biomass varied considerably from a mean of 87.31 in the day at 6:00 hours to a peak of 1,067.57 during the night at 22:00 on 16/11/2016. Low biomass was obtained from a mean of 226.06 during the day at 6:00 and reached a peak of 1,067.57 during the night at 22:00 on 10/12/2016. On 12/01/2017, biomass of fish was low from 152.15 in the day at 6:00 to a peak of 839.55 during the night cycle at 2:00 (Fig. 3c). There were no clear patterns in the fluctuations on the remaning dates.

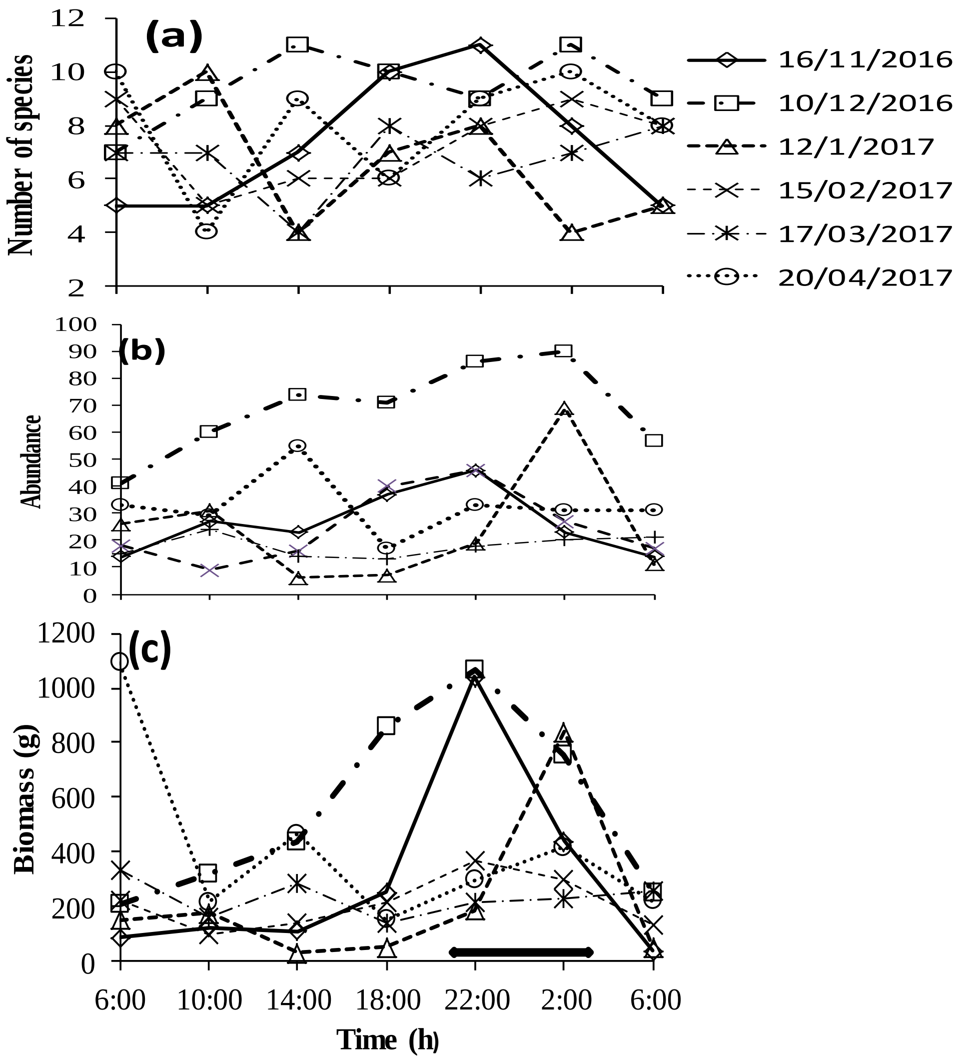

Figure 3: Diel fluctuations in the (a) number of species, (b) abundance and (c) biomass (wet weight) of fish caught from Kakum River Estuary

Benya lagoon

The number of species caught on 20/11/2016 varied from 4 at 6:00 hours at the start of the sampling to a peak of 10 at 14:00 hours. The number fluctuates between 1 and 6 for the rest of the period. On 25/04/2017, number of species varied from 3 at 6:00 hours at the beginning of sampling to a peak of 14 at 22:00 hours. No clear patterns were visible on the other sampling dates (Fig. 4a).

Likewise there was considerable variation in the total number of individuals caught per time period with low number from 14 at 6:00 and reached a peak of 91 at 14:00 during the day on 20/11/2016. On 20/12/2016, lower number of fish was caught from 23 at 6:00 to a peak of 107 at 18:00 during the day and a lower number of fish were caught on 15/01/2017 from 57 at 6:00 to a peak of 93 at 10:00 during the day (Fig. 4b). There were no clear patterns in the fluctuations on the remaning dates.

The total biomass varied considerably from a mean of 76.48 at 6:00 and reached a peak of 718.4 mean at 14:00 during the day on 20/11/2016. On 20/12/2016, low biomass was obtained from a mean of 158.96 at 6:00 during the day cycle to a peak of 617.28 mean at night 22:00 hours. Low biomass of fish was recorded from a mean of 296.48 during the day at 6:00 to a peak of 1222.28 mean during the night period at 22:00 on the 15/01/2017 (Fig. 4c). There were no clear patterns in the fluctuations on the remaning dates.

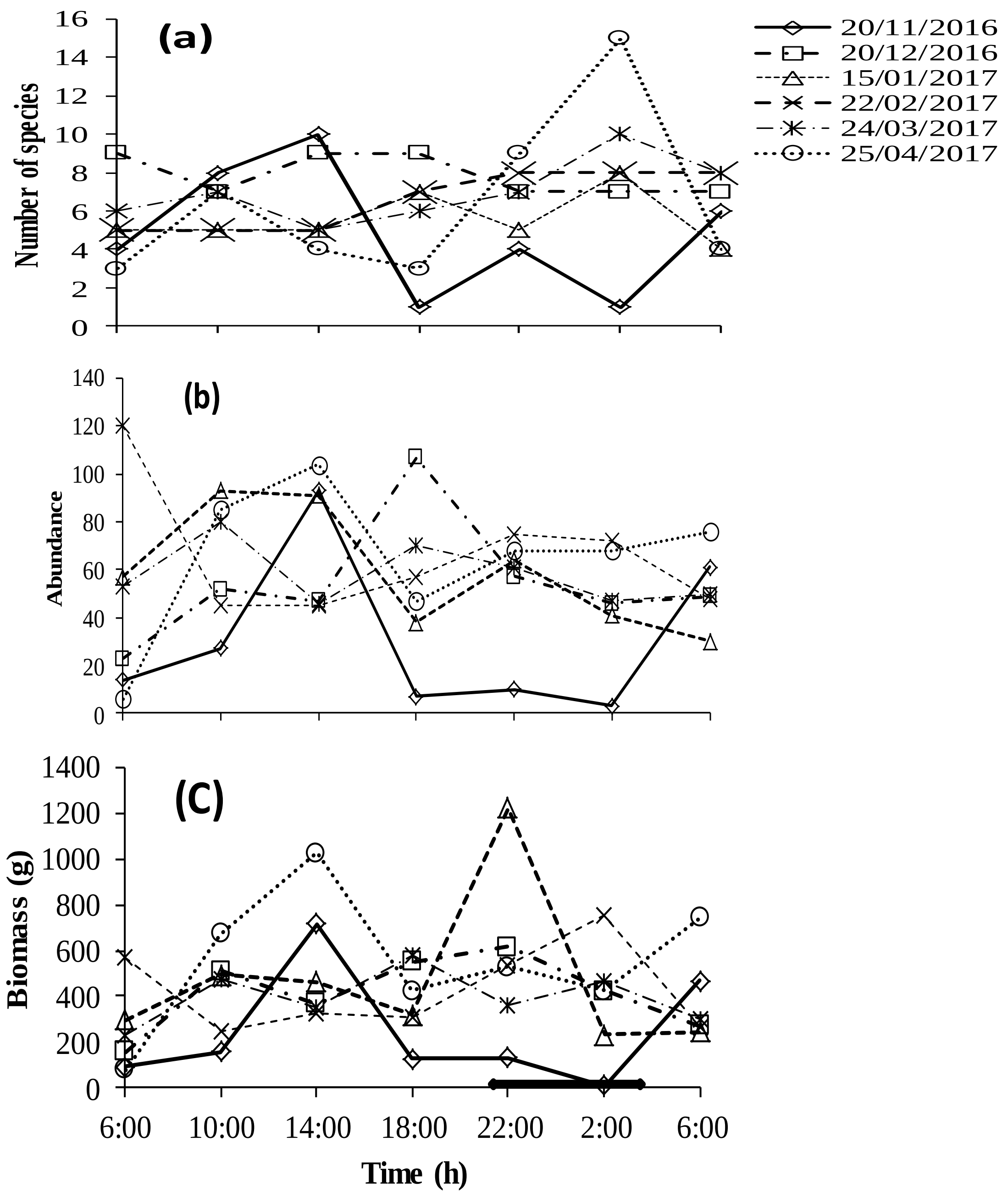

Figure 4: Diel fluctuations in the (a) number of species, (b) abundance and (c) biomass (wet weight) of fish caught from Benya Lagoon

4.8 Diel Variations in Temperature and Salinity

Kakum Estuary

Surface water temperature ranged from 26.2 °C to 36.2 °C at the different sampling times. The peak water temperature was recorded on 16/11/2016, 15/02/2017, 17/03/2017 and 20/04/2017 at 14:00 h measurements (Fig. 5a). There were no clear patterns in the fluctuations on the remaning dates. Temperature was highest on 17/03/2017 and low on 16/11/2016 through out the times of sampling

Salinity ranged from 2.1 ‰ to 30.3 ‰ at the different sampling times (Fig 5b). There was not much variation in salinity between 10/12/2016, 12/01/2017, 15/02/2017 and 17/03/2017 with exception of 16/11/2016 where high salinity of 16.57 ‰ was recorded at 2:00 hour and on 20/04/2017, where two peaks of salinity occurred at 10:00 and 22:00 hours with low salinity in the other sampling times.

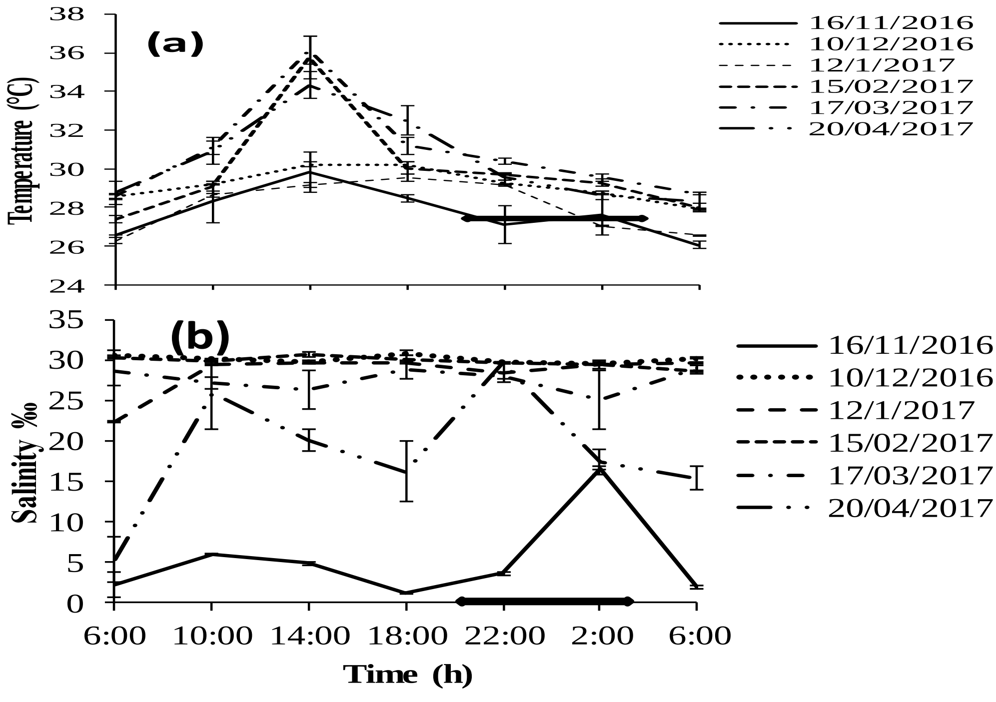

Fig. 5: Diel Variation of (a) temperature and (b) salinity (Error bars: +/- 1 SE) in the Kakum River Estuary (↔: dark period) on Nov 2016- April 2017

Benya Lagoon

Surface water temperature ranged from 24.6 °C to 32.9 °C at the different sampling dates. The peak water temperature of 32.9 °C and 32.8 °C was recorded on 20/11/16 and 25/04/2017 respectively at 14:00 hour measurements (Fig. 6a). The highest temperature was measured in 20/11/ 2016 and 25/04/2017 with the lowest temperature being measured on 15/01/17.

There were similar pattern in the fluctuations of temperature in all the months where high temperature occurred at 14:00 hour measurements with exception of 24/03/2017 where there was a drop in temperature from 29.8 °C at 10:00 to 26.2 °C at 14:00 hour and increased to 29.7 °C at 18:00 hours.

Salinity ranged from 27.8 ‰ – 32.2 ‰ during the study period. There was not clear pattern in the fluctuations of salinity between the different times of sampling. The peak salinity of 31.3 ‰, 31.6 ‰ and 30.8 ‰ was recorded on 15/01/2017, 22/02/2017 and 24/04/2017 respectively (Fig. 6b). The highest salinity was measured on 22/02/ 2017 at 6:00 hours at the start of the study with the lowest salinity on 24/03/2017 at 2:00.

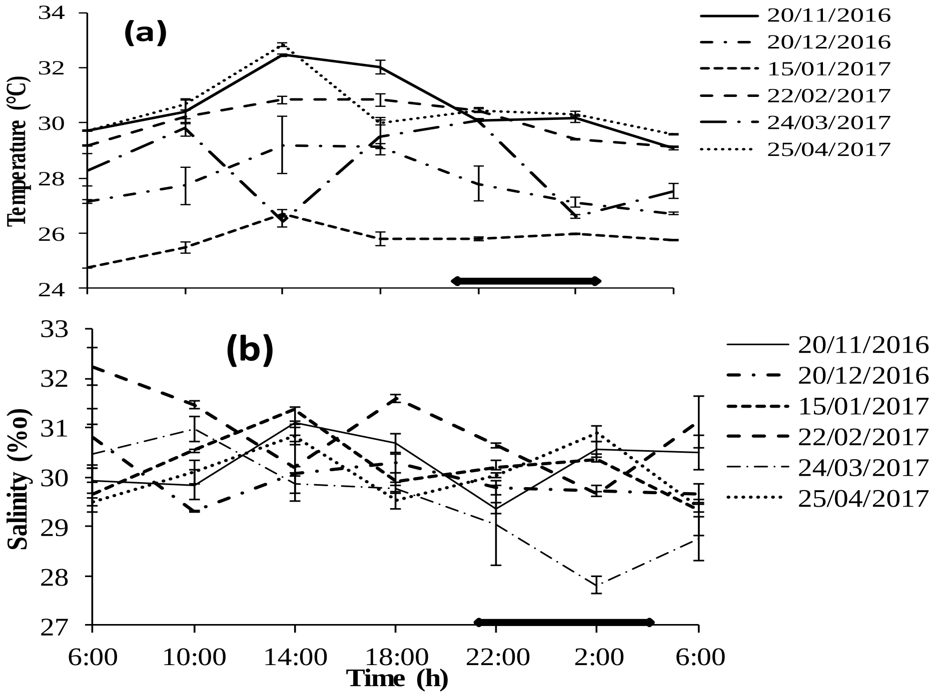

Figure 6: Diel Variation of (a) temperature and (b) salinity (Error bars: +/- 1 SE) in the Benya lagoon (↔: dark period) on Nov 2016- April 2017

4.9 Diel fluctuations in number and biomass of fish, and environmental parameters (combined data)

Kakum River Estuary

Fish abundance of the combined data at different sampling times (Fig. 7a) was clearly higher at 22: 00 and 2: 00 hours and lower in the other sampling times, ranging from a mean of 24 fishes to a mean of 44 fishes.

Fish biomass (g) was higher at 22 hours and 2 hours (Fig. 7b) and lower in the other sampling times ranging from a mean of 150 g at 6:00 h from the beginning of sampling to a mean of 540 g at 22:00 h during the night.

Combined data for the diel surface temperatures of the estuary (Fig. 7a) showed a clear diurnal cycle with a peak at 14:00 and low temperature in the other sampling times.

The salinity of the estuary (Fig. d) showed a clear diurnal cycle with a peak at 10:00 and 22:00 hours measurements.

There were similar pattern in the fluctuations of fish abundance, biomass and salinity at 18:00, 22:00, 2:00 and 6:00 hours where abundance, biomass and salinity increased to a peak at 22:00 and 2:00 hours and declined at 6:00 the next day (Fig. 7).

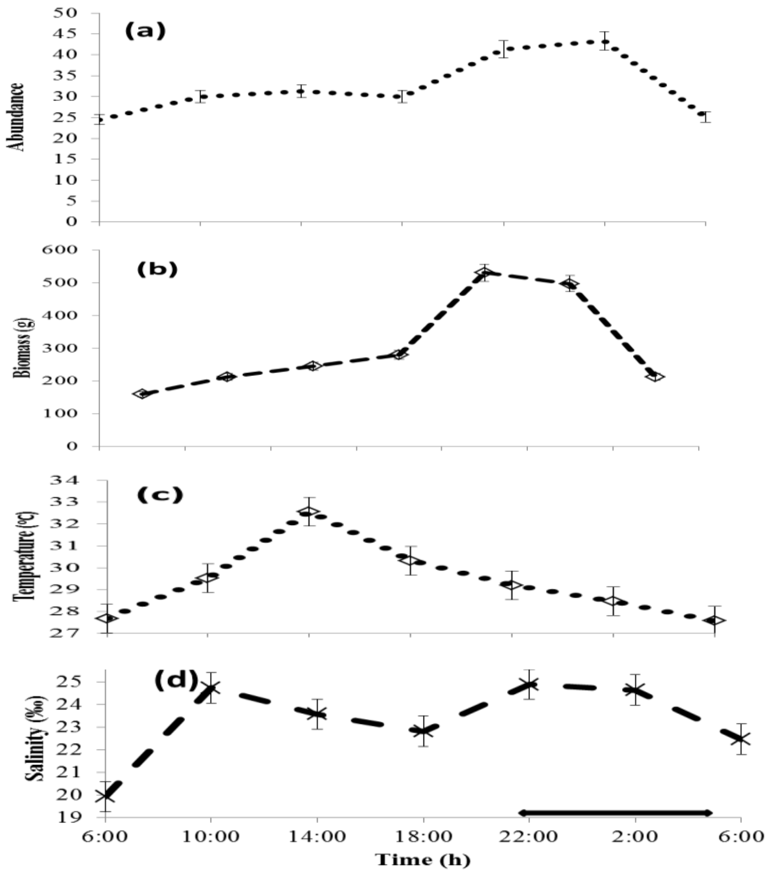

Figure 7: Mean (a) abundance and (b) biomass (wet weight) of fish caught, mean (c) temperature (^{o}C) and (d) salinity of Kakum River Estuary (↔: dark period) from November 2016 – April 2017 (vertical bars denoted standard erro)

4.11 Diel fluctuations in number and biomass of fish, and environmental parameters (combined data)

Benya lagoon

The mean of the total number of fish caught in the lagoon over the diel period varied considerably from 45 during the day at 6:00 hour to a peak of 73 during the day at 14:00 hours and the mean biomass of fish caught from the lagoon varied from 230 during the day at 6:00 to a peak of 565 during the night at 22:00 hour (Fig. 8a).

Diel surface temperatures of the lagoon varied from 28.13 ^{o}C which continued to increase reaching a peak of 29.75 at 14:00 duriing the day with a decline in the remaining times (Fig. 8c)

The trend in salinity changes therefore did not suggest a diurnal fluctiation (Fig. 8d). The salinity of the lagoon was high from 6:00 at the start of sampling to 14:00hour measurments and gradualy decreased in the remaning sampling times.

Similar pattern occurred in the fluctuations of fish abundance, biomass and temperature at 6:00, 10:00 and 14:00 hours where abundance, biomass and temperature increased from 6:00 during the day to reach a peak at 14:00 hours and declined at 18:00 (Fig. 8).

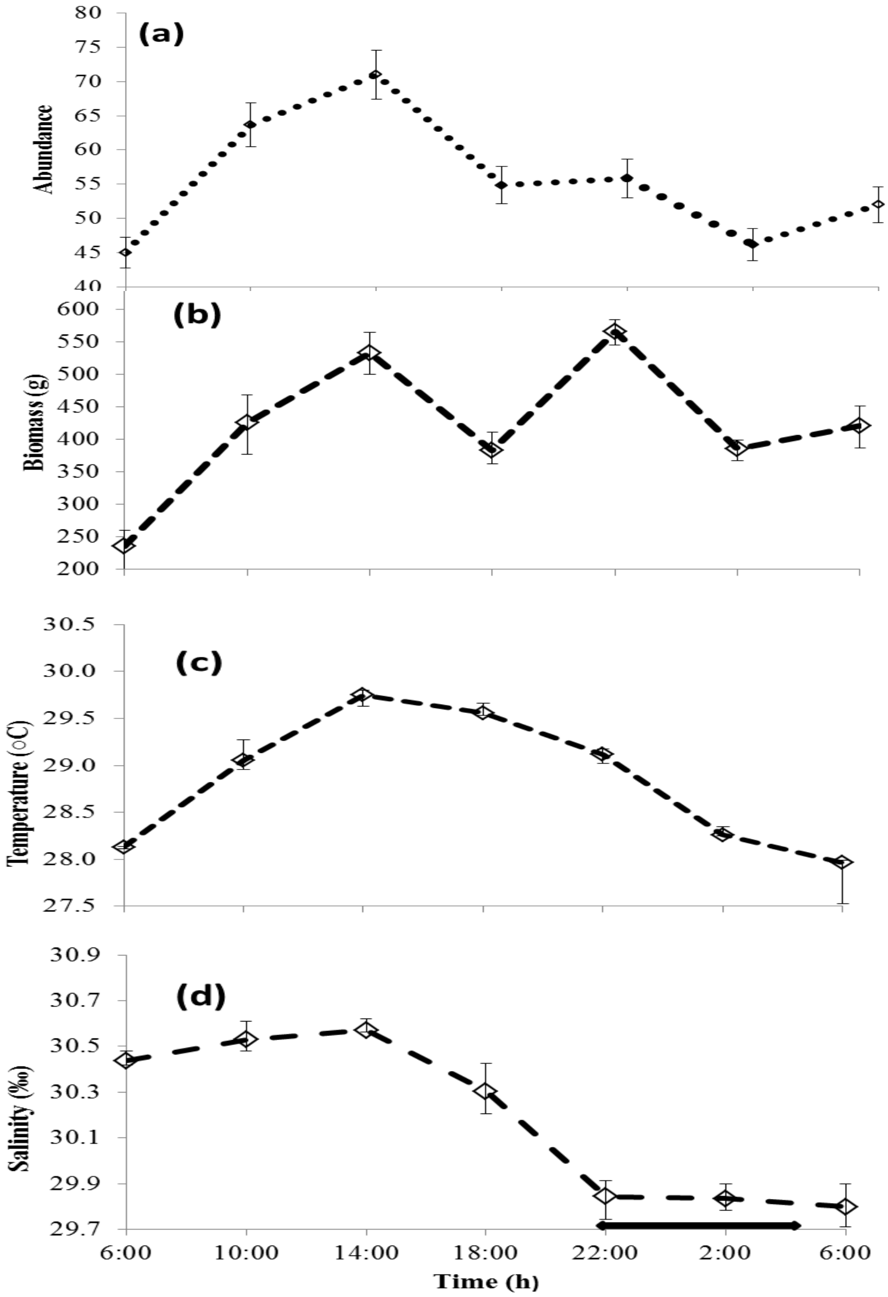

Figure 8: Mean (a) abundance, (b) biomass (g) of fish caught, (c) temperature (°C) and (d) salinity (‰) of Benya Lagoon (↔: dark period) from November 2016 – April 2017 (vertical bars denoted standard erro)

4.12 Food Habits of Juvenile Marine Fishes

Mugilidae

Members of the family Mugilidae namely *Liza falcipinnis, Liza dumerillii, Mugil bananensis, Mugil cephalus* and *Mugil curema* consumed mainly diatoms, green algae, detritus, blue green algae, zooplankton and sand (Fig. 9). Apart from mollusk larvae that were found in the stomachs of *L. falcipinnis, L. dumerilli, M. bananensis,* and *M. curema* form Benya lagoon, fish flesh was found in the stomachs of *M. bananensis* and *M. cephalus* from the estuary and in the stomachs of *L. falcipinnis*, and *M. dumerillii* from Benya lagoon. Fish eggs were common only in the stomachs of *M. curema.* All the other food items were common in the stomachs of all the species from the two water bodies. Copepods were the dominant zooplankton in the diet of the Mugilidae from both the estuary and the lagoon.

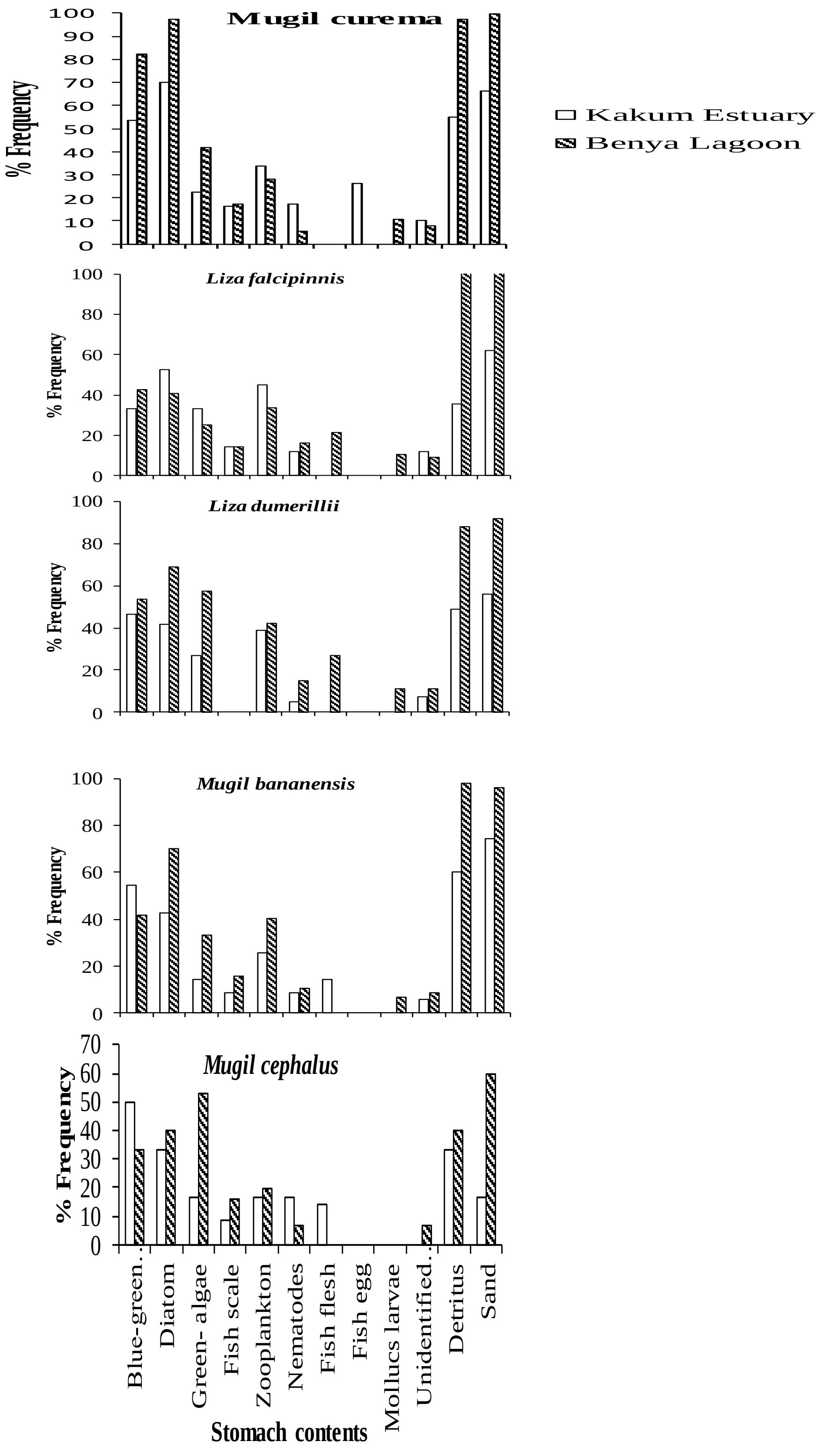

Figure 9: Frequency of occurrence of food items in the stomach of *Mugil curema, Liza falcipinnis, Liza dumarilli, Mugil bananensis,* and *Mugli cephalus* from Kakum River Estuary and Benya Lagoon

Carangidae

A total of 51 *Caranx hippos* from Kakum River Estuary and 23 from Benya lagoon were examined. This species from Kakum river estuary and Benya lagoon consumed nematodes, fish, shrimps and fish (Fig. 10). The most common item eaten by this species from the estuary were shrimps which occurred in about 68.63% and the least occurring food items nematodes (7.84%). *C. hippos* from Benya lagoon also consumed more on shrimps which occurred in 80.1% of the sstomachs examined and the least food iteams eaten were nematodes which occurred in 18.70% of the stomachs.

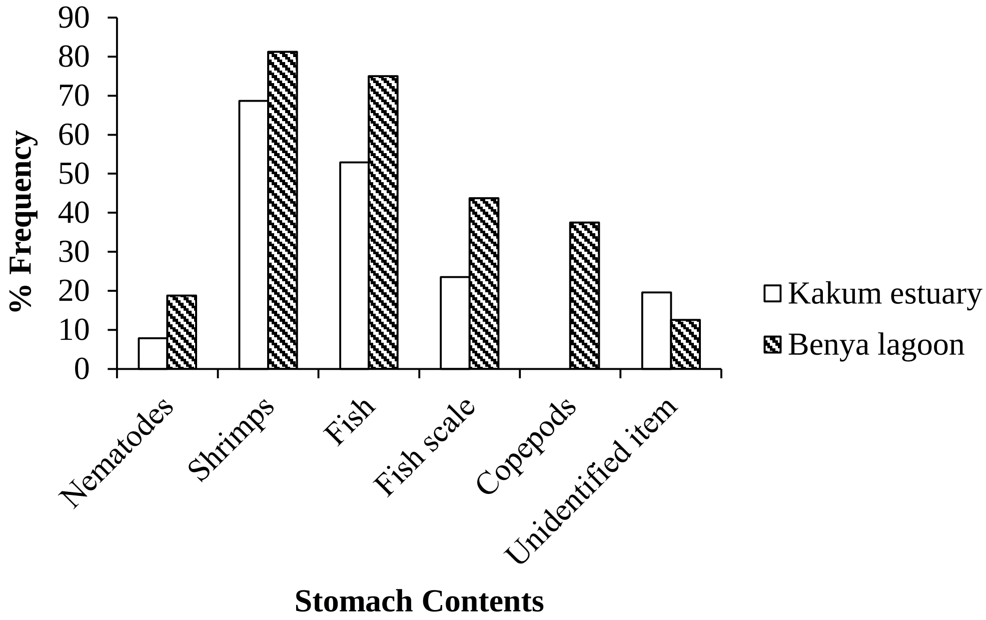

Figure 10: Frequency of occurrence of food items in the stomachs of *Caranx hippos* from Kakum River Estuary and Benya Lagoon

Clupeidae

Sixteen stomachs of *Sardinella aurita* from Kakum river estuary and 51 from Benya Lagoon were examined (Fig. 11). Copepods, protozoans, fish eggs, fish fry, diatoms, dinoflagellates, fish larvae and detritus were the food components recorded from the stomachs of this species from both estuary and the Lagoon. This species from the estuary and the lagoon preyed more on copepods which occurred in 78.57% of stomachs of the former and 82.69% of the latter. Dinoflagellates were the least common food items consumed by *Sardinella aurita* from the lagoon (9.62%) while in the estuary, they consumed 42.86% of the stomachs examined. Fish fry occurred in 36.81% *S. aurita* from the estuary but did not occur in the stomchs of this species from the lagoon. The other food item consumed by this species was detritus with an occurrence of 57.14% and 34.62% for the estuary and the lagoon respectively.

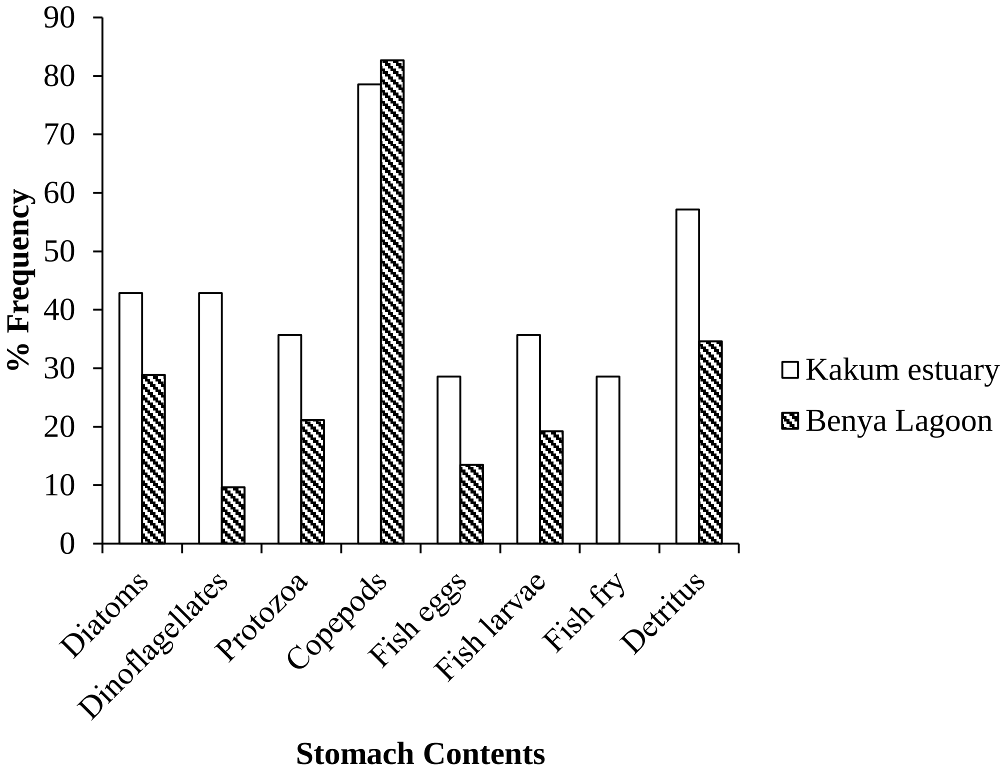

Figure 11: Frequency of occurrence of food items in the stomachs of *Sardinella aurita* from Kakum River Estuary and Benya lagoon

Lutjanidae

Fish of the family Lutjanidae namely *Lutjanus fulgens, Lutjanus goreensis and Lutjanus agennes* mainly consumed fish, shrimps, fish scale, crabs, fish egg, fish flesh, shrimp appendages and unidentified food items (Fig. 12). Apart from fish scales that were not found in *Lutjanus agennes* of the two water bodies, fish, shrimps, and crabs were common in the stomachs of all the species from the two water bodies. The dominant food item in the diet of *Lutjanus agennes* from the estuary was fish with an occurrence of 69% in stomachs examined. Fish and crabs were however the dominant food items in the stomachs of *L. goreensis* from the estuary. In the lagoon, fish scales and crabs were respectively the dominant food items in the diet of *L. fulgens*, and *L. goreensis*, occurred in 52% and 50% of the stomachs examined, *L. goreensis* fed on shrimps and fish scales with an occurrence of 40% of the

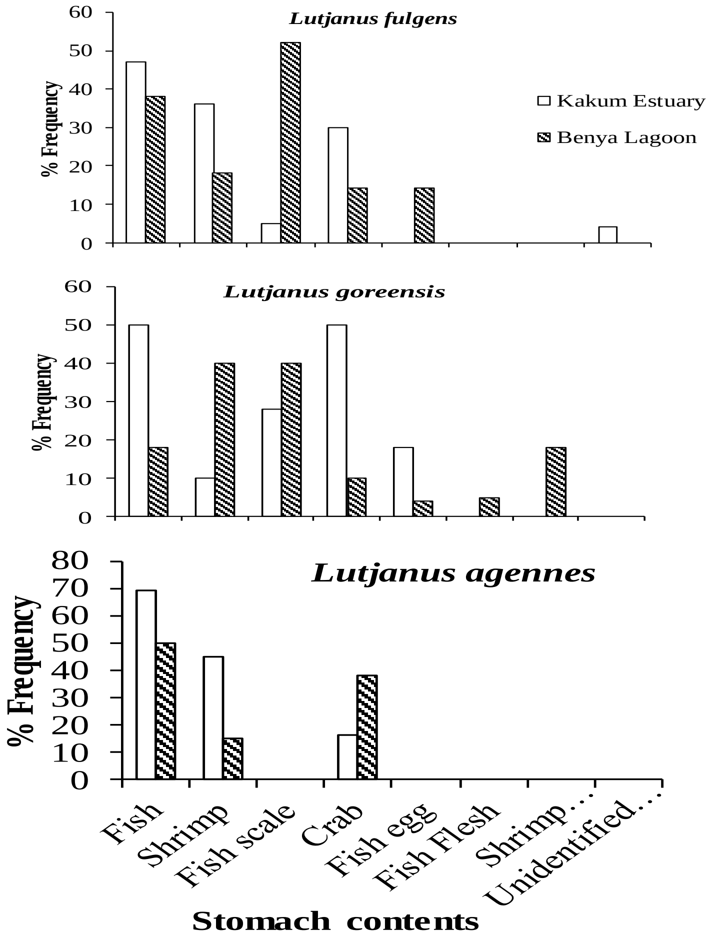

Figure 12: Frequency of occurrence of food items in the stomachs of *Lutjanus fulgens*, *Lutjanus goreensis* and *Lutjanus agnnens* from Kakum River Estuary and Benya lagoon

Gerreidae

Thirty one (31) specimens of *Eucinostomus melanopterus* from Kakum river estuary and thirty four (34) individuals from Benya lagoon were examined. The food items found in the stomachs of this species from both the estuary and the lagoon were copepods, annelids, fish larvae and and unidentified items (Fig. 13). This species from the estuary and the lagoon mostly preferred annelids which occurred in 58.06% and 61.76% of the stomachs followed by copepods which occurred in 48.39% and 44.12%, respectively. Fish larvae had percentage occurrence of 9.68% and 26.47% for both the estuary and the lagoon fish, respectively. Fish larvae and unidentified items had low frequencies in samples from the estuary and the lagoon.

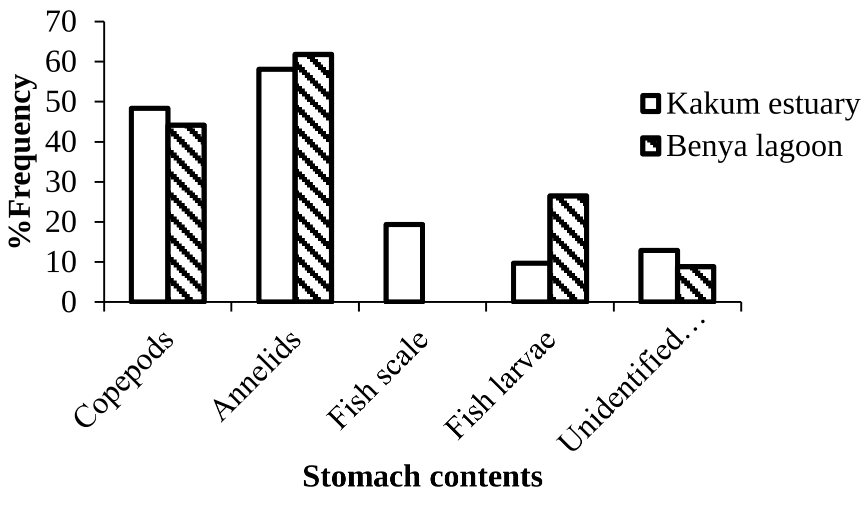

Figure 13: Frequency of occurrence of food items found in the stomachs of *Eucinostomus melanopterus* from Kakum river estuary and Benya lagoon

Bothidae

Thirteen (13) specimens of *Citharichthys stampflii* from Kakum River Estuary and two from Benya Lagoon were examined. Specimens from Kakum River Estuary fed on fish, shrimps, fish scale, and shrimp larvae while at Benya Lagoon, this species fed on fish only.

Acanthuridae

Six (6) specimens of *Acanthurus monroviae* from Kakum River Estuary were examined. The detailed analysis of the food consumed by *Acanthurus monroviae* were algae which was the most consumed food item followed by plant material. Diatoms represented the least occurring food item in the estuarine fish. One specimen of *Acanthurus monroviae* was sampled from Benya lagoon with an empty stomach.

Ariidae

Twelve (12) specimens of *Arius gigas* from Kakum River Estuary and one (1) from Benya Lagoon were examined. The food items found in the guts of the specimen from the estuary were fish, scales, shrimps, and copepods while that from the lagoon had only fish in its stomach.

Gobiidae

Bathygobius soporator

Nineteen (19) individuals of *Bathygobius soporator* from Kakum River Estuary and nine individuals of *Bathygobius soporator* from Benya Lagoon were examined. The food of this fish from the estuary and the lagoon constituted of crustaceans, insects, gastropods and sand grains.

Porogobius schlegelii

Six (6) individuals of *porogobius schlegeli* from Benya Lagoon were examined. Copepods which were the most eaten food item occurred in five stomachs, followed by fish which occurred in four (4) stomachs and fish scale occurred in one of the stomachs examined.

Sciaenidae

One (1) *Pseudotolithus typus* was recorded from Kakum estuary and one (1) *P. senegalensis* was obtained from Benya lagoon. Both species had shrimps and fish in their stomachs.

Elopidae

Two (2) specimens of *Elops lacerta* from Kakum River Estuary and one (1) from Benya Lagoon were examined. The food items identified in the stomachs of these specimens were fish, shrimps, and plant materials

4.12 Less common fish species

Only one (1) each of *Plectorhynchus macrolepis* (Haemulidae) *Scomberomorus tritor* (Scombridae) and *Cynoglossus canariensis* (Cynoglossidae) was sampled in the two brackish systems and all had empty stomach.

CHAPTER FIVE

DISCUSSION

5.1 Biodiversity and similarity of the fish communities

Fish is the most important biota of brackish water systems contributing as an essential and beneficial food item (Pailwan *et al.*, 2008). Therefore, a study on fish biota gives indication of the state of ecosystem health.

Marine fisheries resources that were obtained from the estuary and the Lagoon during the period of study were diverse in nature. They include species belonging to the families Clupeidae, Mugilidae, Lutjanidae, Gobiidae, Bothidae, Carangidae, Sciaenidae, Elopidae, Gerreidae, Serranidae, Ariidae, Haemulidae, Acanthuridae, Scombridae and Cynoglossidae. Most of the species recorded in the present study were the same as Oribhabor and Ogbeibu (2012) in a study of the Niger Delta Mangrove Creek Nigeria, and Blay (1997) in Kakum River Estuary and Benya lagoon, Ghana. The current study recorded 25 marine species belonging to 16 families in the Kakum River Estuary and 24 marine species belonging to 16 families from Benya Lagoon. Comparing the number of species recorded in the present study with Blay (1997) in the Kakum River Estuary and Benya Lagoon, Blay (1997) recorded a greater number of fish species than what was recorded in the present study in the lagoon. Blay (1997) recorded 28 species belonging to 14 families in the estuary and 25 species belonging to 11 families in the lagoon. The differences might be attributed to the interaction between fish and its habitat (physical, as well as biological characteristics) which may be factors in predicting changes in overall abundance, breeding population size and other aspects of population structure (Emmanuel & Onyema, 2007; Emmanuel, 2009).

Salinity is an essential factor that influences the community structure of brackish systems in both the tropics and subtropics due to species differences in salinity tolerance (Little *et al*., 1988). This might account for the presence or absence of some species in the estuary or the lagoon in spite of the close proximity of two brackish systems.

The result from the estuary and the lagoon showed a high diversity of fish community with most of the fish biota being dominated by marine species. These marine species include *Mugil curema*, *Liza falcipinnis*, *Mugil bananensis, Liza dumerilii, Sardinella aurita, Caranx hippos,* among others. This indicates that marine fishes migrate largely to utilize the estuary and the lagoon as feeding and spawning grounds by the adult and spend their life at sea while the juvenile fishes are nursed in the brackish water systems before they move to the marine habitat in their adult stage. This agrees with Albaret and Lae (2003) in Ebrie Lagoon in West Africa and Blay (1997) in Kakum River Eatuary and Benya Lagoon. According to Emmanuel and Oyenma (2007), marine fish species like *Caranx hipos*, *Liza falcipinnis*, *Mugil cephalus*, and *Penaeus notialis* occur in nearly freshwater to hyperhaline waters. Species must have had ability to adapt and cope with the variable conditions of the brackish water environment. Many fishes have evolved specialized physiological and behavioral adaptation; increasing the specialization of these adaptations to cope with localized conditions may be a strategy to exist as a permanent lagoon resident (Zander *et al.*, 1999). The observed high diversity of the fish species recorded in both the estuary and the lagoon in the current study may also be attributable to fairly good environmental conditions that are ideal to favourable for fish survival and good growth. The clossness of index of diversity of marine species from both the estuary and the lagoon indicated a high similarity betweent them. However, the high equtability value of 0.89 indicates an even distribution of number of individuals among the species.

5.2 Species size distribution and length-weight relationship

The size ranges of the most common marine fishes such as *Liza falcipinnis, Liza dumerilii, Mugil cephalus, Mugil curema, Mugil bananensis* (Mugilidae), *Sardinella aurita* (Clupeidae), *Lutjanus goreensis, Lutjanus fulgens, Lutjanus agennes* (Lutjanidae), *Caranx hippos* (Carangidae) were generally smaller than their normal reportd sizes. The smaller specimens, the modal length class and the weight of individual species of the fish community encountered throughout the study were much smaller at the estuary and the lagoon and is attributed to the mesh size (20 mm stretched mesh) of the cast net in sampling. This community structure is similar to reports by some researchers which indicate dominance of a few species in the total fish biomass of brackishwater habitats (Quinn, 1980; Little *et al.,* 1988; Green *et al.,* 2009, Okyere *et al.,* 2011). A similar situation was recorded for the fish biota of the creek in South-Western Nigeria (Emmanuel & Onyema, 2007).

The observation of juvenile fishes in the estuary and the lagoon indicates that these water bodies are mainly utilized by juvenile marine fish species as feeding and nursery grounds (Whitfield, 1990). In view of the commercial importance of majority of the fish species and the active anthropogenic activities ongoing in the estuary and the lagoon, enforcement of fisheries management regulations, especially with respect to conservation regulation to prevent the impact of the anthropogenic practices that affect marine juvenile fishes that use both the estuary and the lagoon as nursery and feeding ground will be necessary. The recognition of a highly rich and diverse fish biota in the estuary reflects a high productive system that merits management planning and possible conservation status.

The length-weight relationships were highly significant ($P < 0.05$) for the fish species in the estuary and the lagoon. The correlation coefficients (r^2) ranged between 0.78 in *Mugil curema to* 0.97 in *Eucinostomus melanopterus* from Kakum River Estuary while in Benya Lagoon, the correlation coefficients (r^2) ranged from 0.88 in *Mugil curema* to 0.99 in *Caranx hippos*. The coefficient of determination (r^2) for length-weight relationships is high for all fish species ($r^2 = 0.78 - 0.99$) indicating that the length increases with an increase in weight of the fish and again indicated that there was strong relationship between the length and the weight of fish species from both the estuary and the lagoon. This is in agreement with previous studies on different fish species from various water bodies: (eg: Konan *et al*., 2007; Tah *et al*., 2012; Koffi *et al*., 2014; Ndiaye *et al*., 2015). Ndiaye *et al*. (2015) reported $r^2 = 0.72 - 0.99$ coefficient of determination (r^2) for 31 fish species. At Kakum River Estuary, the estimates of *b* ranged from 2.38 in *Liza dumerilli* to 3.10 in *Eucinostomus melanopterus* with 95% confidence interval of *b* for all the nine fish species ranging from 0.08 to 0.22. *Eucinostomus melanopterus* and *Sardinella aurita* had exponents *b*, which were statistically significant to 3.0 which showed possible isometric growth in the fish species while the exponents *b* for the remaining seven were statistically not significant to 3.0 indicating possible allometric growth. At Benya Lagoon, the estimates of *b* ranged from 2.61 in *Mugil curema* to 3.04 in *Eucinostomus melanopterus* with

95% confidence interval of *b* for all the nine fish species ranging from 0.01 to 0.20. *Eucinostomus melanopterus* had an exponent *b*, which was statistically significant to 3.0 indicating possible isometric growth in the fish species while the remaining eight species had exponent *b* less than 3.0 which showed possible allometric growth. Values of the length component in the length-weight relationship being isometric implies that the fish species did not increase in weight faster than the cube of their total length while those being allometric implies the species increased in weight faster than in total length. This implies that weight increases with increasing size of the fish. The finding on the *b* estimates of this study is similar to the observations of Ndiaye *et al.* (2015) who reported that estimates of *b* ranged from 2.17 to 3.60 for 31 fish species (which included the Mugilidae, Carangidae, Clupeidae, Lutjanidae and the Gerreidae) sampled in the Saloum Delta, Senegal. The difference in *b* values might be related to differences in geographical areas with different conditions within the environment.

5.3 Food habits of marine fishes

Dietary analysis of the fish species using stomach content analysis is more accurate if the sample size is large (Hyslop, 1980). Sample sizes for some species were relatively small and this could be attributed to the fact that the species had low occurrence during sampling. Generally there is insufficient literature on details of food habits of some of the non-commercially important fish species examined together with the fewer individuals of fish species caught (<10), this limits the effective comparison of the feeding ecology of some fish populations in the Kakum River estuary and Benya Lagoon with fish populations elsewhere.

From the result on the stomach contents of all the fish species examined, it was observed that blue-gree algae, diatom, green algae, fish scales, nematods, fish flesh, fish egg, mollucs, detritus, sand, fish, shrimp, copepods, fish larvae, protozoa, dinofligelates, shrimp appendagies, crabs, annelids and unidentified items were consumed as food. In this study, it is suggested that there are likely three broad feeding groups of fish, which includes those that mainly fed on the plankton (planktophagous) and these species includes the Mugilidae, (predatory) these are the fish species that fed on other macroscopic animals in both the estuary and the lagoon which includes Gerriedae, and the Gobiidae, representing Non-piscivorous species while Lutjanidae, Carangidae, Bothidae, Sciaenidae, and Elopidae representing piscivorous species within the Kakum River Estuary and Benya lagoon. This is in consonance with Fagade and Olaniyan (1974).

The main food componets of *Caranx hippos* in the Kakum River Estuary and Benya Lagoon were shrimps, fish, nematodes, fish scale, crustacean larvae and some partially digested food item with nematodes forming a small portion of the food in the stomachs of this species. In the current study, this species from the Lagoon preferably fed more on fish. This is in agreement with a study on the food and feeding interrelationships of the fishes in the Lagos lagoon by Fagade and Olaniyan (1974) reported that, the preferred food components of *Caranx hippos* were mainly juvenile of clupeids, mostly consisting of juvenile of *E. fimbriata* and some species of cichlids. This situation was different comparatively to *Caranx hippos* from estuary. In the estuary, *Caranx hippos* feed more on shrimps and this might probably be due to different study areas and what was available for the fish species to feed on.

The stomach content showed that the food fed by *Pseudotolithus typus* and *Pseudotolithus senegalensis* in both water bodies were fish and shrimp. The result on food habits from the current study of these species confirms the findings. The report from Blay *et al.* (2006) showed that juveniles of *P. senegalensis* in Ghanaian coastal waters were stenophagous carnivores with high preference for juveniles of shrimps and other fishes including juveniles of *B. auritus*. Nunoo *et al.* (2013) reported that the principal food materials of the Family Sciaenidae were shrimps (Crustaceans). Again, Troadec (1971) reported that four stomachs out of five of *Pseudotholitus senegalensis* contained shrimps. Sidibé (2003) obtained the same results while studying the community of Sciaenidae off the Guinean coast.

The diet of *Elops lacerta* consisted mainly of fish, shrimp and plant materials. Studies on the diet composition in the ten pounder, *Elops lacerta* from Ologe lagoon, Lagos, Nigeria by Lawson and Aguda, (2001) reported that *Elops lacerta* is a predatory species which primarily feed on fish and crustaceans with fish being the most consumed food component. Fagade and Olaniyan (1973) grouped *E. lacerta* amongst piscivores feeding on juveniles of other fish species and crustaceans and identified that penaeid shrimps was the main food component of *E. lacerta*. Plant materials mainly micro algae whose taxonomic status could not be identified by the study were also recorded in the diet of *Elop lacerta*. Presumably they could have been ingested accidentally while feeding on benthic invertebrates.

Lutjanus goreensis in the estuary and the lagoon fed almost exclusively on shrimps, crab, fish scale, fish egg, fish, and shrimp appendages with shrimps and crabs being the most preferred food fed by *Lutjanus goreensis* from the estuary while those from the lagoon fed most on shrimp and fish scale. The food item ingested by *Lutjanus fulgens* were fish, shrimps, fish scales, crab, fish eggs, partially digested item and some unidentified food component. In Kakum River Estuary, this species fed more on fish and shrimp with little on fish scales while in Benya Lagoon, fish scales and fish were the most preferred food component. The main constituents of the diet of *Lutjanus agennes* in the estuary and the lagoon were fish, shrimp, fish scales, and crabs with fish and shrimps being the most preferred food item of *Lutjanus agennes* in the estuary while fish was the only most preferred food component fed by this species from the Lagoon.

The food item consumed by *Bothygobius soporator* from Kakum River Estuary and Benya Lagoon varied from crustaceans and insects, to sand grain and gastropods with gastropods representing the smaller portion in the diet.

There was trophic diversification among the food component fed by *Eucinostomus melanopterus* from both Kakum River Estuary and Benya Lagoon. The food component differed from annelids and copepods to fish scale. This has been repeatedly cited in the literature (Motta *et al.*, 1995; Zahorcsak *et al.*, 2000; Denadai *et al*,. 2012).

The main constituents of the diet of *Sardinella aurita* recorded from Kakum river estuary and Benya lagoon were copepods and detritus, dinoflagellates, protozoa and diatoms. In the present study it was identified that copepods was the most preferred food component for *Sardinella aurita* from both water bodies. This is in agreement with what was reported by Stergiou and Karpouzi (2002) identified that sardine generally feeds on copepods. The presence of unrecognizable detritus as food component in the diet of *Sardinella aurita* has been reported by Nieland (1982). Apart from detritus, an annual average of the diet composition shows the zooplankton–phytoplankton ratio in the *Sardinella aurita* as 3: 2 (Nieland, 1982). Similar feeding habits have been reported for round sardinella in northeastern Mediterranean (Stergiou & Karpouzi, 2002). *Sardinella aurita* has been classified as an omnivorous, filter feeder species with preference for animal prey, whereas it was classified as an omnivore with preference plant material in other areas (Nieland, 1982).

The main constituents of the diet of *Acanthurus monroviae* were algae, diatom and plant material with plant material forming a very small portion of the food recorded.

The diet of *Liza falcipinnis, Liza dumerilli, Mugil bananensis, Mugil cephalus* and *Mugil curema* in the estuary and the lagoon were similar but slight variations were identified in proportions of food components. The most food items fed by these species in both the estuary and the lagoon were algae, diatoms, detrital material and sand particles. The present study indicates that the diet of the mullets (Mugilidae) examined does not differ from that studied in Ghana by Blay (1995a) and elsewhere in West Africa (King, 1988) where mullets have been reported to feed mainly on diatoms, organic detritus and sand grains. The nutritional value of detritus is due to its association with bacteria and protozoa (Buslé, 1981). However, sand particles occurred in the stomachs of all the mullet species examined but was the major stomach content of *Mugil curema*, forming 53% and 74% occurrence of the stomach contents respectively in the Kakum River Estuary and Benya Lagoon. Ingested sand particles are supposedly helpful in the grinding of food particles in the thick-walled pyloric stomach, which acts as a gizzard (Thomson, 1966). Comparatively, results on food habits of grey mullet from the present study confirms the findings of Blay (1995a) who reported on the diet of juveniles of four mullet species (*Liza falcipinnis, Liza dumerilii, Mugil curema* and *Mugil bananensis*) from the Benya lagoon in Ghana. Comparatively, grey mullets in the Benya lagoon utilize a wider range of food items than those found in the Kakum river estuary and these differences could be attributed to variations in the productivity of the water and the range of food items present to the species [Brusle (1981) in Blay (1995a)]. Probably, unfavourable environmental conditions such as salinity and fluctuations in temperature might have inhibited the development of communities of such benthic fauna as polychaetes and nematodes, hence their absence in the diet of the grey mullet from the estuary. The diets of *Porogobius schlegelii* from Benya Lagoon were copepods, fish, and fish scale. Blay (1996) identified eleven items in the food of *Porogobius schlegelii* population in the Fosu lagoon (Ghana) which were detritus, fish scales, copepods, algae, rotifers, fish fry, insect larvae and some plant materials. In the present study however, only the copepods, fish and fish scale were eaten by this species from Benya lagoon. Considering the presence of several macrophagous species in the Benya lagoon where *P. schlegelii* is the only macrobenthophagous fish present (Blay & Asabre–Ameyaw, 1993, quoted in Okyere, 2010), it is conceivable that the consumption of such narrow range of prey by *Porogobius schlegelii* could be related to a resource partitioning with other species which can be a mechanism to reduce competition.

The species sampled from both the estuary and the lagoon was not sexually matured.

5.4 Diel Fluctuations in fish species

Concerning the community structure, a diel pattern was identified mainly related to the number of species, abundance, and biomass, where the species caught were neither diurnal nor nocturnal in Kakum River Estuary and Benya Lagoon. This variation in the number of species and abundance observed in the present study over diel cycles may be due to visual stimulus and the avoidance capacity of the fish to the fishing nets, cryptic behavior and migration chances between day and night which are fundamental factors in capture success (Wardle, 1993). Behavioral studies show that many fishes are primarily active at night, searching for shelter during the day in inaccessible places to the fishing net or in other protection areas; therefore, these fishes are hardly caught in diurnal samplings (Wardle, 1993). In the Kakum River Estuary the highest density and biomass (g) of fish sampled respectively occurred in the night period but the situation was differnent in the lagoon. This occurrence of higher abundance and biomass values in the nocturnal period in the estuary might be attributed to increase in catchability at night or a movement of these individuals into the area at dusk and leaving at dawn or combination of both. Again the occurrence of large biomass at night is considered a common pattern to different environments of the coastal zones (Clark *et al.*, 1996a, b). Wardle (1993) pointed out that the main factor that contributes to high abundance in biomass of fish is the protection of fish against predators due to the absence of sunlight, which would make the visualization of the prey difficult.

The fish community occurred in both the estuary and the lagoon at different times during sampling and the abundance of fish changed on an irregular basis. This suggests that temperature may play an important role in determining the behavior of the marine migrants. Wang *et al*. (1991) reported that the occurrence of the fish larvae and juveniles in the coastal waters of the Tanshui estuary was related to water temperature.

Variation in salinity was also greater in the current study. As a result, although a large proportion of the individuals recorded from the estuary and the lagoon were marine migrants and estuarine species which have a wide tolerance to salinity (Blaber, 1997).

5.5 Summary

In summery, marine fisheries resources obtained from the estuary and the Lagoon were diverse in nature with a high diversity of fish community. In the Kakum River Estuary the highest density and biomass (g) of fish sampled respectively occurred in the night period but the situation was differnent in the lagoon

CHAPTER SIX

CONCLUSIONS AND RECORMANDATIONS

6.1 Conclusions

The Kakum River Estuary and Benya Lagoon are highly dynamic environments, where water temperature and salinity were within the optimal range.

A total of 23 marine fish species belonging to 15 families were collected from both Kakum River Estuary and Benya Lagoon. *Mugil curema* was the dominant species with a composition of 18.50% of the fish community at Kakum River Estuary while at Benya Lagoon the dominant fish spaecis was *Mugil bananensis* with 41.57% composition of the fish community.

The species richness as well as diversity values for the fish communities in the estuary was highest than the lagoon. Furthermore, there was a high similarity among the fish communities in the estuary and the lagoon which may be as a result of the prevailing highly similar environmental conditions.

In general however, larger individuals were not as abundant as smaller individuals as has previously been observed by other researchers in different locations as within the habitats and locations that were sampled during the study. Similarly, larger sizes may not have been sampled as effectively as smaller individuals due to factors such as habitat association and behavioural characteristics of the species. Since the sample was made up of juveniles in both water bodies emphasizes the point that estuaries and lagoons are mostly inhabited by juvenile fishes.

Results of the food habits of the fishes indicated that the fish communities were made up of detritivorous, planktivorous, insectivorous, invertevorous, omnivorous and piscivorous fishes. However, the range of food items eaten by the fish populations in both the estuary and the lagoon were narrower than that reported for other populations in Ghana and elsewhere. Such a relatively narrow spectrum of food may be due to unavailability of a number of their dietary items in these water bodies.

Temperature and salinity are the most important factors that influence the greater variability in the abundance of the fish species in the estuary and the lagoon and also there is a strong correlation between all these variables and their influence on the species composition of the estuary.

Diel changes formed an unusual occurrence pattern in fish assemblage in Kakum River Estuary and and Benya Lagoon which possibly may be characterised by a tidal interchange of species by salinity effect and a partition of the habitat either being a diurnal species, nocturnal species or species occurring in both day and night catches but predominantly in one or the other periods. Diel differences may also be directly influenced by anthropogenic disturbance which is mostly high during 10:00, 2:00, and 14:00 hours.

6.2 Recommendations

The reduced fish faunal diversity in the current study, when compared with Blay (1996) in the same estuary and the lagoon environment warrants further investigations to help understand the dynamics relative to the richness and diversity of finfish biota and their assemblages in shallow water bodies.

The use of the Lagoon and the estuary by juvenile marine finfishes requires management planning and possible conservation measures as well as restricting fishing in these water bodies for proper maintenance of the biodiversity and to ensure sustainable recruitment of juveniles that migrate from the marine environment into shallow water systems.

The levels of certain inorganic pollutants (e.g. mercury and lead) in the estuary and the lagoon should be monitored to investigate their toxicity levels which could be used to advice on the use of the resources

However further study on the fish condition in relation to the tide over diel cycle in the area would provide better understanding on the tidal fluctuation the occurrence of marine species in these ecosystems for the betterment of conservation and management of the fishery resources.

6.3 Summary

In summery, marine fish species occurring in the estuary and the lagoon is higher compered to the adult fishes. This is an indication that, coastal water bodies are used by juvenile marine fishes as a nursery and a feeding ground and spend their adult life at in sisee.

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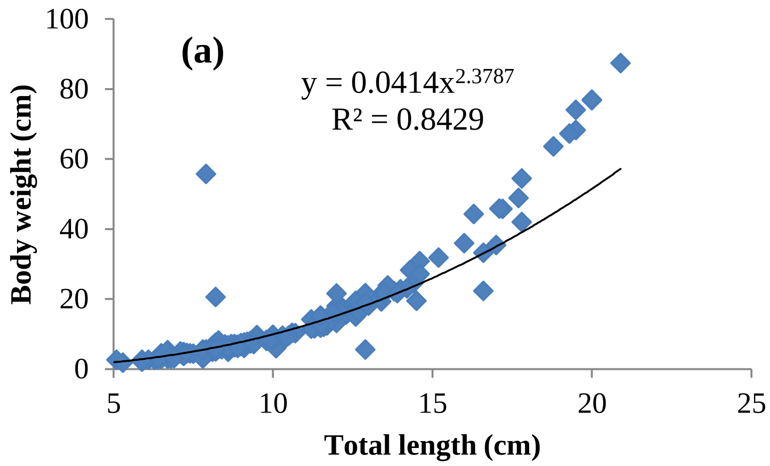
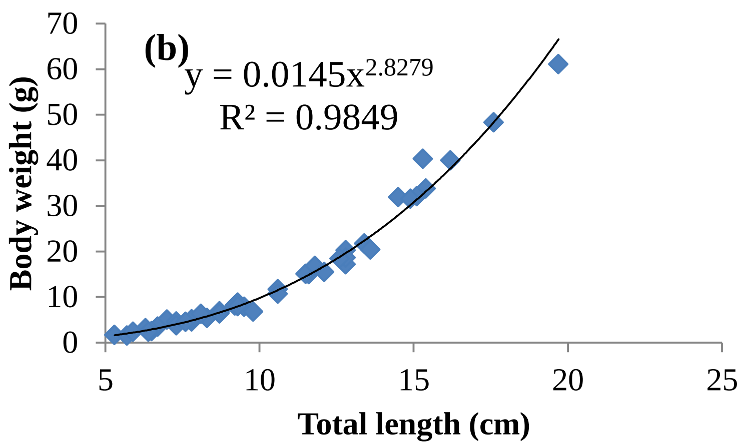
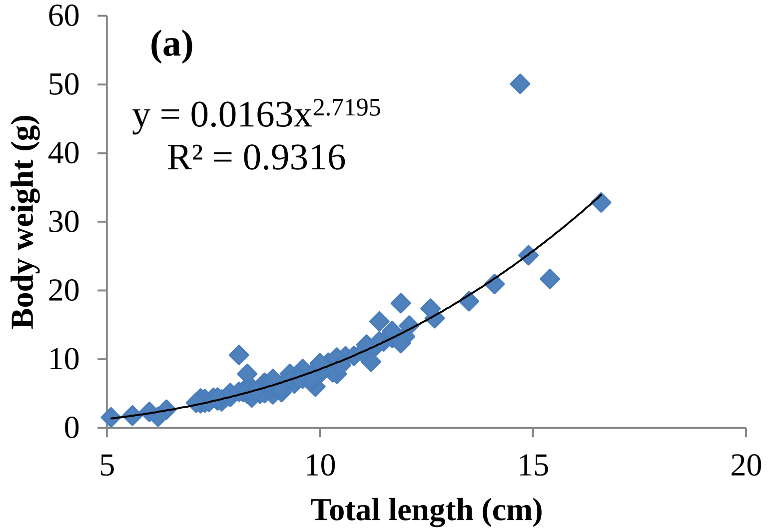
APPENDICES

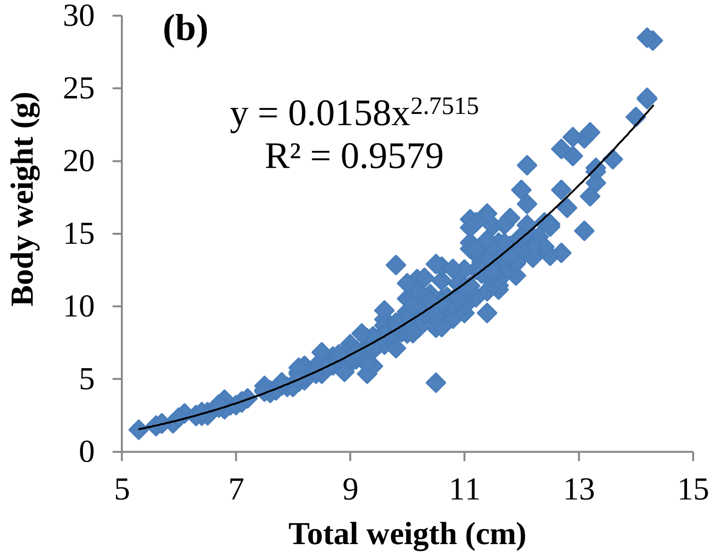
Appendex A: Length-weight relationship for Liza dumerilli form (a) Kakum river estuary and (b) Benya lagoon



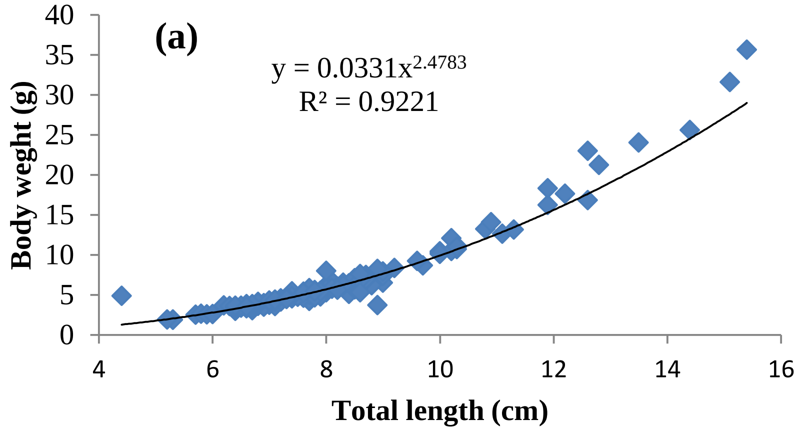


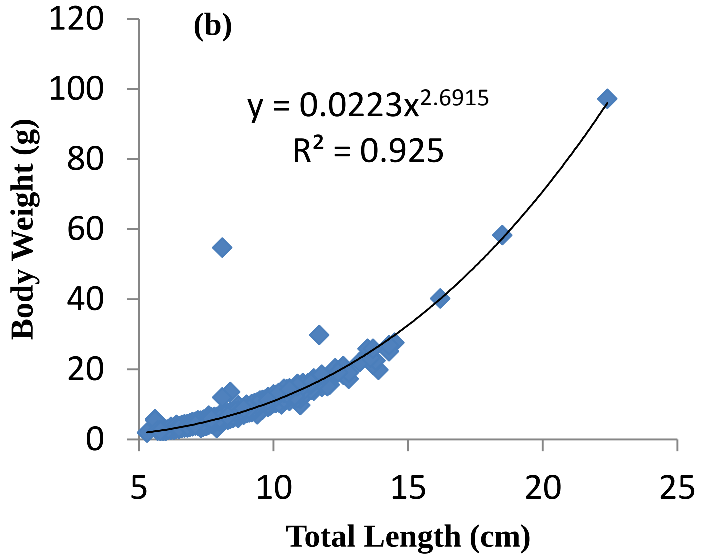
Appendex B. Length-weight relationship for Liza falcipinnis form (a) Kakum river estuary and (b) Benya lagoon



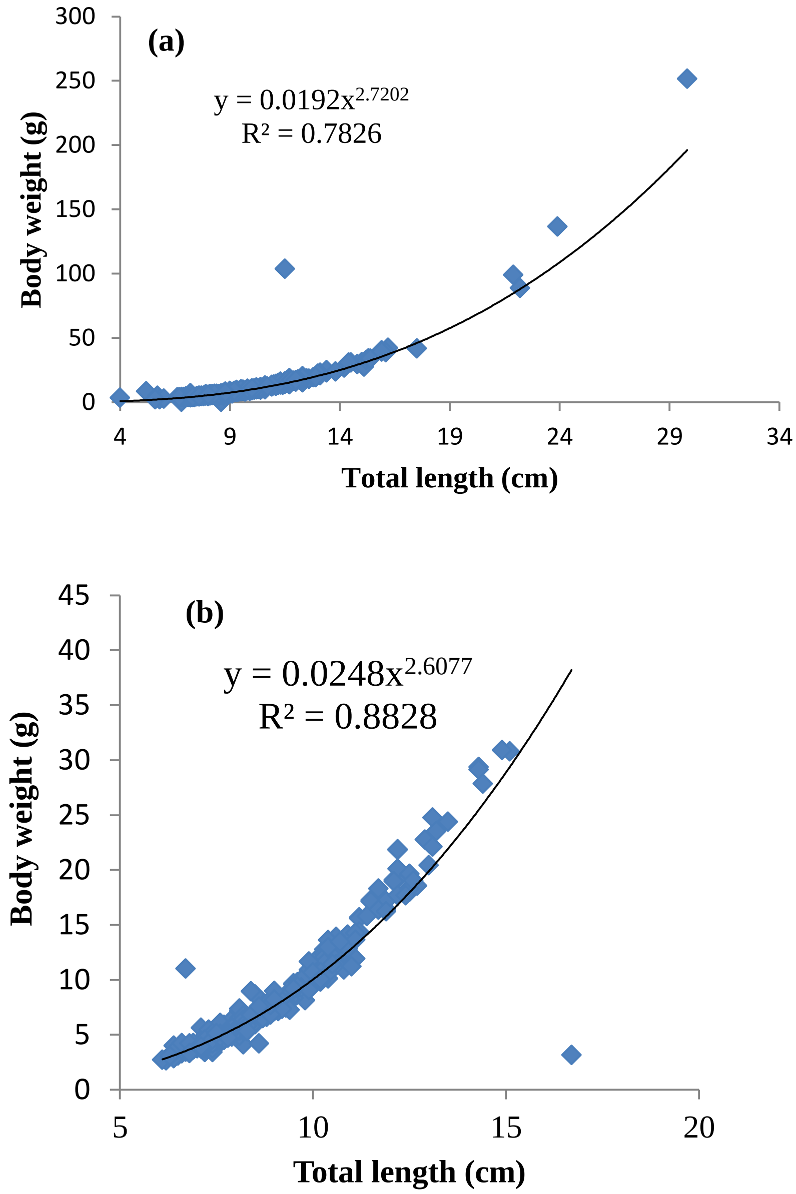


Appendex C. Length-weight relationship for Mugil bananensis form (a) Kakum river estuary and (b) Benya lagoon

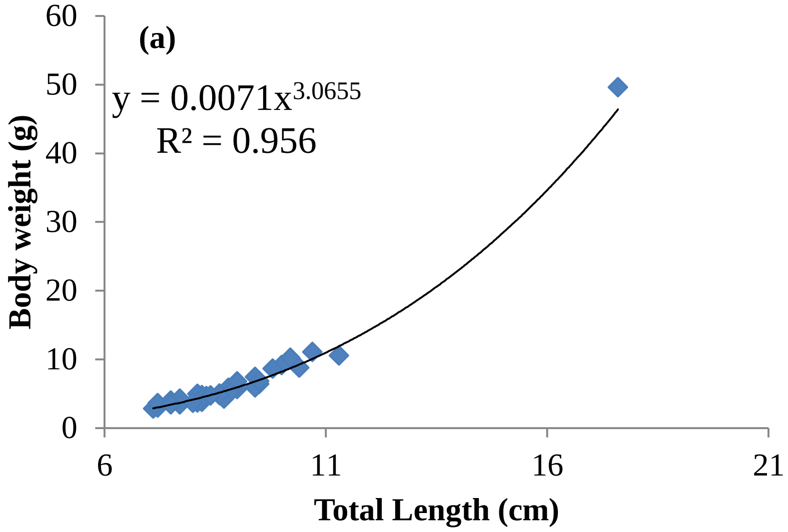


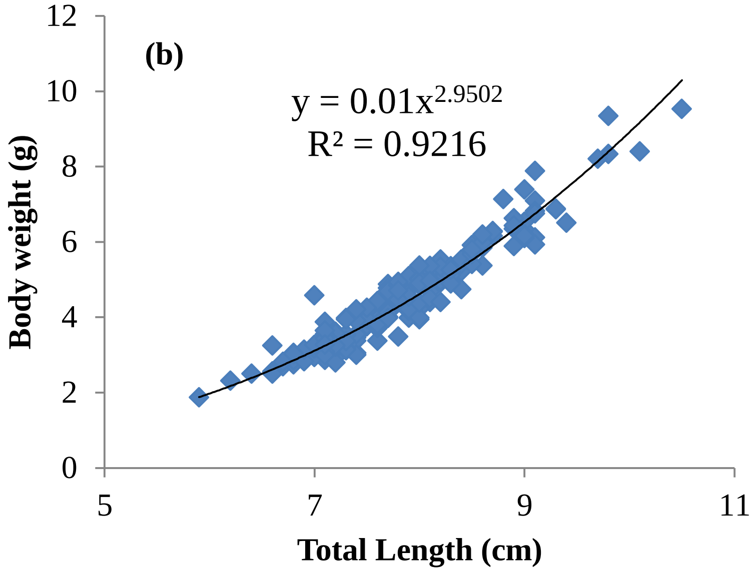


Appendex D: Length-weight relationship for Mugil bananensis form (a) Kakum river estuary and (b) Benya lagoon

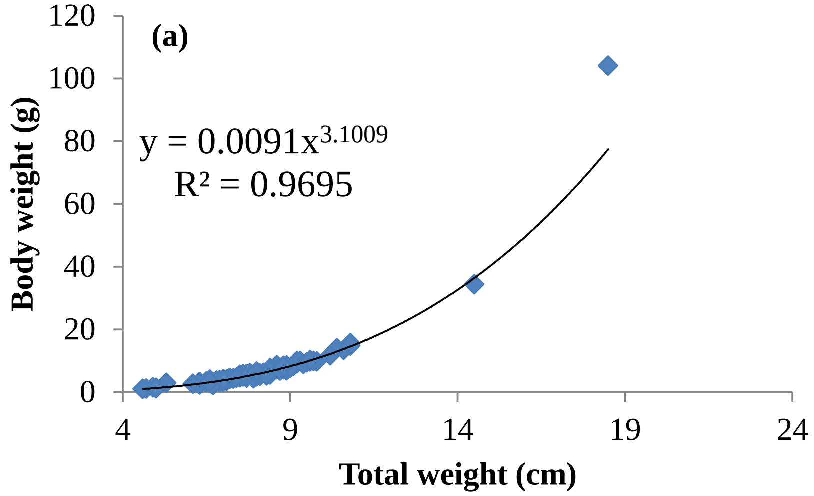


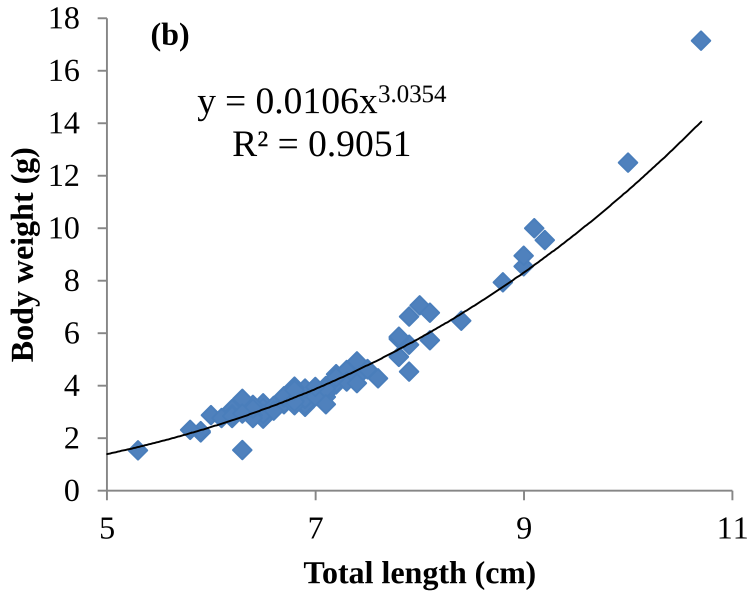
Appendex E: Length-weight relationship for Sardinella aurita form (a) Kakum river estuary and (b) Benya lagoon



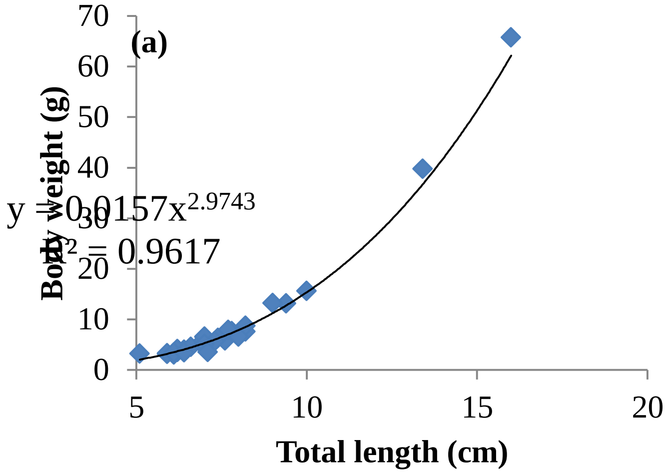


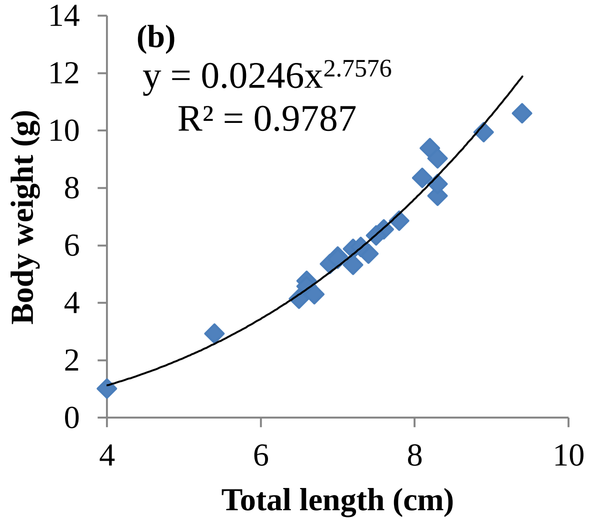
Appendex F: Length-weight relationship for Eusinostomus melanopterus form (a) Kakum river estuary and (b) Benya lagoon



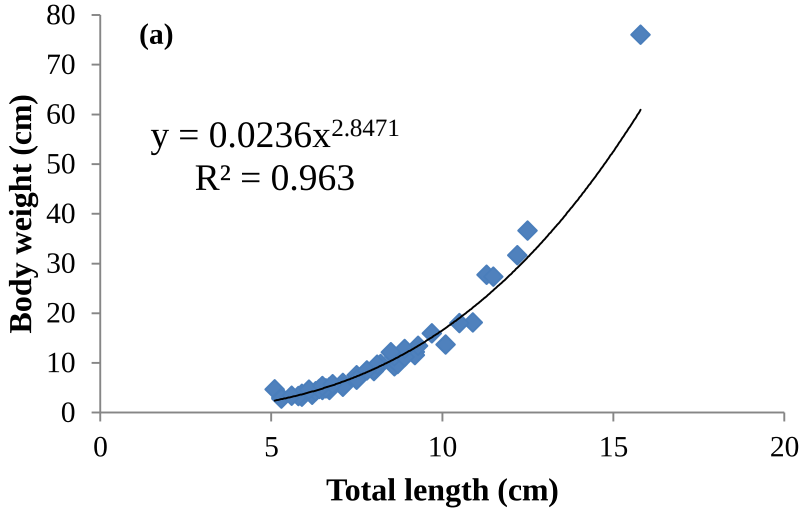


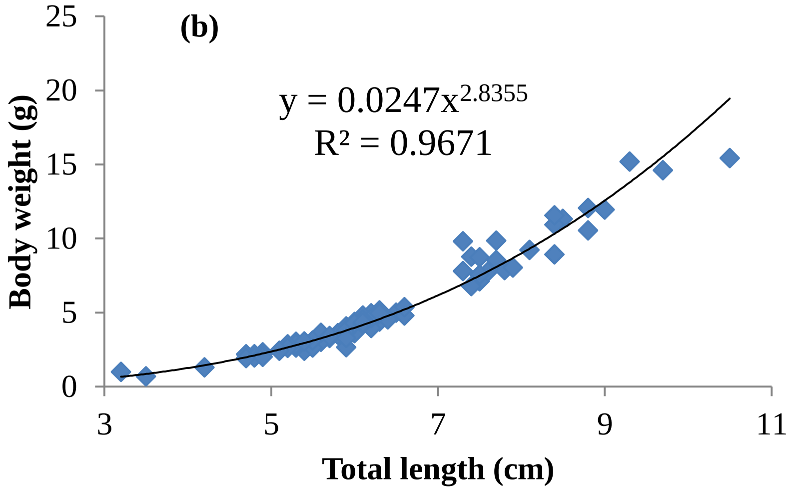
Appendex G: Length-weight relationship for Lutjanus fulgens form (a) Kakum river estuary and (b) Benya lagoon





Appendex H: Length-weight relationship for Lujanus goreensis form (a) Kakum river estuary and (b) Benya lagoon





Appendex I: Length-weight relationship for Caranx hippos form (a) Kakum river estuary and (b) Benya lagoon