SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP)

Synthesis of Scientific and Local Knowledge on Sardinella Species in Ghana

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Cover photo: Sorting of beach seine catch at Moree (Credit: Hen Mpoano)

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ACRONYMS

DA	District Assembly
EUC	Equatorial Under Current
FAO	Food and Agriculture Organisation
FGD	Focus Group Discussion
GC	Guinea Current
GUC	Guinea Under Curent
GCLME	Guinea Current Large Marine Ecosystem
GSS	Ghana Statistical Service
GUC	Guinea Under Current
ITCZ	Inter-Tropical Conversion Zone
LEK	Local Ecological Knowledge
LME	Large Marine Ecosystem
MFRD	Marine Fisheries Research Division
NOAA	National Oceanic and Atmospheric Administration
ROMS	Regional Ocean Modeling System
SEK	Scientific Ecological Knowledge
SST	Sea Surface Temperature
WRI	Water Research Institute
SFMP	Sustainable Fisheries Management Project USAID United States Agency for International Development

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ACKNOWLEDGEMENTS

This publication was a joint effort between the University of Rhode Island staff from the Fisheries Center, Department of Fisheries, Animal and Veterinary Sciences and staff from Hen Mpoano. Working together, it was possible to scan a great number of documents for scientific knowledge and interview many stakeholders in the sardinella fishery for their local knowledge. This type of collaboration is essential to understanding the complex world of fisheries and to move towards sustainability.

The nine community enumerators from Western Region, Central Region, Greater Accra and Volta Region who worked tirelessly in the ten communities (Half Assini, Axim and Takoradi, Elmina, Moree, James Town, Tema, Prampram Abutiakope and Adina) to make the data collection possible; thank you!

Many thanks goes to the fishermen participants from Ghana who spent time in interviews and follow up validation events. The importance of this participation cannot be overlooked as there is no monetary or other incentive other than cooperation. The sharing of knowledge needs to be expanded in the future so both parties are fully engaged and can take advantage of the overall picture.

The authors wish to express appreciation to the SFMP project for funding this work and for preparing and sharing this publication.

INTRODUCTION

Types of Knowledge

Scientific information about the *Sardinella* species in Ghana is scattered throughout many hard to find journals, workshop reports and grey literature (Figure 1). Much of the scientific literature is dominated by information about the northern West African *Sardinella* stock, not the stock in the Gulf of Guinea that is subject to different environmental conditions that might affect biological properties and behavioral patterns. Extensive review of available information was conducted using search engines (such as Google Scholar and SCOPUS) and universities and is summarized in this document.

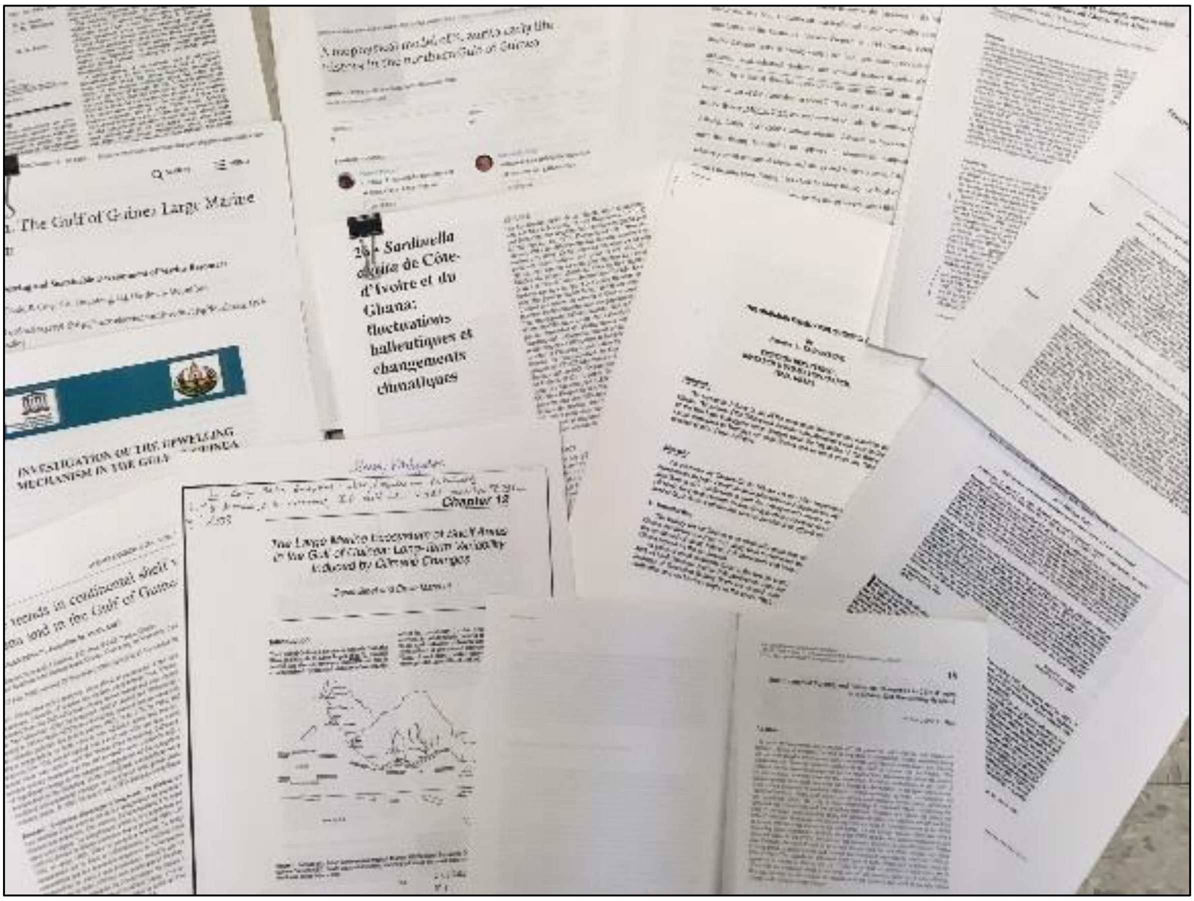


Figure 1. The information about Sardinella species in the Gulf of Guinea is spread out among many journals, reports and languages. Some are not readily available.

Scientific ecological knowledge (SEK) is defined as a formalized process based on the scientific method that is passed through a strict and universally accepted set of rules qualifying it for a particular use (Raymond et al., 2010). The cost of monitoring observations of the ocean and its processes, as well as measuring ecological relationships between habitat and the organisms in a constantly changing environment makes scientific knowledge expensive and specific in time and space. These scales are often mismatched in developing decision-making tools. Uncertainty and inherent variability in the data affect overall conclusions on a large scale that sometimes are needed for real time management.

In articles published between 1978-1980, Johannes described the complex interface between social and ecological systems that typify fisheries and proposed that to fully understand them we cannot rely solely on academic science. He proposed the use of fishermen's knowledge to supplement information and for use in management (Johannes, 1977 1978, 2000).

Fisheries are very complex systems as they are a combination of the biological and ecological natural systems with human systems. As such, it is difficult to fully understand human behaviors, beliefs and consequences of actions observed in these systems in addition to the variation often observed in natural systems. These cultural norms influence how a person sees the environment, sees his/her role in the environment and the ability to change how a person manages the environment. Local ecological knowledge (LEK) can supplement the SEK, can fill in gaps where no SEK exists, or point to differences of opinion between scientists and fishermen (Jelavic, 2010). Fishermen's life and livelihood depend on their ability to understand the environment and the behavior of the targeted resources. Much of this knowledge is passed down through generations of fishermen living in fishing communities and new information is added through real life experiences. Most of this knowledge is not in written form, nor is it found in any established format. However, it is usually of such breadth and depth that it is invaluable in understanding the past, present and future of fisheries resources. In order to maximize catch, fishermen tend to closely observe those environmental factors that contribute to fishing success: water currents and tides, moon phases, weather, and wind direction, as well as fishermen skills including knowledge about setting and mending the fishing gear.

Figure 2. Fishermen from Elmina participating in collaborative research project sharing knowledge.

The objective of the LEK is to discover patterns of belief that can be separated into cultural domains that can add new knowledge about *Sardinella*, fishing and environments. Four focus group discussions (FGD) were conducted by staff from Hen Mpoano from May to July 2016 in different fishing communities: New Takoradi (Western Region), Elmina (Central Region), Tema New Town (Greater Accra Region), and Abutiakope (Volta Region). A total of 105 fishermen attended the FGDs. FGDs were held to collect initial data for the development of the survey instrument to be used for the one-on-one data collection (Figures 2 and 3).

Following the FGDs, semi-structured interviews were conducted with 84 fishermen in 7 selected fishing communities (25 in the Western Region; 27 in the Central Region; 17 in the Greater Accra Region, and 14 in the Volta Region). The respondents were made up of fishermen who were identified as being knowledgeable about *Sardinella*. Both opportunistic and snowballing non-random sampling strategy were used based on availability and willingness of individuals to participate in the survey in the selected communities

The individual interview responses were compiled and analyzed as qualitative data and then quantitatively evaluated using cross-tabulation chi square, factor analysis, free list and consensus analysis. The objective of this analysis is to discover the content and the structure of domains- what goes with what and how they go together. It enables us to describe the interwoven linkages between themes and people and places (Bernard et al., 2017). It is not the study of people themselves but rather of culture, cultural norms and consensus. Consensus analysis allows for analysis of inter-cultural variability and placement in a cultural domain. The "truth" for one person may not be the "truth" for another.

> *"I hope that all that I have contributed would go a long way to benefit us all and sardinella would come in abundance".*

The LEK in this document is organized into boxes alongside appropriate scientific information to show agreement or disagreement with the SEK.

Figure 3. Fisherman from Tema participating in the individual interview (Photo credit: Hen Mpoano).

Incorporating LEK into the decision-making process and creating community based resource management systems can have many benefits. Eliciting and using LEK in the early stages of a management action can make the difference between perception of usefulness and subsequent compliance. Local knowledge is not always accurate but it can be used to develop testable hypotheses that can confirm the reliability of the data. This combination should help to reduce uncertainty and build a more complete understanding of a complex environment.

This document is organized into three chapters: the environment, the fishery, and the fish. The scientific information is compared to the local ecological knowledge and congruence is summarized in the table of the status of knowledge. Critical research gaps are identified based on agreement of knowledge.

Importance of *Sardinella* to Ghana

The importance of the *Sardinella* fishery to Ghana cannot be over emphasized (Figures 4 and 5). Ghanaians obtain nearly 10% of their total protein from fish (GSS, 2002). Both the coastal and inland dwellers are heavily reliant on fish. It is the cheapest animal protein available to Ghanaians, hence, consumed daily by a majority of the population (Heinbuch, 1994). Fish forms two-thirds of animal protein in the Ghanaian diet (Thorpe et al., 2004) making it three times higher than the world average consumption (WRI, 2003).

The small pelagic fisheries, which is the mainstay of the artisanal fisheries, in a good year contributes 70% of the total landings (MFRD, 2007). The local Ghanaian fish market is dominated by *Sardinella*, anchovy and chub mackerel which are small pelagics caught by the canoe and semi-industrial fishing fleets (Demarcq and Aman, 2002). It is estimated that Ghana’s 2030 population will require two times the current catch levels and fish imports. This projected fish demand can be met significantly by a sustainably managed *Sardinella* fishery given the high growth rates of small pelagic fish (Bailey et al., 2010).

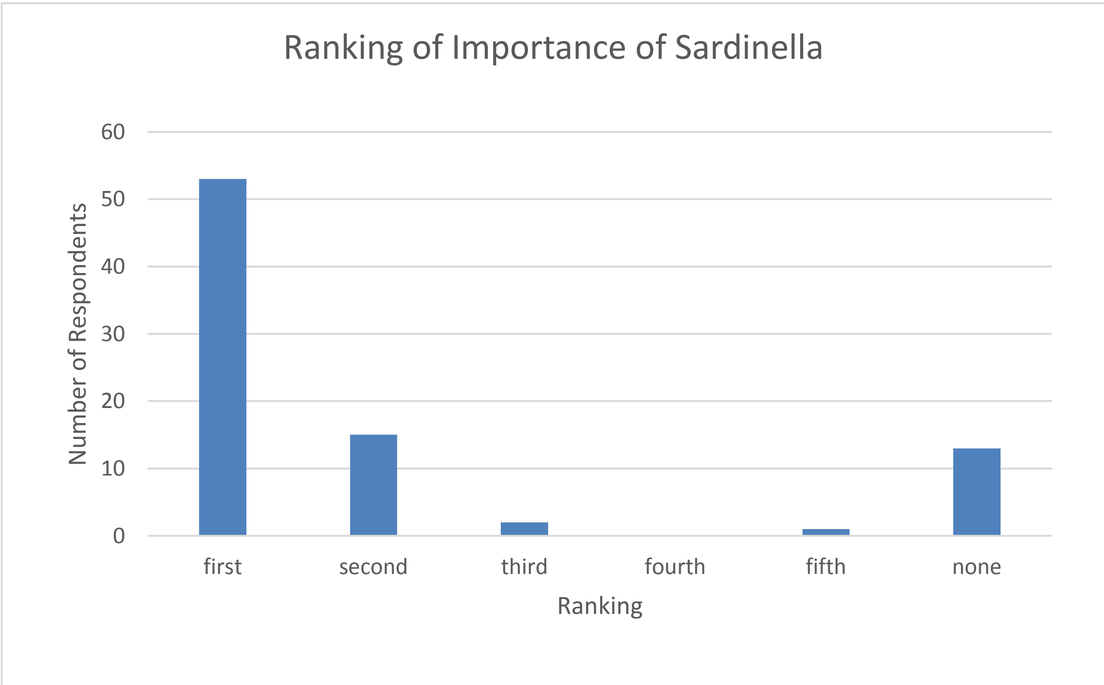


Figure 4. Sardinella was listed as the primary fish captured by 53 of the 84 respondents.

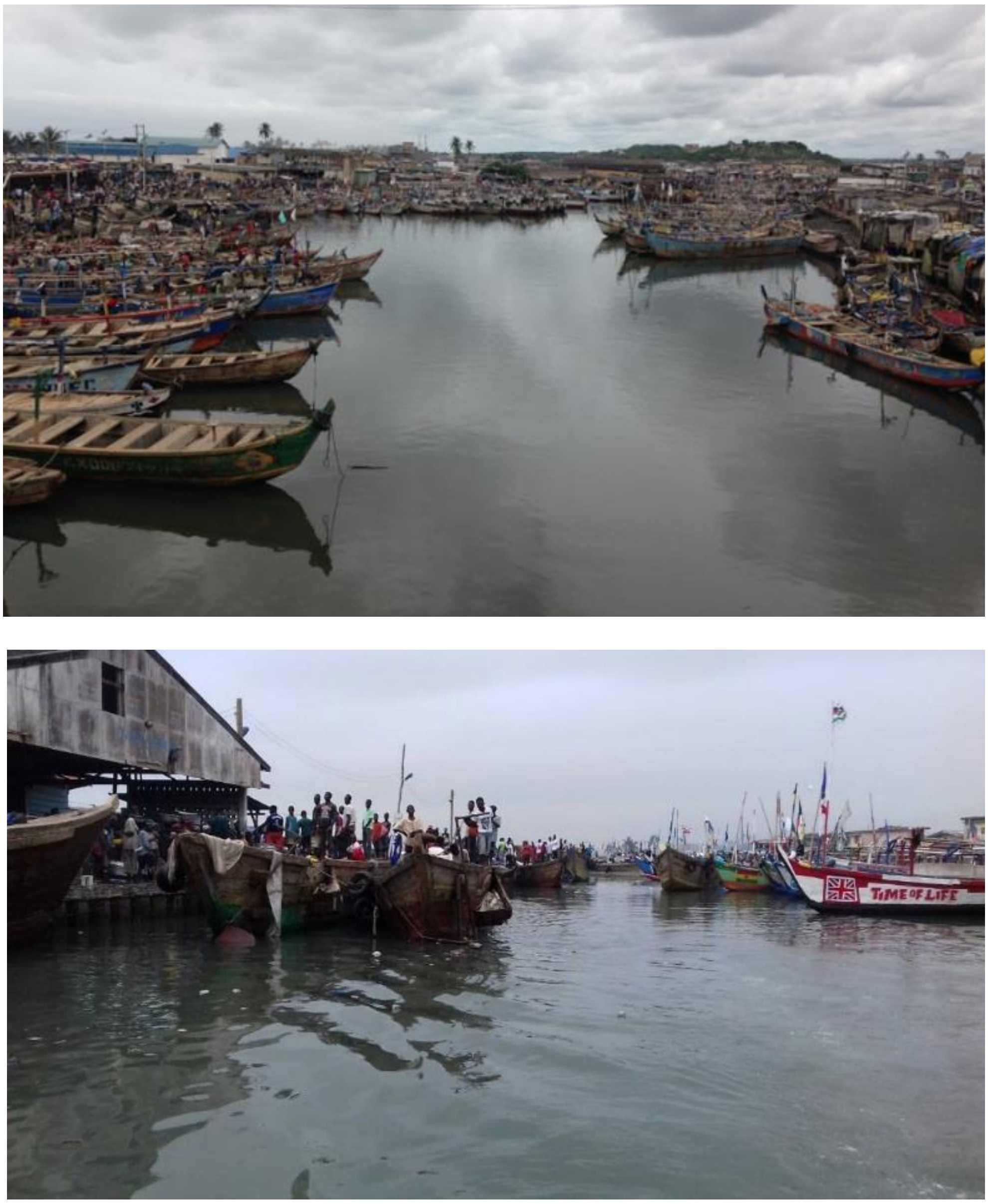


Figure 5. One of the principal ports for landing Sardinella- the Port of Elmina (M. Boucher)

" If we do not fix the problems in the sardinella fishery there will be unemployment and hunger; there will be no future and food for my kids".

Fisherman from Half Assini

THE ENVIRONMENT

Ghana is located in the center of the West African coast (Figure 6). On the south, it borders the Gulf of Guinea and the Atlantic Ocean. The Guinea Current Large Marine Ecosystem (GCLME) extends from the Bissagos Islands to Cape Lopez and encompasses 16 countries from Guinea Bissau to Angola (Figure 7).

Figure 6. Map of Ghana.

Source: http://www.justmaps.org/maps/africa/ghana/

The productivity of the GCLME is affected by two major processes: nutrients from land drainage and rivers and turbulent diffusion through a stable pycnocline and periodic uprising of nutrient rich mid-depth water (Binet and Marchal, 1993).

Currents

Two currents bring their waters to the Guinea Current (GC) along the coast of West Africa: the Equatorial Counter Current moving eastward and the Canary Current moving southwest (FAO 1990) (Figure 8). There are 2 major currents that flow along the coastline of Ghana, the Guinea Current and the South Equatorial Current. Closer to shore the Guinea Current flows from west to east, and the South Equatorial Current flows from east to west. The GC is not very deep-on average it extends from the surface to 15 m near the coast and 25 m offshore. Underlying the GC is the Guinea Under Current (GUC) which originates from the Bight of Biafra as a return branch of the Equatorial Under Current (EUC) (Figure 9). The GUC starts out as a surface current but dives underneath the GC off the Ghana coast (Figure 10).

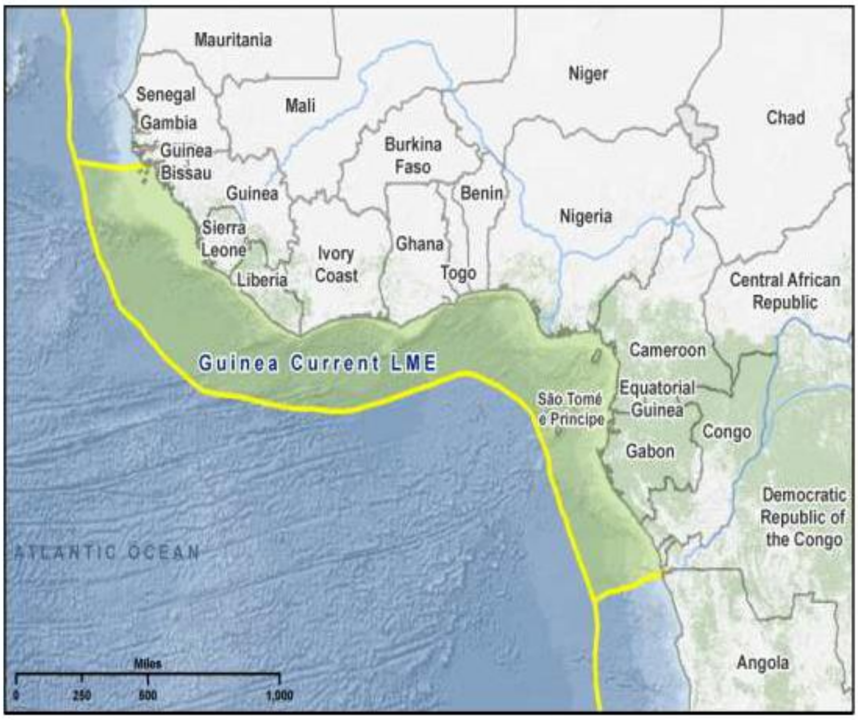


Figure 7. Guinea Current Large Marine Ecosystem

Source: NOAA project office

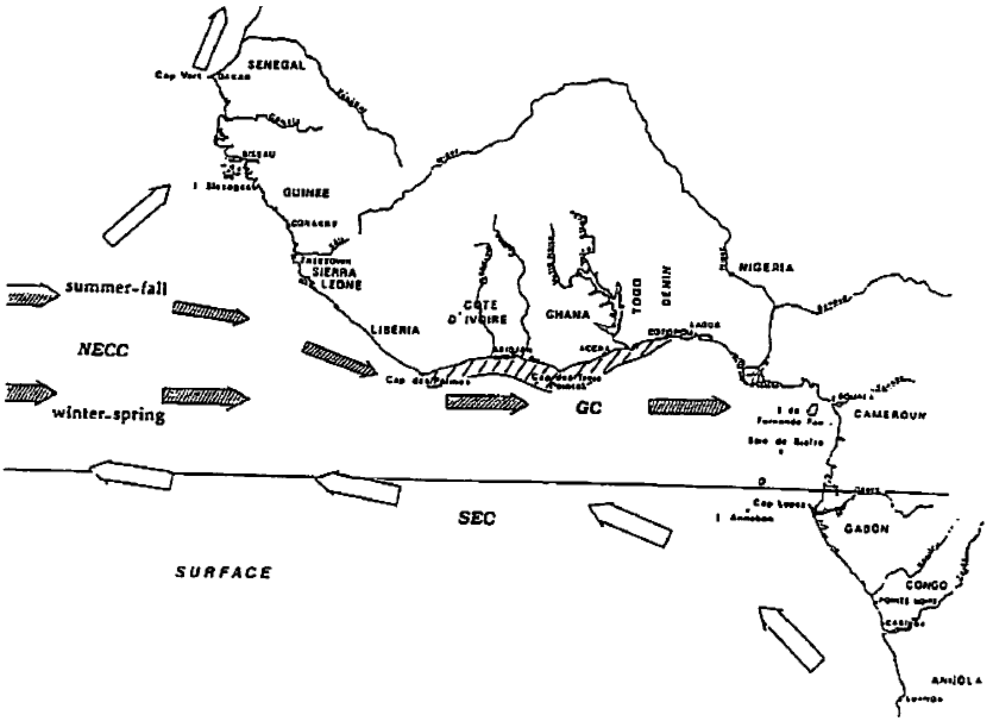


Figure 8. Surface circulation in the eastern tropical Atlantic. NECC: North Equatorial Counter Current; GC: Guinea Current; SEC: South Equatorial Current. Hatched belt along the coast: Seasonal upwelling and Sardinella aurita fishery area

(From Binet and Marchal, 1993)

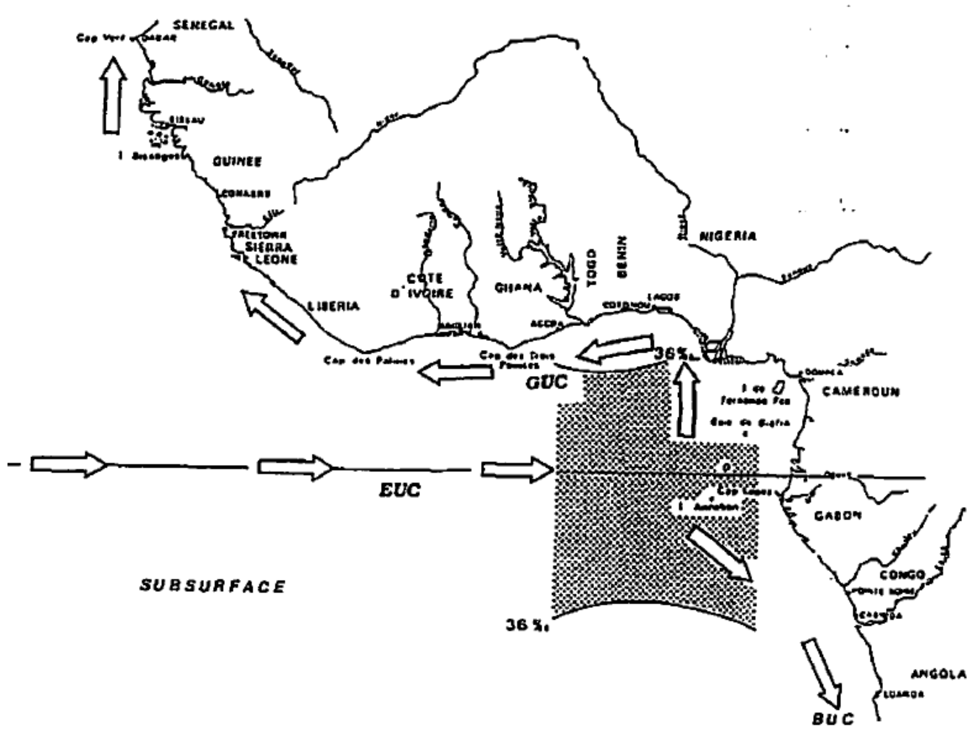


Figure 9 Subsurface circulation in the eastern tropical Atlantic. EUC: Equatorial Under Current, GUC: Guinea Under Current; BUC: Benguela Under Current. Dotted region is the area of the subsurface salinity maximum (>36x10-3) located around 50 m in depth

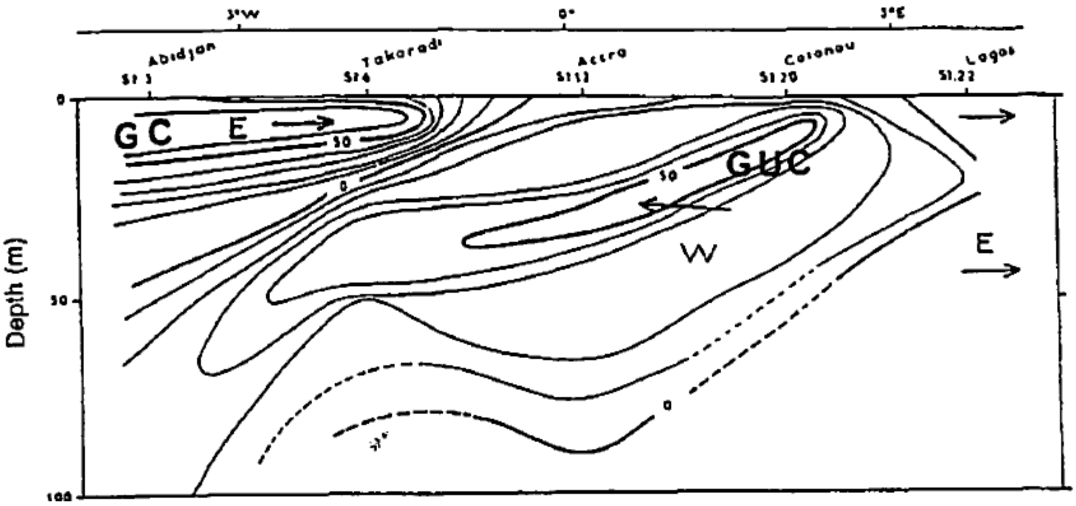


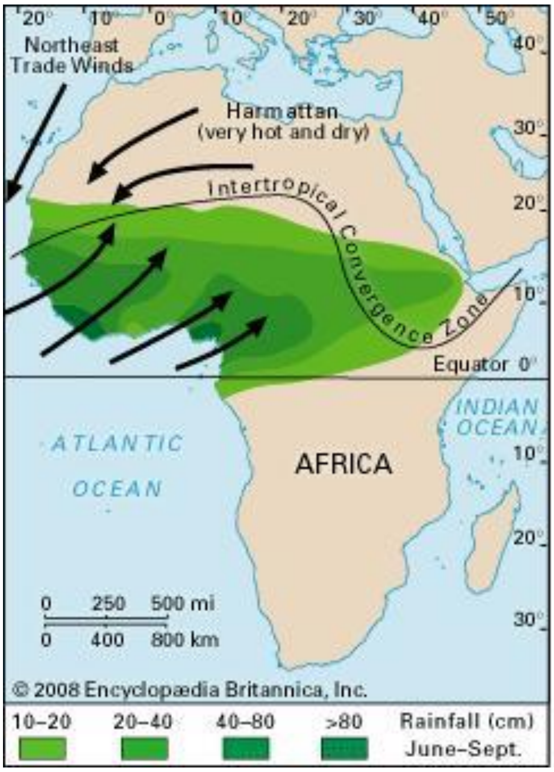
Figure 10 Longitudinal section of the zonal components of circulation off the Ivory Coast to Nigeria: 0-100 m profile on the continental shelf at 10-23 nm from shore; May 1972. Zonal velocities are indicated in cm/s; each contour line corresponds to 10 cm/s vari

Wind and Rainfall

Wind and rainfall are major factors of environmental importance to the fisheries in Ghana controlling degree upwelling and nutrient enhancement. Ghana is only a few degrees north of the Equator, giving it a warm climate. It lies within the tropical belt at 4-12^{o}N latitude and is heavily influenced by the West African Monsoon. The climate is characterized by a wet season and the dry season. The changing seasons have a significant impact on oceanographic conditions which effects marine resource distribution and fisheries.

North Ghana experiences its wet season from May to November. In the northern and central regions, annual rainfall is less than 1100 mm. Southwest Ghana is the wettest area experiencing two wet seasons, one from March – July and the other in September and November. Annual rainfall in this area is 2000 mm (Asante and Amuakwa-Mensah, 2014). The greatest range in temperatures occurs in northern Ghana with an average temperature of 27-30°C in the dry season to 24-27°C in the wet season. In the south, the temperatures do not fluctuate as much between the dry and wet season with average temperatures reaching 25-27°C and 22-25°C respectively.

The wet seasons are influenced be the movement of the tropical rain belt (the Inter-Tropical Conversion Zone, ITCZ). In areas south of the ITCZ, south-westerly winds blow towards land bringing moist air from the Atlantic Ocean intensifying the Guinea Current. During the wet seasons squalls develop seasonally that correspond to coastal upwelling (Hagos and Cook, 2007). The upwelling zone becomes larger in winter and reduces in the summer and fall. In the wet season, the sea surface water temperature rises as upwelling becomes weaker (Figures 11a and b).



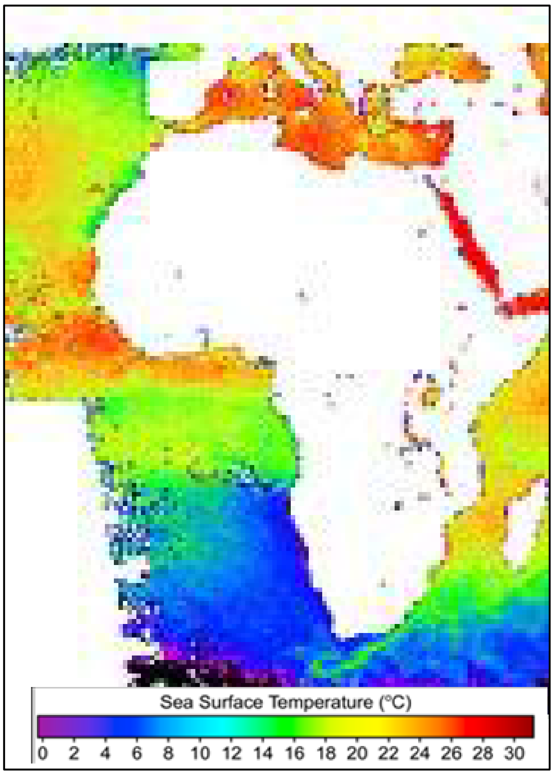
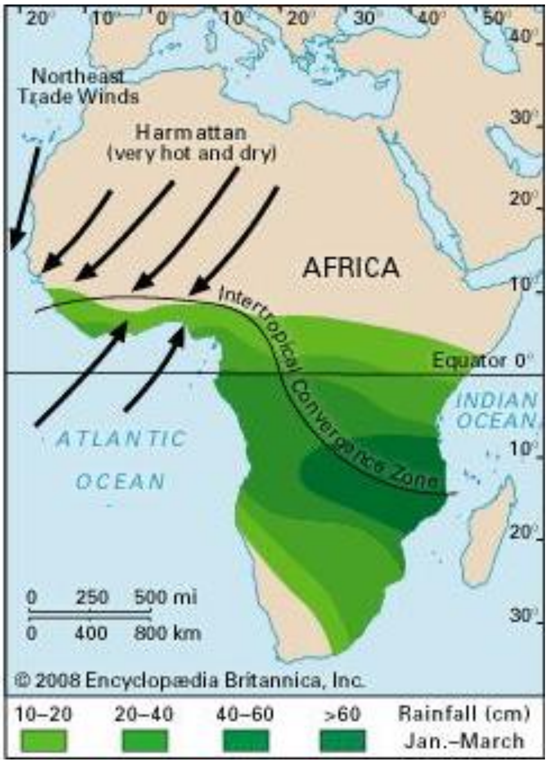


Figure 11. a and b. Wet season conditions. (a) Changing ITCZ and wind patterns with resulting (b) change in sea surface temperatures

(From Encyclopedia Britannica, Inc., 2008 and http://fas.org/irp/imint/docs/).

North of the ITCZ, the dominant wind direction is from the northeast which brings a dry desert wind from the Sahara (known as the "Harmattan"). The shifting of these two prevailing wind directions over the course of a year is called the West African Monsoon (Fontaine and Bigot, 1993). During the dry season, sea surface water temperatures get colder as upwelling increases and the dust from the Harmattan block sunlight from reaching the ocean's surface (Figures 12a and b).



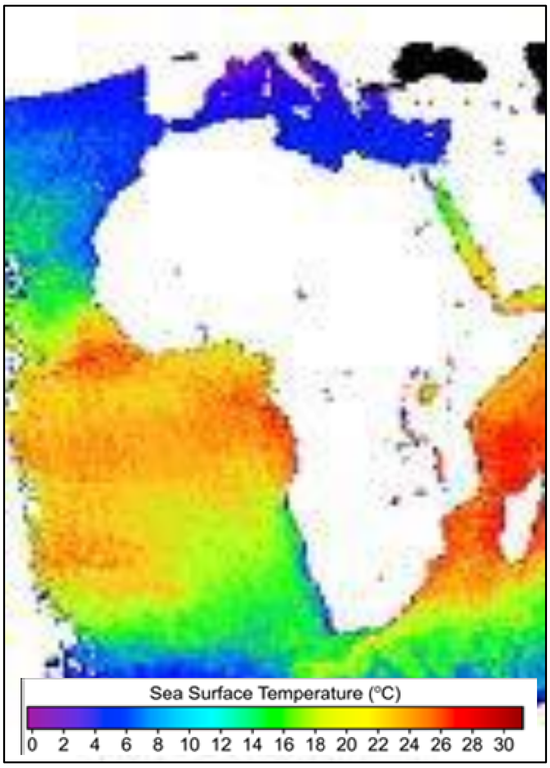


Figure 12. a and b. Dry season conditions. (a) ITCZ drops southward allowing for stronger NE trade winds causing more upwelling and (b) cooler sea surface temperatures

(From Encyclopedia Britannica, Inc., 2008 and http://fas.org/irp/imint/docs/rst/Sect14/Sect14_11.html).

Upwelling

In most current systems, wind can be the primary driver in upwelling events. However, the role of wind is not as obvious in the Guinea system. Two main upwelling cells are present (downstream of Cape Three Points in Ghana and downstream of Cape Palmas in Liberia).

> *"The sea and the fish in it have their seasons and it is how God designed it. From November to January we have something called "harmattan" and there is a type of fish that comes with that season (sardinella, moon fish). During that time the seas become cold and it brings fish to the surface"*
>
> Fisherman from New Takoradi

However, this upwelling is still poorly understood. Djakoure et al., (2017) used a Regional Ocean Modeling System (ROMS) model to assess the role of the Guinea Current as a mechanism for the upwelling. The model simulations indicated that there were different mechanisms controlling upwelling east of Cape Palmas and east of Cape Three Points. The widening shelf east of Cape Palmas affects the influence of the coastal structures on the current dynamics and shallowing of the thermocline. Local wind effects and the large continental shelf appear to control upwelling east of Cape Three Points.

Two seasonal upwellings occur along the continental shelf of Ghana, a major upwelling from late June/early July to September/early October, and a one month long minor upwelling during January or February (FRU/ORSTOM, 1976; Longhurst and Pauly, 1987; Mensah and Koranteng, 1988). During the major upwelling period the surface temperature (SST) drops from 25° C to 17° C or less, which brings nutrient rich waters to the surface for *Sardinella aurita*, *Sardinella maderensis* and other species. There is evidence for continuous upwelling offshore throughout the year, however the gradients are most pronounced from June to October with the coolest temperatures occurring in August and September (Bakun, 1978). In the summer, the temperature decreases as the GC moves east to an absolute minimum east of Cape Three Points however there are two areas where temperature increases abruptly: Cape Palmas and Cape Three Points (Bakun, 1978).

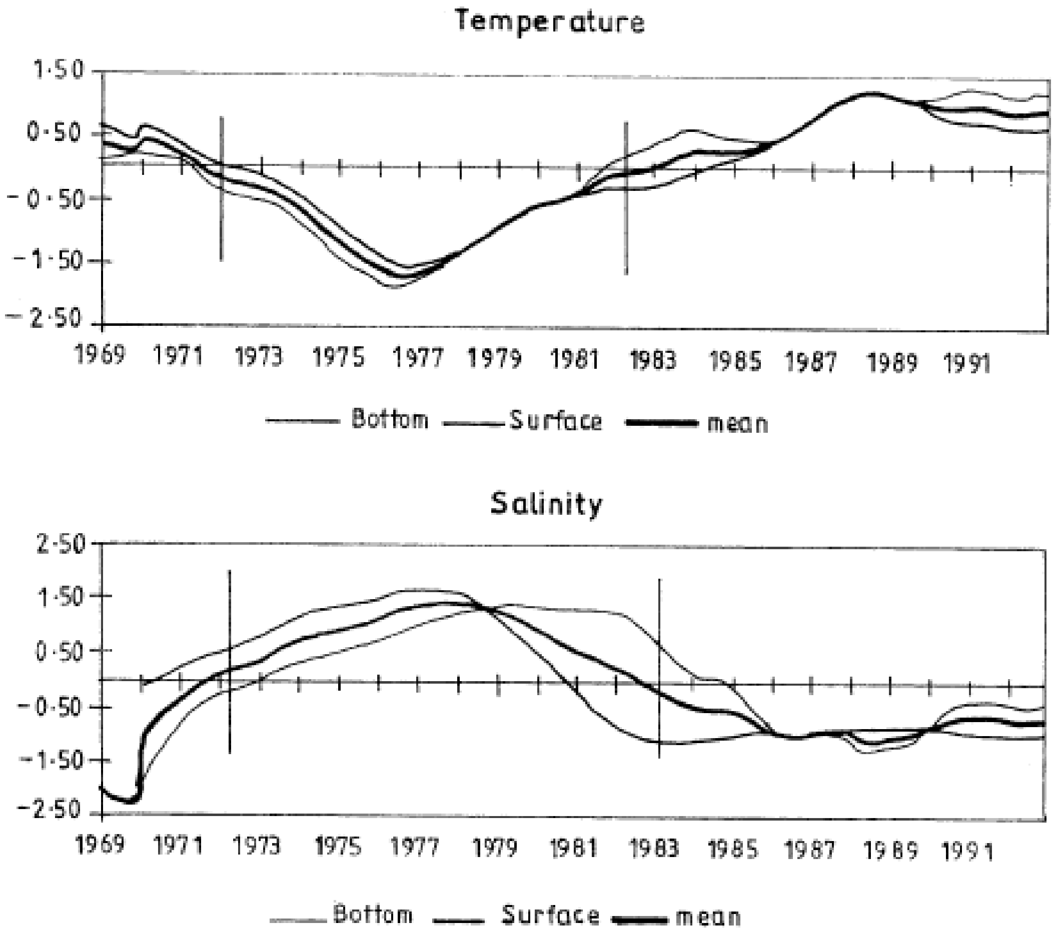


Figure 13. Climatic periods of temperature and salinity in the Gulf of Guinea. Plots were obtained from calculating temperature and salinity anomalies using extracted trend values as the data

Climate also affects the conditions for fish production. Koranteng and McGlade (2001) found three distinct climatic periods (before 1972, between 1972-1882 and after 1982 in which both surface and bottom temperatures and salinities varied as a result of environmental changes (Figure 13).

They described a very strong relationship between time periods and *S. aurita* landings with high landings during the initial colder period before 1972; a collapsed phase between 1973-1982 and a recovery phase after 1982.

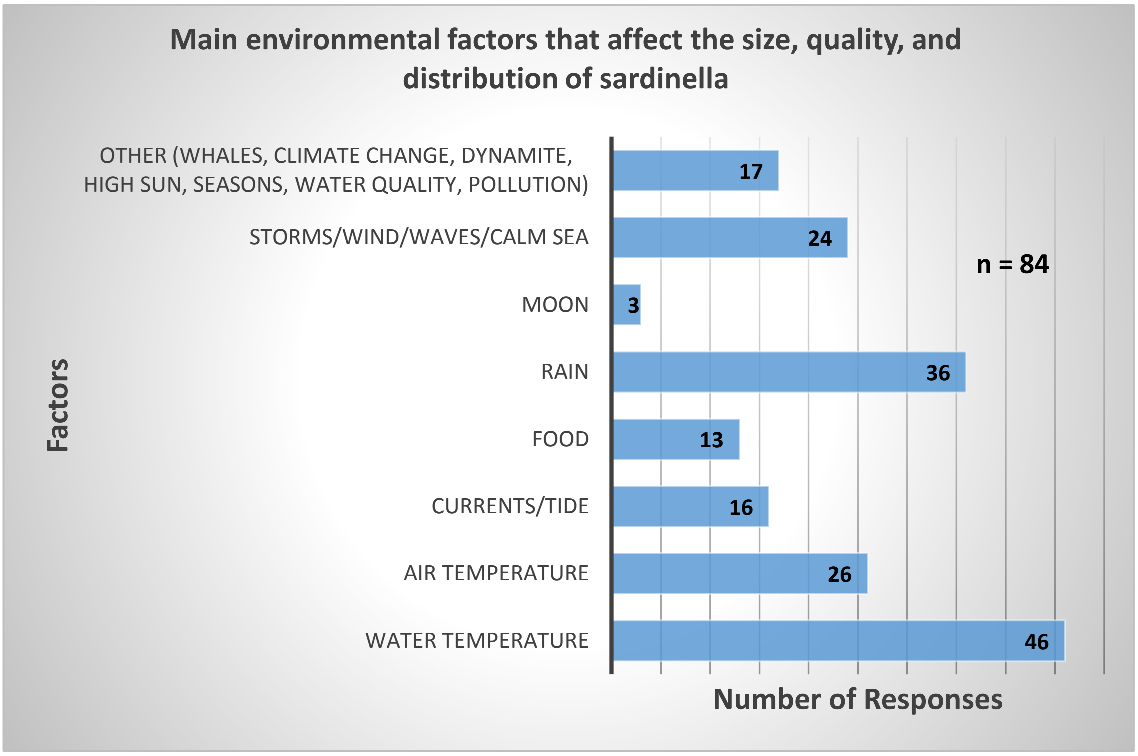


Figure 14. Fishermen responses when combined by region, noted water temperature and rain as being the primary factors controlling sardinella abundance.

But when looked at regionally using free list analysis, there were differences of opinion on the ranking of factors (Table 1).

Table 1. Fishermen responses when combined by region, noted water temperature and rain as being the primary factors controlling sardinella abundance (proxy for upwelling) based on their location.

	All			Western			Central			Greater Accra			Volta		
Environmental Factor	Frequency (%)	Average	Salience	Frequency (%)	Average Rank	Salience	Frequency (%)	Average Rank	Salience	Frequency (%)	Average Rank	Salience	Frequency (%)	Average Rank	Salience
Water temperature	50.6	1.85	0.37	62.5	2.13	0.406	50.6	1.85	0.369	26.7	1.5	0.2	35.7	2	0.268
Rain	49.4	1.95	0.35	54.2	1.92	0.372	49.4	1.95	0.345	60	1.89	0.461	64.3	2	0.435
Air temperature	43	1.97	0.31	66.7	1.44	0.569	43	1.97	0.308	53.3	2.63	0.317	35.7	2.2	0.226
Storms/wind/waves/calm sea										46.7	2.14	0.317	42.9	1.67	0.339

The western area (west of Cape Three Points) identified air temperature, while those east of Cape Three Points (Central region) identified water temperature as the driver. Wind was not listed as a primary factor.

> *"Round sardines like cold water while the flat like warm water"*
>
> Fisherman from the Accra Region

Rain is also identified as a strong environmental driver. Fishermen from Accra and Volta rated it highly. The strongest association was with those fishing 1-10 years and 31-40 and 41-50 years (Table 2) and beach seines and gillnets (Table 3).

Table 2. Free list analysis of environmental factors split by years fishing category.

	Years 1-10			Years 11-20			Years 21-30			Years 31-40			Years 41-50		
Environmental Factor	Frequency (%)	Average	Salience	Frequency (%)	Average Rank	Salience	Frequency (%)	Average Rank	Salience	Frequency (%)	Average Rank	Salience	Frequency (%)	Average Rank	Salience
Rain	50	1.5	0.4				53.6	1.8	0.384	40	1.5	0.342	80	2	0.567
Water temperature	50	1.75	0.38	53.8	1.86	0.41	57.1	1.75	0.414						
Food	37.5	2	0.25										40	1	0.4
Air temperature				50	1.54	0.42	35.7	2	0.256	50	2.4	0.308			
Storms/wind/waves/calm sea				42.3	2.18	0.282									
Currents/tide										30	1.67	0.233			

Table 3. Free list analysis of environmental factors evaluated by gear type.

	Beach seine			Gillnet			Purse seine			Trawl		
Environmental Factor	Frequency (%)	Average	Salience	Frequency (%)	Average Rank	Salience	Frequency (%)	Average Rank	Salience	Frequency (%)	Average Rank	Salience
Water temperature	40	1.75	0.3	41.7	1.6	0.347	57.8	1.96	0.398			
Rain	50	1.8	0.39	66.7	1.75	0.5	48.9	2	0.337			
Air temperature	50	2	0.33				37.8	2.24	0.243	77.8	1.29	0.722
Storms/wind/waves/calm sea										33.3	1.67	0.259
Currents/tide				41.7	2.4	0.257						

No fisherman was able to describe the relationship between wind, current, air and water temperature and upwelling.

Bottom Topography

The continental shelf of Ghana covers an area of 22,500 km^2. Its depth ranges from 24 km to 80 km offshore (Figure 15). The shelf is widest between Takoradi and Cape Coast extending to 100 km but narrows to its minimum width of 20 km as it heads east to Cape Saint Paul (Figure 15) (Bernaczek, 1986). At depths of 10 to 50 m, the bottom type is a mix of hard and rocky bottom to soft bottom (mud to sandy mud) (Buchanan, 1957). There is a section of dead madreporarian corals that starts at 75 m and runs throughout the shelf. Beyond the coral, the bottom falls off abruptly marking the start of the continental slope. The coastline and coral belt are comprised of soft sediment while the area between Takoradi and Tema is primarily hard bottom containing flat rocks and shoal covered by large branched corals and briozoons (Rijavec, 1980; Bannerman and Cowx, 2002). Corallinaceous algae covers the areas of mixed gravel and pebble.

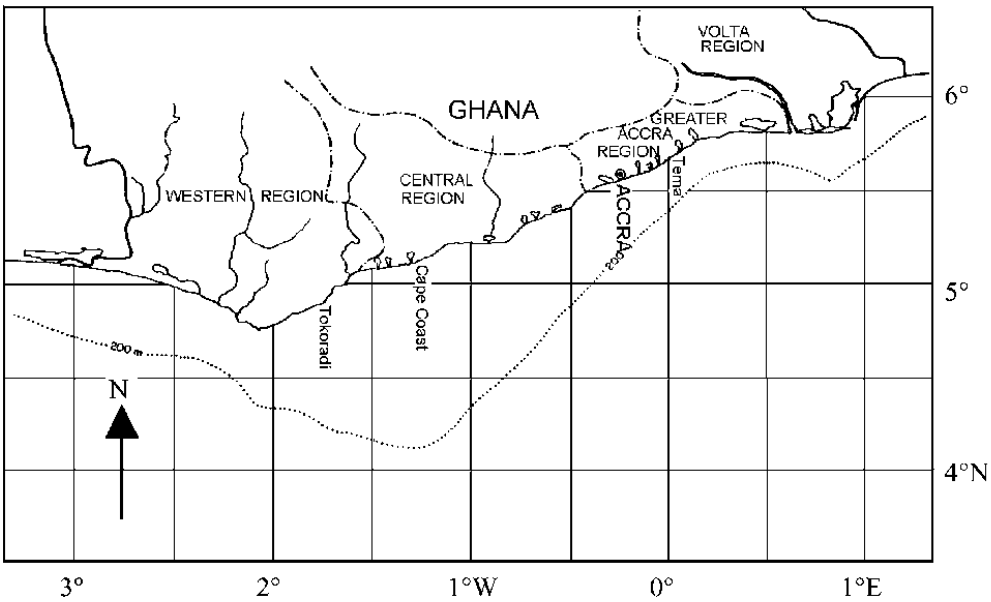


Figure 15. Coastal map of Ghana with outline of the continental shelf
(Doyi, B. A. 1984).

Figure 16. Small pelagic fish feeding on plankton

Although sardinella are pelagic, they do spend a great deal of time on or near the bottom feeding on small planktonic invertebrates, fish larvae and phytoplankton (Figure 16).

THE FISH AND THE FISHERY

Two Main Species

The two-main species of sardinella found off the coast of Ghana are the Round Sardinella, *Sardinella aurita* (Valenciennes, 1847) and the Flat Sardinella, *Sardinella maderensis* (Lowe, 1839) (Figure 17). Based on landings, *S. aurita* is generally considered to be of more

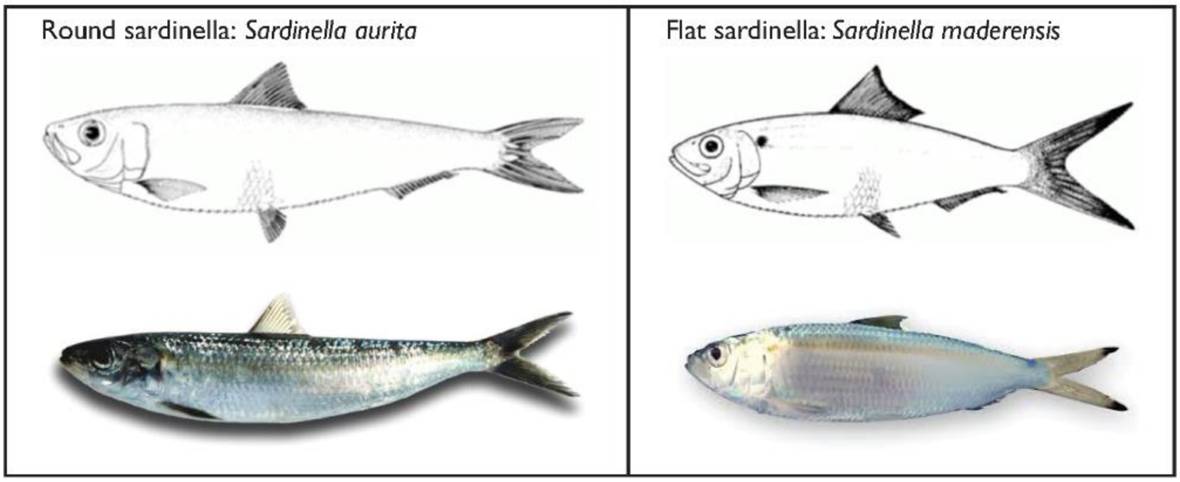


Figure 17. Sardinella aurita and Sardinella maderensis (source: Interafrican Bureau for Animal Resources).

commercial importance than *S. maderensis* (Figure 18). However, catches of *S. aurita* have significantly dropped in the past 15 years whereas those of *S. maderensis* have remained relatively constant with a few highs and lows. *S. maderensis* is caught year-round and *S. aurita* is mostly caught during the upwelling periods (June-Sept) (Dec-Mar). These two species belong to the family Clupeidae and are coastal small pelagic species that inhabit warm waters preferring temperatures of 24 degrees C.

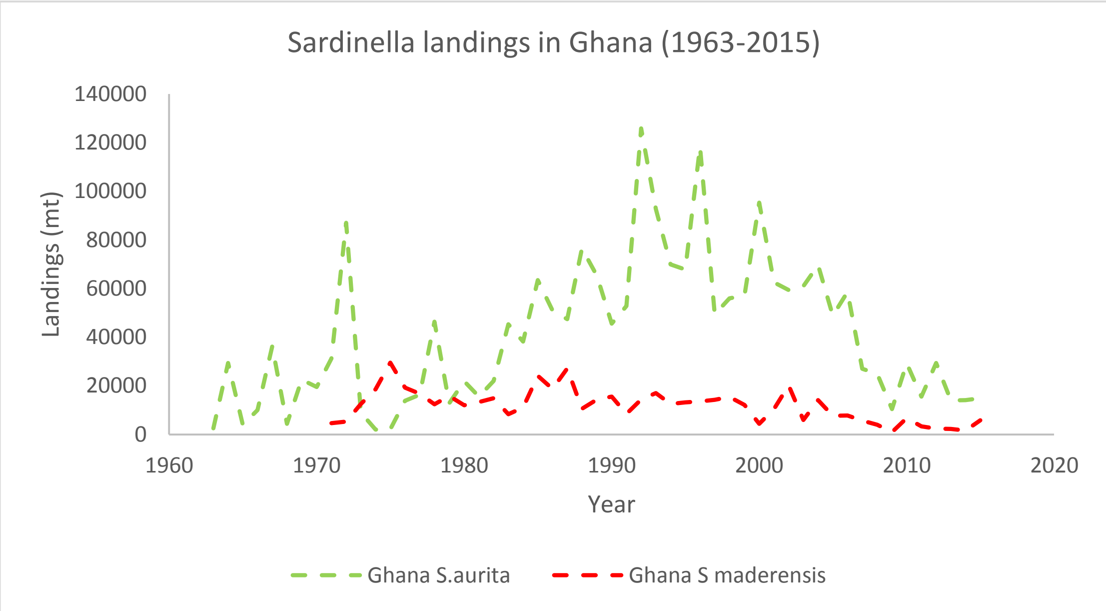


Figure 18. Landings of Sardinella aurita and Sardinella maderensis in Ghana from 1963 to 2015 (FAO searchable database).

Local Knowledge: When do you find sardinella in abundance?

When all respondents' answers were combined the time range of sardinella is from June through January (not found in the months of February through May) but they are mostly found between the months of July through September. When sorted by the home port of the respondents, the abundance time range widens as you move east; in the western range sardinella are only found during the months of June through September, and as you move east, the range expands. In the Volta region the range is from June through January however, both species are found in this area (Figure 19 a and b).

The is a significant correlation between when the fishermen land their catch and their perception of abundance by season (Chi Square= 18.89, $p = 0.004$). A partial correlation between region and gears fished showed a significant effect between region and abundance only (Kendalls tau = 0.349, $p = 0.000$).

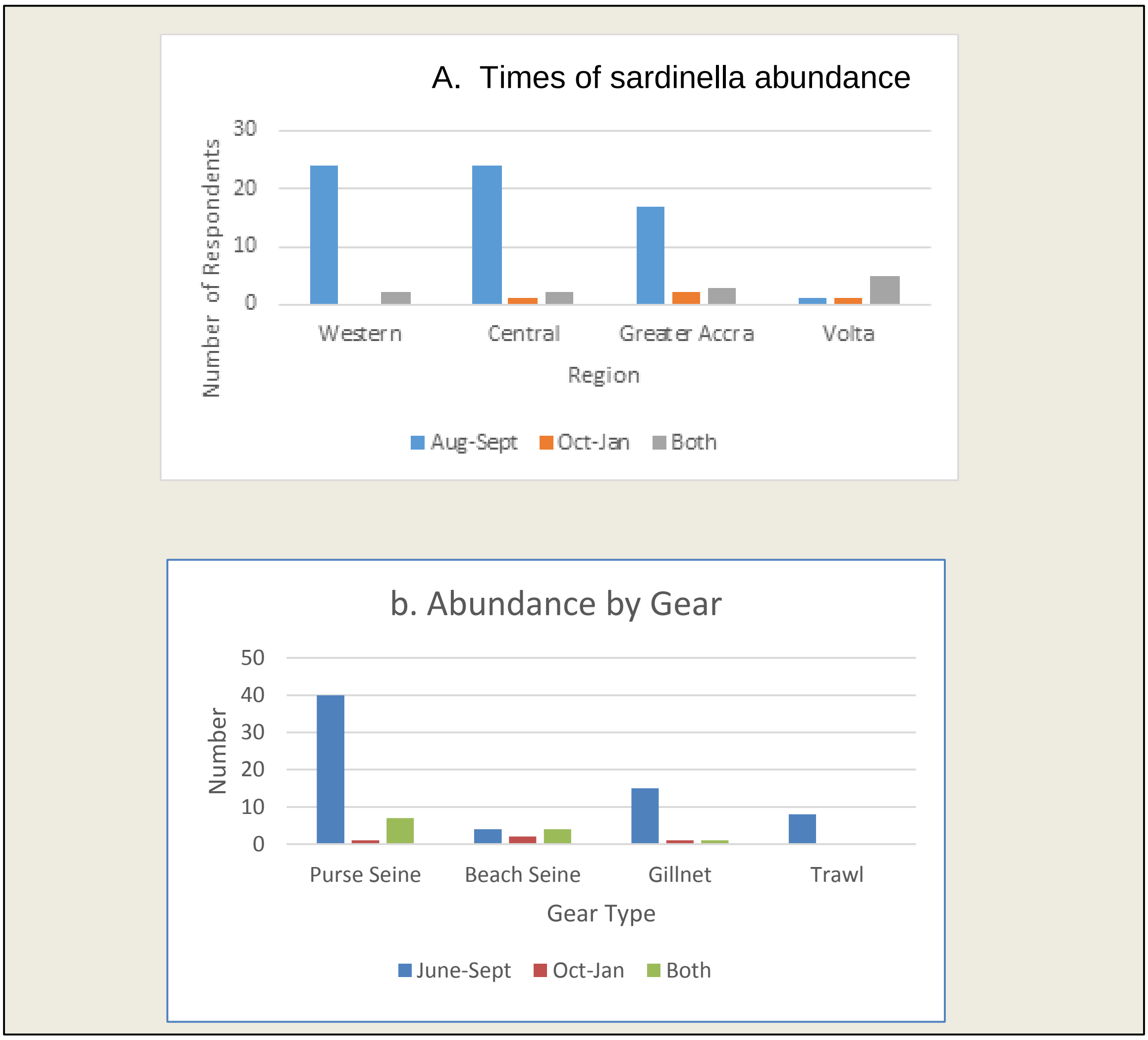


Figure 19. a. and b. The perception of abundance of sardinella is affected by region fisherman is from and although gear may play a role, it does not have a significant effect.

Local Knowledge: Landings
There was an overwhelming agreement in regards to the state of the sardinella population and 94% of respondents agreed that the population is decreasing in the waters where they fish and 88% said there was a decrease in the overall waters of Ghana. But in the Volta region, respondents stated there was an increase in the population in the areas where they fish.

The *S. aurita* fishery in Ghana is considered seasonal and occurs mostly from July to September coinciding with a major upwelling period. There are also some landings during the minor upwelling period of January to March (Mensah 1991). Upwelling starts the production cycle needed for *sardinella* survival. Phytoplankton, zooplankton and larval fish are the primary diet for both *S. aurita* and *S. maderensis*.

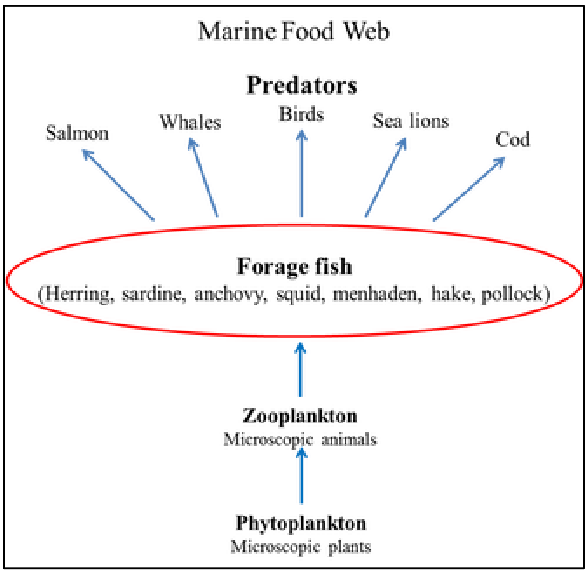


Figure 20. General food web for small pelagics

Local Knowledge: Prey

When fishermen were asked what they thought sardinella ate, the top answer was anchovy followed by small shrimp/animals. However, those fishermen with the most years of experience, 41-50 years, agreed that sardinella eat small particles and not anchovy.

The LEK did not distinguish between the two species of *Sardinella*. Therefore, this is general information about the two species that fishermen have observed.

The majority of fishermen listed "abundance" as one of the unique characteristics of sardinella (Figure 21). This characteristic appears to be the most at risk as most fishermen claimed abundance was decreasing.

Fishing Gear and Methods

There are many gear types used to harvest sardinella in Ghana. They are harvested by subsistence fishermen in the coastal lagoons and beaches; artisanal fishermen from canoes and semi-industrial vessels and by industrial vessels as bycatch. Landings by gear type has not been available except for specific studies (such as for the Central region by Bampoe, 2011) (Table 4).

Table 4. Assemblages of prey by gear (Bampoe, 2011). APW = Ali-Poli-Watsa (purse seine) and STN= set net in the Central Ghana area.

Common Name	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Madeiran sardinella	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

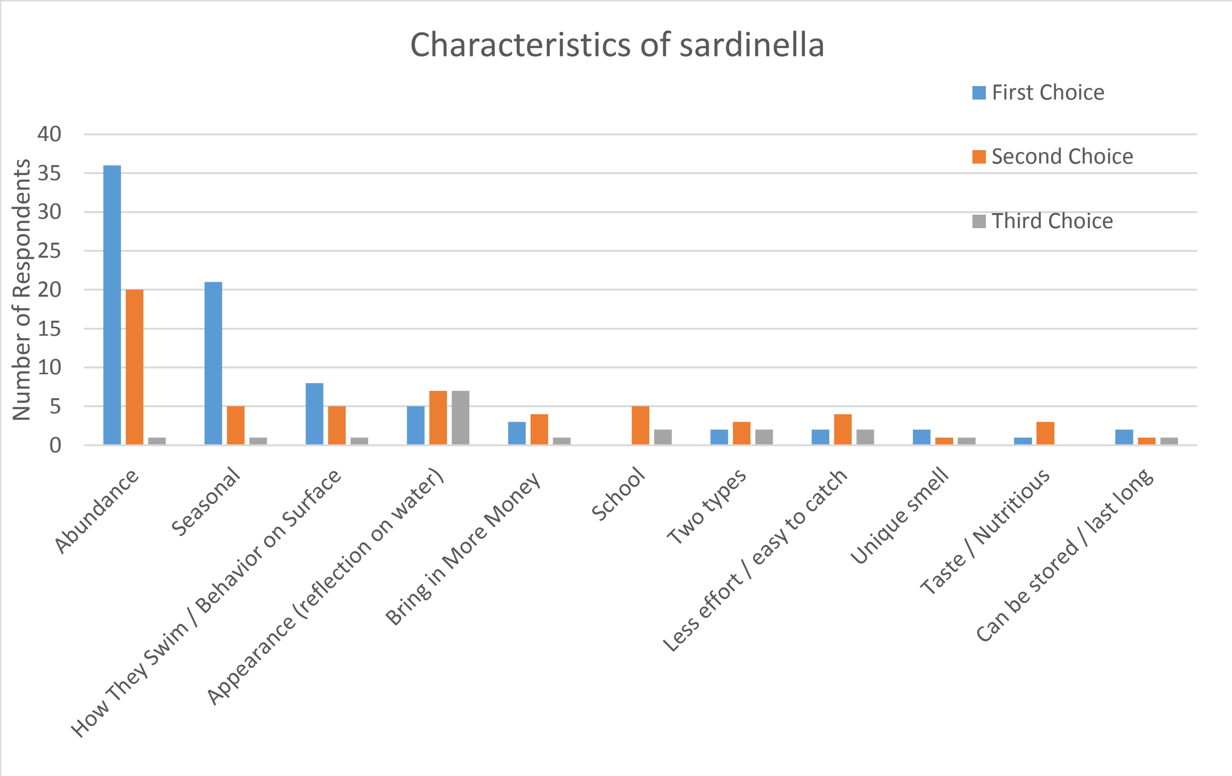


Figure 21. Fishermen's response to the question of unique characteristics of the sardinella.

Marquette et al. (2002) describes several gear types as targeting sardinella in Moree: set nets (tenda adado), Drift nets (ali and libias) and beach seines.

a. beach seining

b. catch from beach seine

Figure 22 a-b. Beach seine and fishing gear photos

c. gill net.

d. gill net

e. purse seine.

f. purse seine with light boat on top

g.trawl net.

h.trawl door that keeps the spread open on the bottom

Figure 23 c-h. Beach seine and fishing gear photos

The following are some available general descriptions of the gears (Table 5) but see CRC publication (In press) for more updated information.

Table 5. General gear description (FAO 2011).

Gear	Material	Mesh sizes used (in mm)	Description
Set Nets	Nylon Monofilament; synthetic multifilament	25 - 102	Set nets are a form of gillnet with strings of single, double or triple netting walls, vertical, near by the surface, in midwater or on the bottom, in which fish will gill, entangle or enmesh. Set nets have floats on the upper line (headrope) and, in general, weights on the ground-line (footrope). Set nets or consist in single or, less commonly, double (both are known as "gillnets", strictly speaking) or triple netting (known as "trammel net") mounted together on the same frame ropes. Several types of nets may be combined in one gear. These nets can be used either alone or, as is more usual, in large numbers placed in line ('fleets' of nets). The gear can set, anchored to the bottom or left drifting, free or connected with the vessel.
Purse seine	Synthetic multifilament	25 – 50	The purse net is a surrounding net. The size of the net varies but is generally in the region of 400 to 600 meters in length and 35 to 50 meters deep. The net has a minimum mesh size of 25 mm in the bunt while the rest of the net is constructed of a variety of meshes up to about 50mm in size.
Trawl	Nylon multifilament	50 – 60	The trawl nets are cone-shaped net (made from two, four or more panels) which are towed, by one or two boats, on the bottom or in midwater (pelagic). The cone-shaped body ends in a bag or coded. The horizontal opening of the gear while it is towed is maintained by beams, otter boards or by the distance between the two towing vessels (pair trawling). Floats and weights and/or hydrodynamic devices provide for the vertical opening. Two parallel trawls might be rigged between two otter boards (twin trawls). The mesh size in the codend or special designed devices is used to regulate the size and species to be captured.
Beach Seine	Synthetic multifilament	25 – 51	The typical beach seine consists of a seine body (or central section) and codend, to which anterior and posterior wings are attached. The gear has a head rope (also referred to as floatline) with floats to keep the upper part of the seine on the surface, and a footrope (also referred to as leadline) with sinkers to keep the gear on or close to the bottom and prevent fish from escaping from the area enclosed by the seine. Hauling ropes or warps are attached to both ends of the wings of the seine. The longer the hauling lines and the wings are, the larger is the fishing area that could be covered with the seine (FAO, 2011).

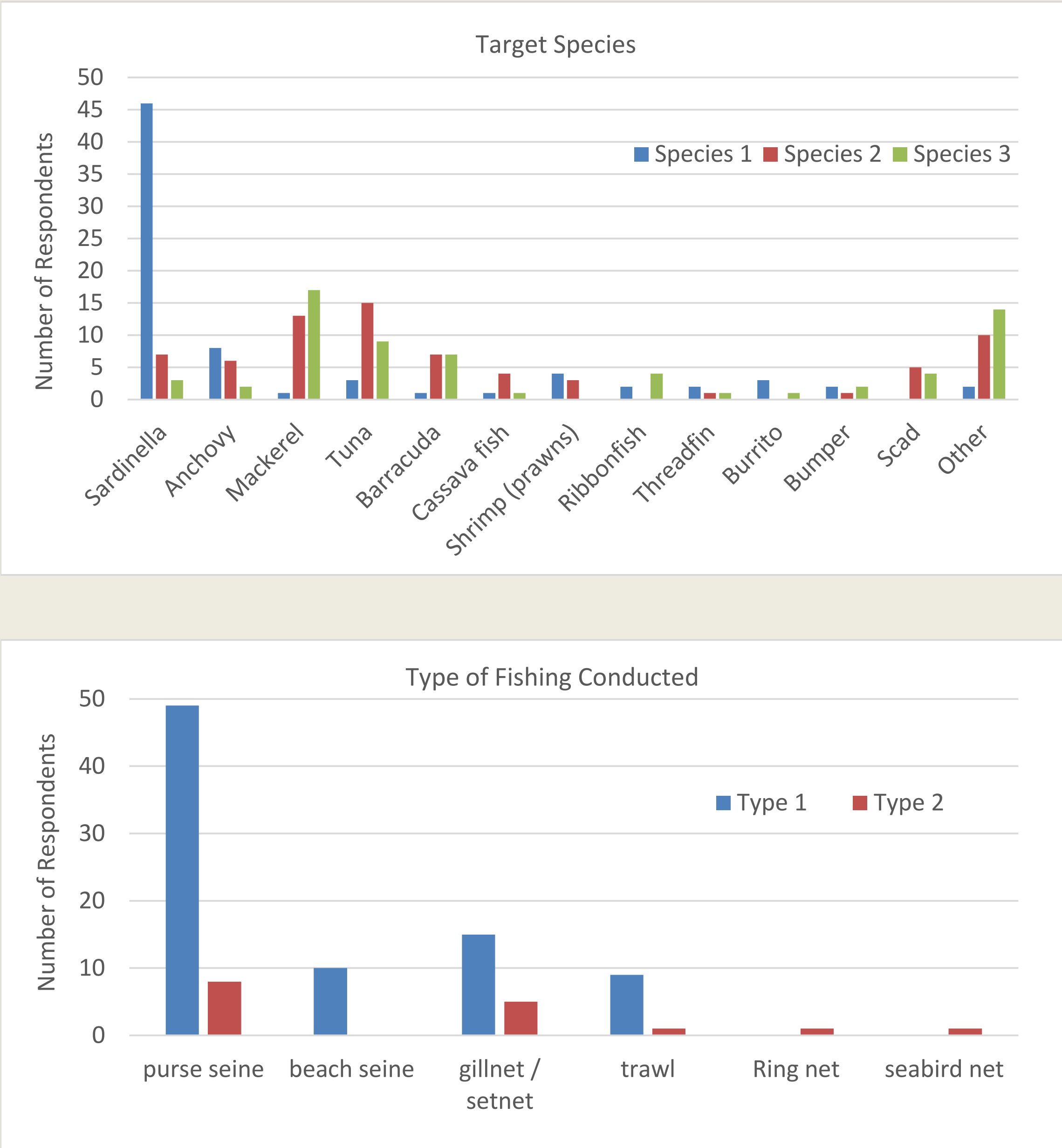


Figure 24. a and b. Type of fishing conducted and target species

Local Knowledge: Gear types

The majority of those interviewed were purse seiners (59%); other main gears included beach seine, gillnet, and trawl. Many fished with more than one type of gear. Sardinella was the primary target species of the purse seiners and gillnetters (69% and 47%, respectively). 30% of the beach seiners targeted sardinella and anchovy; 22% of the trawlers targeted sardinella (burrito was the primary species targeted by the trawlers, 33%).

Management

Under the decentralization reforms in the 1980 and the early 1990s, many central government responsibilities were shifted to the District Assemblies (DAs) with limited success. In 1997, community based fisheries management committees were initiated as part of a World Bank project. The objective of this initiative was for artisanal communities to develop the capacity to formulate and adopt constitutions with stringent by-laws with financial and practical support and legal backing from the DAs. However, most of these collapsed soon after the project was terminated. The principal reason given was that they were conceived and planned with little real input from the people themselves. The present emphasis is on developing a new co-management approach through the creation of District Fisheries Management Committees and the reorganization of the local community groups with a strengthened Fisheries Act (Finegold et al., 2010).

The perception of power plays a huge role in co-management. The success of co-management hinges on an incentive structure (ec0nomic, social, political) that induces various individuals to participate. The co-management process often involves giving up individual short-term benefits for real or perceived long-term benefits and involves great personal loss (Pomeroy et al., 2001). The LEK focused on evaluating the investment in management which was assessed using a ranking analysis approach then evaluating significance through a Chi-Square test. Several indicators were used:

A. If parents fished;
B. If they were part time
C. If they belonged to a fishing organization
D. If they thought their children should go fishing if the fishery improved
E. If any change in perception between above and if the fishery did not improve
F. Current participation in management
G. Knowledge of existing organizations

Seven distinct groups of respondents were identified through the ranking analysis, where individuals with the lowest level of investment in management were given a score of 0 and individuals with the highest level of investment in management were given a score of 7, based on the 7 variables describes in the above section (Table 6). Most respondents received a score of 2 (20 respondents) (Table 6). Respondents who received a score 2 were also the oldest average age group. Additionally, the lowest scoring groups were found to be motivated on average by interest, passion, or peer pressure, whereas higher scoring groups were on average motivated by family tradition and/or inheritance.

Table 6. The average responses for each variable of each ranking group

1.	Parents Fish	Other Occupation	Fish Org Knowledge	Fish Org Member	Children Fish if Better	Children Fish Perception Change	Participate Now
0	No	Yes	No	No	No	No	No
1	Yes	Yes	No	No	No	No	No
2	Yes	No	No	No	No	No	No
3	Yes	Yes	No	No	No	No	No
4	Yes	No	No	No	Yes	Yes	No
5	Yes	No	Yes	Yes	Yes	Yes	Yes
6	Yes	No	Yes	Yes	Yes	Yes	Yes
7	Yes	No	Yes	Yes	Yes	Yes	Yes

There are fishermen who are more invested in management than others. Based off this preliminary assessment, those who belong to organizations may be more invested in the future of the fishery. Additionally, younger/ less-experienced fishermen surprisingly seem to have a higher investment. This may be attributed to the fact that they will have a higher

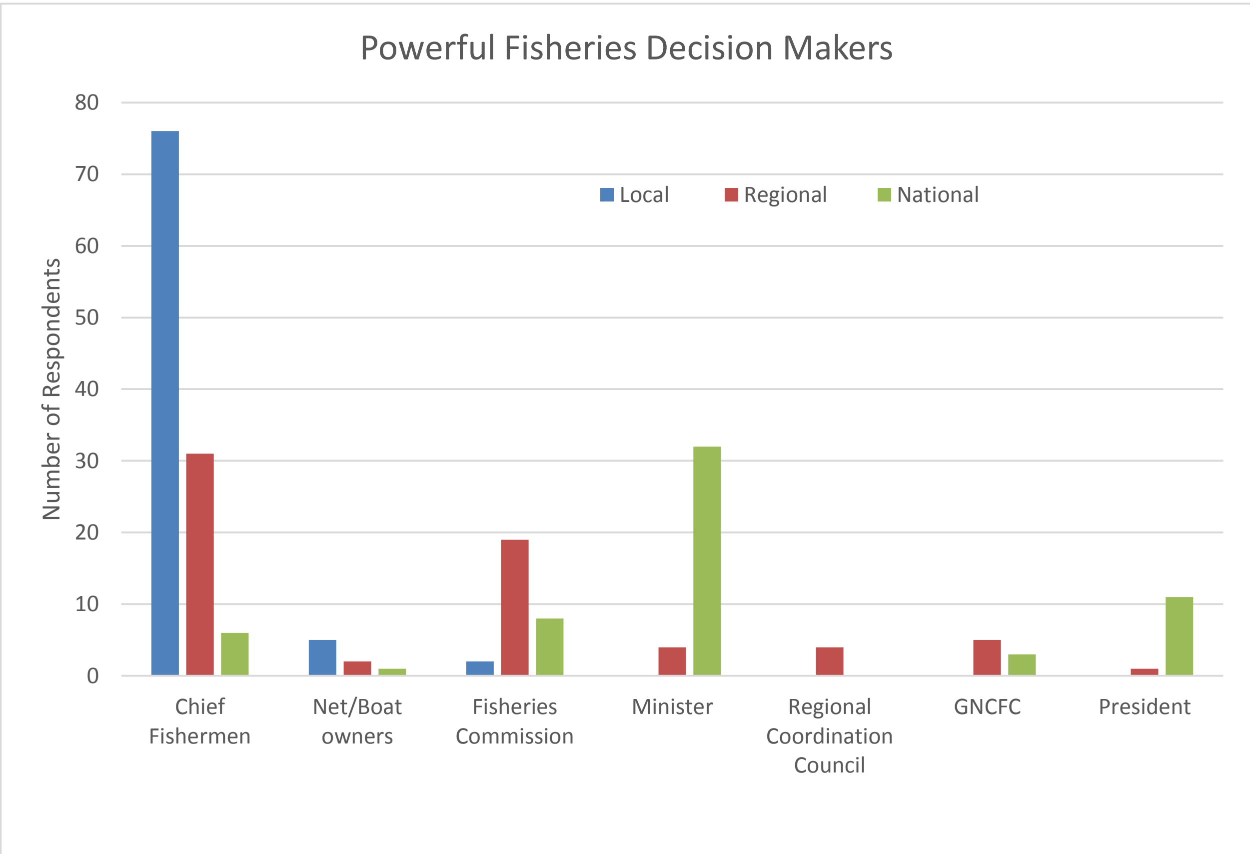


Figure 25. Important decision makers at the local, regional and national level.

dependency upon the fishery than older fishermen as they will have to continue working over a longer period of time. Also coming from a fishing family may have a strong influence on investment in management. Respondents from Tema/ Canoe Beach and New Takoradi displayed a higher pessimism for the future of the fishery. This finding may be attributed to the fact that Tema/Canoe Beach had the highest number of respondents' that are involved in an alternative livelihood, however, there were very few respondents from New Takoradi who were involved in an alternative livelihood. This may indicate that there is greater overexploitation of the fishery in this region.

The chiefs were noted as being the important decision makers at local and regional levels (Figure 24) yet the majority of respondents could not identify the fishing associations involved in management (Figure 25).

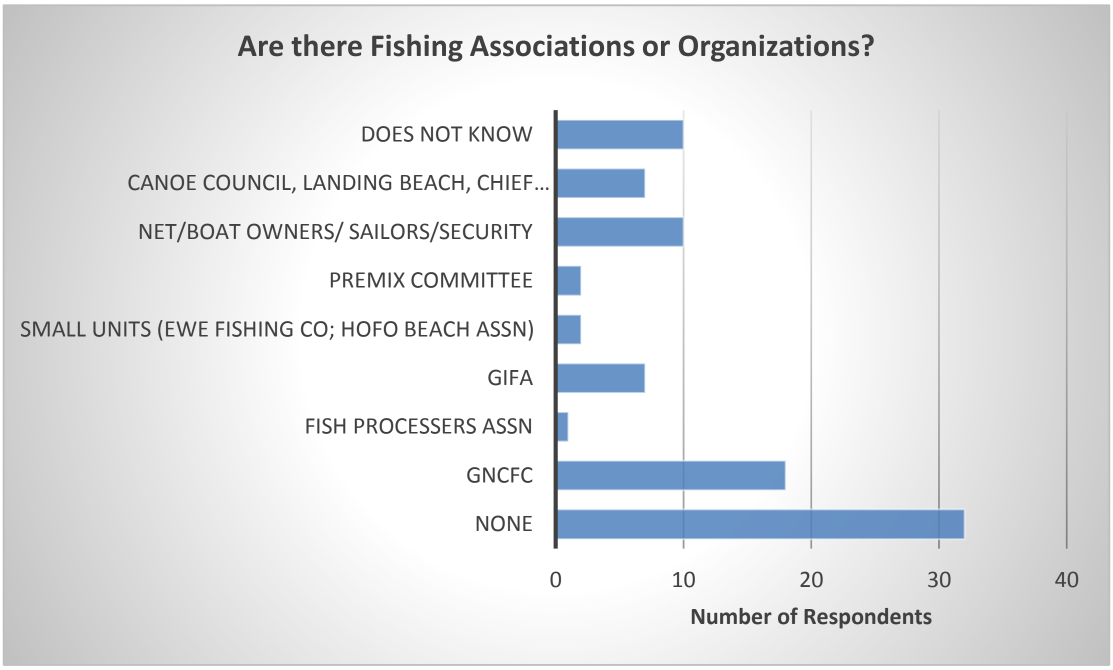


Figure 26. Most of the fishermen interviewed did not know about the fishing organizations or associations in existence or they felt they were ineffective.

"Our talk with you- when will it end? I'm asking because for us to revamp the fisheries we need to depoliticize the fisheries. Fishermen are not politicians. We were interested in the fish and had no time to vote when there is fish to be caught. You learned folks introduced us to politics, you convinced us to engage in it and now it has messed up the fisheries. If it is not taken out, you guys can bring all the intervention but it will not work. When politics is taken out of fisheries and we fishermen go about our fishing duty then the government can bring the laws and tell us whether we vote for them or not. This is what the law says and we will on the basis of that obey. Take our words to those that matter, tell them the politicians are using us fishermen as scape goats for their political benefit"

Fisherman from New Takoradi

The Round Sardinella: *Sardinella aurita*

<u>Distribution</u>

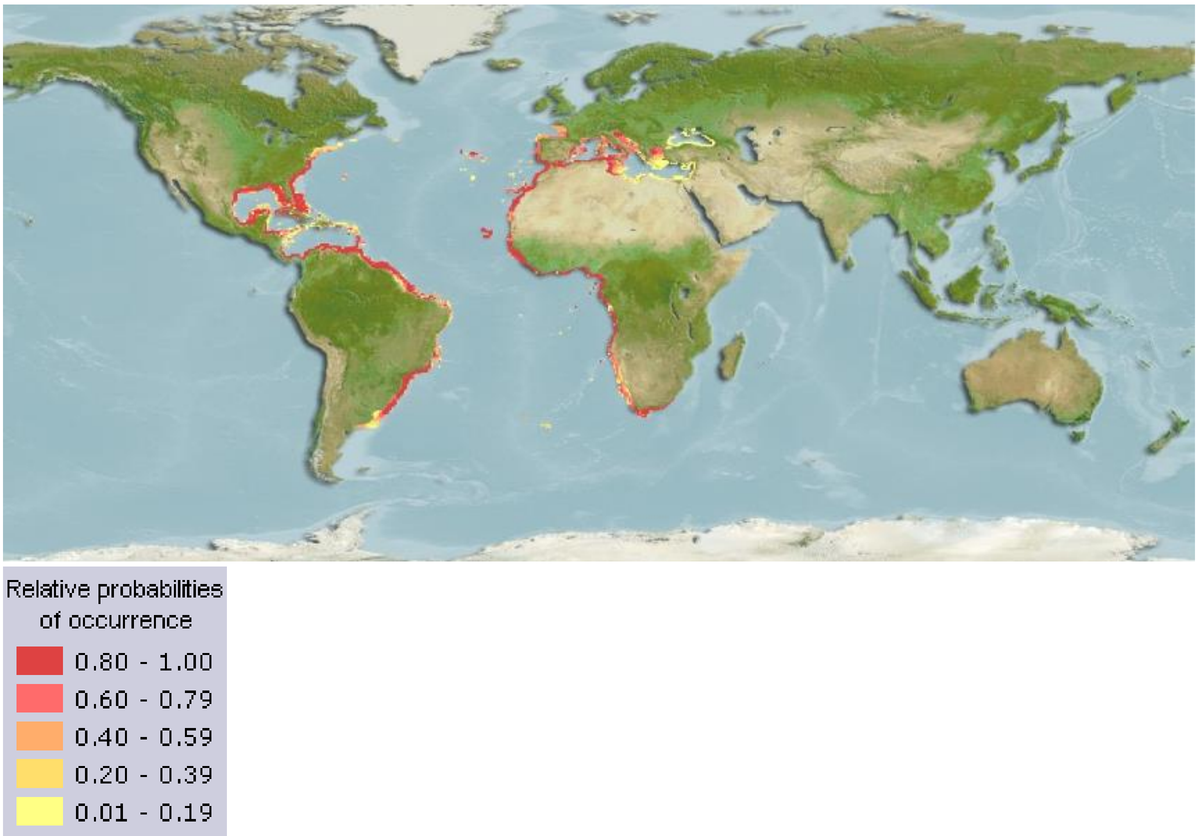


Figure 27. Map of distribution of S. aurita. (Source: www.aquamaps.org).

The overall range of *S. aurita* extends to the western and eastern Atlantic Ocean, the Mediterranean and Black Seas (Figure 26) (Smith and Sandwell, 1997). The stock off the Ivory Coast and Ghana extends from off Jacqueville in Ivory Coast to Port Seguro in Togo (Anon, 1976).

S. aurita is a highly migratory species. The bulk of the stock winters at depths from 50 to 80 m off central Ghana (Zei, 1962; Anon, 1976; Koranteng, 1989; Brainerd, 1991). Around July and August, when the coastal upwelling begins, the fish migrate towards the coastal areas of the Ivory Coast and western Ghana (Zei, 1966; Brainerd, 1991; Koranteng, 1995). This is when the fishing season begins as the fish are accessible. Approaching the coast, they turn eastward and continue to Togo and Benin (Anon, 1976; Koranteng, 1989). At the end of the season, in October through December they return to deeper waters and resting grounds for wintering (Brainerd, 1991).

Off West Africa, the species is considered to comprise of three distinct "stocks". These are the North Transitional Zone from Mauritania to Guinea, the Central Upwelling Zone located along the Ivory Coast and Ghana, and the South Transitional Zone from southern Gabon to Southern Angola (Whitehead, 1985). However, Koranteng (1989) offers doubts as to whether there indeed exists separate stocks off Cote d'Ivorie and Ghana. This is due to the migratory pattern of *S. aurita* as described above. There is another school of thought and that is that there are two separate stocks, one located on the eastern side of Cape Three Points and the other on the western side of the Cape Three Points (Koranteng, 1989; Koranteng, 1995; Binet and Marshall, 1993) (Figure 27).

S. aurita can be found from inshore and near surface down to 350 meters or deeper (Whitehead, 1985).

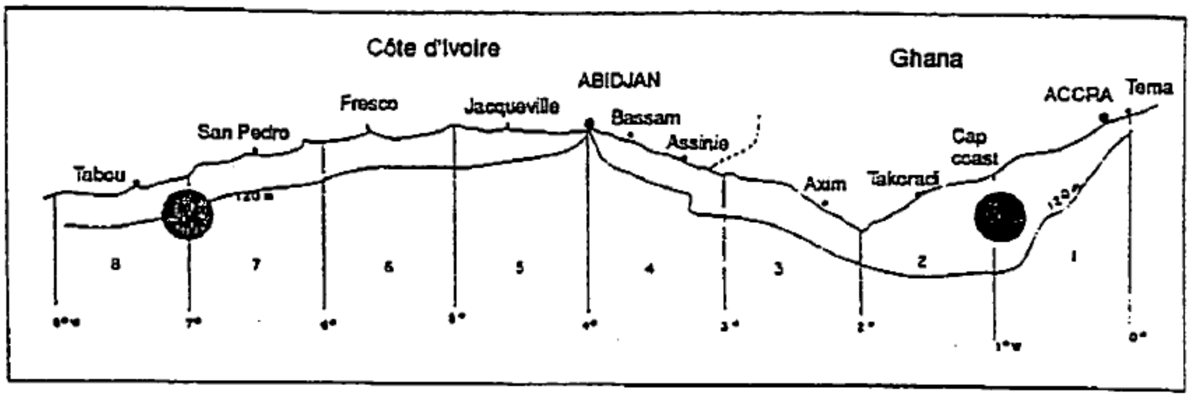


Figure 28. The map shows fishery divisions along Cote d'Ivoire and Ghana. Black dots correspond to the barycenters of the two populations of Sardinella aurita (Binet et al., 1991 as reported in Binet and Marchal, 1993).

A hydrodynamic model was developed by Kone et al. (2016) for the Gulf of Guinea and produced a realistic environmental picture of *S aurita* spawning and larval retention. Two spawning areas were found to be favorable to larval retention and survival – Cape Palmas and Cape Three Points. They produced a conceptual model of the early life history of *S. aurita* (Figure 28). A LEK map was also generated (Figure 29).

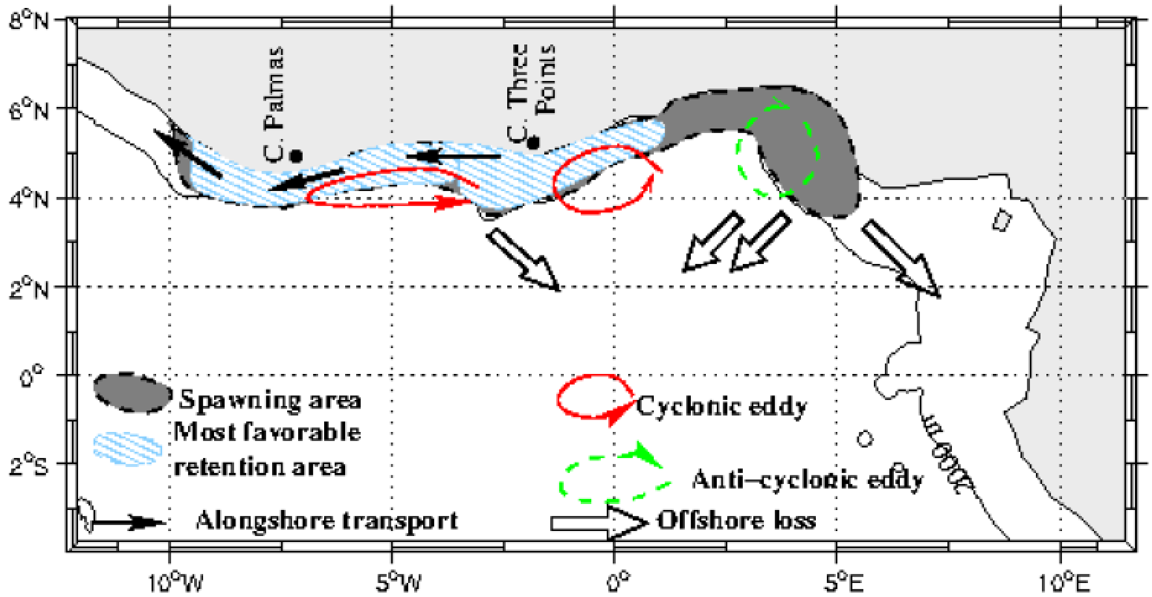


Figure 29. A conceptual model of the early life history of S. aurita on the northern Gulf of Guinea (Kone et al., 2016).

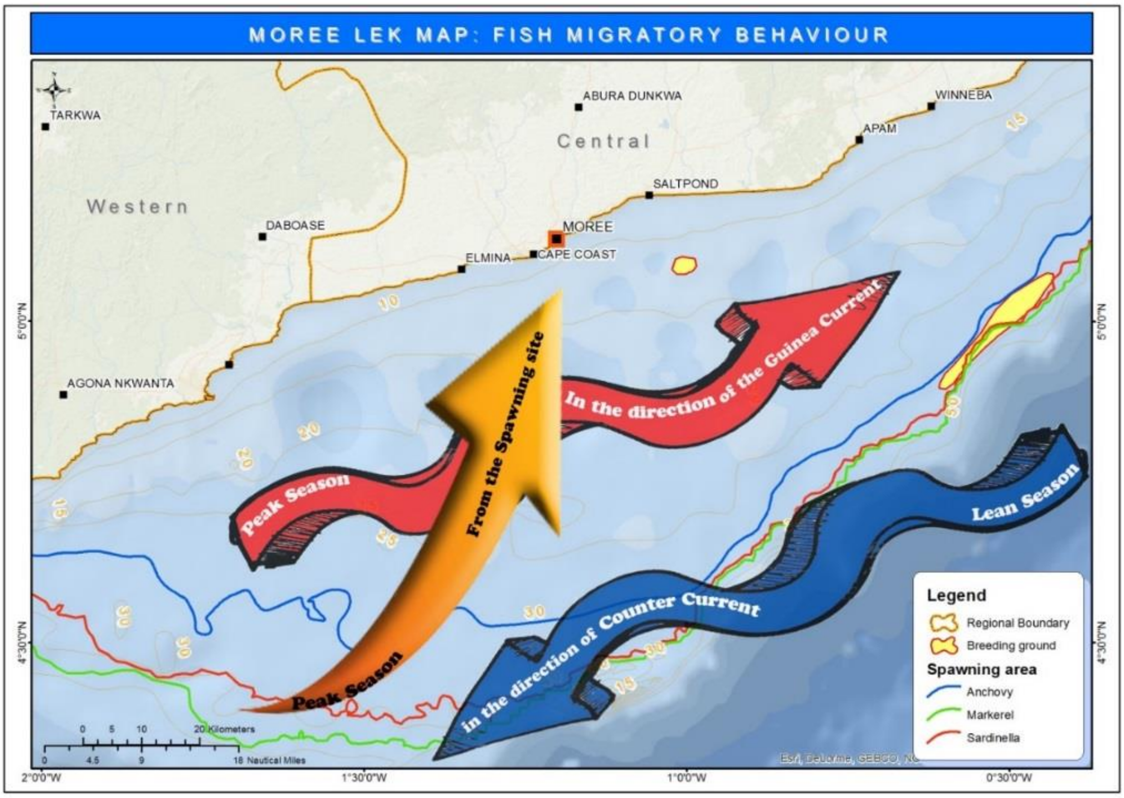


Figure 30. Local Knowledge map produced by the fishermen of Moree.

Fishermen stated that sardinella do not literally move from west to east of Ghana but that the food moves. The appearance of sardinella coincides with upwelling and the sardinella moves from off the continental shelf towards the shelf as the upwelling begins. Fishermen in the western regions encounter fish first because their coast extends further into the sea than that of Volta and Accra (Figure 30). They move in relation to the shape of Ghana- they travel using the continental shelf as their route.

Growth and Maturity

The modal length size of the *S. aurita* in Côte d'Ivoire was between 15 cm and 18 cm in the sixties and seventies. In the 1980s, this modal size increased to 18 cm and 24 cm. In Ghana, a similar increase in length was observed between the early 1960s (14 cm -17 cm) and the 1980s (17cm - 21 cm). *S. aurita* is known to grow isometrically (b=2.90) in the Gulf of Guinea. As compared to *S. maderensis*, it is a slower growing species and has a smaller von Bertalanffy growth coefficient (K) = 0.51 and is also longer living, longevity was estimated at 5.9 years (Elmina samples).

Local Knowledge: Size

When asked what the largest size sardinella they have ever caught was, the average size was 18 cm and smallest size average was 7.8 cm. The largest sardinella caught was 30.5 cm and the smallest was 3.8 cm.

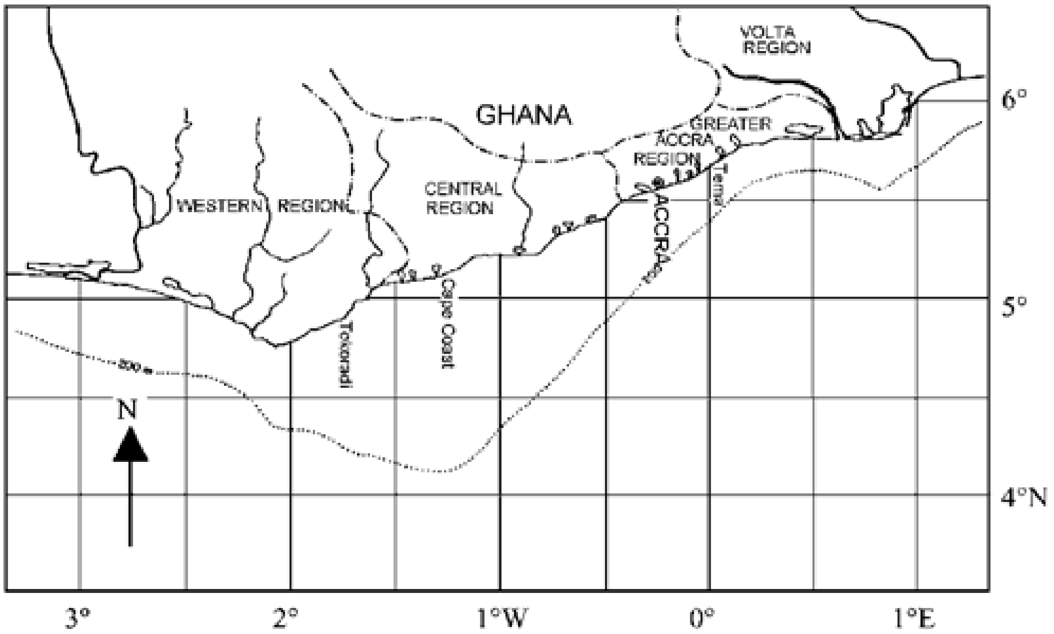


Figure 31. Nature of Ghana's coastline

Males mature sexually at a smaller size than the females (Tsikliras and Antonopoulou, 2006). The length at first maturity of the *S. aurita* in Côte d'Ivoire seems to have increased from 15 cm in the 1960s and 1970s to 18-19 cm at the end of 1980s to 19-20 cm in 1990s (attributed to increasing impact of the minor upwelling on the ecosystem). The female population maturity size off Ghana was reported to have increased from 14.5 cm to 17.1 cm (Quaatey and Maravelias, 1999). Samples taken at Elmina determined that the length at sexual maturity of *S. aurita* was 16.40 and 16.74 cm (total length) for males and females, respectively.

Spawning

The spawning of *S. aurita* is synchronized with the occurrence of the major upwelling (July - September) (Bakun, 1996; Lett et al., 2006) and maximum production of phytoplankton (Arístegui et al., 2006; Fréon et al., 2006). Minor sporadic spawning can occur during the minor upwelling (Mensah and Koranteng, 1988). It is able to spawn in any favorable conditions and consequently there is two possible recruitments per year.

Some reports noted that this species could spawn outside the upwelling season (Pezennec and Koranteng 1998; Quaatey and Maravelias, 1999) and Koranteng (1989) noted that eggs and larvae of Sardinellas species are found almost year-round suggesting that the species spawns year-round; however, there was a higher abundance found during upwelling periods.

> Fishermen were not able to distinguish the sexes unless females contained eggs. Fishermen from Half Assini and Moree identified the presence of eggs in August, September and October

Fecundity showed a significant positive correlation with total length and body weight. For *S. aurita*, fecundity ranged from 4,834 to 63,917. A study done off Elimina looked at the occurrence of different gonadal stages of males and females of *S. aurita* (Osei, 2015). They found that both sexes had similar patterns and reported on Stages II to V. They also found that the highest abundance of resting / recovering spawning (Stage II) males and females occurred from October to December with peaks in November (Figure 31). Pre-spawning (Stage III) males and females increased in proportion from October to February with the majority found in February suggesting that Stage II animals of the previous month were developing into Stage III. Spawning (Stage IV) males were observed from February to September with maximum abundance found in July. Stage IV females were highest in March and April with a peak in July to September. Post-spawning (Stage V) males and females peaked in June.

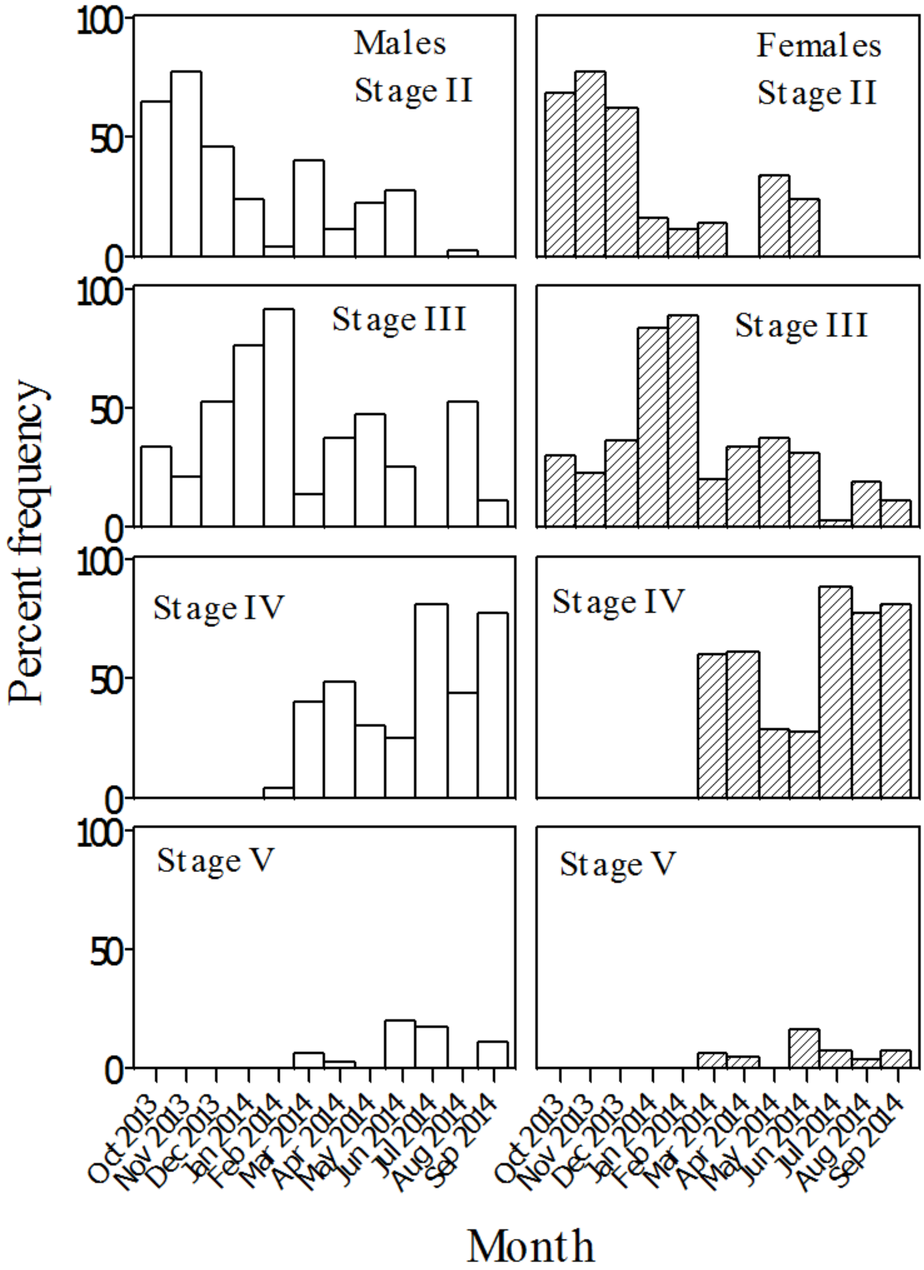
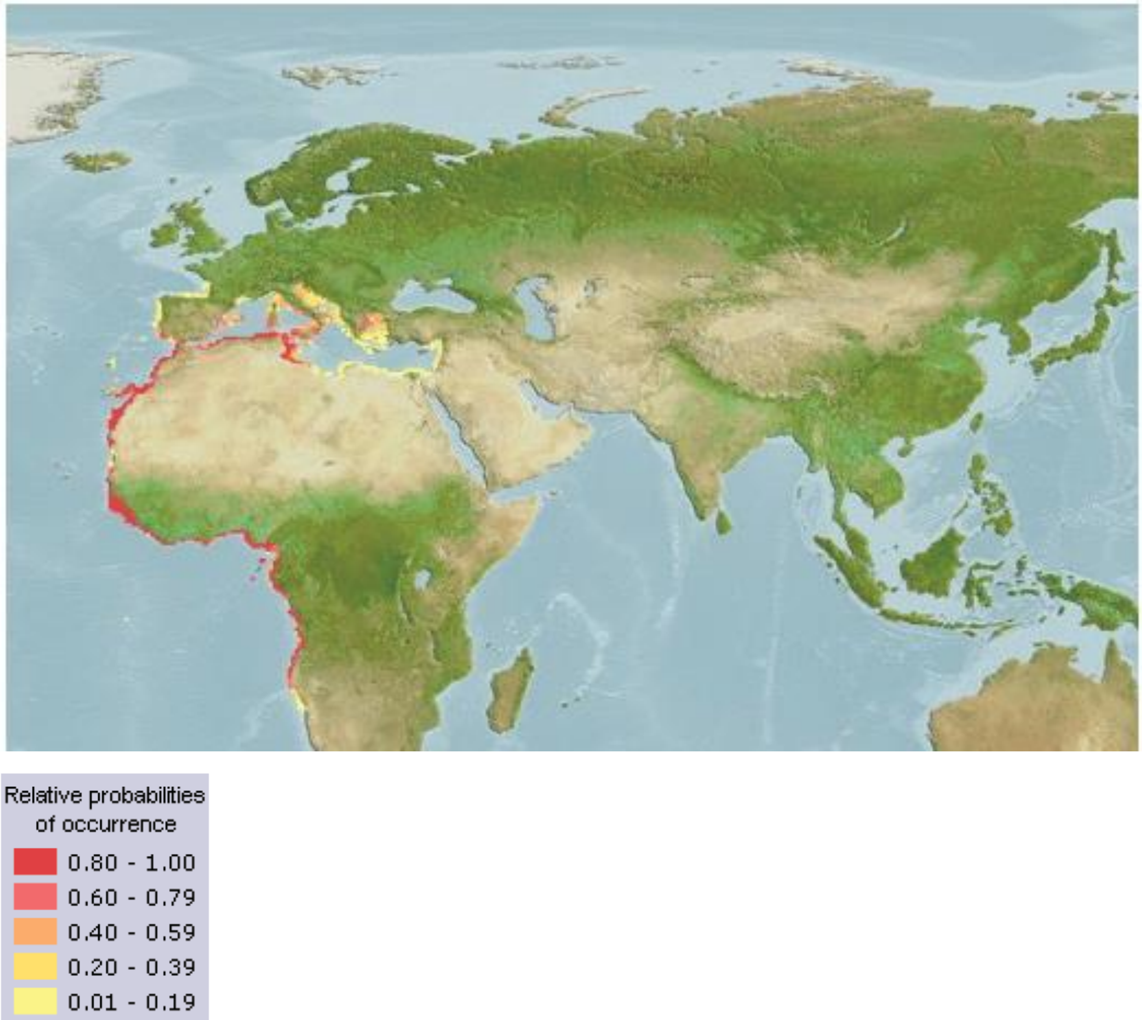


Figure 32. Monthly occurrence frequency of gonadal stages in males and females of Sardinella aurita from commercial catches at Elmina landing quay

The Flat Sardinella: *Sardinella maderensis*

Distribution



Source: Osei, 2015.

Figure 33. Map of distribution of S. maderensis. Source: www.aquamaps.org.

As seen in Figure 32, *S. maderensis* are found in the Mediterranean Sea (southern and eastern parts, also penetrating Suez Canal) and the Eastern Atlantic Ocean (Gilbraltar southward to Angola and a single recorded specimen from Walvis Bay, Namibia) (Whitehead, 1985). This species is widely distributed in the Gulf of Guinea and the Eastern Central Atlantic (Cury and Fontana, 1988). Largest concentrations are found off the Ivory Coast and Sierra Leone (Zei, 1966).

The movements of *S. maderensis* are correlated with seasonal upwelling (Froese and Pauly, 2002). This species is known to be strongly migratory, however, movements in the central stocks along the Ivory Coast and Ghana are not so marked and it is considered more of a coastal species and relatively sedentary with limited seasonal migrations along the coast (Cury and Fontana, 1988).

S. maderensis is found from the surface down to 50 m (Whitehead, 1985).

Growth and Maturity

As with *S. aurita*, the same is true with *S. maderensis* in that males mature sexually at a smaller size than the females (Youmbi et al., 1991). Samples taken at Elmina determined that the length at sexual maturity for *S. maderensis* was 15.43 and 15.56 cm (total length) for males and females, respectively.

This species also grows isometrically in the Gulf of Guinea (b=2.77). It grows faster than S. aurita, higher von Bertalanffy growth coefficient (K) = 0.6, and is expected to live up to 5 years (Elmina study; Osei, 2015).

Spawning

S. maderensis breeds once a year during the warm season (July to September) in coastal waters (Minta, 2003).

Fecundity showed a significant positive correlation with total length and body weight. For *S. maderensis*, fecundity ranged from 7,597 to 33,984 (fish studied at Elmina).

A study done off Elmina looked at the occurrence of different gonadal stages of males and females of *S. aurita* (reported above) and *S. maderensis*. For both species they found that both sexes had similar patterns and reported on Stages II to V. For *S. maderensis* it was found that the highest abundance of resting / recovering spawning (Stage II) males and females occurred from October to November (Figure 33) and peaked again in May. Pre-spawning (Stage III) males increased gradually from October to a peak in March and declined sharply in May to another peak in July. Stage III females increased from October to a maximum in March and then declined. Spawning (Stage IV) males only occurred in 7 of the 12 months sampled, peaking in September. Stage IV females were observed only from April to September, also peaking in September. Post-spawning (Stage V) males were only present in June and September and at very low values and females were present from May to September.

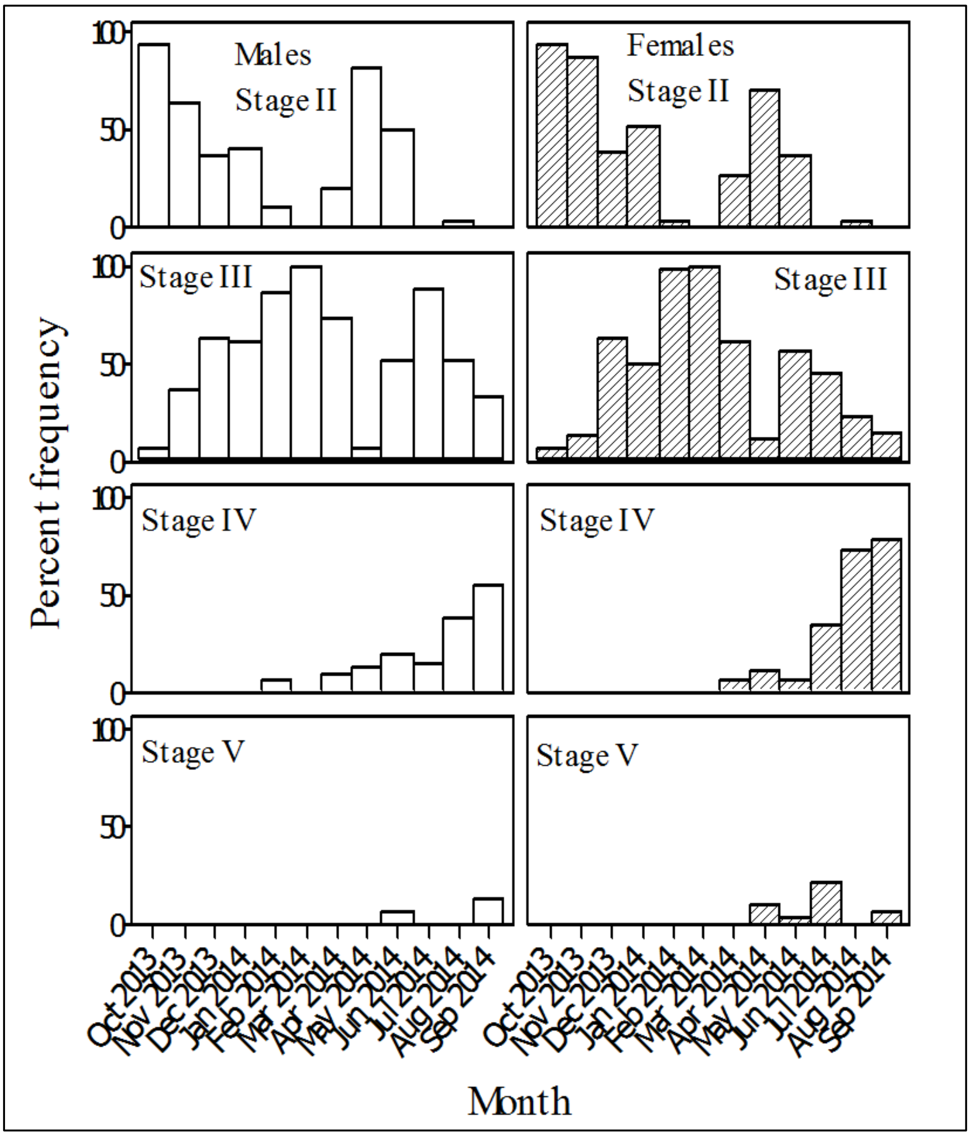


Figure 34. Monthly occurrence frequency of gonadal stages in males and females of Sardinella maderensis from commercial catches at Elmina landing quay (Osei, 2015).

SOME IMPORTANT POINTS

> *"Once you get what you are looking for from us that is the end. We don't hear from you again"*
>
> Fisherman from Elmina

Validation activities were conducted in December 2016 and January 2017 in 7 communities by the staff of Hen Mpoano. At the meetings, the results of the surveys were presented and an opportunity was given to the fishermen to explain their views. This step is one of the most important in education and outreach for co-management. Often, the information in the LEK was confusing because of context or vocabulary. Without the ability to discuss these issues, the information can be misinterpreted. Just as with SEK, peer review is a critical step in assessing the validity of the information collected.

Figure 35. Fishermen attended the validation meetings to continue working with the knowledge created.

STATUS OF KNOWLEDGE

The following table summarizes the two sources of information and whether or not there is agreement between the sources of knowledge.

Table 7 Comparison between local knowledge and scientific knowledge

Area	Scientific Knowledge	Local Knowledge	Agreement?
Environment Temperature Upwelling	There is considerable information about the physical and chemical properties of the environment, however it is large scale rather than place specific.	Place specific knowledge	Can be combined for greater understanding
Currents	Some information available	Should explore further	
Fishery Gear	We have not seen any recent data on the fishery. Published information is outdated.	The fishery has changed a great deal in the last two years. The transshipment of sardines from the trawlers to shore fishery has become one of the largest providers of product. The catch for the other gears has dropped.	No
Landings	Published	This product is not counted as landings.	No
Fish Species	Information available. Landings data sometimes combines and sometimes does not.	Could use more information from the local areas.	Yes
Abundance	Information available from acoustic surveys and fisheries surveys	Yes	Yes, except for the Tema and Volta Region
Growth Spawning	Yes	Yes	Yes
Movement	Some research and modeling on movement	Fishermen talk about appearance rather than movement. Interference from coast morphology and depth	No
Prey	Information available	Experience dependent	Only more experienced fishermen said small particles. Need for education
Management	Perception of co-management being done	Perception of not being included in decision making	No

RESEARCH GAPS

Based on the comparison, there are several areas that would benefit from further outreach, education and research:

A. Need for new supply and value chain analysis.
B. Update gear design and fishing methods.
C. More research on movement and currents.
D. Education on fish life history at fisherman level.
E. Need for more on the ground interaction with fishermen through collaborative research and extension.
F. Strengthen fishing associations and promote communications.

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