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Classification of artisanal fisheries métiers in Ghana: A case study of the Central region.

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DEDICATION

This thesis is dedicated to my parents, Mr. David Bampoe and Miss Christiana Hammond, in honour of their love, toil and dedication and to my fiancé, Alexander Opoku-Acheampong for spurring me on to higher heights. I love you all so much!

ABSTRACT

The management of multi-species fisheries is usually challenging because of the high number of fleets and gears targeting numerous species. In recent times, the concept of metiers has been used to enable further understanding of spatio-temporal variation of species and behaviour of fishers. In the present study, an output-based approach (i.e. the use of landing data) was used to identify potential metiers in the artisanal fisheries of the Central region of Ghana. The landing data was over a five-year period – 2004-2008 and based on species caught by five main gears, namely *Ali-Poli-Watsa* (a type of purse seine net), beach seine, drift gill net, hook and line and set net gears. Multivariate analyses, namely Canonical Correspondence Analysis, Redundancy Analysis (RDA) and Generalized Additive Models (GAM) – were used to analyze catch per unit effort (CPUE) and revenue per unit effort (RPUE) on yearly and monthly basis respectively. The environmental variables used in the multivariate analyses were gear, year, month and temperature. It was observed that changes in catch and revenue rates followed seasonal patterns, with some gears recording their maximum revenue rates in the second semester of the year. Initially, three major gear groups were identified. Subsequent analyses led to the generation of two models – prey-gear niche and niche timeline – to further explain the interactions of the various gears across months and the implications of these to fisheries management was discussed. The results from the multivariate analyses were supplemented with data obtained from interviews of fishers in Winneba fishing community. It was observed that even though fishers had high fidelity to particular gears during fishing seasons, they sometimes diversified their target species. Lack of an alternative occupation to fishers threaten their livelihoods, thus it was recommended that fisheries managers or scientists explore ways of enhancing the resilience of fishers.

TABLE OF CONTENTS

List of Tables

List of Figures

List of plates

CHAPTER ONE

1.0 INTRODUCTION

Fishing has been a major economic mainstay for most Ghanaians, particularly those living in coastal areas. In terms of labour occupation, fishing is second to farming and trading in Ghana (Lawson & Kwei, 1974). Even though the Food and Agriculture Organization (FAO) (2010) identifies only three fishery sectors – industrial, semi-industrial and artisanal, Ghana's marine fishery is classified into four major sectors, namely industrial, semi-industrial, artisanal and tuna (Amador et al., 2006). Of these four sectors, the artisanal sector constitutes a major part (about 70-80%) of the national fish production. The activities of this sector are thus of major importance to the nation, and for an effective resource management to take place, a good knowledge of its aquatic biota, habitat and human users of the resources is required (Lackey, 2005).

Artisanal fisheries are often complex by virtue of the fact that they involve spatial and temporal changes in their exploitation, variation in gears and target species as well as changes in fishing patterns and fish supply (Tzanatos et al., 2005). This often poses a challenge to the monitoring and management of this sector (*ibid*). In order to incorporate these characteristics into current management schemes, the concept of métier can be adopted. According to Mesnil and Shepherd (1990), *a métier is a coherent functional entity in terms of vessel type and size, gear, target species, spatial and temporal fishing pattern, which can be summarized by a consistent array of catchabilities by species and ages.* A métier-based approach will aid in stratified sampling survey designs and in the understanding of spatio-temporal patterns in the allocation of fishing effort (Tzanatos et al., 2006).

1.1 JUSTIFICATION

There are about 334 artisanal fishing centers existing along the 539 km coastline of Ghana, where over a hundred thousand people find their full-time or part-time employment (Amador et al., 2006). Due to its contribution to food supply and employment, artisanal fisheries have been a focus of current fisheries research in Ghana. For instance, Marquette et al. (2002) undertook a study on Moree (a fishing community[1] in the Central Region) in order to establish a link between population growth, fisheries resource and fishing activities. Their results showed a complex link existing among these factors that may be a factor defining how fisheries resources are exploited by fishers. Ninsin (1991) investigated the effect of technology and social changes on the economy and structure of Mumford fishing community. He found out that the adoption of modern technology, i.e. modernization of inshore vessels in Mumford, led to significant changes such as credit and indebtedness, social re-stratification, decline in formal education and social consciousness.

Fishers are usually driven by their need for food as well as employment (income) and will always seek to meet these needs when utilizing the marine resources. Therefore, having knowledge about motivations, behavior and attitude of fishers is important for the assessment and management of a fishery (Jennings et al., 2001). In order to understand fishers' behavior, a study to identify and/or characterize métiers needs to be carried out as has been done in Greece (Tzanatos et al., 2006) and France (Marchal, 2008). The present study was conducted in that regard so as to build on the already-mentioned studies.

1.2 OBJECTIVES OF THE STUDY

The specific objectives of this study were:

- To analyze landing or catch statistics from the Marine Fisheries Research Division (MFRD), Ministry of Fisheries to identify possible métiers existing in the Central region; and
- To evaluate and classify métiers according to their activity patterns, production and revenue

Some relevant questions to help achieve these objectives are: Are fishers tied to a specific gear or métier? Do they change métiers in the course of a season or year? If not, are there

[1] Fishing community: a community that is substantially dependent on, or engaged in, the harvest or processing of fisheries resources to meet social and economic needs; the fishing vessel owners, operators, crew and fish processors based in such a community (http://stats.oecd.org/glossary/detail.asp?ID=993; accessed on 03/12/2010)

high and low fishing seasons? Do they revert to other occupations in periods of low catch or do they stay idle?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 OVERVIEW OF MARINE FISHERIES IN GHANA

The length of Ghana's coastline is about 536 km (Mensah et al., 2006) with a continental shelf, ranging from 20-90 km in width (Amador et al., 2006). The country is divided into ten administrative regions, four of which are coastal, namely Volta, Greater Accra, Central and Western regions. Fishing is a popular economic activity in these four regions. The fisheries sector contributes approximately 3.9% and 11% of the national and agriculture gross domestic product (GDP), respectively [Ghana Statistical Service (GSS), 2008 budget cited in Asiama et al. 2008]. Currently, the average per capita fish consumption ranges from 20 to 25 kg (Amador et al., 2006). Fisheries serve as a major source of food (protein), employment and foreign exchange to the nation (Mensah et al., 2006).

2.1.1 GHANA'S MARINE FLEET STRUCTURE

Ghana's marine fishery is classified into four major sectors, namely artisanal (canoe), semi-industrial (inshore), industrial, and tuna fishery (Amador et al., 2006).

Artisanal fishery:

This is by far the most diverse sector, in terms of gears used and species caught (Finegold et al., 2010). The dug-out canoe is the main fishing vessel used. It is mainly constructed from a single log of wood of the tree species *Triplochiton scleroxylon* (locally known as *wawa*) and *Ceiba petandra* (locally known as *onyina*) (Amador et al., 2006; Doyi, 1984). Based on the size and gears deployed, the artisanal fleet has been further divided into three groups:

- *Small-sized (one-man) canoes:* These are usually 4-5 m long and 0.4-0.5 m wide, mainly propelled by paddles (Doyi 1984). They are used to operate cast nets (in lagoons) and bottom hand lines and long lines (in inshore waters).

- *Medium-sized canoes:* These are 6-11 m long and 0.7-1.0 m wide, mostly propelled by sails, paddles and outboard motors (*ibid.*).

- *Large canoes:* These are 12-18 m long and 1.3-1.8 m wide, usually propelled by outboard motors (*ibid.*). There are two groups of large canoes – *Ali-Poli-Watsa* and beach seine canoes; these names are based on the gears used by these two groups; *ali* is a type of gill net whereas *poli* and *watsa* are types of purse seine nets (Finegold et al., 2010). The *Ali-Poli-Watsa* canoes are the larger of these two groups (*ibid.*). The beach seine canoe has an unusual long bow to prevent breaking waves from entering it while in operation (Doyi 1984).

Semi-industrial fishery:

This fleet comprises of locally-built wooden vessels, ranging from 8-37 m in length (Mensah et al., 2006). They operate purse-seine and bottom trawlers depending on prevailing environmental conditions; the purse-seine is used during upwelling season and bottom trawlers in the non-upwelling season (*ibid.*). By virtue of the gears they use, this fleet targets both pelagics and demersal fishes.

Industrial fishery:

This fleet consists of large, foreign-built steel trawlers, tuna bait-boats (discussed briefly in next paragraph), shrimpers and purse-seiners mostly targeting demersal fishes (*ibid.*). Unlike the afore-mentioned fleets, these vessels are usually equipped with cold storage (freezing) facilities and thus are able to stay longer at sea.

Tuna fishery:

This fishery targets tuna by the use of a host of gears such as the pole and line. Until 1973, the fishery was exploited by foreign-owned vessels (Finegold et al., 2010). The tuna caught are predominantly for export and the main species exploited are skipjack tuna (*Katsuwonus pelamis*, Linnaeus 1758), yellowfin tuna (*Thunnus albacares*, Bonnaterre 1788) and big eye tuna (*T. obesus,* Lowe 1839) (Acquay, 1992).

2.1.2 GEAR COMPOSITION OF THE ARTISANAL FISHERY

A host of fishing gears is deployed by the artisanal fishery and they include seine nets, gill nets, cast nets, traps and hooks and lines (Doyi, 1984).

- *Seine nets:* These are active gears used to surround schools of fish or to sweep an area of the seabed close to inshore. There are two groups of seine nets: beach seine (those operated from the shore) and purse-seine nets (characterized by a purse line at the bottom of the net, which aids in closing the net in order to retain caught fishes). Beach seines usually target both small pelagic and demersal species with affinity to the surf zone such as anchovy (*Engraulis encrasicolus,* Linnaeus 1758), bigeye grunt (*Brachydeterus auritus,* Valenciennes 1832), West African ilisha (*Ilisha africana,* Bloch 1795), lesser African threadfin (*Galeoides decadactylus,* Bloch 1795), round scad (*Decapterus punctatus*, Cuvier 1829) and Crevalle jack (*Caranx hippos,* Linnaeus 1766).

  The purse seine is of three types, namely *ali*, *poli* and *watsa* nets, targeting mostly small pelagics, particularly sardinella (*Sardinella* spp.) and anchovy (*Engraulis encrasicolus*). The main body of the *ali* net is a gill net, constructed with 25-30 mm netting and its bunt with 12 mm netting; the *poli* net is constructed with 13 mm mesh and fine yarn R75-100 tex[2]; and the *watsa* net, which was originally without purse line and rings, has now been modified to include these in addition to small netting.
- *Gill nets:* These are long curtains of netting into which fishes swim and become caught or entangled by their gills. The three main types are set, drifting and encircling gill nets. They are used in the capture of both pelagic and demersal species since they are usually deployed at the surface, mid-water and bottom of the water column.
- *Cast nets:* These are conical nets, often thrown from the shore or a canoe to catch fish by falling on them. In Ghana, two types of cast nets are used – those without pockets and those with pockets.
- *Traps:* These are usually made from materials such as wood, netting, bamboo, palm fronds and metals. They vary in shapes and forms, catching both shell- and fin-fishes.

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[2] Tex: unit measure of fibre (g/1000m). http://en.wikipedia.org/wiki/Units_of_textile_measurement#Tex. Accessed on 14/04/2011.

- *Hooks and lines:* This gear uses natural or artificial baits, placed on hooks affixed to the end of a line, to attract fish. The most common types include hand line, trolling line and long line. They are commonly used to catch demersal fishes such as sea breams (*Dentex* spp., *Sparus* spp.), snappers (*Lutjanus* spp.) and groupers.

2.2 FISHERIES AS A SOURCE OF LIVELIHOOD TO COASTAL COMMUNITIES

Livelihood, as defined by WordWeb dictionary[3], is *the financial means whereby one lives*. In fisheries, the concept of livelihood has been recently adapted to help understand the main factors affecting the vulnerability or strength of individual or family survival strategies (Allison & Ellis, 2001). This approach is characterized by three components, namely livelihood activities (things people engage in to make a living); vulnerability context (risks involved in the pursuit of making a living); and policy and institutional context (structures that promote or hinder access to resources and activities) (Ellis & Allison, 2004). A defining principle of the livelihood approach is that poverty policy should focus on maximizing the utilization of assets of poor individuals or households (*ibid.*). The approach incorporates terms like vulnerability, sustainability, resilience and sensitivity in classifying livelihood systems (Allison & Ellis, 2001). Vulnerability is a measure of how prone a system is to external threats (*ibid.*); sustainability is the ability of a system to retain its productivity in the face of major shocks or stresses (Conway, 1985 cited in Allison & Ellis 2001); resilience is the ability of a livelihood system to recover from stress or shocks; and sensitivity is the magnitude of the response elicited by a system as a result of an external disturbance (Allison & Ellis, 2001). Thus, a robust system exhibits high resilience and low sensitivity whereas a vulnerable one exhibits low resilience and high sensitivity (*ibid.*).

A much broader concept is the 'Sustainable Livelihood Approach', which seeks to provide understanding to the multi-dimensional nature of poverty affecting fishing communities, based on the premise that other socio-institutional factors, other than those related to the catch, may equally lead to poverty (Béné, 2006). According to Bennett (n.d.), poverty in fishing communities arises as a result of:

[3] WordWeb dictionary software available at http://wordweb.info/

- Uneven distribution and access to wealth (in terms of access to means of production and credit);
- seasonal and long-term variation in fisheries resources, especially pelagic stocks;

In Ghana, the aim of government fisheries policies has been to increase fish production for both local consumption and export while alleviating poverty in fishing communities (Seini et al., 2002). This is due to the large number of people involved in this sector. Besides fishing, other fishing-related activities take place in rural or fishing communities of Ghana. These include boat-building, net mending, fish handling and processing, fish selling and sale of fishing inputs and thousands of people are engaged in them. Seini et al. (2002) estimates the number of people secondarily related to fishing at 1.5 million. Consequently, a change in the fishing activity or strategies affects these related activities and the community as a whole (Béné, 2006).

Poverty alleviation in artisanal fisheries involves poverty reduction (relieving people from poverty through mechanisms such as wealth generation and capital accumulation) and poverty prevention (preventing people from falling deeper into poverty through risks reduction and creation of safety-net mechanisms) (*ibid.*). Fisheries acts as a safety-net mechanism by serving as an alternate or additional source of income, employment and food for households in times when the capacity of other sources is threatened (*ibid.*).

The recent decline in fish stocks in Ghana undermines the capacity of the marine fishing industry in alleviating poverty (Mensah et al., 2006). According to Atta Mills et al. (2004), developments such as mechanization of the fishing industry, increased number of European fleets and Exclusive Economic Zone (EEZ) declaration by neighbouring countries have affected the output of Ghana's fishing industry. The number of canoes as well as the number of fishers has been increasing (Figure 1). Finegold et al. (2010) estimated the current number of canoes to be about 13,500. They attributed this increase to fuel subsidies, population pressure and lack of alternate opportunities for livelihood diversification.

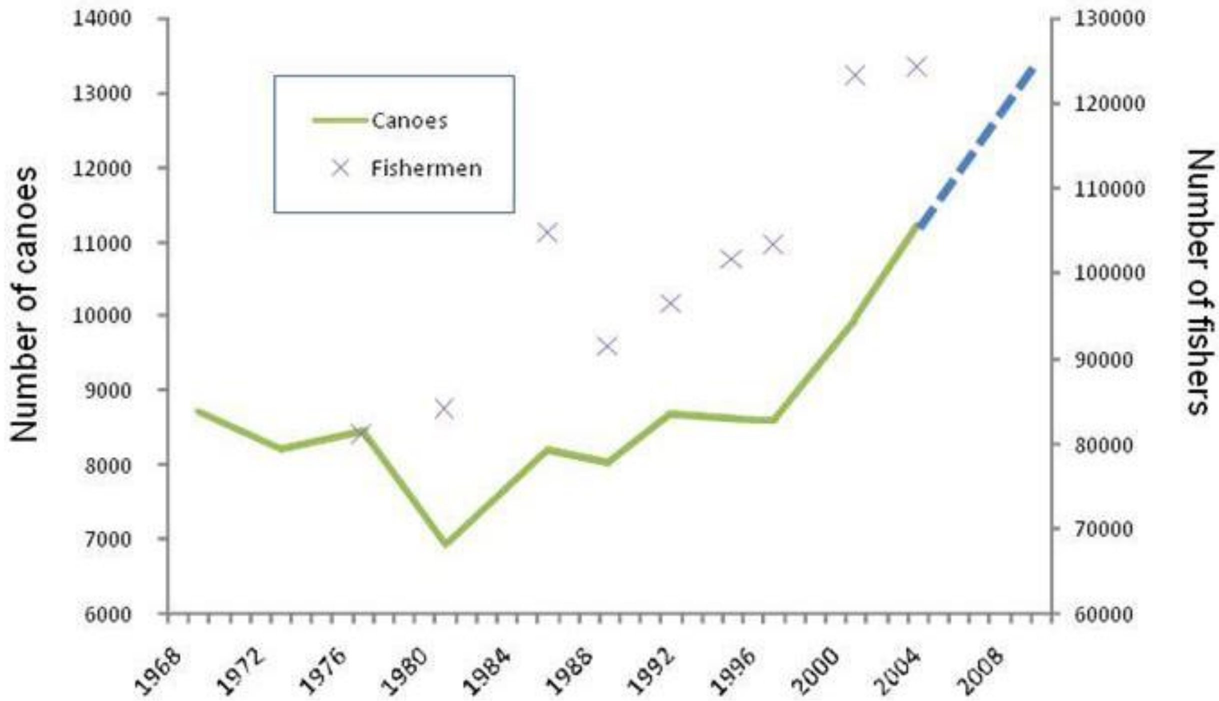

Figure 1: Number of canoes and canoe fishers in Ghana from 1969 to 2008; dashed line represents a projection until 2010 [Adapted from Finegold et al. (2010)].

2.3 THE CONCEPT OF MÉTIERS IN FISHERIES

The fisheries sector continues to be a target of various researches due to the role it plays in the nation's economy. Due to the unpredictable nature of fisheries, fishers are constantly seeking novel ways or strategies of exploiting the resource. The problems of managing multi-species or mixed fisheries stems from the fact that various species are caught in the same area by a variety of fleet or gears (Pelletier & Ferraris, 2000). It is proposed that effective management can be achieved if attempts to understand the behavior guiding fishing practices of fishers are made. In order to do this, the concept of métier has been adopted (*ibid.*). A métier is a group of fishing operations characterized by types of gear, target species, fishing area/ ground and season (Katsanevakis et al., 2010; Tzanatos et al., 2006). The identification of métiers is considered as a first step in studying the link between total fleet effort and mortality of exploited stocks since fishing operations affect stocks in various ways (*ibid.*).

Tzanatos et al. (2006) identified métiers of small-scale fisheries in the Patraikos Gulf of the Mediterranean Sea, using landing data of 144 fishing trips between August 2004 and July 2005. Variables used included catch weight, income and target species. A total of twelve métiers were classified and it was found out that most fishing operations of these métiers coincided with the spawning season of target species. This finding will aid in the management of stocks in that area. In a similar study, Katsanevakis et al. (2010) used landing profile over a five-year period (2002 – 2006) to classify potential métiers for boat seine fishery in Greek territorial waters. They identified a total of nine (9) métiers – five (5) in the Aegean and four (4) in the Ionian Seas respectively. In a related study, Marchal (2008) compared métiers and catch profiles for some French demersal and pelagic fleets. His study showed that there is a link between métiers and catch profiles and that the ability to predict this link depended on fleet type. For instance, gill net and pelagic fleets gave better forecasting scores than the bottom trawl fleet, implying that it is relatively easier to predict métiers from catch profiles of pelagic fleets than it is for bottom trawl fleets.

2.3.1 METHODS USED TO CLASSIFY MÉTIERS

Even though métiers should determine fishing intention at the start of a fishing trip, there are cases where fishing intentions can be indirectly determined from catch profiles from fishing trips (Marchal, 2008). The methods used so far in the identification of métiers can be classified as (*ibid.*):

- Input-based: involves the use of existing data from log books (e.g. gear and mesh size used, fishing grounds visited and season) or direct interviews from stakeholders;
- Output-based: involves the use of catch profiles on the assumption that they reflect fishing intention. Methods under this group include selecting key species based on a certain catch proportion, conducting multivariate analysis of catch profiles and then further classifying fishing trips of similar catch profiles into métiers;
- Combined methods: As the name suggests, this group involves the use of both input- and output-based methods.

Many characteristics define fishing operations and it will be important to consider them in entirety in the identification of métiers. Pelletier and Ferraris (2000) propose a two-step approach to analyze catch and effort data – i) identifying species composition from catch data and ii) fishing tactics from both catch and effort data. They further suggest the use of multivariate analyses, which reduce large data sets by accounting for both quantitative and qualitative (categorical) variables. Examples of multivariate analyses include cluster analysis, principal components analysis (PCA), two-way correspondence analysis (TWCA) and multiple correspondence analysis (MCA) (*ibid.*).

Most of the studies on métiers so far have used cluster analysis to identify and classify métiers (Katsanevakis et al., 2010; Marchal, 2008; Tzanatos et al., 2006). Tzanatos et al. (2006) applied hierarchical agglomerative cluster (HAC) analysis (based on Ward's minimum criterion method) to a presence-absence matrix of fishing operations by target species of longlines and trammel nets; Marchal (2008) used clustering based on Ward's minimum variance criterion for French demersal and pelagic fleets; and Katsanevakis et al. (2010) applied both HAC analysis, based on Euclidean distances and Ward's minimum variance criterion and principal components analysis (PCA) based on the covariance matrix to landing profiles.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 THE STUDY AREA

The study was based on the Central region of Ghana (Figure 1). The region has a surface area of 9,826 km^2 and a current population of 2,107, 209 (approx. 8.7% of total population of the country) (GSS, 2011). It is the second most populous region with a current population density of 217 persons/ km^2 and an estimated population growth rate of 2.7% per annum (*ibid.*).

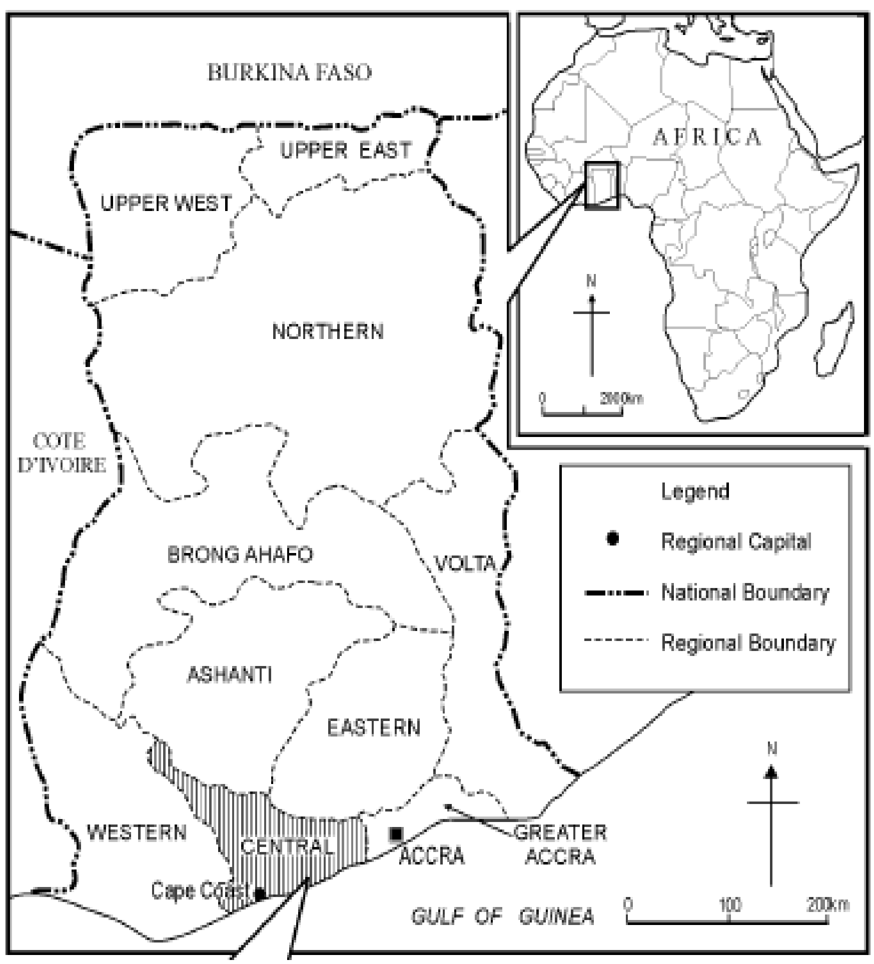

Figure 2: Map of the study area [Adapted from Mensah (2005)]

The regional capital is Cape Coast and there are seventeen (17) metropolitan, municipal and district assemblies (MMDAs) in this region[4]. Agriculture (including fishing) is the dominant occupation (Mensah, 2005). Out of a total of 124,219 fishermen recorded in the 2004 Canoe Frame Survey, about 35.7% (44,303) is from the Central region with a total number of 4,545 canoes (Amador et al., 2006). Thus, this region is important in terms of its contribution to fisheries in Ghana.

3.2 DATA SET

The research was based on both primary and secondary data. The primary data was obtained from structured interviews while the secondary data was obtained from the Marine Fisheries Research Division (MFRD) of the Ministry of Fisheries (Ghana). The data obtained from MFRD comprised of:

- daily sea surface temperature (2004 – 2008) taken from Winneba station and
- landing data from (2004 – 2008) comprising of fish catch (in kg), effort (in days) and average first-hand price [in Ghana cedi (GH¢)/ kg].

Both the daily sea surface temperature (SST) and landing data were available in Excel spreadsheets. The landing data comprised of annual summaries on national marine fish production disaggregated by gears, regions and districts.

Other secondary sources of data used included published journals and documents.

3.3. RESEARCH AND DATA COLLECTION TOOLS

Structured interview schedules (copy found in Appendix 2) were used to obtain information from forty fishers in Winneba. Winneba is the capital of the Awutu-Effutu-Senya (AES) district in the Central Region. It was chosen because it is one of the most important coastal districts in the region and also for logistic reasons. Another reason was the fact that the researcher had some

[4] http://ghanadistricts.com/region/?r=3. Accessed on 14/04/2011

prior contact persons in the district to help follow up on certain aspects, should they not be finished by the stipulated fieldwork period.

Due to short timeline, respondents' selection was based on availability and willingness to participate in the interview. Before they were administered, the interview schedules were pretested and modified. The interviews were used to elicit information such as personal details, fishing activities, fishers' knowledge on the fishery and management measures, costs involved in fishing and access to funds (Plates 1 & 2). A total of forty fishers were interviewed and in order to facilitate the process, four evaluators assisted in conducting the interviews. Before going through the interview schedules with the fishers, the purpose of the study as well as other vital information were explained to them, while emphasizing on the confidentiality of information they provided. This was necessary since initially, some of them shied away because they assumed evaluators were government officials, who could use the information they provided against them.

Trips to the fishing sites were usually made on Tuesdays since most fishers in Ghana do not go fishing on this day. Prior to the field study, the Municipal Fisheries Officer for Winneba, Mr Anthony Appiah, was consulted and the researcher's intentions made known to him.

Plate 1: Researcher interviewing a fisher (In the background are other fishers preparing their gears for the next fishing activity)

Plate 2: An evaluator interviewing a fisher while he mends his gill net

3.4. DATA ANALYSIS

The landing data for Central region was extracted from the entire data set of Ghanaian artisanal fisheries for 2004-2008 and entered into Microsoft (MS) Excel. The names of constituent fish species, which were originally in both English and local names, were converted to scientific names with the aid of identification guide provided by Kwei and Ofori-Adu (2005) and FishBase (Froese & Pauly, 2011). Naming was done to the species taxonomic level; however fish names not clearly distinguishable were classified to the family or genus level. Species were then given a three-letter code using the first letter and first two letters of their genus and species names respectively (Appendix 1). For species with family or genus names only, the first three letters of either name was used.

Catch per unit of effort (CPUE) was expressed as weight (kg) per effort day and revenue per unit of effort (RPUE) as GH¢ per effort day. In order to make revenue from 2004-2007 comparable with 2008, the average annual inflation factors were used to transform original price data into

2008 price equivalents (International Monetary Fund – 2010 World Economic Outlook) (IMF, 2010). The mean monthly and annual sea surface temperatures for all years were also tabulated in Excel.

Three matrices were initially developed for analysis: years by species in CPUE (25 rows x 72 columns), years by species in RPUE (25 rows x 72 columns); and dummy environmental variable (Gear) (25 rows x 5 columns). Five types of gears were used – *Ali-Poli-Watsa* (APW), beach seine (BS), drift gill net (DGN), hook and line (HL) and set net (STN). Each row comprised of year and this was replicated for each of the five gears, i.e. 5 gears x 5 years while each column also represented each fish species. The matrices were subjected to canonical correspondence analysis (CCA) using the statistical package for Canonical Community Ordination (CANOCO 4.5) (Ter Braak & Šmilauer, 2002). CCA is very appropriate in analyzing sparse multivariate data, thus making it suitable for the ordination of nominal responses. It is an example of a direct gradient method which relates species and sites to available environmental data (*ibid.*). CCA and other correspondence analysis methods are often useful when (Ter Braak & Verdonschot, 1995):

- relationships are unimodal;
- the data have positive values but many zeroes; or
- the data are compositional, i.e. relative values are relevant to the problem.

CCA yields a biplot (an ordination plot) showing approximate weighted averages of species (indicated by points) in relation to available environmental variables (indicated by arrows pointing in the direction of highest gradient) or triplots, which includes, in addition, the 'station' (years or months) data (Ter Braak & Šmilauer, 2002).

Redundancy analysis (RDA), another type of multivariate analysis, is performed in cases where the lengths of gradients of axes are shorter (i.e. < 3 standard deviations). Preliminary detrended correspondence analysis (DCA) performed on the RPUE data detected short lengths of gradients, thus RDA, rather than CCA, was used in the RPUE analysis. RDA differs from CCA in that it is a method of direct gradient analysis to model linear responses. It also results in biplots or triplots and these have the same interpretations as those obtained from CCA.

Standard options in the treatment of the observations were followed in CANOCO. The CPUE data was log-transformed [$\log_{10}(y+1)$] and standardized to a mean of zero and standard deviation of one to standardize their distributions. This was necessary as catches of different species spanned orders of magnitude. Rare species were also down-weighted to prevent undue distortions in analyses. The significance of the contribution of environmental variables to each CCA axis was tested by Monte-Carlo permutation test (at $\alpha = 0.05$) and forward selection option in CANOCO.

Subsequent matrices were generated for species per gear per year as well as per month in order to analyze variation in species occurrence. In these analyses, the environmental variables used were months and temperature (both average monthly and annual). The null hypothesis tested in all CCA is that there is no relationship between species data and environmental variables.

Finally generalized additive models (GAMs) were used to generate response curves for the important species (in terms of CPUE or RPUE) in each gear type in relation to environmental variables. GAMs are natural extensions of generalized linear models (GLMs) that use a smooth semi-parametric term to express the effects of predictor(s) on the response variables (Ter Braak & Šmilauer, 2002). The two main assumptions of GAMs are that functions are additive and components are smooth (Guisan & Edwards, 2002). A link function is used to establish the relationship of the mean of the response variable to the 'smoothed' function of the predictor(s) or environmental variables. The appropriate level of the 'smoother' for a predictor is best achieved by using the concept of effective degrees of freedom to specify the level of smoothing (*ibid.*). Unlike linear or polynomial GLMs, GAMs do not have a specific form and are thus suitable in situations where the shape of the response curve has to be determined by the observed data or where the assumptions for the shape of the response curve are being validated (Ter Braak & Šmilauer, 2002). GAMs were fitted using standard options in CANOCO version 4.5 and assuming a Gamma error distribution with log link function. The gamma error distribution has become frequently used in the analysis of CPUE data, owing to the difficult distribution of these brought about by frequent zeroes and few, but very large, catches (Arkhipkin et al., 2004; Damalas et al., 2007; Fraile et al., 2010; Maunder & Punt, 2004). For conformity with the previous analysis, a gamma error distribution was also assumed in the GAMs of total revenue per fishing (effort) day (RPUE) even though this continuous variable normally takes only positive values.

The significance of each response variable to the model was tested by a stepwise procedure using p-values based on F-tests, Chi-squared statistics and Akaike Information Criterion (AIC). The F-test and Chi-squared statistics (at $\alpha = 0.05$) were used to evaluate the significance of each added factor and the non-linear contribution of a non-parametric term, respectively (Damalas et al., 2007). The AIC value is based on residual deviance of the fitted model – the smaller the value, the better the model is able to predict values of the response variables (Ter Braak & Šmilauer, 2002).

In the analyses of data obtained from the administered questionnaires, the common species caught by the various groups of fishers as well as fishing seasons in which those species were caught were tabulated. Only species cited at least three times were considered. Other sections considered include fishing experience of fishers (in years), gear(s) used by fisher, time spent per fishing trip and share of catches.

CHAPTER FOUR

4.0 RESULTS

4.1 ANNUAL SERIES OF TOTAL CATCH, EFFORT AND REVENUE PER GEAR TYPE

Generally, there were fluctuations in total catch, effort and revenues in all gears over the years. Changes in 2008, be it an increase or decrease in total catch or revenue, were quite sharp. Even after the fish prices in 2004-2007, had been transformed to 2008 price equivalents, there was still a sharp difference between 2008 prices and the preceding years. However, this observation did not affect the values of annual total revenues greatly.

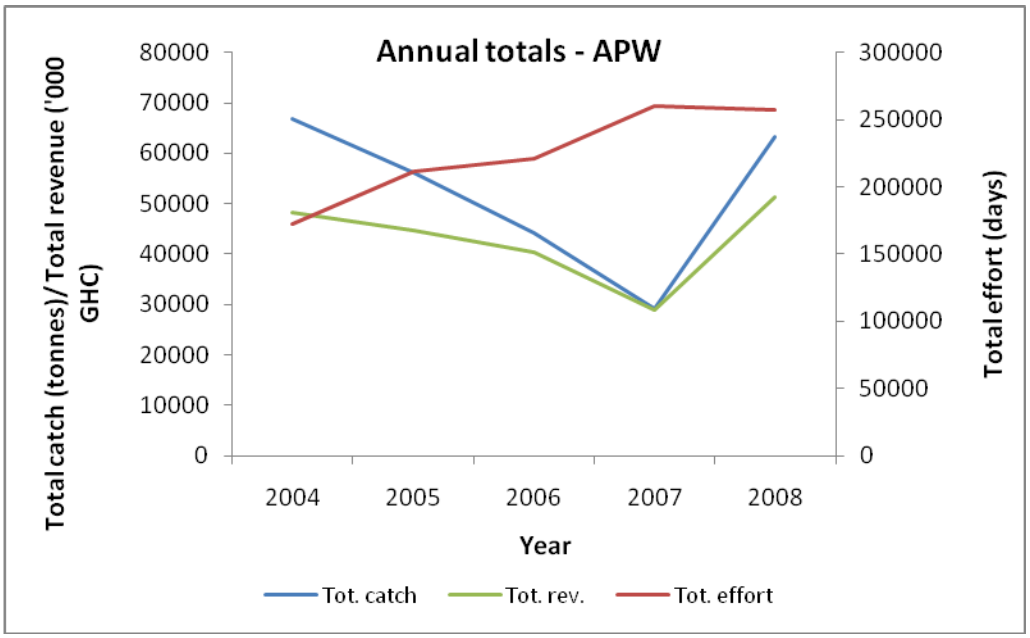

Figure 3: Annual trends in total catch (Tot. catch), effort (Tot. effort) and revenue (Tot. rev.) for *Ali-Poli-Watsa* (APW) gear

Ali-Poli-Watsa (APW):

This is the most important gear group in terms of landings and revenue, with annual landings in the Central region fluctuating between 30 and 70 thousand tonnes, for a total revenue variation between 30 and 50 million new Ghana cedi (GH¢[5]). In other words, the unit price of fish caught by this important gear fetches normally just under 1 GH¢/ kg, which makes it about an average price of fish in the region. There was a great decline in total catch and revenue from 2004 to 2007 simultaneous with increasing effort (Figure 3). This declining trend was, however, followed by a sharp increase in 2008. This gear group also has the largest effort input and this fluctuated between 150 and 270 thousand effort days with an increasing trend between 2004 and 2007; it stabilized, however, in 2008.

Beach seine (BS):

The beach seine group made a lower contribution to total catch (3-6 thousand tonnes) and revenue (2-5 million GH¢) in the Central region [Figure 4]. The annual effort also fluctuated between 25 and 35 thousand effort days.

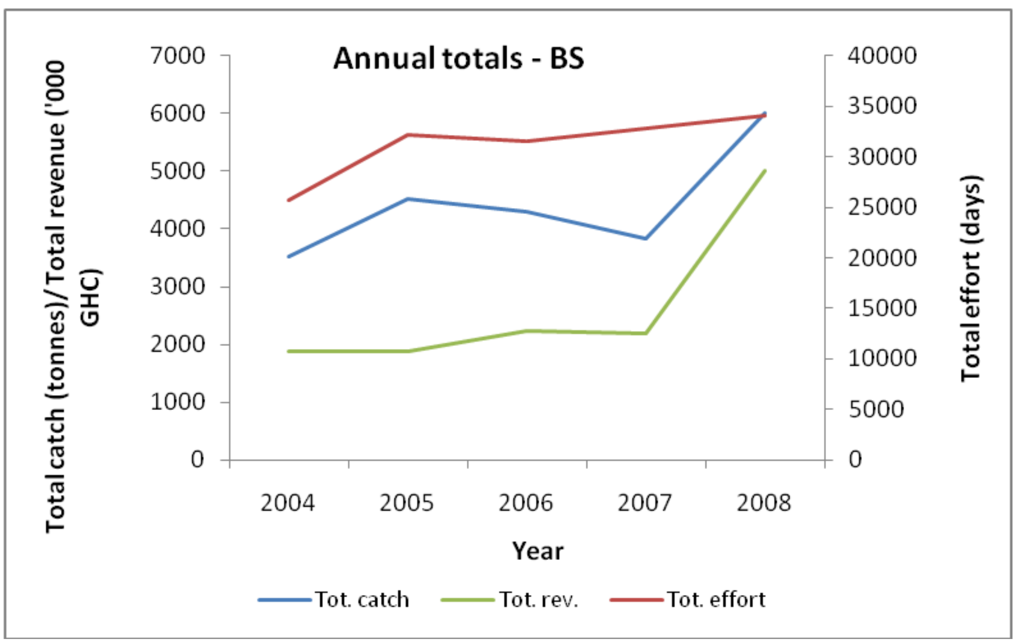

Figure 4: Annual trends in total catch (Tot. catch), effort (Tot. effort) and revenue (Tot. rev.) for beach seine (BS) gear

[5] 1 GH¢ = 0.783 USD = 0.559 € = 5.535 NOK as at 31st December, 2008 (http://www.oanda.com/currency/historical-rates/ Accessed on 28/04/2011).

The annual catch, effort and revenue were relatively stable between 2005 and 2007 but in the case of annual catch and revenue, there was a sharp increase in 2008.

Drift gill net (DGN):

Similar to catch trend observed in beach seine gear type, drift gill net did not account much for total catch in the Central region; its annual catch varied between 500 and 3,000 tonnes for a total revenue range of 1-5 million GH¢ (Figure 5). Total catch and revenue steadily increased from 2004 to 2007, sharply increasing in 2008. The annual effort fluctuated between 4-9 thousand effort days. Apart from 2005, which was characterized by a sharp increase, the annual effort remained fairly stable. The distance between the total revenue and total catch (Figure 5) indicates that the species caught with drift nets fetch, on average, higher unit prices than those of previous gears.

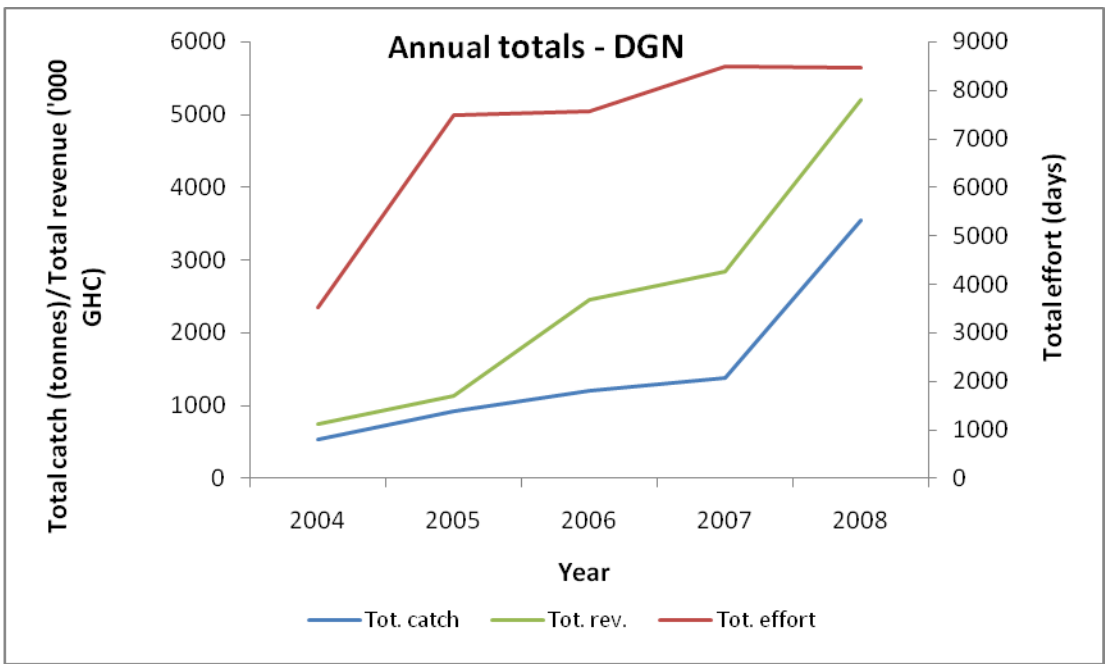

Figure 5: Annual trends in total catch (Tot. catch), effort (Tot. effort) and revenue (Tot. rev.) for drift gill net (DGN) gear

Hook and line (HL):

The annual landings fluctuated between 2-8 thousand tonnes with a corresponding total revenue between 4-12 million GH¢ (Figure 6) in Central region. With the exception of 2005 and 2008, the annual catch, effort and revenue had a declining trend. Annual effort ranged between 30-50 thousand effort days. Also for hook and lines, the species caught are in general valuable, as the line of revenues stands clearly above the line of catches (Figure 6).

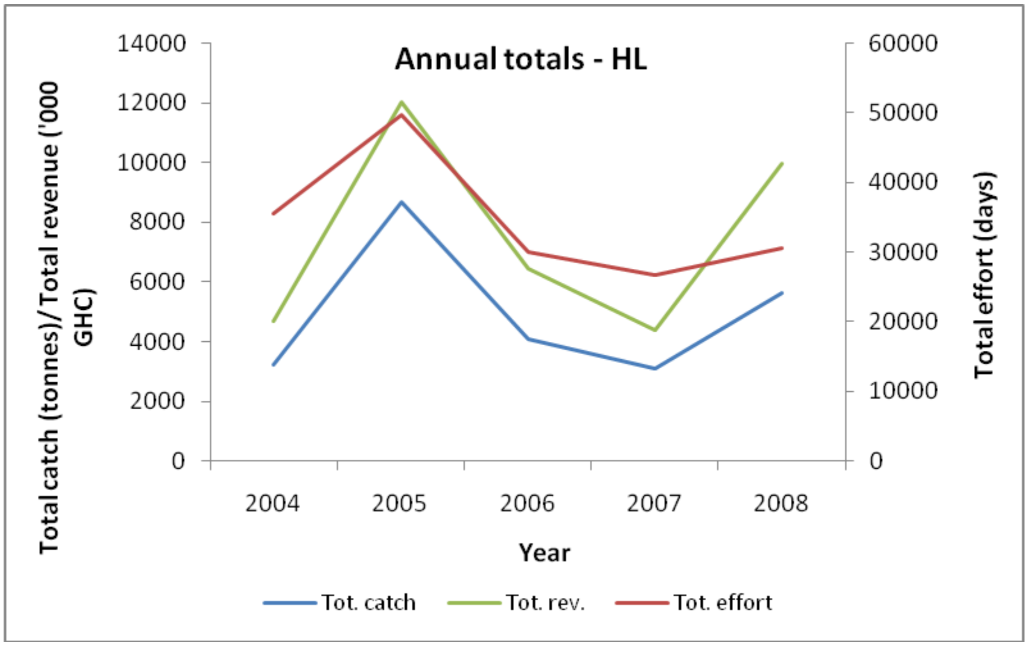

Figure 6: Annual trends in total catch (Tot. catch), effort (Tot. effort) and revenue (Tot. rev.) for hook and line (HL) gear

Set net (STN):

Though the set net gear group generally had relatively low contribution in terms of total catch (4-12 thousand tonnes) and revenue (2-10 million GH¢) to the Central region, it had a high effort input, fluctuating between 100-200 thousand effort days (Figure 7). Annual catch and effort had quite similar trends; both increased in 2005, decreased in 2006 and then shot up again in 2007. Annual effort had an increasing trend between 2004 and 2007 but decreased in 2008. This last year was also characterized by a decrease in total yield and effort. The species caught by this gear fetched in general lower prices relative to other gears and species.

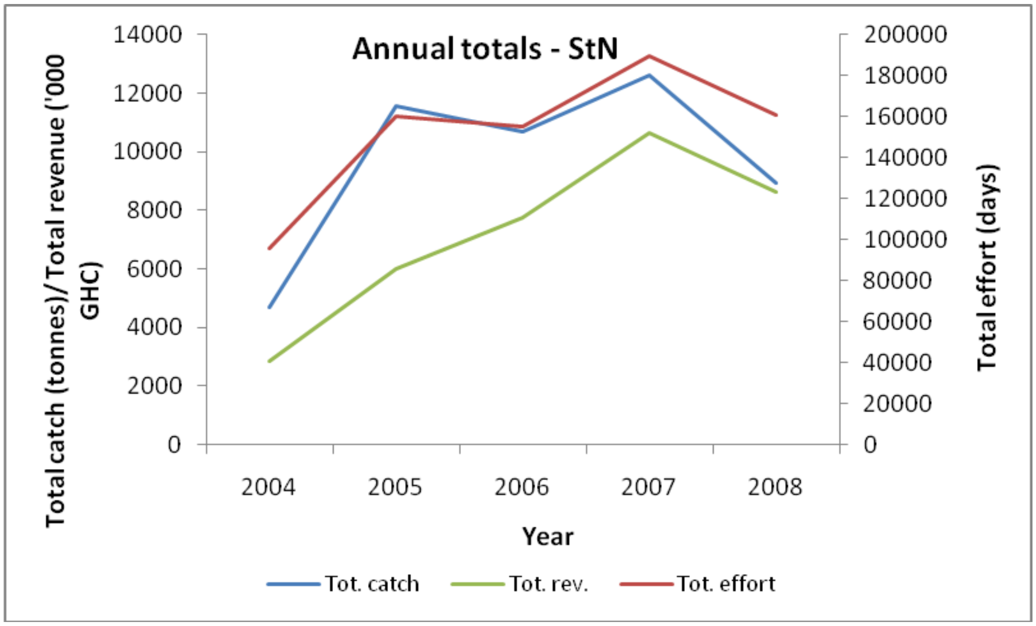

Figure 7: Annual trends in total catch (Tot. catch), effort (Tot. effort) and revenue (Tot. rev.) for set net (STN) gear

4.2. TRENDS IN TEMPERATURE ACROSS MONTHS AND YEARS (2004-2008)

The trends in monthly and annual mean temperature are shown in Figures 8 and 9. Monthly trends in all five years were somewhat similar; mean temperature fluctuated between 21.0 and 29.5 °C (Figure 8). Mean temperature was usually low (21.0-24.5 °C) between June and September and relatively high (25.0-29.5 °C) between January-April (except in 2004) and September-November. While the monthly seawater temperatures generally followed the same patterns, with a general cooling between June and September, the onset of this trend varied slightly among years. Further, in 2006 and, in particular, 2007 the average temperatures never reached the minima normally observed in the cooler season. This contributed greatly to them being considered warm years (Figure 9). In contrast, in 2005 remarkably low and high temperatures were observed, making it a warmer year than usual.

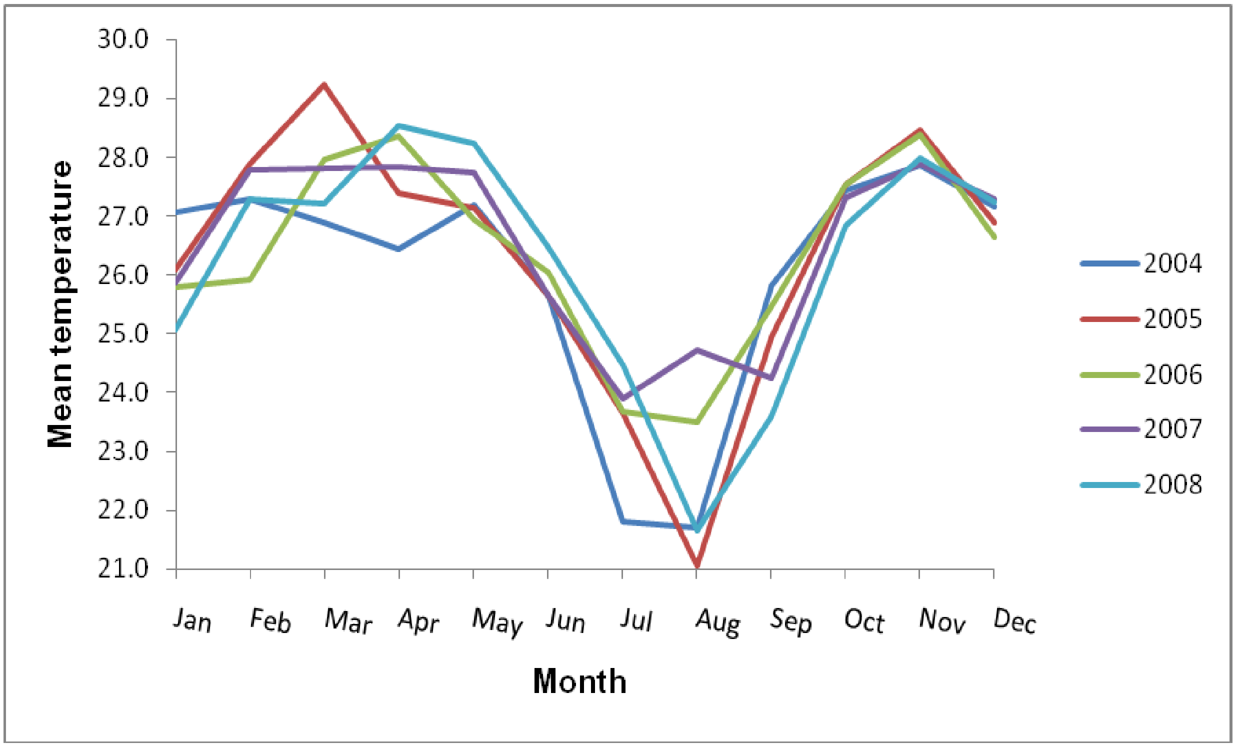

Figure 8: Monthly mean sea surface temperature from Winneba reading station (2004-2008)

Annual temperature fluctuated between 26.0 and 26.5 °C between 2004 and 2008 (Figure 8), with the highest (26.5 °C) observed in 2007. The lowest mean temperature was 26.2 °C and this occurred in 2004.

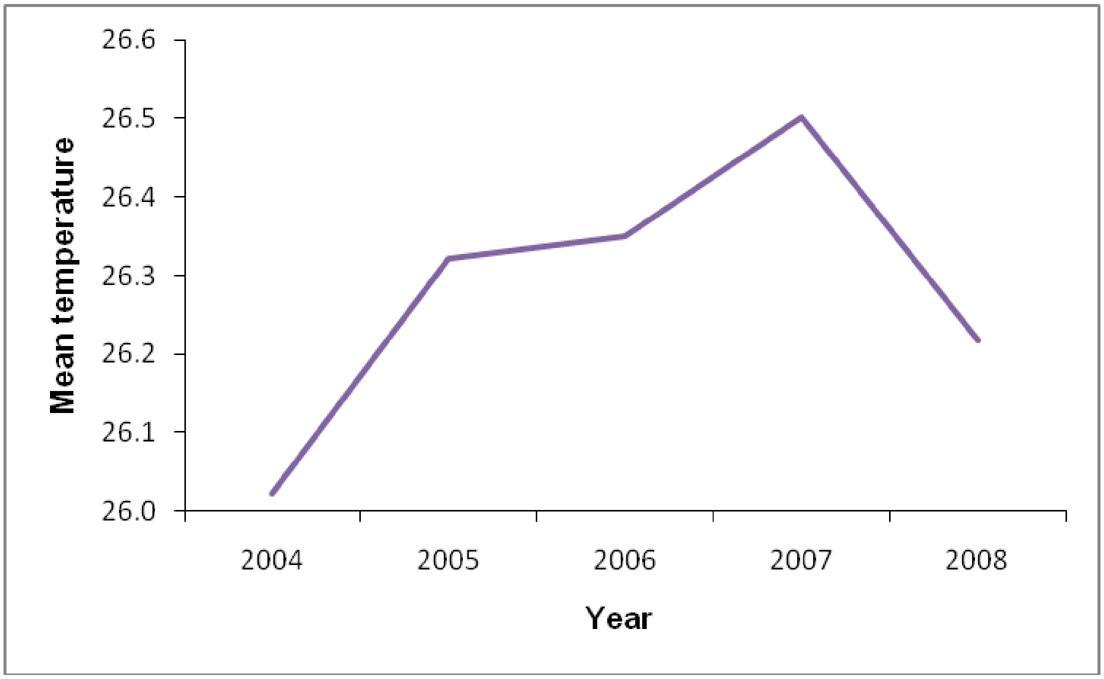

Figure 9: Annual mean sea surface temperature from Winneba reading station

4.3. GENERAL MULTIVARIATE ANALYSES OF CATCHES AND REVENUES PER GEAR TYPE DISAGGREGATED BY SPECIES (CANOCO)

4.3.1. Total catches (All gears)

A strong association existed between species and types of gear (the environmental variable), as clearly depicted in the biplot of total catches obtained in the canonical correspondence analysis (CCA) (Figure 10). Monte Carlo permutation tests (199 permutations) confirmed the significance of the species-gear association as well as for all four canonical axes (p = 0.005). The first two axes explained 50.1% and 71.5% of the variance in species data and species-environment relation respectively. The species showed different patterns of association with the five (5) main gears – hook and line (HL), drift gill net (DGN), set net (STN), *ali-poli-watsa* (APW) and beach seine (BS) along these two axes. A relatively good separation of species composition of the total catches was achieved between DGN and the other four gears along Axis 1, which explained 39.6% of the variance in species-environment relation. Like DGN, the species composition of HL seemed to be relatively specific, and this gear and its species contrasted with the remaining gears along Axis 2, which explained 31.9% of the variance in species-environment relation.

However, species caught by STN, APW and BS appeared to overlap. Species caught by the five gears can be mostly grouped into three guilds: small pelagics, large pelagics and demersals. The dominant ones in HL include *Parapristipoma octolineatum* (Valenciennes, 1833), *Dentex gibbosus* (Rafinesque, 1810), *Dentex congoensis* (Poll, 1954), *Lutjanus agennes* (Bleeker, 1863) and *Scomber japonicus* (Houttuyn, 1782); *Katsuwonus pelamis* (Linnaeus, 1758), *Euthynnus alletteratus* (Rafinesque, 1810), *Tetrapturus albidus* (Poey, 1860), *Makaira nigricans* (Lacepède, 1802) and *Istiophorus albicans* (Latreille, 1804) for DGN; *Priacanthus arenatus* (Cuvier, 1829), *Dasyatis margarita* (Günther, 1870), *Sardinella aurita* (Valenciennes, 1847), *Sphyraena sphyraena* (Linnaeus, 1758) and *Brachydeuterus auritus* (Valenciennes, 1832) for STN, APW and BS. Two pelagic fishes, *Thunnus albacares* (Bonnaterre, 1788) and *Coryphaena hippurus* (Linnaeus, 1758), were caught by both HL and DGN gears.

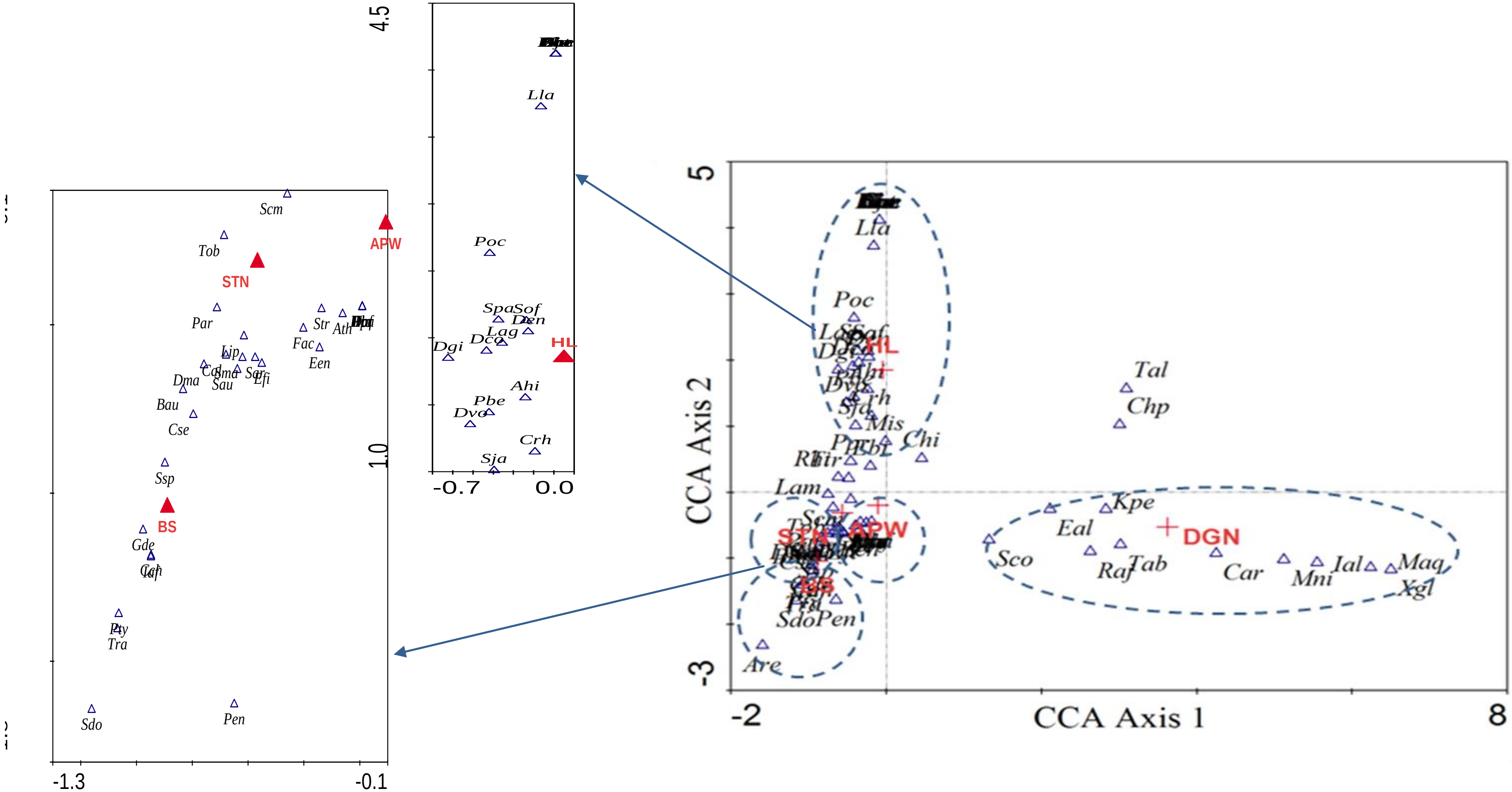

Figure 10: CCA biplot for the total catches (by species) of all five gears from 2004 to 2008. Only the first two axes, the most important, are depicted. Species codes are the first letter of the genus and first two letters of the species names (See Appendix 1 for full names and codes). Parts of the original axes plan are enlarged in the insets to aid visualization of the individual species. The five most important gears are labeled in bold red fonts (HL= hook & line, STN= set net, APW= *Ali-Poli-Watsa*, BS= beach seine and DGN= drift gill net).

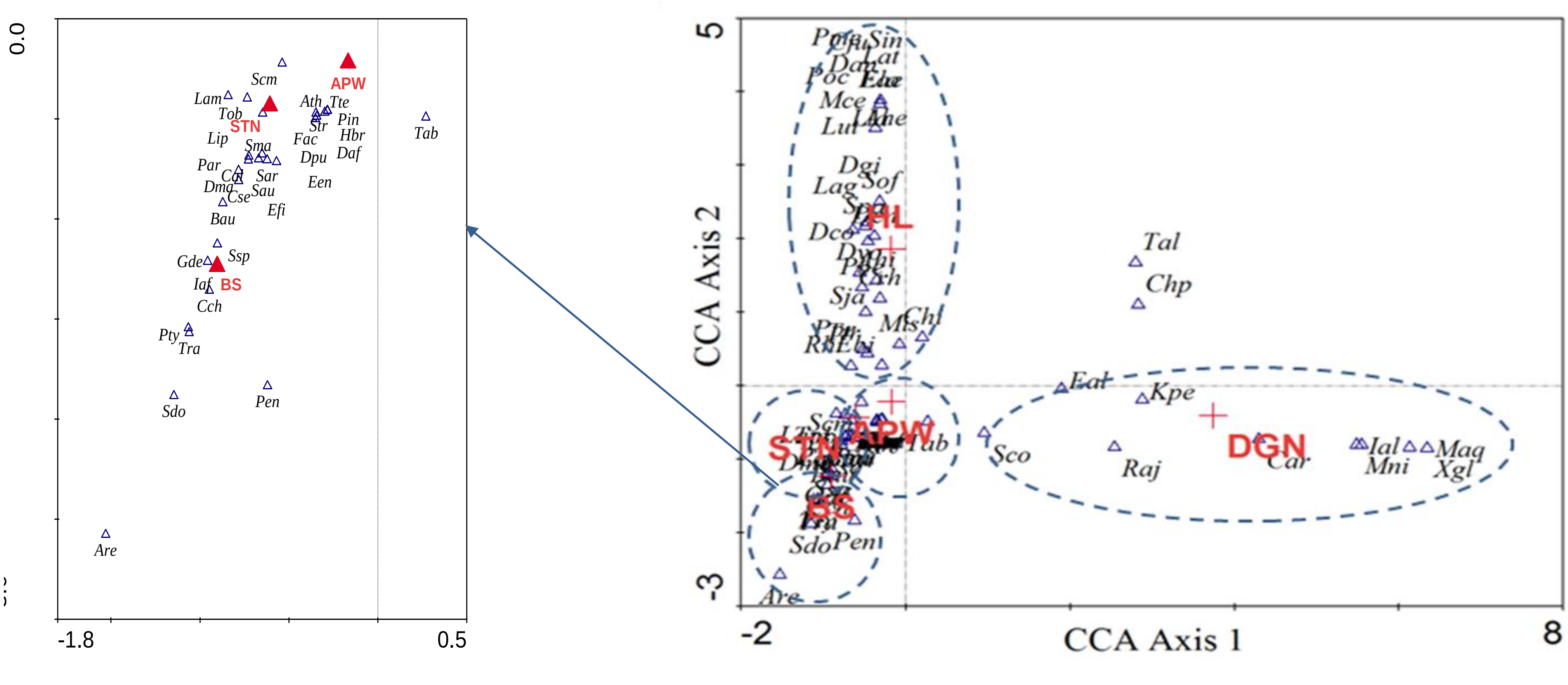

Figure 11: CCA biplot for the total revenue (by species) of all five gears from 2004 to 2008. Only the first two axes, the most important, are depicted. Species codes are the first letter of the genus and first two letters of the species names (See Appendix 1 for full names and codes). Part of the original axes plan is enlarged in the inset to aid visualization of the individual species. The five most important gears are labeled in bold red fonts.

4.3.2. Total revenue (All gears)

The association between revenues and species for the different gears was even more distinct than their association with total catches, and this resulted in a clearer separation of gear groups in the CCA (biplot of total revenue in Figure 11). This strong association between species and the environmental variables suggest a more clear stratification of income among gear groups, despite them often sharing the same species. A Monte Carlo test (199 permutations) confirmed the significance of the species-environment relation as well as that of all four canonical axes ($p = 0.005$). The first two axes explained 51.1% and 71.3% of the variance in species data and species-environment relation respectively. Axis 1, explaining 39.3% variance in species-environment relation, differentiated DGN gear from the other gears with respect to total revenue (Figure 11). The HL gear was also differentiated from the other gears by Axis 2 (explains 32% variance). These two gears, particularly the drift nets, generate good incomes and these can be attributed to high-priced species as *Pagellus bellottii* (Steindachner, 1882), *Dentex* spp., *Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817), *K. pelamis, M. nigricans* and *I. albicans* depicted in Figure 11. In Figure 11, *T. albidus* associated with APW and not DGN as in Figure 10. A similar observation was made for *Lichia amia* (Linnaeus, 1758), which did not associate with any particular gear in Figure 10.

4.4. ANNUAL SERIES OF HARVEST RATES (CPUE) PER GEAR TYPE DISAGGREGATED BY SPECIES (CANOCO)

4.4.1. ALI-POLI-WATSA (APW) – PURSE SEINE

About 67% (48 out of 72 species) of the total species used in analyses was caught by the APW gear. The species for all the years sorted out well along Axes 1 and 2 in the CCA biplot (Figure 12). The first two axes explained 72.2% of the variance in species data but none of the canonical axes explained any variance for the species-environment relation. The non-significance of the canonical axes were confirmed by Monte Carlo tests (199 permutations) ($p = 1.00$). Axis 1 contrasts species composition of 2008 (right) from the remaining years (left), while Axis 2 contrasts that of 2005 (top) and 2004 (bottom) along a gradient of increasing CPUE. In 2004, CPUE of *Trachurus trachurus* (Linnaeus, 1758), *Pomadasys incisus* (Bowdich, 1825) and *Sardinella* spp. were relatively higher than in other years. *L. amia* and sea breams (unspecified) only occurred in 2004. In 2005, *Hemiramphus brasiliensis* (Linnaeus, 1758), *D. margarita*, *Elegatis bipinnulata* (Quoy & Gaimard, 1825), *Selene dorsalis* (Gill, 1863) and *Callinectes* spp. had relatively higher CPUE than in other years. Also, in 2008, *K. pelamis*, *Ethmalosa fimbriata* (Bowdich, 1825), *Pseudotolithus typus* (Bleeker, 1863) and *T. albidus* achieved relatively high daily catch rates. Species located near the origin of the axes were caught throughout the years, although with varying abundance. Some major species of this gear include *Engraulis encrasicolus* (Linnaeus, 1758), *B. auritus*, *Auxis thazard thazard* (Lacepède, 1800), *Caranx hippos* (Linnaeus, 1766), *S. aurita* and *Sardinella maderensis* (Lowe, 1838) which accounted for about 7-31% of the landings along the years. An automatic forward selection procedure indicated 2008 as the only significant environmental variable in explaining the variance in species-environment relation.

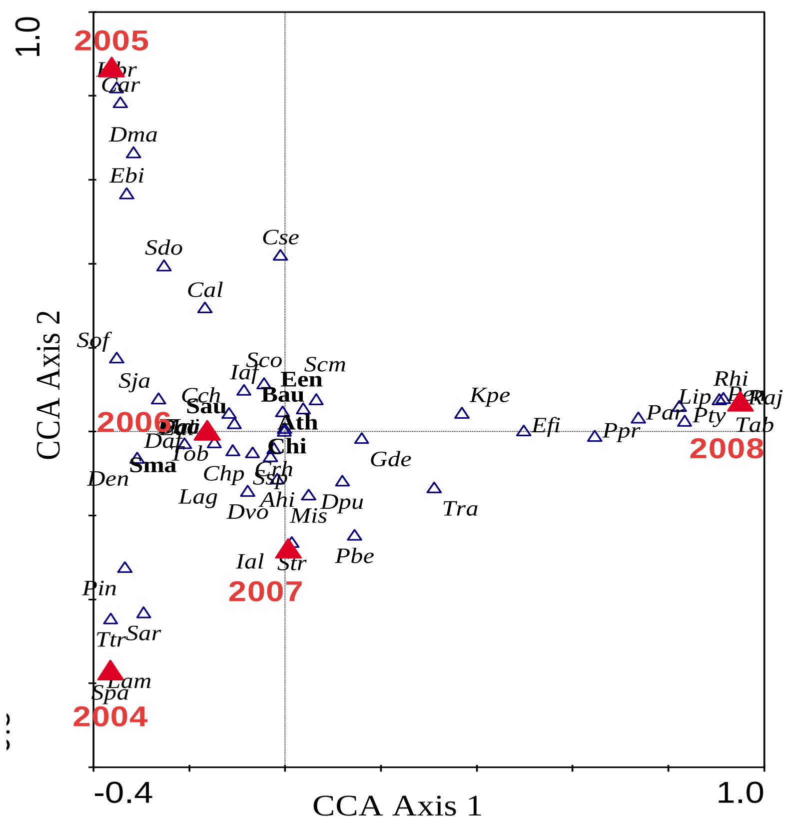

Figure 12: CCA biplot of CPUE of species caught by *Ali-Poli-Watsa* (APW) gear (2004-2008). Major species (in terms of CPUE) are in bold fonts.

4.4.2. BEACH SEINE (BS):

Species caught by the beach seine were relatively lesser than those caught in the previous gear and they sorted out well along Axes 1 and 2 in the CCA biplot (Figure 13). The first two axes explained 78.3% of the variance in species data but none of the canonical axes explained any variance for the species-environment relation. Monte Carlo tests (199 permutations) further confirmed the non-significance of all four canonical axes (p = 1.00). Axis 1 contrasted species with high catch rates in 2008 from those abundant in the other years, while Axis 2 contrasted those species with high catch rates in 2006. *E. encrasicolus* was caught in both 2005 and 2006; however, it was relatively abundant in 2006. In 2008, CPUE values of *S. aurita* and *Cynoglossus senegalensis* (Kaup, 1858) were relatively high. Some species were characteristic of particular years. For example, *Caranx rhoncus* (Geoffroy Saint-Hillaire, 1817) was caught only in 2004; *E. alletteratus* in 2005; *P. bellottii*, *D. congoensis*, *P. octolineatum* and *Lagocephalus laevigatus* (Linnaeus, 1766) in 2006; *Sardinella* spp. in 2007 and *E. fimbriata* and bonito in 2008.

The important species of this gear include *S. dorsalis*, *B. auritus*, *Argyrosoma regius* (Asso, 1801), *Trachipterus* spp., *S. sphyraena*, shrimps, *Ilisha africana* (Bloch, 1795), *Galeoides decadactylus* (Bloch, 1795), *P. typus* and *Chloroscombrus chrysurus* (Linnaeus, 1766); they are located near the origin of the axes (Figure 13). An automatic forward selection procedure indicated that none of the environmental variables (years) was significant in explaining the variance in species-environment relation.

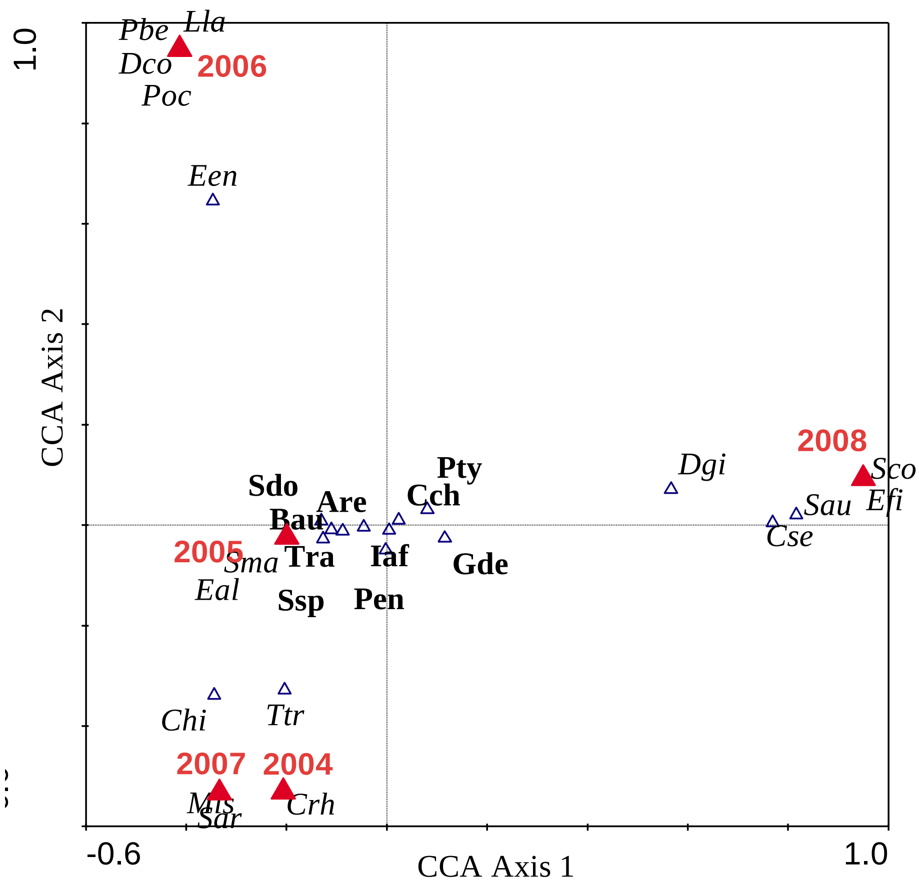

Figure 13: CCA biplot of CPUE of species caught by beach seine (BS) gear (2004-2008). Major species (in terms of catch) are in bold fonts.

4.4.3. DRIFT GILL NET (DGN):

The species for all the years sorted out well along Axes 1 and 2 in the CCA biplot (Figure 14). The first two axes explained 88.9% of the variance in species data but none of the canonical axes explained variance for the species-environment relation. Monte Carlo tests (199 permutations) further confirmed the non-significance of all four canonical axes ($p = 1.00$). As in the case of the foregoing plots, Axis 1 contrasted species with high catch rates in 2008 while Axis 2 contrasted species with high catch rates in 2007. The CPUE values of *Myliobatis aquila* (Linnaeus, 1758) and shrimps were relatively higher in 2007 than in the other years. However, the contribution of shrimps to the overall catch rates was almost negligible (0.4 kg/day). The daily catch rates of *T. albidus* and rays were relatively higher in 2008. Species caught by this gear were predominantly large pelagics and they include *E. alletteratus*, *K. pelamis*, sharks, *M. nigricans*, *I. albicans*, *C. hippurus* and *Xiphias gladius* (Linnaeus, 1758), located near the origin of the axes. An automatic forward selection procedure confirmed 2008 as the only significant environmental variable in explaining the variance in species-environment relation.

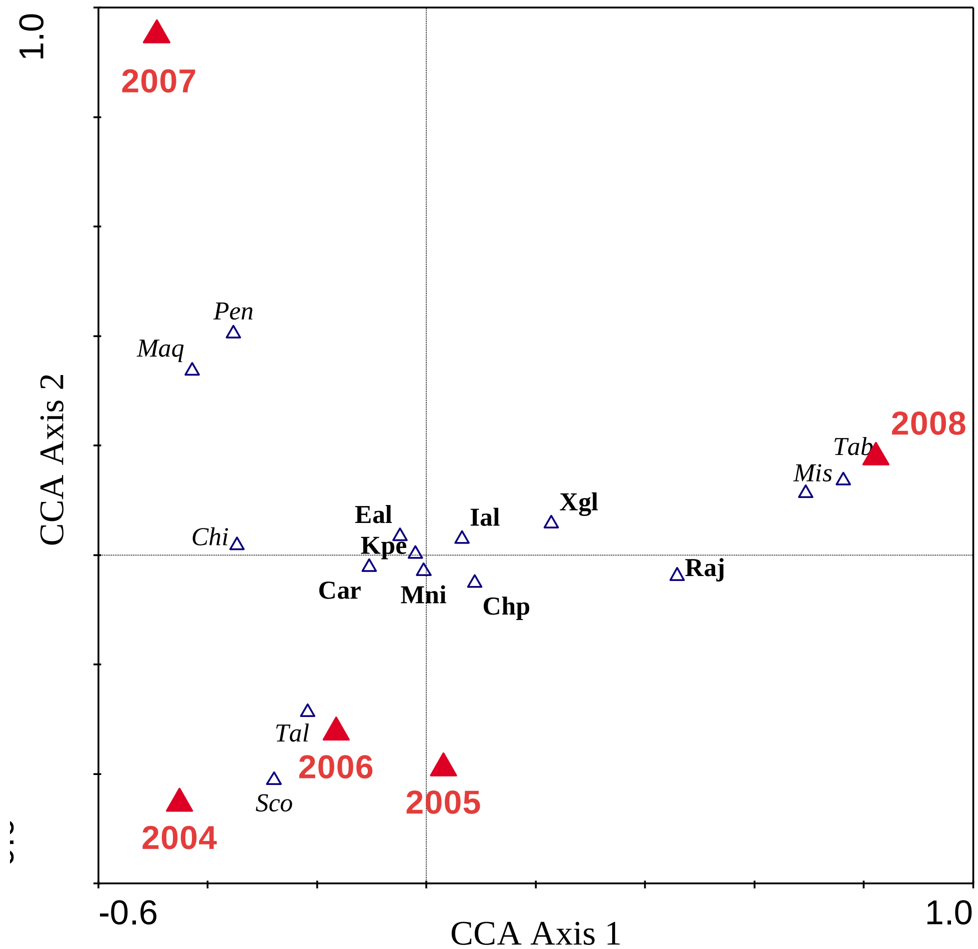

Figure 14: CCA biplot of CPUE of species caught by drift gill net (DGN) gear (2004-2008). Major species (in terms of catch) are in bold fonts.

4.4.4. HOOK AND LINE (HL):

The species for all the years sorted out well along Axes 1 and 2 in the CCA biplot (Figure 15). The first two axes explained 82.5% of the variance in species data but none of the canonical axes explained any variance for the species-environment relation. Monte Carlo tests (199 permutations) further confirmed the non-significance of all four canonical axes (p = 1.00). Once again, species with high daily catch rates in 2008 (right) was contrasted from the other years (left) along Axis 1. Axis 2 contrasted daily catch rates of species in 2004. *Synodus indicus* (Day, 1873) and *T. trachurus* only occurred in 2004 while guitar fish, sea breams (unspecified), *C. senegalensis* and *K. pelamis* were caught in 2008.

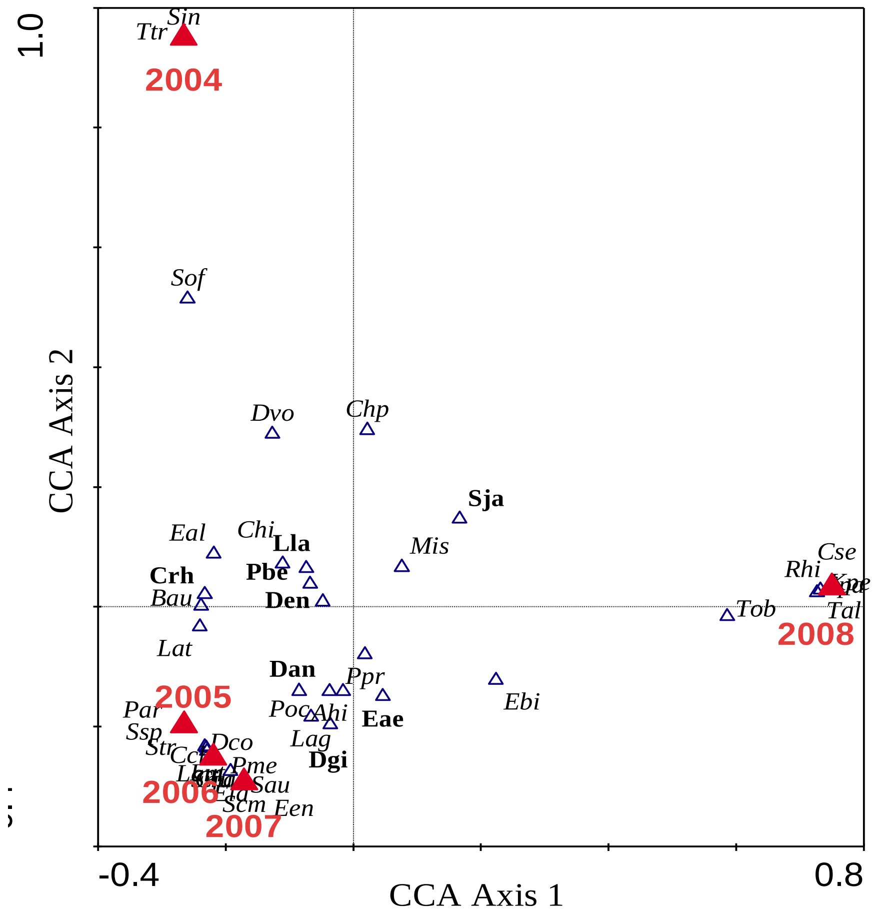

Figure 15: CCA biplot of CPUE of species caught by hook and line (HL) gear (2004-2008). Major species (in terms of catch) are in bold fonts.

The CPUE of *Sepia officinalis* (Rong, 1831) was highest in 2004 even though it was caught in almost all the years. *Thunnus obesus* (Lowe, 1839) had its highest CPUE value in 2008. Major species caught by this gear were mostly demersal fishes and they include *P. bellottii*, *Dentex* spp., *S. japonicus*, *Dentex angolensis* (Poll & Maul, 1953), *D. gibbosus*, *E. aeneus* and *L.*

laevigatus. However, an automatic forward selection procedure indicated that none of the environmental variables (years) was significant in explaining the variance in species-environment relation.

4.4.5. SET NET (STN):

As usual, the species caught by this gear strongly associated with the years along Axes 1 and 2 in the CCA biplot (Figure 16). The first two axes explained 71.1% of the variance in species data but none of the canonical axes explained any variance for the species-environment relation. Monte Carlo tests (199 permutations) further confirmed the non-significance of all four canonical axes (p = 1.00). Axis 1 contrasted daily catch rates of species caught in 2008 (right) from those that were more characteristic of 2004-2007 (left). These spread along Axis 2. Species like sea breams (unspecified) were only caught in 2004; *P. octolineatum*, *S. officinalis*, *E. bipinnulata* and *Fodiator acutus* (Valenciennes, 1847) in 2005; *Auxis thazard thazard* (Lacepède, 1800) in 2007; and sea snail, *L. amia* and *E. alletteratus* in 2008. Rays had a relatively higher CPUE in 2008 than in 2004 and 2006. *Trachipterus* spp., *L. agennes* and *C. sengealensis* had relatively high CPUE in 2007 though they were caught in other years too. The major species caught by this gear are *S. aurita*, *G. decadactylus*, *Sardinella maderensis* (Lowe, 1838), *Callinectes* spp., *B. auritus*, *S. sphyraena*, *I. africana* and *P. bellottii*. These, in addition to other species, were constant along the years, thus their location close to the origin of the axes. However, an automatic forward selection procedure indicated that none of the environmental variables (years) was significant in explaining the variance in species-environment relation.

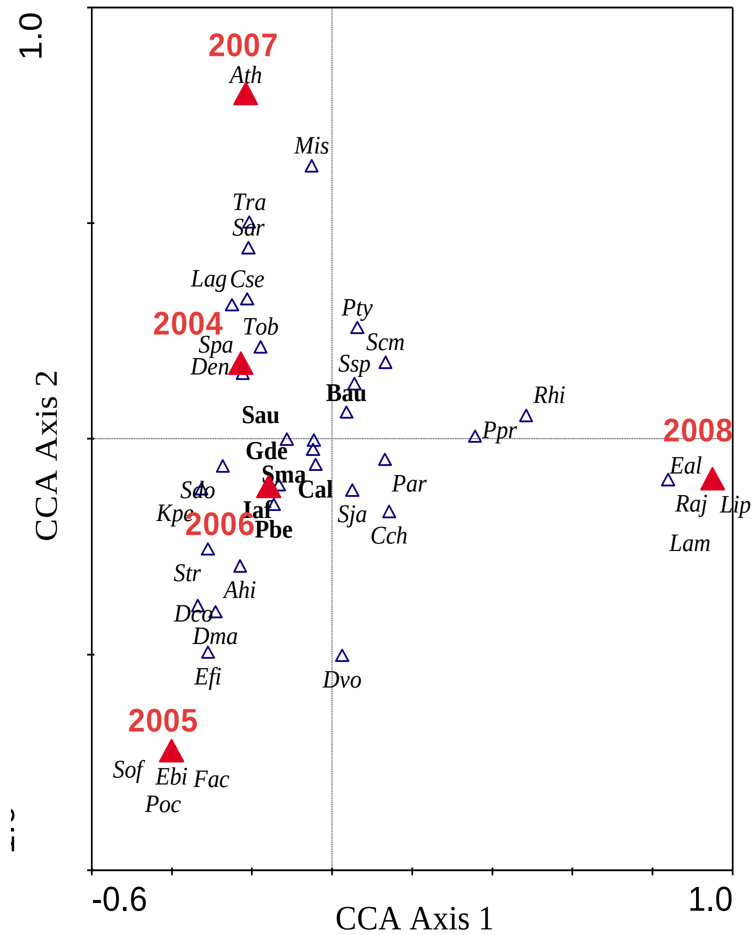

Figure 16: CCA biplot of CPUE of species caught by set net (STN) gear (2004-2008). Major species (in terms of catch) are in bold fonts.

4.5. MONTHLY SERIES OF CATCH RATES (CPUE) DISAGGREGATED BY GEAR

To further investigate the yearly trends observed in the foregoing CCA biplots, monthly analyses were done. Years 2004 and 2008 were chosen since they were usually contrasted along the biplots axes. Also, these two years were relatively similar with regard to sea climate (temperature regime) but were sufficiently separated in time.

4.5.1. APW –2004 VERSUS 2008

In the biplot obtained from the CCA of monthly CPUE in 2004 (Figure 17), Axis 2 separated species and months along a temperature gradient. It can be deduced, for example, that *S. dorsalis*, *Trachipterus* spp., and *E. fimbriata* mainly occur in November and December, which are usually warm months of the year. Species like *D. punctatus*, *P. arenatus*, *L. laevigatus* and *K. pelamis* were typical of cold months (July – August). *S. maderensis*, *S. aurita*, *E. encrasicolus* and *B. auritus* were present year round in varying abundances but their highest CPUE was recorded in May (warm), June (mid-temperature) and August (cold), respectively.

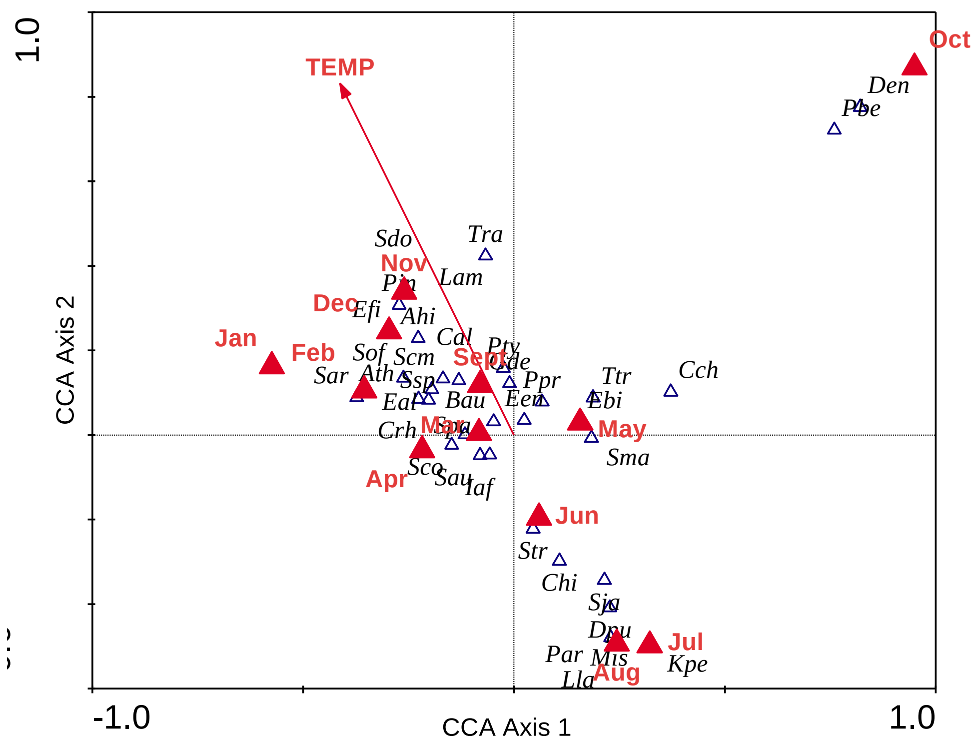

Figure 17: CCA biplot of monthly CPUE of species caught by *Ali-Poli-Watsa* (APW) gear in 2004.

Dentex spp. and *P. bellottii*, which are not typical catches of *Ali-Poli-Watsa* gear, were also caught in October (warm) with corresponding daily catch rates of 171.03 and 5.97 kg/day, respectively. However, Monte Carlo tests (199 permutations) did not confirm the significance of the canonical axis in explaining variance in species-environment relation. An automatic forward selection procedure confirmed temperature as the only significant environmental variable (p = 0.005).

In the biplot obtained from the CCA of monthly CPUE in 2008 (Figure 18), Axis 2 separated species and months along a temperature gradient. Like in 2004, *Ablennes hians* (Valenciennes, 1846), *P. typus* and *E. alletteratus* mainly occurred in warm months (May–June). *S. aurita*, *B. auritus*, and *E. encrasicolus* were present throughout the year, with their highest daily catch rate occurring in June (mid-temperature).

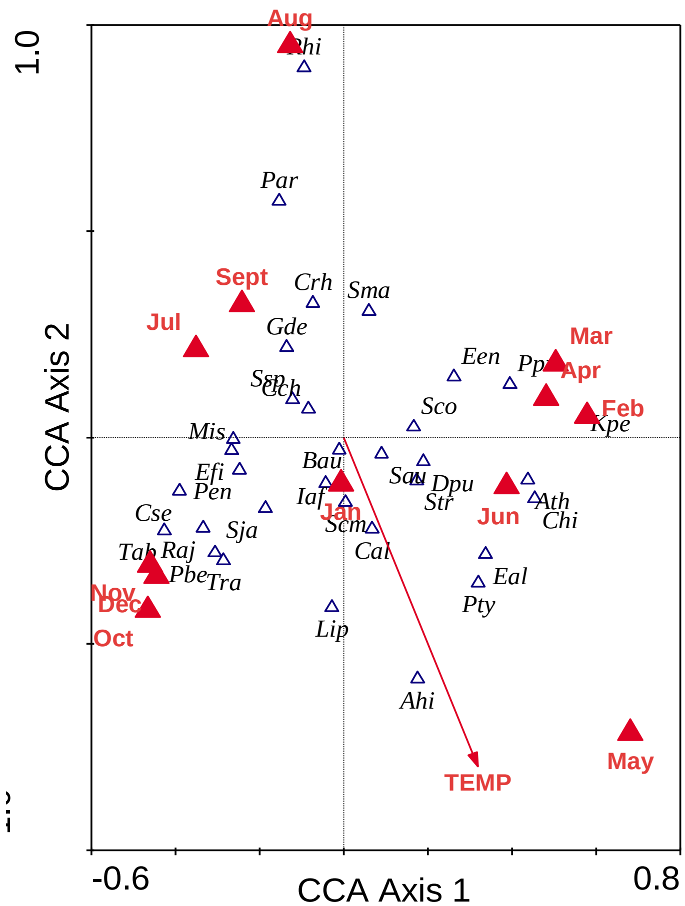

Figure 18: CCA biplot of monthly CPUE of species caught by *Ali-Poli-Watsa* (APW) gear in 2008.

A. thazard thazard was not abundant year round and recorded its highest daily catch rate in April (warm). *P. arenatus* and guitar fish occurred in coldest months (August-September). An automatic forward selection procedure confirmed temperature as the only significant environmental variable (p = 0.045).

In 2004, species caught from January-April and September-December were similar (Figure 17) but in 2008, it was species caught in January, July and September-December that were similar (Figure 18) by virtue of their close association to each other. Most species caught in 2008 had relatively lower CPUE than in 2004.

4.5.2. BS –2004 VERSUS 2008

In the CCA biplot of monthly CPUE in 2004 (Figure 19), species and months were contrasted along both Axes 1 and 2 along a temperature gradient. *B. auritus*, *C. chrysurus*, and *I. africana*, were caught throughout the year in varying abundances but the daily catch rate of *B. auritus* peaked in January and November (warm months) while that of *C. chrysurus*, and *I. africana* was high in September (mid-temperature month). Highest CPUE of *G. decadactylus*, *P. typus* and *S. dorsalis* occurred in January-February (warm months), July (cold month) and September (mid-temperature), respectively. *S. aurita* and *T. trachurus* mainly occurred in November (warm month) even though the former species is not a typical catch of this gear. An automatic forward selection procedure confirmed temperature as the only significant environmental variable (p = 0.02).

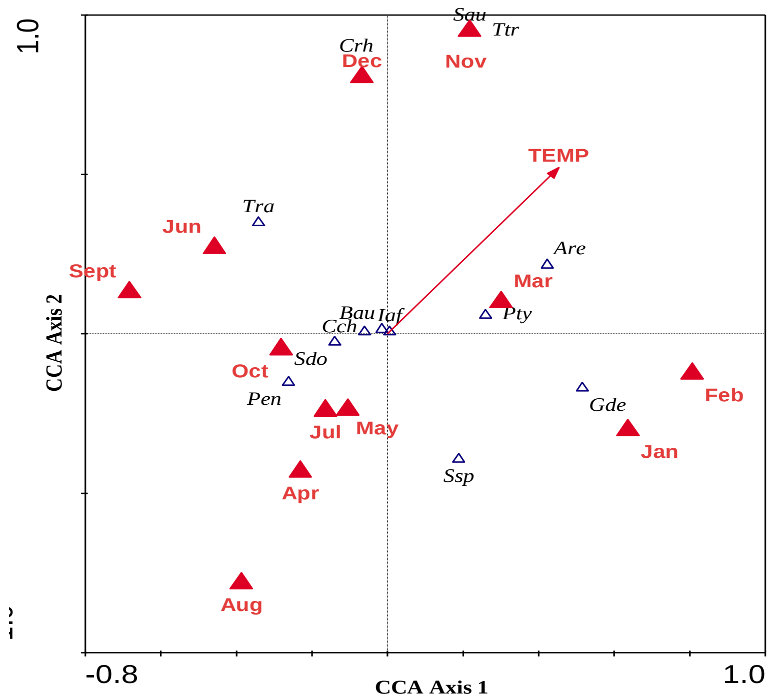

Figure 19: CCA biplot of monthly CPUE of species caught by beach seine (BS) gear in 2004.

In the CCA biplot of monthly CPUE in 2008 (Figure 20), the species were associated to Axis 1 along a temperature gradient. Important species such as *S. dorsalis*, *C. chrysurus*, *Trachipterus* spp. and *S. sphyraena* were present throughout the year with the daily catch rates of the first two species peaking in December (warm) and the last two in November (warm). *E. fimbriata* occurred only in February and October (warm months) with its highest daily catch rate occurring in October. An automatic forward selection procedure confirmed temperature as the only significant environmental variable ($p = 0.015$).

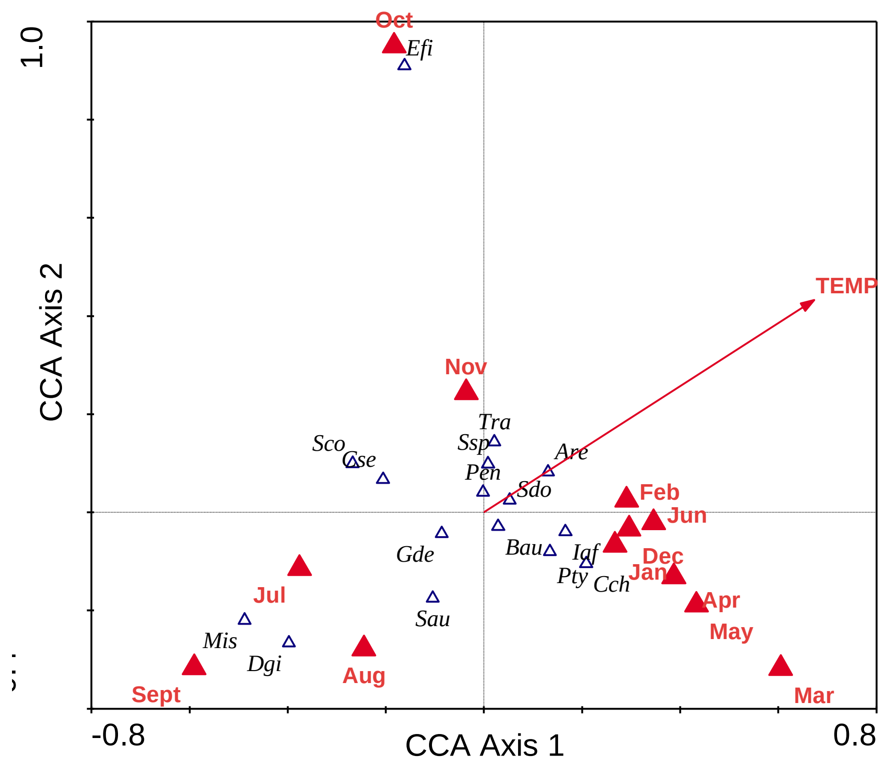

Figure 20: CCA biplot of monthly CPUE of species caught by BS gear in 2008.

In 2004, *G. decadactylus* was caught only in January and February (Figure 19) but in 2008, it was quite regular, occurring in all months except March and June. In addition to the four species that occurred throughout 2004, *P. typus*, *A. regius*, *S. sphyraena*, *Trachipterus* spp. and *G. decadactylus* occurred throughout 2008; these were located near the origin of the axes (Figure 20).

The CCA biplots of drift gill net, hook and line and set net gears (not shown) gave similar trends in both years contrasted (2004 vs. 2008). For the drift gill net gear, *K. pelamis,* sharks and *I. albicans* were common in both years, though not caught throughout the year. The major species of the hook and line gear, such as *Dentex* spp., *L. laevigatus*, *Dentex* and *P. bellottii* were caught almost throughout both years. For the set net gear, *B. auritus, G.decadctylus* and *S. maderensis* occurred throughout 2004 and 2008.

4.6. GENERALIZED ADDITIVE MODELS (GAM) OF MONTHLY CPUE BY GEARS – 2008

Figures 21-24 show GAM plots of CPUE (response variable) fitted to a smooth function of the factor score months (predictor) for all the five gears in 2008. 2008 was chosen because it was the end of the years series analyzed. The smooth curves were fitted to the catch rate observations of the major species of all the five gears. The plots, in many cases, showed that CPUE clearly fluctuated across months and seasons within a given year.

APW: Overall, the catch rates of this gear were relatively constant, hiding the fluctuating seasonal and asynchronous contributions of the different species. With the exception of ethmalosa (*E. fimbriata*), sardinella (*S. aurita*) and frigate tuna (*A. thazard thazard*), the change in catch rate of species across months was unimodal (Figure 21). The catch rate of anchovy (*E. encrasicolus*), Crevalle jack (*C. hippos*) and big eye grunt (*B. auritus*) peaked between March (warm) and August (cold) while that of frigate tuna and sardinella generally decreased over the months, with less pronounced change between July (cold) and November (warm). However, it was only responses of frigate tuna, Crevalle jack, anchovy and ethmalosa were significant in the model ($p < 0.05$).

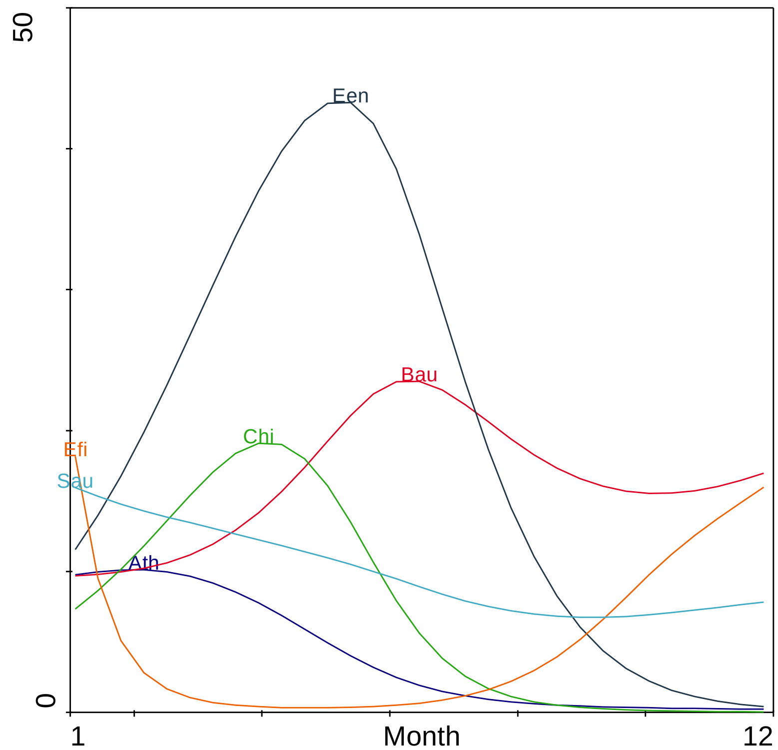

Figure 21: Plots of the smooth components of GAM for CPUE of most important species of *Ali-Poli-Watsa* (APW) gear in terms of months - 2008. See Appendix 1 for complete species names and codes.

BS: Overall, this gear seems to suffer marked changes in catch rates along the year, particularly in the second semester. The change in catch rates of one of the important species of this gear, longneck croaker (*P. typus*), was less pronounced across months (Figure 22). Its catch rate was fairly stable between January (warm) and June (mid-temperature) but started decreasing steadily beyond that. Others like Atlantic bumper (*C. chrysurus*), big eye grunt, ribbonfish (*Trachipterus* spp.), African moonfish (*S. dorsalis*) and shrimps had their maximum catch rates in December (warm) while *G. decadactylus* had its maximum between August and September (both cold months). However, only the responses of big eye grunt, Atlantic bumper, shrimps, African moonfish and ribbonfish were significant in the model ($p < 0.05$).

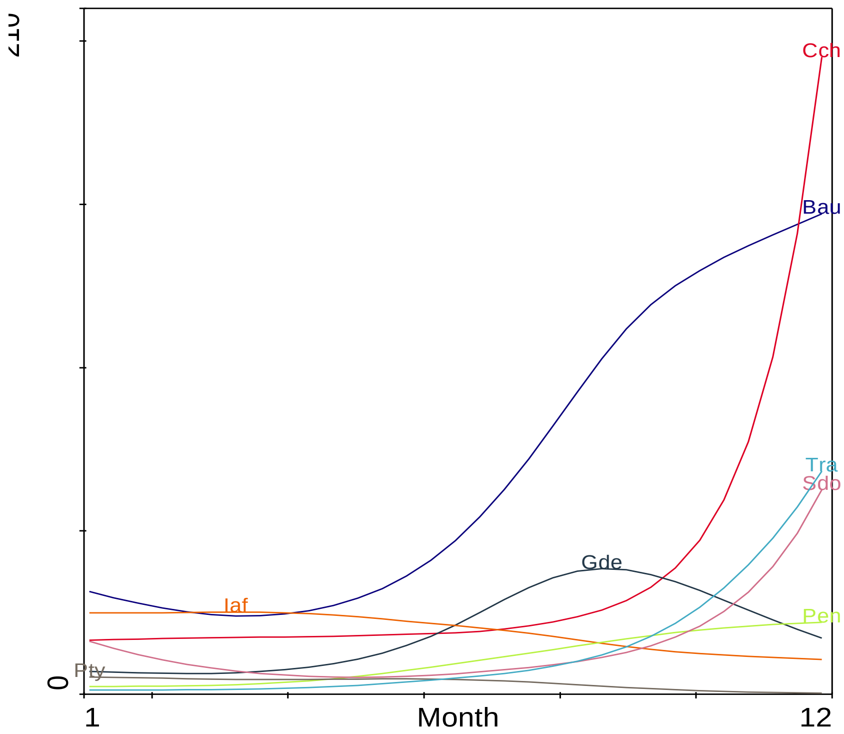

Figure 22: Plots of the smooth components of GAM for CPUE of most important species of beach seine (BS) gear in terms of months - 2008.

DGN: GAM plot for DGN showed very little or constant variation along the year and was therefore not clearly interpretable (not shown).

HL: Overall, the highest catch rates obtained by this gear tend to occur in the warmer seson, with clear lows in the cool season. Species like sea breams (unspecified) - sparidae, skipjack tuna (*K. pelamis*) and chub mackerel (*S. japonicus*) showed clear seasonal, and often asynchronous, contribution to the catches by this gear. For the other important species of hook and line gear, the seasonal change in catch rates was less pronounced. For instance, between January (warm) and June (mid-temperature), the catch rates of sea breams (*Dentex* spp.), white grouper (*E. aeneus*) and red Pandora (*P. bellottii*) were almost unobservable in relation to the others. Maximum catch rates of red Pandora and skipjack tuna occurred in June-July (mid-temperature) and September-November (warm) respectively. the catch rate of sea breams (unspecified) decreased till about

August (cold), beyond which it gradually increased. However, only the responses of chub mackerel and skipjack tuna were significant in the model ($p < 0.05$).

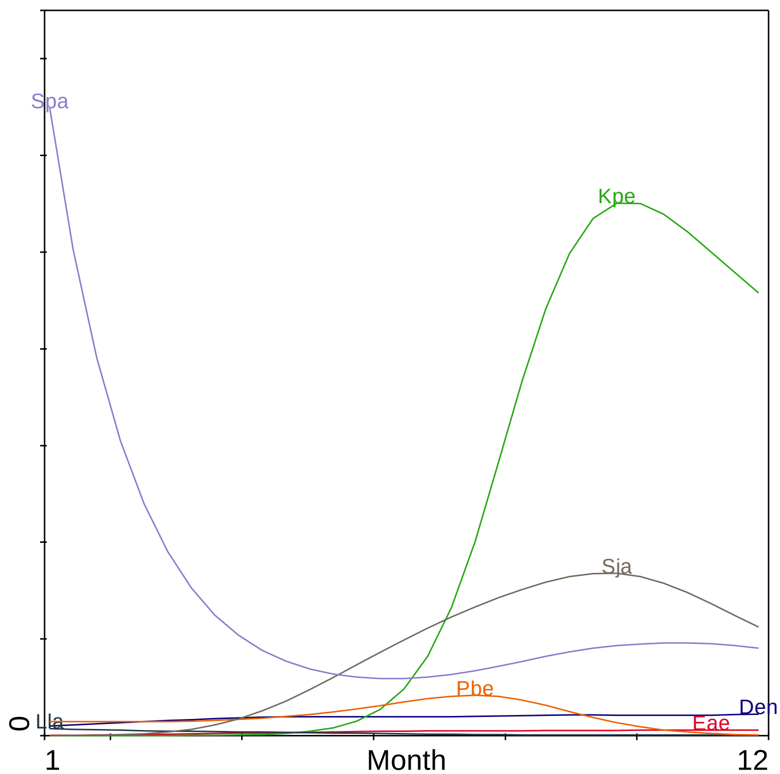

Figure 23: Plots of the smooth components of GAM for CPUE of most important species of hook and line (HL) gear in terms of months - 2008.

STN: Overall, the catch rates obtained by this gear were almost constant, though there were fluctuations in the species-specific contributions. The catch rate of West African ilisha (*I. africana*) increased across months and had its maximum value in December (warm) (Figure 24). The maximum catch rate of Madeiran sardinella (*S. maderensis*) and crabs (*Callinectes* spp.) occurred in April (warm) and that of barracuda (*S. sphyraena*) was in July (cold). The catch rate of big eye grunt declined between January and April (warm months) as well as in October-

December (warm); between May (warm) and September (cold), it increased. However, only the response of West African ilisha was significant in the model ($p < 0.05$).

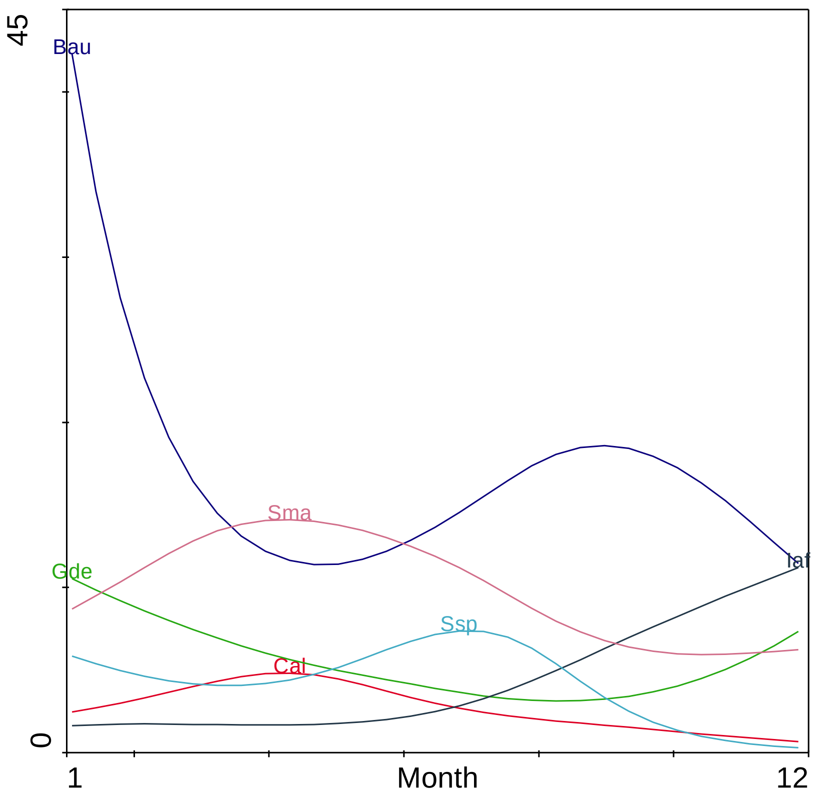

Figure 24: Plots of the smooth components of GAM for CPUE of most important species of set net (STN) gear in terms of months - 2008.

4.7. GENERALIZED ADDITIVE MODELS (GAM) OF MONTHLY RPUE BY GEARS – ALL YEARS

Figures 25-27 show GAM plots of daily revenue rates (RPUE, response variable) fitted to a smooth function of the factor score months (predictor) for all the five gears between 2004 and 2008. The smooth curves represent fits to individual species, but only those contributing most to the overall revenue were considered. The plots show that revenue rates are not uniform across months.

APW: Overall, revenue rates by this gear appeared to have a clearer seasonal trend in most of the years, with the exception of 2007, the warmest year in the series. Revenue rates fluctuated from month to month and the patterns differed in each year, with relatively high scores in 2004 (Figure 25). Maximum revenue rate for 2004 and 2005 occurred in June and July respectively while that of 2008 occurred in September. In 2007, revenue rate increased between January and March, then declined and started increasing again from July.

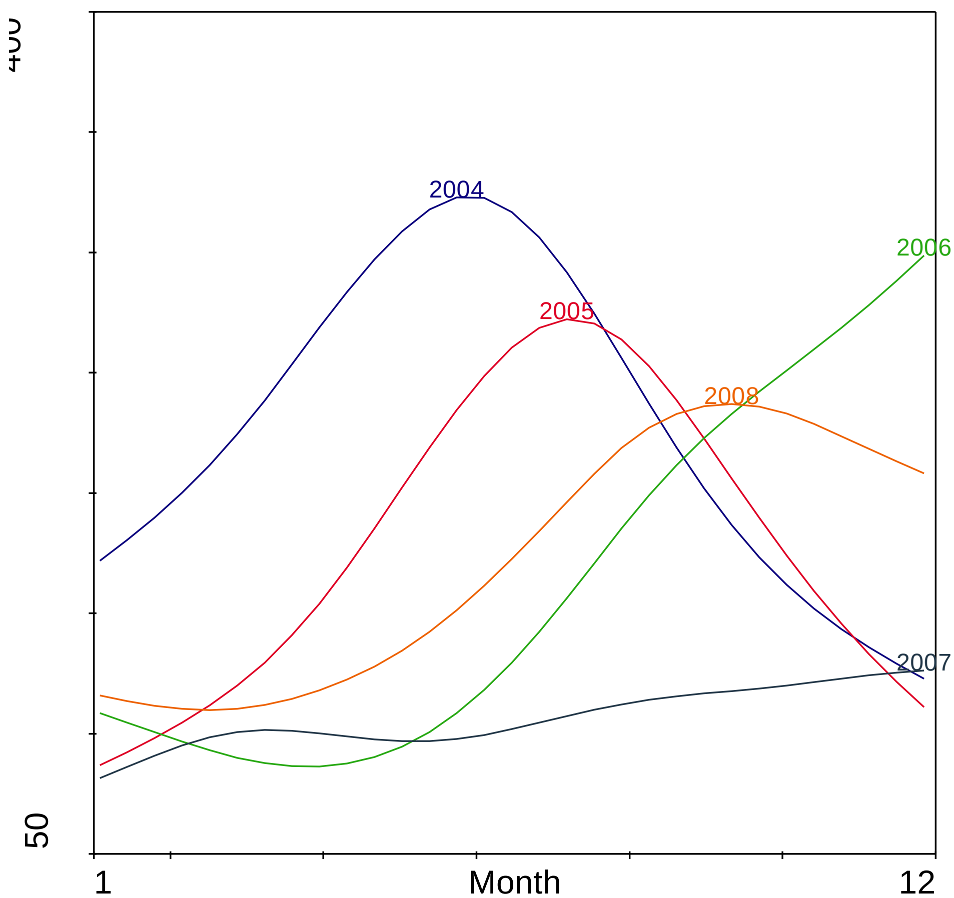

Figure 25: Plots of the smooth components of GAM for monthly revenue rate (RPUE) from fishing with *Ali-Poli-Watsa* (APW) gear in different years

Conversely, the revenue rate for 2006 decreased between January and April, beyond which it increased and reached its maximum value in December. Thus, while the highest revenue rates tended to be obtained by mid-year (during the cold season) in cold years, in warmer years, it was obtained by the end of the year. However, it was only the response of 2006 that was significant in the model ($p < 0.05$).

BS: Overall, the revenue rates by this gear were not stable over the years, with only the curve of 2004 having a clear maximum in August (Figure 26). In 2006 and 2007, the revenue rates decreased between January and June. However, in the case of 2006, it increased beyond this point till December but for 2007, beyond June, the revenue rate was relatively stable.

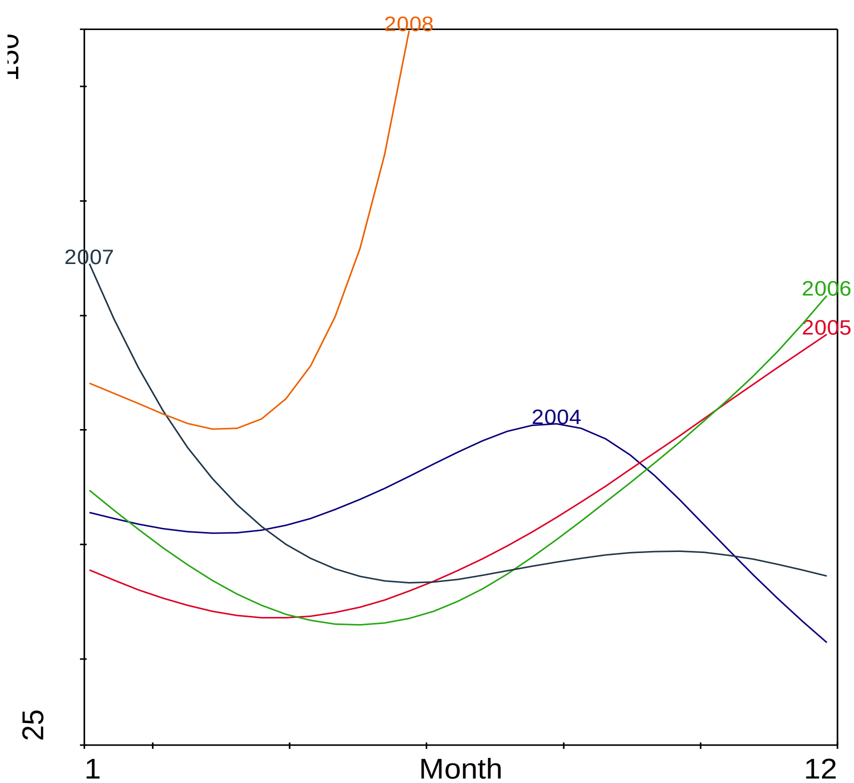

Figure 26: Plots of the smooth components of GAM for monthly revenue rate (RPUE) from fishing with beach seine (BS) gear in different years

In the case of 2005 and 2008, revenue rates dipped between January and March but increased beyond then. However, it was the responses of 2005-2008 that were significant in the model.

DGN: Overall, the revenue rates by this gear, with the exception of 2008, did not vary so much (plot not shown). In 2005, revenue rates increased between January and March. The maximum revenue rates for 2008 and 2006 occurred in August and September respectively.

HL: In 2004, the revenue rates by this gear increased between January and March, beyond which it decreased; it began to rise again around September (plot not shown). However, in 2005, revenue rates were relatively stable across months. In 2006, maximum revenue rate occurred between May and June.

STN: Overall, the revenue rates obtained by this gear showed clear seasonal patterns in most years, except in 2004 (Figure 27). The revenue rates in 2004 were relatively constant across months, with no clear maximum. In the other years, the revenue rates were substantially higher in the second semester of the year, particularly in 2007 and 2008, when it clearly peaked in August-September.

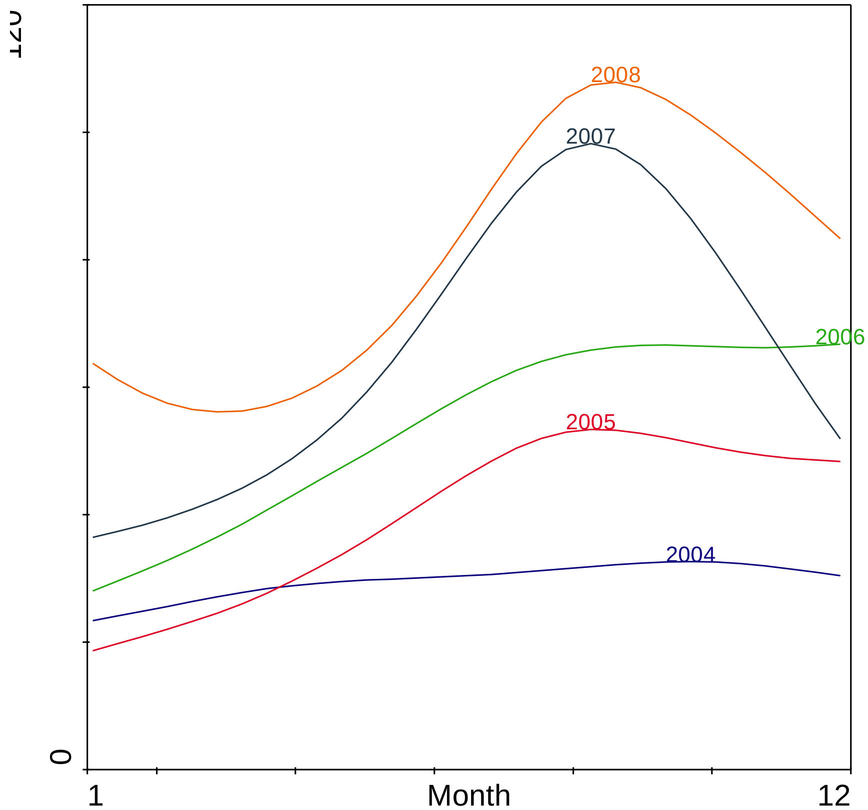

Figure 27: Plots of the smooth components of GAM for monthly revenue rate (RPUE) from fishing with set net (STN) gear in different years

4.8. INTERVIEW OF FISHERMEN

When asked to list the fish species they usually caught, the fishers cited a total of about twenty-three different species. However, the common ones cited included round sardinella (small pelagic), red Pandora (demersal) and barracuda (relative large pelagic). With some exceptions, more than one gear tended to identify a particular fish species as important catch, and when this happened the main catch period tended to be synchronized. For most gears and frequent species, the main fishing season sited was July-August. Information on the fish species targeted by the interviewed fishers with their corresponding gears and fishing seasons (months) is provided in Table 1.

Table 1: Main target species, fishing gear and fishing season as cited by interviewed fishers

Species	No. of times cited by fishers	Gear used (No. of fishers)	Peak fishing season
<u>Clupeidae</u>			
***Sardinella aurita* (Round sardinella)**	22	DGN (4)	July-August
		STN (1)	August
		SN (7)	August
		Nets (unspecified) (10)	July-August
<u>Engraulidae</u>			
***Engraulis encrasicolus* (Anchovy)**	4	SN (3)	July-August
		Nets (unspecified) (1)	July-August
<u>Scombridae</u>			
***Scomber japonicus* (Chub mackerel)**	5	DGN (2)	July-August
		SN (2)	July/August
		STN (1)	August
***Auxis thazard thazard* (Frigate tuna)**	4	DGN (1)	August
		SN (3)	August
		Nets (unspecified) (1)	July
<u>Sparidae</u>			
***Pagellus bellottii* (Red Pandora)**	10	DGN (2)	July-August
		STN (1)	August
		SN (1)	August
		HL (6)	August
<u>Sphyraenidae</u>			
***Sphyraena sphyraena* (Barracuda)**	11	DGN (3)	August
		SN (5)	August
		Nets (unspecified) (3)	July-August

(DGN = drift gill net; STN = set net; SN = seine net; HL = hook and line)

Even though most of the interviewed fishers said they usually set off on their fishing trips in the early hours of the day, the average number of hours spent at sea ranged from 4-42 hours, depending on the gear used by fisher. The average number of people and hours per fishing trip is given in Table 2. Most fishers did not clearly cite the specific nets they used, however, those who were specific about the gear they used, cited seine nets, set nets, drift gill nets and hook and line as their common gears. A few fishers (22%) said they used more than two gears per fishing trip, with the remainder 78% using only one gear. This implies that the fidelity of fishers to gear is very high. The number of people that accompanied each fisher per each fishing trip ranged from 2-30, depending on the size of canoe. The average number of people was 3 for small canoes and 21 for medium/ large ones.

Table 2: Number of persons per trip, time spent at sea and share of catch by different gears

Type of gear	Number of fishers in group	Average number of persons per fishing trip	Time spent at sea (hours)	Share of catch
Drift gill net	4	3	1-7	Not specific; catch-dependent
Hook and line	6	4	13-72	Canoe owner: 33.3%; family – 33.3%; Crew – 33.3%
Seine net	7	14	4-27	Canoe owner: 40-50%; Family/ Crew: 40-50%
Set net	1	4	12	Canoe owner: 50% Crew/ Outboard motor: 50%

The age of interviewed fishers ranged between 17 and 80 years (average = 41±16), with most of them (52%) being in the 30-49 age group. Fishing experience of fishers also ranged between 1 and 60 years, with an average of about 23±14. About 57% of the interviewed fishers owned a canoe and for those equipped with outboard motors, the engine capacity ranged from 8-50 HP. However, capacity of 8 and 40 HP were common. When asked whether they have a secondary occupation, most fishers answered in the negative; only two cited carpentry and cab driving as their alternate source of livelihood.

CHAPTER FIVE

5.0 DISCUSSION

The main purpose of this study was to identify potential métiers in the Central region, based on their activity patterns, production and revenue. The output-based method was used in the identification of these métiers. Considering the entire Central region for the present study was too broad to allow for detailed analyses of the various groups. It would have been advantageous to have considered individual gear groups or a district at a time. For example, Katsanevakis et al. (2010) considered only boat seines for two major sites while Tzanatos et al. (2006) limited his study to a number of fishing operations of small-scale vessels within a year. Despite these shortfalls, the multivariate analyses – canonical correspondence analysis (CCA), redundancy analysis (RDA) and Generalized Additive Models (GAM) – still revealed some patterns in species composition of the various gears. Another limitation in this study was disparity between fish prices in 2008 and prices in the preceding years. Thus, an average inflation rates as at 2008 were used to correct the differences. Even after the prices had been transformed, the disparity between 2008 prices and the other years persisted. This is because inflation rate is but one of the many factors that influence the price of fish; other factors include volume of traded fish at a time, species of the traded fish, quality of fish, production costs, transportation charges as well as shifts in market supply and demand (Mensah et al., 2006; Seini, 1995).

The five gear groups analyzed differed widely in their catch composition, effort and revenues, and there were also considerable temporal variations and fluctuations within some of these groups. In terms of catch weight and revenue, the *Ali-Poli-Watsa* (APW) gear was the most important gear with an annual average catch and revenue of about 52,000 tonnes and 42.7 million new Ghana cedi (GH¢) respectively while the drift gill net (DGN) gear recorded the lowest catch of approximately 1,500 tonnes and revenue of about 2.5 million GH¢. With the exception of hook and line (HL) and set net (STN), total catch usually decreased in years when effort (fishing day) was relatively stable. This could have been as a result of influx of fishers. In other words, fishers using other gears may have switched to these gears during those periods when they were not catching their target species in their usual quantities. However, in this study, the number of fishers as a measure of effort was not used so this fact could not be ascertained even though it was reflected in the analyses.

In the analyses of total catch and revenue, the species associated well with the various gears (environmental variables) and canonical axes, rejecting the null hypothesis that species caught are not related to type of gear used. From these two analyses, three gear groups were identified, namely hook and line (HL) (Group 1), *Ali-Poli-Watsa* (APW), beach seine (BS) and set net (STN) (Group 2), and DGN (Group 3) (Figures 8 &9). This finding validates previous observations (Marchal, 2008) with regard to the species-specific selection patterns of the drift gill net and hook and line: species like *P. bellottii, Dentex* spp. and *E. aeneus* are very important, in terms of catch and revenue, to the hook and line gear; *K. pelamis, M. nigricans* and *I. albicans* for drift gill net. In the total revenue biplot, however, the identified groups were more distinct and this could have been due to price of individual species since the only difference between total catch and revenue is price. Subsequent analyses were thus carried out to investigate if the year or monthly trends for each gear would lead to further disaggregation into more distinct groups of métiers.

The analyses (CCA) by individual gears (Figures 10-14) were done to find out if variation in catch rate (CPUE) was explained by year (environmental variable). None of the four canonical axes were significant in the species-environment relation ($p > 0.05$), implying that year was not enough in explaining the patterns in data. However, there were variations in the catch rates along the years. Probably, other factors may have contributed to these variations or the changes were too sharp to be determined at the year level. In the CCA biplots of *Ali-Poli-Watsa* and drift gill nets, 2008 was significant in the species-environment relation ($p < 0.05$). For instance, in the *Ali-Poli-Watsa* gear, some species such as *S. aurita* and *A. thazard thazard* had relatively low catch rates in 2008 while others like *C. hippos, B. auritus, E. encrasicolus* had high catch rates. It was quite unexpected that the ccatch rate of *S. aurita* was relatively lower in this year, which was, on average, a relatively cold year. For DGN gear, species such as *I. albicans,C. hippurus, K. pelamis, X. gladius,* and *M. nigricans* had relatively higher catch rates in 2008 than in 2007 while other species like sharks and *E. alletteratus* decreased in catch rates. However, in all plots, the 8-10 most important species of each gear (species which catch rates were relevant to the overall weight) were more or less present throughout the years, though with varying catch rates. Further, it was observed that the three gears – *Ali-Poli-Watsa* (APW), beach seine (BS) and set net (STN) had some major species in common. These were *B. auritus, S. aurita, S. maderensis, S. sphyraena, I. africana* and *G. decadactylus.* This may have been the reason for the merging of these gears into one group in the total catch and revenue biplots (Figures 8 & 9).

In Ghana, there are two major events that influence fish distribution and production (Kwei & Ofori-Adu, 2005):

- The thermocline event (from March to June and October to December): It is often characterized by long periods of high water temperatures (27-30°C) and low primary production. This subsequently leads to low production of fish;
- The upwelling event (from July to September and January to February): It is characterized by short periods of mixing of nutrient-rich bottom water with surface waters. This leads to high plankton growth, thereby increasing fish production.

The CCA done on monthly basis (Figures 15-18) was to ascertain the seasonal patterns in catch and revenue rates of the various species. In some gears, the contribution of temperature to the variation in catch rates of species was insignificant while in others like *Ali-Poli-Watsa*, beach seine and hook and line gears, it was significant.

In the case of APW, temperature was a significant environmental variable for both years analyzed (2004 and 2008). In 2004, July and August were relatively cold (low temperature) months and were characterized by *S. japonicus, C. hippos* and *D. punctatus.* Two demersal rock fishes, *P. bellottii* and *Dentex* spp., which are predominantly caught with hooks/long lines and bottom gill nets (Kwei & Ofori-Adu, 2005), were caught by *Ali-Poli-Watsa* in October (warm). In 2008, August was the coldest month (21.6°C) while July and September were mid-temperature months (24.5 and 23.6°C respectively). Unexpectedly, *S. aurita* and *S. maderensis* had their maximum catch rate in June (mid-temperature month, but was relatively cool in 2004). This could have been because the cold period in 2008 started a little earlier than it usually does, thus causing the upwelling event to have occurred a month earlier. Also, two demersal fishes, guitar fish and *P. arenatus*, usually caught with bottom trawls (*ibid.*) were caught by this gear in

August. The occurrence of these atypical fishes in APW gear could imply that the fishers were probably fishing at different depths or areas than they usually do following a lower catch of their usual target species in those months. It could also mean that fishers switched gears during these periods. In the case of beach seine, *S. aurita*, *T. trachurus* and *C. rhonchus* were caught in warm months (November and December) – 27.9 and 27.2°C respectively. The capture of *S. aurita* by this gear is consistent with the observations made by Mensah et. al (2006) regarding the exploitation of juvenile sardinellas by the beach seine gear in non-upwelling months. The fact that temperature was not significant in explaining the variation in the other three gears could either mean that the target species of those gears are not so adversely influenced by temperature or another factor may have masked its effect .

The GAM plots were generated for the most important species due to the large number of species involved. Also, these species were important in the overall CPUE of the gears. The plots showed variation in the catch of the various gears across months. Not all the species that were common to more than one gear were caught in the same month in all cases. Even for the species that were usually caught all year round, they were either caught in low numbers by one gear and a higher number in another. For example, *S. aurita, B.aurita* and *I. africana* are caught by both *Ali-Poli-Watsa*, beach seine and set net but with varying catch rates across months. Similarly, drift gill net and *Ali-Poli-Watsa* catch *K. pelamis* and *E. alletteratus* in varying rates. Revenue rates (RPUE) varied with years and months as well. The variation in RPUE of drift gill net and hook and line were not as sharp as that observed in *Ali-Poli-Watsa*, beach seine and set net. This could be due to the fact that these two gears generally had constant catches over the years. The curves of revenue rates for *Ali-Poli-Watsa*, beach seine and set net had somewhat similar patterns over the years, i.e. the shape of curves in most years were almost of the same form even though the maximum revenue rates were observed in different months. For instance, in 2004, maximum revenue rate for *Ali-Poli-Watsa* occurred in June while that of beach seine and set net occurred in August and October respectively. Generally, for *Ali-Poli-Watsa*, beach seine and set net gears, the maximum revenue rates occurred in the second semester of the year.

The citations of the fishers (Table 1), to some extent, match the observations regarding the interactions of gears by target species. More than one gear targets a particular species and also species caught are also dependent on seasons or time of year since majority of fishers cited July-August as the peak fishing season. The major species mentioned by them were among the select few that were considered important to the various gears. Regarding variability in revenue rates across months, the interviews could not answer that. This was because fishers were not asked to state their incomes. However, the fishers were asked how they share daily proceeds from their fishing trip. Even though there is no uniform method for the share of proceeds, usually there is a part given to the canoe owner, net owner, family and lastly the crew members; the percentages varies from region to region and from gear to gear (Amador et al., 2006). In this study, the percentage ranged between 33-50% for canoe owner and 33-50% for family or crew. This gives an indication of what each person who participates in the fishing activity get and since this is solely based on how good or bad a catch is it has implications on the revenue they get. This in the long run, will impact on their livelihoods particularly, because most of them do not have any secondary occupation. However, since interviews were only based in Winneba, responses may not fully tell the story for the entire region, especially if other types of gears are used in the other districts. Future interviews schedules should include questions relating to income and costs involved incurred by fishers so as to give an idea of their daily or monthly income ranges.

The general definition of métiers involves various components, namely vessel type, and size, gear, target species, spatial and temporal fishing pattern (Katsanevakis et al., 2010; Mesnil & Shepherd, 1990; Tzanatos et al., 2006). However, in the present study, gears, target species and seasonal patterns were the criteria used. As a result of this, it was impossible to clearly identify métiers. Nevertheless, the variations in activity patterns of the gears analyzed led to the generation of two models (Figure 28, Table 3) to explain the interactions of these gears in terms of target species and months. Overall, the *Ali-Poli-Watsa* gear had the broadest niche breadth (range of exploitation), followed by beach seine and set net (Figure 28). Generally, the hook and line and drift gill net had few of their species shared with other gears.

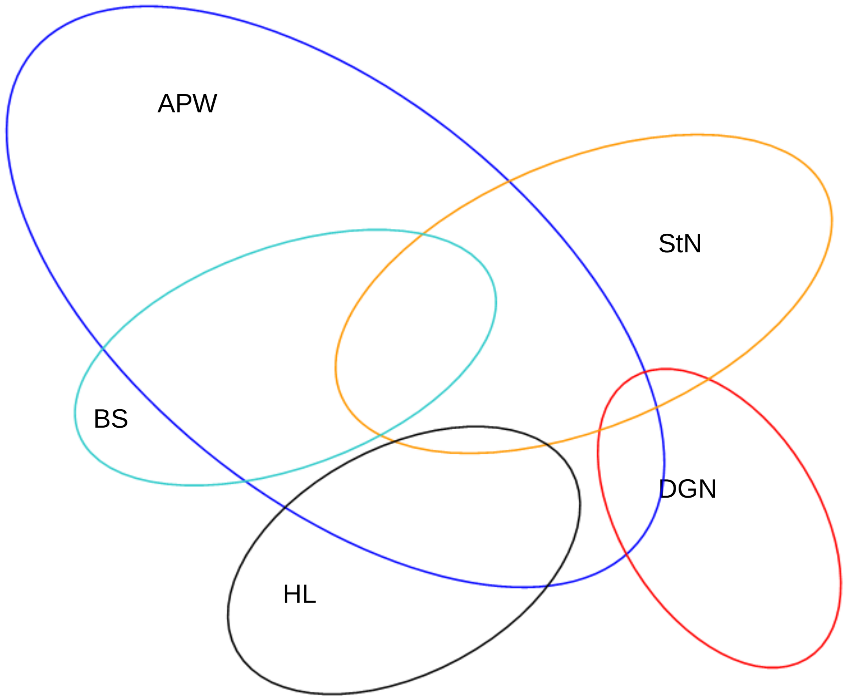

Figure 28: Prey-gear niche model (the size of oval is related to the volume of catches)

A niche timeline model, providing information on the interactions of these gears across months was also constructed (Table 3). This model highlights some of the most important species of the various gears (in terms of assigned catch rate rankings), divided into their ecological groups – pelagics, semi-pelagics and demersals; these species were persistent in the CCA biplots. The various assemblages have been distinguished by the gear(s) that catch them in particular months. In some groups like large pelagics and demersals, the number of gears interacting was few as compared to the small pelagics. For example, West African ilisha, Madeiran and round sardinella are targeted by *Ali-Poli-Watsa*, beach seine and set net almost every month. Red Pandora and sea bream are also caught partially by only hook and line and partially by both hook and line and set net. Basically, these two models give an indication on the temporal use of these resources (fish), a vital information for the management of artisanal fisheries in the Central region.

Table 3: Assemblages of prey by gear (only the most important prey are shown)

Common name	Group	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Atlantic sailfish	*Large pelagics*	DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN				DGN
Sharks			DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN
Skipjack tuna		DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN	DGN	
Atlantic little tuna	*Medium pelagic*	APW	APW, DGN	APW, DGN	APW, DGN	APW, DGN	APW, DGN	APW, DGN	APW, DGN	APW, DGN	APW, DGN	APW, DGN	
Anchovy	*Small pelagics*	APW	APW	APW	APW	APW	APW	APW	APW	APW	APW	APW	APW
Madeiran sardinella	*Small pelagics*	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	STN
Round sardinella		APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN	APW, STN
Chub mackerel	*Small pelagic*	STN	HL	HL	APW, HL, STN	APW, HL, STN	APW, HL, STN	APW, HL	APW, HL, STN	APW, HL, STN	HL, STN	HL, STN	HL, STN
Atlantic bumper	*Semi-pelagic*	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN
Bigeye grunt		APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN
West African ilisha	*Small pelagic*	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS	APW, BS, STN	APW, BS, STN	APW, BS, STN	BS, STN	BS, STN	APW, BS, STN	APW, BS, STN
Lesser African threadfin	*Demersal*	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, STN	BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN	APW, BS, STN

Red Pandora	*Demersals*	HL	HL	HL, STN	HL	HL, STN	HL, STN	HL	HL	HL, STN	HL, STN	HL, STN	HL, STN
Seabream		HL	HL	HL	HL	HL, STN	HL, STN	HL, STN	HL	HL	HL, STN	HL, STN	HL
Smooth puffer	*Demersal*	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL	HL

APW = *Ali-Poli-Watsa;* BS = beach seine; DGN = drift gill net; HL = hook and line & STN = set net.

For instance, if a closed season is to be implemented, these models will provide baseline information to the fishery scientists or manager as to which group of fishers the measure will affect.

In summary, fishers' ties (links) to a specific gear have been revealed in the present study. Even though there were changes in the type of species caught by some gears in some periods, the possibility of the fishers changing gears in the course of the season was not investigated so it cannot be concluded that they change gears. Further, most fishers claimed they use only one gear type aboard their canoes even though it is known that they carry more than one gear, making it possible to switch between gears based on the availability of resources (Mensah et al., 2006). Based on the multivariate analyses as well as responses of interviewed fishers, it has been shown that there are high and low fishing seasons. Since most fishers do not have a secondary occupation, it implies their livelihood is threatened since they have to sustain themselves and their dependants, they may resort to practices that might harm the resources. Thus it is imperative that fisheries managers explore ways of enhancing the resilience of these fishers.

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APPENDICES

1. Table of species caught with their corresponding ecological groups and gears.

	Common name	Scientific name	Code	Ecological group	Gear group				
					APW	BS	DGN	HL	StN
1	African moonfish	*Selene dorsalis* (Gill, 1863)	Sdo	Demersal	x	X			
2	African red snapper	*Lutjanus agennes* (Bleeker, 1863)	Lag	Demersal	x			x	x
3	African sicklefish	*Drepane africana* (Osório, 1892)	Daf	Demersal					
4	African striped grunt	*Parapristipoma octolineatum* (Valenciennes, 1833)	Poc	Demersal					
5	Anchovy	*Engraulis encrasicolus* (Linnaeus, 1758)	Een	Pelagic	x				
6	Angola dentex	*Dentex angolensis* (Poll & Maul, 1953)	Dan	Demersal				x	
7	Atlantic bigeye	*Priacanthus arenatus* (Cuvier, 1829)	Par	Demersal	x				x
8	Atlantic bumper	*Chloroscombrus chrysurus* (Linnaeus, 1766)	Cch	Pelagic	x	X			x
9	Atlantic emperor	*Lethrinus atlanticus* (Valenciennes, 1830)	Lat	Demersal				x	
10	Atlantic horse mackerel	*Trachurus trachurus* (Linnaeus, 1758)	Ttr	Pelagic					
11	Atlantic little tuna	*Euthynnus alletteratus* (Rafinesque, 1810)	Eal	Demersal	x		x	x	
12	Atlantic sailfish	*Istiophorus albicans* (Latreille, 1804)	Ial	Pelagic			x		
13	Atlantic white marlin	*Tetrapturus albidus* (Poey, 1860)	Tab	Pelagic					
14	Ballyhoo halfbeak	*Hemiramphus brasiliensis* (Linnaeus, 1758)	Hbr	Pelagic					
15	Barracuda	*Sphyraena sphyraena* (Linnaeus, 1758)	Ssp	Pelagic	x	X			x
16	Bastard grunt	*Pomadasys incisus* (Bowdich, 1825)	Pin	Demersal	x				
17	Big eye tuna	*Thunnus obesus* (Lowe, 1839)	Tob	Pelagic					
18	Bigeye grunt	*Brachydeuterus auritus* (Valenciennes, 1832)	Bau	Benthopelagic	x	X		x	x
19	Blue marlin	*Makaira nigricans* (Lacepède, 1802)	Mni	Pelagic			x		
20	Bonga shad	*Ethmalosa fimbriata* (Bowdich, 1825)	Efi	Pelagic	x				x
21	Bonito	Scombridae	Sco	Pelagic	x		x		
22	Chub mackerel	*Scomber japonicus* (Houttuyn, 1782)	Sja	Pelagic	x			x	x
23	Common dolphinfish	*Coryphaena hippurus* (Linnaeus, 1758)	Chp	Pelagic			x	x	
24	Common eagle ray	*Myliobatis aquila* (Linnaeus, 1758)	Maq	Benthopelagic			x		

	Common name	Scientific name	Code	Ecological group	Gear group				
					APW	BS	DGN	HL	StN
25	Congo dentex	*Dentex congoensis* (Poll, 1954)	Dco	Demersal				x	
26	Crabs	*Callinectes spp.*	Cal		x				x
27	Crevalle jack	*Caranx hippos* (Linnaeus, 1766)	Chi	Semi-pelagic	x		x	x	
28	Cuttlefish/ Inkfish	*Sepia officinalis* (Rong, 1831)	Sof					x	
29	Daisy stingray	*Dasyatis margarita* (Günther, 1870)	Dma	Demersal					x
30	False scad	*Caranx rhonchus* (Geoffroy Saint-Hilaire, 1817)	Crh	Benthopelagic	x			x	
31	Flat needlefish	*Ablennes hians* (Valenciennes, 1846)	Ahi	Reef-associated	x			x	
32	Flathead grey mullet	*Mugil cephalus* (Linnaeus, 1758)	Mce	Benthopelagic					
33	Flying gurnard	*Dactylopterus volitans* (Linnaeus, 1758)	Dvo	Reef-associated				x	
34	Frigate tuna	*Auxis thazard thazard* (Lacepède, 1800)	Ath	Pelagic	x				
35	Guitar fish	Rhinobatidae	Rhi	Demersal					x
36	Leer fish	*Lichia amia* (Linnaeus, 1758)	Lam	Pelagic					
37	Lesser African threadfin	*Galeoides decadactylus* (Bloch, 1795)	Gde	Demersal	x	x			x
38	Lizard fish	*Synodus indicus* (Day, 1873)	Sin	Reef-associated					
39	Longneck croaker	*Pseudotolithus typus* (Bleeker, 1863)	Pty	Demersal	x	x			x
40	Madeiran sardinella	*Sardinella maderensis* (Lowe, 1838)	Sma	Pelagic	x				x
41	Meagre	*Argyrosoma regius* (Asso, 1801)	Are	Benthopelagic		x			
42	Mediterranean rainbow wrasse	*Coris julis* (Linnaeus, 1758)	Cju	Reef-associated					
43	Miscellaneous		Mis		x			x	x
44	Other snappers	Lutjanidae	Lut	Demersal					
45	Pink dentex	*Dentex gibbosus* (Rafinesque, 1810)	Dgi	Demersal		x		x	
46	Rainbow runner	*Elegatis bipinnulata* (Quoy & Gaimard, 1825)	Ebi	Reef-associated	x				
47	Rays unspecified	Rajidae	Raj				x		x
48	Red Pandora	*Pagellus bellottii* (Steindachner, 1882)	Pbe	Demersal	x			x	x

Table of species (cont'd)

	Common name	Scientific name	Code	Ecological group	Gear group				
					APW	BS	DGN	HL	StN
49	Ribbonfish	*Trachipterus* spp.	Tra	Bathypelagic	x	X			x
50	Round sardinella	*Sardinella aurita* (Valenciennes, 1847)	Sau	Pelagic	x				x
51	Round scad	*Decapterus punctatus* (Cuvier, 1829)	Dpu	Demersal	x				
52	Rubber lip grunt	*Plectorhinchus meditarraneus* (Guichenot, 1850)	Pme	Demersal				x	
53	Sardinella unspecified	*Sardinella* spp.	Sar	Pelagic	x				x
54	Sea snail	Liparidae	Lip	Demersal					
55	Seabream	*Dentex* spp.	Den	Demersal	x			x	
56	Seabreams unspecified	Sparidae	Spa	Demersal					
57	Senegalese tonguesole	*Cynoglossus senegalensis* (Kaup, 1858)	Cse	Demersal					x
58	Sharks	Carcharhinidae	Car	Pelagic			x		
59	Sharpchin flyingfish	*Fodiator acutus* (Valenciennes, 1847)	Fac	Pelagic					
60	Shortfin pompano	*Trachinotus teraia* (Cuvier, 1832)	Tte	Pelagic					
61	Shrimps	Penaeidae	Pen	Demersal		X			
62	Skipjack tuna	*Katsuwonus pelamis* (Linnaeus, 1758)	Kpe	Pelagic	x		x		
63	Smooth puffer	*Lagocephalus laevigatus* (Linnaeus, 1766)	Lla	Pelagic				x	
64	Smoothmouth sea catfish	*Arius heudelotii* (Valenciennes, 1840)	Ahe	Demersal					
65	Swordfish	*Xiphias gladius* (Linnaeus, 1758)	Xgl	Pelagic			x		
66	Tuna unspecified	Scombridae	Scm	Pelagic	x				x
67	West African goatfish	*Pseudupeneus prayensis* (Cuvier, 1829)	Ppr	Demersal	x			x	x
68	West African ilisha	*Ilisha africana* (Bloch, 1795)	Iaf	Pelagic	x	X			x
69	West African ladyfish	*Elops lacerta* (Valenciennes, 1847)	Ela	Pelagic					
70	West African Spanish mackerel	*Scomberomorus tritor* (Cuvier, 1832)	Str	Pelagic	x				
71	White grouper	*Epinephelus aeneus* (Geoffroy Saint-Hilaire, 1817)	Eae	Demersal				x	
72	Yellowfin tuna	*Thunnus albacares* (Bonnaterre, 1788)	Tal	Pelagic			x		

2. Copy of Interview schedule used to interview fishers in Winneba fishing community

Name of interviewer…………………………………………………………………..

Case No.: …………   Name of community……………………..

Personal details of interviewee/ respondent

1. Gender……………….
2. Age ………………
3. Occupation ……………………………………….
4. How long have you been involved in this occupation? …………………………

Knowledge about fishery

5. How many permanent fishermen are there in this community…………………..
6. Do some of the fishermen come from outside Winneba? Yes [ ] No [ ]
7. Is fishing done all year round Yes [ ] No [ ]

If yes, which month(s) is/ are the peak fishing period………………………….

If no, which month(s) do the fishing activity occur…………………………….

Fishing Efforts

8. What is the size of your canoe?

Length…………   Breadth…………….   Number of seats………..

9. How many fishermen do you have on your canoe per trip…………………….
10. How many types of gears do you use on your canoe? ....
    What are they? ………………………………………………………………..
11. Do you use outboard motor on your canoe? Yes [ ] No [ ]

If yes, what is the capacity (horse power) of the outboard motor…………………..

12. How long do you stay out at sea?

    ……………………………………………………………...

13. How do you store the fish caught at sea? …………………………………………………

Fish Catch

14. What main type of fishing do you practice? ……………………………………………….
15. What species of fish are usually caught? ………………………………………………….

    ……………………………………………………………………………………………..

    Which of the species do you catch most? ....
16. How far seaward do you fish? ……………………………………………………………

Knowledge of challenges to the fishery Industry

17. In your opinion, has there been any change in the quantity of fish caught? Yes [ ]   No [ ]

    If yes, have they increased or decreased? …………………………

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

    ………………………………………………………………………………………………

    ………………………………………………………………………………………………

19. In your opinion, has there been any change in the size of fish caught. Yes [ ]   No [ ]

    If yes, have they increased or decreased? ………………………

20. In your opinion, what might be the reason for the increase/decrease in fish size?

    ………………………………………………………………………………………………

    ………………………………………………………………………………………………

21. Has there been the disappearance of any particular species? Yes [   ]   No [   ]

    If yes, which species? ……………………………..

Knowledge of fishery conservation and management practices

22. Do you know of any fishery laws? Yes [ ] No [ ]

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

    National …………………………………………………………………

    Traditional………………………………………………………………

23. Do all the fishermen in this area adhere to these laws? Yes [ ] No [ ]

24. In your opinion, what can be done to further protect the fishery?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

25. In your opinion, what can be done to increase the abundance of fishery?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Socio-economics

26. How many wives and children do you have? Wife ………….. Children…………………
27. Are any of them involved in fishing? [ ] Yes [ ] No

    If yes, what roles do they play? ....

28. How much does a complete net cost? ……………………………………………………
29. Do you own a canoe? [ ] Yes [ ] No

i) If yes, how much did it cost? …………………… Price range of canoe: ..……………...

ii) If no, how much does it cost to hire it per trip? ………………………………………….

30. How do you share your catch per trip (in percentage)?

    Canoe owner ………………………….. Wife/ family ………………………

Fish seller (monger) ………………….. Other ………………………………

31. What is the price range of outboard motor (based on horse power)? ……………………
32. Does the community or government provide you loans to buy materials you need?

    [ ] Yes [ ] No

i) If yes, under what conditions? …………………………………………………………
ii) If no, how do you obtain the needed money? ……………………………………………

Comments (if any)