

COMPARATIVE STUDIES OF THE DYNAMICS AND
MANAGEMENT OF FISH POPULATIONS IN AN OPEN
AND CLOSED LAGOON IN GHANA.

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DECLARATION

I declare that this thesis entitled “Comparative studies of the dynamics and management of the fish populations in an open and closed lagoon in Ghana” is the result of original work conducted by myself, under the supervision of Professor Chief John Vanderpuye. All sources of information have been appropriately acknowledged. It has not been accepted for any degree and is not concurrently being submitted for any degree.

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DEDICATION

Dedicated to my parents, Mr. and Mrs. S.R.R. Croffie, my husband, Clement Entsua-
Mensah, and my children Nana Akua, Maame Adwoa and Kobby.

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ABSTRACT

Comparative studies have been done on the dynamics and management of the fish populations in Abrubi lagoon (closed lagoon) and Densu delta (open lagoon) in Ghana from May 1994 to April 1996. Some environmental parameters of the lagoons, which affected fish populations were also monitored.

There was a noticeable increase in temperature during the dry season (November to March) in both study areas. Temperatures ranged from 26°C to 33°C. On the whole, changes in pH were gradual and steady with no definite pattern in both study areas. The major rains were from May to July with minor rains from September to November; December to March were generally dry months. The depth of the water increased with the onset of the rains. Fluctuations in salinity were closely linked to amount of rainfall.

The three stations in each study area showed a pattern of salinity gradation with lowest salinity occurring at Station 1 (riverine portion) and highest salinity recorded at Station 3 the area nearest to the sea. Dissolved oxygen levels were high in the wet season but low in the dry season. Differences in oxygen levels were not significant between months and between stations in both study areas. Analysis of variance tests showed that levels of phosphate and nitrate were not significantly different between months and between stations in both study areas. Levels of total dissolved solids and conductivity followed each other closely.

Maximum Catch per Unit Effort (CPUE) values were recorded when the depth of the lagoon was low. Eighty-three thousand, eight hundred and forty-three kilogrammes of fish were obtained from the Densu delta by experimental cast net fishing during the study period and sixty-six thousand nine hundred and ninety-nine kilogrammes of fish from Abrubi lagoon.

The five dominant species in Abrubi lagoon were *Sarotherodon melanotheron*, *Hemichromis fasciatus*, *Tilapia zillii*, *Liza falcipinnis*, and *Ethmalosa fimbriata*. In the Densu delta they were *Sarotherodon melanotheron*, *Gobiodes ansorgii*, *Tilapia zillii*, *Mugil cephalus* and *Ethmalosa fimbriata*. *Sarotherodon melanotheron* was the most dominant species, accounting for 68% of the catch in the Densu delta and 75% of the catch in Abrubi lagoon during the study period.

The overall species diversity was not markedly different between Abrubi lagoon and Densu delta. At 5% significance level (Mann Whitney U test), the species diversity in the dry season was different from that of the wet season in Stations 1 and 3 but not in Station 2 in both study areas.

The Evenness component varied in a manner similar to diversity. Breaching of the lagoon affected species diversity in Abrubi lagoon. The peak of diversity occurred just before the peak of rainfall in Abrubi lagoon. Marine incursions and the opening and closing of the sluice gates of the Weija dam affected diversity in the Densu delta.

The Forage / Carnivore ratio of 2.86 for Abrubi lagoon and 5.15 for Densu delta indicates that both study areas had balanced fish populations.

The Multi-Dimensional-Scaling (MDS) obtained for the six sites in the two study areas indicate that temperature and salinity were strong environmental factors determining the presence of fish species

There was monthly variation in male: female ratio with females predominating most of the time. From the Gonadosomatic Index (GSI) obtained *S. melanotheron* spawns from February to March.

The overall length -frequency distribution showed a modal length of 8.5-9.0 cm SL in Abrubi lagoon and 5.0-5.5 cm SL in Densu delta. The length at first maturity was 7.2 cm SL in Abrubi lagoon and 4.8 cm SL in Densu delta.

The von Bertalanffy growth parameter ($L_{\infty} = 12.0$ cm SL, $K = 0.67$ for Densu delta and $L_{\infty} = 15$ cm SL, $K = 0.79$ for Abrubi lagoon) implies fast growth which might compensate for the rather high fishing and natural mortality rates.

Direct and indirect management practices can be used to manage the fisheries. Direct management involves gear control, catch control, fishermen control and season control. Indirect management involves mangrove afforestation, environmental protection and introduction of alternative trades to the fishermen.

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ABBREVIATIONS

BW	Body Weight
CPUE	Catch Per Unit Effort
CBFMC	Community Based Fisheries Management Committees
CIFA	Committee for Inland Fisheries of Africa
CSPWD	Cape St. Paul's Wilt Disease
GEF	Global Environmental Facility
GERMP	Global Environmental Management Project
GSI	Gonadosomatic Index
ICZM	Integrated Coastal Zone Management
NGO	Non Governmental Organizations
MOFA	Ministry of Food and Agriculture
MDS	Multi-Dimensional Scaling
PRIMER	Plymouth Routines In Multivariate Analysis
SL	Standard Length
TL	Total length
VGBF	von Bertalanffy Growth Function

CHAPTER ONE

1.0 INTRODUCTION

1.1 General

The main objective of this thesis is to appraise the abundance, diversity and seasonality of the fish communities in the Densu delta (Accra) and Abrubi lagoon (Komenda). The study also identifies issues that affect the sustainability of the fishery of the most dominant species, *Sarotherodon melanotheron*, and finally, it examines the potential management options to improve the fisheries of the two lagoons.

Coastal lagoons may be defined as areas of relatively shallow water that have been partly or wholly sealed off from the sea by the formation of spits or barriers built up above high tide level by wave action. Over 13% of coastlines in the world consists of shallow marine waters lying behind barrier pits or islands (Bird, 1982). The longest length of such a barrier coastline is along the eastern seaboard of USA and the Gulf of Mexico.

Lagoons are also common along the eastern coasts of South America and India, around the shores of the Baltic, Mediterranean, Black, and Caspian Seas, in southern Britain and western France, along the Western African Coast, in south-eastern Australia, northern Alaska and Siberia (Gierloff-Emden, 1961). Lagoons vary greatly in size, depth and salinity and thus it is difficult to generalize on their ecology: each is a case unto itself (Colombo, 1977). Webb (1958) and Davies (1960) have described the formation of lagoons by sand movement along the West African coast.

Bernard (1937) and de Rouville (1946) recognized two types of lagoons that fringe the West African Coast corresponding to the two types of estuaries described by Boughey (1957). These are the 'open' and 'closed' lagoons. The 'open' lagoon (often referred to as an estuary) has sufficient volume of water at all seasons to maintain a permanent outflow from their mouths into the sea. In Ghana, such lagoons occur more in the western part of the coastline where the rainfall is heavy (mean of about 1250 mm per annum) and where they are continuously fed by rivers.

Seasonal rivers and streams feed the closed lagoons in Ghana. They usually lie behind a sand barrier which separates them from the sea and are normally opened for one or two months in a year during the rainy season between May and September. Most of these lagoons are located on the eastern coastal region where rainfall is low.

Climatic variations and sea level fluctuations control the development of estuaries around the world. Whitfield (1992) recognized five distinct types of estuarine systems on the South African subcontinent. They are permanently open estuaries, temporarily open estuaries (closed lagoons), river mouths, estuarine bays and estuarine lakes.

A mixture of fresh and seawater influences lagoons at all times, and one may dominate at one time or other. They are simple systems that are easily disturbed both by natural processes and by pollution from adjacent urban and industrial development. As a result they are affected by an array of physical, chemical and biological factors. Due to their generally shallow nature and small size, environmental factors have a marked bearing on the flora and fauna inhabiting lagoons (Colombo, 1977).

Lagoons and their wetlands are some of the most biologically and ecologically important ecosystems. While the definition of wetlands vary throughout the world, it is generally agreed that they include ecosystems that are periodically to permanently flooded with shallow water, or have substrate saturated with water for some period during the spawning season of some fish species.

The fish community structure depends on both biotic and abiotic factors. Among the abiotic factors are; salinity, oxygen, pH, conductivity, total dissolved solids, phosphates, nitrates and silicates. Salinity is the most important characteristic in lagoons. Wide fluctuations in salinity may occur annually, seasonally or with the tide and may vary from the lower reaches nearest the sea to the riverine upper reaches.

Temperature changes in lagoons are most noticeable in temperate and polar latitudes and often affect fish population densities (Whitfield 1990). In tropical areas, annual temperature changes are less marked but exist nonetheless. The annual shifts from wet and dry periods strongly influence the rate at which essential 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,1973).

Associated with all lagoons in tropical areas are coastal wetland mangrove swamps. In Ghana *Avicennia* sp. and *Rhizophora* sp. are the most common plants found in and around wetlands. The mangroves, which support fisheries, act as windbreaks and prevent soil erosion, are under constant threat from anthropogenic activities.

These include salt winning and indiscriminate harvesting of mangroves as fuel wood for cooking and smoking of fish. In Ghana, exploitation of mangrove wood is very important because of the high density of rural populations along the coast, and the dwindling nature of the country's wood resources.

Paspalum vaginatum and *Sporobolus* sp. are some grasses which occur in wetland areas. The grasses are used for thatched mats. In the frontal zones of the coastline, varying densities of coconut cover occur. There is evidence that in some areas the coconut and other vegetation have been reduced by more than 80% over the last 40 years (K.A.A. de Graft-Johnson¹ pers. comm.). Sand winning, erosion, aging and the disease commonly known as Cape St. Paul's wilt are some of the factors responsible for the loss of the coconut trees.

Wetlands present unique environments and habitats providing valuable products and services, which include the support of fisheries, flood assimilation, regulation and supply of water and protection of biodiversity. Wetlands also provide important roosting, nesting and feeding sites for many species of birds, especially migratory ones.

The coastal wetland habitat also forms an integral part of the marine fishing industry and provides important spawning and nursery grounds for many fishes. Fish are a major component of the nektonic community in lagoons.

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The mobility of fish enables them to avoid unfavorable conditions, exploit a wide variety of habitats and food sources, evade predatory attacks, and move from the freshwater to the brackish environment (Whitfield, 1994).

Fish also reside in the lagoons as marine or freshwater "visitors", euryhaline "permanent residents", and migratory catadromous or anadromous "transients". They face complex environmental factors, each of which may vary widely. The fish diversity in wetlands can be used as a bio- indicator of ecosystem quality.

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

In Ghana, lagoon fisheries are artisanal. They become prominent during periods when catches from marine fishing are low and they play a significant role in the economic lives of the people living close to the lagoons. For example; the yield of Sakumo 2 lagoon near Tema, has been estimated at 50 kg of fish per day (Pauly 1976) or 114 t yr⁻¹ (Koranteng, 1995). Corresponding figures for the Muni lagoon (Winneba) and Densu-delta are 75 t yr⁻¹ and 2701 yr⁻¹ respectively (Koranteng, 1995).

The dominant fish species that occurs in these lagoons is the black-chin tilapia *Sarotherodon melanotheron* = *Tilapia melanotheron* (Ruppell 1852). It constitutes a very important part of lagoon fisheries in Ghana (Eyeson, 1983; Blay and Ameyaw, 1993; Koranteng, 1995). Denyoh (1982) reported that 90% of all fishes caught in lagoons were *S. melanotheron*.

The Ghana Fisheries Law of 1991 (PNDCL 256), the Fisheries Commission Act of 1993 (Act 457) and the proposed Fisheries Management and Development Act, provide a framework for fisheries management in Ghana. Institutions responsible for regulating fishery activities in the Coastal zone are the Ghana Navy and the Fisheries Department. The Fisheries Department is concerned with setting standards for enforcement. Some traditional authorities are also involved in granting permits for artisanal operations.

Unfortunately coastal lagoons and estuaries do not easily fit into the usual "marine" and "inland" categories that the Fisheries Department, (Ministry of Food and Agriculture), Ghana, is organized. As a result issues pertaining to lagoon fisheries have received scant attention.

This situation needs to be remedied, considering the fact that the country is endowed with over 90 lagoons (Friends of the Earth, 1994). They could be exploited to produce viable fingerlings for increased fish production through marine fishery enhancement and aquaculture.

Apart from fishing, farming, salt winning and animal husbandry are other general land-use practices around lagoons. There is growing evidence of deterioration of lagoons and wetlands under stress from man-induced interference and from global climatic changes (Biney, 1985). Degradation of wetlands ultimately results in narrow habitat dimensions, which reduce the survival ability of species, which cannot adapt (Jude and Pappas, 1992).

The complexity of fishing gears (which are able to exploit different niches), excessive fishing pressure and over exploitation, are some of the factors which have a negative impact on the lagoon ecosystem (Koranteng, 1995). Observations have shown that the mangroves, which filter inland water as it flows to the sea, and serve as a nursery and habitat for many shell and finfish are being rapidly destroyed (Entsua-Mensah, 1996).

In the past, management of these fisheries in the lagoon was linked to traditional practices in the form of taboos and local customs. Many of the traditional rules and regulations (taboos) controlling the fishing activities are no longer respected. This is mainly due to migration of fishers and the introduction of Christianity and other western practices.

There is therefore an urgent need for the adaptation of effective conservative measures as well as a search for wiser and sustainable management of the resources of the lagoons. The communities need to become more involved in managing the lagoon resources than they are now.

The World Bank has assisted the Environmental Protection Agency through the Global Environmental Management Project (GERMP), as well as through various sectoral projects in urban infrastructure, fisheries, health and education. None of these, however, addresses coastal zone problems in an integrated fashion.

Initiatives that have addressed international and regional coastal priorities are under the Global Environmental Facility (GEF). The Coastal Wetlands Management Project in Ghana is attempting to protect and manage sustainably a number of wetland areas that are important for bird migration and fishing and have been designated as RAMSAR sites.

1.2. Objectives

The objectives of this study are:

1. To study the species diversity and fishery of the Densu delta and Abrubi lagoon as well as the biology of the black chin tilapia *Sarotherodon melanotheron*.
2. To provide management options for the fisheries of the Abrubi lagoon and Densu delta. The basic questions to be answered are:
 - a. What are the factors limiting fishery production in the two lagoons?
 - b. What changes occur to the water quality in the lagoon environment that affects the growth performance of *Sarotherodon melanotheron*, the dominant fish species in the two lagoons?
 - c. What has been the level of exploitation of the fishery of *S. melanotheron*?
 - d. How can the fishery be managed to minimize the effects of environmental changes and fishing pressure?

Sarotherodon melanotheron serves as an important source of protein in a number of coastal West African countries and its fishery is a good source of employment and income. This study aims to augment the previous studies and it relates the biology and population dynamics of *Sarotherodon melanotheron* to environmental changes in an open and a closed lagoon. It also examines the factors that limit its production. The existing traditional management systems in fishery management are also discussed in this study.

1.3 Structure of the Thesis

Chapter One introduces the thesis. Chapter Two provides a literature review and Chapter Three describes the study areas. Chapter Four deals with the materials and methods used in the study. The results are spread in Chapters Five to Seven where they are also discussed. Chapter Eight looks at issues affecting the fisheries and suggests management options. Major conclusions of the thesis are provided in Chapter nine.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water Quality of Lagoons

A general understanding of the nature, dynamics and history of the lagoons is scientifically and economically important. For example, where a lagoon is used for

waste disposal, it is necessary to understand the physical and biological dynamics of the area to avoid undue pollution (Kwei, 1977).

In West Africa, Watts (1958) and Olaniyan (1961) analyzed lagoon and estuarine waters with a view to understanding the dynamics of fresh and seawater. Hill and Webb (1958) studied the ecology of the Lagos lagoon. The authors analyzed the physical properties of the lagoon deposits and studied the reactions of *Branchiostoma nigeriensis* to its environment. Sandison and Hill (1966) and Sandison (1966) studied the effect of salinity changes in the Lagos lagoon. They showed that during the rainy season in July to October, the population of certain organisms become seriously depleted due to the inability of these species to tolerate the drastic changes in salinity and the tremendous increase in suspended particles.

Akoaka (1971) studied the hydrography (temperature, salinity and transparency) of the lagoons in the Cote d'Ivoire and related these to the fishing conditions during the dry and wet seasons. Yoloye (1974) studied lagoons in Ghana and Nigeria in an attempt to define the hydrographic conditions favourable to the growth of *Area senilis*, a bivalve.

Early studies on the quality of lagoon waters in Ghana were undertaken by the Institute of Aquatic Biology in 1968. The bacteriological quality of lagoon and seawaters in the Accra-Tema coastal area was assessed. Pople (1972) studied the hydrography of the Kpeshie lagoon to determine the effect of the changes in temperature, salinity and water levels on the growth of the oyster *Ostrea tulipa*. A survey of the Korle lagoon (Fig 1) was undertaken by Amuzu (1976) who concluded that the northern riverine portion of the lagoon was polluted.

In an assessment of the state of pollution of some lagoons and estuaries in Ghana, twelve were classified as polluted to various extents (Biney, 1982). Two, the Korle and Chemu, were grossly polluted. The eight estuaries studied were generally clean or only slightly polluted.

Odei *et al.* (1980), after studying the suitability of the Volta estuary for water sports, advised the Ghana Tourist Board 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 (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 (Biney, 1985) and lagoons (Biney, 1986, 1990) in Ghana also showed that the quality of these waters is affected by the transfer of solutes from the ocean and the influx of fresh water.

The Committee For Inland Fisheries of Africa (CIFA)'s working party on Pollution and Fisheries was established in 1985, after it was observed that an increase in pollution loads in aquatic ecosystems had resulted in a decrease in water quality in most African

countries (Biney *et al.*, 1994). Metals and organic pollutants with high biochemical oxygen demand and pesticides were identified as major potential problems. Studies showed that there was the need for cooperation at a regional level aimed at scientifically sound pollution control measures and the maintenance of water quality adequate to protect aquatic life and fisheries. A bibliography and directory of West African coastal lagoons is given by Burgis and Symoens (1987) and in Davies and Gasse (1988).

In Nigeria, waste water from most parts of more than 186 urban centers were carried in open drains into streams and rivers, a characteristic feature of many developing countries (Sridhar *et al.*, 1981). Ekundayo (1977) reported that the eutrophication of Lagos Lagoon was due primarily to extensive pollution by large quantities of industrial and domestic wastes and faecal pollution. However, this lagoon, once very productive for fish, is now considered unsuitable for fishing (Adeyanju, 1979). According to Calamari (1985) analytical water quality data on the lagoon at Lagos does not exist. In Cote d'Ivoire, Pages and Citeau (1978) analyzed the concentrations of faecal coliforms in the central part of the Ebrie Lagoon over one year and found several heavily contaminated areas.

The ecology of the Sakumo 2 lagoon was studied by Pauly (1975). He found that the extreme hydrographic conditions in the lagoon caused a reduction in fauna, as compared with a typical open lagoon or with the littoral shore.

Pauly also proposed and put together the food web in the lagoon. Kwei (1977) carried out primary productivity studies on the Mukwe and Sakumo 2 lagoons and reported a higher plankton count, more live phytoplankton and greater diversity in the open lagoon than in the closed lagoon.

The ecological state of wetlands in Ghana was evaluated by Biney *et al.* (1995). Under the Ghana Coastal Wetlands Management Project, which aims at providing effective conservation measures as well as strategies for wiser and sustainable management of the resources of lagoons, the limnology and ecology of the Muni, Sakumo 2 lagoons and the Densu delta were studied in 1995 by Biney. He found phosphate and nitrate levels higher in the Sakumo 2 lagoon and Densu delta than in the Muni lagoon.

2.2. Species Abundance and Distribution in Estuaries and Lagoons.

The morphology of the shore region (Werner *et al.*, 1978), turbidity (Blaber and Blaber, 1980), oxygen content (Tonn and Magnuson, 1982), food availability (Fagade and Olaniyan, 1973), salinity and temperature (Thorman, 1986a), competition (Hansson, 1984) and complexity of aquatic vegetation have been found to be major structuring forces of fish communities in temperate countries. The effect of salinity and temperature has been confirmed by Thiel *et al.* (1995) on the Elbe estuary in Germany.

A number of studies have dealt with seasonal variation of estuarine fish community dynamics. These include McErlean *et al.* (1973), (United States of America), Yannez-Arancibia, (1978;1981) (Mexico), Blaber and Blaber (1980), (Australia),

Thorman (1986b), (Sweden), and Promfret *et al.* (1991), Elliot and Dewailly (1995), (United Kingdom), Whitfield (1983), (South Africa).

In other studies there has been emphasis on the use of various community parameters such as species richness, diversity and biomass to estimate characteristics of species assemblages (Dahlberg and Odum, 1970), (US), Warburton ,(1978) (Mexico), Shenker and Dean (1979) (US.), Whitfield (1983, 1990, 1994), (South Africa), Thiel *et al.* (1995) (Germany). The size of the catchment area has been identified as an important factor governing both fish species diversity and abundance in South African estuaries (Marais, 1988).

Srivastava's (1971) bibliography of fish provides information on the estuarine fishes of the Gulf of St. Lawrence, Canada. Pillay (1967) elaborately listed the estuarine fishes of the Indian Ocean coastal zone and West African estuaries. Green (1968) referred to some of the European species of estuarine fishes. Estuarine fishes tend to support the statement that faunal diversity is greater in tropical than in temperate latitudes (Saila, 1975).

Edwards (1978), Yanciez Aranciba (1978) and Warburton (1978) have also studied the ecology of fishes in Mexican coastal lagoons. In the Lagos lagoon, Nigeria, Fagade and Olaniyan (1973) examined the trophic relationship of 26 fish species, which used a wide variety of food organisms. Daget (1976) studied the effects of salinity on the fish community of Cote d'Ivoire.

The fish assemblages of the lower Bonny River, Niger Delta, were studied by Chindah and Osuampke (1994) whilst Lae (1994) studied changes in fish and crustacean communities in a lagoon in Togo.

There is a paucity of information on the diversity of fishes in Ghanaian lagoons. The fishes of the lagoons in Ghana were first documented in 1947 by Irvine, though not in great detail. This was followed by subsequent documentation by Pillay (1962) and Mensah (1979) who reviewed the work of Pauly (1975) and Kwei (1977). With the exception of species lists from a study on the Sakumo lagoon by Pauly (1975) and by Koranteng (1995) on the Muni, Sakumo and Densu delta, very little information on fish population ecology is available.

Most of the studies were on single species. Eyeson (1979, 1983, and 1992) studied the breeding activities of *Sarotherodon melanotheron* in lagoons in the Central Region of Ghana. The fishery of the population of *S. melanotheron* in the Fosu lagoon was assessed by Blay and Asabere- Ameyaw (1993). Blay and Eyeson (1982) studied the feeding activity and food habits of the shad *Ethmalosa fimbriata* in the coastal waters of Cape Coast.

Later on Blay (1995a and b) reported on the food and feeding habits of four species of juvenile mullets (*Liza falcipinnis*, *L. dumerilii*, *Mugil bananensis*, and *M. curema*) in the Elmina lagoon. He observed that though all four species were diurnal feeders their feeding times differed.

Some work has also been done on shellfish occurring in the lagoons. Djangmah *et al.* (1978, 1979, and 1980) studied the physico-chemical characteristics and oxygen binding properties of the multiple haemoglobin of the West African Bloody cockle, *Anadara senilis* (L). They also looked at fluctuating salinity on the behaviour, of the species and on the osmotic pressure and ionic concentration of its haemolymph.

Yankson (1980, 1982) reported on aspects of the conchological features of *Anadara senilis* and studied its sexuality and gonad maturation. Croffie (1991) studied the growth, breeding and biochemical properties of *Anadara senilis* in the Benya and Sakumo 1 lagoon Yankson (1990, 1991) also conducted preliminary studies on the rearing of the West African mangrove oyster *Crassostrea tulipa*.

2.3. A Review of the Literature on the Biology and Population Dynamics of *Sarotherodon melanotheron melanotheron* (Ruppell 1852).

Family: Cichlidae

Order: Perciformes

Class: Actinopterygii

Synonyms

Tilapia heudoleti macrocephala (Bleeker 1852)

Tilapia melanotheron (Ruppell 1852)

Chromis macrocephalus (Bleeker, 1862)

Chromis microcephalus (Gunther, 1862)

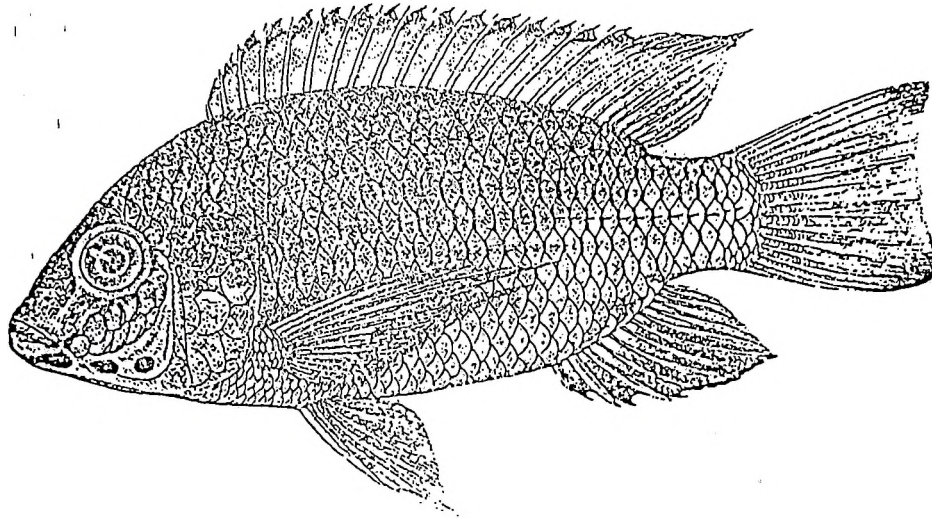


Fig 2.1 *Sarotherodon melanotheron melanotheron* (after Boulenger, 1915)

Sarotherodon melanotheron was proposed by Ruppell in 1852 as a new binomen, the proposal being accompanied by a definition of the genus, which validates both names according to the International Code. The genus *Sarotherodon* has a worldwide distribution and is found in Africa, Central and South America, West Indies, Madagascar, Syria and Coastal India. *S. melanotheron* occurs in both fresh and brackish water from Senegal to Zaire, and is abundant in the mangrove zone (Trewavas 1983). It was introduced to the former USSR, Hawaii and Japan.

Its biology and ecology has been extensively dealt with by Trewavas, (1983). The taxonomy and morphology of the fish are highlighted in Trewavas and Teugels (1991) and Teugels (1992). *Sarotherodon melanotheron* has a moderately deep and compressed body shape, with a nostril on each side of the head and an interrupted lateral line. The dorsal fin has 7-25 spines and 5-30 soft rays. The spines in the anal fin are 3-15, with 4-15 soft rays. It can grow up to 220 mm SL.

The operculum of the mature female is transparent, appearing purple from the red gills showing through. The cheek, operculum and part of the sub operculum of the mature male are a metallic gold colour. There are black patches on the lower parts of the head, on the nape and pectoral girdle and on the ventral fins. These develop in both sexes as they reach maturity. The fish can control the intensity of the black colour to a certain degree but not the position (Barlow and Green, 1970).

Trewavas (1983) found that in Ghana the relative mean size of the head is greater in males than in females, although in one population from the Mouree lagoon (in the Central Region), the females had bigger than average heads. She postulated that this particular population may have big heads due to growth phenomenon dependent on the ecological conditions of that lagoon, or as a result of a genetic factor developed.

The genital papilla is small, sub conical or leaf shaped in the male but a short funnel with scalloped edges in the female. Its breeding activities are highly organized, with parental care in three forms: mouthbrooding, substrate brooding of eggs then mouthbrooding of young. Spawning occurs throughout the year. Experimental work by Shaw and Aronson (1954) showed that *S. melanotheron* can live, breed and produce viable offspring in freshwater aquaria, as long as the embryos are allowed to develop normally in the parental mouth.

Williams (1962) reported the stomach contents of *S. melanotheron* from Lagos lagoon as sand, mud, benthic diatoms and filamentous algae, from which he concluded that *S. melanotheron* is an aufwuchs and detritus feeder. According to the same author, as with other species, juveniles have been found to be more carnivorous than the adult.

Pauly (1976) found the main food of fry of 2.5 cm TL in Sakumo Lagoon to be harpacticoid copepods, with some amounts of phytoplankton, benthic diatoms and zooplankton. At 4 cm TL copepods were only occasionally present and above 4 cm the adult regime was adopted. Pauly *et al.* (1988) reported on the detritus, energy consumption and conversion efficiency of *Sarotherodon melanotheron* in the Sakumo 2 Lagoon.

Williams (1962) also tested the tolerance of the species at Lagos, by gradual transfer from fresh water to sea water at a chloride concentration of 37.5 ‰ with no mortality and by direct transfer from brackish water on the one hand and salt water on the other. On transferring to a concentration of 3.7 ‰ the mortality was 50%. This demonstrates the wide salinity tolerance of the species.

Fagade (1970) and Fryer and lies (1972) have pointed out the importance of Cichlid species as a commercial fish. Some studies have been carried out on the biology and fishery of *S. melanotheron* in a few lagoons in Ghana. Pauly (1976) did some preliminary studies on the biology, fishery and potential use for aquaculture of *Tilapia melanotheron* in the Sakumo 2 lagoon.

Blay and Asabere-Ameyaw (1993) assessed the fishery of the population of *S. melanotheron* in the Fosu lagoon and suggested that the population may be stunted. Eyeson examined the egg and fry swallowing habits of *Sarotherodon melanotheron* and *Tilapia zillii* in (1983). In 1992 he reported on the residual bi-parental oral brooding in *S. melanotheron*.

In tropical fish, seasonal fluctuations in their environment are usually less marked than in temperate waters. Also catch data in tropical countries, especially for lagoons are difficult to obtain. The analysis of length-frequency data represents the most useful method to estimate growth parameters and mortality rates in tropical fish. It can be considered as complementary to age-based methods or used as a first approximation. Pauly(1979) contended that:

- the builders of tropical models have at their disposal much less information on fish species especially those of commercial importance than the model builders working in temperate areas of the world;
- much of the work in tropical areas is poorly documented and often remains unpublished.

In this light Pauly (1980) looked at the relationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Pauly advocated for the use of length-based stock assessment for tropical countries because the data were easy to obtain. Hilbom and Walters (1992) preferred the use of catch data for the purposes of stock assessment. In this study experimental catch as well as length based stock assessment was used because commercial catch data on a regular basis were difficult to obtain from the lagoons.

2.4 Management of Lagoon Fisheries

Management of fisheries in the sense of manipulation of the environment to enhance yield potential by improving aquatic productivity is common in many West African lagoons. Brush park fisheries or "acadja" a traditional form of low technology aquaculture is practiced in inland and brackish waters. In coastal lagoons the most sophisticated forms of brush park fisheries occur in Benin (Kapetsky 1981). Acadjas are also found in Ghana (Mensah 1979), Togo (Welcomme, 1971, 1972), Nigeria (FAO 1979) and Cameroon (Stauch, 1966). Welcomme observed in 1972 that *Tilapia melanotheron* and *Chrysiichthys nigrodigitatus* dominated the catch of "acadja" fisheries by 67-95% by weight.

In the past, management of the fisheries in Ghana was linked to traditional beliefs in the form of taboos and other cultural practices. Most lagoons are believed to be the abode of some god or goddess, represented by a shrine and a fetish priest or priestess. Certain taboos and practices are associated with these gods.

With the introduction of Christianity and other western practices (Ntiamo-Baidu 1991), and migration of fishers, many of the traditional rules and regulations are not adhered to. These rules protected the lagoon habitat and prevented over-exploitation of the resources. Ntiamo-Baidu and Hollis (1988), Ntiamo-Baidu (1991), and Ntiamo-Baidu and Gordon (1991) reported on traditional conservation strategies associated with Sakumo 2, Djange, Muni lagoons and the Densu delta and their use as RAMSAR sites. The Save the Seashore Birds project in Ghana has monitored bird life on the coastal wetlands since 1986.

In 1988, Ghana ratified the Convention on Wetlands of International Importance, especially as waterfowl habitats (Ramsar Convention). Ghana, as a result, was obliged to designate parts of her wetlands which satisfied the criteria as Ramsar sites for inclusion into the world wide lists of such sites (FOE, 1994). The Densu delta (Sakumo lagoon 1), Sakumo lagoon 2, Songhor lagoon, Muni lagoon as well as Keta lagoon are Ramsar sites in Ghana. Ntiamo-Baidu and Gordon (1991) reported that over 90% of the birds these sites support are migratory.

A coastal zone indicative plan (Agyepong *et al*, 1990) proposed the development of a management system for the whole coastal zone, protection of selected coastal areas, and the setting up of a coastal database as the main actions required to guide future sustainable actions. The requirement to manage fishery resources in a rational manner has prompted continuous research and development into various methods of evaluating their status and assessing the impact of exploitation (Cox, 1992).

Kapetsky (1981) made a review of fishery management practices in tropical coastal lagoons and estuaries. He observed that in the sense of regulation of entry, gears, fishermen and fishing seasons, few coastal lagoon or estuarine fisheries could be said to be well managed particularly in West Africa. Fisheries may be regulated to some extent by traditional controls rather than by central government authority. Regulations tend to be based on fishermen's experience or administrator's perceptions rather than on a body of applied research.

Community based fishery management, as one of the options for good fishery management, has recently been advocated by certain scientists as part of Integrated Coastal Zone Management (ICZM). Munoz (1995), Dayaratne *et al.* (1995) and Dayaratne (1996) found it useful for the fisheries of the Philippines and Sri Lanka. This is based on the concept of community based resource management where major stakeholders take an active role in managing the resources. The ICZM is a shared responsibility of the coastal community, local government and non governmental organizations (NGO's). This approach is being emphasized by the new Fisheries Development and Management Act.

A recent IDA / Ghana government team reviewed progress made in the implementation of the Fisheries Sub-Sector Capacity Building Project in April 1998. They reported satisfactory progress being made towards the involvement of communities in the management of fisheries resources. Community Based Fisheries Management Committees (CBFMC) have been formed in 37 out of 189 villages in districts in the Greater Accra and Western Regions (Aide Memoire, MOFA, 1998). Unfortunately, most of these CBFMC's are involved in marine artisanal fisheries and not in lagoon fisheries.

CHAPTER THREE

3.0 STUDY AREA

The coastline of Ghana, which forms part of the Gulf of Guinea, is between latitudes 4° 30' N at Cape Three Points and 6° N in the extreme east and stretches for a distance of 550 km between 3° W and about 1° E. (Fig. 3.1). The shoreline is made up of a series of rocky headlands linked by sandy beaches behind which lie many brackish lagoons. Ghana lies in the equatorial belt and temperatures along the coast range between 25 and 35°C with very little variation throughout the year. There are two wet seasons in a year, the major one from May to July and the minor one from September to November. Annual rainfall varies between 215 cm in the southwest and 82 cm in the southeast (Biney 1990).

Kitson (1916) and Dickson and Benneh (1970) have described the geology of the coast of Ghana. There is the Western section, between Newtown in the Western Region and Axim, which has stretches of beach sand behind which lies swamp. The Central section stretches from Axim to Apam and is mostly rocky cliffs interrupted where rivers emerge and fringes of sandbars separate off coastal lagoons. The eastern section is from Apam to Keta where there is an alternating succession of lagoons and coastal plain, with or without low cliffs.

Most of the rivers in southern Ghana (the Tano, Ankobra, Pra, Ayensu and Densu) flow into the sea often through coastal lagoons or estuaries. The two study areas are the Abrubi lagoon (a closed lagoon) and Densu Delta which encompasses Sakumo I (an open lagoon).

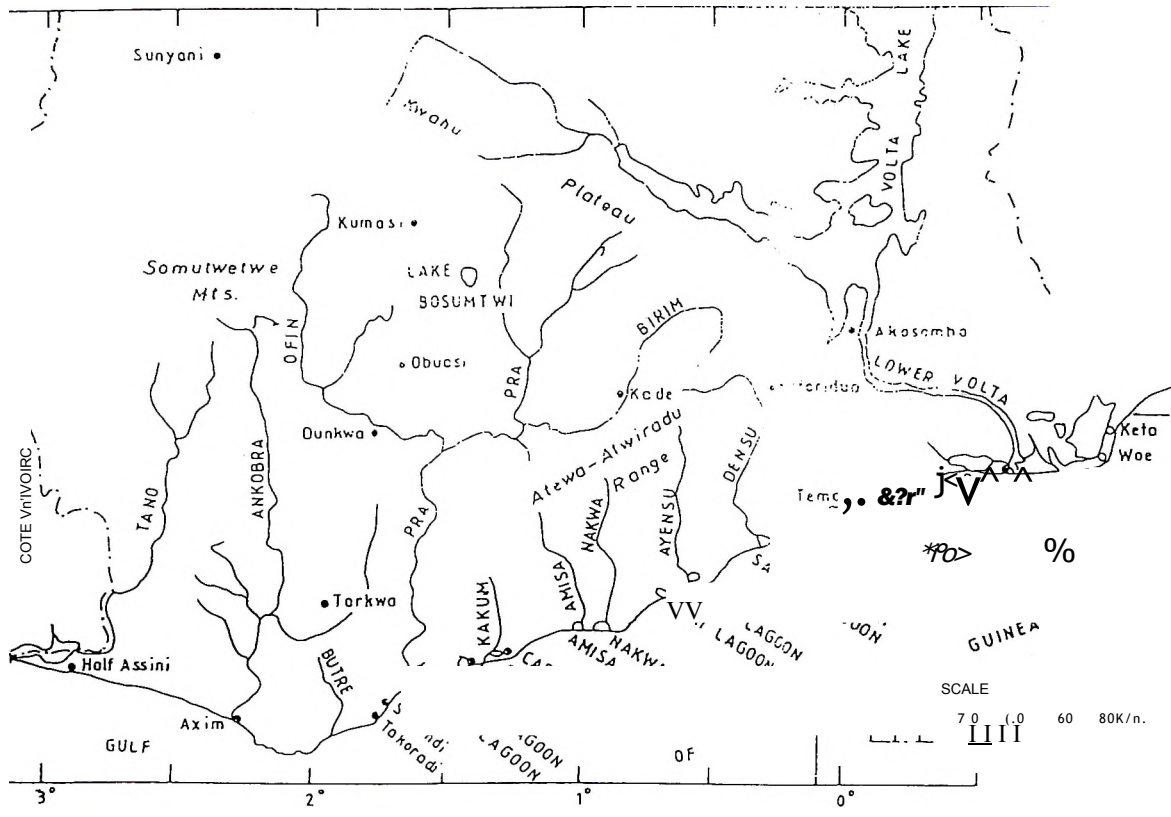


Fig3! 1 Map of Southern Ghana Showing Major Rivers and Lagoons

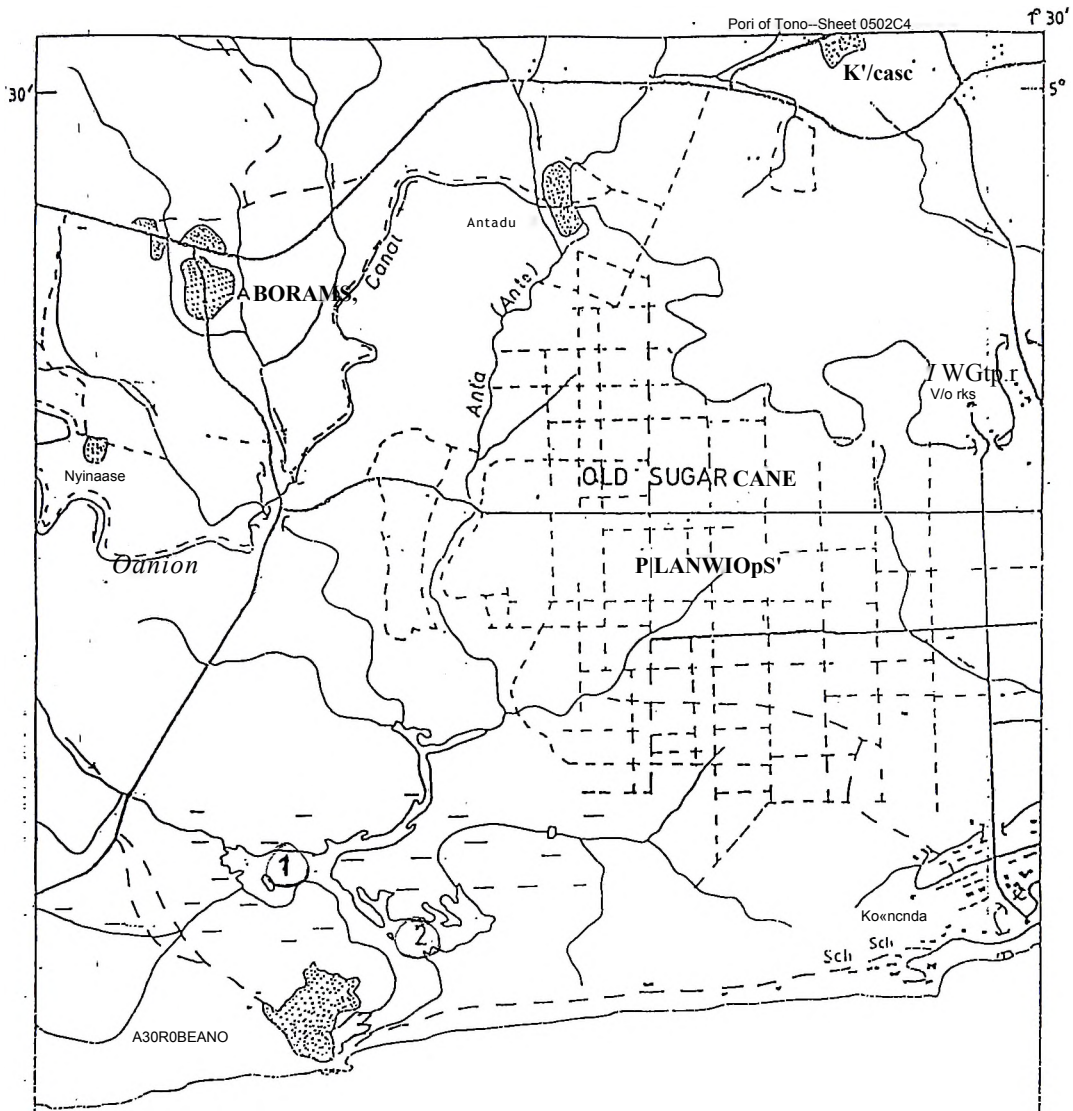
3.1 Abrubi Lagoon

This is a closed lagoon situated on latitude 5°03'N and longitude 0°30'W and located at about 1.5 km west of Komenda and 30 km from Cape Coast in the Central Region of Ghana. It has a wetland area of 1.7 km² and open water of 0.95 km². It is shallow in the dry season with an average depth of 0.8 m but can rise to mean depths of 3.5 m in the wet season (Fig. 3.2)

The Abrubi lagoon is separated from the sea by a sand bar that is manually breached when the lagoon floods into the village during the rainy season. Water enters the lagoon through River Antaa and other minor streams that dry up seasonally. During the wet season fresh water enters the lagoon via land run off and direct precipitation. Interstitial water seeps from the sea into the lagoon under the sand bar.

There is one human settlement, Abrobeano, with a population of about 3000 situated at the edge of the lagoon. Tradition holds that a god, Nana Abrubi, guards the lagoon. Fishing is banned on Saturdays and for a month prior to the 'Nyeyi' festival which falls in the second week of September. The festival time is a time of harvest and one in which the dead are remembered. The people of Komenda own the lagoon since residents of Abrobeano are settlers.

Apart from fishing, farming of cassava, tomatoes, pepper and pineapples is carried out in the wetland areas of the lagoon.



LEGF.KQ

ROAD

TRACKS/MAJOR FOOTPATHS

FOOTPATHS

TOWNS/VILLAGES

AREA LIABLE
TO FLOOD

METRES 1000

III

SCALE

MILES

1/4 0

1 KILOMETRE

3.2 THE STUDY AREA SHOWING THE SAMPLING STATIONS (ABRUBI LAGOON)

3.1.1 Flora

The Abrubi lagoon is fringed by a coconut plantation, which is rapidly being wiped out by Cape St. Paul's Wilt disease (CSPWD). There are a few mangroves, *Avicennia nitida* and *Rhizophora racemosa* and other forest vegetation. Grasses such as *Paspalum vaginatum*, *Sporobolus* sp. and herbs such as *Sessuvium portulacastrum* dominate the lagoon margin and mud flats. The savanna date palm *Phoenix reclinata* and *Acrostichum aureum* also occur around the lagoon. In the lagoon there are marshes of *Cyperus articularis* and aquatic plants such as *Pistia stratiotes* and *Nymphaea lotus*.

3.1.2 Fauna

Monkeys are found inhabiting some of the trees around the lagoon. There is a diverse avian population in and around the lagoon. There are lily-trotters, kingfishers, weaverbirds, wild duck, hawks, terns and herons. These usually come out to feed after it rains.



3.2 DENSU DELTA

The Densu Delta and wetlands cover an area of some 34 km² comprising 21 km² of lagoon (Sakumo) and marsh, 11 km² of salt pans, 1.4 km² of shrub and a coastal strip of dunes and beach covering 0.25 km² (Ntiamoah-Baidu and Hollis, 1988). It is situated on longitude 5°30 N and latitude 0° 20 W and located about 17 km west of Accra (Fig.

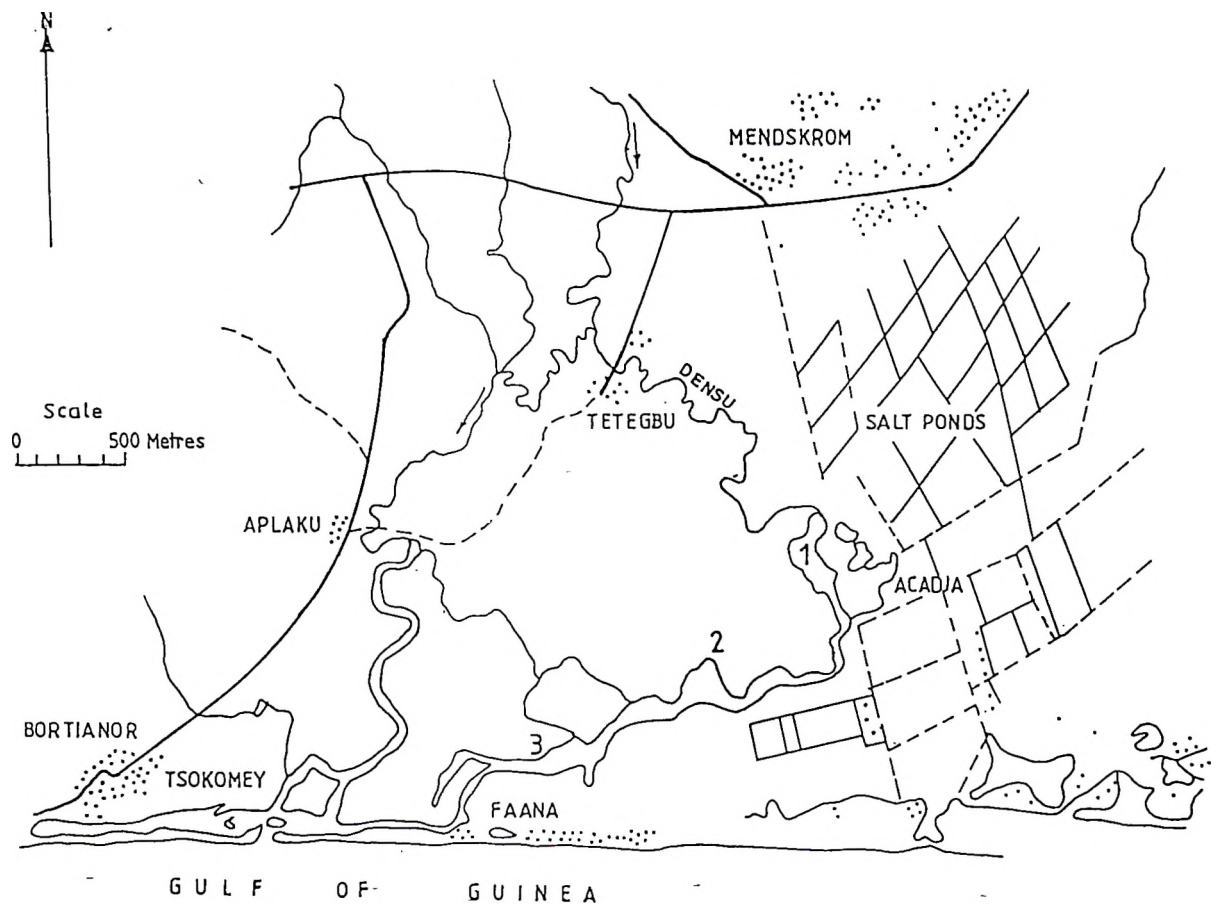
The Weija dam, built on the Densu River, controls the flow of water to the Delta and thus affects its ecology. The delta is quite shallow in the dry season with an average depth of 0.9 m but the water level can be high in the middle part in the rainy season and when the sluice gates of the dam are opened (nearly 5 m).

The Delta is almost surrounded by a housing estate and other residential accommodation with a population of over 20,000 (Friends Of the Earth, 1994). Domestic sewage from the residential area is discharged directly into the delta.

Pineapples, maize, cassava and tomatoes are grown in the upper and middle parts of the catchment area of River Densu. Parts of the Delta have been turned into an intensive salt mining operation owned by the Panbros Salt Industries.

3.2.1 Flora

The sand dunes on the southern end of the delta are fringed with coconut trees. *Sessuvium portulacastrum* and *Paspalum vaginatum* are present on the banks of the lagoon. The mangrove swamps are made up of *Avicennia* and *Conocarpus erectus* . The estimated mangrove cover is about 150 ha (de Graft Johnson 1991). The mangroves are cut for fuelwood and also used for 'acadjia fishing'.



3.2.2 Fauna

Ntiamoah-Baidu and Gordon (1991) reported the existence of some 57 species of waterfowl with an estimated population of 35000 at peak migration periods. The area has been designated as a RAMSAR site.

3.3 The fisheries

Fishing in both the Abrubi lagoon and Densu delta is carried out through small-scale operations. Due to the shallow nature of the lagoons, most fishing is done without the use of a fishing craft (like canoes) except in the rainy season. The lagoons support artisanal fishing for both commercial and subsistence purposes. Cast nets operated from a canoe, or by fishermen standing in the water, are generally used; gillnets are sometimes used but not encouraged in Abrubi lagoon.

Fishermen at Abrubi lagoon are mostly marine fishermen who fish in the lagoon during the 'lean' marine season for subsistence. They are Fantis and believed to have migrated from Nakwa and Asaafa, also in the Central Region of Ghana. Most of the fishermen at the Densu delta are believed to have migrated from the coastal part of the Volta Region of Ghana. Some of them are Fantis and others are Ga from the Greater Accra Region.

The fishermen fishing in the lagoons in both study areas operate on either full or part-time basis. There are one-man units and team units, and each of these categories varies in daily and annual productivity. The usual practice is one fisherman fishing with a cast net. The most important fishing gear in the two study areas is the cast net (Fig 3.4).

The cast net has pockets around the lip and may vary in size between 3-5 m high and 10-20 m in circumference. The mesh size ranges from 10-40 mm and made of yams of R75-100 tex (Doyi, 1985).

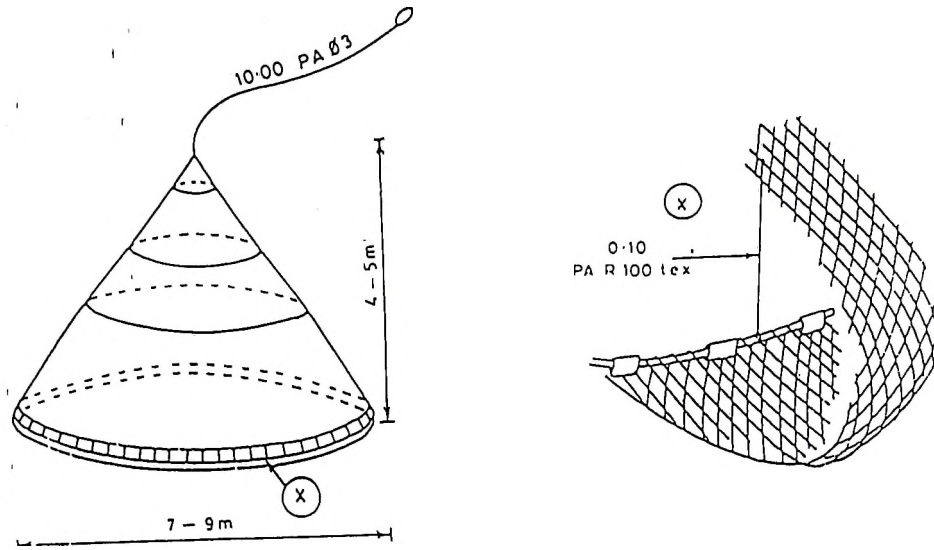


Fig. 3.4 Cast net (after Doyi, 1984).

There is a multiplicity of fishing gears in use in the Densu delta. Apart from cast nets, drag nets, hook and line and traps are also used. Some fishers also catch fish with their bare hands from bushy banks of the lagoon. Fishing with bottles is done mainly by women. A hole 3 - 4 cm in diameter is made at the side of an ordinary beer bottle (Mensah, 1979). Bits of cassava and gari which serve as bait are put in the hole. The bottle is stuck to the bottom of the lagoon. One end of a long stick is kept in the bottle whilst the other end remains above the water to indicate the position of the bottle. The bait normally attracts cichlids which are caught whilst feeding (Appendix 3.1).

Two types of dragnets are used, one is a seine net with a bag and the other one is without a bag. In the Densu wetlands, the pocket seine net is also called "Agutsidor". This is used by Ewe fishers and is said to have originated from the Keta area in the Volta Region of Ghana.

The net has the shape of a beam trawl and a rectangular opening with 90 cm vertical sticks **forming** partitions or pockets across the entrance. Each net is 90 - 100 m long and has a mesh size of 18 -20 mm (stretched). The gear has no floats or sinkers.

Various traps are used in the lagoons to catch finfish and crustacea. The most important of these are the woven and the lagoon crab trap. The woven trap is baited and set at the bottom of the lagoon with two sticks fixed into position. It is used for catching cichlids. The crab traps are usually operated by boys in both study areas. The crab holes were found to be concentrated in *Paspalum* and *Sesuvium* beds. The crab trap is made of empty cans and wood and is used in the *Sesssvium* beds in the Densu delta to catch the common land crab (*Cardiosoma* sp.) which lives in holes along the banks of the delta.

In the 'acadja' method of fishing, several whole twigs or branches of trees are dumped in the water, especially in sheltered areas. These serve as fish aggregating devices and also feeding and spawning areas. Where mangroves are available, their branches are used in this operation. According to Mensah (1979), this is a traditional aquacultural practice in lagoons. The 'acadja' fisher leaves the pile for two to three weeks for the environment to stabilize. In harvesting, the area is surrounded with a net and the twigs and branches are then removed and put at a different but nearby area of the lagoon (App.3.3). The net is closed, forming a bag and the fish collected. The target are cichlids, but mullets and crabs are also caught. At Abrubi some of the fish is sold to women from Abrobeano and Komenda, most of it is eaten by the families of the fishermen. At the Densu delta the fishers sell their catch directly to the women who come from Dansoman, Glefe, Tsokome and Accra. The fish are gutted near the lagoon.

CHAPTER FOUR

4.0 MATERIALS AND METHODS

4.1. *Physico-Chemical Parameters.*

This was used to assess the relationship between the target species and the environment.

Sampling was carried out in the middle of every month from May 1994 to April 1996 at the Abrubi lagoon and Densu-delta. The Abrubi lagoon (closed lagoon) and Sakumol lagoon (Densu-delta, open lagoon) were geographically divided into three strata for sampling purposes. There was one sampling station per stratum; the stations were chosen to reflect the salinity gradient from south to north.

Station 1: the Riverine portion or the upper reaches

Station 2 : the Middle part or the middle reaches

Station 3 : the nearest area adjacent to the sea or the lower reaches

On each sampling occasion surface water samples were collected in standardized 250 ml bottles from each of the 3 stations and analysed at the former Institute of Aquatic Biology now Water Research Institute. Standard spectrophotometric methods were used in the analysis for phosphates, nitrates, and silicates.

Specific determinations were:

Orthophosphate - determined using ammonium molybdate and ascorbic acid (Mackereth *et al.*, 1978).

Nitrate-nitrogen - measured by the indophenol blue method (FAO,1975).

Silicates - measured using molybdate colourimetric method.

Dissolved oxygen - determined by a modification of Winkler method (FAO, 1975).

pH - measured in the field with a portable Griffin pH meter.

Temperature- determined using a mercury-in- glass thermometer.

Total dissolved solids and *conductivity* were obtained using a Hach model conductivity meter.

Salinity values were obtained from a Fisher conductivity meter model 152.

Depth - measured using a metre rule.

4.2. Fish Sampling

Experimental fishing was conducted in the Densu-delta and Abrubi lagoon using the cast net as the standardized gear. Each month from May 1994 to April 1996 fish were caught at each station with cast nets of stretched mesh size of 25 mm from the 3 (Lower, Middle, Upper reaches) stations at both study sites. The catch per hour of the cast net fishers was established through experimental fishing sessions.

A fisherman was taken from the Institute of Aquatic Biology for experimental fishing in the Densu delta as the fishermen were mainly of the Ewe tribe and he was an Ewe. This arrangement enabled useful information on the fishery to be collected following interaction with the local fishermen. At Abrubi lagoon one fisherman was hired locally for the experimental fishing, as strangers were not allowed in the lagoon.

Random samples of *Sarotherodon melanotheron* were obtained from the catch at each station for length measurement and other biological investigations. Standard length (SL) and total length (TL) of each fish were measured to the nearest mm.

Total body weight (BW) was taken to 0.1 g accuracy. Sub samples were taken for further investigations on the relationships between standard and total lengths. Length-frequency histograms were produced for each month by regrouping the data into 5 mm intervals.

No experimental catch data were obtained from Station 2 in May 1994 in the Densu delta because the sluice gates of the Weija Dam had been opened and the level of the water was high thus fishing was difficult. The total catch was weighed to the nearest 0.1g. The fish were preserved in 5% formalin and counted and weighed in the laboratory.

The fish collected were sorted by species, with the assistance of keys provided by Schneider (1990) and Irvine (1947). All species taken at any station were ranked according to frequency of occurrence. Shellfish in and around the lagoon were identified with the help of Edmunds (1978). Every month a whole day (different days at the study sites) was spent observing fishing activities at the two sites. The catches made by local fishermen were inspected for species composition.

4.2.1 Fishing Effort

The fishing effort was estimated as the total number of fishers working in the lagoon daily in man-hours. The average man-hours spent fishing per day was calculated for each month. The fishers in the lagoon usually fish from 0500GMT to 1900GMT (14 hours). Experimental fishing was conducted between 0700-1000GMT, 1100-1400 GMT and 1500-1800GMT. This gave 9 hours of fishing. This enabled the catch per day to be estimated as follows:

Catch(C) = Catch per man-hr (cpue) x No. of hours available for fishing x Average Number of fishermen

the assumptions made were that the fishers fished for 14 hours and the experimental catch was equivalent to the catch of the local fishermen. The species richness, diversity, evenness, frequency of occurrence and relative abundance of fish were calculated for all fish species. To test for statistical differences between samples (both in terms of fishes and in diversity indices) the samples were divided into two groups, those occurring in the dry season (November-April) and those occurring in the wet season (May-October). The differences were calculated with a two-tailed Mann-Whitney U-test.

4.2.2 Catch Per Unit Effort

The Catch Per Unit Effort (CPUE) at each station was calculated as catch/fisher/hour(c/f/hr).

Analysis of variance was performed on the calculated CPUE values to determine the differences in catch rates between the two study sites, between stations of the same lagoon and between wet and dry seasons.

The following were also observed and recorded:

- (a) the number of fishers in the two study sites;
- b) the catches made at each station;
- (c) the fishing methods including fishing gears used; and
- (d) fish species caught.

4.3 Ecological guilds

The fishes were put in ecological guilds and classified according to Elliot and Dewailly (1995) as follows:

ER - a truly lagoon resident species and spends its entire life in the lagoon;

MA - marine adventitious visitors, appears irregularly in the lagoon but has no apparent lagoonal requirements.

CA - diadromous (catadromous or anadromous migrant species) which use the lagoon to pass between salt and fresh waters for spawning and feeding;

MS - marine seasonal migrant species, which have regular seasonal visits to the lagoon, usually as adults;

MJ - marine juvenile migrant species, which use the lagoon primarily as a nursery ground, usually spawning and spending much of their adult at sea but often returning seasonally to the lagoon;

FW - fresh water adventitious species, which occasionally enter brackish waters from fresh waters but have no apparent lagoonal requirements.

4.4 Forage/Carnivore (F/C) Ratio

On the basis of their feeding habits, the fish were classified as either forage (F) species, and carnivorous feeders (C). The F/C ratio is defined as the ratio of the total weights of forage species (F) to carnivorous species (C).

The E value of a species is defined as the percentage by weight of the species relative to the entire weight of all the fish caught. E is influenced by its reproductive potential, food habits, growth and adaptation to the environment (Swingle, 1950). The E value and F/C ratio were derived by using Swingle's (1950) formulae.

I. 5. Fish Species Diversity, Composition and Relative Abundance

Measures of species diversity are frequently seen as indicators of the well being of ecological systems (Magurran, 1988). A whole range of indices and formulae have been devised by ecologists for measuring diversity (Hellawell, 1978). Diversity is made up of 2 components; the variety and the relative abundance of species. It can be measured by recording the number of species (species richness) and by describing their relative abundance (evenness) or by using a measure which combines the two components.

4.5.1 Species Richness Indices

A number of indices have been derived to measure species richness and are based on the relationship between the total number of species (S) and the total number of individuals (N). Two well known indices are the Margalef's (1958) diversity index (*D_{mg}*) and Menhick index (1964) (*D_{meri}*). They are calculated as follows:

$$D_{mg} = \frac{S-1}{\ln N}$$

$$D_{meri} = \frac{S}{4N}$$

Although both indices are easy to calculate, Margalef's index is used in this study because it gives the greatest degree of discrimination (Magurran, 1988).

4.5.2 Species Diversity

In any community a few species would be very abundant, some would have medium abundance whilst most would be represented by only a few individuals. The most widely used measure of diversity are the information theory indices (Magurran, 1988).

These indices are based on the rationale that the diversity, or information in a natural system can be measured in a similar way to the information contained in a code or message (Magurran, op cit).

Shannon and Weiner independently derived the function which has become known as the Shannon index of diversity, H' (Magurran, 1988). Diversity was described by using the Shannon Weiner Information Index (H') (Shannon and Weaver, 1949) and its component parts, richness (number of species) and evenness (Pielou, 1975). It is based on the information theory and is a measure of the average degree of uncertainty in predicting to what species an individual chosen at random from a collection of S species and N individuals will belong. The equation for the Shannon Diversity Index H' is given by:

$$H' = - \sum_{i=1}^S p_i (\ln p_i) \quad \text{Where } p_i = \frac{N_i}{N}$$

Where p_i is the proportion of individuals found in the i th species

or

$$H' = - \sum_{i=1}^S \left(\frac{N_i}{N} \right) \ln \left(\frac{N_i}{N} \right)$$

N_i is the number of individuals of the i th species and N is the total number of individuals of all S species. As N_i and N are population parameters they are estimated from the corresponding sample parameters n_i and n and the index becomes:

$$H^1 = - \sum_{i=1}^S \left(\frac{n_i}{n} \right) \ln \left(\frac{n_i}{n} \right)$$

This index which was used in the study measures change in species number and species evenness. The Shannon Diversity Index assumes that all individuals are randomly sampled from the population and that all species are represented in the sample. The value of the Shannon Diversity Index usually falls between 1.5 and 3.5 and rarely surpasses 4.5 (Margalef, 1972)

4.5.3 Evenness

Measuring the evenness gives an indication of how abundant a particular species is in the system; (the number of individuals and biomass) and how it is distributed among the other species (Ludwig and Reynolds, 1988). A number of indices have been proposed in an attempt to quantify the evenness component of diversity. The most common evenness index used by ecologists (and one used in this study) is that by Pielou (1975) which relates H' (Shannon Diversity Index), to the maximum value that H' can attain when all the species in the sample are equally abundant. It is denoted by:

$$J = \frac{H'}{\ln S'}$$

4.6 Similarity Coefficients

Similarity coefficients are based on the presence or absence of data. They may vary from 0 when a pair of sampling units are completely different to 1 when sampling units are identical. Similarity Coefficients may measure the similarity in abundance of the few commonest species or concentrate on the occurrence of rare species. Some of the similarity coefficients are the Canberra Coefficient, the Correlation Coefficient and the Bray-Curtis Coefficient.

The Bray-Curtis Coefficient has become common in ecological work resulting from terrestrial application (Bray-Curtis, 1957). It is also sometimes referred to as the Czekanowski coefficient (Clarke and Warwick, 1994)

The advantage of Bray-Curtis over the other coefficients is that it allows all species to contribute to the definition of similarity whilst retaining some of the information on the prevalence of a species ensuring that the commoner species are generally given greater weight than the rare ones. It is also a balance between the Canberra and Correlation Coefficients; all species contribute to the definition of similarity (Clarke and Warwick op cit).

The computer software package PRIMER (Plymouth Routines in Multivariate Ecological Research) was used to compute Bray-Curtis species similarities with 4th root transformation (Field *et al.*, 1982). Bray-Curtis is the main coefficient calculated by the CLUSTER routine in PRIMER which also allows a range of transformations of the data. The Bray-Curtis similarity between species i and i is computed from:

$$S' = 100 \left(1 - \frac{\sum y_{ij} + \sum y_{lj}}{\sum y_{ij} + \sum y_{lj}} \right)$$

Where y represents the entry in the i^* row and the j^m column of the data matrix that is abundance or biomass for the i^* species in the j^* sample.

$S' = 0$ if two species have no samples in common that is they are never found at the same sites.

$S' = 100$ if the y value (counts and biomass) for the two species are the same at all sites.

4. 7. Multi-Dimensional Scaling

Ordination is a term used to describe a set of techniques in which sampling units, in this thesis (months) are arranged in relation to one or more coordination axes such that their relative positions to the axes and to each other provides maximum information about their ecological similarities. Several methods of ordination are available. These include:

- a) Principal Component Analysis, PCA first used in ecology by Goodall (1954). PCA has several limitations, particularly when dealing with community data sets that have strong linearities.
- b) Principal Co-ordinates analysis, PCoA (Gower, 1966);
- c) Correspondence Analysis and Detrended Correspondence Analysis, DECORANA (Hill and Gauch, 1980). This technique is more robust with nonlinear data sets than PCA.

There are also two non-linear methods, polynomial ordination and non metric Multi-Dimensional Scaling.

The ordination technique adopted in this thesis is the non-metric Multi-Dimensional Scaling (MDS). It has greater flexibility than Principal Component Analysis and does not make assumptions. MDS has been recommended as one of the best ordination techniques available (Clarke and Warwick, 1994)). Ordination serves to summarize community data by producing a low dimensional ordination space in which similar species and samples are close together and dissimilar entities apart.

MDS constructs a “map” or configuration of the sample in a specified number of dimensions which attempt to satisfy all the conditions imposed by the rank similarity matrix. For example, if sample 1 has higher similarity to sample 2 than it does to sample 3 then sample 1 will be placed closer on the map to sample 2 than sample 3. The MDS configuration is constructed to preserve the similarity ranking. For most data sets there is some distortion or stress between the similarity rankings and the corresponding distance ranking in the ordination plot. The principle of MDS is to choose a configuration of points which minimizes the stress. Stress increases with reducing dimension of the ordination (Clarke and Warwick, 1994)

Cluster analysis is a technique that accomplishes the sorting of objects or sampling units into groups based on their overall resemblance to one another. The results of cluster analysis are summarised in a dendrogram (Ludwig and Reynolds, 1988).

Matrices of Bray-Curtis coefficients were calculated for the similarities between the fish species occurring in the various months and the distributions of species for each station. A dendrogram and a 2-dimensional scatter plot were derived from each matrix, the former by group average and the latter by non-metric Multi-Dimensional Scaling (MDS). Fish groupings by month which could be identified and the scatter plot were interpreted as indicating months showing similar fish species assemblages.

The reliability of the scatter plot were indicated by the stress coefficients used by Clarke and Warwick (1994); i.e.

Stress < 0.05: This gives an excellent representation with no prospect of misinterpretation, (a perfect representation would be one with stress < 0.01).

Stress < 0.1 corresponds to good ordination with no real prospect of a misleading interpretation.

Stress < 0.2: Gives a potentially useful 2- dimensional picture though for values at the upper end of the range not much reliance should be placed on the detail of the plot.

Stress > 0.3 indicates that the points are close to being arbitrarily placed in the 3-dimensional ordination space. Values of stress in the range of 0.2 - 0.3 are treated with skepticism and usually discarded.

The combination of clustering and ordination can be a very effective way of checking the adequacy and mutual consistency of representatives.

4. 8 Biology of Sarotherodon melanotheron

4.8.1. Sex Ratio and Maturity Stages

The sex of a sub sample of fish was determined by examination of the gonads and the sex - ratio calculated. Sex and maturity stages were determined macroscopically in the field or microscopically in the laboratory after each field trip. For each female fish examined, the ovaries were removed and weighed to 0.1 g accuracy. Gonad condition of female fish was graded on a five stage maturity scale (Table 4.1) adapted from Laevastu (1965). The occurrence and size of fish at different stages of maturity were recorded. In this study female maturity stages were used as it was difficult to distinguish the maturity stages of the males.

Table 4.1.

Gonad Maturity stages of *melanotheron*, May 1994-April 1996

(After Laevastu, 1965)

STAGE	STATE	MALES	FEMALES
0	Immature	Testes very small; appear as transparent almost invisible. 2 strands close to dorsal wall of central cavity	Very small ovaries; transparent eggs invisible to the naked eye.
I	Maturing / Virgin and recovering spent	Testes very small appear as transparent slightly visible. 2 strands close to dorsal wall of central cavity	Ovaries yellowish brown; eggs invisible to naked eye and ovaries small.
II	Ripening	2 strands of testes appearing whitish but not transparent	ovary yellowish brown; eggs granular but not singly visible to naked eye; occupy one-third of the central cavity
III	Ripe	2 strands of testes appearing milky but milt does not flow with slight pressure on them	Ovary full of discernible eggs; occupy about two-thirds of central cavity.
IV	Running - Ripe	2 strands of testes appearing milky; milt flows with slight pressure on them.	Ovary full of almost spherical eggs; discernible with naked eyes; eggs flow with slight pressure on ovaries.
V	Spent	2 strands of testes appearing milky and flabby.	Ovary not yet fully free of eggs but flabby.

4.8.2. Gonadosomatic Index (GSI)

Although gonad development and subsequent spawning may depend on various external stimuli, individuals must reach a certain age or size before they are capable of reproduction.

The Gonadosomatic Index (GSI) is used to follow the reproductive cycle of the fish over the year at monthly intervals. The index assumes that an ovary increases in size with increasing development and compares the mass of the gonad with the total mass of the animal. The Gonadosomatic index, which expresses the weight as percentage of the body weight was calculated for fish at stages III and IV maturity using the relationship:

$$\text{GSI} = \frac{\text{Gonad weight} \times 100}{\text{Body weight}}$$

The mean **GSI** was obtained for each month.

4.8.3. Length at first maturity (Lm)

The mean length at first reproduction, or mean length at sexual maturity, (**Lm**) is defined as the length at which 50% of all female fish are sexually mature. The length at first maturity was determined analytically following Ni and Sandeman (1984) and Koranteng (1993), using the logistic equation of the form:

$$P = \frac{1}{1+e^{-(a+bL)}}$$

where P is the proportion of female fish mature at each length L and a and b are constants.

The logit of the equation is for P=0.5,

$$\text{logit } P = \ln\left(\frac{P}{1-P}\right) = a+bL.$$

$$\ln \left(\frac{P}{1-P}\right) = a+bL$$

This defines the mean size at first maturity (**Lm**),

$$\ln(P)/(1-P)=0 \text{ and } Lm = a/b$$

4.8.4. Condition Factor K

The Condition Factor is a traditional way of estimating the condition of a fish and calculated as the ratio between the weight and length. It is also an index of the well being of the fish (Tesch, 1968). Monthly mean condition factor (K) was obtained from:

$$K=BW/L^3*100.$$

Where **BW** is the body weight of the fish in grams and **L** is the length of the fish in centimeters. Condition factors calculated from monthly samples give an indication of the seasonal variations in the condition of the fish.

This may vary with food abundance and the average reproductive status of the stock. Fish with a high condition factor are relatively heavy for their length while fish with a low condition factor are light for their length.

4.9 Population Dynamics of *Sarotherodon melanotheron*

4.9.1. Length-Frequency Distribution

The length composition of a population will often exhibit modes which may correspond to cohorts or age classes and the smallest mode could correspond to the youngest age classes (Peterson 1892, cited in Pauly, 1983). These modes will be most pronounced in fish with a short spawning season and rapid and uniform growth, in which case the mean or modal length of the first few age groups can be determined.

Since the modes in a length-frequency analysis suggest mean fish lengths at successive ages, they may be compared with lengths determinations made on scales or bones. Because all fish grow at approximately the same rate, a cohort can be followed during the first part of its life by tracing the peaks in length / frequency samples (Pauly, 1983).

Ideally, a random sample of fish measured should reflect the distribution of different sizes of fish in the total fish stock. However, the selectivity of the sampling gear (in this case cast net), may result in fish of a certain size being under represented or over represented in the sample. There is therefore the need to correct for selection to know the probability of capture at each length group. The length frequency data was corrected for selection by this equation:

Corrected Adjusted Frequency = Sampled Frequency / Probability of Capture

4.9.2. Length-Weight Relationships

Length-weight relationship was established according to the following formula:

$$W = aL^b \text{ (Carlander, 1969)}$$

$$\text{Where } \log W = \log a + b \log L$$

Where **W** is the body weight in grams and **L** is the standard length (**SL**) in mm, **a** is constant determined empirically, **b** is an exponent with a value nearly always between 2 and 4 often close to 3. If the fish is growing isometrically then the length exponent takes the value of 3, in which case weight increases as the cube of the length. A value significantly larger or smaller than 3 indicates allometric growth (Ricker, 1979).

4.9.3 Growth and Mortality Parameters

Several models have been used to express growth using simple mathematical equations (Allen 1971). The model most commonly used in fisheries work to express the growth of fish is the von Bertalanffy Growth Function (VBGF). The integration of the formula is well documented (von Bertalanffy, 1934, 1951; Beverton and Holt, 1957; Gulland, 1969), while the integration of the generalised VBGF has been discussed in detail in Pauly (1979). This model, based on physiological concepts, has been found to fit data from a wide range of species, although the use of any single model is unlikely to represent growth over the entire life span.

The von Bertalanffy equation, in terms of length, is:

$$L_t = L_{\infty} (1 - \exp [-K(t - t_0)])$$

In this equation, L_t is the predicted mean length at age t . L_{∞} is the theoretical maximum (or asymptotic) length that the species would reach if it lived indefinitely, K is a growth coefficient which is a measure of the rate at which maximum size is reached. As a fish is unlikely to grow according to the above equation throughout its whole life, the theoretical age, at zero length t_0 often has a small negative value.

From the monthly length-frequency distributions from the two study sites, the asymptotic length (L_{∞}) and growth constant (K) of the von Bertalanffy Growth Function (**VBGF**) were estimated using the Compleat **ELEFAN 1** computer programme (Gayanilo *et al.*, **1989**). This has been incorporated into **FISAT (FAO/ ICLARM Stock Assessment)** software.

The method restructures monthly length-frequency samples to form peaks and troughs above and below a running average. It aims at obtaining the best goodness of fit (R_n) for a curve running through the samples, giving the best Loo and K values (Gayanilo *et al.*, 1989).

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4.9.4 , L_c (Length at first capture)

The catch curve, incorporated into the ELEFAN 11 method is a graphical representation of numbers of survivors of fish plotted against their absolute ages. The probabilities of capture were estimated by extrapolating the descending limb of the catch curve so that the numbers of fish on the limb could be represented on the curve as expected numbers. The ratio of expected numbers: actual numbers gave the probability of capture for the mean lengths as used to determine the length at first capture (L_c) at zero probability.

The length at 1st capture and the overall level of fishing mortality determines the optimum exploitation strategy. Therefore it is important to have an estimate of L_c or L_{50} when assessing a fishery. L_c is the length at which 50% of the fish entering the gear (Fig.4.1.) are retained or the average length of the entire catch (Beverton and Holt, 1957).

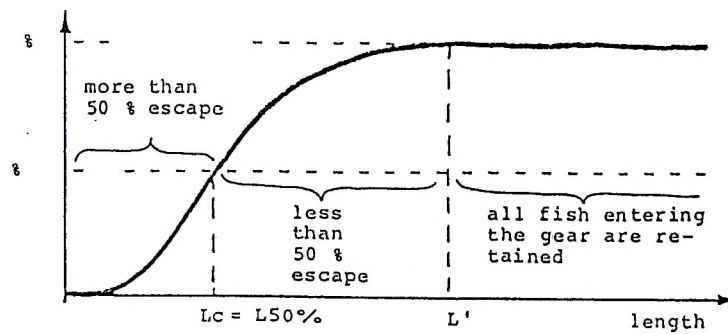


Fig. 4.1 Gear selection curve

4.9.5 Mortality Parameters

The growth parameter estimates were used in the ELEFAN 11 programmes for estimation of the instantaneous total mortality coefficient (Z) by length-converted catch curve analysis (Sparre *et al.*, 1989). The natural mortality coefficient (**M**) was derived from Pauly's (1980) empirical equation:

$$\log M = 0.1228 - 0.1912 \log L^{\circ} + 0.7484 \log K + 0.23911 \log T$$

with mean surface temperature of the water (**T**) as 29 °C.

The instantaneous fishing mortality coefficient (F) was computed as:

$$F = Z - M \text{ (Ricker, 1975).}$$

4.9.6. Exploitation Level and Growth Performance Index 0

The exploitation level (E) was calculated as F/Z.

Also determined was the growth performance index,

$$0 = \log K + 2 \log L_{\infty} \text{ (Pauly and Munro, 1984)}$$

4.10. Management (Issues and Options)

In order to ensure the sustainable use of the lagoon resources especially the fisheries, issues affecting the fisheries and management options are provided for the two study sites.

4.11. Statistical Methods used

ANOVA: A statistical procedure used to determine whether means from two or more samples are drawn from populations with the same mean.

Student's t-test: A statistical procedure that determines whether the data are normally distributed. It also determines if means are distinct.

Chi-squared: This measures the deviation of ratios.

linear Regression: used to analyse how a single dependent variable is affected by the values of one or more independent variables.

Correlation: Measures the relationship between two data sets. It determines if large values of one set are associated with large values of another (positive correlation) or if small values of one set are associated with large values of another (negative correlation) or if the two values are not associated, (zero correlation).

Mann Whitney U test: Non parametric version of a simple t-test.

Bray Curtis Similarities: As explained in section 4.6.

CHAPTER FIVE

5.0 PHYSICO-CHEMICAL PARAMETERS

5.1 Introduction

Lagoons are influenced by a mixture of fresh and seawater at all times, though one may dominate at one time or other. As a result of this, several factors, (physical, chemical and biological) affect lagoons. Due to their generally shallow nature and small size, environmental features have a marked bearing on the nature of the flora and fauna inhabiting lagoons (Colombo, 1977). They respond to the total resulting stimulus or stress rather than a single environmental entity (Kinne, 1971).

Salinity, conductivity, total dissolved solids, phosphates, nitrates and silicates all affect the distribution and abundance of lagoon organisms. The relationships between physico-chemical parameters and fish yields have not been adequately investigated in Ghana. In order to study the effect of the environment on the behavior of the fish species, hydrographic data were collected from Abrubi lagoon and Densu Delta. In this chapter the physico-chemical parameters of the two study areas, the rainfall pattern and any interactions between the parameters are presented.

5.2 Results

Tables 5.1a and 5.1b. show the physico- chemical parameters in the sampling stations.

Station 1 - St. 1

Station 2 - St.2

Station 3 - St.3

table 6.1a Physico-Chemical Parameters of the Abrubi Lagoon, May 1994-April 1998

Station 1 1994-1996										
Month	Worth pH	Oxygen (mg/l)	Temp (°C)	Depth (m)	TDS (mg/l)	Salinity (ppt)	P04(mg/l)	N03(mg/l)	SK52 (mg/l)	Cond (uS/cm)
May	7.3	4.4	27	2.5	6100	2	0.212	0.37	19.4	12300
June	7	4	26	2.4	2030	3.2	0.092	0.01	182	3040
July	6.8	5	26.5	2.2	2140	3.5	0.172	0.081	29	3260
August	7.2	7.4	28	1.5	2072	42	0.12	0.11	23.4	4140
September	6.5	6.5	27.5	0.48	7240	8	0.272	0.034	19.4	13340
October	6.8	6.3	29	0.69	7440	6.3	0.001	0.012	18.7	10800
November	7.4	4.7	30	1.4	2370	5	0.013	0.043	17.4	4750
December	6.8	4	30	0.87	3560	4	0.168	0.021	9.1	5433
Jan-95	7.6	5.5	29	0.88	1350	4.7	0.145	0.07	13.1	4690
February	7.8	5	30	1.07	2074	3.7	0.21	0.083	11.4	4400
March	8	4.8	30	1.03	5670	3.7	0.022	0.094	12	3600
Apr	7.54	4.3	27	1.35	4120	2.5	0.096	0.048	9.3	2220
May	7.2	4.8	26	1.5	2630	2	0.011	0.031	10.4	3216
June	6.7	5.4	26	2.02	2252	2	0.025	0.01	123	4218
July	6.8	6.4	27	2	2152	2.3	0.04	0.016	18.4	4109
August	12	5.8	26	2.4	2040	3.4	0.014	0.114	18.7	5324
September	7	7.4	28	1	3321	4	0.303	0.12	20.4	6200
October	7.7	7	29	0.8	3350	2	0.165	0.22	4.7	5548
November	7.5	5.2	30	0.46	2864	4	0.086	0.34	5.3	6005
December	7.3	5	30	0.98	3100	25	0.02	0.61	2.1	7554
Jan-96	7	5	32	1.35	4104	3	0.013	0.721	3.8	5433
February	6.3	3.3	33	1.74	5234	2.6	0.05	0.056	3	6200
March	6.5	3	30	1.08	5300	3	0.007	0.034	2.7	10600
Apr	7	2.8	30	1.28	4416	2	0.002	0.014	4	9384
Mean	7.12	5.13	28.63	1.37	3622	350	0.09	0.14	12.78	6074

Station 2 1894-1996										
Month	pH	Oxygen (mg/l)	Temp (°C)	Depth (m)	TDS (mg/l)	Salinity (ppt)	P04(mg/l)	N03(mg/l)	Si02 (mg/l)	Cond (uS/cm)
May	7.3	5.5	28	2.2	6200	2	0.161	0.08	2129	12400
June	7.5	4.3	28	2.4	2170	32	0.027	0.01	15.09	4200
July	7.13	4.5	29	2	2110	3	0.004	0.65	24.09	4330
August	12	5	27	1.7	2430	32	0.046	0.141	215	4850
September	6.8	7.4	26	1.23	2760	10	0.035	0.18	15.5	5520
October	7	6.3	28	1.85	6810	85	0.048	0.22	11.1	13250
November	12	5	30	1.58	5030	8	0.45	0.044	17.6	10040
December	6.5	4.6	31	1.73	3120	4.4	0.174	0.028	6.4	5900
Jan-95	6.8	5.8	30	1	13320	4	0.02	0.023	6.1	62300
February	7.5	5.7	32	0.88	5220	6	0.118	0.03	7.7	10560
March	8.5	5.2	33	0.9	5190	75	0.205	0.034	9.4	11850
April	7.5	6.5	30	0.63	4670	12	0.112	0.038	7.6	9320
May	7.3	6	28	1.48	4000	4	0.004	0.003	4.2	7980
June	7.5	4.3	28	2.7	14440	6	0.032	0.011	19	18738
July	8.7	3.8	29	2.4	20330	10	0.038	0.013	21.4	40572
August	6	5.5	27	1.6	24300	13	0.046	0.141	21.3	48500
September	6.5	10.4	27	1.2	25774	18	0.068	0.078	4.8	51420
October	7.3	9.6	28	1.4	3150	5	0.175	0.042	32	6280
November	7.5	4	30	0.9	3280	8	0.03	0.012	3	6546
December	12	3.8	30	1.58	3320	6.7	0.001	0.28	4.9	6820
Jan-96	8	2.7	31	2	4130	6	0.002	0.001	2.8	9543
February	7.5	3	30	1.8	4456	5.8	0.043	0.014	32	10340
March	12	2.8	32	1.2	5470	45	0.04	0.028	15	10950
April	7.5	4.5	30	1.5	4660	4	0.08	0.063	2.5	8433
Mean	7.19	5.23	29.25	1.57	7348	6.57	0.08	0.09	10.71	15852

Station 3 1994-1996										
Month	pH	Oxygen (mg/l)	Temp (°C)	Depth (m)	TDS (mg/l)	Salinity (ppt)	P04(mg/l)	N03(mg/l)	Sr02 (mg/l)	Cond (uS/cm)
May	7	4	29	2.03	2513	52	0.01	0.016	14.8	5006
June	7.03	3.8	28	1.9	2210	3.4	0.011	0.13	16.5	4400
July	7.1	3	27	2.06	2040	3	0.021	0.01	19.3	4080
August	7.24	3.5	26	2.14	2470	4.3	0.11	0.236	20	4920
September	6.42	6	28	1.8	1390	132	0.024	0.023	9.4	2770
October	7.2	5.8	30	0.75	7090	10.4	0.11	0.012	19.6	14200
November	7.5	3	31	1.5	2100	9.6	0.06	0.01	8.4	4200
December	6.4	3	32	1	3600	8	0.174	0.028	4.9	7200
Jan-95	7	4.5	31	1.08	63400	5	0.02	0.04	18.4	126900
February	7	4.6	32	1.38	30080	8.7	0.12	0.25	11.3	60224
March	8.2	4	31	0.7	6050	8	0.185	0.04	14.3	12120
April	6	3.5	28	0.5	4640	9	0.085	0.046	20.8	9280
May	6.5	3	29	1.2	5216	9.4	0.231	0.125	18.4	10433
June	8.5	2.5	28	2	10284	18	0.34	0.074	22.3	20568
July	7	5.6	27	3.5	24126	10	0.441	0.184	16	62000
August	7.5	5	26	2.3	12470	13.6	0.011	0.236	19.4	24920
September	8	7	28	1.7	31270	15.4	0.023	0.104	15	58353
October	6.5	6.2	28	2.8	7721	10	0.135	0.5	12.3	15468
November	7	3	30	1	3150	85	0.04	0.254	11.7	6305
December	7.5	3.3	31	1.2	4310	8	0.002	0.009	5.4	6620
Jan-96	7.2	3	32	0.9	3007	6.5	0.024	0.1	2	6004
February	8.1	2.7	33	0.5	2778	45	0.013	0.004	2.8	5344
March	8	3.7	32	0.75	5270	9	0.022	0.015	3	10550
April	7.5	4	30	1	4165	82	0.0514	0.03	4.4	8344
Mean	7.08	4.08	29.46	1.51	10056	8.78	0.09	0.10	13.02	20425

Table 6.1b Physico-Chemical Parameters of the Densu-delta May 1994-April 1996

Station 1 1994-1996 Densu

Month	pH	Oxygen (mg/l)	Temp (°C)	Depth (m)	TDS (mg/l)	Salinity (ppt)	P04(mg/l)	N03(mg/l)	SKJ2(mg/l)	Cond (uS/cm)
May-94	7	5.8	28	3.8	405	3	0.15	0.02	2.26	810
June	7.2	6	29	3.5	490	4	0.1	0.76	2.8	960
July	7	6.2	27	2.7	268	2	0.08	0.43	1.8	524
August	7	7	26	2.2	204	4	0.05	0.38	2	408
September	6.8	7.4	28	1.69	380	3	0.04	0.43	3	720
October	6.8	6.8	29	1.7	230	5	0.17	1.36	2.4	406
November	7.2	5.5	30	1.8	210	6	0.06	0.38	9.8	420
December	7.4	5.2	31	1.4	228	6	0.04	0.38	7.4	588
Jan-95	7	5	30	1	1530	5	0.01	0.26	6	2040
February	7.5	4.8	32	0.9	748	5	0.05	0.28	7.3	1404
March	8	4.5	30	1.3	1140	6	0.13	0.3	5.4	2380
April	7	6	31	1.8	500	4	0.2	0.243	4.8	1030
May	7.2	8	28	2.2	470	2	0.08	0.63	3.3	820
June	7	7	28	2.4	560	2	0.08	0.8	3	1000
July	7	7.2	28	2.8	450	3	0.09	0.77	2	900
August	6.8	8.2	29	2	880	4	0.142	1.17	1.8	1832
September	6.5	7	30	1.8	1050	4	0.183	1.5	2	2000
October	6.8	6.1	31	1.5	1100	5	0.166	1.36	2.4	2060
November	6.5	6	31	1.4	660	5	0.06	0.5	3.2	1030
December	6.8	5.5	32	1	450	7	0.04	0.3	4.4	934
Jan-96	7	5.4	30	0.9	700	8	0.02	0.2	5.8	1400
February	7.2	5.2	33	0.8	780	8	0.02	0.23	7.2	1634
March	6.8	5	30	0.8	870	12	0.03	0.4	8.4	2060
April	7	5.8	29	1.2	1020	10	0.05	0.44	10.3	2230
Mean	7.02	6.11	29.58	1.77	638.04	5.13	0.09	0.56	4.52	122458

Station 2 Densu delta 1994-1995

Month	pH	Oxygen (mg/l)	Temp (°C)	Depth (m)	TDS (mg/l)	Salinity (ppt)	P04(mg/l)	N03(mg/l)	SiO2 (mg/l)	Cond (uS/cm)
May-94	7	4	29	3	35600	10	0.15	0.03	2.17	71000
June	7.2	4.5	29	2.5	42700	10	0.14	0.55	3.5	85400
July	7	4.5	28	2	24000	6	0.24	0.85	2	48000
August	7.2	5	27	1.5	18000	8	0.1	0.4	3.5	36000
September	7	3.8	28	1.2	27300	8	0.1	0.43	8	55000
October	6.5	4.7	30	0.8	40500	10	0.12	0.48	12.8	81000
November	7.3	4	32	0.5	50300	12	0.26	0.44	17.6	100400
December	7.2	3.8	31	0.4	44200	14	0.27	0.06	8.5	90000
Jan-95	6.8	5	30	0.6	88500	11	0.01	0.03	0.7	137000
February	6.5	4.8	32	0.5	81000	13	0.06	0.7	4.4	162000
March	7.8	4	30	0.8	85000	15	0.02	0.4	2.2	190000
April	7	5.5	31	1.5	62000	10	0.05	0.53	2.5	124000
May	7.2	6	28	4.8	47000	8	0.24	0.82	3.8	99700
June	7	6.6	28	3	46000	8	0.25	1.3	4.8	98000
July	7	6.8	27	3.5	45200	7	0.13	0.65	6	87200
August	7.3	7	27	3	40800	8	0.11	0.54	7	88300
September	7	7	28	2.8	59000	10	0.1	0.5	8.5	118000
October	6.8	6.5	29	1	74000	12	0.08	0.42	10	149000
November	6.5	5.2	29	0.8	79000	12	0.1	0.43	12	150000
December	6.3	5	30	0.6	82000	14	0.12	0.09	7.5	163000
Jan-96	6.8	4.8	31	0.5	72000	12	0.14	0.18	5.3	144000
February	6.8	4	32	1.4	64000	16	0.2	0.5	3.8	138000
March	7	4.3	33	0.5	50100	21	0.22	1.67	1.7	100000
April	7	5	30	0.8	70000	18	0.3	1.3	2	124000
Mean	6.58	5.07	29.54	1.58	54508	11.38	0.15	0.57	5.88	100958

Station3 Densu-delta 1994-1996

Month	pH	Oxygen (mg/l)	Temp (°C)	Depth (m)	TDS (mg/l)	Salinity (ppt)	P04(mg/l)	N03(mg/l)	St02 (mg/l)	Cond (uS/cm)
May-94	7	4.8	28	4.3	68000	8	0.08	0.65	7.04	132900
June	7.2	5.2	28	3.5	93800	10	0.14	0.26	6.4	187600
July	7	6.5	27	3	48100	8	0.25	0.04	3.12	90000
August	7	7	26	2.8	36800	8	0.14	0.62	6.4	56600
September	7	4.3	27	2.2	42600	10	0.06	0.53	5.8	85600
October	6.9	4	28	1.7	37800	12	0.17	1.46	3	75600
November	6.8	3.5	30	1	74700	25	0.13	0.043	12.4	149000
December	7	3	31	0.8	89600	26	0.27	0.63	9.3	179000
Jan-95	6.5	3.8	30	0.8	283000	18	0.114	0.51	2.5	570000
February	6.5	3.5	32	1	50400	21	0.2	0.31	3.8	110000
March	6.5	4.3	29	1.5	102000	28	0.16	0.4	1.76	205000
April	7	4	30	1.8	78000	24	0.09	0.6	9	145000
May	7	4.5	28	3.5	28300	15	0.08	0.68	8	56600
June	7.4	7.6	27	3	30000	8	0.14	0.21	6.8	62000
July	7	8	27	2.5	32000	10	0.11	0.11	4	60000
August	7.5	8.4	26	2.3	28000	8	0.08	0.14	5.3	57000
September	7.4	6.8	28	1.8	26000	8	0.03	0.09	6	52000
October	7	6	29	1.2	35000	10	0.04	1	2	71000
November	6.5	5.8	30	0.5	45000	14	0.13	1.23	3.1	89000
December	6.5	4.8	30	0.5	20000	16	0.12	0.8	3.8	42000
Jan-96	7	4	31	0.8	32000	18	0.21	0.5	2	65500
February	6.5	3.5	32	0.8	40000	20	0.23	0.4	2	78300
March	7	3.5	33	0.9	52000	22	0.4	0.83	1.8	10100
April	7	4	30	1	55000	14	0.08	0.1	4	11200
Mean	6.57	5.07	29.04	1.51	59504	15.13	0.14	0.50	4.57	110042

5.2.1 Temperature

During the 24-month study period, the mean surface temperature of Abrubi lagoon was 28.6°C. (Fig. 5.1a). The highest temperature of 33°C was obtained at St.1 and St.3 in February 1996 and at St.2 in March 1995. Minimum temperature of 26°C was obtained in St.1 (June 1994, May, June and August 1995), St.2 (September 1994) and St.3 (September 1994, September 1995).

In the Densu Delta, the highest temperature of 33°C was obtained at St. 1 in February 1994, and St.2 and St.3 in March 1996 (Fig.5.1b). Minimum temperature of 26°C was obtained, St.1 in August 1994, 27°C at St.2 in August 1995 and in July and August and 1995. Temperatures remained within the range of 26-33°C, with very little differences between the stations in both study areas. The warmest months, were from November to March, reflected in all the 6 stations. This period was the dry season. Lower temperatures were recorded from April to August in both study areas.

5.2.2 pH

Figures 5.2a and 5.2b show the variation in pH during the study period; the pH ranged from 6.0 to 8.3 in the Abrubi lagoon and 6.3 to 7.8 in the Densu delta. On the whole, changes in pH were gradual and generally steady although no definite pattern observable. The riverine portions in both study sites showed slightly acidic behaviour in the months of September and October. There was a gradual increase to a maximum of 8.3 in Abrubi lagoon during the dry season in March 1995, decreasing at the onset of the wet season (April - July 1995). Abrubi had a mean pH value of 7.12 ± 0.5 and Densu-delta had mean values of 7.0 ± 0.6 .

Fig 5.1a Seasonal variations in water temperature at St.1,2, and 3, Abrnbi lagoon, May 1994-April 1896

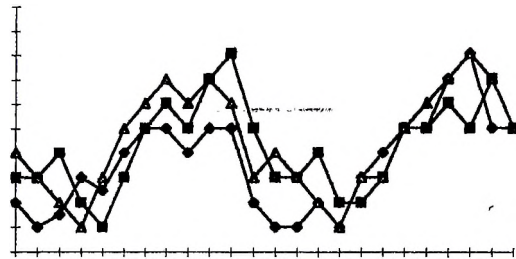
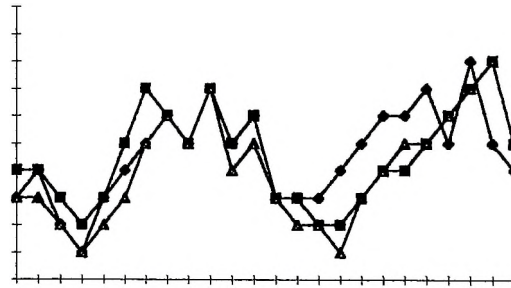


Fig.5.1b Seasonal variations in water temperature, at St.1,2, and 3, Densu-delta, May 1994-April 1996



Months

Fig 5.2a Seasonal variations in pH at St1,2, and 3 Abrubi lagoon, May 1994-April 1996

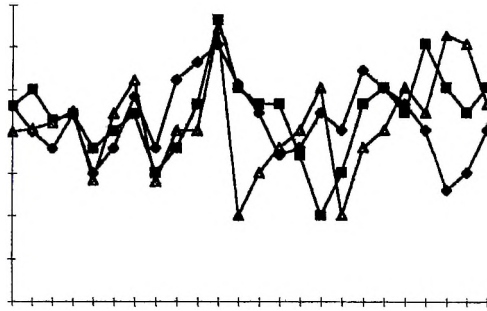
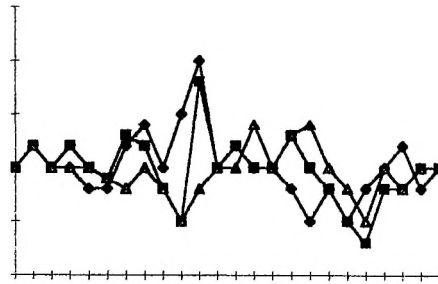


Fig 5.2b Seasonal variations in pH at St. 1, 2, and 3 Densu della, May 1994-April 1996



5.2.3 Rainfall

The pattern of rainfall during the study period is shown in Fig.5.3. Abrubi lagoon recorded heavy rainfall in September and October 1994 and in June 1995. This resulted in the breaching of the lagoon to the sea manually in September 1994 and June 1995. Abrubi had a higher mean annual rainfall than the Densu-delta, except the first four months of 1996 when the delta had a higher amount of rainfall. The major rains were from May to July with minor rains from September to November. December to February were generally dry months. In both study areas, the rains began in March 1995 and March 1996.

5.2.4 Seasonal Changes in Depth with Rainfall

In both study areas the mean depth of the water fell gradually but steadily during the dry season but rose with the onset of the rains. Analysis of variance indicated that there was a significant difference in depth ($p < 0.05$) between months but not between stations in both study areas (Appendix. 5.1a and b).

The difference in depth between the two lagoons was assessed using Students t-test. The difference in depth was statistically different from Station 1 in the Densu-delta and Abrubi lagoon, ($t = 1.92$, $P < 0.05$), but not in Stations 2 and 3. Station 1 was the riverine end and had fresh water entering it from the streams and River Antaa around Abrubi lagoon and from farmlands and the River Densu in the Densu-delta.

Fig 5.3 Seasonal variations in total monthly rainfall, Abrubi lagoon and Densu delta, May 1994 - April 1996

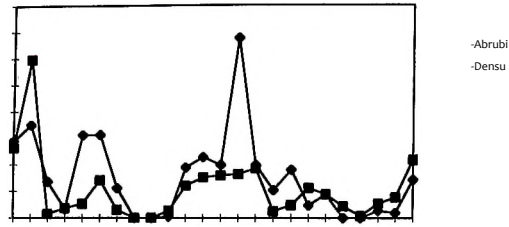


Fig 5.4a Seasonal variations of Rainfall with depth, Abrubi lagoon, May 1994-April 1996.

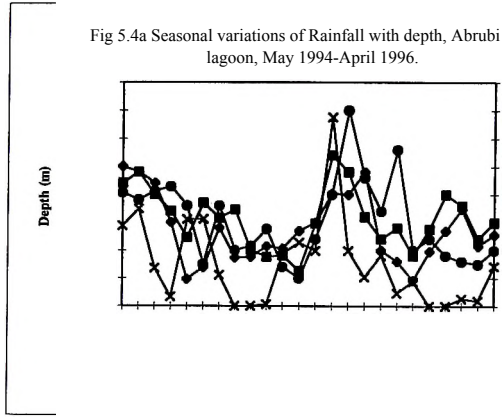
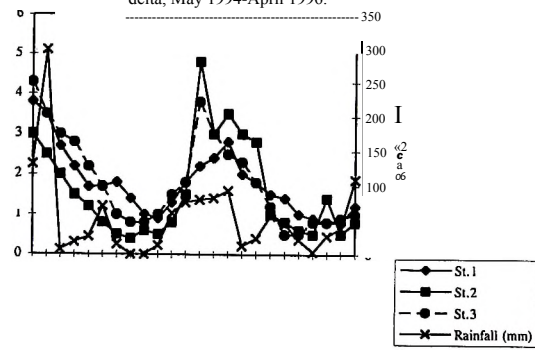


Fig. 5.4b Seasonal Variations of Rainfall with Depth, Densu delta, May 1994-April 1996.



5. 2. 5 Salinity

Salinity fluctuations in the lagoons were closely linked to the amount of rainfall (Figs.5.5a and 5.5b). Abrubi, usually closed, was generally influenced by the amount of fresh water entering it. The 3 stations in both study areas showed a pattern of salinity gradation with the lowest salinities occurring at Station 1 (Riverine portion) where fresh water entered. The highest salinities were recorded at Station 3 in the Densu delta, that is to be expected as Densu delta was open to the sea. At Abrubi there is interstitial seepage of water across the sand bar at Station 3. Salinity went down as low as 2‰ in the rainy season (Tables 5.1a and 5.1b). Salinity went up to 18‰ when the lagoon was breached to the sea.

There was a distinct salinity gradient in both study areas. There was a decline in salinity at most stations following the onset of the rainy season in June after which there was an increase until March/April. The rise in salinity in Abrubi lagoon in September/October 1994 and June/July 1995 (Station 1 and 2) was due to the fact that the lagoon was breached in September 1994 and June 1995. This was due to the high amounts of rainfall recorded during those months, 155.3 mm and 337.9 mm respectively. Breaching of the lagoon at the Abrubi lagoon resulted in intrusion of seawater as far as St. 1, thus raising the salinity levels at all the stations from September-December 1994 and June to October 1995. The formation of the sand bar reduced salinity levels (December 1994 and October 1995).



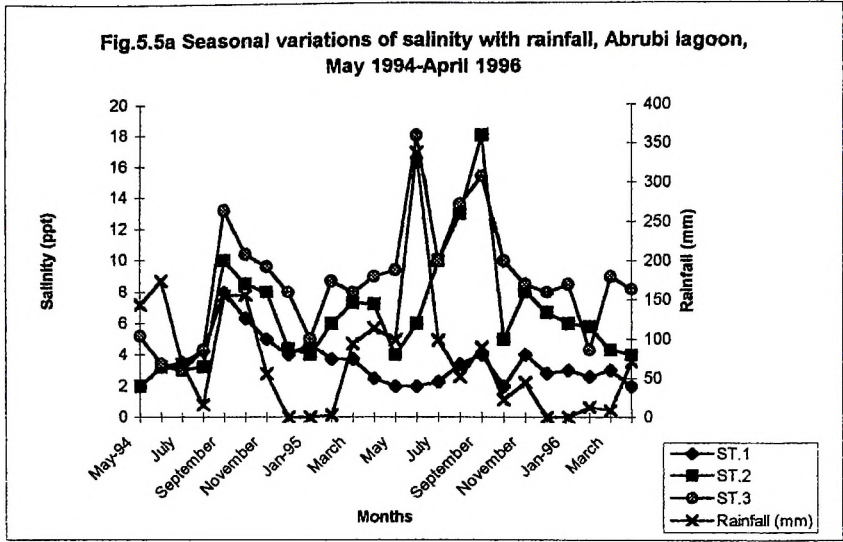
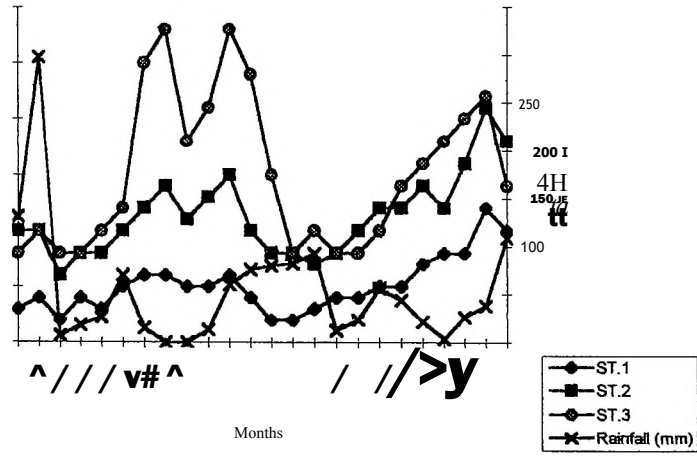


Fig.5.5b Seasonal variations of salinity with rainfall, Densu delta, May 1994-April 1996



The decrease in rainfall in the dry season, from December to February resulted in an increase in the salinity levels in all stations in the Densu delta. The high salinity values at Station 3 from November 1994 to March 1995 coincided with the dry season. Low salinity levels were recorded in all stations after heavy rainfall (Fig 5.5a and 5.5b.) The Upper reaches of both study sites (Station 1) had lower salinity values in the rainy season than the other two stations.

The Densu delta is in contact with the sea all year round, so salinity values were generally higher than the Abrubi Lagoon, especially at the seaward end (St. 3). Results from the Analysis of Variance (ANOVA) (Appendix. 5.2.) showed that salinity was greater at station 3 than at stations 1 and 2 in both study areas ($P < 0.001$). The ANOVA results also showed that the differences in salinity were significant between stations and between months. The difference between the two study areas was also significant with the Densu-delta recording higher salinities than Abrubi (see also Tables 5a and 5b).

5.2.6 Oxygen

High dissolved oxygen values occur at low temperatures, and this was generally reflected in most of the stations between the months of April and October. Low values of dissolved oxygen occurred in the dry season (November to March) when temperatures were high, (Fig.5.6 a and 5.6 b.). The middle and riverine portions of Abrubi were well oxygenated. In this study, the mean concentrations of dissolved oxygen ranged from 2.7 -10.4 mg/l with a mean value of 4.80 mg/l for Abrubi lagoon and 3.0 (December 1994) to 8.4 mg/l (August 1995) with a mean value of 5.40 mg/l for the Densu delta .

Fig 6.6a Seasonal variations in dissolved oxygen, Abrubi Lagoon, St.1,2 and 3, May 1994-April 1996

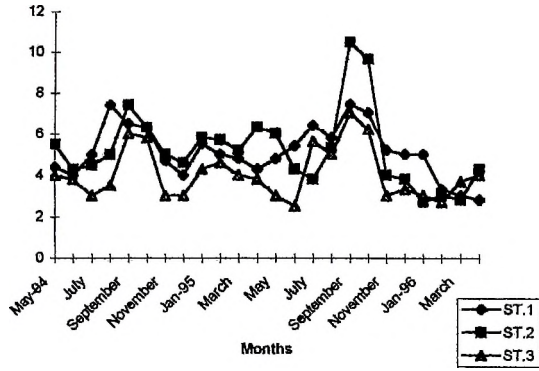
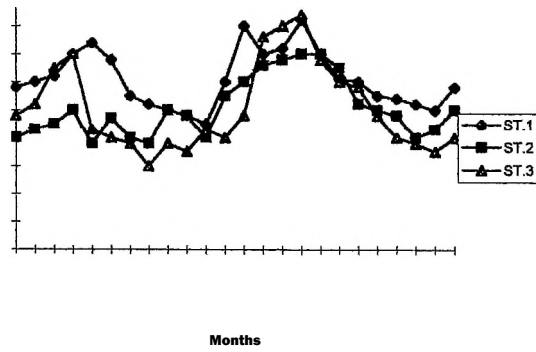


Fig 5.6b Seasonal variations in dissolved oxygen, Densu delta, St.1,2, and 3, May 1994-April 1996



Results from the ANOVA indicated that differences in oxygen levels was significant between months and between stations in both study areas (Appendix. 5.3).

5.2.7 Phosphates

The changing concentrations of phosphates and nitrates were monitored at all sampling sites in order to obtain a comprehensive picture of the nutrient status of the lagoons. The phosphate levels ranged from 0.001 (December 1995) at Station 2 to 0.44 mg/l (July 1995) at Station 3 in the Abrubi lagoon with an average value of 0.08mg/l. In the Densu delta values ranged from 0.01 (January 1995) to 0.4 mg/l (March 1996), with an average value of 0.16 mg/l (Figs.5.7 a and 5.7b). High levels of phosphate were recorded in the Abrubi lagoon at Station 1, (0.27 mg/l), September 1995; Station 2, (0.21 mg/l) March,1995 and July 1995 (Station 3, 0.44 mg/l). The average levels of phosphates were higher in the Densu-delta than Abrubi lagoon, especially during the dry season at Station 2 and Station 3. Analysis of variance tests showed that levels of phosphate were not significantly different between months and stations in both study areas.

5. 2. 8 Nitrates

Nitrate levels were higher in Densu-delta than in Abrubi lagoon at all the stations (Figs 5.8a and 5.8b). Nitrate levels were also generally higher in the rainy season than the dry season. Nitrate levels ranged from 0.01 mg/l (June 1996) to 0.7 mg/l (January 1996) in Abrubi lagoon with mean value of 0.16 mg/l and 0.02 to 1.67 mg/l in Densu delta with a mean value of 0.52 mg/l. Analysis of Variance tests showed that levels of nitrate were not significantly different between months and between stations in both study areas.

5.2.9 Total Dissolved Solids (TDS) and Conductivity

Fluctuations in these two parameters in all the six stations followed each other closely (Figs 5.9 and 5.10). Total dissolved solids and conductivity in the Densu-delta were high in the dry season and low in the rainy season. In the Abrubi lagoon the conductivity shot up in the dry season (Fig. 5.10a) and in June 1995, September 1994 when the lagoon was breached to the sea. Low conductivity and TDS values were recorded in Station 1 of both study areas as a result of the inflow of fresh water.

5.2.10 Silicates

Levels of silicates ranged from 1.5 (Station 2, March 1996) - 29 mg/l (Station 1, July 1994) at Abrubi lagoon with a mean value of 12.18 mg/l. At the Densu delta levels ranged from 1.7 mg/l (March 1996) to 17.6 mg/l (November 1994) with a mean value of 5.12 mg/l. Levels of silicate were generally higher at Abrubi lagoon than Densu delta, silicate levels were also higher in the rainy season than the dry season (Fig. 5.1 la). In the Densu delta low levels of silica were recorded from July 1995 to January 1996 (Fig. 5.11b).

Fig 5.7a Seasonal variations in phosphate levels, Abrubi lagoon, St.1,2,3. May 1994-June 1996

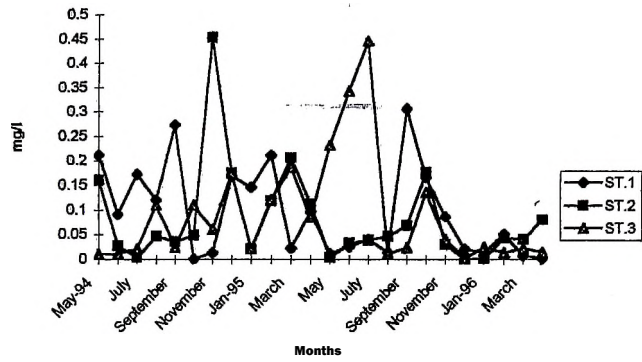


Fig 5.7b Seasonal variations in phosphate levels, St.1, 2 and 3, Densu-delta May 1994-April 1996

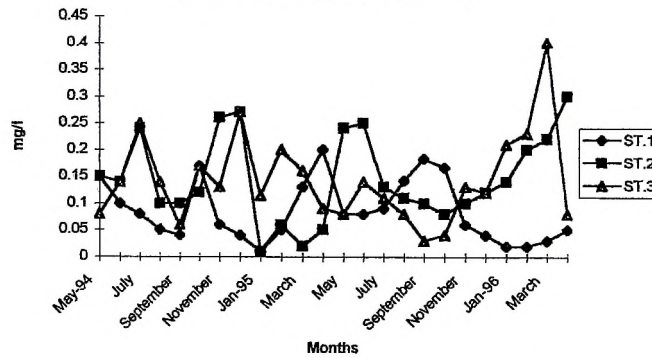


Fig 5.8a Seasonal variations in nitrate levels, St1,2, and 3, Abrubi lagoon, May 1994-April 1996.

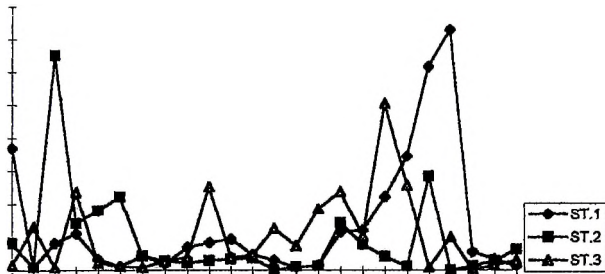


Fig 5.8b Seasonal variations in nitrate levels St1, 2, and 3 Densu delta May 1994-April 1996.

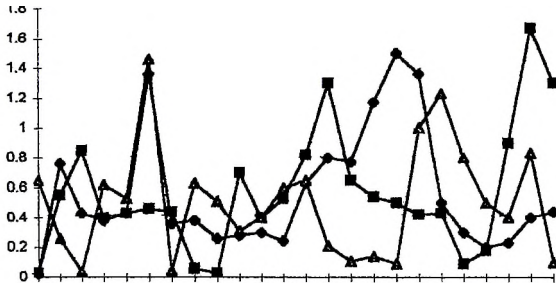


Fig 5.9a Seasonal variations in TDS, Abrubi lagoon, St.1, 2 and 3, May 1994-April 1996

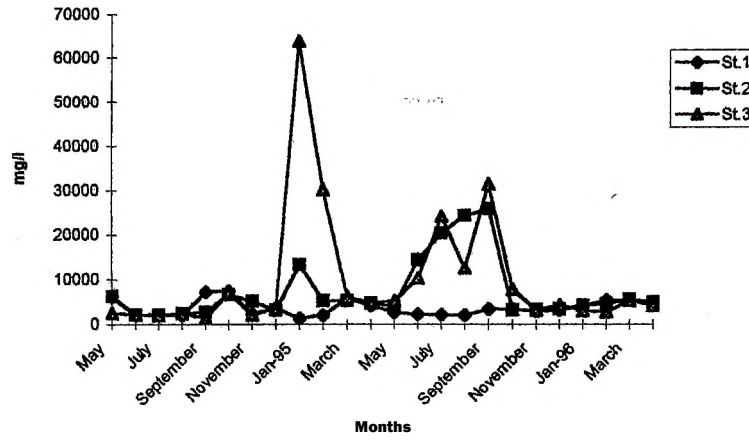


Fig 5.9b Seasonal variations in TDS, St.1, 2 and 3 Densu delta, May 1994-April 1998

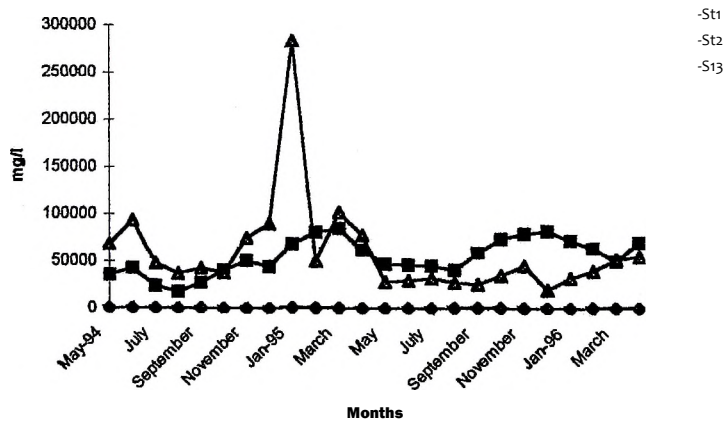


Fig 5.10a Seasonal variations in conductivity, St.1, 2 and 3 Abrubi lagoon, May 1994-April 1996

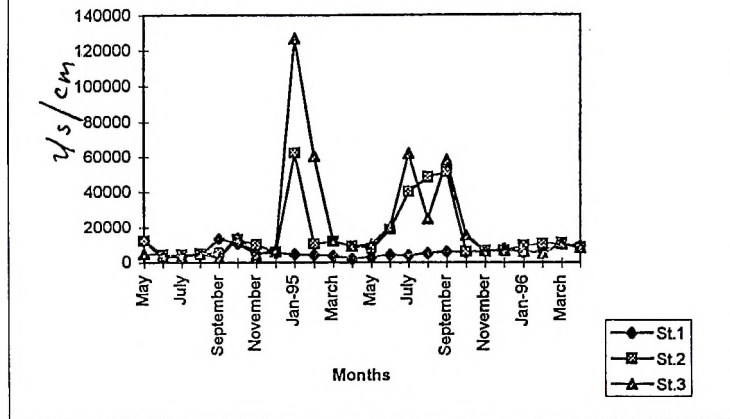


Fig 5.10b Seasonal variations in conductivity, St.1, 2 and 3, Densu delta May 1994-April 1996

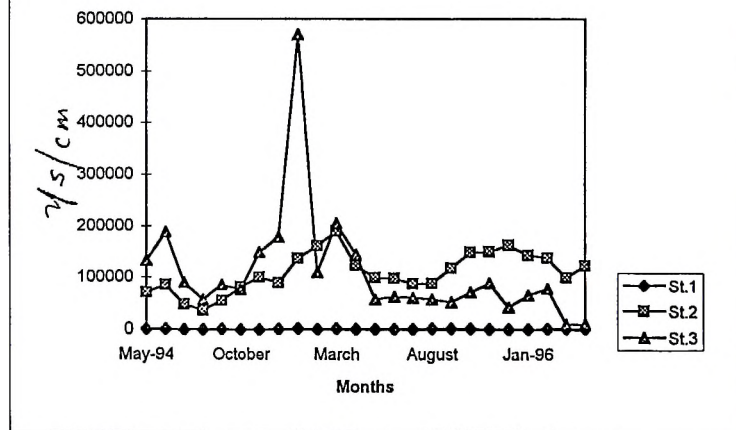


Fig 5.11a Seasonal variations in silicates, St. 1, 2 and 3, Abrubi lagoon, May 1994-April 1996

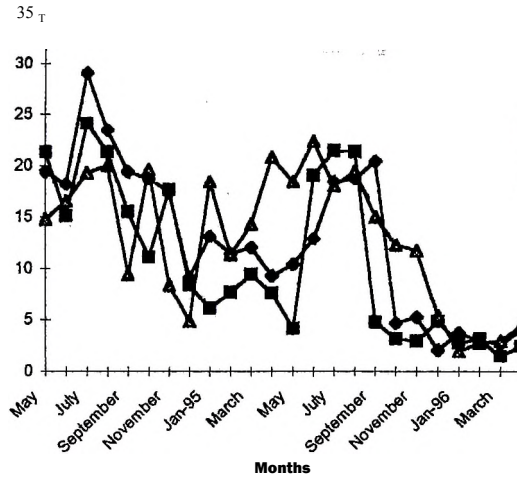
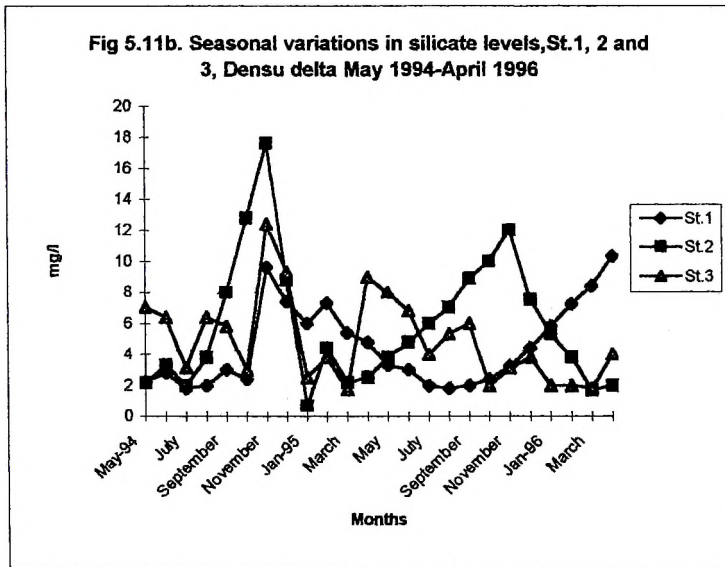


Fig 5.11b. Seasonal variations in silicate levels, St. 1, 2 and 3, Densu delta May 1994-April 1996



5.3 Discussion

As a result of its low depth and large surface area, water temperature in a lagoon is almost always similar to air temperature. The temperature of shallow coastal lagoons follow closely the temperature of the land (Kwei 1977, Biney 1990). Generally there was noticeable increase in temperature during the dry season in both study areas.

Biney (1986), in a preliminary study of lagoons along the coast of Ghana, found that temperatures ranged from 25 °C to 36 °C and that open lagoons had lower temperatures than closed ones. In this study temperatures were not significantly different in the two study areas. Mean temperatures in this study fell within the range obtained by Biney (1986). Apart from the effects of air temperature, the temperature of the lagoons in the study area could have been influenced by the inflow of sea water, fresh water from the rivers (Antaa and Densu) and streams, runoff and direct rainfall.

The pH ranges recorded in both study areas are typical of those occurring in lagoons in Ghana (Biney, 1990). Table 5.2 shows the various physico-chemical parameter ranges recorded by Biney (1986, 1990) for lagoons in Ghana. Most of the values obtained during this study fell within the range given by Biney (op cit.), (Tables 5a and 5b).

Table 5. 2 Some physico chemical parameters of Lagoons in Ghana. (Biney, 1990).

Parameter	Mean values.	This study
Temperature	25-36 °C	Abrubi 26 - 33 °C Densu delta 27-33 °C
pH	7-8.2	Abrubi 6.3- 8.3 Densu delta 6.0-8.2
Salinity	1.1-39.3 ppt	Abrubi 2-18 ppt Densu delta 2 -28 ppt
Dissolved Oxygen	0.0-8.0 mg/l	Abrubi 2.7 -10.4 mg/l Densu delta 3.5 -8.4 mg/l
Phosphates	0.0-0.85 mg/l	Abrubi 0.01 -0.45 mg/l Densu delta 0.021-0.27 mg/l
Nitrates	0.0-8.68 mg/l	Abrubi 0.01-0.7 mg/l Densu delta 0.02 - 1.67 mg/l
Depth	0.45-1.75 m	Abrubi 0.4 -3.5 m Densu delta 0.4 - 4.8 m

In the open ocean the pH of sea water falls within the limits of 7.5-8.4 (Riley and Chester, 1971, Biney 1990). In his studies of dissolved oxygen and primary productivity of two Ghanaian lagoons, the Sakumo 2 and Mukwe, Kwei (1977) found a daily rhythm of low carbon fixation and dissolved oxygen concentration during the mornings which rose to a peak around 1300 hours GMT in the afternoon and dropped afterwards.

Apart from their proximity to the sea, photosynthesis by phytoplankton may significantly increase the pH of lagoon waters during the day. Biney (1986) found that most open lagoons had lower pH values than closed ones. Abrubi lagoon had higher mean pH values than Densu delta possibly due to its lentic nature which encourages algal blooms.

In the hot months, there is more photosynthetic activity, more carbon dioxide is taken out of the system resulting in a higher pH. However since neither primary productivity nor chlorophyll measurements were made, it is not possible to explain clearly the slight changes in pH. Depositions from domestic waste may also contribute to the acidic nature of the lagoons at certain months (Figs 5.2a and 5.2 b). The near neutral pH of the Densu delta could be due to the effects of the Densu River which flows through the lagoon and into the Gulf of Guinea, as reported by Biney (1990). With the Abrubi lagoon a pH of 7.03 indicates the effects of the River Antaa for most of the study period.

The pH range, which is not directly lethal to fish, is 5-9 (Alabaster and Lloyd 1982). However the toxicity of several common pollutants is markedly affected by pH changes in this range, and increasing acidity or alkalinity may make these poisons toxic. Below a pH of 5, fish mortalities may be expected, although some may be acclimated to values as low as 3.7 (Alabaster and Lloyd 1982). The pH values recorded in this study fell within the range not directly lethal to fish.

The opening and closing of the sluice gates of the Weija Dam also control the depth of the Densu-delta. The Densu Delta recorded high amounts of rain in June 1994. The sluice gates were opened in May 1994. As shown in Fig.5.4b the water depth followed rainfall closely.

The frequency and amounts of rainfall very closely control salinity fluctuations in lagoons. Figures 5.5a and 5.5b. show the relationship between the fluctuations in salinity and amounts of rainfall. Abrubi lagoon is closed for most parts of the year and is mainly influenced by the River Antaa and some interstitial seepage under the sand bar. The salinity in a normally hypersaline lagoon has been found to be as low as 4‰ when it is filled with rain water and before it bursts its mouth into the sea (Kwei 1977). When it is finally cut off from the sea again, the salinity increases to as high as 80‰. This situation has been found in the Muni lagoon (Biney, 1995), and in coastal lakes in South Africa (Whitfield, 1994).

Abrubi is not a hypersaline lagoon as demonstrated by the salinity values in Table 5a. The influence of River Antaa and rainwater is very strong. It is manually breached during months of very heavy rain to prevent flooding of its banks. Dyer (1972) observed that lagoons undergo salinity changes depending on the different ratios of river flow to tidal prism. Densu delta although it is associated with the River Densu had higher salinities because it was open to the sea.

Kwei (1977) does not hold the view that an open lagoon is constant in salinity as held by Pople(1972), and the results of this study agree with that of Kwei (1977). It is evident that the upper reaches of the Densu delta generally had lower salinity values than the lower reaches nearer to the sea. Rainfall has both a diluting and enriching effect due to the restoration of flow in rivers and streams which are dry in the dry season.

The increase of the salinity after the rainy season is followed by the disappearance of purely freshwater fish species, then by a steady stream of marine fish species which are mostly represented by juvenile stages. Thormann (1986b) found that species richness increased with salinity in Swedish estuaries. According to Thiel (1995), Peterson and Ross found a positive relationship between salinity and turbidity and marine fish species abundance, and a negative one with freshwater species abundance along a coastal river lagoon gradient in old Fort Bayou, Mississippi, USA.

The Densu delta was better aerated than the Abrubi lagoon because it is in contact with the sea and has constant oxygen renewal through wave action. This was verified by Biney (1990) in his review of the characteristics of freshwater and coastal ecosystems in Ghana. Abrubi is a closed lagoon and its stagnant nature for most of the year encourages the growth of both micro- and macrophytes which oxygenate the waters by their photosynthetic activities.

According to Olaniyan (1961), other factors like micro-organisms, abundance of organic matter and wind could determine the dissolved oxygen concentration in aquatic environments, but these were not investigated in this study. The low oxygen values observed from November to March in the two lagoons could be attributed to the combined effects of high temperatures and salinities pertaining during that period. The higher values recorded from April to October coincided with the rainy season when temperatures and salinities were generally low.

Biney (1982) showed that the mean dissolved oxygen content in lagoons in Ghana has concentrations of 0.0 to 8.0 mg /l. In lagoons, the many organisms living in the bottom deposits, rapidly consume the oxygen, and thus many sediments are anoxic, except for a thin surface layer. The correlation of resistance to anoxic or hypoxic conditions and habitat is well documented e.g. Theede *et al.* (1969), Vemberg (1972), and Van Winle and Magnum (1975). Where excessive organic enrichment occurs, the multiplicity of microorganisms produced may also consume all the oxygen within the water body as well (McLusky, 1981).

The sensitivity of fish to low concentrations of dissolved oxygen (DO) differs between species, between various life stages, between the different life processes, swimming ability and specialized behavior (Alabaster and Lloyd, 1982). However, the general pattern which emerges is that, providing other environmental factors are favourable, a minimum constant value of 5 mg/l in rivers would be satisfactory for most stages and activities in the life cycle of most fish species (Alabaster and Lloyd *op cit*). Most species living in tropical lagoons and estuaries are able to tolerate levels of dissolved oxygen lower than 5 mg/l. In this study the mean dissolved oxygen levels were within tolerable limits for fish.

Nutrient levels in Abrubi were prominent and more easily detected than the Densu delta because Abrubi is a closed lagoon and smaller. Abrubi lagoon had higher phosphate levels at Station 1 due probably to pineapple farming which occurs alongside the upper reaches of the lagoon close to the riverine end.

Levels of phosphates and nitrates were erratic at the seaward end of Abrubi lagoon, this could be due to pollution by domestic sewage. Phosphates are not as mobile as nitrates and are usually bound to soil particles.

Most lagoons are characterized by a summer phosphate maximum, this is due to the release of phosphate from the sediments where bottom waters become anoxic with high respiratory rates from bottom dwelling organisms (Nixon, 1982). In the study the two lagoons both had high levels of phosphate in the dry season. High levels of phosphate may be attributed to a possible phosphorus load in the lagoon waters following the rainy season.

The rivers and streams feeding these lagoons drain farmlands which use organo-phosphates fertilizers and the phosphates may be washed into the lagoons during the minor and major rains. The Densu delta has the most urbanized catchment and thus had relatively higher levels of phosphate.

While phosphorus may be introduced as a result of domestic and industrial activity, the high levels of nitrates may result from nitrogen fixation by blue-green algae. Zooplankton and fish excretion may also contribute to elevated levels of nitrates (Biney, 1990). The author reported lower concentrations of nitrogen and relatively high concentration of phosphates in the Sakumo 2 and Fosu lagoons in Ghana.

Investigations in limnology during the past two decades have demonstrated that fixation of molecular nitrogen by microflora can serve as a major input of nitrogen to aquatic ecosystems (Wetzel, 1983). The high productivity of coastal lagoons may also be due to exchanges between sea water and fresh water.

Seasonal fluctuations in the concentrations of total dissolved solids and conductivity in the two lagoons followed each other closely. There were high silica levels during the rainy season, after which the silica levels went down after finding its way into lagoon sediments (Biney, 1986). The water level also fell continuously but gradually in the dry season but rose quickly with the onset of the rains.

Unfortunately there are few lagoons for which primary production and fisheries data are available. There are hardly any lagoons in Ghana for which fisheries statistics are available. Nixon (1982) showed that data from landings of finfish and shellfish from coastal lagoons and embayments around Long Island, New York, indicate that the total yield per unit area of unpolluted intensively fished lagoons can appreciably exceed that of such well known fishing areas as the Peruvian shelf and North Sea.

CHAPTER 6

6.0 FISH SPECIES DIVERSITY, COMPOSITION AND RELATIVE ABUNDANCE.

6.1 Introduction

Most fish found in coastal lagoons use them as areas for feeding and growth since they provide protection from predators and ensure high food availability (McErlean *et al.*, 1973). Measuring the species numbers and diversity is generally a more sensitive and reliable index of environmental health than are individual 'indicator' organisms (Dahlberg and Odum, 1970). The behaviour of diversity indices needs to be understood as the indices are variously affected by sample size and seasonal phenomena.

In this chapter the fishing effort of the two lagoons was assessed and results obtained from experimental fishing presented. The fish were identified to species level and species richness, diversity, evenness and frequency of occurrence calculated. The relationship between species number and weight and temperature, salinity and oxygen during the study period was analyzed by Bray-Curtis cluster analysis and non-metric Multi Dimensional Scaling using the PRIMER (Plymouth Routines In Multivariate Ecological Research) software (Clarke and Warwick, 1994).

6.2 Fishing Effort

Saturday is a non-fishing day in the Abrubi lagoon but in the Densu-delta fishing goes on all week. The average number of fishers, obtained from the observers *data, are presented in Table 6.1a and 6.1b.

The total number of fishers working in the lagoon daily ranged from 11 to 51 in the Abrubi lagoon and 11 to 74 in the Densu delta (Table 6.3a and 6.3b). The fishing effort varied between 34-221 man-hours per day with an average of 165 in the Densu-delta and 34- 152 man-hours per day with an average of 84 in Abrubi lagoon. The peak periods for fishing were 7-10 hours GMT and 15-18 hours GMT in both study areas.

6.3 Experimental Fishing and Catch Per Unit Effort (CPUE).

The catch in grams per man- hour of experimental fishing is shown in Tables 6.2a and 6.2b. The combined estimate was obtained from a simple average of the strata values. At Abrubi lagoon the highest average catch of 4944 g was recorded at Station 1 in September 1994 and the lowest of 900 g in station 3 in May 1994. In the Densu delta the highest catch of 2324 g was recorded in Station 2 in March 1995 and the lowest of 543 g at Station 1 in May 1995. The catch consisted mainly of *S. melanotheron*. The ANOVA ($p < 0.05$) shows that there was a significant difference in CPUE values between stations and between months in Abrubi lagoon. In the Densu delta the ANOVA ($p < 0.05$) shows that there was a significant difference in CPUE values between months but not between stations.

The calculated CPUE's (catch/fisher/ man-hour) are given in Table 6.2 a and 6.2 b.

On monthly basis the highest average CPUE, (Fig 6.1a and 6.1b) considering all stations was in September 1995 (3.78 kg/man-hr) for Abrubi lagoon and the lowest was in June 1995 (1.28 kg/man-hr).

**Table 6.1a Average numbers of cast net fishers
Abrubi lagoon**

Month	7-10GMT	11-14GMT	15-18GMT	Fishers
May'94	2	5.5	4	11.5
June	6.3	4	5	15.3
July	18.4	17	14	49.4
Aug	17.7	12	7	36.7
Sep	22.8	18	10	50.8
Oct	12	8.7	7	27.7
Nov	8	5.5	3	16.5
Dec	10	6.4	4	20.4
Jan'95	8	8.3	3	19.3
Feb	10	6.1	8	24.1
Mar	9.3	6	5	20.3
Apr	7	5	5	17
May	8	5	14	27
June	8	7.4	5	20.4
July	15	17.8	18	50.8
Aug	24	10	14	48
Sep	18	24	10	52
Oct	20	18	12	50
Nov	14	10	8	32
Dec	10	9.7	9	28.7
Jan'96	9	12	4	25
Feb	8	10	5	23
Mar	12	8	6	26
Apr	15	7	4	26

**Table 6.1b Average numbers of cast net fishers
Densu-delta**

Month	7-10GMT	11-14GMT	15-18GMT	Fishers
May'94	4.5	4	3	11.5
June	12	6.8	9	27.8
July	11	8	22.3	41.3
Aug	25	23	25.7	73.7
Sep	24	24.1	19	67.1
Oct	20	27	20	67
Nov	25	18.5	14	57.5
Dec	21	14	17.8	52.8
Jan'95	25	19	15.3	59.3
Feb	28	23	19.2	70.2
Mar	20	22.6	20	62.6
Apr	25	20	26.8	71.8
May	4	6	5.3	15.3
June	6.2	3	3	12.2
July	16.4	10	7.3	33.7
Aug	26.1	22	18.2	66.3
Sep	25	18	14.4	57.4
Oct	20	17	13	50
Nov	27	17.5	14	58.5
Dec	22	14	22	58
Jan'96	26.8	22	17	65.8
Feb	28.8	25	20	73.8
Mar	26	21	18	65
Apr	20	16	22	58

**Table 6.2a. Catch in grains per man-hour of Experimental Cast net Fishing, Abrubi Lagoon
May 1994-April 1996**

Month	St.1	St.2	St.3	Av
Ma/94	1550	1453	900	1301
June	2120	1594	1059	1591
July	1935	1650	1767	1784
Aug	3403	1922	1946	2423
Sep	4944	2058	2090	3030
Oct	4210	2799	2208	3072
Nov	3320	2072	1880	2424
Dec	2174	1754	1360	1762
Jan'95	3422	2438	1732	2530
Feb	4196	3400	2238	3274
Mar	2634	2342	1586	2187
Apr	3432	1380	2124	2312
May	2490	1843	2144	2159
June	2850	1538	2009	1277
July	2930	1620	2142	2230
Aug	3004	3324	2422	2916
Sep	4458	3789	3110	3785
Oct	4844	3200	2302	3448
Nov	4321	2251	2144	2905
Dec	3441	2200	2004	2548
Jan'96	3340	3884	2334	3186
Feb	3017	1747	2245	2336
Mar	4417	2843	2620	3293
Apr	3556	2485	2967	3002
Average	3333.667	2316.083	2055.542	2532.292
			S.E.	678.9315

**Table 6.2b. Catch in grams per man-hour of Experimental Cast net Fishing, Densu delta
May 1994-April 1996**

I Densu				
Month	St.1	St.2	St.3	Av
Ma/94	655	0	1204	619
June	1151	834	890	958
July	1220	1366	1744	1443
Aug	2308	1205	1800	1771
Sep	2214	1850	1051	1705
Oct	1405	1200	1325	1310
Nov	1263	1254	2094	1537
Dec	1345	1231	2230	1602
Jan'95	1244	1176	2221	1546
Feb	1093	948	1442	1161
Mar	2064	2324	1008	1798
Apr	1463	2100	1187	1583
May	543	1200	948	897
June	834	1234	1159	1075
July	1354	971	2234	1519
Aug	1228	1144	1968	1446
Sep	1543	1432	1553	1509
Oct	1362	1744	1445	1517
Nov	1048	1461	2009	1506
Dec	788	1354	2109	1417
Jan'96	934	1144	1467	1181
Feb	756	1038	874	889
Mar	1095	1200	871	1055
Apr	2158	1644	1115	1639
	1294.5	1293.917	1497.833	1361.79

Table 6.3a Average Daily Catch, Fishing Effort and Estimated Total Catch of Castnets

Abrubi Lagoon, May 1994-April 1996						
Month	CPUE g/man-br	Raising factor 14/9	No. of fishermen per day	Catch day/kg	No. fishing days	Total catch kg
May/94	1301	1.55	11.5	23.19	27	626.14
June	1591	1.55	15.3	37.73	26	980.99
July	1784	1.55	49.4	136.60	27	3688.22
Aug	2423	1.55	36.7	137.83	15	2067.49
Sep	3030	1.55	50.8	238.58	15	3578.73
Oct	3072	1.55	27.7	131.90	27	3561.20
Nov	2424	1.55	16.5	61.99	26	1611.84
Dec	1762	1.55	20.4	55.71	20	1114.29
Jan'95	2530	1.55	19.3	75.68	27	2043.49
Feb	3274	1.55	24.1	122.30	24	2935.21
Mar	2187	1.55	20.3	68.81	27	1857.98
Apr	2312	1.55	17	60.92	26	1583.95
May	2159	1.55	27	90.35	27	2439.56
June	1277	1.55	20.4	40.38	26	1049.85
July	2230	1.55	50.8	175.59	27	4740.94
Aug	2916	1.55	48	216.95	15	3254.26
Sep	3785	1.55	52	305.07	15	4576.07
Oct	3448	1.55	50	267.22	27	7214.94
Nov	2905	1.55	32	144.09	26	3746.29
Dec	2548	1.55	28.7	113.35	20	2266.96
Jan'96	3186	1.55	25	123.46	27	3333.35
Feb	2338	1.55	23	83.28	24	1998.68
Mar	3293	1.55	26	132.71	27	3583.11
Apr	3002	1.55	26	120.98	26	3145.50
				2964.69		66999.02

Table 6.3a Average Daily Catch, Fishing Effort and Estimated Total Catch of Castnets

Densu delta, May 1994-April 1996						
Month	CPUE(g)	Raising factor 14/9	No. of fishermen per day	Catch day/kg	No. fishing days	Total catch kg
Ma/94	619	1.55	11.5	11.03	28	308.94
June	958	1.55	27.8	41.28	30	1238.41
July	1443	1.55	41.3	92.37	31	2863.58
Aug	1771	1.55	73.7	202.31	31	6271.62
Sep	1705	1.55	67.1	177.33	30	5319.86
Oct	1310	1.55	67	136.04	31	4217.35
Nov	1537	1.55	57.5	136.99	31	4246.54
Dec	1602	1.55	52.8	131.11	24	3146.58
Jan'95	1546	1.55	59.3	142.10	31	4405.12
Feb	1161	1.55	70.2	126.33	28	3537.20
Mar	1798	1.55	62.6	174.46	30	5233.80
Apr	1583	1.55	71.8	176.17	31	5461.33
May	897	1.55	15.3	21.27	31	659.44
June	1075	1.55	12.2	20.33	30	609.85
July	1519	1.55	33.7	79.34	31	2459.69
Aug	1446	1.55	66.3	148.60	31	4606.54
Sep	1509	1.55	57.4	134.26	31	4161.93
Oct	1517	1.55	50	117.57	31	3644.59
Nov	1506	1.55	58.5	136.56	30	4096.70
Dec	1417	1.55	58	127.39	24	3057.32
Jan'96	1181	1.55	65.8	120.45	31	3733.96
Feb	889	1.55	73.8	101.69	28	2847.40
Mar	1055	1.55	65	106.29	31	3295.03
Apr	1639	1.55	58	147.35	30	4420.38
				2808.62		83843.15

In the Densu-delta considering all stations, the highest average CPUE was in March 1995 (1.79 kg/man-hr), the lowest was in May 1994 (0.62 kg/man-hr). In both study areas, maximum CPUE values were recorded when the depth of the lagoon was low and minimum CPUE values were recorded when level of the water was high, in the wet season.

In both study areas there was a decline in numbers of fishers from May to June 1994/95 when the rains started and the lagoon filled up (Tables 6.1a and 6.2b). At the peak of the floods in June and July 1995, (Abrubi lagoon) and June (Densu delta) there was a sharp decrease in cast net fishing (Figs. 6. 1a and 6.1b). CPUE declined during this period.

There was virtually no correlation between rainfall and CPUE, $r = -0.39$ for Densu delta and $r = -0.26$ for Abrubi lagoon. There was a weak negative correlation between depth and CPUE, $r = 0.47$ for Densu delta and $r = -0.46$ for Abrubi lagoon. As rainfall increased there was a decrease in CPUE (Figs. 6.1a and 6.1b) and there was a fall in CPUE with increase in depth (Figs. 6.2a and 6.2b.)

From May 1994-October 1994, the weekly catch from cast nets, 'acadjá', bottle fishing, dragnets, and crab traps were noted from certain fishermen from the Densu delta (Table 6.3c). Only six months data were obtained from all the gear due to lack of resources to sustain data collection for 24 months .

Fig 6.1a Changes in CPUE and Rainfall, Abrubli lagoon, May 1994-April 1996

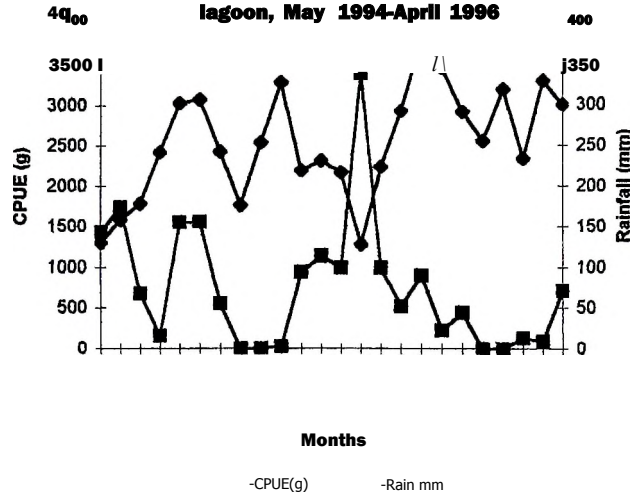


Fig.6.1b Changes in CPUE and Rainfall, Densu delta, May 1994-April 1996

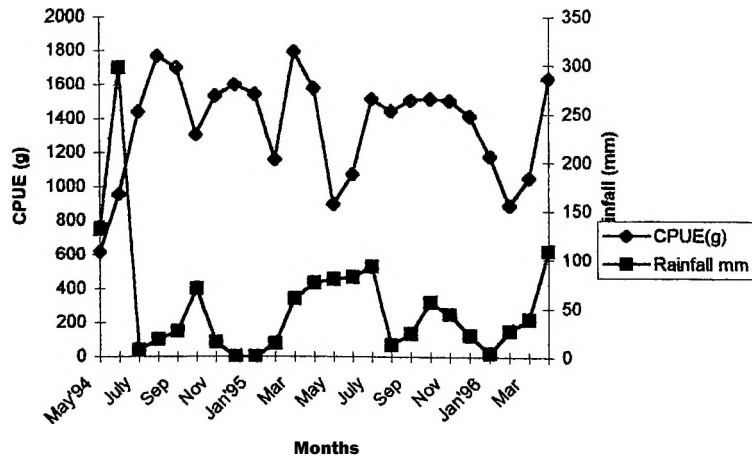


Fig 6.2a Changes in CPUE and Depth, Abrubl lagoon, May 1994-April 1996

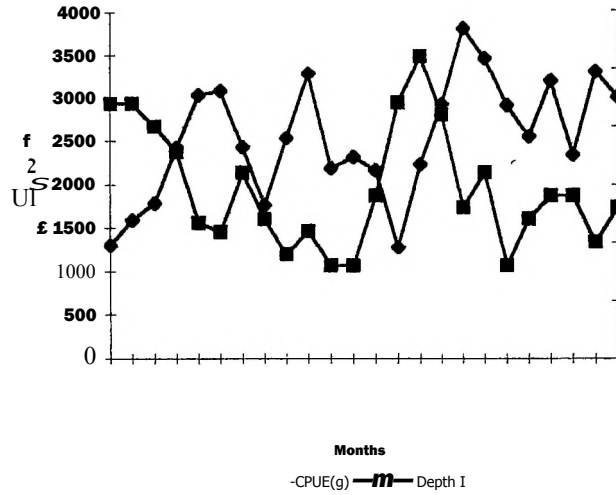


Fig 6.2b Changes in CPUE and Depth, Densu delta, May 1994- April 1996

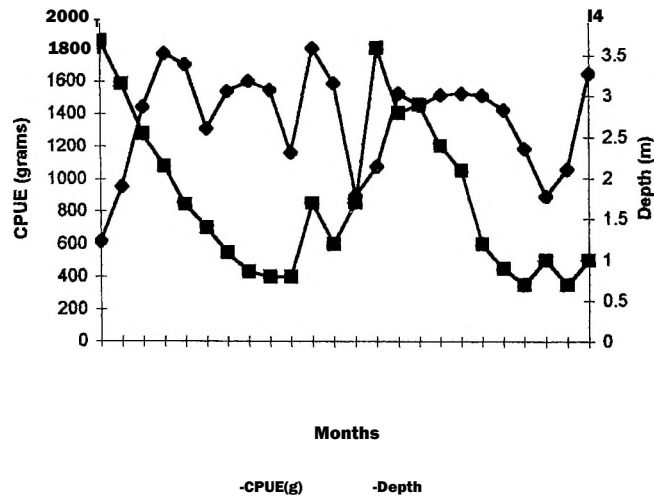


Table 6.3c Average catch from all gear (May - October 1994)

Gear	Catch (kg)	Percentage of total catch
Cast net	34.2	63
Acadja	5	9
Bottle fishing	2.5	5
Handpicking	1.5	3
Dragnet	10	18
Crab traps	1	2
Total	54.2	100

6.4 Total Fish Production

Using the calculated experimental catch/man-hour and the estimated man-hours per day, the total quantity of fish produced by the fishers during the study period from experimental cast net fishing was 66,999kg for the Abrubi lagoon, and for the Densu-delta, 83,843 kg (Table 6.3a and 6.3b)

6.5 Species Composition

The shell fish species found in the two study areas are shown in Tables 6.4a and 6.4b. In addition, 4 and 10 species of shellfish were observed at the Abrubi lagoon and Densu delta respectively. The fish species composition of both study areas is shown in Table 6.5a and 6.5b. A total of 10,231 specimens belonging to 19 species and with a total biomass of 184,917g were taken from the Abrubi lagoon from May 1994 to April 1996 by experimental fishing (Table 6.7a and 6.8b). In the same period a total of 10,515 individuals of 22 species with a total biomass of 98,053g were taken from the Densu delta (Table 6.7b and 6.8b).

Table 6.4a Checklist of all shell fishes found in Abrubi Lagoon (May, 1994 -April, 1996)

Family	Species
1 Potomidae	<i>Tympanotnus fuscatus</i> (L)
2 Turtellidae	<i>Turitella meta</i> (Reeve)
3 Ostreidae	<i>Crassostrca tulipa</i> (Lamarck)
4 Penaidae	<i>Penaets notialis</i> (Burker)

Table 6.4b Checklist of all shell fishes found in Densu delta (May, 1994 -April, 1996)

Family	Species
1 Portunidae	<i>Callinectes latimanus</i> (Rathbum, 1897)
2 Ocypodidae	<i>Uca tangeri</i> i (Eydoux, 1835)
3 Gecarcinidae	<i>Cardiosoma armatum</i> (Heridots, 1851)
4 Potomididae	<i>Tympanotonus fuscatus</i> (L)
5 Turitellidae	<i>Turitella meta</i> (Reeve)
6 Veneridae	<i>Tivela tripla</i> (L)
7 Grapsidae	<i>Sesarma africana</i> (de Britto Capello, 1864)
8 Penaeidae	<i>Parapertaeopsis atlantica</i> (Balss, 1918)
9 Penaidae	<i>Penaeus notialis</i> (Burker)
10 Ostreidae	<i>Crassostrea tulipa</i> (Lamarck)
	<i>Anedara Senilis</i> (L)

Table 6.5a Species composition of the fish community of the Abrubi Lagoon, May 1994-April 19!

Fish Species	Authority	Common Name Category	
Cichlidae			
<i>Sarotherodon melanotheron</i>	Rupell 1852	Blackchin tilapia	ER
<i>Tilapia zillii</i>	Gervais 1848	Red chin tilapia	FW
<i>Hemichromis fasciatus</i>	Peters 1852		FW
<i>Hemichromis bimaculatus</i>	Gill 1862	Jewelfish	FW
Mugilidae			
<i>Mugil cephalus</i>	Linnaeus 1758	Mullet	CA
<i>Liza faldppinis</i>	Valenciennes 1836	Mullet	CA
Eleotridae			
<i>Kribia kribensis</i>	Boulenger 1907	Sleeper gobies	ER
Clupeidae			
<i>Ethmalosa Umbriata</i>	Bodwich 1825	Shad "	CA
Clariidae			
<i>Ciarias anguillaris</i>	Linnaeus 1758	Catfish	FW
<i>Heterobranchius bidorsalis</i>	Geoffrey St.Hilaire	Catfish	FW
Gerridae			
<i>Genes melanopterus</i>	Bleeker 1863	Mojarra	CA
Soleidae			
<i>Pegusa lascaris</i>	Risso 1810	Sandsole	MA
Carangidae			
<i>Caranx hippos</i>	Linnaeus 1766	Horse mackerel	MS
<i>Trachinotus ovatus</i>	Linnaeus 1758	Pompano	MS
Serranidae			
<i>Epinephelus aenus</i>	Geoffrey St.Hilaire 1809	White grouper	MA
Sciannidae			
<i>Psuedolrtius senegalensis</i>	Valenciennes 1833	Cassava grouper	MJ
Elopidae			
<i>Sops lacerta</i>	Valenciennes 1846	Ten pounder	CA
Lutjanidae			
<i>Lutjanus fulgens</i>	Valenciennes 1830	Snapper	MS
Gobidae			
<i>Periophthalmus papilio</i>	Bloch and Schneider 1801	Mud skipper	ER

Table 6.5 b Species composition of the fish community of the Densu-Delta, May 1994-April 1996

Fish Species	Authority	Common Name	Category
Cichlidae			
<i>Sarotherodon melanotheron</i>	Rupell 1852	Blackchin tilapia	ER
<i>Tilapia zillii</i>	Gervais 1848	Redchin tilapia	FW
<i>Hemichmmis fasdatus</i>	Peters 1852		FW
<i>Sarotherodon galilaeus</i>			FW
Mugilidae			
<i>Mugil cephalus</i>	Linnaeus 1778	Mullet	CA
<i>Liza faldppinis</i>	Valenciennes 1836	Mullet	CA
Gobidae			
<i>Goboides ansorgti</i>	Boulenger 1909	Barreto	ER
<i>Porogobius schlegeli</i>	Gunther 1861	Schlegel's goby	ER
<i>Periophthalmus paplio</i>	Bloch and Schneider 1801	Mudskipper	ER
Clupeidae			
<i>Ethmalosa fimbriata</i>	Bodwich 1825	Shad	CA
Clariidae			
<i>Clarias anguillaris</i>	Linnaeus 1758		FW
		Catfish	
Gerridae			
<i>Gerres melanotherus</i>	Bleeker 1863	Mojarra	CA
Soleidae			
<i>Pegusa lascaris</i>	Risso 1810	Sandsole	MA
Carangidae			
<i>Caranx hippos</i>	Linnaeus 1766	Horse mackerel	MS
<i>trachinotus goreensis</i>	Cuvier 1832	Pompano	MS
Serranidae			
<i>Epinephelus aenus</i>	Geoffrey St.Hilaire 1809	White grouper	MA
Sciannidae			
<i>Psuedolithus senegalensis</i>	Valenciennes 1833	Cassava croaker	MJ
Pomadasyidae			
<i>Pomadasyys rogerii</i>	Cuvier 1830	Burro	MA
Lutjanidae			
<i>Lutjanus fulgens</i>	Valenciennes 1830	Golden African snapper	MS
Polynemidae			
<i>G alaeoides decadactylus</i>	Bloch 1795	Threadfin	MA
Psettodidae			
<i>Psettodes belcheri</i>	Bennet 1831	Spot tail spiny turbot	MA
Bothidae			
<i>Citharichthys stampHii</i>	Steindachner 1894	Smooth flounder	MA
<i>Syacium microrum</i>	Ranzani 1840	Channel flounder	MA

Figure 6.6a Species composition of the fish community in the Densu-OeRa, May 1994-April 1996 given as Relative Frequency in all stations

Fish Species	Category	Stn1	Stn2	Stn3	Av
Freshwater Species					
<i>Tilapia zilli</i>	FW	96	46	42	61.33
<i>Hemichromis fasciatus</i>	FW	36	46	0	28.00
<i>Clarias anguillaris</i>	FW	33	29	0	20.67
<i>Sarotherodon galilaeus</i>	FW	25	0	0	8.33
Euryhaline Species					
<i>Sarotherodon melanocheilus</i>	ER	100	100	100	100
<i>Mugil curema</i>	CA	29	75	75	59.67
<i>Liza ferdinandina</i>	CA	21	50	62	44.33
<i>Ethmalosa fimbriata</i>	CA	42	62	67	57
<i>Porogobius volitans</i>		21	21	21	21
<i>Gobiosoma robustum</i>	ER	62	100	100	87.33
Marine Species					
<i>Gerres melanocheilus</i>	CA	0	46	71	39
<i>Caranx hippos</i>	MS	0	0	33	11
<i>Lufjanus fulgens</i>	MS	0	42	52	31.33
<i>Chromis striata</i>	MA	0	42	29	23.67
<i>Syadum rufivum</i>	MA	0	38	46	28.00
<i>Epinephelus aeneus</i>	MA	0	0	17	5.67
<i>Pseudocrenilabrus senegalensis</i>	MJ	0	0	29	9.67
<i>Pomadasys rogeri</i>	MA	0	0	17	5.67
<i>Galaxias decedactylus</i>	MA	0	0	17	5.67
<i>Pegusa lascaris</i>	MA	0	0	17	5.67
<i>Psettodes belcheri</i>	MA	0	0	17	5.67
<i>Trachinotus goraensis</i>	MS	0	0	17	5.67

Figure 6.6b Species composition of the fish community in the Abrubi Lagoon, May 1994-April 1996 given as Relative Frequency in all stations

Fish Species	Category	Stn1	Stn2	Stn3	Av
Freshwater Species					
<i>Tilapia zilli</i>		67	67	67	67
<i>Hemichromis fasciatus</i>		100	96	67	87.67
<i>Hemichromis bimaculatus</i>		46	42	0	29.33
<i>Clarias anguillaris</i>		54	0	0	18
<i>Heterobranchius bidorsalis</i>		58	0	0	19.33
Euryhaline Species					
<i>Sarotherodon melanocheilus</i>		100	100	100	100
<i>Mugil cephalus</i>		0	42	83	41.67
<i>Liza ferdinandina</i>		58	38	83	59.67
<i>Ethmalosa fimbriata</i>		0	58	79	45.67
Marine Species					
<i>Gerres melanocheilus</i>		0	29	38	22.33
<i>Caranx hippos</i>		0	0	25	8.33
<i>Lufjanus fulgens</i>		0	29	17	15.33
<i>Epinephelus aeneus</i>		0	8	33	13.67
<i>Pseudocrenilabrus senegalensis</i>		0	12	20	10.67
<i>Pegusa lascaris</i>		0	12	17	9.67
<i>Trachinotus ovatus</i>		0	10	22	10.67
<i>Epiplatys spilargenteus</i>		0	20	32	17.33
<i>Kribia kribensis</i>		33	29	0	20.67

opectee	tvmyw y uorra	ouly	rwy	o-p	uu	IVUV	uw	OOIJ	rtJL-	IVId	mfi	
<i>S. melanotheron</i>	90	110	115	143	leo	147	103	95	110	153	130	92
<i>H. fasciatus</i>	6	5	9	13	14	10	18	0	10	5	18	15
<i>r.zm</i>	4	6	5	8	7	8	4	1	5			14
<i>H. bimaculatus</i>	8	3	5	6	2	2						8
<i>H. bklorahs</i>	2	2	4	3	1	1	1	2				3
<i>K. kribensis</i>				6	8	8			2			
<i>C. engulVaris</i>	4	2	4	2	1							2
<i>L. Faldpinnis.</i>				2	4	8	3	2	1	1		

Stn.2	Species	Ma/94	June	July	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb	Mar	Apr
	<i>S. melanotheron</i>	00	92	112	120	117	132	115	112	118	132	123	120
	<i>M. cephalus</i>			18	14	10	8						
	<i>Lfatcipinnis</i>						22	14	16	17	19		
	<i>E. fimbriata</i>					2	3	12	14	4	5	5	
	<i>T.zifUI</i>	9	8	12	8			4	2	2	6	3	1
	<i>H. fasciatus</i>	7	12	8	2		6	6	3	2	4	4	3
	<i>E. lacerte</i>					6	3	8	5				
	<i>G. melanothervs</i>					4	7	3	2				
	<i>K. kribensis</i>					10	9	14	8				
	<i>L. fulgens</i>						4	2	3				
	<i>H. blmacuaftus</i>	5	10	4	5							12	8
	Total	109	122	154	149	149	194	178	165	143	166	147	132

Stn.3	Species	Ma/94	June	July	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb	Mar	Apr
	<i>S. melanotheron</i>	60	62	72	68	90	110	82	85	88	92	169	120
	<i>T.zilHI</i>	10	14	35	41					3	8	12	14
	<i>H. fasciatus</i>	12	18	38	44					8	12	22	30
	<i>E. lacertt</i>						14	21	10	6			
	<i>E. fimbriata</i>						28	32	10	13	18	22	3
	<i>M. cephalis</i>					5	8	11	6	4	2	3	4
	<i>T. ovatus</i>							1	3				
	<i>L. fahipinnis</i>					12	6	12	6	2	4	5	1
	<i>E. genus</i>					8	11	6	4				
	<i>C. hippos</i>					3	6	8	2				
	<i>G. melanothervs</i>					2	12	14	4	2			
	<i>P. lascaris</i>						2	5					
	<i>K. Kribensis</i>				22	40							
	<i>L. fulgens</i>						3	3					
	<i>P. senesjalensis</i>						1	4					
	Total	82	94	145	175	160	201	199	130	126	138	233	172

98	98	88	90	90	115	120	83	100	103	94	119
12	19	8	11	12	9	5	8	15	14	14	16
12	7	5	4	8	8						
8	9	7									3
8	2	3						2			1
		8	12	9	3						
3		3	3	1	1			2			2
					1	2	1	3	1	2	2

May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'96	Feb	Mar	Apr	
114	83	92	86	114	133	123	99	130	128	132	117	
9	11	23	14					8		6		
			12	14		8	6					
			10	7	9	4	5	5	3			
6	5	3	14	5	7	9	2	8			2	
8	12	20			10	3	1	2	2	3	5	
			4	2	2							
			18	12	8							
				4	1	2	2					
4	2				2						6	
141	113	138	156	158	172	149	118	153	133	141	130	3610

May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'96	Feb	Mar	Apr	
115	104	90	84	88	112	90	98	93	88	112	105	
18					2	1	1	2	2	10	8	
27					5	2	3	2	2	8	12	
8	4	8	21	13	8	4	5	2	2	8	2	
4	8	12	24	4	8	10	2	2	4	1	1	
2	11	19	8	12	3	8	2	11	3	1	1	
	8	2	3	4								
		13	8									
		12	2	3	3							
			1	1								
			9	6	18							
			8	3								
			5	2								
174	135	156	173	138	159	115	111	112	101	140	129	3494

Species	May	June	July	Aug	sep	uct	NOV	ua	87	94
Sjneleanotheroi	63	95	88	87	98	118	100	93	87	94
M.cephalus					5	3	2			
G.ansorgii	13	20	48	50	38	22	18	17	18	
T. zillii	20	58	40	31	41	12	2	4	3	2
H.fasciatus		5	7	8		10				
L. faldpinnis					12	15				
P.schlegali	2	8	15							3
EJimMata					12	15	2			
S.gaklaaus	14	1Q	12							
C. anguillaris	4	2	5							

Total 116 198 215 176 206 195 124 114 108 99

Species	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb
S.melanotheroi	0	98	98	92	102	196	120	112	102	112
Tjffi	0	22	12	6	8	7	8	12	6	3
Hfasciatus	0	15	18	6						
M.cephalus	0	15	10	11	14	13	10	4	12	11
L.fajcipirmis	0					3	8	12	10	8
LJulgens	0	1	1				3	6	2	1
C. anguMaris	0	10	11			2				
G.melanoptenr.	0		2			4	6	3	1	1
EJimbriata	0		8	3	2	2			6	2
G.artsorgli	0	15	32	28	40	14	8	3	5	8
C.stampfiii	0						4	6	4	5
SJHcrorum	0					1	1	4	2	

Total 0 176 192 146 166 242 168 162 150 151

Species	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb
Sjneleantwroi 47	70	139	80	107	100	110	132	120	124	124
M.cephalus	8	14	16	20	14	3	2	3	5	
G.ansorgii 32	15	19	22	15	22	15	6	10	12	
T.zillii 12	8		4	6						
L.fajcipmnis				8	10	2	3	2		
P.schlogali			22	8						
S.micmrum			4	2	6	3	1	3		
E.fimbriata	6	10	11	9	1	4	2	8	2	5
E.aanus					1	4	2			
C.hippos		5	2					3	3	
Lfuijgens		3	1		5	1	4	2		
P.senegalensis					2	2				
C.stampfiii						1	4			
P.rogerii							2	2		
G.decadactylus						1	2			
P.fascaris					2			1		
T.gor&ensis						2		1		
P.belcharii							3			
G.melanopteru. 4	2	2	3	5	2	6	8	6	5	
Total 95	109	214	151	177	169	153	171	151	151	

112	73	84	97	90	93	113	102	93	82	114		
6			50	34	22	8	4	5	5	14		387
	24	38	18	6		10					12	352
	8	9				3					8	77
						2						40
								6 8				42
		2				3						54
		14										66
		2				3						30

12ft 130 138 136 165 134 122 142 110 107 95 118 134 126 3336

Mar	Apr	May	Jun	Jui	Aug	Sep	Oct	Nov	Dec	Jan'96	Feb	Mar	Apr	
123	110	93	110	85	98	92	119	107	93	92	109	118	88	2469
2	4	23	32	18	19	10	5	3	2	1	2	6	3	214
	8	10	5	8	12	3	2						3	90
14	3					2	10	3	6	8	12	4		162
10						4	8	8	6	5	7			89
								4	5	6	2			31
	4	2	8									1		38
3						6	4	4	3					37
4	3	6				6	6	9	12	10	5	6		84
10	6	27	20	28	40	31	14	6	13	8	12	4		372
3						3	7	2	2	1				37
						1	2	1		3				15
														0
														0
														0

189 138 161 175 139 169 152 177 147 142 134 149 139 94 3638

Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb	Mar	Apr	
109	80	80	84	142	113	97	84	100	106	91	147	61	88	2411
21					17	8	5	4	10	12	8	6		176
30	13	9	3	8	8	5	21	28	10	15	3	6	12	339
8	12	10				6						5	18	89
				10	11	2	6	5	3	4	8	1	4	79
		9	15	12										66
		8				8	1	1	3					40
6			6		12	8	10	3	8	21	3			128
				2										9
	4			6	8	4	2	2	3	4				34
1			1	2	4		6			2				33
		3	5					3		1	2			18
			2							3				19
														9
							1	2			2			6
							1							6
			2							1				6
						3	1							7
2						5	2	6	2	2	2	2		66
177	105	123	118	176	171	154	140	154	148	156	175	81	122	3541

Station 1

Species	Ma/94	June	July	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'96	Feb	Mar	Apr	
S.melanotheron	920	1608	1244	2042	3430	2532	1840	1734	2237	3184	1830	1860	1422	1150	1520	1800	2186	2914	3541	1893	1006	1884	2067	2207	
H.fasciatus	299.7	280	250.7	600	820	590.4	932	330	663	952	692	530	438.2	832.4	412	520	1083	1325	668	1392	1000	854	2008	874	
T.zilij	82.5	93.5	90	200.8	180.6	243.7	120.5	15	363.2				333.7	386.3	213.8	178.4	144.7	820.4	445.6						
H.bjmaajatus	63.8	40.2	70.3	148.2	63.4	50.2						160.3	43.5	165.3	143									55	
H.bidorsalis	83.2	76.8	140	150.7	38.4	35.7	28.9	63.5				324	200	488.5	315						214			20	
K.kribensis				100	100.2	125.6			50						76.6	224.3	315	28							
C.anguitaris	100.8	21.5	140	55.7	28.4						112	224			285	315	53.4	63.4			586			180	
L.fafdpkinsis				105.6	283	632.4	398.6	31.5	108.8	50								68.5	112	156	532	279	342	220	
Total	1550	2120	1935	3403	4944	4210	3320	2174	3422	4188	2634	3432	2490	2860	2930	3004	4458	4844	4321	3441	3340	3017	4417	3556	

Stn.2

Species	Ma/94	June	July	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'96	Feb	Mar	Apr
S.melanotheron	844	854	932	1134	1016	2100	1406	1040	1200	2500	1942	1040	1236	1000	944	1400	2102	1891	1422	1090	2210	1400	2422	1300
M.cephalus			170	350	480	90.2							214	167.7	314	283					418.5		315	
L.falcipinnate						140	110	163.2	621.9	530						312	318		281	318				
E.fimbriate					38.6	59.4	120	140.3	118.2	112	120.6					333.7	281	300	175.5	385	352	163.5		
T.zA5i	270	240	158	187.5			81	63.2	170.4	95.3	72	23.8	118.3	134.5	62					153.4	719.8			351
H.fasciatus	140	60	210	53.5			69.3	63.8	54.8	303.5	162.7	110.8	76.2	122.9	200	300	380	263.4	312	253	171.6	184	183.5	106
E.facerta					208.4	62.3	160	99.7											187.5	95	18.2			
G.melanotherus					115	80.8		38.9	24							294.6	296	118						
K.krfcenais					200	110	88.2	87.5								320.7	283.8	113						
L.fulgens						87	43	66.4									244.8	83.4	24.5	63.8				
H.bimaculatus	199	420	180	197							98.6	240	151.8	35.8										420
Total	1453	1594	1650	1922	2058	2799	2072	1754	2438	3400	2342	1380	1843	1538	1620	3324	3789	3200	2261	2200	3884	1747	2843	2485

Stn.3

Species	Ma/94	June	July	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan'96	Feb	Mar	Apr
S.melanotheron	620	640.4	800	692	1324	1080	883	914	887	1143	1083	1224	1236	1038	633	645	1730	800	1543	1234	1734	1645	1823	2248
T.zffilij	155.6	190	512.8	582.4					92.5	150	100.9	243.8	250					86.4	29.9	22.4	46.3	114	210	179.6
Ufaedatus	124.4	228.6	454.2	613.6					212	300	140	410.8	353					150.3	50	154	42.1	107.7	359	358.4
E.lacerta						218.4	112.3	92	102.9															
E.Rmbriata						165.3	263	98.6	200	312	90	38.4	120	222.9	170	377.7	410.3	98.6	120.2	190.6	13.3	48.3	114.4	44.8
M.cephalus					258.7	200.8	132.2	72	120.7	114	88.6	163.8	119	242.8	370	497.9	250.8	810	280.3	210	88.3	120	60.3	72.8
T.ovatus							12.1	38.4																
L.falcipinnis					213.2	205.4	145.8	69.8	88.3	219	83.5	43.2	66	290.3	313	388.6	480.6	312	120.6	193	410	210	53.3	63.4
E.aenus					110	110.3	61.3	25.4						215	42.3	81.5	56.4							
C.Wppos					40.3	98	62	20.3							150.3	120.4								
G.melanotherus					23.3	65.4	70.5	29.5	28.6						108.4	82.3	53	44.7						
P.lascarfs						18.2	28.4									36.9	14.3							
K-Kribensis				58	120.5										146.3	88.6	114.6							
L.fulgens						28.6	31								113.4	58.2								
P.senegalensis						19.6	78.4								95.3	44.9								
Total	900	1059	1767	1946	2090	2208	1880	1360	1732	2238	1586	2124	2144	2009	2142	2422	3110	2302	2144	2004	2334	2245	2620	2987

<i>M.cephala/its</i>					134	36	72				
<i>G.ansorgii</i>	434	68.2	112.3	360	238	72	93	360	500		
<i>r. zillii</i>	26	190	152.6	314	400	73	46	81	66	420	
<i>H.fasciatus</i>		67.6	120.3	288		50					
<i>L.falciptinis</i>					226	47					
<i>P.schlegelii</i>	9.6	63	106.0							79	
<i>E.fimbriata</i>					150	37	53				
<i>S.galliaaus</i>	52	78.3	06.7								
<i>C.anguillaris</i>	30	105.7	125								
Total	653	1151	1220	2306	2214	1405	1263	1345	1244	1093	

ST.2

Species	May*94	June	July	Aug	Sep	Oct	Nov	Dec	Jan'95	Feb
<i>S.melanotheron</i>	503	900	630	1035	882	883	656	602	600	
<i>Tjillii</i>	00	100	62	258.1	41.3	45.1	61.3	38.3	48.2	
<i>H.fasciatus</i>	60	72	73							
<i>M.cephalus</i>	43	50	05	314.9	71	60.5	40.8	50	96.4	
<i>Lfalciptinis</i>						44.8	70.8	88.4	50	88.3
<i>Lfulgerts</i>	12.1	5.3					38.7	81.2	19.4	85
<i>C.anguillaris</i>	82.9	124				36.2				
<i>G.ansorgii</i>			10.3			33.4	50.4	34.2	10.3	0.7
<i>E.fimbriata</i>		18	52	58.3	27.2				44.8	14.3
<i>G.ansorgii</i>	53	86.4	83	184	50.3	41.8	15.8	31.5	44	
<i>C.stampflii</i>							42.4	40.3	20.3	36.6
<i>S.mtmwm</i>						138	11.3	51.8	19.4	
Station2	834	1366	1205	1650	1200	1254	1232	1176	948	

ST.3

Species	May*04	June	July	Aug	Sep	Oct	Nov	Dec	Jan'85	Feb
<i>S.melanotheroi</i>	600	534	1021	900	857	958	1700	1800	1900	1300
<i>M.cephalus</i>		100	200	250	20	55.7	61.4	18.3	53.4	28
<i>G.ansorgii</i>	280	120	150	317.3	52	68.6	83.3	27.3	63.4	24
<i>Tjillii</i>	158.4	54		33.4	28					
<i>L.falciptinis</i>					23.2	35.3	55.4	82.4	24	
<i>P.schlegelii</i>			115	44.2						
<i>Sjrvrorum</i>				37.1	11.4	44.3	23	7.4	23.8	
<i>E.fimbriata</i>	44	89	114	15.8				40.3	28.4	36
<i>E.aenus</i>					6.1	40.4	283			
<i>C.hippos</i>			80	53.7				64.3	14.8	
<i>Lfulgens</i>		46	30.3			60.9	84	55.4	33.2	
<i>P.senegalensis</i>					7.3	10.2				
<i>C.stampflii</i>						8.6	43.2			
<i>P.rogerii</i>							33	16.3		
<i>G.decadactylus</i>						10.3	9.2			
<i>P.lascaris</i>					9			0.4		
<i>T.goreertsis</i>						14.6		11.9		
<i>P.belcherii</i>										
<i>G.melanopteni</i>	106.4	28	43	20	21.4	18.4	63.6	100	60	54
Tow	1204.8	880	1744	1800	1061	1325	2084	2230	2221	1442

Fish species richness and composition varied along the longitudinal (upper reaches Vs lower reaches) gradients of both the Abrubi lagoon and Densu-delta. In the Abrubi lagoon a total of 4 freshwater, 6 euryhaline and 8 marine species were found. The dominant species were *Sarotherodon melanotheron* (Rupell, 1852), *Hemichromis fassdatus* (Peters, 1852), *Tilapia zillii* (Gervais, 1848,), *Liza falcipinnis* (Valenciennes, 1836, and *Ethmaiosa fimbriata* (Bodwich, 1825)

In the Densu delta, a total of 3 freshwater, 7 euryhaline and 11 marine species were found. Five euryhaline species were dominant; these are *Sarotherodon melanotheron*, *Gobioides ansorgii* , *Tilapia zillii*, *Mugil cephalus*, *Ethmaiosa fimbriata*. The mud skipper *Periophthalmus papilio* was present in both study areas all year round.

The numbers of marine, euryhaline and freshwater species are summarized in Table 6.9a and 6.9b. The marine species decreased from 13 at the seaward end in the Densu-Delta to 0 in Station 1, whilst the freshwater species increased from 0 at the seaward end to 3 in the Upper reaches in Station 1. In the Abrubi lagoon, marine species decreased from 8 at seaward end (Station 3) to 0 at the riverine end (Station 1).

Table 6.9 a Total Numbers of Fish species, Marine, Euryhaline and Freshwater Species (Abrubi lagoon).

Abrubi lagoon Species	Stations		
	1	2	3
Marine	0	3	8
Euryhaline	4	6	6
Fresh water	4	2	1
Total	8	11	15

Table 6.9 b. Total numbers of fish species, marine, euryhaline and freshwater species, Densu delta.

Densu delta Species	Stations 1	2	3
Marine	0	4	13
Euryhaline	7	6	6
Fresh water	3	2	0
Total	10	12	19

Sarotherodon melanotheron was clearly the most dominant species in terms of numbers and weight. This is similar to Pauly's (1975) observations on the fishery of the Sakumo lagoon. Pauly (1975) classified the fish in the Sakumo 2 lagoon as:

- 1) Fresh water fishes which swim into the lagoon through the temporary rivers; *Tilapia zillii*, *Clarias anguillaris*, *Heterobranchus bidorsalis*, *Hemichromis fassdatus*, *Hemichromis bimaculatus*.
- 2) Those that spend most of their life time in the lagoon, *Sarotherodon melanotheron*, *Porogobius schlegeli*, *Gobioides ansorgii*, *Periophthalmus papilio*.
- 3) Those that have their juvenile forms washed into the lagoon from the sea after the rainy season; *Ethmaiosa fimbriata*, *Syadum microrum*, *Gerres melanopterus*, *Mugil cephalus*, *Liza fuidppinis*, *Elops lacerta*.
- 4) Marine species which make short incursions into the lagoon; *Lutjanus fulgens*, *Caranx hippos*, *Epinephelus aenus*, *Trachinotus ovatus*, *Pegusa lascaris*, *Pseudotolithes senegalensis* This classification agrees with that of Elliot and Dewailly, (1995) used in this study.

Fig.6.3a. Percentage distribution of the main species by numbers St.1, Abrubi lagoon May 1994-April 1996

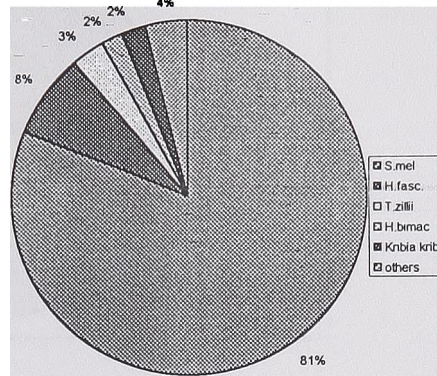


Fig 6.3b. Percentage distribution of the main species by numbers St.2, Abrubi lagoon May 1994-April 1996

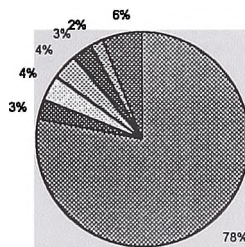
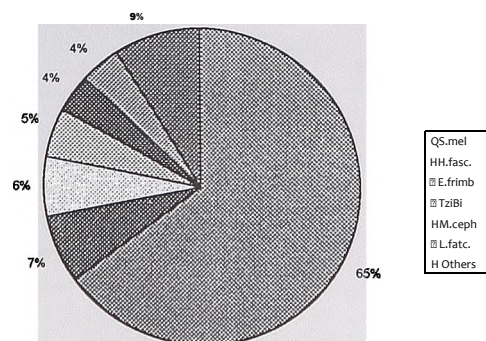


Fig. 6.3c. Percentage distribution of the main species by numbers St.3, Abrubi lagoon May 1994-April 1996



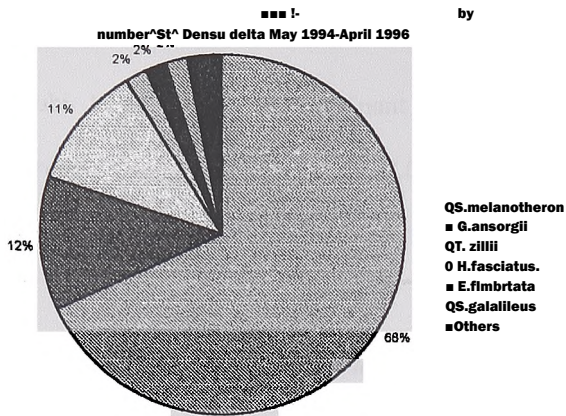


Fig 6.4b, Percentage distribution of the main species by numbers, SL2 Densu delta May 1994-April 1996

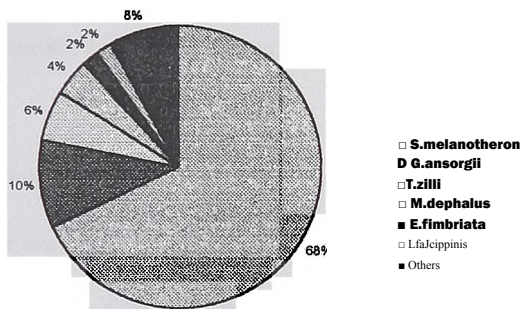
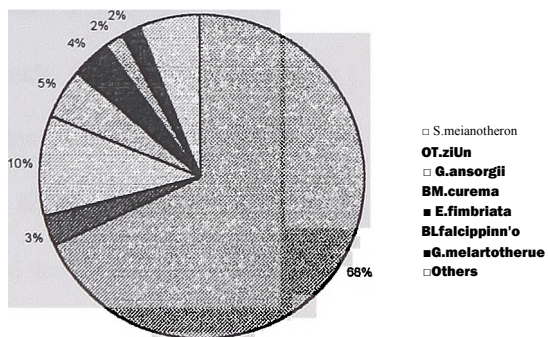


Fig 6.4c. Percentage distribution of the main species by numbers, St.3 Densu delta, May 1994-April 1996



In Abrubi lagoon the five dominant species were; *Sarotherodon melanotheron*, *Hemichromis fasciatus*, *Tilapia zillii*, *Liza falcipinnis* and *Ethmalosa fimbriata* (Figs. 6.3a, 6.3b, 6.3c).

Sarotherodon melanotheron and *Periophthalmus papillio* were resident forms. *Ethmalosa fimbriata* used the lagoon as a nursery and growth area. *Hemichromis fasciatus* is predominantly a fresh water species. The influence of the River Antaa on the species diversity of Abrubi lagoon was demonstrated by the presence of *Clarias anguillaris*, *Heterobranchus bidorsalis*, *Hemichromis fasciatus* and *Hemichromis bimaculatus*.

In the Densu delta the five dominant species were *Sarotherodon melanotheron*, *Gobioides ansorgii*, *Tilapia zillii*, *Mugil cephalus*, *Ethmalosa fimbriata* (Figs 6.4a, 6.4b, 6.4c). *Ethmalosa fimbriata* and the mullets (*Liza falcipinnis* and *Mugil cephalus*) were the most upstream migrating species and could be found in Station 1 in both lagoons.

There were a number of occasions when single individuals of a species were caught individually (Tables.6.7 a and 6.7b.). The two lagoons on the whole had a small proportion of freshwater species, 21% for Abrubi and 13.6 % for Densu delta. The greatest difference appeared to be in the proportion of marine species. Abrubi lagoon had 42% and the Densu delta had 50%, but marine species were found in Abrubi lagoon only when the lagoon was breached and not all year round. There was a higher proportion of fresh water species in the upper reaches (Station 1) of the Abrubi lagoon as well as the Densu delta.

In the Densu delta, if Station 2 is taken as a transition point or area of mixing between fresh and saline water, a greater proportion of freshwater species were found below 15‰ and marine species above 15‰ (Figs 6.5a ,6.5b, 6.6a and 6.6b).

6.6 SPECIES ABUNDANCE, RICHNESS, DIVERSITY AND EVENESS

6.6.1 Species Abundance

In the Abrubi lagoon there were more fish caught in terms of weight at the riverine end (Station 1), followed by the mid portion and then the seaward end (Table 6.8a). The highest mean biomass occurred at Station 1 and the lowest at Station 3. *Sarotherodon melanotheron* obtained in Station 1 were bigger than those caught from Station 2 and 3. (Appendix. 7.3.)

The other species of importance by weight in Abrubi lagoon were *Hemichromis fassdatus*, *Tilapia zillii*, *Liza falcippinnis*, *Ethmaiosia fimbriata*, *Mugil cephalus* and for the Densu-delta *Gobioides ansorgii*, *Tilapia zillii*, *Mugil cephalus*, *Ethmaiosia fimbriata*, *Liza falcippinnis*, *Lutjanus fulgens*, *Gerres melanopterus*, *Clarias anguillaris*. Most of the *Hemichromis fassdatus* were obtained in Station 1 at Abrubi lagoon. In terms of numbers more fish were found in Station 2 than Stations 1 and 3.

Fig 65 a Changes in Some Freshwater Species Composition with Salinity

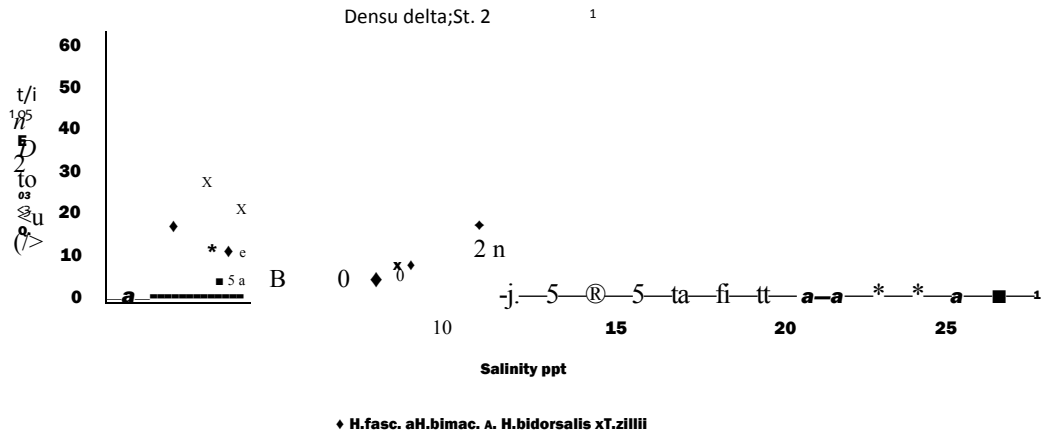


Fig 6,5b Change in Some Marine Species Composition with Salinity,



In the Densu delta, in terms of weight there was more fish caught in the Station 3, followed by Station 1 and Station 2 (Table 6.8a and 6.8b). The highest mean biomass occurred at Station 2 and the lowest at Station 1 at Densu delta.. Station 2 had a lot of juvenile *S. melanotheron* as 'acadja' fishing was practiced there (Table 6.8b). In terms of numbers more fish were found in Station 2 , followed by 3 and 1. Total fish abundance was low in the rainy season, increasing in the early rainy season and attaining maximum values in October, November and December. Juvenile forms of marine fish such as *Lutjanus fulgens*, *Syacium microrum*, and *Gerres melanopterus* were encountered in both study areas.

6.6.2 Species Richness

The highest species richness occurred in November 1994 at Station 3 (Fig 6.7a, b, c) at Abrubi lagoon (Dmg 2.078) and in the Densu delta at Station 3 in October 1995 (Dmg 2.225), (Fig 6.8a, b, c). The lowest species richness occurred at Station 1 in the Densu delta in July 1995 (Dmg 0.391); the lowest species richness occurred at Station 1 in the Abrubi lagoon in July 1994 (Dmg 0.402). This reflected year to year variation and a longitudinal decrease of these parameters from the seaward end to the riverine end. Low CPUE values seem to suggest low species richness. As these are linked there was only an apparent decrease in species richness; gear selectivity could also account for the low species richness.

6.6.3 Species diversity

The overall species diversity was not markedly different between the Abrubi lagoon and Densu delta. At 5% significance level (Mann Whitney U test), the species diversity in the dry season was different from the species diversity in the wet season at Station 1 at both the Densu delta and Abrubi lagoon. Results from Analysis of Variance tests indicated that diversity was not significant between months and within stations in the Densu delta, but was significant between months and within stations in Abrubi lagoon ($p < 0.05$). At Station 2 in both study areas the species diversity was not different during the wet and the dry season. At Station 3 the species diversity was different during the wet season and dry season in both lagoons (Appendix 6.2)

6.6.4 Species Diversity and Evenness

The evenness component varied in a similar manner to diversity (Figs 6.7 and 6.8). In the Densu delta the highest species diversity and evenness occurred at Station 3 in August 1994 and the lowest in February 1995 at Station 1. In the Abrubi lagoon the highest diversity occurred in November 1994 at Station 3 and the lowest in February 1995 at Station 1. Species diversity and evenness decreased from Station 3 to Station 1. The highest values for species diversity and evenness occurred at Station 3 in both study areas.

6.6.5 Change in Species Diversity with rainfall

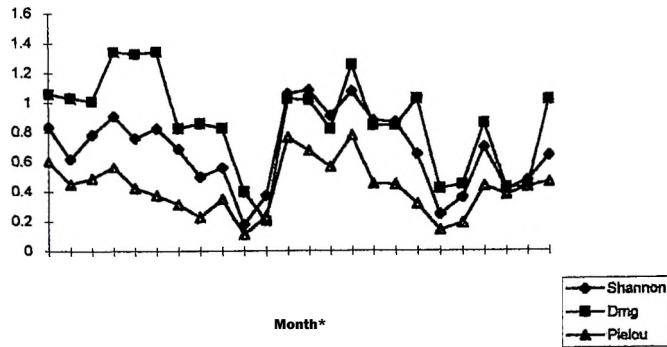
It was observed that the peak of diversity occurred just after the peak of the rainfall at Stations 1 and 2 in Abrubi lagoon (Fig 6.8a). There was some correlation between rainfall and species diversity in Abrubi lagoon Station 1 ($r = 0.48$) and none in Stations 2 ($r = 0.06$) and Station 3 ($r = 0.03$). At Station 1 the species diversity followed the rainfall pattern closely. This is probably because riverine species came into the lagoon during this period. High rainfall and low CPUE seem to affect the number and different species of fish caught in the sample.

At station 3 at Abrubi lagoon, marine species only came in when the lagoon was breached. The diversity peaked after the peak of the rainfall. The diversity in Station 1 followed the rainfall pattern closely, freshwater species were abundant during this period. The species diversity in the Densu delta was affected by marine incursions and the opening and closing of the sluice gates of the Weija dam. The diversity pattern also followed the rainfall pattern closely at all the stations in Densu delta (Fig 6.9b).

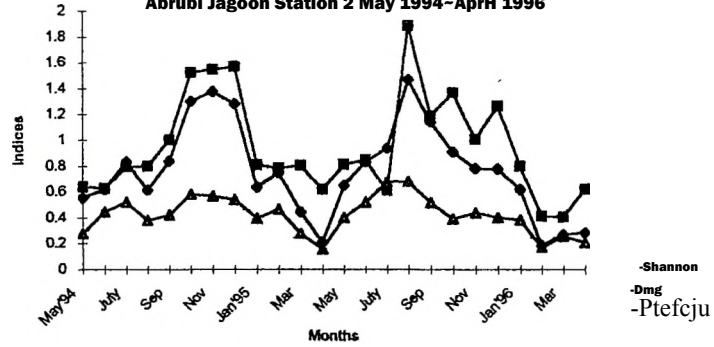
6.1 Forage-Carnivore Ratio

This is defined as the ratio of the total weights of Forage (F) species to Carnivorous (C) species. On the basis of their food habits, 5 species were classified as forage and 13 species classified as carnivorous at Abrubi lagoon (Table 6.10). In the Densu-delta 6 species were classified as forage and 16 species as carnivorous.

**Fig 6.7a Changes in Species Diversity, Richness and Evenness
Abrubi lagoon Station 1 May 1994-April 1996**



**Fig 6.7b Changes in Species diversity, Richness and Evenness.
Abrubi Jagoon Station 2 May 1994-AprH 1996**



**Fig 6.7c Changes in Species Diversity, Richness and Evenness
Abrubi lagoon Station 3, May 1994-April 1996**

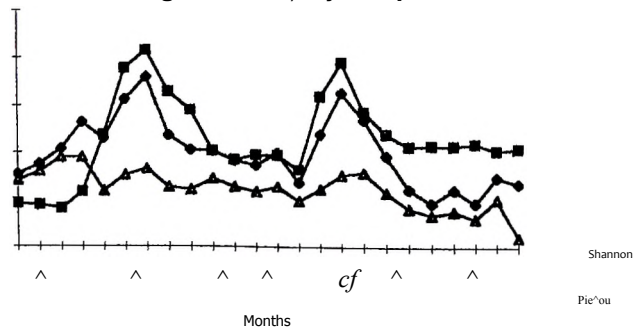


Fig 6.8a Changes in Species Diversity, Richness, and Evenness, Densu delta Station 1, May 1994- April 1996

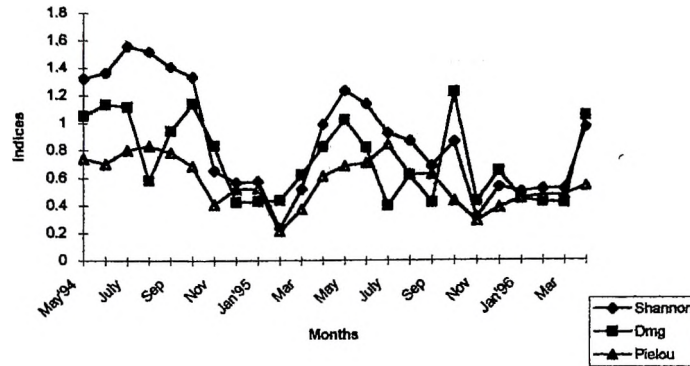


Fig 6.8b Changes in Species diversity, Richness and Evenness, Densu delta Station 2 May, 1994-April 1996

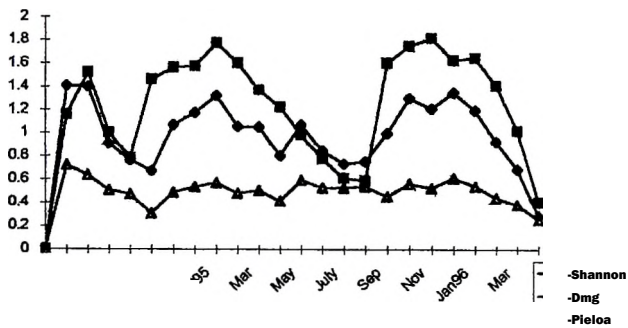
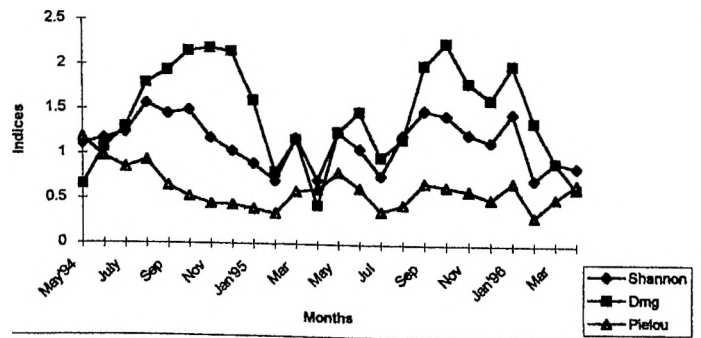


Fig 6.8c Changes in Species Diversity, Richness and Evenness Densu delta, Station 3 May 1994-April 1996



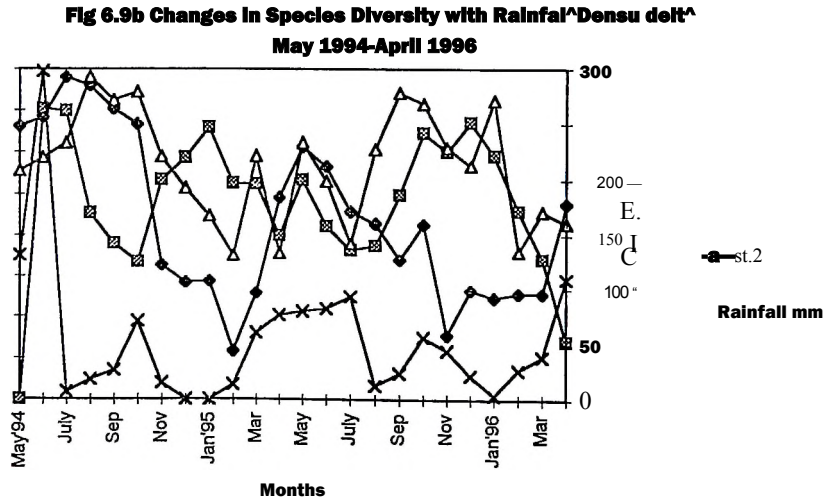
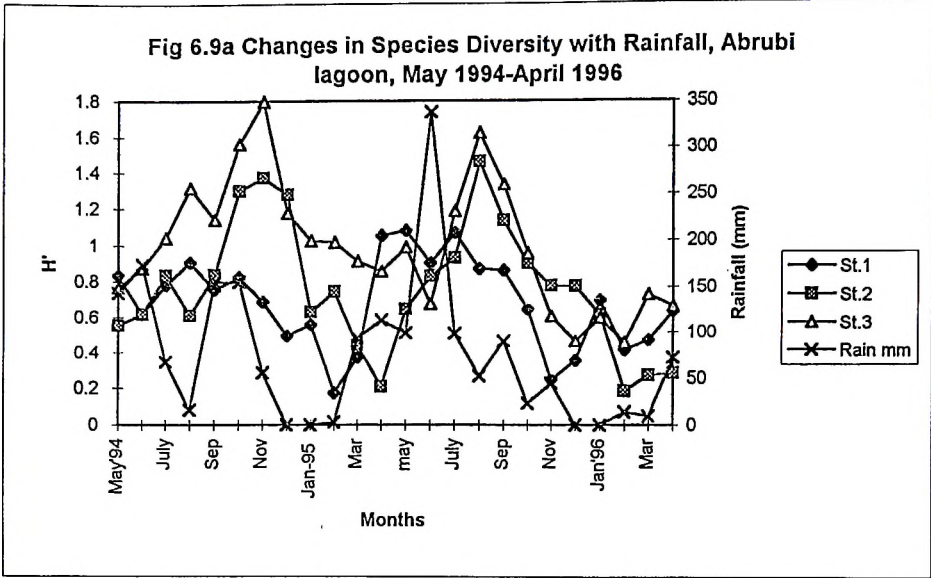


Table 6.10 Forage - Carnivore Ratio of Fish Species in Abrubi Lagoon and Densu delta, May 1994 -April 1996

Abrubi					Densu	
Forage sp.	wt(g)				Forage sp.	wt(g)
	St.1	St.2	St.3	Total		
<i>S. melanotheron</i>	48053	34425	27599.4	110077.4	<i>S. melanotheron</i>	64952
<i>T. zillii</i>	3912.7	2900.2	2966.6	9779.5	<i>T. zillii</i>	5888.8
<i>L. falcipinnis</i>	3319.4	2794.1	3968	10081.5	<i>S. galilaeus</i>	685
<i>M. cephalus</i>	2802.4	4273	0	7075.4	<i>L. falcipinnis</i>	2453.2
<i>E. fimbriata</i>	2699.8	3098.4	0	5798.2	<i>M. cephalus</i>	3712
				142812	<i>E. fimbriata</i>	2738.9
					Total	80430
Carnivores					Carnivores	
	wt(g)					wt(g)
<i>H. fasciatus</i>	26619.2		Forage	142812	<i>H. fasciatus</i>	1799.8
<i>H. bimaculatus</i>	3138.5		Carnivore	50008.7	<i>G. ansorgii</i>	7374.8
<i>K. Kribensis</i>	2750.9		Ratio	2.855743	<i>P. schlegeli</i>	1173.5
<i>C. anguillaris</i>	2165.2	Abrubi	F/C	2.86	<i>G. melanopterus</i>	1200.5
<i>L. falcipinnis</i>	10082.5				<i>C. anguillaris</i>	935.7
<i>E. lacerta</i>	1354.7				<i>C. hippos</i>	541.8
<i>G. melanopterus</i>	1473				<i>L. fulgens</i>	470.6
<i>L. fulgens</i>	844.1				<i>C. stampflii</i>	768.2
<i>E. aenus</i>	702.3				<i>S. microrum</i>	381.5
<i>Tr. ovatus</i>	50.5				<i>E. aenus</i>	119.8
<i>C. hippos</i>	491.3				<i>P. senegalensis</i>	431.1
<i>P. lascaiiis</i>	97.8				<i>P. rogerii</i>	115.8
<i>P. senegalensis</i>	238.7				<i>G. decadactylus</i>	102.9
<i>Total</i>	50008.7				<i>P. lascaris</i>	57.4
					<i>T. ovatus</i>	98.1
					<i>P. belcherii</i>	39
					Total	15610.5
					Densu F/C	5.152295

The E value of a species is defined as the percentage by weight of the species relative to the weight of the entire fish population. The E value of principal fish species are given in Table 6.11 (See Section 4.4).

Table 6.11 Percentage Composition by weight (E values) of principal fish species in Abrubi lagoon and Densu Delta

Abrubi Lagoon

Total Weight of fish in g	1	2	3	4	5
	<i>S.melanotheron</i>	<i>H.fasciatus.</i>	<i>T.zillii</i>	<i>L.falcipinnis.</i>	<i>E.fimbriata.</i>
184917.3	60%	14%	5%	5%	3%

Densu-Delta

Total weight of fish in g	1	2	3	4	5
	<i>S.melanotheron</i>	<i>G.ansorgii</i>	<i>T.zilli</i>	<i>M. cephalus.</i>	<i>E.fimbriata.</i>
98053	66%	7%	6%	4%	2%

The cichlid *Sarotherodon melanotheron* comprised a high proportion of the total fish biomass, E =60% (at Abrubi), E = 66% (at Densu delta). The next important fish was *H.fasciatus* at Abrubi (E =14%) and *Gobioides ansorgii* at Densu (E =7%). All other species had low percentages.

6.8 Bray Curtis Similarity

Considering the variations of sizes of fish, weights and numbers were used. The dendrograms they produced were not similar. Dendrograms of 24 months were produced using group average clustering from Bray -Curtis similarities. The level of discrimination used was 60% .

The cluster analysis of the fish samples by numbers and by weight from the stations in the Abrubi lagoon and the dendrograms suggested a division of the months into 4 main clusters for Station 1; 3 for Station 2; and 4 for Station 3 (Figs. 6.10a, 6.10b, 6.10c, 6.12a, 6.12b, 6.12c.). In the Densu-delta there were also 4 main clusters in Station 1; 2 in Station 2; and 3 in Station 3. (Figs.6.11a, 6.11b, 6.11c, 6.13a, 6.13b, 6.13c).

The cluster analysis of both numbers and weights tended to put years or similar months into groups. The grouping of the various months into distinct clusters of dry and wet seasons indicates a fish species distribution based on a seasonal structure.

6.9 MDS (Multi - Dimensional Scaling)

The matching MDS for the stations (figs. 6.14a, b, c and 6.15a, b, c) shows distinct grouping into wet and dry months. The months were numbered as follows:

May 1994 - 1	January 1995 - 9	September 1995 - 17
June 1994 - 2	February 1995 10	October 1995 - 18
July 1994-3	March 1995 - 11	November 1995 - 19
August 1994 - 4	April 1995 - 12	December 1995 - 20
September 1994 - 5	May 1995 - 13	January 1996 - 21
October 1994 - 6	June 1995 - 14	February 1996 - 22
November 1994 - 7	July 1995 - 15	March 1996 - 23
December 1994 - 8	August 1995 - 16	April 1996 - 24

Fig. 6.10a. upcuici) UUIIIJJUii LiUII Uy imiUUCI S kJLQUUU J. rvuiuu

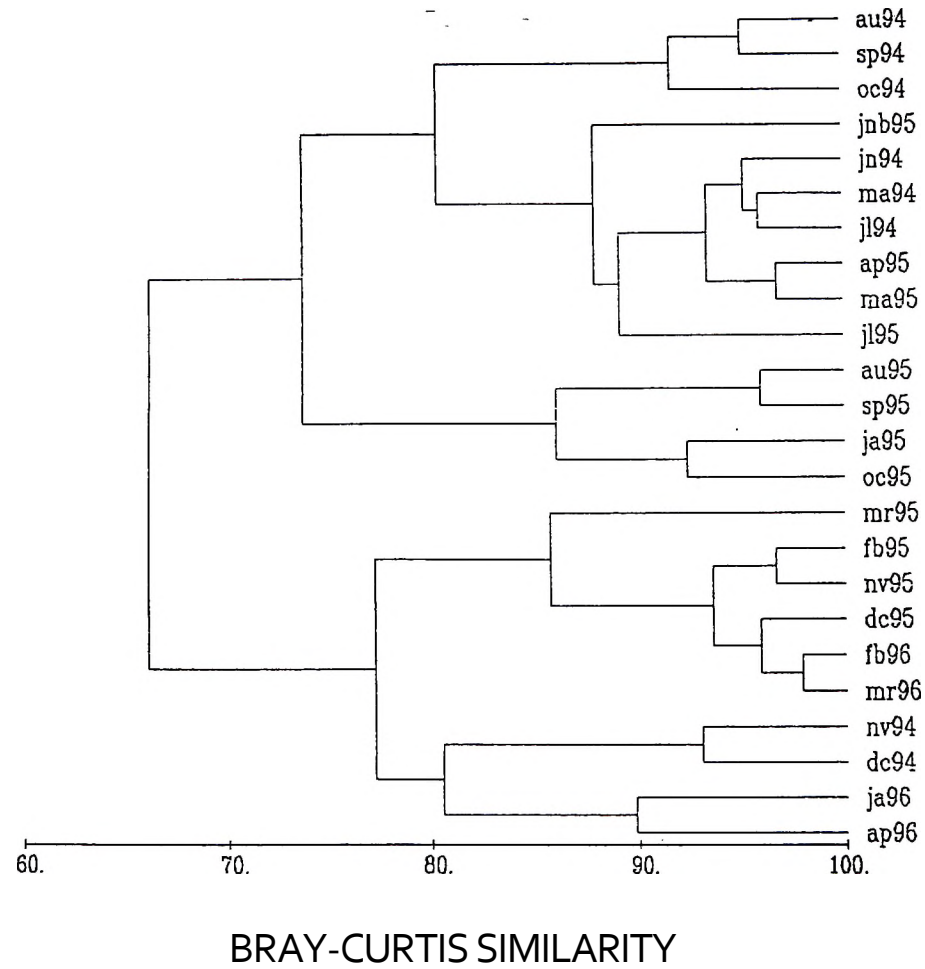


Fig. 8.iob..Species composition by numbers Abrubi Station 2

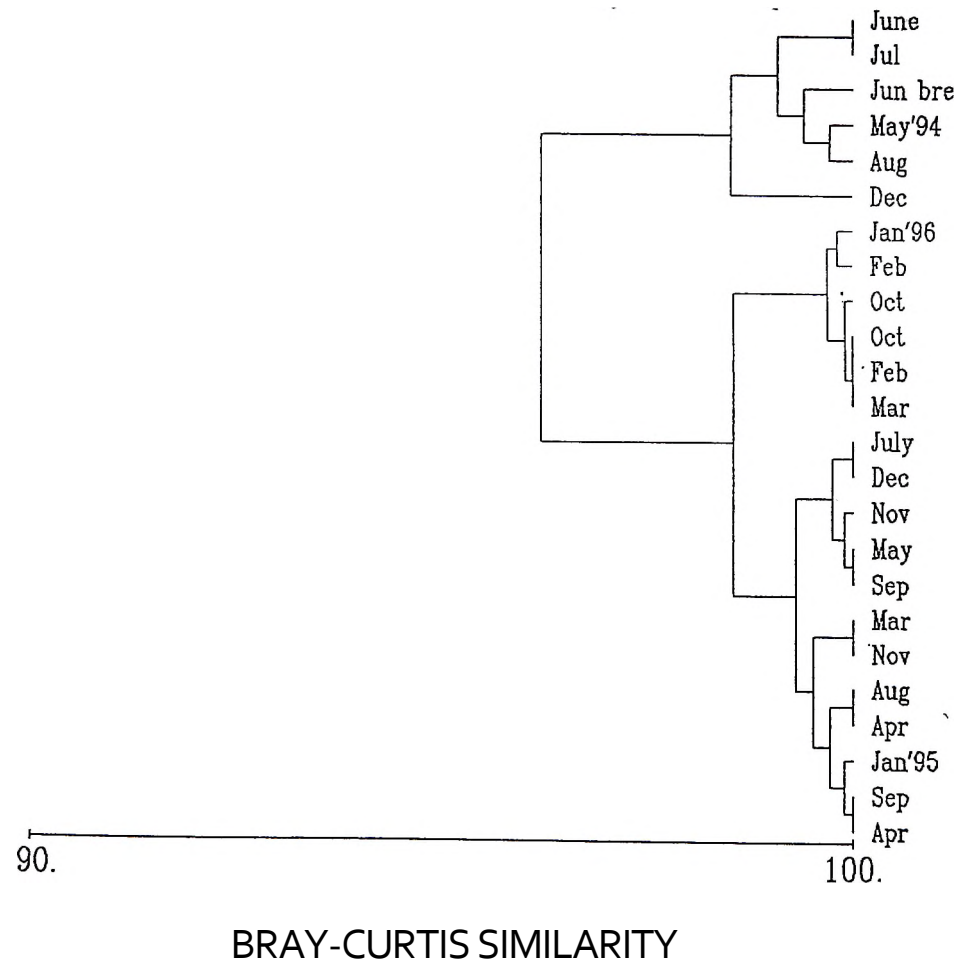


Fig. 6-ioc. Species composition by numbers Abrubi Station 3

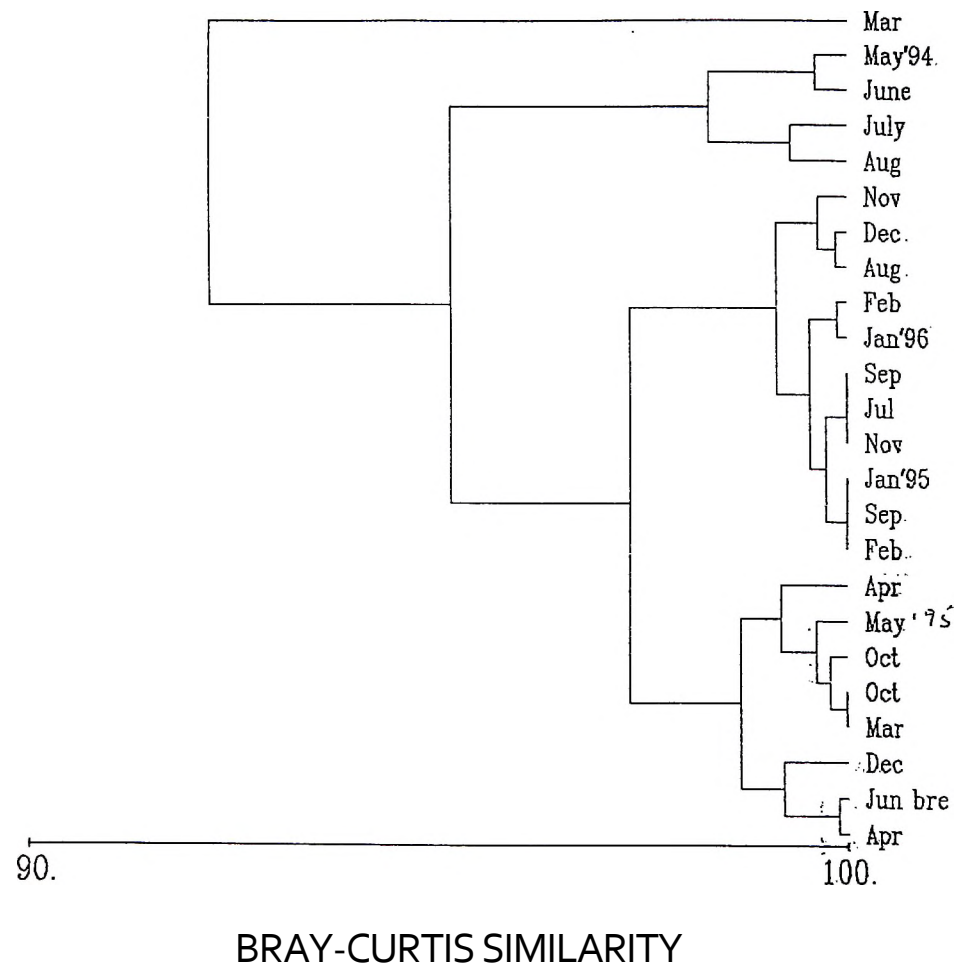
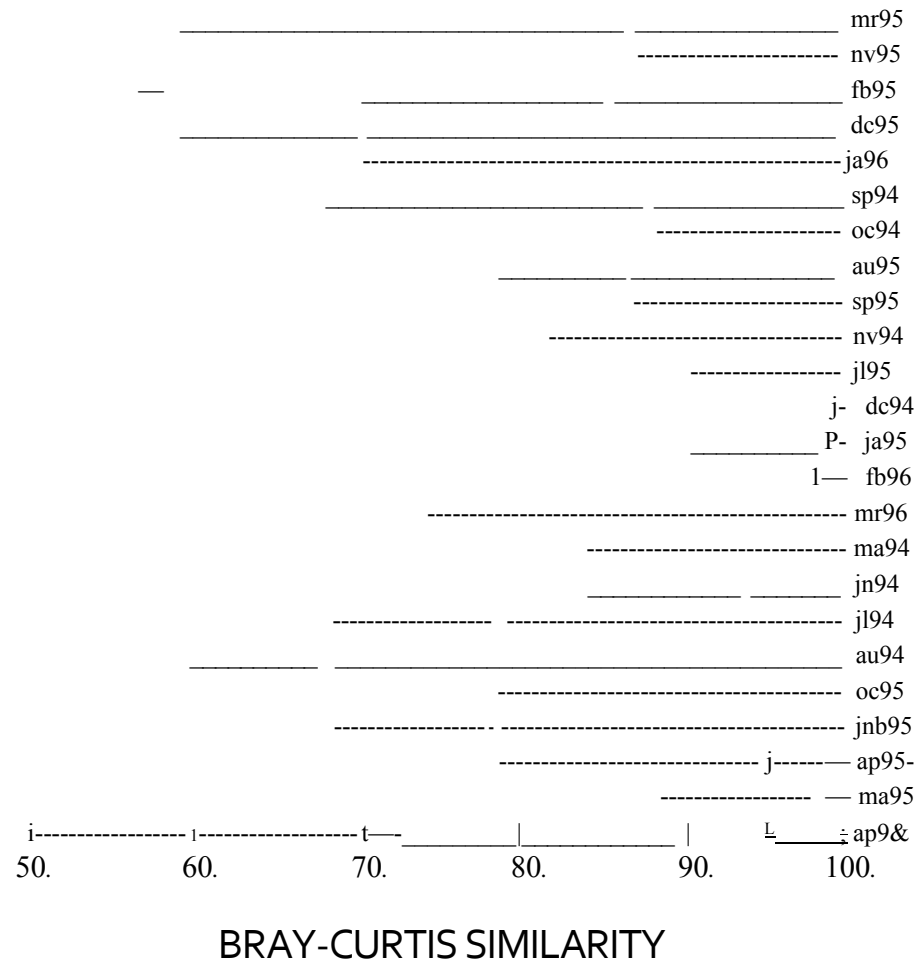


Fig. e.11.a Species composition by numbers Densu Station 1



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50. 60. 70. 80. 90. 100.

BRAY-CURTIS SIMILARITY

Fig. 6.UC. Species composition numbers Densu Station 3

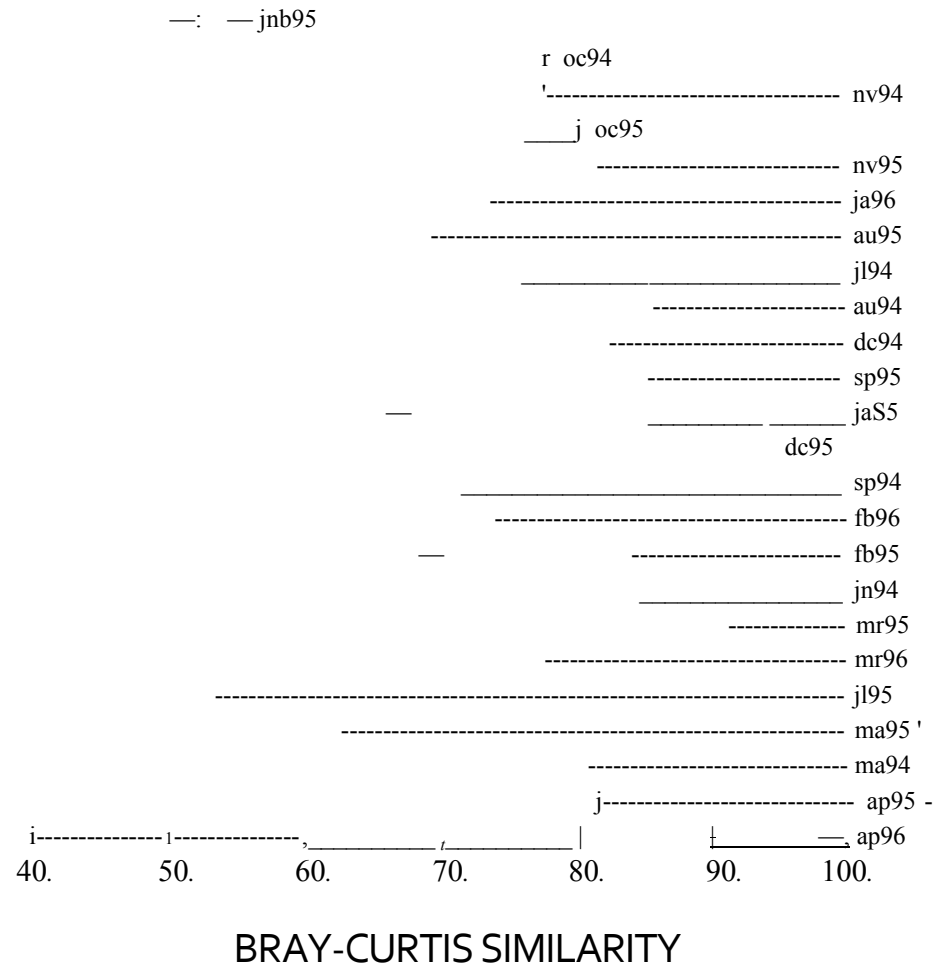


Fig. 6.12a

Species composition by weight Abrubi Station 1

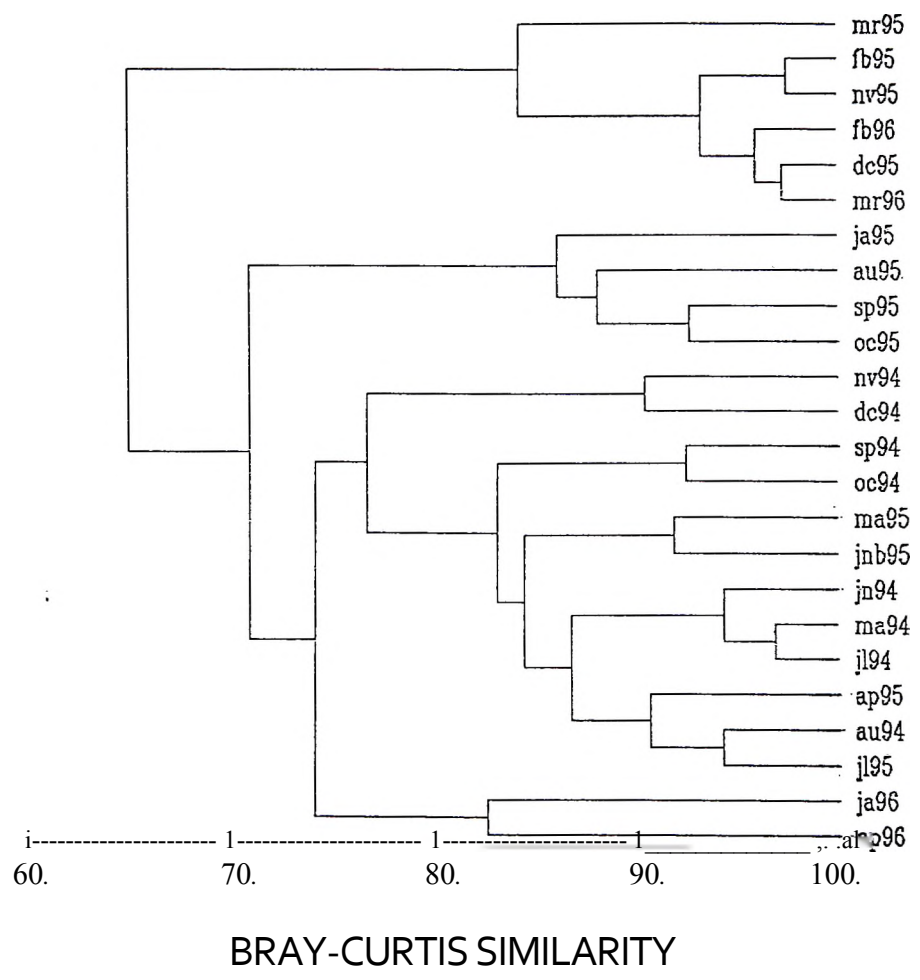


Fig. 6.12b. Species composition by weight Abrubi stn 2

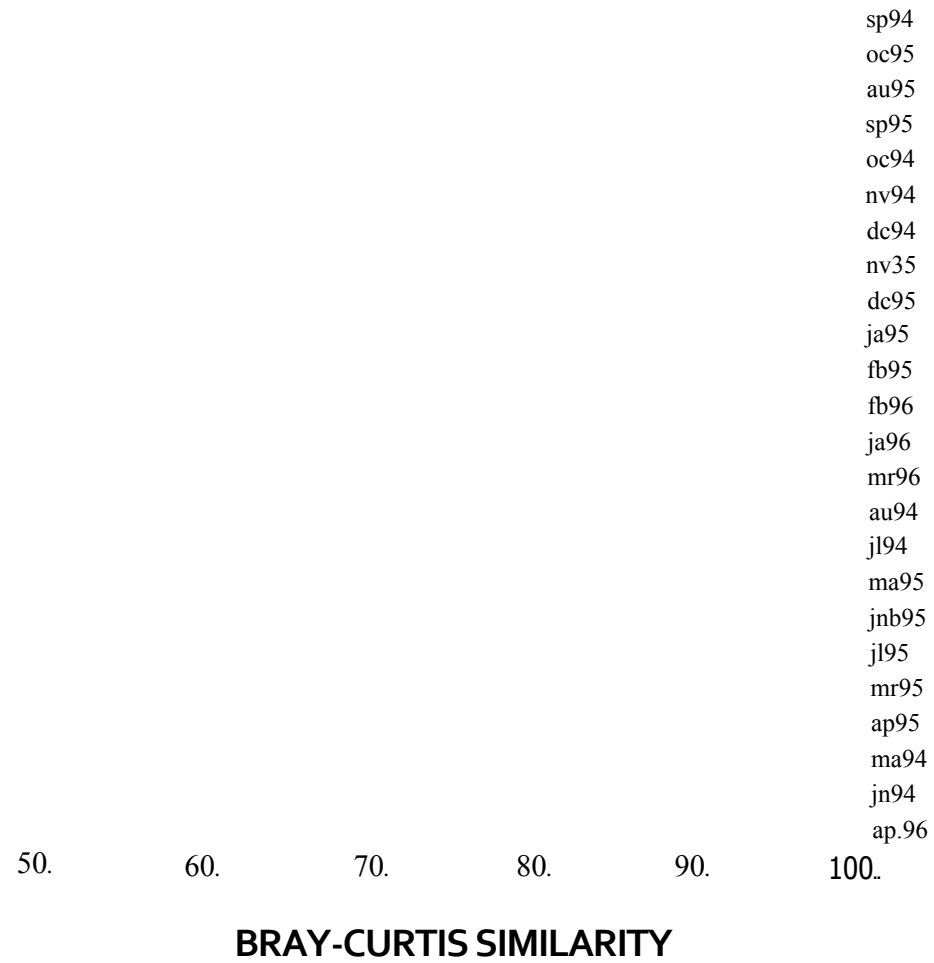
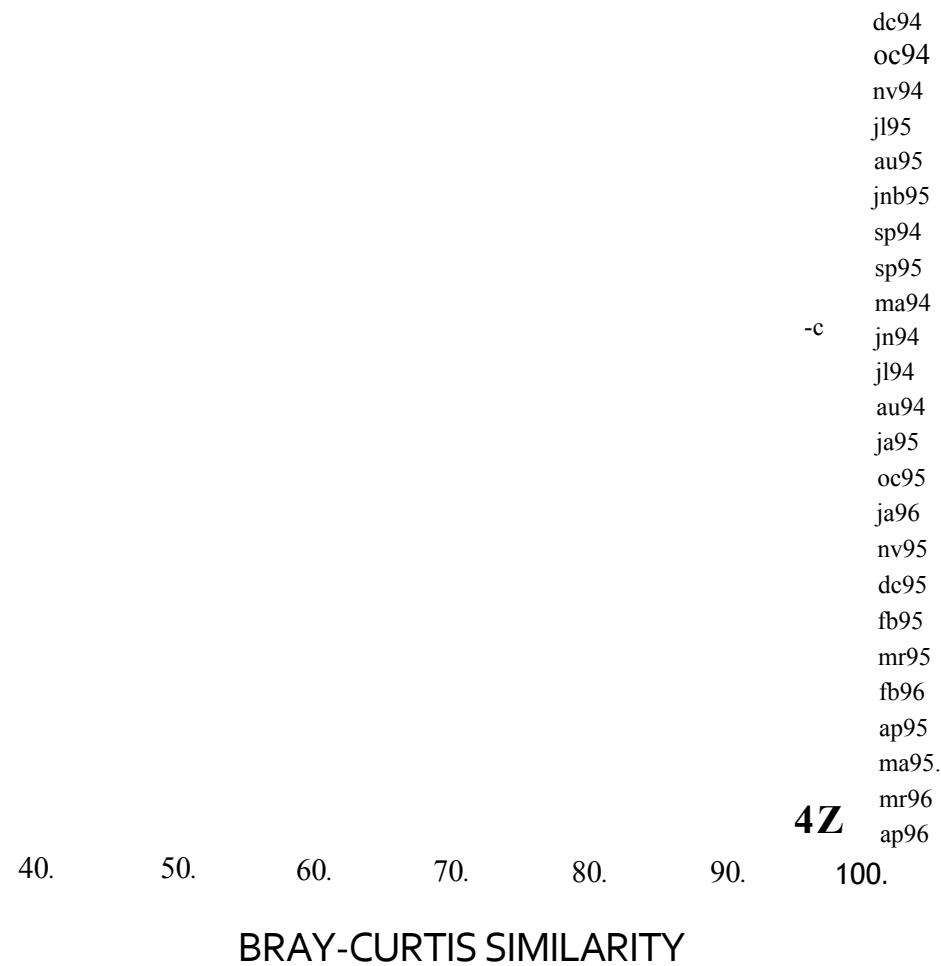


Fig. 6.12.c

Species composition by weight Abrubi Station 3



BRAY-CURTIS SIMILARITY

Fig. 6.13b. Species composition by weight Densu Station 2

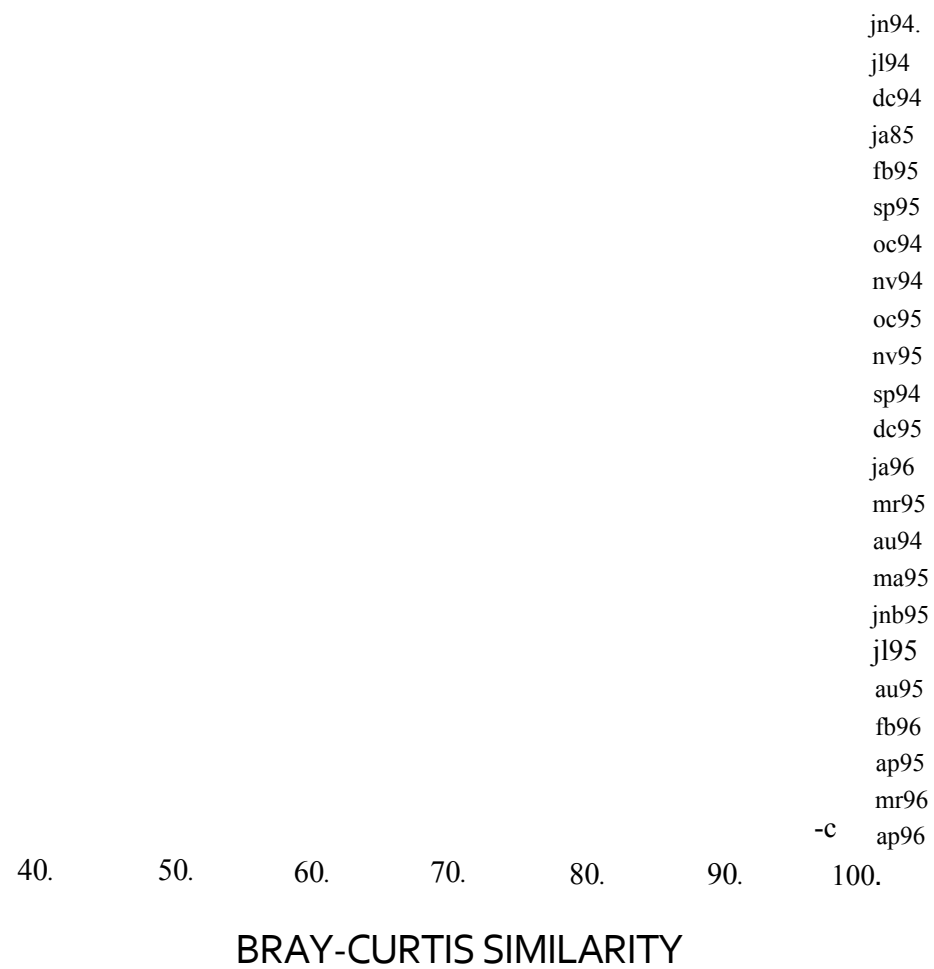
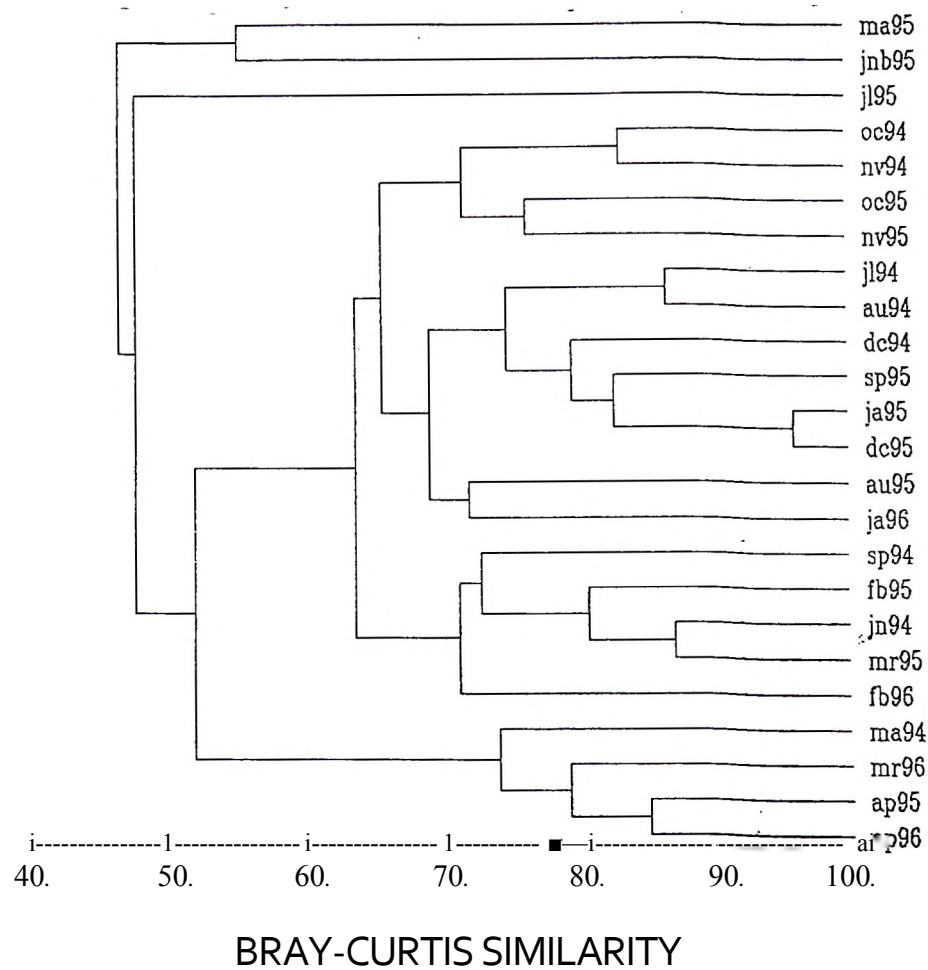
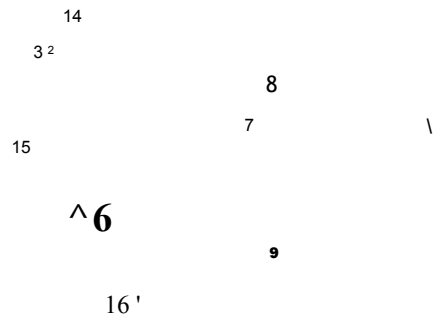
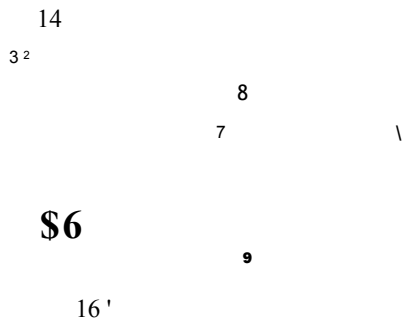
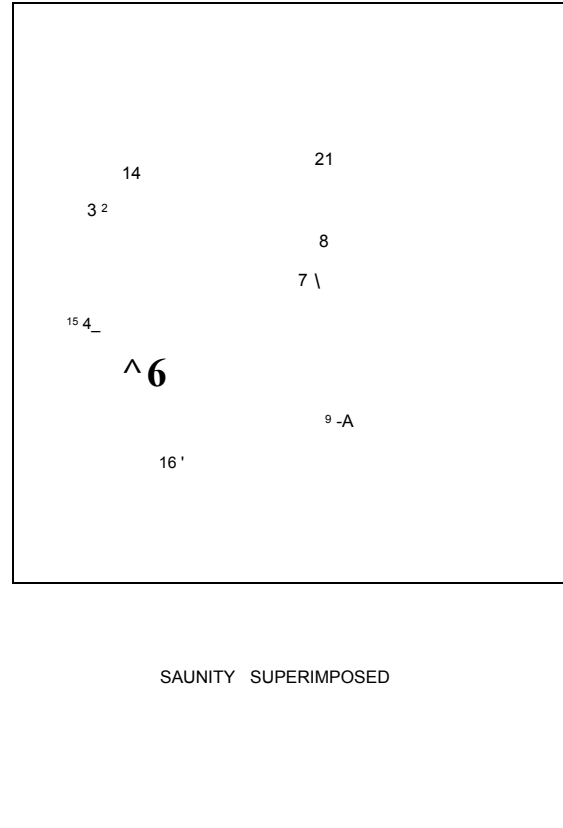
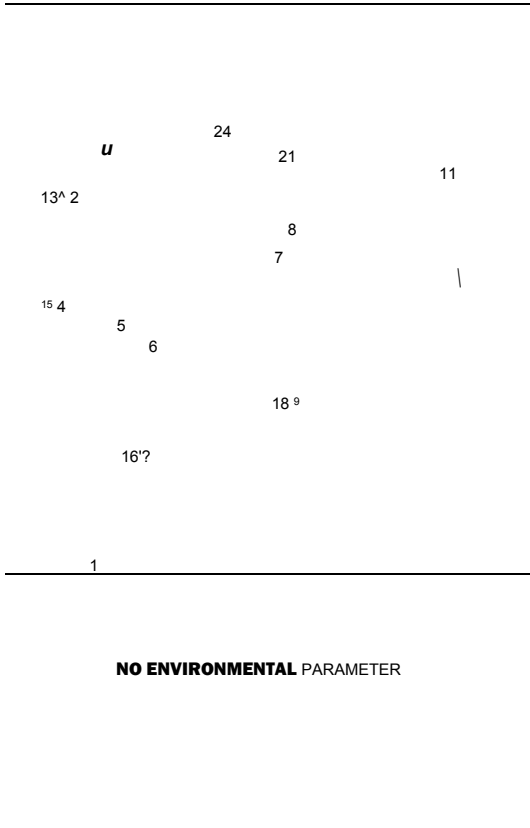


Fig. ease. Species composition by weight Densu Station 3



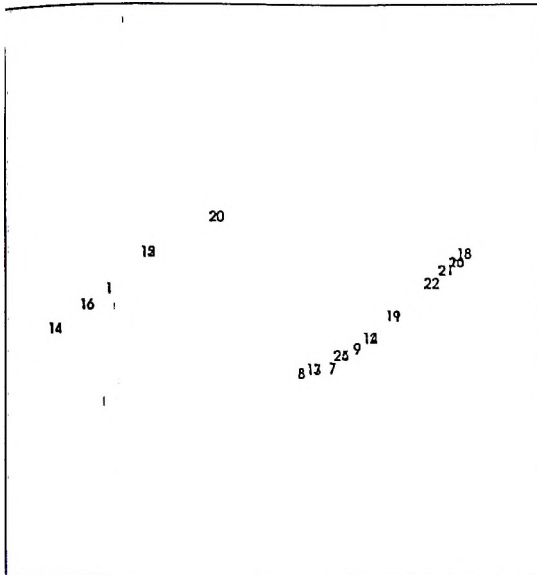
s. 6^* MDS for Station 1 Abrubi (Stress = 0.11)

i

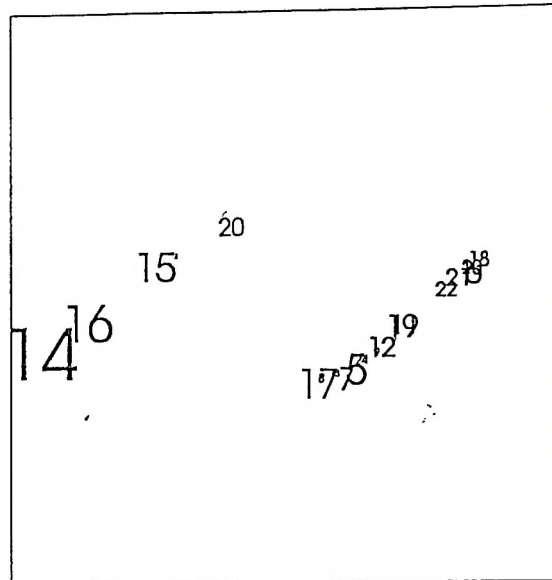


tg. 6.-14J. MDS for Station 2 Abrubi (Stress - 0.01)

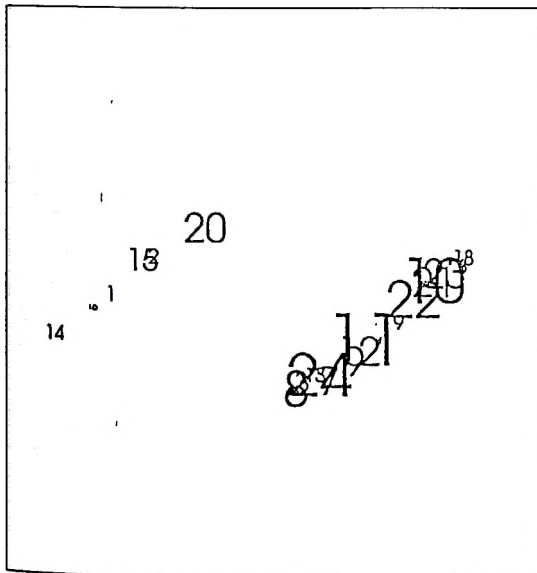
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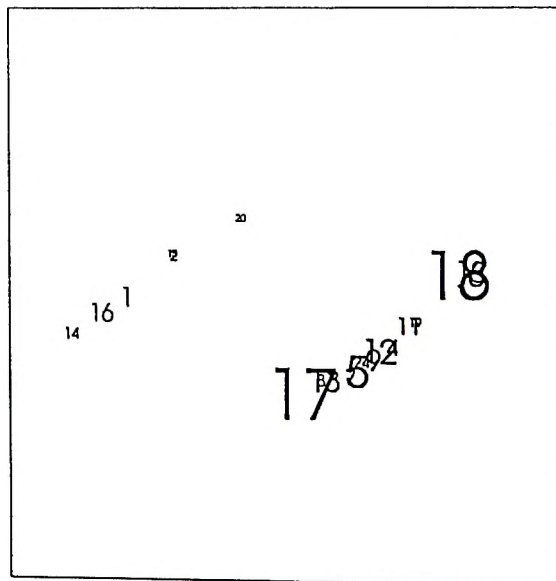
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SALINITY SUPERIMPOSED



TEMPERATURE SUPERIMPOSED

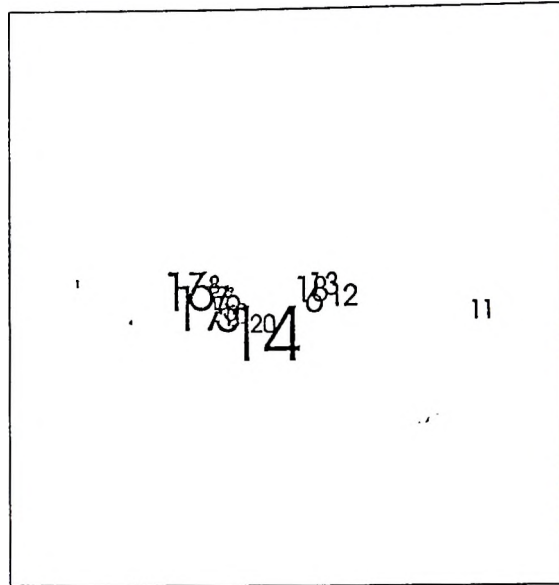


DISSOLVED OXVGEN SUPERIMPOSED

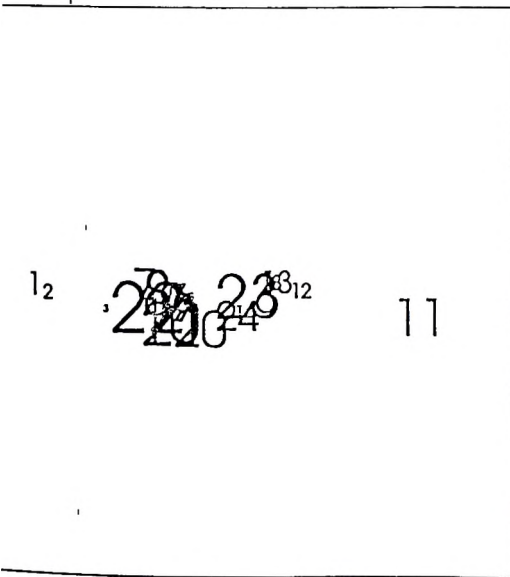
> 6.14c.MDS for Station 3 Abrubi (Stress = 0.01)



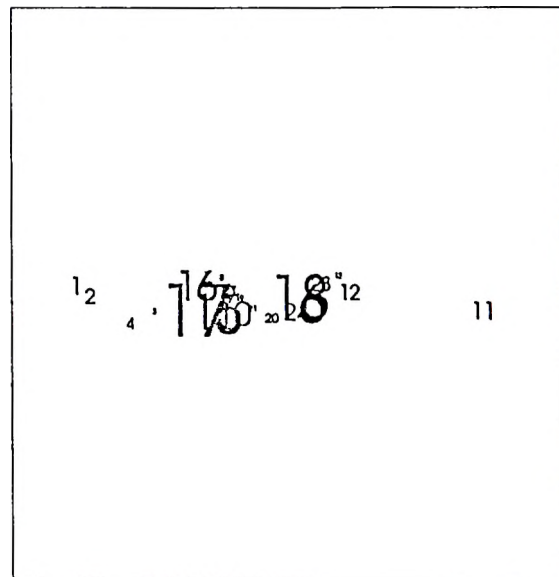
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SALINITY SUPERIMPOSED

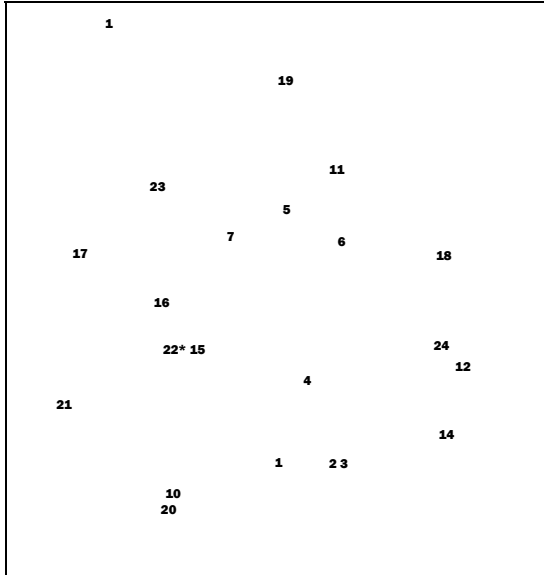


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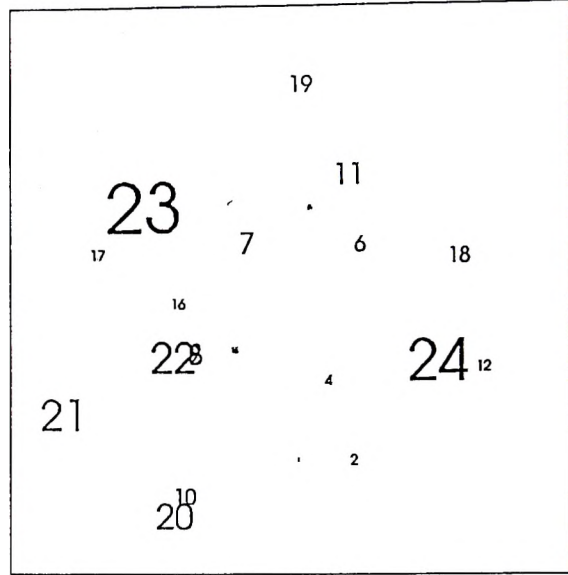


DISSOLVED OXYGEN SUPERIMPOSED

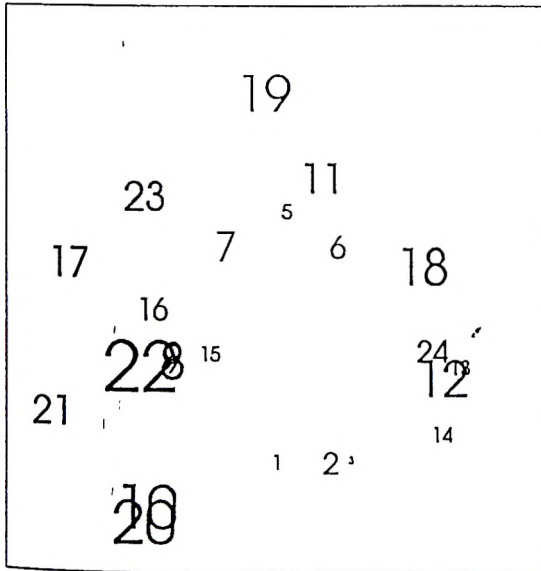
fig. 6/tiaMDS for Station 1 Densu (Stress = 0.18)



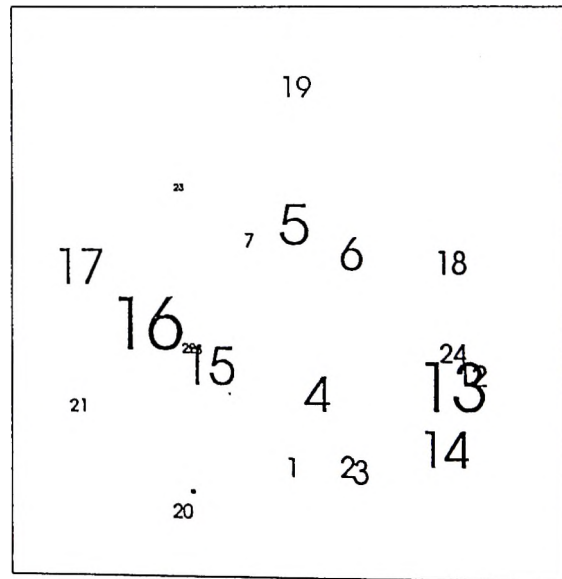
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SALINITY SUPERIMPOSED

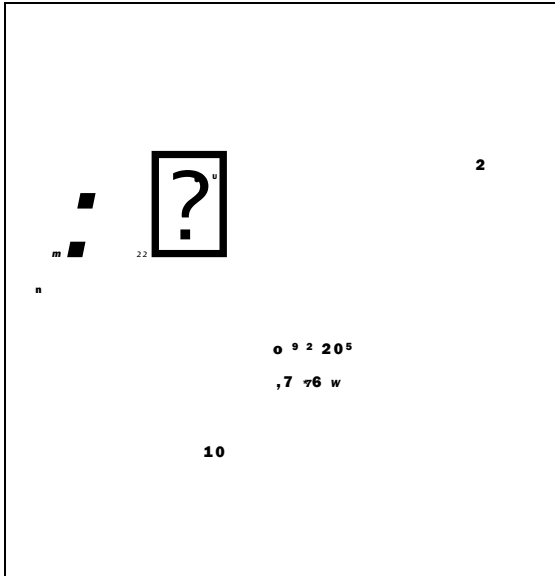


TEMPERATURE SUPERIMPOSED



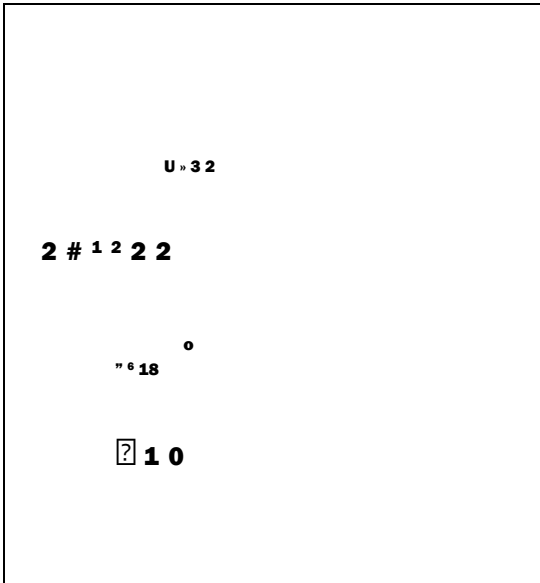
DISSOLVED OXYGEN SUPERIMPOSED

6.#*, MDS for Station 2 Densu (Stress = 0.17)

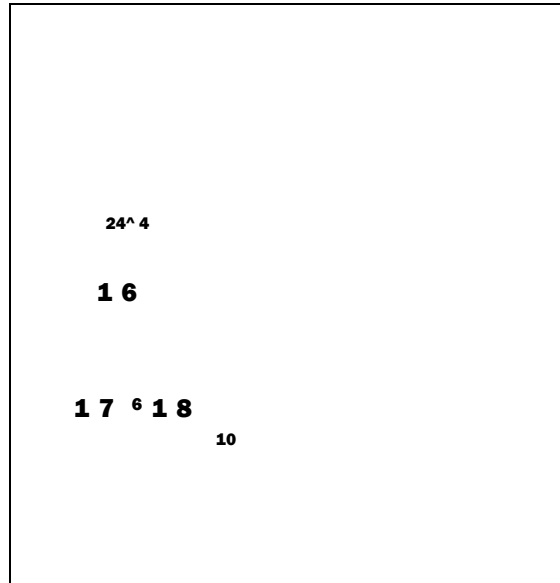


NO ENVIRONMENTAL PARAMETER

SAUNITY SUPERIMPOSED

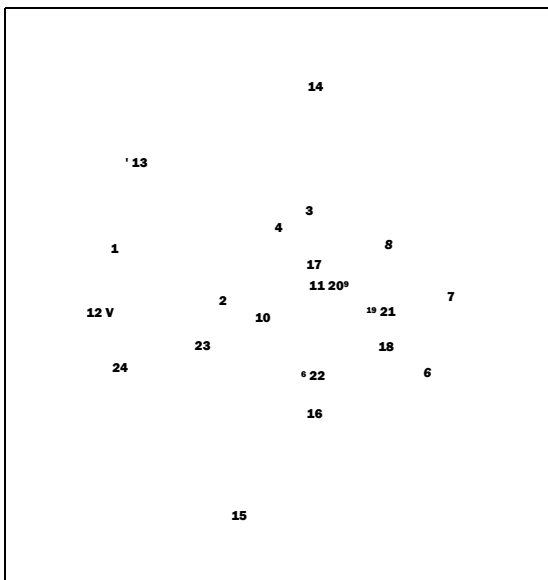


TEMPERATURE SUPERIMPOSED

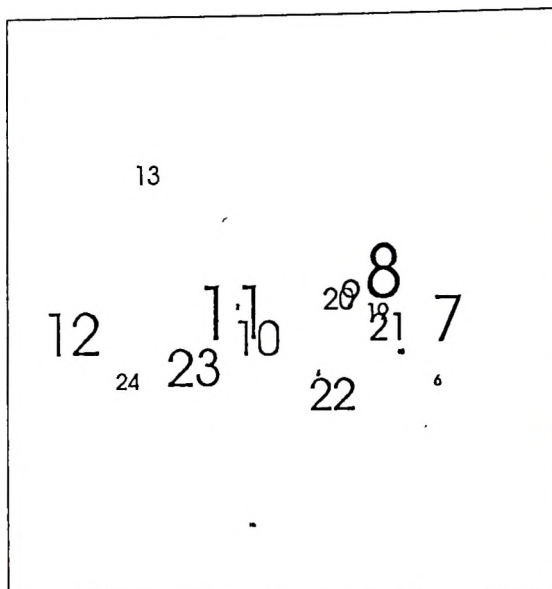


DISSOLVED OXYGEN SUPERIMPOSED

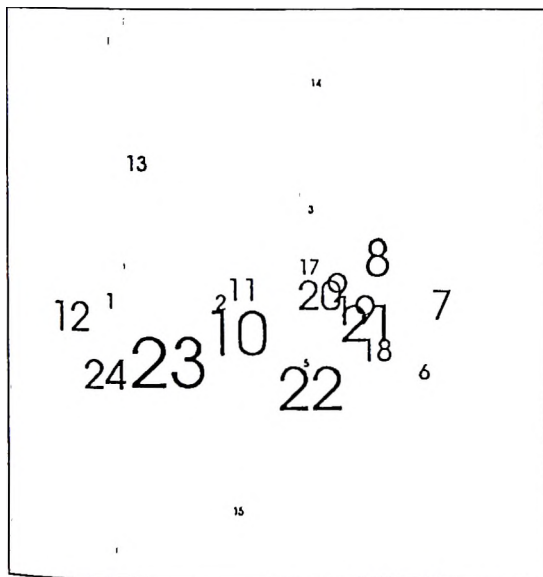
MDS for Station 3 Densu



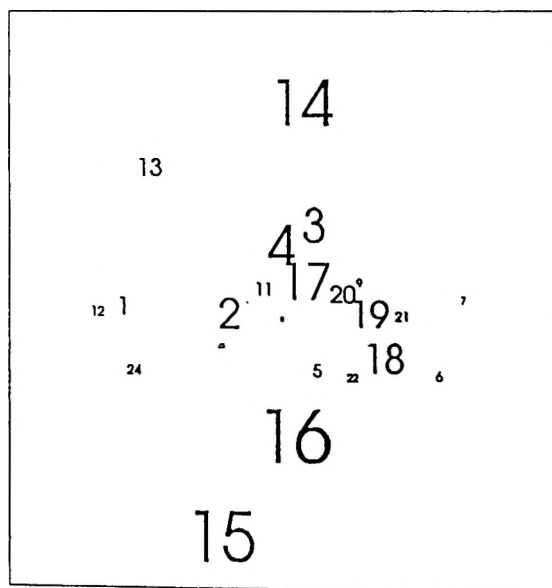
NO ENVIRONMENTAL PARAMETER



SALINITY SUPERIMPOSED



TEMPERATURE SUPERIMPOSED



DISSOLVED OXYGEN SUPERIMPOSED

November to March were generally dry months and May to July were wet months. September and October had minor rains. The bold numbers indicate months in which the particular environmental parameter has a strong effect.

At Abrubi Station 1, (Fig.6.14a), when no environmental parameter was superimposed on the data, the MDS showed wet months (1, 13, 12, 2) and dry months (23, 22, 10, 19, 20), were associated. When salinity was superimposed, months 14, 5 and 6 stood out. The same result was obtained when temperature and oxygen were superimposed. This was because the lagoon was breached to the sea during those months, resulting in an increase in salinity in the riverine portions. This also affected dissolved oxygen levels.

In Abrubi Station 2 there was a clear association of dry months (Fig 6.14b). In Station 3, month 11 (March 1995), stood out when salinity, temperature and dissolved oxygen were superimposed. This was a dry season month and temperatures were high. Months 1, 2 and 4 were rainy season months and they stood out separately from the rest.

The Abrubi lagoon was breached in September 1994 (5) and June 1995 (14). As a result salinities rose in the lagoon in these months. November 1994 (7), December 1994 (8), November 1995 (19), January 1995 (21), were all in the dry season, there were more marine species during this period. In August 1994 (4), the level of the water had gone up and salinities were low, there was a dominance of fresh water species in this period. This is reflected in months 3 and 15, (July 1994 and July 1995),

In the Densu delta (Figs. 6.15a, b, and c) wet and dry season months also stood out, but the pattern was more obvious on Station 1 and 2 than in Station 3. The stress coefficients were higher than in Abrubi lagoon, but were still lower than 0.2, indicating that the data gave a useful 2- dimensional picture.

The MDS when salinity and temperature were superimposed were closely correlated. When dissolved oxygen was superimposed, the MDS for all the two study areas show strong grouping of the fish species to those occurring in the wet and dry months, especially in the Abrubi lagoon. The distinction was less obvious in the Densu delta.

Dissolved oxygen was clearly a factor in Densu Station 2, and Abrubi Station 2 (Figs 6.14b. 6.15b.) The reliability of the scatter plots was indicated by the various stress coefficients, with Abrubi lagoon giving a good ordination with low stress levels (< 0.1). Both clustering and MDS have worked well because the months are strongly grouped into wet and dry seasons.



6.10 Discussion

The influence of water level fluctuations on changes in CPUE was also observed by Blay and Asabere- Ameyaw (1993). They did not find any relationship between CPUE and rainfall, but a negative correlation was observed between rainfall and CPUE in this study. Chindah and Osuampke (1994) observed that higher catches were made in the dry season than in the wet season for most of the gear types employed in the collection of fish assemblages of the Lower Bonny river in the Niger delta. Blaber *et al.* (1990) working on the Emberly Estuary in Australia found that total rainfall and river runoff were significantly correlated to fish distribution.

Variations in the catches between stations and between months were significant in the Abrubi lagoon probably because the lagoon was breached in the rainy season and marine fish came in at that time. There was low water level when the lagoon was breached and fishing intensity was high.

Kapetsky (1984) found that the mean yields from coastal lagoons, continental shelves and sub-tropical reservoirs fell within a narrow range of 41- 51 kg ha yr⁻¹ (Table.6.12.). Higher yields have been obtained from lagoons in Ghana, Togo, Cote d'Ivoire and Benin. Acadja fishing is intensively practised in Benin (Kapetsky, 1981) thus accounting for the high yields obtained there (Table 6.13).

Table 6.11 Fishery Yields From Various Ecosystems. (After Kapetsky 1984)

Systems	Kg ha-1 yr-1		n	Percent exceeding 200 kg ha-1 yr-1	
	Mean	Median		Mean	Median
Coastal lagoons	51	113	107	13	8
Continental shelves	48	59	20	5	Q
Coral Reefs	41	49	15	0	0
River Flood plains	32	40	33	0	0
Reservoirs	13	24	148	0	0
Natural Lakes	5	26	43	2	0
African/ Asian Reservoirs	42	75	41	10	5

Table 6.13 Fishery yields from various lagoons in West Africa

Country	Lagoon	Surface area Hectares (ha)	Fishermen Number	Yield (tonnes)	Source
Cote d'Ivoire	Ebrie	56,600	9.4	151	Lae, 1992a
Cote d'Ivoire	Ebrie	56,600	5.5	61	Ecoutin <i>et al.</i> 1994
Cote d'Ivoire	Abby, Tendo, Ehy complex	42,400	8.4	153	Dominique, 1994
Ghana	Sakumo	100	-	150	Pauly, 1975
Ghana	Sakumo	100		114	Koranteng <i>et al</i> 1997
Ghana	Muni			75	Koranteng, 1995
Ghana	Densu	2000		270	Koranteng, 1995
Ghana	Densu	2000	11	165	This study
Ghana	Abrubi	170	17	124	This study
Togo	Lake Togo	6400	28	150	Lae 1992
Benin	Aheme	850	96.5	7319	FAO 1971
Benin	Port Novo Nokoue	15,700	70.1	12890	CTFT 1969
Nigeria	Lagos, Lekki	96,500	9.5	8203	FAO 1969

The fish fauna of the Abrubi Lagoon and Densu-delta had 19 and 22 species respectively. Pauly (1975) reported 15 species for the Sakumo 2 lagoon. Koranteng (1995) found 13 finfish belonging to 13 genera and 8 families for the Sakumo 2 lagoon, 15 finfish belonging to 14 genera and 9 families for the Densu-delta and 3 finfish belonging to 3 genera and 2 families in the Muni lagoon. In all these lagoons *Sarotherodon melanotheron* was the most dominant species.

Tilapias have certain physiological qualities that make them resilient in changing environments. They show a great tolerance to low oxygen concentration and are able to use the upper water layer with higher oxygen concentration (Holding 1993).

They can resist very high carbon dioxide concentrations, high turbidities and organic pollution (Magid and Babiker, 1975). They are also eurythermal (Welcomme, 1972).

Pauly (1976) observed that in closed lagoons, *Sarotherodon melanotheron* is sometimes the only fish species present. Lae (1994) reported that *Sarotherodon melanotheron* accounted for 50% of the total fish catch from the Togo lagoon. Hem and Avit (1994) found that among the 18 species of fish harvested in Acadja enclosures in lagoons in Benin, *Sarotherodon melanotheron* accounted for 79% of the biomass. Pauly (1976) attributed the strong abundance of *Sarotherodon melanotheron* in the Sakumo lagoon to the fact that it feeds on the fine fraction of mud at the bottom of the lagoon.

Fagade and Olaniyan (1973) reported from studies on fish species in the Lagos lagoon that although the mullets and tilapia species feed in bottom deposits, the mullets feed by

stirring up the bottom and filtering the particles brought by suspension with their gill rakers. The tilapia species mainly pick up food particles from the substratum or from attached surfaces. The above authors however felt that the abundance of *Sarotherodon melanotheron* in the Lagos lagoon system could be because there was no predator capable of utilizing *Sarotherodon melanotheron*.

Sarotherodon melanotheron has a high reproductive capacity and is known to be a protracted breeder spawning 3-4 times a year (Fryer and lies 1972). The protection it gives its eggs from predators gives it an advantage over other cichlids and fishes.

A lot of juvenile *Sarotherodon melanotheron* were caught at Stations 1 and 2 in Abrubi lagoon and at Station 2 in the Densu-delta. This was where 'acadja' fishing was practiced.

The two lagoons had a small proportion of freshwater species (FW), 21% for Abrubi Lagoon and 13.6 % for Densu-delta. The greatest variability appears to be in the proportion of marine species. The Abrubi lagoon had an influx of marine species when the lagoon was breached to the sea. There was a higher proportion of freshwater species in the upper reaches of both study areas (Station 1).

The results of this study show that freshwater species, (*Hemichromis fassdatus*, *Clarias anguillaris*, *Heterobranchus bidorsalis*, *Hemichromis bimaculatus*) tend to move down into the middle and lower reaches in the wet season and back up river in the dry season.

Clarias anguillaris, *Heterobranchus bidorsalis* could also inhabit dense vegetation and areas with periodic low dissolved oxygen.

The rapid increase of salinity after the rainy season in the Densu delta was followed by the disappearance of purely freshwater fish especially in Station 3. There was an increase in marine fish mainly represented by juvenile stages. The high fish species number in the Densu-delta (Station 3) could be attributed to the spawning, feeding and migration of marine species. Juveniles of *Lutjanus fulgens*, *Ethmalosa fimbriata*, *Gerres melanopterus*, *Elops lacerta*, *Mugil cephalus*, *Liza falcipinnis* and *Caranx hippos* enter the lagoons to feed and shelter while their gonads start to mature.

Warburton (1978) suggested that the gobiid species present in lagoons may have an affinity with the Mugilidae and Soleidae and that gobids feed on the rich organic detritus at the bottom of the lagoon. The gobids were mainly present at Station 2 in the Densu delta, which was very muddy.

A lot of marine larval fishes were observed in the dry season in this study. Pauly (1975) in Sakumo lagoon, Ghana, Fagade and Olaniyan (1973) in Lagos Lagoon, Nigeria, Koranteng *et al.* (1997) in Sakumo lagoon, Ghana and Elliot *et al.* (1990) in Forth Estuary, Scotland have all pointed out the importance of coastal lagoons and estuaries as nursery area for juvenile marine fish.

Juvenile forms of some freshwater fishes, *Hemichromis fassdatus* and *Sarotherodon galilaeus*, from the Weija reservoir which could reach the estuary are heavily exploited by fishers operating below the dam. Removal of these juveniles could affect the recruitment into the Densu delta. Abruhi lagoon was closed for most of the year but when the lagoon was breached to the sea in September 1994 and July 1995 the numbers of marine fish species increased.

The ichthyofauna of coastal lagoons throughout the world is characterized by the numerical dominance of a few species (Kennish, 1990). The relatively low taxonomic diversity that occurs in lagoons and estuaries could arise from physiological difficulties in dealing with the unpredictable stresses from the environment. (Constanza *et al.*, 1993).

There are also problems with the salinity gradients existing there which affect the mobility of the organisms. Most of the few endemic species in lagoons and estuaries originate from freshwater or marine environments and many marine organisms require estuarine environments for a portion of their life cycles. The diversity of fish species within an area is partly a function of the number of available niches and partly area size (Wootton, 1990). Thus it is not unexpected that the Densu-delta which has a larger area had a greater species richness.

Varying species tolerance and preference for different salinity levels could be another reason for differences in species richness, diversity evenness and biomass in the two study areas.

Many studies have shown that the distribution and abundance of fish in lagoons and estuaries is smaller than the number of species within the sea or freshwater environment (Mclusky, 1981).

The changes in the fish community structure of the Densu-delta and Abrubi Lagoon may be in response to abiotic as well as biotic environmental factors. The abiotic factors may be the salinity gradient and low oxygen seasonally along the lagoon and delta. Salinity fluctuations appear to be a major factor governing the diversity and abundance of fish in estuaries. Yannez-Aranciba (1978) working in Mexican estuarine lagoons recorded major declines in fish species diversity, densities and biomass when salinities rose above 34‰ or declined below 15‰.

Similarly, Wallace (1975) showed that species diversity and abundance in the estuarine lake St. Lucia in South Africa declined during hypersaline periods. Thiel *et al.* (1995) observed that in the Elbe estuary in Germany as salinity decreased upstream, species number, species diversity, evenness and frequency of occurrence of marine fish species all decreased. Freshwater fishes are less tolerant of increases in salinity whereas marine species are able to cope with great reductions in salinity (Remane, 1971).

Amadi (1990) reasoned that if salinity is established as a major parameter limiting the spatial distribution of fishes, then the occurrence of fishes can be correlated to rainfall and therefore to the two seasons (wet and dry) in West African waters and estuaries.

Amadi's observation of the catch and effort in the Lagos lagoon was that more fish was landed in the dry season than wet season. Results from this study support this observation as CPUE was negatively correlated to rainfall.

Blaber and Blaber (1980) working on juvenile fish distribution and turbidity in Moreton Bay, Queensland, Australia, showed that although salinity may influence fish distribution in estuaries, turbidity is significant in relation to different distribution patterns. Later Cyrus and Blaber (1992) observed that salinity and turbidity also influenced food distribution in estuaries. The relationship between fish abundance and turbidity was not studied in the Abrubi lagoon and Densu delta.

Chemical and organic pollution can also cause changes in fish populations. Studies by Biney *et al.* (1994) have referred to organic and heavy metal pollution as some important factors for the reduction of fish species in African waters.

The lowering of salinity levels from the lower reaches to the upper reaches in both study areas resulted in reduced numbers and biomass of marine species and the increase in the numbers of euryhaline and fresh water species. In this study species richness was higher in Station 3 in both study areas.

It was clearly observed that most of the freshwater species were found at Station 1 in both study areas. The determining salinity was 10-15‰. Very few marine species were found below 10‰.

The ability of fish to move in and out of the lagoon is important to provide them a means of escape from adverse environmental conditions either in the sea or the river, low concentrations, of dissolved oxygen or siltation. As lagoon environments become more hostile due to pollution and habitat degradation, the lagoon fish community will be reduced in diversity and dominated by more tolerant species (Whitfield, 1994).

There was higher fish numbers in the Densu delta but lower biomass than in the Abrubi lagoon. *Sarotherodon melanotheron* caught in the Densu-delta were smaller in size than those caught in the Abrubi Lagoon. This could be due to the higher fishing pressure of the fish in the Densu-delta than the Abrubi Lagoon. Both lagoons were fished throughout their expanse as they were relatively shallow and therefore easily exploitable with the cast net. There were more fishermen in the Densu-delta than Abrubi Lagoon.

The F/C ratio was determined as 2.71 for Abrubi Lagoon and 1.52 for Densu-delta. Both values fall within the range of 1.4-10 observed for balanced populations (Swingle, 1950). This implies that both the Abrubi Lagoon and Densu-delta had balanced fish populations.

There could have been predation on the other fishes by *Clarias anguillaris*, *Hemichromis fassdatus*, *Elops lacerta*, *Epinephelus aenus* and *Caranx hippos*. This may not have been on a large scale as *Sarotherodon melanotheron* had a high E value of 60% in Abrubi Lagoon and 66% in the Densu-delta.

This suggests that the fish has the ability to maintain a high abundance under the prevailing conditions in the lagoon. Blay (1985) observed that *Sarotherodon galilaeus* also had this ability in the Dawhenya reservoir near Accra.

The MDS obtained for the six sites in the two study areas indicate that temperature, salinity and oxygen were strong environmental factors determining the presence of fish species. This can be observed from the MDS plots. The influence of temperature may be due to the dry season when temperatures were higher. Levels of species diversity and evenness were highest immediately after the wet season; this could be due to the seasonal migration of non residents. Some of the clusters put years into groups, implying that there could be different environmental factors pertaining in 1994, 1995 and early 1996.

The low stress value obtained for Abrubi lagoon (0.01 Station 1) and (0.11 Station 2 and Station 3) gives confidence that the 2-dimension plot is an accurate representation of the seasonal grouping of the fish species. In the Densu-delta the stress values were bigger because of the nature of the water body. There was difficulty in indicating the relationship between the species numbers and the months in which they occur. The delta is open to the sea all the time. All the same the stress levels, (0.15-0.18) gives a good ordination.

CHAPTER 7

7.0 BIOLOGY AND POPULATION DYNAMICS OF *SAROTHERODON*

MELANOTHERON.

7.1 Introduction

The current approach to fisheries management is largely based on the utilization of global models (Schaefer, 1957), analytical models (Beverton and Holt, 1957) and recruitment models (Beverton and Holt, 1957, Ricker, 1954) which require experimental data sets comprising total catches. It is difficult to use many of the basic methods applicable to ‘temperate fishes’ to tropical fishes. This is because the methods for ageing individual fish are based predominantly on ‘annuli’ on scales, otoliths and other bony structures of

Early methods of analysing length frequency data into the component groups which represent separate age classes were graphical. Graphical methods have been superseded by computer programs which search for the parameters that are the best description of the length frequency distribution (King, 1995). Programs include ELEFAN (Gayanilo *et al.*, 1989), MIX (McDonald and Green, 1985) and MULTIFAN (Fournier *et al.*, 1990). The Bhattacharya method has been incorporated into these computer programs, and the ELEFAN (Electronic Length Frequency Programme) program has also been incorporated into a new suite of fisheries tools called FISAT (FAO/ ICLARM Stock Assessment) software.

A knowledge of the biology of a species is necessary for an adequate understanding of its life history in relation to the problems of conservation. In this chapter, data on some biological studies on *S.melanotheron* are provided and discussed. The ELEFAN and FISAT programs were chosen for the estimation of growth, mortality and recruitment patterns.

7.2. Biological studies

7.2.1 Sex ratio

Tables 7.1a and 7.1b show the monthly sex ratios of *Sarotherodon melanotheron* in the Abrubi lagoon and Densu-delta respectively from May 1994 to April 1996. Overall 2904 (39.8%) out of 7294 specimens sexed were males in Abrubi lagoon and 4390 (60.2%) were females. The pooled samples for the different months for Abrubi lagoon showed a significant departure from a 1:1 ratio ($\chi^2 = 142.55$, $P < 0.05$), the observed ratio being 1:1.51. The sex ratio was approximately 1:2 in favour of females in most months of the study period, except in December 1995 when it was 1:1 and September 1994, June 1995 and July 1995 when it was in favour of males.

In the Densu delta 2934 (42.8%) out of 6855 sexed were males and 3921 (57.2%) were females, a pooled ratio of 1:1.34 was obtained. This was also significant ($\chi^2 = 92.81$, $P < 0.05$), suggesting that the sexes were biased in favour of females except in June 1994, June 1995 and July 1995 when it was in favour of males. In both study areas there was monthly variation of the male: female ratio.

Table 7.1a Monthly sex ratio of *S.melanotheron* in Abrubi lagoon May 1994-April 1996 j

Month N	Unsexed M	F	M:F	P = 0.5	X =J.	
May-94	238	4	90	144 1:1.6	*	4.34
Jun	262	14	120	128 1:1.06		0.07
Jul	299	2	125	172 1:1.37		2.94
Aug	331	2	140	188 1:1.34		2.69
Sep	367	3	188	168 1:0.89		1.43
Oct	389	2	113	272 1:2.40	*	22.08
Nov	300	6	124	170 1:1.37		2.35
Dec	292	12	92	188 1:2.04	*	9.36
Jan-95	316	8	120	188 1:1.56	*	4.79
Feb	377	20	114	243 1:2.13	*	12.22
Mar	422	18	144	260 1:1.80	*	9.23
Apr	332	16	110	206 1:1.87		7.77
May	327	10	132	184 1:1.39		2.28
Jun	275	3	160	112 1:0.7	*	5.81
Jul	270	1	162	107 1:0.66	*	7.33
Aug	260	14	93	153 1:1.64		3.46
Sep	292	12	105	175 1:1.66	*	4.81
Oct	360	10	140	207 1:1.5		3.52
Nov	333	12	115	206 1:1.79	*	7.57
Dec	280	28	120	132 1:1		0.48
Jan-96	311	17	88	206 1:2.34	*	12.38
Feb	319	8	130	161 1:1.23	*	0.01
Mar	338	24	100	204 1:2.04	*	6
Apr	341	9	79	216 1:2.73	*	9.58
			2904	4390 1:1.51		142.55*

Table 7.1b Monthly sex ratio of *S.melanotheron* in Densu delta May 1994- April 1996 9

Month N	Unsexed M	F	M:F	P=0.05	X =3	
May-94	110	28	30	52 1:1.73		0.17
Jun	263	14	133	116 1:0.87		2.07
Jul	325	20	174	131 1:0.75	*	7.57
Aug	259	14	95	160 1:1.57		2.8
Sep	307	20	107	180 1:1.68	*	3.9
Oct	414	12	161	241 1:1.49	*	4.8
Nov	330	14	143	173 1:1.20		0.37
Dec	337	15	113	209 1:1.84	*	7.85
Jan-95	309	18	120	171 1:1.43		1.59
Feb	330	20	114	194 1:1.7	*	4.34
Mar	344	16	103	228 1:2.21	*	13.75
Apr	278	15	94	169 1:1.79	*	5.33
May	246	14	106	126 1:1.18		0.07
Jun	278	8	152	118 1:0.77		3.74
Jul	324	9	213	152 1:0.71		0.66
Aug	301	3	130	168 1:1.29		1.82
Sep	272	4	86	182 1:2.11	*	11.63
Oct	316	14	101	201 1:1.99	*	9.2
Nov	309	6	143	160 1:1.11		0.19
Dec	292	7	142	143 1:1		0.06
Jan-96	265	8	123	134 1:1.08		0.02
Feb	354	17	120	217 1:1.8	*	7.37
Mar	293	14	108	171 1:1.58		3.51
Apr	269	11	123	135 1:1.09		0
			2934	3921 1:1.34		92.81*
			2904	3869 1:1.34		

* significant at 5%

7.2.2 Gonadosomatic Index (GSI)

Female GSI values were used from the two study areas as it was difficult to separate maturity stages in males. Figure 7.1a and 7.1b illustrate the changes in GSI values with rainfall during the study period. The monthly mean GSI values ranged between 3.70 (December, 1994) and 9.09 (July 1995) with an average value of 6.34 in Abrubi lagoon and 3.63 (April 1995) and 9.56 (September 1995) with an average of 5.88 in the Densu-delta. These values correspond with increasing monthly rainfall. There were low GSI values from November 1994 to February 1995 at Abrubi lagoon and October 1995 in the Densu delta. The GSI values were not significantly different between the two study areas ($t = 0.96 < P 0.05$).

Assuming that females with stage 3 or above had gonads which were mature (Tables 7.2a and b), it was observed that these were never less than 5.25 cm SL for Abrubi lagoon and 3.25 cm SL for the Densu-delta. Immature ones never exceeded 7.75 cm SL in Densu delta and 9.75 cm SL in the Abrubi lagoon. Some of the adult male and females were found carrying eggs or fry in their mouths and occasionally in some female stomachs.

7.2.3 Seasonal Changes in Gonadal Stages

Gonadal maturity stages for females were described for *S. melanotheron* following that of Laevastu, 1965. Stage 1 females, with very small ovaries and eggs invisible to the naked eye occurred throughout the study period in both lagoons. In Abrubi lagoon none were found after the fish had attained a length of 9.75 cm SL (Table 7.2a). In the Densu delta no Stage 1 female was found after the fish had attained 7.75 cm SL (Table 7.2b).

Fig.7.1a Changes in monthly GSI, K, with Rainfall, Abrubal lagoon, May1994-April 1996

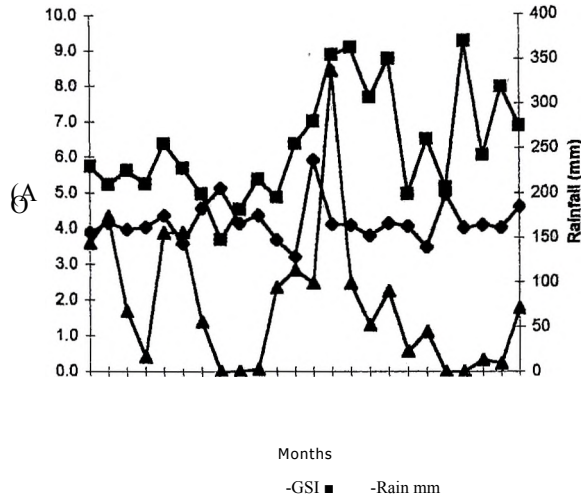


Fig.7.1b. Changes in monthly GSI, K, with Rainfall Densu- delta, May 1996-April 1996

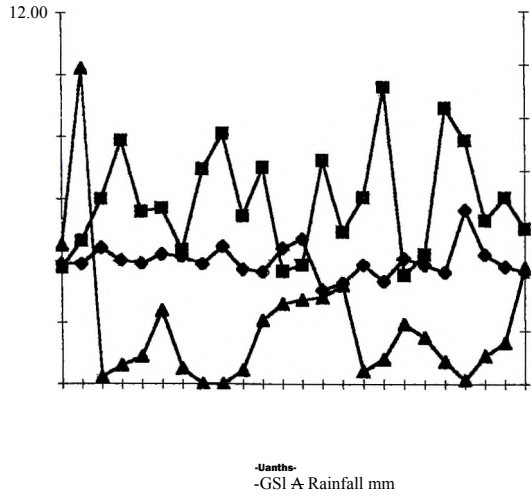


Table 7.2 a Proportion of mature female *S. melanotheron* caught from Abrubi lagoon May 1994 - April 1996

Abrubi							
.cm	N	F	Stage 1	Stage 2	Stage 3	Stage 4	% Mature
4.25	31	28	9	9	0	0	0
4.75	89	52	8	27	0	0	0
5.25	215	110	44	45	8	16	12.7
5.75	363	213	53	84	43	23	35.6
6.25	540	386	88	122	116	70	48.1
6.75	674	421	91	101	128	100	54.1
7.25	774	543	80	110	203	150	65
7.75	772	515	44	90	270	111	74
8.25	786	519	34	80	205	100	78
8.75	846	621	26	72	300	223	84.2
9.25	863	604	12	60	232	300	88
9.75	595	396	0	0	218	170	98.3
10.25	497	314	0	0	154	160	100
10.75	261	113	0	0	53	60	100
11.25	122	80	0	0	46	34	100
11.75	50	21	0	0	13	8	100
12.25	31	18	0	0	9	9	100
12.75	15	6	0	0	3	4	100
13.25	4	2	0	0	2	0	100
	7528	4962					2566males

Table 7.2 b Proportion of mature female *S. melanotheron* caught from Densu delta May 1994 - April 1996

cm	N	F	Stage1	Stage 2	Stage 3	Stage4	% Mature
2.25	4	2	2	0	0	0	0
2.75	29	18	18	0	0	0	0
3.25	133	70	38	21	9	2	15.7
3.75	305	188	29	44	34	21	38
4.25	675	420	90	110	115	105	52.3
4.75	909	589	106	144	221	118	57.8
5.25	1243	831	113	178	385	155	65
5.75	1067	724	92	140	292	200	68
6.25	977	513	31	122	187	173	70.1
6.75	711	486	19	50	192	225	85.8
7.25	462	273	11	27	113	122	86
7.75	337	193	0	0	105	88	100
8.25	184	96	0	0	42	54	100
8.75	98	62	0	0	27	35	100
9.25	51	38	0	0	17	21	100
9.75	31	21	0	0	11	10	100
10.25	15	8	0	0	4	4	100
10.75	3	1	0	0	1	0	100
	7234	4533					2701males

Generally, proportions of Stage 2 were low in both study areas. There was dominance of Stage 3 and 4 females in both lagoons. Hardly any Stage 5 females were observed. It was difficult to identify 5 male reproductive stages in males, because of the small sizes of the male sex cells and the difficulty in distinguishing maturity stages. It was however, possible to distinguish ripe Stage 3 and 4 males from the rest. There were 2 strands of testes appearing with milt

7.2.4 Condition factor (K)

Figures 7.1a and 7.1b also illustrate the changes in Condition Factor of female *S.melanotheron* in Abrubi lagoon and Densu delta from May 1994 to April 1996. The condition (K) of *S.melanotheron* ranged between 3.22 to 5.93 with a mean value of 4.2 in the Abrubi lagoon and 3.03 to 5.59 with a mean value of 4.08 in the Densu -delta. The Condition Factor was not significantly different between the two study areas, ($t = 1.24$, $p < 0.05$)

7.3 Population Dynamics

7.3.1 Length-Frequency Distribution

From the catch of cast nets, 7631 specimens of *S.melanotheron* were measured from Abrubi Lagoon and 7125 from the Densu-delta. Figures 7.2a and 7.2b show the length frequency distribution of *Sarotherodon melanotheron* from the Abrubi lagoon and Densu-delta from May 1994 to April 1996. The modes of lengths were measured each month and are presented in Table 7.3a and 7.3b. No samples of *S.melanotheron* were obtained from other gears in the Densu-delta, only samples from cast nets were used.

Fig. 7.2a Length Fequency Distribution of *S.melanotheron* from Abrubl Lagoon, May 1994-April 1996.

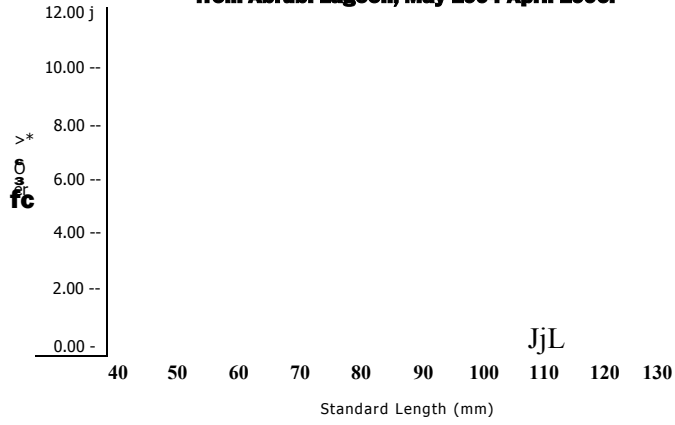


Fig. 7.2b Length Frequency Distribution of *S.melanotheron* from Densu Delta, May 1994-April 1996

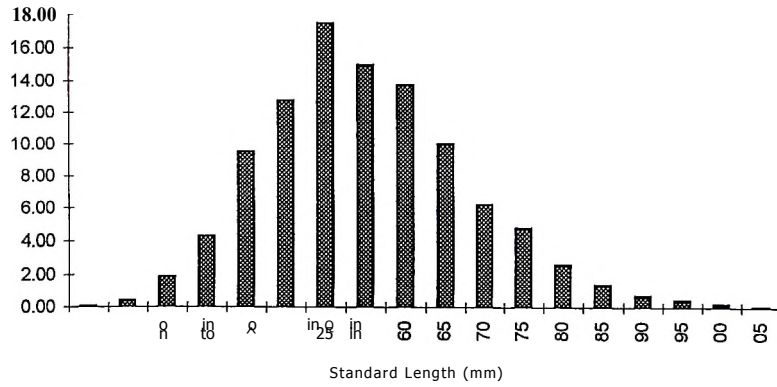


Table 7.3a

Modal lengths mm (SL) of *S.melanotheron* caught in the experimental fishing with castnets, Abrubi lagoon, May 1994- April 1996

Month	ST.1	ST.2	ST.3	Av	N
May-94	100	55	85	80	238
Jun	80	60	80	70	262
Jul	100	80	70	80	299
Aug	100	65	80	80	331
Sep	100	70	85	85	361
Oct	100	90	95	95	387
Nov	80	75	75	75	300
Dec	90	65	85	80	292
Jan-95	100	85	90	90	316
Feb	90	80	90	85	377
Mar	85	75	95	85	422
Apr	90	75	85	80	332
May	75	75	90	80	327
Jun	80	65	80	75	275
Jul	90	75	80	75	270
Aug	90	80	85	85	260
Sep	85	80	85	80	292
Oct	75	55	90	70	360
Nov	90	65	70	75	333
Dec	90	65	80	75	280
Jan-96	100	70	85	85	311
Feb	90	70	80	80	319
Mar	75	75	65	70	338
Apr	80	55	100	80	341
					7623

Table 7.3b

Modal lengths mm (SL) of *S.melanotheron* caught in the experimental fishing with castnets, Densu delta, May 1994- April 1996

Month	ST.1	ST.2	ST.3	All	N
May-94	50	0	40	45	110
Jun	50	60	70	60	263
Jul	45	60	5	50	325
Aug	55	60	60	60	259
Sep	55	35	60	50	307
Oct	50	60	65	60	414
Nov	50	45	70	55	330
Dec	50	50	70	55	337
Jan-95	55	55	65	60	309
Feb	50	55	60	55	330
Mar	50	55	50	50	344
Apr	55	60	50	55	278
May	50	55	55	55	246
Jun	40	55	60	50	278
Jul	45	55	55	50	324
Aug	45	55	60	50	301
Sep	40	55	55	50	272
Oct	55	60	50	55	316
Nov	55	50	50	50	309
Dec	60	50	50	50	292
Jan-96	50	50	60	50	265
Feb	70	45	55	55	354
Mar	65	45	55	55	293
Apr	60	50	45	50	269
					7125

Samples of *S.melanotheron* from experimental fishing ranged from 4.5 cm (45 mm) SL to 14 cm SL, in the Abrubi lagoon and 2.8 cm (28 mm) to 11 cm SL (110 mm) SL in the Densu-delta. The over all length-frequency distribution showed a modal length of 8.5 - 9.0 cm SL in Abrubi lagoon and 5.0 -5.5 cm SL in Densu delta. (Appendix 7.1)

7.3.2 Length at First Maturity (Lm)

The length at which 50% of females become mature (Lm) was found analytically after Ni and Sandeman (1984) and Koranteng (1993) as 7.14 cm SL in the Abrubi lagoon and 4.8 cm SL in the Densu-delta.. Considering the observed maximum length (Lmax) to be 14 cm SL for Abrubi lagoon and 11 cm SL for the Densu-delta, the ratio of Lm/Lmax was computed as 0.51 for Abrubi lagoon and 0.44 for Densu-delta. This suggests that the fish would have at least obtained 50 % of its maximum observed length by the time it first becomes mature for Abrubi lagoon and 44 % in the Densu delta (Appendix 7.2)

7.3.3 Length-Weight Relationship

Figures 7.3 and 7.4 show the length-weight relationship of *S.melanotheron* in the Densu-delta and Abrubi lagoon. The length-weight relationship of *Sarotherodon melanotheron* is described by the equation:

$$W = 0.061 \times SL^{2.61} \quad r = 0.98 \text{ (Densu-delta)}$$

$$W = 0.085 \times SL^{2.70} \quad r = 0.97 \text{ (Abrubi Lagoon)}$$

These values of the length-weight of *Sarotherodon melanotheron* compare favourably with that from 8 other lagoons in Ghana as shown in Table 7.4 .

Fig. 7.3

ABRUBI LAGOON. _

-Length/ WeightRelationship of
Abrubi

Sarotherodon melanatheron
Lagoon May 1994 - April 1996

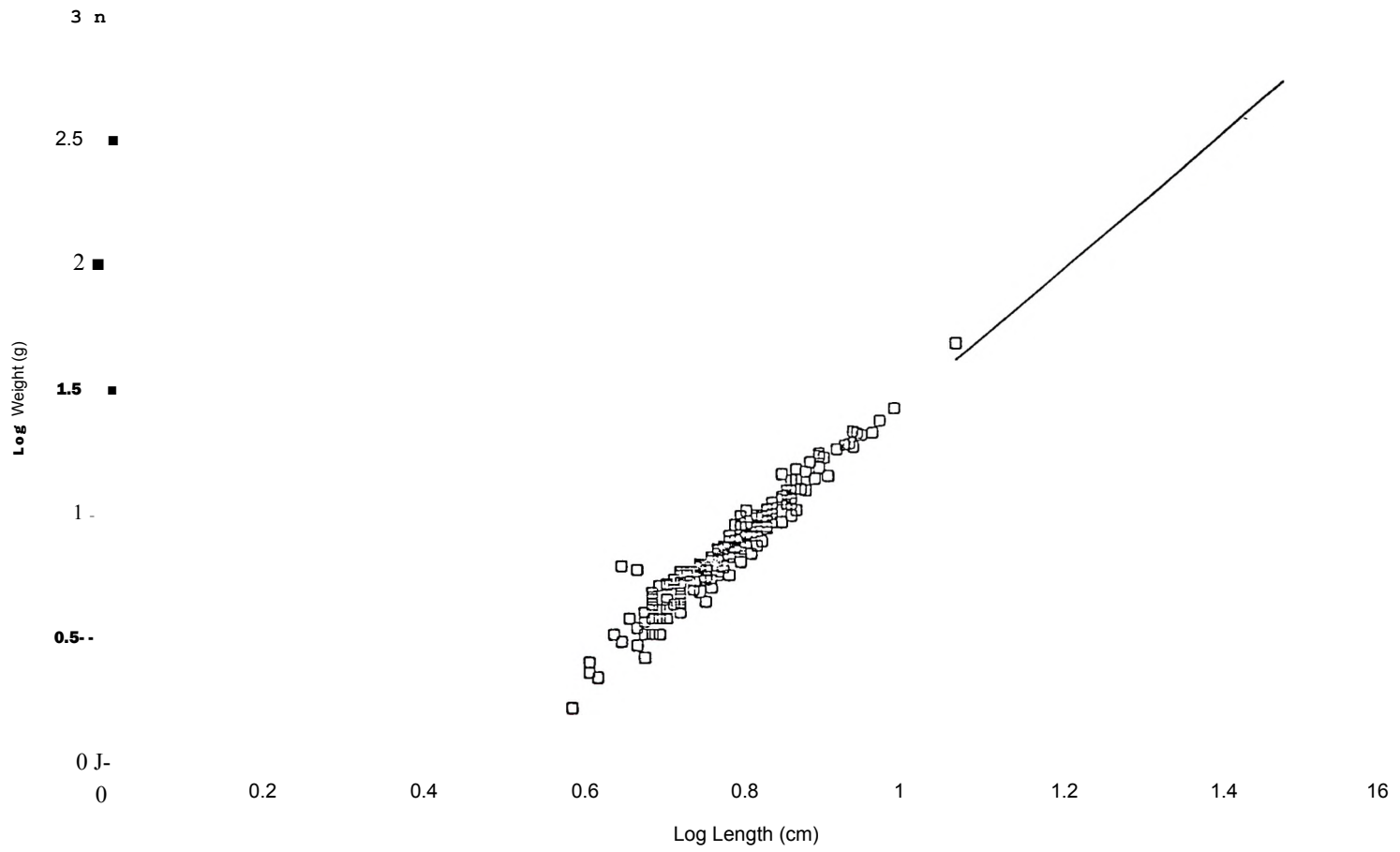
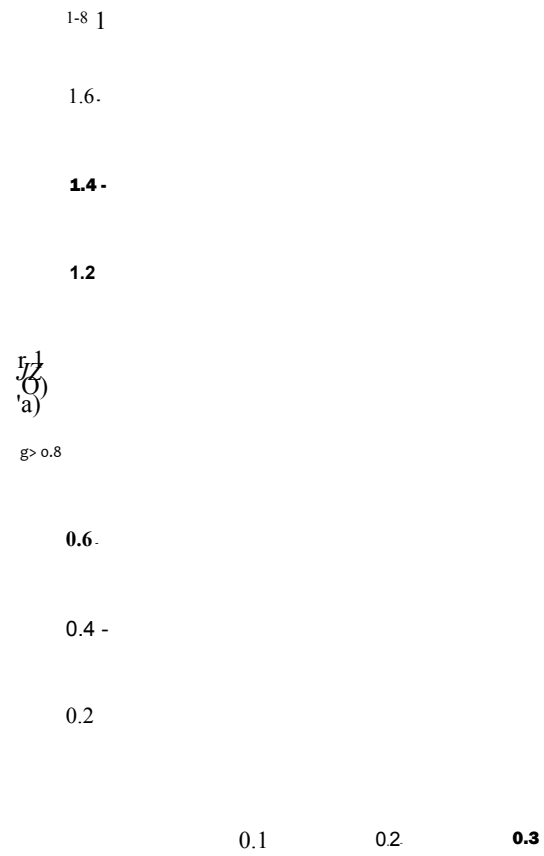


Fig. 7.4.

DENSU delta



Length / Weight Relationship of Sarotherodon melanotheron

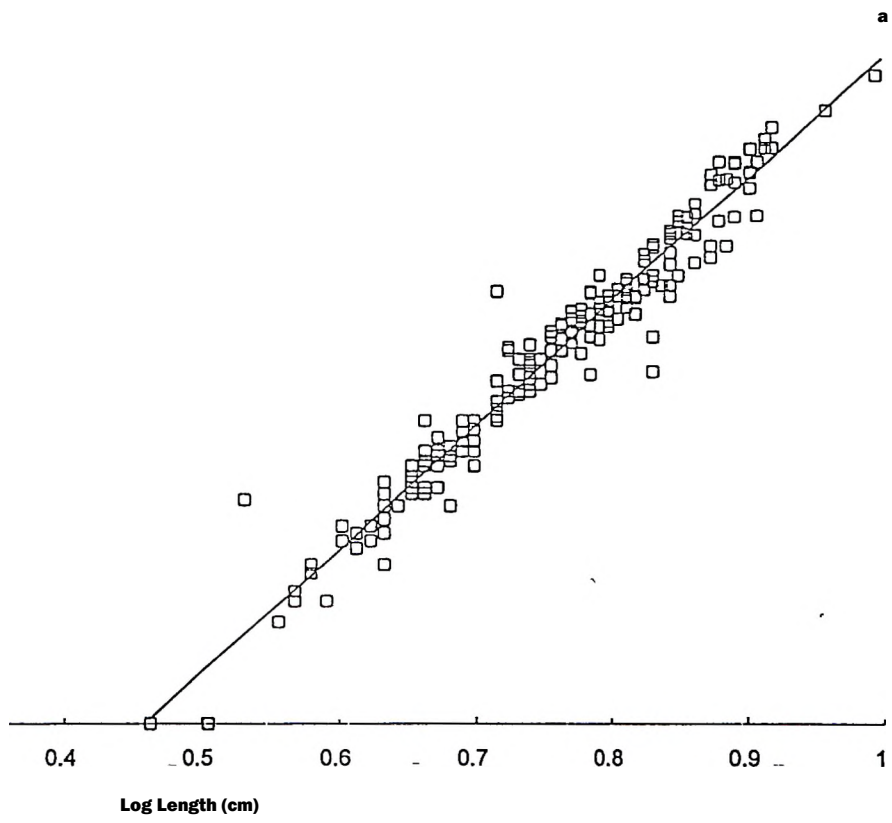


Table 7.4 Length-Weight Relationships from other lagoons in Ghana.

Lagoon	a	b	N	Min length Max length(cm)
Aglor 'F	0.673	2.85 r = 0.96	50	Min 13.9 Max 19
KetaT	0.0374	2.94 r = 0.87	100	Min 3.2 Max 5
Benya 'P	0.034	2.99 r = 0.98	100	Min 3.1 Max 10.6
Fosu T	0.004	2.94 r = 0.93	100	Min 3 Max 8
Densu delta 4*	0.061	2.61 r = 0.98	400	Min 2.8 Max 11
Abrubi 'F	0.085	2.70 r = 0.97	400	Min 4.5 Max 14
Fosu *	0.040	2.65 r = 0.97	500	
Densu t	0.054	2.77 r = 0.98	200	Min 2.9 Max 10
Muni	0.061	2.61 r = 0.98	200	Min 2.9 Max 8.6
Sakumo t	0.62	2.63 r = 0.96	200	Min 3 Max 11.6

t Koranteng (1995)

* Blay and Asabere-Ameyaw (1993)

'F This study

The exponent value did not differ significantly from 3 in the two study areas indicating isometric growth. Substituting L_{∞} in this equation shows that the fish has an asymptotic weight, W_{∞} of 125g for the Abrubi Lagoon and 44.2g for the Densu-delta.

7.3.4 Growth Parameters

Figures 7.5a and 7.5b show the monthly length frequency experimental data distribution of *S.melanotheron* fitted with growth curves obtained from ELEFAN 1 in the two study areas. From the length frequency data, growth parameters L_{∞} , K and t_0 for the fish from the two lagoons are given in Table 7.5. From these values, the growth performance index Φ' was calculated as 2.28 for Abrubi lagoon and 2.05 for the Densu-delta.

The desired growth parameter estimates of the *Sarotherodon melanotheron* obtained from the ELEFAN program are shown in Table 7.5

Table 7.5 Estimates of von Bertalanffy Growth Parameters for *S.melanotheron* caught from Abrubi Lagoon and Densu delta, (May 1994-April 1996) with Corresponding Growth Performance Indices Φ' and Theoretic Maximum Weight

Parameter	Abrubi Lagoon	Densu-delta
L_{∞} (cm SL)	15, (18 cm TL)	12, (14.3 cm TL)
K (yr ⁻¹)	0.79	0.67
t_0 (yr)	-0.015	-0.02
W_{∞} (g)	125	45.6
Φ'	2.28	2.05

From this table, L_{∞} was taken as 12. cm SL (14.3cm TL) for Densu-delta and K as 0.67yr⁻¹ For the Abrubi lagoon, L_{∞} was 15 cm SL (18cm TL) and K was 0.79 yr⁻¹

A comparison of the growth parameter of *S. melanotheron* from other lagoons is shown in Table7.6

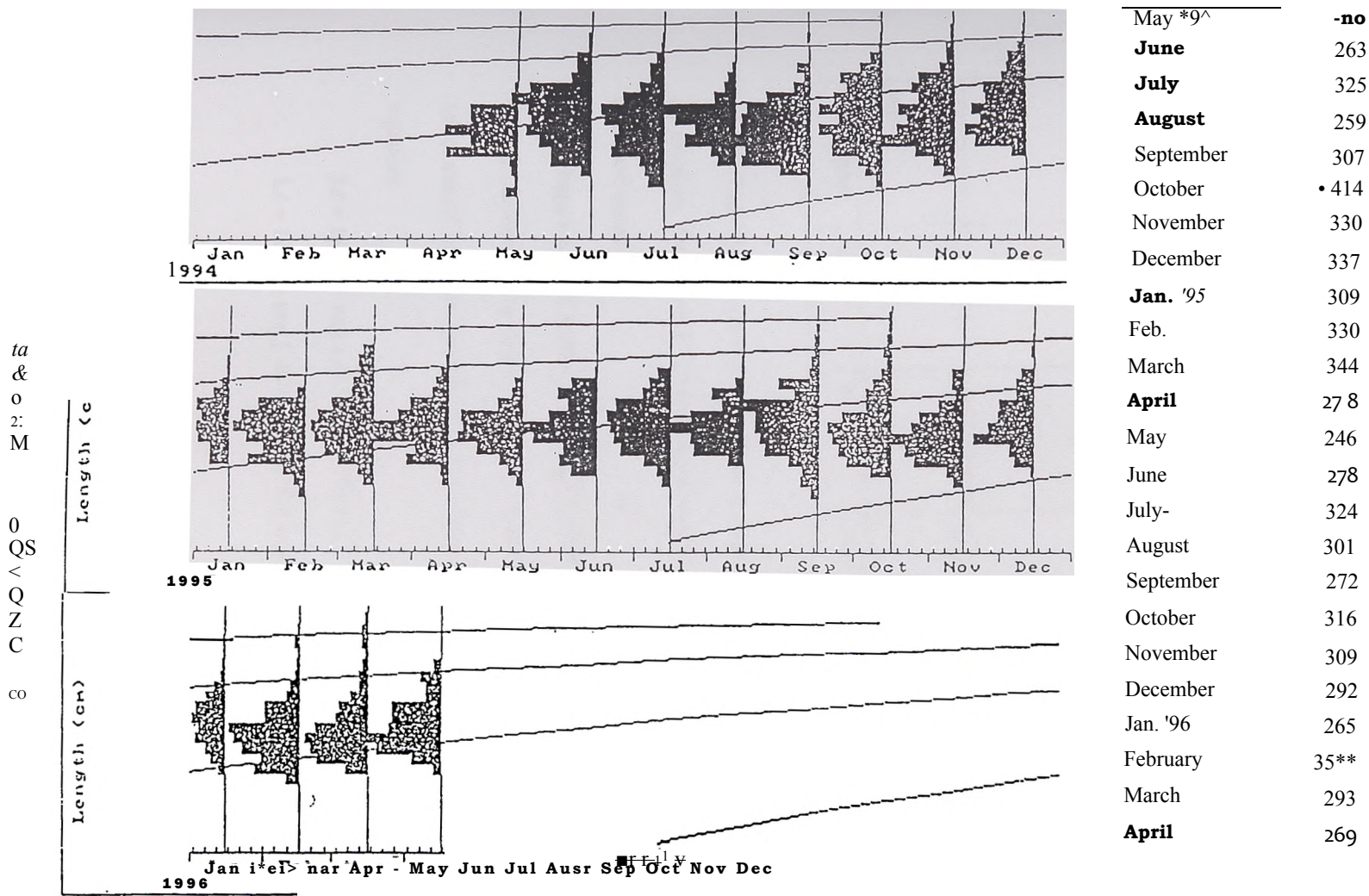


Fig. 7.5b MontWyicngmfrequency date of £ melanotheron fitted with growth curves Densu Delta

Table 7.6 Comparison of growth parameters of *S.melanotheron* from other lagoons

Parameter	L _∞ (TL)	κ ⁽ⁱ⁾ j	t ₀ (yr)	Author	Year
Fosu lagoon	16.1	0.82	-0.23	Blay and Asabere-Ameyaw (1993)	1993
Sakumo lagoon	14.4	0.75	-0.016	Koranteng <i>et al.</i> , (1997)	1997
Togo lagoon	32.6	0.44	-0.21	Lae	1996

Figures.7.6a and b show the resultant growth curves fitted to the length-frequency distributions for the study period (using values from table 7.7). Using Pauly's (1983) empirical equation,

$$\log_{10}(-t_0) = -0.3922 - 0.2752 \log_{10} L_{\infty} - 1.038 \log_{10} K,$$

t₀ was calculated to be -0.02yr for Densu-delta and -0.015yr for the Abrubi lagoon. Thus on an annual basis, the growth of the population can be described by the von Bertalanffy equation:

$$L_t = 15 \{1 - \exp[-0.79(t + 0.015)]\} \text{ Abrubi Lagoon}$$

$$L_t = 12 \{1 - \exp[-0.67(t + 0.02)]\} \text{ Densu-delta}$$

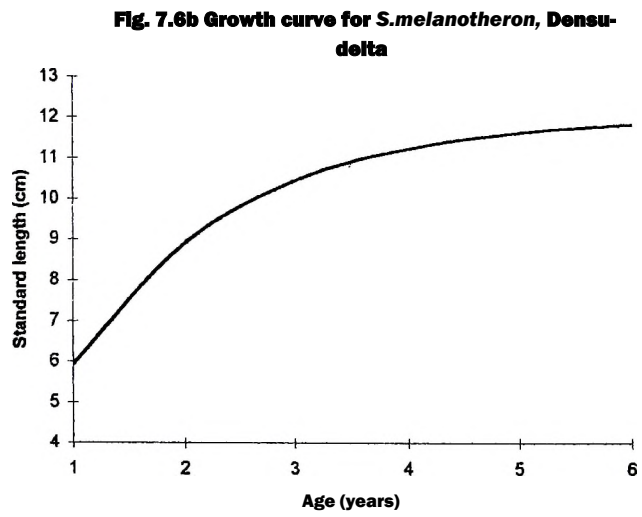
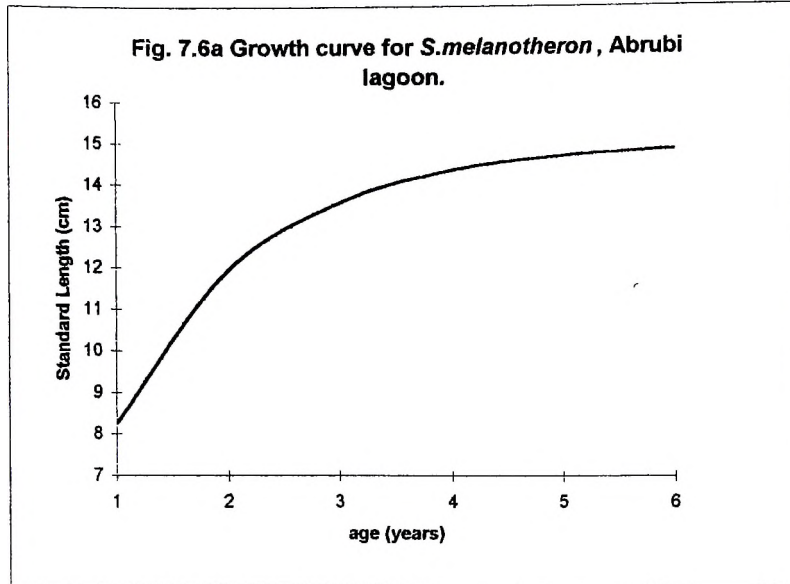


Table 7.7b Length at age t using the von Bertalanffy equation

Age	Lt Abrubi lagoon	Lt Densu delta
1	8.26	5.94
2	11.25	8.9
3	13.57	10.42
4	14.33	11.20
5	14.71	11.59
6	14.88	11.79

The longevity, (t_{\max}) of the fish estimated from the equation:

$$t_{\max} = 3/k \text{ (Pauly, 1983)}$$

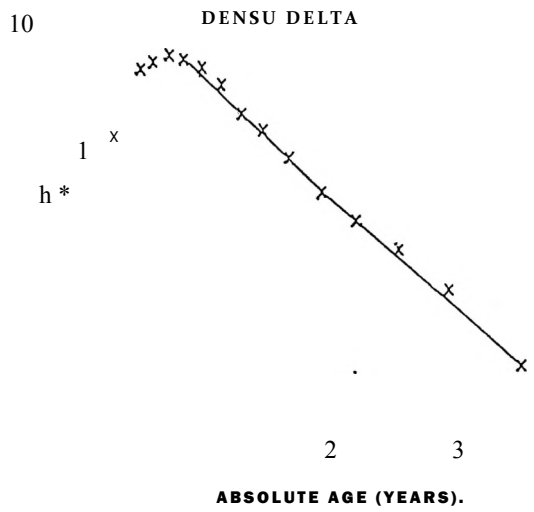
is 4.47 years for the Densu-delta and 3.79 years for the Abrubi lagoon. Both approximate 4 years showing the fish is a short-lived species.

The relationship between Standard Length and Total Length TL of *Sarotherodon melanotheron* was found from regression analysis and the regression line was :

$$TL = - 06187 + 1.2457 SL \text{ in millimeters.}$$

7.3.5 Mortality Parameters

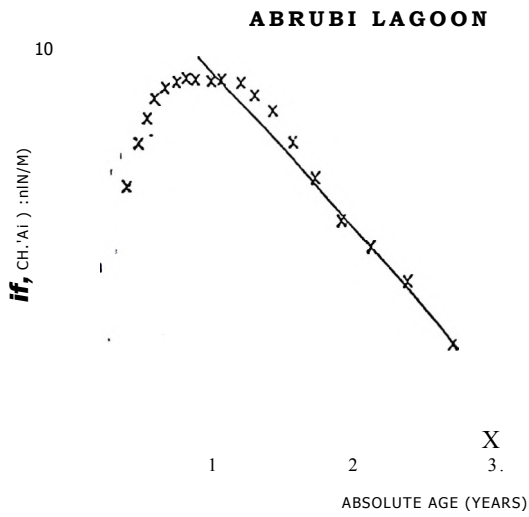
Figures. 7.7a and 7.7b show the length converted catch-curve for *Sarotherodon melanotheron* from Abrubi Lagoon and the Densu-delta. The total mortality rate (Z) was determined only for fish that were fully exploited (the descending right arm of the curve). The slope of the regression curve indicates that $Z = 4.66/\text{yr}$ for Densu-delta and $5.37/\text{yr}$ for Abrubi lagoon taking the mean surface temperature as 29°C , the mean fishing mortality (F) was $3.47/\text{yr}$ for Abrubi Lagoon and $2.84/\text{yr}$ for the Densu-delta.



1

Cutoff Length (L')	= 5.50
Mean Length (From C)	= 6.67
Z from mean length	= 3.03
Z from Catch Curve	= 3.14
Z entered	= 4.66
M	= 1.80
M used	= 1.8
F = Z - M	= 2.86
F/Z	= 0.61

Fig. 7 . 7a Length-- converted catch curve of 5. meia-nofchex-on from Densu-Delto," May ' 1994 - April 1996 .



Cut off Length (L')	= 7.5
Mean Length (From U)	= 9.14
Z from mean length	= 2.82
Z from Catch Curve	= 3.12
Z entered	= 5.37
M	= 1.88
M used	= 1.9
F = Z - M	= 3.47
F/Z	= 0.64

Fig. 7.7b Length converted catch curve of *S. melanothereon* from Abrubi Lagoon May, 1994 - April, 1996

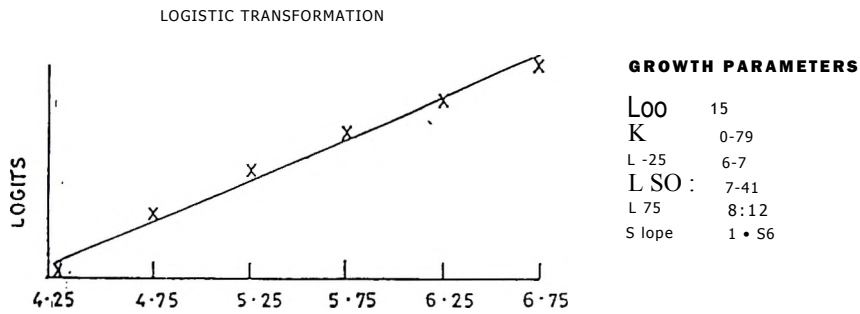
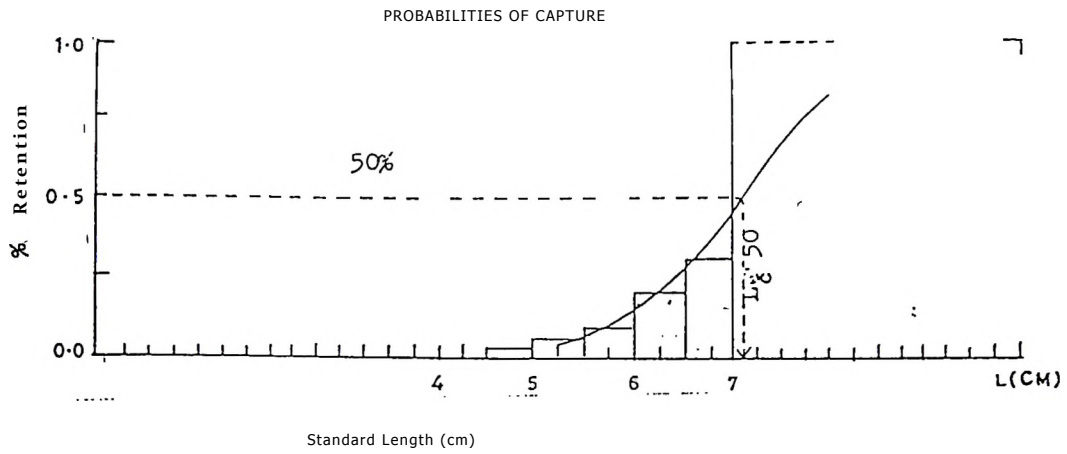
The exploitation level (E) estimated as F/Z was calculated as 0.64 for the Abrubi Lagoon and 0.61 for the Densu-delta. By substitution the natural mortality for the Abrubi Lagoon was 1.89/yr and 1.8/yr for the Densu-delta. The instantaneous fishing mortality was therefore higher than the natural instantaneous mortality.

The probabilities of capture estimated from the analysis from the catch curve are shown in Figs. 7.8a and 7.8b. The resultant curve was fitted using a linearised form of the logistic curve; the corresponding regression yielded values of $a = 11.77$, $b = 1.56$, (Abrubi lagoon) and $a = 12.63$ and $b = 2.55$ for Densu delta. The L_{25} , L_{50} and L_{75} values are the lengths at which 25%, 50% and 75% of the fish would be caught.

7.3.6 Length at First Capture (Lc)

The ELEFAN11 programme computed the length at first capture (Lc). The selection curve generated by the ascending part of the length converted catch-curve for *S.melanotheron* is shown in Figs. 7.8a and b. From the curve the mean length at first capture (LC_{50}) is extrapolated as 74.1mm SL for Abrubi lagoon and 49.5 mm SL for the Densu-delta. The ratio L_c/L_{max} was therefore 0.53 for Abrubi lagoon and 0.45 for the Densu-delta indicating that the fish is fully exposed to fishing mortality when it has achieved 45% of its maximum observed length in the Densu -delta and 53 % in the Abrubi lagoon.

Selection curve I of *S. melanoheron* caught by cast net in
Abrubi Lagoon ~



REGRESSION ESTIMATES

o₋₁₁₋₇₇
 $b = 1.56'$
 $n = 6$
 $r^2 = 0.99$

Fig.7.8a Probabilities of capture of *S. melanoheron* Abrubi Lagoon
May, 1994 - April, 1996

Selection curve for *S. melanoitheroi* 'Densu Delta @aught' by cast net -

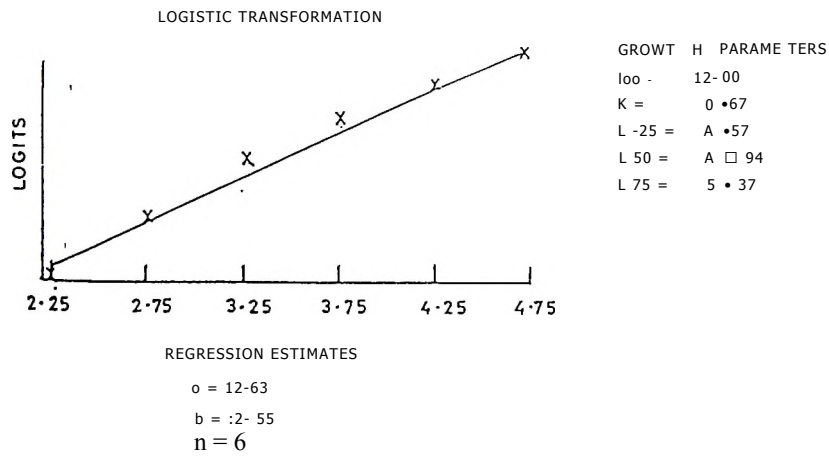
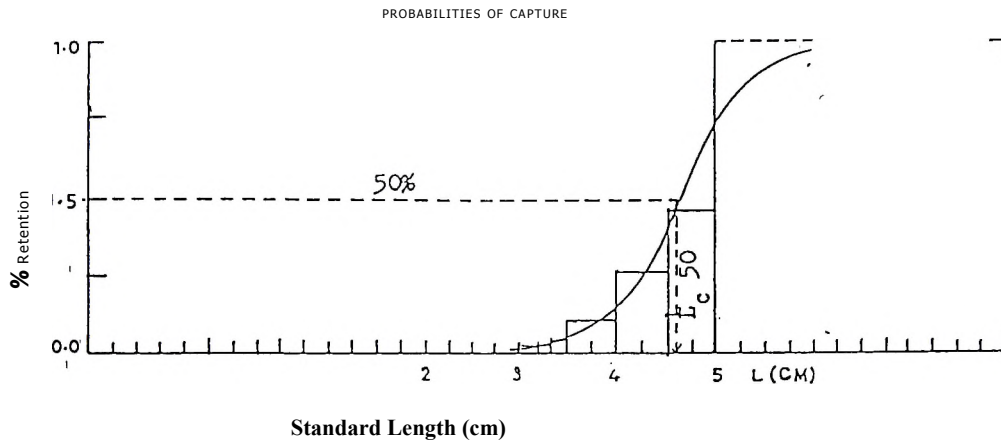


Fig 7 8b Probabilities of capture of *S. melanotheron* Densu Delta
May, 1994 - April, 1996

7.3.7 Exploitation Rate

The exploitation rate also referred to as the exploitation ratio, is a measure of the intensity by which a fish stock is exploited. For the fish population in the Abrubi lagoon E was estimated as 0.64 and 0.61 for the Densu-delta.

7.3.8 Recruitment Pattern

The annual recruitment pattern of *S.melanotheron* in the Abrubi lagoon and Densu-delta as obtained from FISAT is provided in Fig. 7.9a and 7.9b. It shows that recruitment occurred throughout the year. There was a major peak and possibly two or three minor secondary peaks in both lagoons. In both lagoons there was peak recruitment in March, 12.39% for Abrubi lagoon and 19.25% for Densu delta. There was minor recruitment in July for Densu delta and August at Abrubi lagoon.

20

L L
AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN

LOO = 15, K = . 79 j c l: 0, , WP = 0, t0 = -. 015-

Fig7*9#Ret:ruiement Pattern of **S melanotheron** Abrubi Lagoon.
< May ,1994— April ,1996.

Absolute Time	Percent Recruitment
1 Aug	12 15
2 S ep	11 28
3 Oct	6 91'
4 Nov	e 58
5 Dev	1 1 08
6 Jon	7 04
7 Feb	6 35
e Mor	12 39-
9 Apr	8 21
1 0 Moy	11 3 8
11 J un	2 3 1
1 2 J ul	0 00

20

RECRUITMENT (%)

10

S -

OCT NOV OEC JAN FEB MAR APR MAY 'JUN JUL AUG.

LOO = 12; K = -67 , c = 0, WP = 0, t 0 - . 02

Fig7. 9bRecruitment Pattern of S. melanotheron Densu Delta
' May , 1994 — April ,1996,

Absolute Time	Percent R ecruiement
1 Oct	2 .f-2
2 N ov	2 .64
3 Oec	6 = 48.
4 Jon	11 . 31
5 Feb.	8 .68
6 Mor	1 9".2 S
7 Ap.r	10 .25
e Moy	7 - 25
9 Jun	4 =65
1 0 Jul	13 . 05 f
11 Aug	12 .22
12 Sep	0 .60

7.3 Discussion

Generally there was a predominance of females in both study areas. The males are distinguished from the females by the genital papilla and the metallic gold colour of the operculum. The females predominated (about twice) the males in October 1994, December 1994, February, 1995, January 1996, March 1996 and April, 1996 in the Abrubi lagoon. The same could be said for the dominance of females in the Densu-delta in December 1994, March/April 1995 and September/October 1995 (Tabled 7.1a and b). Since males of *S.melanotheron* are known to be the brooding parents, it is possible that the sexes become more segregated during the brooding period. In both lagoons the male: female sex ratio was found to be unity in December 1995.

To facilitate quantitative comparisons of the reproductive cycle of *S.melanotheron* from the two lagoons, female GSI values were used. Figures 7.1a and 7.1b illustrate changes in GSI values during the study period. The continuously high incidence of monthly GSI values (>4.0) of the fish imply continuous spawning through out the year. However the occurrence of many ripe (Stage 111) and running ripe (Stage IV) females in February, March and April suggest a peak spawning period of the fish can be defined by these months (Table 7.2a and b).

Eyeson (1979) observed that no spawning occurs in the absence of male fish, and that overcrowding and weather conditions may also possibly affect spawning. Hyder (1970) suggested that temperature and light changes associated with heavy rainfall periods

influence reproductive activity. Aronson (1957) found that heavy rains caused gonadal regression in *Tilapia macrocephala* (*S.melanotheron* with big heads from Nigeria). In this study high amounts of rainfall in May and June 1995 in Abrubi lagoon coincided with high GSI values (Fig 7.1a.) but GSI values fell in August rising again in February 1996. In the Densu delta high GSI values coincided with low rainfall (Fig 7-1b.).

The length of the brooding period in *Tilapia* species is extremely variable (see reviews by Aronson, 1949, Fryer and lies, 1972). In *Tilapia melanotheron*, (*S. melanotheron*) this has been found to be around 14 days at a temperature of 27°C. Blaxter (1969), however, recognised that development is hastened at high temperatures. The average temperature in both study areas was 29°C.

Eggs were found in the mouth of a few female *S. melanotheron* from the Abrubi lagoon but were normally found in males. Only male specimens from the Densu-delta had eggs in their mouths. This confirms reports by Eyeson (1992) that even though *S. melanotheron* shows a paternal brooding habit, some strains in Ghana also exhibit the potential for female oral brooding. Since the eggs or fry were not digested in the samples from this study, it can be assumed that this is not a cannibalistic behaviour as observed by Aronson (1949) in aquaria. Eyeson (1983) observed that fish specimen caught from the Moree lagoon near Cape Coast and Elmina lagoon spit out or swallow the eggs or fry in panic at capture.

The condition factor calculated from monthly samples may be used to detect seasonal variations in the condition of the fish. This may vary with food abundance and average reproductive stage of the stock (King, 1995). But according to Nikolsky (1972) supported by Pauly (1976) in cases of gear selectivity, condition factors cannot be used as an indicator of the average physiological situation of the fish. The gear used in this study was the cast net and there was heavy evidence of selectivity.

Sarotherodon melanotheron obtained from the Densu-delta were of smaller sizes (2.25 cm - 11.0 cm) than those obtained from the Abrubi lagoon (4.25 cm -14.0 cm SL). From the growth curves obtained most of the fish are caught in their first and second years. Specimens from the Densu-delta had sizes comparable to those encountered for the Fosu lagoon (2.9 -12.9 cm SL by conversion), (Blay and Asabere -Ameyaw 1993) and Sakumo 2, Muni lagoon and Densu-delta, (Koranteng 1995).

Blay and Asabere -Ameyaw (1993) estimated 6.2 cm Total length for *S.melanotheron* caught from the Fosu lagoon at Cape Coast. Comparatively larger sizes reaching 25.0 cm TL have been reported for lagoons in La Cote d'Ivoire (Daget and litis, 1965), 27.0 cm TL in the Lagos lagoon Nigeria (Fagade, 1974) and 32.6 cm TL in the Togo lagoon, Togo (Lae, 1996). In this study specimens measuring 19 cm SL (23 cm TL) were obtained from the Aglor lagoon north of the Keta lagoon complex (Table 7.4).

Pauly (1995) plotted 427 data pairs of **L_∞** and **K** estimates from 92 African fishes. The data were extracted from 130 studies. On the basis of this, he suggested the existence of 3 groups of fish “small”, “medium” and “large”.

Table 7.8. Characteristics of three groups of African Fishes (After Pauly, 1995).

Group	Length (cm)	K(year-l)	Longevity (year)	Main food
Small	2-12	0.6-6	0.5 -5 ^a	Zooplankton insects
Medium	12-50	0.1-10 ^b	2-30	Many ^c
Large	50 -350	0.02 -0.5	6-60+	Fishes

a - from longevity $3/K$, but omitting cultivated fish

b - these high values apply only to cultivated fish

c ranging from detritus to phyto- and zooplankton but also including benthic invertebrates and small fish: medium fishes are those with the widest range of diets.

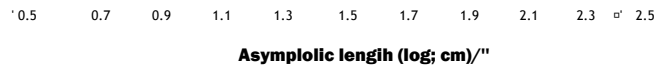


Fig. 7.10 Auxometric grid (Plot of log K us log L_{∞}) of African fishes, showing the location of the three groups identified (Pauly 1995)

From this data he obtained the relative abundance of these three groups, 7% for “small” fish, 71% for “medium” and 22% for “large “ sized fish. From results obtained from this study, $L_{\infty} = 12\text{cm}$, 15cm SL , $K = 0.67$, 0.79 yr^{-1} , *Sarotherodon melanotheron* can be classified as a “medium” sized fish or falling between “small” and “medium”

A comparison of the growth parameters of *Sarotherodon melanotheron* from Abrubi lagoon ($L_{\infty} = 15 \text{ cm SL}$, (17 cm TL), $K = 0.79$) and the Densu delta ($L_{\infty} = 12 \text{ cm SL}$ (14.3 cm TL) $K = 0.67$) to that of *S.melanotheron* from the Togo lagoon ($L_{\infty} = 32.6 \text{ cm TL}$ $K = 0.44$; Lae, 1996) shows that the population from Abrubi lagoon grow nearly twice as fast, and those from the Densu delta grow 1.5 times faster than those from the Togo lagoon.

The population from Abrubi lagoon also attains an asymptotic length which is nearly half of those from the Togo lagoon and that from the Densu delta attains an asymptotic length which is a third that of the *S. melanotheron* from the Togo lagoon. The growth performance index of the two lagoons was not significantly different as the parameter is species specific (Pauly and Munro, 1994).

In this study, the maturity ratio of L_m / L_{∞} was 0.51 for Abrubi lagoon and 0.44 for Densu delta. In comparison with Pauly's (1976) and Ntiamoa -Baidu's (1991) data on sizes, it is apparent that the average sizes of *S. melanotheron* in some lagoons (e.g. Sakumo 2 lagoon) have declined. The maturity - length ratio L_m / L_{∞} of lake tilapias having normal growth are known to attain an average of 0.70 (Iles, 1970). If Iles's (1970) observation holds, then the growth of *S. melanotheron* in the two study areas falls below the average value for lake tilapias.

Blay and Asabere-Ameyaw (1993) suggested that the combined effects of heavy fishing and predation by birds could have caused stunting in the populations of *S. melanotheron* in the Fosu lagoon. Pauly (1976) also concluded that the population of *S. melanotheron* in the Sakumo lagoon was stunted. But Lae (1996) disagreed with Pauly's (1976) contention that the population of *S. melanotheron* may be stunted. Lae suggested that the stocks were so heavily exploited that they consisted of relatively young fishes and supported this idea with his studies on the fish in Lake Togo.

This study tends to support the view of Koranteng (1995) and of Lae (1996) that the high fishing effort could lead to overfishing when the total yield decreases with increasing fishing effort. Also the high fishing effort has resulted in a higher percentage of relatively young fish.

The length- weight relationship of *S. melanotheron* determined in this study for the two study areas and for eight other lagoons are presented in Table. 7.4a and 7.4b. It can be seen that the estimated values for slope (b) ranged from 2.61 to 2.99 with an average of 2.88 (near 3) as for most fishes exhibiting isometric growth (Carlander, 1969; 1977). There was a clear disparity of the intercepts of 'a' in each equation. Tesch (1968) attribute these differences to sex ratios, maturity of the fish and seasons for the collection of the data.

The continuous reproduction of *S. melanotheron* and the lowering of the age at first sexual maturity leads to an increase in the number of reproductive cycles each year. In this study, the longevity of *S.melanotheron* in the two lagoons was found to approximate 4 years. This compares favourably with the report on the species from the Fosu lagoon (Blay and Asabere-Ameyaw, 1993) which portrays the fish as a short lived species.

This rather short life-span suggests fast growth, which could compensate for the high natural and fishing mortality rates (3.47/yr, 1.89/yr) for Abrubi lagoon and (2.48/yr, 1.8/yr) for Densu delta. Pauly (1984) suggested that high fishing and natural mortality is not uncommon for tropical fish.

Pauly also attributed this to high predation by birds and high salinities which may produce fish kills. The Densu delta is a designated Ramsar site with a high bird population and Abrubi lagoon also has a high bird population (pers. observation.).

Mortality in fishes is linked to their size and to the value of K . In addition to this it appears that the natural mortality of fishes also correlates directly to environmental temperature (Pauly, 1980). Fishes occurring at higher temperatures have more chance to encounter 'hungry' predators rather than satiated ones because tropical fishes have to eat more than temperate fishes to satisfy their higher metabolism needs (Winberg, 1960). The high mortality rates observed in both study areas could also be due to multiple recruitment.

The present exploitation rate of the *S. melanotheron* stock in the Abrubi lagoon ($E = 0.64$) and ($E = 0.61$) for the Densu-delta is indicative of its overexploitation. For *S. melanotheron* in the Fosu lagoon, E was estimated as 0.62 by Blay and Asabere-Ameyaw (1993), for the Sakumo 2 lagoon, Koranteng *et al.*, (1997) estimated E as 0.61. These values and those obtained from this study are all higher than the optimum rate of 0.50 suggested for exploited stocks (Gulland, 1971; Pauly, 1983). *Sarotherodon melanotheron* may therefore be overexploited in all these lagoons.

CHAPTER EIGHT

8.0 ISSUES AND MANAGEMENT OPTIONS TO IMPROVE THE FISHERIES IN THE ABRUBI LAGOON AND DENSU-DELTA

8.1 Introduction

Lagoons are simple systems in a delicate natural balance and are therefore easily susceptible to any detrimental environmental impact from pollution or by other human activities which, if uncontrolled, would exceed their capacities and their ability to sustain their levels and use. Lagoons and estuaries constitute a third of the major primary subdivision of global fisheries. The lack of general awareness of this fact has impeded adequate research into the characteristics of artisanal and estuarine fisheries as well as formulation of management strategies designed for estuaries (Bemacksek, 1984).

During this study, a number of issues impacting on the fisheries of the Densu-delta and Abrubi lagoon has been identified. A summary of the advantages and disadvantages in pursuing certain management options has been provided. The issues and management options suggested would help offer an integrated approach to set priorities and plan for the future of the lagoons and improve the fisheries. The issues identified for the two study sites have been categorized under the following headings:

1. Water quality
2. Habitat degradation
3. Overfishing
4. Education
5. Population Pressure



6. Poverty

7. Lack of management policy

8.2 ISSUES

8.2.1 Water Quality

The transfer of solutes from the sea and the influx of fresh water -control the quality of Ghanaian coastal wetland waters. They are also affected by human interference in the carbon flow by the release of sewage, organic matter, nutrients and sediments into them. Lagoons receive pollutants from agricultural pesticides and fertilizers from their immediate catchment area and from flood waters of larger streams and rivers.

The major cause of deterioration in water quality in Ghanaian lagoons is due to pollution from domestic activities (Biney, 1995). This is due to inadequate provision of basic sanitary facilities in most coastal settlements. Thus sewage and garbage are either deposited on lagoon banks or beaches. Pollution can directly affect lagoons by increasing the amount of toxic chemicals or by indirectly changing water quality parameters and consequently the suitability of the lagoon habitat for fish (Alabaster and Lloyd, 1982).

The main impact on fisheries are related to the increases in biochemical oxygen demand (BOD) and the nutrient and ammonia levels caused by the effluent. The impact of the discharge on the fish community is related to their volume and concentration. Although such pollutants may reach toxic levels, chronic exposure of the fish may affect their population parameters such as fecundity, recruitment, and age at first maturity and mortality.

Nature of the problem:

The amount of freshwater from the Densu River is reduced by the Weija reservoir which provides water for irrigation and drinking purposes. The opening and closing of the sluice gates of the reservoir affect the flow of water. A housing estate, and other residential infrastructure surround the delta. Domestic sewage from these areas is discharged directly into the delta. Effluent also come from farmlands, construction sites and a quarry.

Materials present in the effluent may accumulate excess fertilizer elements particularly nitrates and phosphates. During the study, observations showed that the fertilizer NPK was very popular amongst farmers in the area. Industrial waste coming from the industries situated upstream the Densu river, may contain heavy metals detrimental to the flora and fauna, especially the fish. Although the average nutrient levels in the Densu delta and Abrubi lagoon seemed within the normal range for lagoons see (Biney, 1990) the danger of eutrophication occurring is quite imminent.

In the Abrubi lagoon water enters the lagoon through the river Antaa. Drainage from the surrounding areas occurs during the rainy season. Domestic sewage from the village is discharged into the lagoon at some parts of the lower reaches.

8.2.2 Habitat Degradation

As a result of their high levels of biological productivity, lagoons and their wetlands provide feeding and breeding habitats for a number of commercially important fish species. Degradation caused by human settlements and industrial development causes loss of lagoon resources that prevent fish and shellfish from benefiting from the productivity of the lagoons.

A. Exploitation of mangroves

Mangrove vegetation, which provides breeding and nursery grounds for commercially important fish species are under threat from clearing to make way for construction of salt pans and also cutting for fuel wood (Entsua-Mensah, 1996).

Nature of the problem:

In the Densu delta mangroves and other trees are being cut for “Acadja” fishing and fuel wood and also to make way for salt production. Salt mining activities tend not only to desiccate the soil but also make it too compact for seeds to regenerate. Clear cutting of mangrove is practised and the harvested areas are left to regenerate from coppice shoots. Unfortunately the harvesting of mangroves occurs at rates which far outstrip their regenerating capacity.

During the study, some of the fishermen claimed that when mangroves are used to smoke fish it imparts a pleasant flavour. Most of the mangroves around Abrubi lagoon have been cut for fuel wood and for fish smoking but there are still some dense patches of *Paspalum vaginatum* and *Acrosticheum aureus* which constitute part of the ‘mangrove’ vegetation.

B. Cape St. Paul's Wilt (CSPWD) Abrubi Lagoon.

The disease is caused by a mycoplasma - like organism believed to be transmitted by the insect *Myndus adiopodoumensis*. The disease was first found in Ghana in 1932 near Cape St. Paul and spread slowly to other areas around Keta. The spread was slow at first but intensified after 1942 and in recent years has reached epidemic proportions in the important coconut growing areas of the Central and Western Regions. Komenda - Edinafo- Eguafo -Abrem (KEEA) district (where Abrubi lagoon is situated) is the worst affected district in the Central Region. (CSIR Annual, Report 1994).

It affects the leaves and stem of coconut trees, leaving the leaves yellow and the stem hollow. In all cases of disease outbreak, the disease first occurs on isolated coconut palms, then foci develop around these palms then the whole farm is affected (Dery and Nkansah - Poku, 1997, cited in CSIR Annual Report, 1994). The disease duration is from 3 -96 months; it is initiated in the dry season months of January - April and develops very fast in the rainy season.

Nature of the Problem:

Coconut trees bind the sand on the sand bar separating the sea and Abrubi lagoon. This helps to check erosion of the beach, therefore, hollow dead coconut trees will only encourage erosion and this can have adverse consequences for the surrounding villages.

Coconuts and other products from the coconut tree are economically important to the livelihood of the village of Abrobeano and the nearby town of Komenda. Some of the fishermen work on the coconut plantation on part-time basis, especially during the low

marine fishing season from May to early July. The destruction of the coconut plantation by CSPWD will be a great economic loss to the community.

8.2.3 Overfishing

The consequences of heavy fishing pressure on fish populations include changes in the size structure and fish species composition of catches. Large, predator fishes and intermediate fishes are replaced by short lived species. This was clearly obvious in the predominance of *Sarotherodon melanotheron* in both study areas.

Nature of the problem:

Fishing goes on all week in the Densu-delta and throughout the year except for a few days during the annual Homowo festival of the Ga people. Fishing at many areas of the delta becomes impossible, but not prohibited when the flood gates of the Weija Dam are opened. The virtually open access and apparently uncontrolled fishing in the Densu-delta do not augur well for the sustainability of fishery resources in the delta.

The fishers surveyed consider fishing in the delta as free for all, and many do not know of any taboos or cultural practices with regard to fishing in the delta. According to the fishermen, fishing pressure has increased considerably during the last decade due to the presence of migrant fishermen, improvement in gears and the increase in population.

At Abrubi there is intense fishing pressure in the lagoon during the off peak marine fishing season. Nonetheless fishing is prohibited on Saturdays. The present study indicates that the fishery of *S.melanotheron* in both the Abrubi lagoon and Densu delta is operating at or above the optimum sustainable level.

8.3.4 Education

A study conducted by Friends of the Earth (FOE, 1994) showed that in wetland communities in Ghana two out of every three adults are illiterate. This could account for the degradation and poor management of wetland resources. The study also found that in communities where the literacy rate was relatively high, direct dependence of the population on the wetland resources is relatively lower.

Nature of the problem:

Most fishermen in the two study areas have no expectation of ever owning their own canoes, living comfortably or sending their children to school. The full-time fishers can not change to other jobs because their training is limited to fishing. They usually lack any formal education, which can secure them more modern occupation. There is lack of awareness of the benefits of conservation amongst the majority of the fishers, even though some of them have good indigenous knowledge of the ecology of the wetlands.

8.2.5 Population Pressure

Population growth in coastal areas in Ghana is generally higher than inland areas. This is due to migration from inland areas, and consequently, there is a greater increase in the numbers of coastal inhabitants than other areas. Obviously such large numbers of people exert enormous pressure on the coastal ecosystems.

In many cases the level of acceptable exploitation of fisheries as well as harvesting of mangroves and other types of vegetation is seriously threatened as a result of the massive influx of people.

Nature of the problem:

The population around the wetlands in both study areas is increasing rapidly (personal observation). The rate of urbanization around the Densu delta is alarming and there are a lot of young children of school going age loitering at Abrobeano.

8.2.6. Poverty

Poverty and environmental degradation have been characterized as being part of a vicious cycle. This vicious cycle of absolute poverty and environmental degradation has been well documented in coastal communities by Westing (1989) and Lonergan (1993; 1996). The World Bank study in 1996 in Ghana also confirms this. The report indicates that environmental degradation undermines basic services such as water supply and land productivity.

The poverty arising from lack of basic health facility, low income and declining natural ecosystem productivity forces fishermen to place a greater priority on their immediate subsistent needs.

Fishermen operating in an over exploited area or poorly managed fishery tend to use smaller mesh sized nets as a means to increase their catch. Pauly *et al.*(1989) and Pauly (1994) described such a situation as *Malthusian overfishing*, which “occurs when poor fishers, faced with declining catches and lacking any other alternative, initiate wholesale resource destruction in their effort to maintain their incomes”. Pauly *et al.* (1989) gave the symptoms of *Malthusian overfishing* as:

1. use of gears and mesh sizes that are not sanctioned by government;
2. use of gears not sanctioned within the fisherfolk communities;
3. use of gears that destroy the resource base; and
4. use of gears such as dynamite or sodium cyanide that do all of the above and even endanger the fisher folk themselves.

Nature of the problem:

In both of the study areas, most of the fishermen are also marine fishermen and do not receive fixed monthly wages. Whatever money they get depends entirely on the fish they land. The intensity of marine fishing goes down when the rains start, that is late April and early May until the end of July.

Some of them rely heavily on lagoon fisheries for subsistence. Some lagoon fishers in the Densu delta use drag nets or beach seine to exploit fish. A large part of the drag net is made up of 10 mm mesh netting (Doyi, 1984) and this results in the gear catching substantial quantities of young fish. This situation is made worse by the fact that in Ghana, there is a market for all sizes of fish, and therefore there appears to be some benefit in catching juvenile fish. Other fishers migrate to Abidjan, Liberia and Senegal.

8.2.7 Lack of Policy Instruments

Recently there has been a decentralization of political and state power in order to enhance participatory democracy through local (community and district) level institutions with the District Assembly as the pivot (World Bank, 1996). It has also been realized that there should be a close link between modern and traditional systems.

There are challenges when it comes to environmental management that need to be addressed by traditional knowledge in order to succeed. There is the need to focus on local and culturally accepted procedures for conflict management and resolution over issues connected with the management of environmental resources.

Tradition holds that every lagoon has a god or goddess protecting it with its unique set of rules and regulations (see Table 8.1) and a fetish priest acting as a custodian of the lagoon. The fetish priest serves as a link between the living and the spirits. He or she performs the traditional rites and is responsible for enforcing the laws and the regulations governing the use of the lagoon.

Table 8.1 Traditional Management Practices in Some Lagoons in Ghana (After Entsua -Mensah and Dankwa, 1997)

LAGOON	REGION	NEAREST TOWN	LOCATION	NAME OF GOD	SACRED DAY	TABOOS
Berlibangara	Western	Newtown	5°05' N S'W W	Nana Berlibangara	Wednesday	Men can enter lagoon any time, women only i transport. Outboard motors banned.
Efasu	Western	Efasu	5°05' N 3°05' W	Nana Efasu	Wednesday	"
Ndmakaka panyli	Western	Newtown	S'W N 2°58' W	Nana Berlibangara	Wednesday	"
Ndumaka akyi	Western	Newtown	5°06' N 2°58' W	Nana Berlibangara	Wednesday	"
Duen	Western	Gyawue Wharf	S'W N 2°58' W	Nana Tanoë	Wednesday	No drag nets allowed. Manatees sacred. Rituals when one is killed. Women not permitted to look at manatees.
Butre Estuary	Western	Butre	4°05' N 1°55' W	Nana Butre	Saturday	Yam, sheep, drinks and money are offered to the god before breaching of the lagoon. Men can enter lagoon at any time.
Nyana lagoon	Central	Gomoa Nyayaano	N 0°24' W	Nana Nyanya	Friday	Fishing banned on Fridays. Bathroom and beach sandals not used in lagoon.
Kako Kofi (Gomao Fetteh)	Central	Gomoa-Fetteh	5°26' N 0°s' W	7 gods	Friday	No fishing on Fridays. Sheep killed when lagoon is opened.
Oyibi	Central	Gyahadze	5°21' N 0°39' W	Nana Oyibi		Cooking pans not allowed to collect water or fish. Mangroves cannot be cut without permission. Shrine for lagoon god beside lagoon.

Table 8.1 continued

Muni	Central	Winneba	5°01' N 0°39' W	Kwaku Muni	Wednesday	No fishing on Wednesdays and for 2-3 weeks when lagoon fills during rains. Only indigenous Efutus (Winneba) allowed to enter lagoon. E fishermen banned.
Amisa	Central	Asaafa and Amisano	5°12' N 1°01' W	Nana Amisa	Saturday	Anybody cutting mangroves close to the lagoon fined. Shoes not worn in the lagoon.
Fosu	Central	Cape Coast	5°01' N 1°01' W	Nana Fosu	Tuesday	Goddess believed to live at edge of lagoon, E nobody allowed to enter. Pacified with drink E sheep during Afahye festival-only occasional canoes allowed on lagoon for regatta.
Benya	Central	Elmina	5°01' N 1°01' W	Nana Benya	Tuesday	Priest determines fishing seasons, offenders are severely punished. Lagoon opened during Bakatue festival. Six weeks fishing ban prior to festival.
Abrubi	Central	Abrobeano	5°03' N 1°32' W	Nana Abrubi	Saturday	Sandals not permitted in lagoon.
Brenu	Central	Brenu Achinum and Ampenyi	5°04' N 1°26' W	Nana Brenu	Wednesday	Lagoon opened in June/July at Bakatue festival. 2 weeks earlier nobody allowed to enter lagoon. Fines imposed on anybody who enters.
Densu delta (Sakumo 1)	Greater Accra	Accra	5°01' N 1°20' W	N/A	None	None
Sakumo 2	Greater Accra	Tema	5°37' N 0°11' W	N/A	Friday	Drag nets not allowed and no other nets of < 2.5 cm mesh. Closed season Oct/Nov - Mar/April. Crab collection not affected by these rules.

Table 8.1 continued

Djange	Greater Accra	Old Ningo	5°44' N 0° 11' E	N/A	Friday	Mollusc <i>Tympanotonus fuscatus</i> cannot be removed. Poles, sticks and drag nets prohibited. Tilapia from lagoon can be smoked or boiled but not fried. Closed season for 3 weeks after lagoon is breached.
Songor	Greater Accra	Ada-Foah	5°49' N 0° 1' E	Yomo		No fishing or salt collection is allowed in Lufein's lagoon. Priest offers sacrifices at beginning of fishing season before people are allowed to start salt collection.
Avu	Volta	Avuto	5°58' N 0° 53' E	Mama Blewa	Thursday	Fishermen using loop nets must be naked. Soap not allowed. Cooking utensils must not be washed into lagoon. Sandals not allowed. No fishing one week before Mama Blewa festival.
Aglor	Volta		5° 1' N 0° 1' E	2 gods, Djole and Bomi	Every 5th day after Dabala market day	Aglorkope Festival held to celebrate fishing in lagoon Feb/Mar. White pans and red clothing not allowed in lagoon. Cooking utensils not washed in lagoon.
Keta	Volta	Anloga , Anyako, Keta	5° 1' N 0° 1' E	N/A	None	No taboos, no festivals.

8.3 MANAGEMENT OPTIONS TO IMPROVE THE FISHERIES

It is important to note that management of fisheries that exists in lagoons depends on understanding the socio-economic nature of fisheries as well as the biological knowledge of the resources and capture characteristics of the fishery. Some management options are hereby proposed (Fig.8.1).

8.3.1 Water quality

Most of the waste that enters the lagoons in the two study areas are from domestic activities. Community based activities to improve water quality can be designed in such a way as to ensure proper garbage disposal. It is essential to monitor the levels of phosphates, nitrates and silicates in the lagoons because these are indicators of the amount of organic matter which influence phytoplankton growth and hence primary productivity. District Wetland Management Units have been set up in most wetland areas, but most are not very effective as it is difficult to get the communities to accept new forms of garbage disposal.

Environmental education activities especially involving children should be conducted to enable the wetland communities maintain a healthy environment. Any activity which will affect primary productivity; siltation, dumping of sewage and industrial effluent into the lagoons should be curtailed. Failure to do so could result in low phytoplankton diversity and primary productivity thus affecting fish diversity. The EPA should develop control strategies for toxic pollution and eutrophic sources.

8.3.2 Species Diversity

Generally, the species diversity in the two study areas, especially Abrubi lagoon was high. There was an increase in diversity in Abrubi only when the lagoon was breached to the sea. The maintenance of a lagoon - sea connection will permit the ingress and egress of anadromous and catadromous fin and shell fish. A link of such a nature may be expensive to build in the short - term but could be considered for the long term by the government.

8.3.3 Habitat Degradation

The loss of mangrove cover is one of the most drastic catastrophes experienced by lagoons and which could have contributed to the apparent loss of the shellfish fishery at Abrubi lagoon and Densu delta. To provide greater habitat for fish in the lagoon, especially for juveniles, re-planting of mangroves along the Abrubi lagoon is highly recommended. This is also likely to improve oyster production because the prop roots of some of the mangroves serve as substrate for the oysters. There has been a programme for planting mangroves in other West African countries, e.g. Benin and Sierra Leone (EEC, 1987). The potential of shellfish (oysters and cockles) aquaculture amongst the mangroves should be assessed.

Resistant varieties of coconut should be made available to farmers at affordable prices, to stem the spread of Cape St. Paul's Wilt. Research undertaken by the Oil Palm Research Institute indicates that healthy coconut plantations sometimes harbour more *M.adiopodoumensis* than diseased plantations. This has led researchers to believe that there could be more than one vector or that *Myndus* may not be the vector.

This aspect of CSPWD is being investigated. Two natural enemies of *M.adiopodoumensis* have been identified, an ant, *Pheidole* sp. and an unidentified acarine. If they prove effective the farmers would have a cost-effective solution.

8.3.4 Overfishing

The current exploitation level of fish at Abrubi lagoon (0.64) and Densu delta (0.61) is above the optimal (0.50, Gulland, 1971).The complexity of fishing gears (Densu delta) and increasing population pressure (Abrubi lagoon) suggest higher exploitation levels in the near future. The lack of viable livelihood options for fishermen makes it difficult to implement the limitation of fishing effort as a strategy. It would be better to manage the fish stocks and the fishermen. This can be done by :

- (a) protecting juvenile fish;
- (b) protecting the spawning stock of *Sarotherodon melanotheron*, the dominant fish;
- (c) mesh size control;
- (d) closed restricted areas;
- (e) closed seasons; and
- (f) gear restrictions;

These regulations need to be enforced and monitored by the Monitoring Control and Surveillance Division, Fisheries Department of the Ministry of Food and Agriculture. The District Assemblies and local fishing communities should be encouraged to manage lagoon fishery resources.

'Acadja' or brush park fisheries as a non regulatory means of management for lagoon fisheries has its advantages and disadvantages and Kapetsky (1981) sums it up very well; "The suitability of brush park fisheries for dissemination as a management technique should be based on intensive studies of traditional allocation of fishing rights, fishery biology, fishery and forestry economics, environmental considerations such as possibilities for environmental degradation, and ecological aspects such as the presence of toledos and fouling organisms". From personal observation this opinion holds for any form of aquaculture in lagoons.

8.3.5 Education

There is a general lack of awareness of the benefits of conservation amongst the majority of people living in coastal communities. In the two study areas there were some fishermen who were quite knowledgeable about the laws of nature and had invaluable indigenous knowledge. The fishermen and school children as well as all adults should be educated on the effects of irresponsible fishing. The local communities should be involved in the planning, implementation and enforcement of policies and programmes.

The Environmental Protection Agency has started educating communities through the District Wetland Management Communities. The Wildlife Society of Ghana and other Non Governmental Organizations like the Friends of the Earth and Green Earth are also very much involved in educating people living on the Ramsar sites. A lot of educating still needs to be done.

The Fisheries Department could embark on education programmes related to appropriate fishing techniques. A social fund has been recommended by the World Bank to be set up to support local community initiatives and to improve sanitation. Education will resolve the issue of low awareness as well as poor understanding of environmental issues amongst coastal communities.

Data collection on fisheries is very poor for lagoon fisheries. There is the need to establish a National Lagoon Fishery Information System to provide a solid technical, ecological and economic database support for policy, investment and resource management decisions of lagoons and their wetlands. The Fisheries Department, the Universities, Non governmental Organizations, Research Institutions and Environmental Protection Agency should encourage Wildlife Officers and fishery Extension Officers to obtain data on lagoon fisheries catches.

8.3.6 Population Pressure

The use of the land around the Densu delta for settlement should be properly planned. Urban encroachment on the wetland is occurring at a very fast rate. The Family Planning Programme should be intensified around the Abrubi lagoon.

8.3.7 Poverty

The Village Social Fund recommended by the World Bank could also provide the funding for the setting up of small scale industries. Building responsibility around beneficial projects, which involve the communities in the two study areas, should be encouraged. Policies and programs that enable women to participate and contribute to the effective sustainable management of the lagoons should be put in place. Other trades for example

carpentry and masonry can be introduced to the coastal communities by the Department of Social Welfare so that the pressure on fishing can be curtailed.

8.3.8 Traditional management

Traditional management practices are a way of ensuring that the fish in the lagoon grow to maturity and breed without being disturbed. They are also meant to regulate the harvesting of fish, preserve the water quality and conserve the mangroves. Below are some of the traditional management strategies practiced in some lagoons in Ghana (Entsua- Mensah and Dankwa, 1997).

The principal traditional management practices employed in all the lagoons studied are:

- (a) closed fishing seasons (usually some weeks before festival times);
- (b) closed fishing days (all lagoons apart from the Densu delta and Keta lagoon believed to be sacred days of the gods);
- (c) restriction of mesh sizes (cast nets with mesh sizes below 25 mm not allowed in Muni, Abrubi and Berlibangara lagoons);
- (d) restriction of certain gears (outboard motors not allowed in Berlibangara and drag nets not allowed in certain lagoons);
- (e) regulation of entry (only indigenous people are allowed to fish in the Muni, Fosu, Abrubi, Avu, Aglor, Berlibangara, Duen and Ndumakaka lagoons);
- (f) regulation of access by gender;

Traditional management practices should be encouraged around all lagoons. They serve to conserve the resources of the lagoons and to protect the flora and fauna. They should be backed by legislation and the scientific basis for managing the wetlands explained to the local people.

The ban on fishing in some lagoons prior to festival times could be an important and effective management or conservation practice. This allows the fish to grow and breed without disturbance. On the other hand the high fishing pressure on the stocks after the ban is lifted defeats the purpose of the ban.

The virtually open access and apparently uncontrolled fishing in areas where no closed seasons exist, e.g. the Densu delta and Keta lagoon does not augur well for the sustainability of the fishery resources. The prohibition of fishing on specific days and the restriction of certain gears, e.g. drag nets, reduces the fishing pressure on the lagoon resources.

The fact that women were not allowed to enter the lagoon during menstruation period for fear of defiling the lagoon and the community incurring the displeasure of the gods was an inherent taboo amongst all the coastal communities.

The most rational future for lagoon management along the coast of Ghana may well be through central government devolving some of its regulatory powers to traditionally respected leaders for community participation over the best way to organize the catches for the communities.

Three steps could be put in place.

- First, the District Assemblies should be assisted by the Fisheries Department and traditional authorities to determine total allowable catches for each lagoon in their area, and the probable blend of gear and effort needed to achieve that.
- Then the traditional authorities should be supported financially by the District Assembly to register traditional fishermen and their gear, and to license them to fish each year for an appropriate fee.
- Finally, either the traditional authorities or the district Assembly could undertake legally backed enforcement of a system of appropriate controls and fines.

This format should be sufficiently accurate to ensure sustainability of the fisheries, sufficiently sensitive to maintain the local fishermen's lifestyles, bring traditional authorities back into control of local situations and maintain rules of importance to local communities.

CHAPTER NINE

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

Fluctuating hydrological features and physico-chemical parameters probably contribute to the species diversity in the two study areas. The Densu delta, being open to the sea and having constant oxygen renewal due to wave action, was better aerated than Abrubi lagoon. It also had higher average salinity and more marine species making incursions into it than the Abrubi lagoon, which was closed, to the sea for most parts of the year. Phosphate levels were also higher in the Densu delta as it was situated near an urban area and had the effects of agro-chemicals .

In both study areas the most important gear was the cast net. In the Densu delta there are also drag nets, bottles, “acadjas”, and various traps were also used. However, the relatively high diversity of fishing gears in the Densu delta than Abrubi lagoon does not augur well for management and conservation of fishery resources. *Sarotherodon melanotheron* caught in the densu delta were of smaller sizes than those caught in Abrubi lagoon.

In the Abrubi lagoon, for management and conservation purposes there is a ban on fishing 2 weeks prior to the “Nyeyi festival”. There is no fishing in this lagoon on Saturdays, whereas fishing goes on all week in the Densu delta. There is only one settlement near the lagoon and fishing pressure was a bit lower than in the densu delta.

Fishing is very important in both study areas and the most important fish is the black chin tilapia, *Sarotherodon melanotheron* which displays isometric growth. Females predominated males in from March to September 1995 in Abrubi lagoon and in Densu delta from April to November 1995. There was peak recruitment in March for both lagoons and a minor one in July for the Densu delta and August in Abrubi lagoon.

Sex ratio varies seasonally during the year. There is the possibility of differential sexual migration between the lagoon and the riverine areas.

The growth parameter values of $L_{\infty} = 12$ cm SL, $K = 0.67$ for Densu delta and $L_{\infty} = 15$, $K = 0.79$ for Abrubi lagoon indicates fast growth. The growth performance index of *S.melanotheron* is not significantly different between the two lagoons.

The probabilities of capture indicate that 25% of the fish are caught at 4.6 cm SL, 50% of the fish are caught at length 4.9 cm SL and 75% at length 5.4 cm SL in the Densu delta. In the Abrubi lagoon, 50% of the fish are caught at 7.4 cm SL and 75% at 8 cm SL. This indicates that most of the fish are caught just before maturity or at maturity as the length at first maturity is 7.14 cm SL for Abrubi and 4.8 cm SL for Densu delta.

The longevity of *S.melanotheron* is estimated to be 4 years in each of the lagoons implying that the species is a short lived and fast growing one, a situation which could compensate for the estimated high natural and fishing mortality rates.

The exploitation rate of *S.melanotheron* in each of the study areas could be considered as above optimum indicating high harvest levels. The smaller sizes of fishes in the Densu delta than Abrubi lagoon could be due to excessive fishing effort.

The Forage / Carnivore ratio of both study areas indicate that the lagoons are in ecological balance. The grouping of the various months into distinct clusters of wet and dry seasons indicate a fish species distribution based on a seasonal structure.

9.2 Recommendations

Rapid increases in fishing pressure in the absence of management constraints can result in overfishing and eventual stock depletion. The existence of fishery regulations does not assure successful stock management. Effective management should include educational programs to solicit active cooperation from the fishermen and local community.

There should be development of research and management resources to understand fishermen and their gear. Data from scientific stock assessment should be used in management processes.

The diversity of fishing gears in the Densu delta implies exploitation of most niches. In order for the fishers not to suffer the “tragedy of the commons”, the open access nature of fishing in the delta, facilitating the use of all types of gears should be curtailed.

Mulletts , *Mugil cephalus* and *Liza falcipinnis* are recommended to be considered for aquaculture. This is because they are the main catadromous species of high value encountered in both study areas.

Acadja fishing practised in the Densu delta appears to offer a number of biological and economic advantages for the management of lagoon fisheries. Among these are the low level of technology required, potential for increase in the biological productivity of the lagoon system as a whole through nutrient input from the wood used, and a possible effect on adjacent capture fishery yield.

However, the large quantities of branches required for acadja fishing could adversely affect the environment causing local deforestation. This could also contribute to the general ecological imbalance of the lagoon system unless mangroves are replanted.

Direct and indirect management practices can be used to manage the fisheries. Direct management involves gear control, catch control, fishermen control and season control. Indirect management involves mangrove afforestation, environmental protection and introduction of alternative trades to the fishermen.

9.3 Recommendations for future studies

1. Since food and feeding habits are important aspects of fishery management studies, especially to find out predator-prey relationships, the stomach content of major fishes should be weighed, preserved and analysed in the laboratory. This is to enable food web relationships in the lagoon to be established.
2. The various types of gears used in the lagoons, apart from cast nets, could be monitored to provide information on any changes in fishing patterns. The probabilities of capture using FISAT of other important species could be monitored based on their length frequency data. A database on other biological parameters of the fish species could also be established.
3. Information on prices of fish caught from lagoons could be collected in conjunction with studies on the socio-economics of the lagoons.

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Appendix3.i A bottle trap. Note hole on the side for entry of fish (Densu delta)



Appendix3.2 A type of drag net used in the Densu delta



Appendix 3.4 Acadja fishing - Densu delta



Appendix 3.5 Abrubi lagoon



App.6.1a Analysis of Variance Table to test the significance of differences in Depth between stations and months under Investigation between stations and months of Investigation

Abrubi ANOVA

Source of Variance	SS	df	MS	F	P-value	Fcrit
Months	18.9634	23	0.824496	4.24125	1.52E-05	1.766604
Stations	0.482436	2	0.241218	1.240839	0.296638	3.199588
Error	8.942364	46	0.194399			
Total	28.3882	71				
Total	243*68.9	95				

App.5.1 b Analysis of Variance Table to test the significance of difference* in Depth between stations and months of investigation

Densu ANOVA

Source of Variance	SS	df	MS	F	P-value	Fcrit
Months	65.6837	23	2.855813	11.2256	4.3E-12	1.766804
Stations	0.724253	2	0.362126	1.423443	0.251294	3.199588
Error	11.70248	46	0.254402			
Total	78.11043	71				

App.6.2a Analysis of Variance Table to test the significance of differences in Salinity between stations and months of Investigation

Abrubi ANOVA

Source of Variance	SS	df	MS	F	P-value	Fcrit
Months	390.7794	23	16.99041	2577106	0.000808	1.766804
Stations	337.9103	2	168.9551	29.60478	5.45E-09	3.199588
Error	2625231.46	5.707023				
Total	991.2128	71				
Total	1278.08	95				

App.5.2b Analysis of Variance Table to test the significance of differences in Salinity between stations and months of Investigation

Densu delta

ANOVA Table

Source of Variance	SS	df	MS	F	P-value	Fcrit
Months	991875	23	43.125	3.912722	4.08E-05	1.766804
Stations	1225	2	612.5	55.57199	5.35E-13	3.199588
Error	507	46	11.02174			
Total	2723.875	71				

F_{0.05}(2, 46) = 4.01
Differences are highly significant

App.5.3 Analysis of Variance Table to test the significance of differences in oxygen levels between stations and months of Investigation

Abrubi ANOVA

Source of Variance	SS	df	MS	F	P-value	Fcrit
Months	115.8044	23	5.034976	6.186318	8.41E-08	1.766804
Stations	19.64778	2	9.823889	12.07031	6.11E-05	3.199588
Error	37.43889	46	0.813889			
Total	172.8911	71				

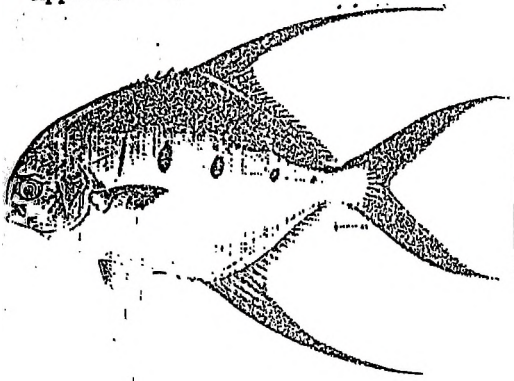
Densu ANOVA

Source of Variance	SS	df	MS	F	P-value	Fcrit
Months	80.85986	23	3.515646	6.600431	3.15E-08	1.768804
Stations	1729194	2	8.645972	16.23233	4.03E-06	3.199588
Error	2450139	46	0.532639			
Total	122.6532	71				

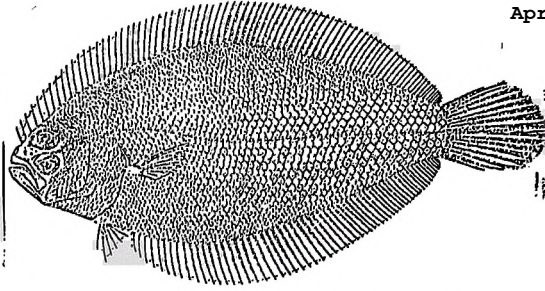
Appendix 6.2 Indices of Diversity, Richness and Evenness, Abrubi Lagoon and Densu

delta					Dantu Months						
Abrubi			Wei-Dry		Shanno	Dmg	Pielou	Wei-Dry	Rainfall m		
Months	Shanno	Dmg	Pielou	Rln mm	May'94	1.3212	1.0518	0.7373	2	131.4	
May'94	0.834	1.0569	0.6016	1	143.6	June	1.3633	1.1345	0.7006	2	297.8
June	0.6182	1.0304	0.446	1	174	July	1.559	1.1171	0.8012	2	7
July	0.7823	1.0089	0.4861	1	67.5	Aug	1.521	0.5802	0.8311	2	17.9
Allo	0.6076	1.3437	0.5639	1	16.2	Sep	1.4079	0.9384	0.7858	2	26.1
Sap	0.7587	1.3275	0.4235	1	155.3	Oct	1.3328	1.1378	0.6849	2	70.3
Oct	0.6241	1.3422	0.3751	1	155.7	Nov	0.6533	0.6298	0.4059	1	15
Nov	0.6873	0.823	0.3128	2	55.4	Dec'	0.5674	0.422	0.5164	1	0
Oec	0.4967	0.8543	0.226	2	0	Jan'95	0.5723	0.4271	0.5209	1	0
Jan-95	0.5539	0.8243	0.3473	9	0	Feb	0.2339	0.4352	0.2129	1	13.4
Feb	0.1776	0.3945	0.1104	2	2.8	Mar	0.5136	0.6183	0.3705	1	60.2
Mar	0.3701	0.2001	0.2299	2	94.3	Apr	0.9834	0.8217	0.611	1	75.8
Apr	1.0553	1.0208	0.7612	2	113.6	May	1.2258	1.01476	0.6836	2	79.5
may	1.0797	1.01	0.6708	1	99.2	June	1.1314	0.81422	0.7029	2	61.9
Juno	0.9048	0.6154	0.5622	1	337.9	July	0.9158	0.3917	0.8335	2	92.9
July	1.07	1.1460	0.7719	1	99.1	Aug	0.8592	0.6125	0.6198	2	12.3
Aug	0.6706	0.8355	0.4474	1	51.9	Sep	0.6797	0.4163	0.6187	2	23.7
Sep	0.8607	0.8357	0.4423	1	90	Oct	0.8531	1.2107	0.4292	2	56.2
Oct	0.6471	1.0162	0.3112	1	23	Nov	0.311	0.4254	0.2831	1	44
Nov	0.2463	0.4128	0.1374	2	44.3	Dec	0.5268	0.642	0.38	1	21.7
Oec	0.3544	0.4423	0.184	2	0	Jan'96	0.4903	0.4391	0.4463	2	3.8
Jan'96	0.6941	0.8509	0.4313	2	0	Feb	0.5101	0.4192	0.4643	2	26.7
Feb	0.412	0.4192	0.375	2	13.4	Mar	0.5125	0.4083	0.4665	2	38.5
Mar	0.4695	0.4254	0.4274	2	9.3	Apr	0.9529	1.03385	0.5316	2	109.1
Apr 0.6332	1.007	0.4567	2	71.4	Station2 middle						
Station2 Middle					Months Shanno Dmg Pielou Rainfall m						
Months ShaTino	Dmg	Pielou	Rain mm	May'94 0	0	0	1	131.4			
May'94	0.555	0.6394	0.2761	1	143.6	June	1.4078	1.1604	0.7235	1	297.8
Juna	0.6196	0.6244	0.4489	1	174	July	1.3959	1.5216	0.6353	1	7
July	0.8349	0.7941	0.5188	1	67.5	Aug	0.9078	1.003	0.5066	1	17.9
Aug	0.6114	0.7993	0.3798	1	16.2	Sep	0.7604	0.7824	0.4724	1	26.1
Sep	0.8367	0.9992	0.42	1	155.3	Oct	0.67145	1.457	0.3055	1	70.3
Oct	1.299	1.5180	0.5609	1	155.7	nov	1.0671	1.561	0.4856	2	15
Nov	1.373	1.5438	0.565	2	55.4	Dec	1.1722	1.572	0.5335	2	0
Dec	1.279	1.5668	0.5386	2	0	Jan'95	1.3153	1.769	0.5712	2	0
Jan'95	0.631	0.8059	0.3921	2	0	Feb	1.0526	1.594	0.479	2	13.4
Fab	0.746	0.7624	0.4632	2	2.8	Mar	1.0492	1.3645	0.5045	2	60.2
Mar	0.442	0.8015	0.2744	2	94.3	Apr	0.8	1.217	0.411	2	75.6
Apr	0.21	0.6144	0.1572	2	113.8	May	1.0673	0.9839	0.595	1	79.5
May	0.645	0.8082	0.4005	1	99.2	June	0.8451	0.7745	0.525	1	81.9
June	0.83	0.8461	0.5153	1	337.9	July	0.7297	0.6079	0.5264	1	92.9
July	0.932	0.6088	0.6723	1	99.1	Aug	0.7495	0.5848	0.54	1	12.3
Aug	1.462	1.681	0.679	1	51.9	Sep	0.9954	1.5923	0.4531	1	23.7
Sep	1.135	1.1851	0.511	1	90	Oct	1.2912	1.7387	0.56	1	56.2
Oct	0.903	1.359	0.39	1	23	Nov	1.2035	1.8034	0.522	2	44
Nov	0.776	0.999	0.4332	2	44.3	Dec	1.3416	1.6142	0.61	2	21.7
Dec	0.774	1.257	0.3976	2	0	Jan96	1.185	1.633	0.539	2	3.8
Jan'96	0.6155	0.7951	0.3824	2	0	Feb	0.9187	1.3968	0.4416	2	26.7
Feb	0.185	0.4009	0.1688	2	13.4	Mar	0.6836	1.0132	0.3815	2	38.5
Mar	0.27	0.4041	0.253	2	9.3	Apr	0.2816	0.402	0.2563	2	109.1
Apr 0.284	0.8163	0.2051	2	71.4	Station3 Seaward						
Station3 seaward					Months Shanno Dmg Pielou wel-dry Rainfall m						
Months Shanno	Dmg	Pielou	Rain mm	May'94 1.1094	0.6567	1.1819	1	131.4			
May'94	0.7604	0.4538	0.6976	1	143.8	Juno	1.1737	1.0051	0.9682	1	297.6
June	0.8746	0.4402	0.7961	1	174	July	1.2419	1.3045	0.6477	1	7
July	1.0416	0.4018	0.9481	1	67.5	Aug	1.5622	1.7938	0.9261	1	17.9
Aug	1.3151	0.5808	0.9486	1	16.2	Sep	1.4479	1.9319	0.6469	1	26.1
Sep	1.1436	1.1822	0.5876	1	155.3	Oct	1.49	2.144	0.5262	1	70.3
Oct	1.5611	1.8856	0.7544	1	155.7	Nov	1.1781	2.1806	0.443	2	15
Nov	1.7962	2.078	0.825	2	55.4	Dec	1.0278	2.1393	0.4335	2	0
Dec	1.1798	1.6435	0.6267	2	0	Jan'95	0.8959	1.5944	0.3887	2	0
Jan'95	1.0255	1.4473	0.6058	2	0	Feb	0.7015	0.7972	0.3387	2	13.4
Feb	1.0166	1.0177	0.7167	2	2.8	Mar	1.1806	1.1591	0.5881	2	60.2
Mar	0.9137	0.9172	0.6343	2	94.3	Apr	0.7137	0.4297	0.6096	2	75.8
Apr	0.8604	0.9713	0.5796	2	113.8	May	1.2462	1.2468	0.797	1	79.5
May	0.9904	0.9691	0.6317	1	99.2	June	1.0615	1.4672	0.6256	1	81.9
June	0.677	0.8154	0.4854	1	337.9	Jut	0.7615	0.967	0.3644	1	92.9
July	1.1863	1.5842	0.6092	1	99.1	Aug	1.214	1.1689	0.4373	1	12.3
Aug	1.623	1.9405	0.7544	1	51.9	Sep	1.4826	1.9853	0.6613	1	23.7
Sep	1.3343	1.4248	0.7824	1	90	Oct	1.431	2.225	0.0401	1	56.2
Oct	0.9575	1.1836	0.5693	1	23	Nov	1.221	1.766	0.5942	2	44
Nov	0.6058	1.0537	0.4033	2	44.3	Dec	1.1351	1.6	0.5073	2	21.7
Oec	0.462	1.0616	0.3351	2	0	Jan'96	1.447	1.98	0.6931	2	3.8
Jan'96	0.5979	1.0596	0.3738	2	0	Feb	0.7212	1.355	0.3125	2	26.7
Feb	0.4574	1.0833	0.296	2	13.4	Mar	0.916	0.91	0.5134	2	36.5
Mar	0.7294	1.0118	0.4983	2	9.3	Apr	0.8581	0.624	0.6749	2	109.1
Apr	0.6632	1.028	0.1	2	71.4						

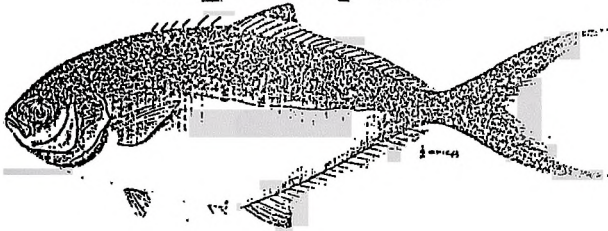
in Abrubi Lagoon and Densu Delta May -1994 -
 April 1996.



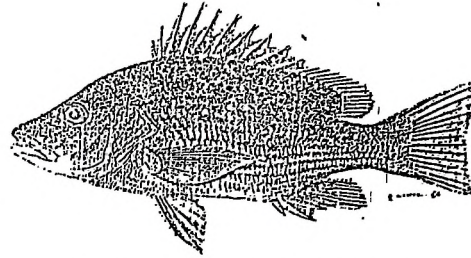
Tachinotus guineensis (d'après Sécrot & Opic, 1981).



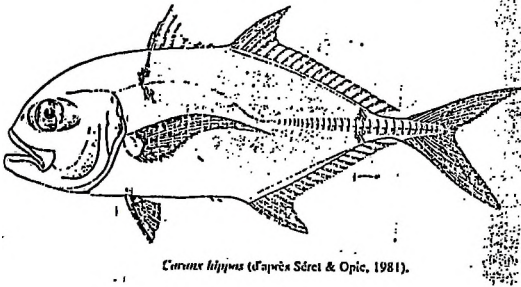
Citharusichthys stansbyi (d'après Blache et al., 1970).



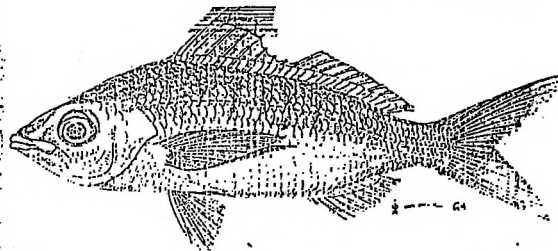
Tachinotus ovalis (d'après Sécrot & Opic, 1981).



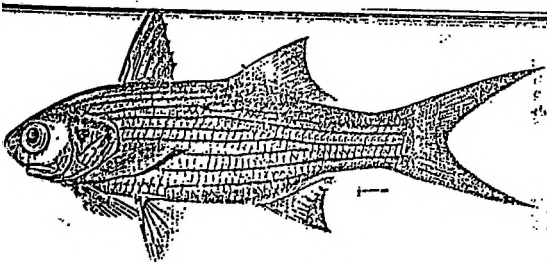
Lutjanus guineensis (d'après Sécrot & Opic, 1981).



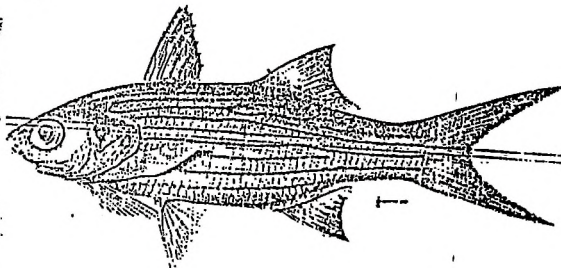
Centropomus littoralis (d'après Sécrot & Opic, 1981).



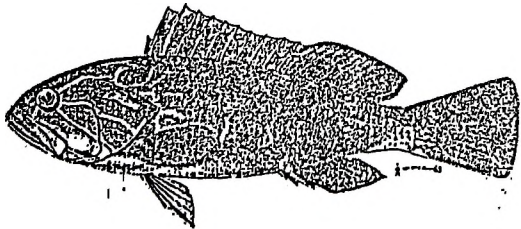
Gerres melanopterus (d'après Sécrot & Opic, 1981).



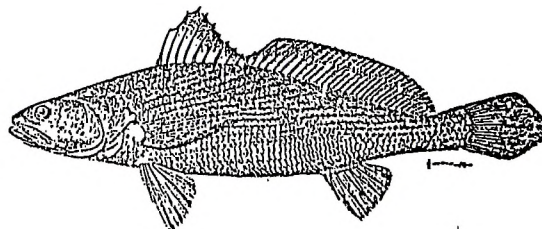
ifrt'iihniyhil surd*OpiCly.Sf).



1 - Cniffbbs >tnfht,ni/ins (rpx) s'rci * Ujlic, im-.*



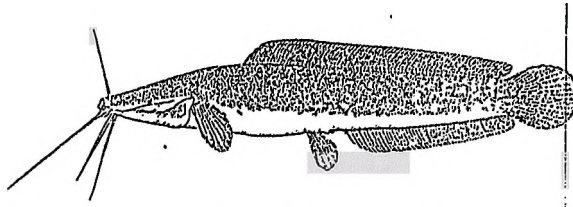
■ fy'iar/M... on.Erv* .Wn'EX'olsV. IVKI



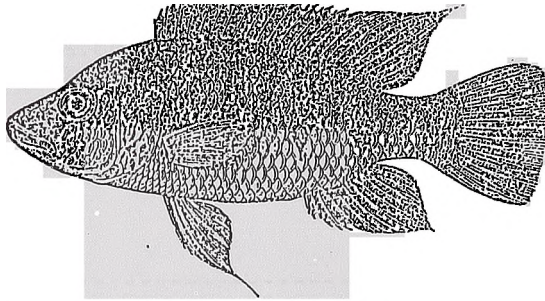
l'to-iitlitt.ilifia sent#,tensls fTTurt* Sdrei * 0 ,re.1

Source: Teugels (1992)

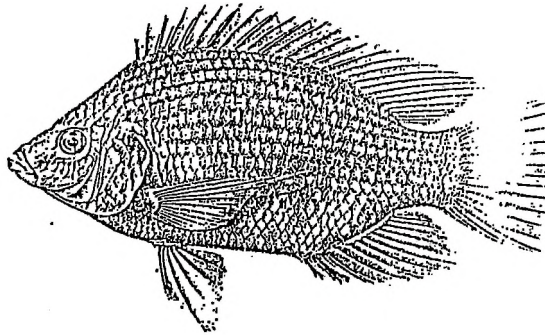
Appendix 6.3b. Freshwater fishes encountered in Abrubi lagoon and
Densu delta May 1994 - April 1996.



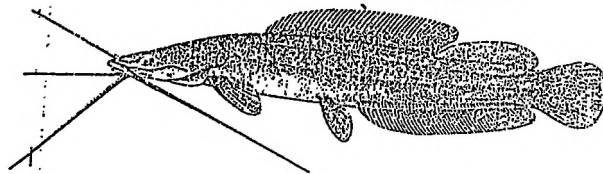
Clarias anguillaris (d'après Teugels, 1992).



Hemichromis fasciatus (d'après Boulenger, 1915).



Sarotherodon galilaeus galilaeus (d'après Boulenger, 1917).



*Itctirtrf>nm1iin l>i<t<rxalix (ll*a)-rcs Tcugtlli. el. j/,_IVIKJ).*

Source: Teugels (1992)

requery data of S.melanotheron Abrubi lagoon May¹⁹⁹⁴

[FiSAT Output : 05-31-1998 (14:48:44)]

Filename: AE)123F.LFQ
Sarotherodon melanotheron AbrubiP

"~ML\DA^E , 15/05/94 15/06/94 15/07/94 15/08/94 15/09/94-15/10/94

4.25		2 . 00				13.00
4.75		6.00		12.00	8.00	16.00
5.25	12.00	15.00		17.00	8 . 00	22 . 00
5.75	15.00	19.00	20.00	12.00	19.00	24.00
6.25	18 . 00	19.00	34.00	18.00	28.00	23 . 00
6.75	17.00	28 . 00	34 . 00	29.00	41.00	30 . 00
7.25	17.00	17.00	37 . 00	31.00	25.00	33.00
7.75	17.00	20.00	24 . 00	29.00	27 . 00	35.00
8.25	20.00	27.00	30.00	38.00	43 . 00	42.00
8.75	19 . 00	18.00	46.00	42.00	52.00	56.00
9.25	25.00	24 . 00	26 . 00	44.00	55 . 00	56.00
9.75	16.00	18.00	37.00	34.00	21.00	25.00
10.25	32 . 00	31.00	7.00	19.00	24 . 00	13.00
10.75	11.00	12.00	3 . 00	3.00	11.00	1.00
11.25	15.00	6.00	1.00	1.00	3 . 00	
11.75	3 . 00			1.00	1.00	
12.25	1.00			1.00	1.00	
12.75				1.00	1.00	
13.25						
13 . 75						
Sum	238.00	262.00	>99.00	331.00	367.00	389.00

ML\DATE ¹	15/11/94	15/12/94	15/01/95	15/02/95	15/03/95	15/04/95
4.25					6.00	
4.75	5.00			11.00	14.00	5.00
5.25	17.00	10.00	8' . 00	14.00	13 . 00	8.00
5.75	17.00	10.00	6.00	12.00	39.00	20.00
6.25	26.00	22.00	15.00	10.00	36.00	32.00
6.75	30 . 00	30.00	14.00	20.00	43.00	39.00
7.25	34 . 00	32.00	31.00	18.00	42.00	34.00
7.75	37.00	32.00	34.00	32.00	43.00	39.00
8.25	31.00	45.00	39.00	40.00	42.00	40.00
8.75	36.00	53.00	54.00	40.00	42.00	44 . 00
9.25	28 . 00	33.00	54.00	68.00	41.00	37.00
9.75	22 . 00	19.00	39.00	40.00	32 . 00	16.00
10.25	14 . 00	4 . 00	14.00	32.00	8.00	10.00
10.75	3 . 00	2.00	8.00	10.00	11.00	5.00
11.25				12 . 00	9.00	1.00
11.75				10.00	1.00	1.00
12.25				7.00		1.00
12.75				0.00		
13.25				0.00		
13.75				1.00		
3um ,	300.00	292.00	316.00	377.00	422 . 00	332.00

ML\DATE	15/05/95	14/06/95	15/07/95	15/08/95	15/09/95	15/10/95
4.25					3 . 00	10.00
4.75					11.00	16.00
5.25	8.00		4.00	5.00	14 . 00	2.00
5.75	12.00	10.00	8.00	7.00	26.00	44.00
6.25	20.00	17.00	10.00	16.00		

10.25	32.00	18.00	37.00	34.00	21.00	25.00
10.75	11.00	31.00	7.00	19.00	24.00	13.00
11.25	15.00	12.00	3.00	3.00	11.00	1.00
11.75	3.00	6.00	1.00	1.00	3.00	
12.25	1.00			1.00	1.00	
12.75				1.00	1.00	
13.25						
13.75						
Sum	238.00	262.00	299.00	331.00	367.00	389.00

ML\DATE	15/11/94	15/12/94	15/01/95	15/02/95	15/03/95	15/04/95
4.25					6.00	
4.75	5.00			11.00	14.00	5.00
5.25	17.00	10.00	8.00	14.00	13.00	8.00
5.75	17.00	10.00	6.00	12.00	39.00	20.00
6.25	26.00	22.00	15.00	10.00	36.00	32.00
6.75	30.00	30.00	14.00	20.00	43.00	39.00
7.25	34.00	32.00	31.00	18.00	42.00	34.00
7.75 1	37.00	32.00	34.00	32.00	43.00	39.00
8.25 1	31.00	45.00	39.00	40.00	42.00	40.00
8.75	36.00	53.00	54.00	40.00	42.00	44.00
9.25	28.00	33.00	54.00	68.00	41.00	37.00
9.75	22.00	19.00	39.00	40.00	32.00	16.00
10.25	14.00	4.00	14.00	32.00	8.00	10.00
10.75	3.00	2.00	8.00	10.00	11.00	5.00
11.25				12.00	9.00	1.00
11.75				10.00	1.00	1.00
12.25				7.00		1.00
12.75				0.00		
13.25				0.00		
13.75				1.00		
Sum	300.00	292.00	316.00	377.00	422.00	332.00

ML\DATE	15/05/95	14/06/95	15/07/95	15/08/95	15/09/95	15/10/95
4.25					3.00	10.00 16.00
5.25	8.00		4.00	5.00		oc'nn
5.75	12.00	10.00	8.00	7.00	14.00	
6.25 i	20.00	17.00	10.00	16.00	26.00	
6.75	29.00	33.00	18.00	18.00	35.00	^9.00
7.25	18.00	42.00	25.00	16.00	20.00	ft'nn
7.75	32.00	27.00	26.00	18.00	41.00	to'nn
8.25	35.00	31.00	21.00	17.00	42.00	
8.75	44.00	32.00	26.00	21.00		oT'nn
9.25	32.00	18.00	32.00	30.00		
9.75	38.00	22.00	25.00	26.00		io'nn
10.25	41.00	32.00	22.00	35.00	9.00	
10.75	13.00	7.00	17.00	15.00	4.00	
11.25	1.00	4.00	14.00	13.00	2.00	3.00
11.75			10.00	5.00		1.00
12.25			7.00	8.00		
12.75			5.00	5.00		
13.25				3.00		
13.75				2.00		
Sum	327.00	275.00	270.00	260.00	292.00	360.00

ML\DATE I	15/11/95	15/12/95	15/01/96	15/02/96	15/03/96	15/04/96
4.25	8.00				7.00	
4.75	16.00				17.00	
5.25	11.00	10.00	12.00	10.00	13.00	5.00
5.75	21.00	16.00	15.00	10.00	15.00	25.00
6.25	37.00	18.00	18.00	6.00	25.00	34.00
6.75	46.00	31.00	18.00	30.00	44.00	28.00
7.25	42.00	18.00	32.00	45.00	35.00	27.00
7.75	38.00	30.00	28.00	29.00	48.00	34.00
8.25	31.00	37.00	18.00	50.00	37.00	37.00
8.75	30.00	34.00	33.00	32.00	22.00	27.00
9.25	33.00	36.00	41.00	44.00	21.00	32.00
9.75	13.00	24.00	43.00	33.00	22.00	34.00
10.25	4.00	21.00	27.00	24.00	12.00	31.00
10.75	3.00	5.00	15.00	5.00	11.00	13.00
11.25			5.00	1.00	4.00	4.00
11.75	1		2.00		1.00	5.00
12.25			2.00		1.00	2.00
12.75			1.00		1.00	3.00
13.25			1.00		1.00	
13.75					1.00	
Sum	333.00	280.00	311.00	319.00	338.00	341.00
^ _	7,631.00					
L FiSATOutput :	05-31-1998	{14 :51	9)]			

Efficiency data of λ -melanotheron Densu delta Majz 1994 -

DEL23 .LFQ

j.

April 1996

ML\DATE	15/05/94	15/06/94	15/07/94	15/08/94	15/09/94	15/10/94
2.25	4.00					
2.75	1.00		12 . 00		2.00	5.00
3.25	2.00	5.00	14 . 00		17.00	14 . 00
3.75	3.00	20 . 00	18.00	15.00	40.00	20 . 00
4.25	24.00	20.00	39 . 00	21.00	38 . 00	43.00
4.75	16.00	26.00	37.00	42.00	43 . 00	43 . 00
5.25	25.00	33 . 00	34 . 00	34.00	41.00	55.00
5.75	16.00	30 . 00	45.00	50.00	40.00	38.00
6.25	16 . 00	32 . 00	47.00	59 . 00	37.00	55.00
6.75	2 . 00	36 . 00	31.00	18.00	25.00	42.00
7.25	1.00	31.00	18.00	10.00	9.00	31.00
7.75		10.00	11.00	7.00	4.00	36.00
8.25		8 . 00	10 . 00	3.00	7.00	19.00
8.75		8 . 00	6.00		1.00	9.00
9.25		2 . 00	2.00		1.00	3 . 00
9.75		2 . 00	1.00		2.00	1.00
10.25						
10.75						
um	110.00	263.00	325.00	259.00	307.00	414.00

ML\DATE	15/11/94	15/12/94	15/01/95	15/02/95	15/03/95	15/04/95
2.25						
2.75				5.00		
3.25	8.00			10.00	9.00	5.00
3.75	15.00			19.00	13.00	6.00
4.25	29.00	13 . 00	31.00	48.00	30.00	32.00
4.75	51.00	44 . 00	32 . 00	36.00	41.00	26.00
5.25	41.00	53 . 00	48.00	50.00	49.00	55 . 00
5.75	35.00	40 . 00	50.00	61.00	52.00	56.00
6.25	40.00	47.00	43.00	54.00	46.00	38.00
6.75	26.00	36.00	50.00	39.00	35.00	30.00
7.25	31.00	37.00	27.00	7.00	19.00	12.00
7.75	26.00	22.00	13.00	1.00	17.00	10.00
8.25	11.00	17.00	6.00		12.00	6.00
8.75	6 . 00	16.00	5 . 00		13 . 00	2.00
9.25	6.00	7.00	2 . 00		8.00	
9.75	3.00	3 . 00	1.00			
10.25	2.00	2 . 00	1.00			
10.75						
um	330.00	337.00	309.00	330.00	344.00	278.00

ML\DATE	15/05/95	15/06/95	15/07/95	15/08/95	15/09/95	15/10/95
2.25						
2.75					4.00	
3.25	5 . 00		6.00		10.00	
3.75	11.00	19 . 00	10.00		9 . 00	16.00
4.25	18.00	27.00	22 . 00	14.00	17.00	35.00
4.75	35.00	25 . 00	41.00	49.00	31.00	42.00
5.25	49.00	47.00	47.00	52.00	34.00	48.00
5.75	46 . 00	53 . 00	49 . 00	71.00	37.00	52 . 00
6.25	47 . 00	36.00	52 . 00	52.00	37.00	40 . 00
G. 75	19.00	21.00	45.00	21.00	42 . 00	21.00

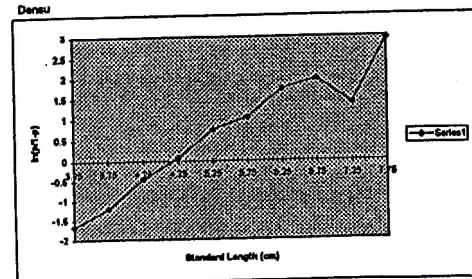
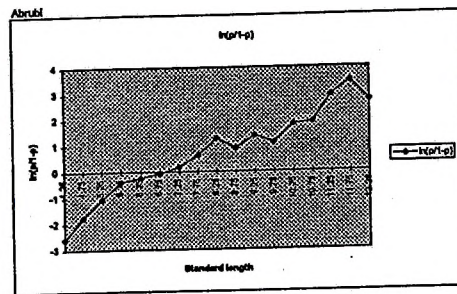
7.25	9.00	29.00	23.00	31.00	14.00	20.00
7.75	6.00	19.00	18.00	9.00	23.00	15.00
8.25	1.00	2.00	11.00	1.00	5.00	8.00
8.75				1.00	4.00	4.00
9.25					2.00	7.00
9.75					2.00	4.00
10.25					1.00	2.00
10.75						2.00
ium	246.00	278.00	324.00	301.00	272.00	316.00

ML\DATE	15/11/95	15/12/95	15/01/96	15/02/96	15/03/96	15/04/96
2.25						
2.75						
3.25	8.00			12.00		
3.75	15.00	4.00	9.00	40.00	18.00	5.00
4.25	42.00	20.00	20.00	33.00	41.00	20.00
4.75	51.00	25.00	25.00	51.00	46.00	45.00
5.25	61.00	63.00	38.00	59.00	51.00	50.00
5.75	46.00	47.00	34.00	63.00	43.00	37.00
6.25	38.00	38.00	42.00	31.00	26.00	34.00
6.75	21.00	35.00	39.00	30.00	24.00	35.00
7.25	7.00	19.00	25.00	11.00	14.00	11.00
7.75	10.00	19.00	16.00	8.00	7.00	11.00
8.25	10.00	14.00	7.00	5.00	7.00	15.00
8.75		1.00	5.00	3.00	5.00	6.00
9.25		4.00	3.00	2.00	2.00	
9.75		2.00	2.00	4.00	4.00	
10.25		1.00		2.00	4.00	
10.75					1.00	
ium	309.00	292.00	265.00	354.00	293.00	269.00
	7,125.00					

SLcm . (N)F	No.ripe	P/ripe	SLcm	P/ripe '1-p	p/1-p
4.25	28	2	4.25	0.07	0.930 0.075269
4.75	52	8	4.75	0.15	0.850 0.176471
5.25	110	29	5.25	0.26	0.740 0.351351
5.75	213	98	5.75	0.4	0.600 0.666667
6.25	386	220	6.25	0.44	0.560 0.785714
6.75	421	286	6.75	0.48	0.520 0.923077
7.25	543	385	7.25	0.54	0.460 1.173913
7.75	515	381	7.75	0.65	0.350 1.857143
8.25	519	404	8.25	0.78	0.220 3.545455
8.75	621	440	8.75	0.71	0.290 2.448276
9.25	604	483	9.25	0.8	0.200 4
9.75	396	297	9.75	0.75	0.250 3
10.25	314	270	10.25	0.86	0.140 6.142857
10.75	113	98	10.75	0.87	0.130 6.692308
11.25	80	78	11.25	0.95	0.050 19
11.75	21	20	11.75	0.97	0.030 32.333333
12.25	18	17	12.25	0.94	0.060 15.666667
12.75	6	6	12.75	1	0.000 0
13.25	2	2	13.25	1	0.000 0

The percentage of sexually mature female *Sarotherodon melanotheron* from Densu delta, May 1994- April 1996

SLcm (N)F	No.ripe	P/ripe	SLcm	P/ripe	1-p	P/1-P
2.25	2	0	2.25	0	1.000	0
2.75	18	0	2.75	0	1.000	0
3.25	70	11	3.25	0.16	0.840	0.190476
3.75	188	43	3.75	0.23	0.770	0.298701
4.25	420	163	4.25	0.39	0.610	0.639344
4.75	589	306	4.75	0.52	0.480	1.083333
5.25	831	565	5.25	0.68	0.320	2.125
5.75	724	535	5.75	0.74	0.260	2.846154
6.25	513	436	6.25	0.85	0.150	5.666667
6.75	486	427	6.75	0.88	0.120	7.333333
7.25	273	218	7.25	0.8	0.200	4
7.75	193	183	7.75	0.95	0.050	19
8.25	96	96	8.25	1	0.000	0
8.75	62	62	8.75	1	0.000	0
9.25	38	38	9.25	1	0.000	0
9.75	21	21	9.75	1	0.000	0
10.25	8	8	10.25	1	0.000	0
10.75	1	1	10.75	1	0.000	0



App. 7.3 **Mean monthly weight of *Sarotherodon melanotheron* , May 1994- April 1996**

Abrubi			Densu delta		
Month	Weight(g)	N	Month	Weight(g)	N
May'94	14.87	238	May'94	0.78	110
Jun	15.56	262	Jun	3.09	263
Jul	22.01	299	Jul	1.5	325
Aug	16.26	331	Aug	3.58	259
Sep	18.66	367	Sep	1.94	307
Oct	11.53	389	Oct	2.05	414
Nov	11.8	300	Nov	3.07	330
Oec	14.92	292	Dec	6.66	337
Jan'95	17.71	316	Jan'95	5.28	309
Feb	12.96	377	Feb	1.81	330
Mar	9.5	422	Mar	3.02	344
Apr	12.89	332	Apr	3.14	278
May	17.7	327	May	2.9	246
Jun	16.94	275	Jun	3.65	279
Jul	20.93	270	Jul	3.28	324
Aug	20.62	260	Aug	5.31	301
Sep	12.95	292	Sep	1.97	272
Oct	8.32	360	Oct	4.07	316
Nov	8.3	333	Nov	2.71	309
Dec	14.84	280	Dec	5.24	292
Jan'96	15.95	311	Jan'96	4.65	265
Feb	16.46	319	Feb	2.47	354
Mar	8.62	339	Mar	3.69	293
Apr	16.23	341	Apr	4.7	269