Thesis for the Degree of Master of Fisheries Science

Fisheries Management of the Small Pelagic Fishes (*Sardinella maderensis, S. aurita* and *Engraulis encrasicolus*) in the Coastal Waters of Ghana

by

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KOICA-PKNU International Graduate Program of Fisheries Science

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가나 연안에 서식하는 소형 유영 어류의 자원관리

Advisor: Prof. Chul-Woong OH

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Wendell Quartey-Papafio

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Abstract

The Ghanaian artisanal fishery accounts for about 70% of the total fish landings. Fish landed are predominantly small pelagics namely, *Sardinella aurita*, *S. maderrensis* and *Engraulis encrasicolus*. High fishing effort, use of modern technologies, fish aggregating devices and increased number of canoes have with time decreased total landings, largely composed of young fish. This study estimates the Maximum Sustainable Yield (MSY) and the F_{MSY} of the fishery. Using the equilibrium assumptions of the Schaefer's Surplus Production Model, 98,161.74t, 15,687.17t, 60, and 70,687.65t were the MSY estimates for *S aurita*, *S. maderrensis* and *E encrasicolus* with F_{MSY} of 6,394.56 canoes, 6,328.68 canoes and 6,409.799 canoes, respectively.

Key words: MSY, artisanal fishery, Assessment

INTRODUCTION

Fisheries in the western Gulf of Guinea, have sustained the livelihoods of coastal dwellers and the economy of the Ghana over the years. In Ghana, it accounted for 4.5% of the country's Gross Domestic Product (GDP) and 12% of the Agricultural GDP in 2010 (Ayivi 2011). Ayivi (2011) reported that approximately 60 million US Dollars is earned annually from the export of fish and the sector directly engages about 10% of the total country's population of 24 million. The fisheries sector provides about 60% of the national animal protein need. The marine fishery is divided into three sectors, the artisanal, semi-industrial and the industrial fishery. Alder *et al*. (2004) reported that the fishing sector has a long tradition of artisanal fisheries supplying the country with more than 70% to the total fish landings. Fish landed are predominantly small pelagics namely, sardine, chub mackerel, anchovy, horse mackerel. Minta (2003) reported that increase in the fishing effort for the small pelagic fishery can be attributed to the increase in number of canoes and gears, the efficiency of the gears operated and increased motorization which was 60% of the total number of canoes in 2003 as of 50% in 1992 (Amador *et al*. 2004).

Ghana is a tropical coastal country located in the western economic zone of Africa. It is bounded in the east by Togo, west by Cote d'Ivoire, north by Burkina Faso and south by the Gulf of Guinea (Atlantic Ocean). The coast of Ghana accommodates four governmental administrative regions out of a total of ten in the country, Volta, Greater Accra, Central and the Western Regions. The stretch of coastline is dotted with several fishing communities that undertake fishing and its related activities as their livelihood.

Ghana has the fifth largest Exclusive Economic Zone (EEZ) in West Africa (218,100 km^2) and a continental shelf area of 24,300 km^2; this varies in width from 20 km off Cape Saint Paul (in the East, Volta Region) to about 90 km between Cape Coast in the Central Region and Takoradi in the Western Region.

Populations of fish and other aquatic organisms are greatly influenced by several factors such as physical, chemical, biological and meteorological factors. Moiseev (1989) and Biswas *et al.* (2005) reported that one of the leading factors is the temperature of the surface layers of the ocean and there is a very close correlation between the catches of such species as salmons, Japanese sardinops, Chilean sardinops, Californian pilchard, and variations of annual air temperature in the North Pacific Ocean.

Orlowski (2003) reported that since 1996 in the Polish EEZ, a noticeable increase in the fluctuations of fish biomass and high water temperature were found for the data from 1989 to 2000 suggesting a high positive correlation. Hannesson (2007) also reported that the variations in the catches of cod, herring, mackerel, anchovy and sardines in the

Northeast Atlantic are related to the variations in the ocean temperature since 1945. It was found that the catches of cod in the North Sea are inversely correlated with temperature, and that recruitment and catches of cod in the Norwegian Sea and Barents Sea are positively related to temperature. There is some indication of a positive correlation between temperature and the catches of mackerel in the North Sea and Norwegian Sea, and between temperature and the catches of sardines in the North Sea. Tian *et al.* (2003) reported the effects of oceanic-climate changes on the abundance of Pacific saury (*Cololabis saira*) in the northwestern Pacific during the last half century.

The abundance of large sized group of saury was significantly correlated with the winter sea surface temperature (SST) in the Kuroshio region, whereas the medium sized group of saury showed high correlations with SST in the Kuroshio–Oyashio transition zone and the Oyashio region, indicating that the two different sized groups may be affected by subtropical and subarctic environment, respectively.

Small pelagic fishery is one of Ghana's main fisheries activities varying with seasons over the years. It's the most important activity in the economy and employment. Ansa-Emmim in 1973 reported that the sardine season begins with the fall in the SST when the sardine initiates their migration. Usually, the bulk of the fish is first seen in the western region of Ghana and moves eastwards, into Togo and Benin. *Sardinella aurita* is the main species involved in this migration, which was known by early fishers and that dictated their fishing activities. The abundance of *S. aurita* may be influenced by a variety of environmental factors such as the strength of the local upwelling (Mendelssohn and Cury 1987) and rainfall (Binet 1982). *S. maderensis* has lower catches in the Ghanaian coastal fishery than *Sardinella aurita*, but *S. maderensis* is believed to be available throughout the year (Muta 1964).

Over the past years, Ghana's small scale fishery has experienced a downward trend by catch and reached to the edge of collapse. The canoe fishery's annual Sardine catch plummeted to just over 17,000 metric tons in 2012 from a high of 120,000 metric tons a dozen years earlier. This has become a great concern to fishermen and fisheries scientists and is now clearly evident that research effort needs to be stepped up especially as regards the stock-environment relationship and possibly to be able to predict the future availability of the fish. This study aim to determine the maximum sustainable yield (MSY) of the three small pelagic fish species.

Maximum Sustainable Yield (MSY) is the maximum limit of the catch that can be harvested in perpetuity. Because of its simplicity, the MSY continues to account for more than 80% of management goals (Pascoe, 1995; Liu *et al.* 1998; Wang 2011). The idea of MSY provides a reference point that estimates the level of fishing effort to get stable amount of fish without extinction. There are two approaches to this model, the first being a simple approach based on the analysis of catch against effort and requires time series data on both variables. The second method provides better estimates of MSY through complicated stock assessment procedures that require data on mortality, recruitment and growth for each species. The simple approach can only be done on a single species basis but is less useful in multi-species fisheries. However, it is less data demanding and could be useful for developing fisheries (Welcomme 2002)

MATERIALS AND METHODS

1. Data Selection

1.1 Input Data

To estimate the Maximum Sustainable Yield(MSY) of the small pelagic fishery (sardine and anchovy) of the coastal waters of Ghana, annual landed catch per unit of effort (CPUE) data from 2000-2013 were used. The catches were considered as an index of abundance. These data were obtained from the Marine Fisheries Research Division of the Fisheries Commission (MFRD) of Ghana, and constitute total landings in Ghana. Data of artisanal fishery were provided.

Landing beaches have fisheries officers stationed there and they randomly sample landed canoes and collect catch data from the fishermen. Sampling is done early in the mornings when fishermen come back from fishing. Samples are collected once every day except fishing holidays and Sundays. The daily catch data collected is submitted to the regional fisheries office which is then submitted to MFRD. MFRD collates all data from sampling sites and analysis it and the results submitted to national office. Therefore, data from artisanal catch was used for the analysis since fisheries of small pelagic fish in Ghana are mainly conducted by artisanal fishermen, operating from canoes.

Effort of the small pelagic fishery of Ghana is determined by the total number of canoes that fish in the coastal waters. The counting of the canoe is done by a total count in a frame survey after every four years by the MFRD- Fisheries Commission, Ghana.

1.2 Location and Description of the Study Area

The country has a coastline of nearly 550 km long (Quaatey 1997; Ali 2004) and the area of the continental shelf is about 24,300 km^2. It borders Côte d'Ivoire to the west, Burkina Faso to the north, Togo to the east and the Gulf of Guinea to the south. It has a total land area of 238 527 km^2 . The countries' exclusive economic zone has an area of 218,100 km^2 (Amador *et al*. 2006). Bounded on the south by the Gulf of Guinea, that supports a marine fishing industry. The fisheries sector has for a long time provided a source of employment for Ghanaians living in close proximity to these resource bases. There is a total number of 292 landing beaches along the coast of Ghana according to the 2016 canoe frame survey carried out(MFRD,). Out of this total, catch and SST data are taken from 52 landing beaches.

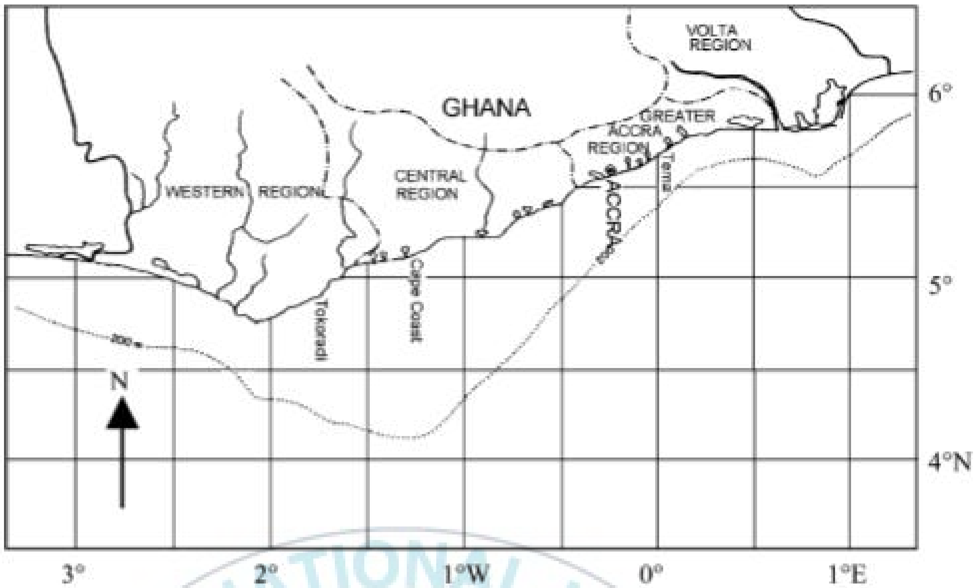

Fig. 1 Map of coastal area of Ghana in Africa

1.3 Characteristics of the small pelagic fishery

The artisanal fishery of Ghana is characterized by the use of different types of gears. These include purse seine nets, beach seine net, set nets, drifting gillnets and hook and line. These gears are operated from dug-out canoes. The canoes are between four to twenty meters. About 50 percent of these canoes are powered by outboard motors with engine power of up to 40 hp (Amador *et al.* 2006).

2. Data Analysis

2.1 Maximum Sustainable Yield (MSY)

Both the Schaefer's model and Fox's model, which are the commonest surplus production models are known to produce almost the same estimates with none of the two being superior to the other (FAO 2014). For this study, the Schaefer's model, as proposed by Graham (1935), was used to estimate the MSY and the fishing effort, F_{MSY}, needed to produce the MSY for the Ghanaian small pelagic fishes using the equilibrium assumptions. In equilibrium conditions it is assumed that the biomass does not change between two consecutive time periods hence the removal in the form of annual yield is equivalent to the production (Masters 2007). The Schaefer model assumes that yield is related to fishing effort by a symmetrical parabola. The intercept (*a*) and the slope (*b*) of regression from Microsoft Excel are used. The following equations were used:

(1) $CPUE = a + bf$ ……… (1)

(2) $Y = af + bf^2$ ………. (2)

Where: *a* = intercept of plot; *b* = slope; f = effort and Y = yield.

(Graham 1935; Schaefer 1954)

From the landings and the effort data, the Catch-per-unit-effort (U_t) was estimated, which is the catch, C, over effort, *U*, in a specific time, t, as follow (King 1995; Quinn and Deriso 1999)

$$U_t = C/E_t$$

To estimate the MSY and the F_{MSY}, the Schaefer surplus production model method was performed:

$$MSY = \frac{U_\infty r}{4q} \quad \text{and} \quad f_{MSY} = \frac{r}{2q}$$

where U is the CPUE, r is the intrinsic growth rate, q is the catchability coefficient (the instantaneous rate of fishing mortality per unit of fishing effort).

RESULTS

1. Maximum Sustainable Yield (MSY)

The small pelagic fishery of Ghana has sardine and anchovy as it main targeted fish species. For each of the three species, the optimal fishing mortality and effort (E_{MSY}) corresponding to its MSY is estimated.

According to the data registered during the period of time, the total number of canoes was 12,728 reporting total catches of 674355.7t for *Sardinella aurita* and a CPUE of 63.77t. The reporting total catch of *S. maderensis* is 102155.5t with catch per unit of effort (CPUE) 9.68t and *Engraulis encrasicolus* is 427904.6t with CPUE 40.82t with the same total fishing mortality and effort. It is realized from that, landings of all three fish stocks are decreasing, meaning current effort levels applied to the fishery are higher than the optimal effort (F_{MSY}) (Fig. 2a–c). More landings could be obtained on a sustainable way if an effort lower than current effort was applied.

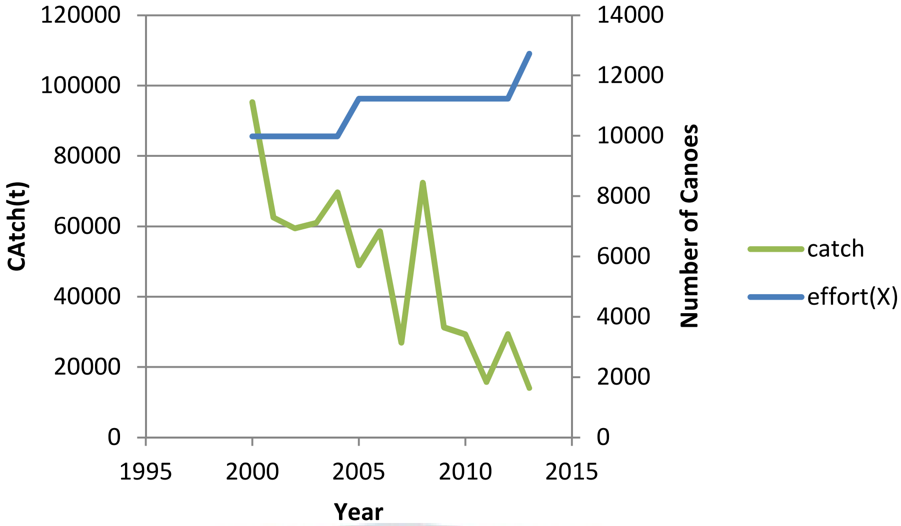

Fig. 2a Catch and Effort of *Sardinella aurita* in the small pelagic fishery of Ghana, 2000-2014

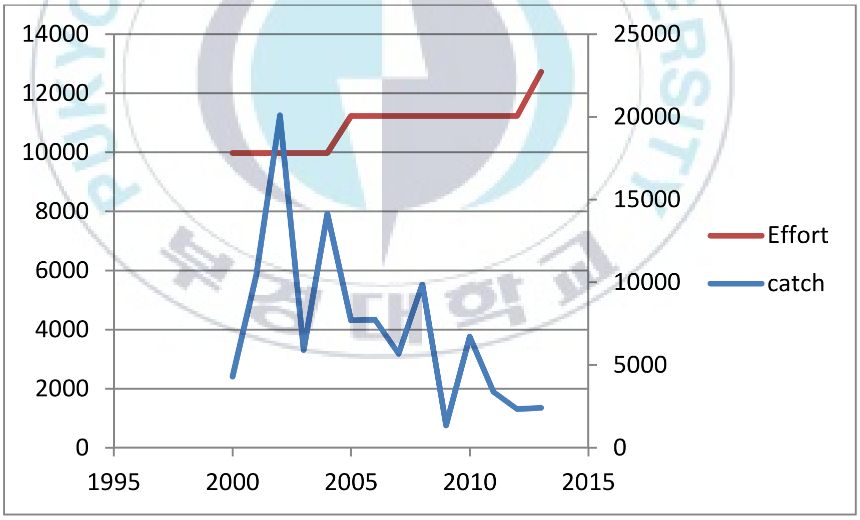

Fig. 2b Catch and Effort and of *Sardinella maderensis* in the small pelagic fishery of Ghana, 2000-2014

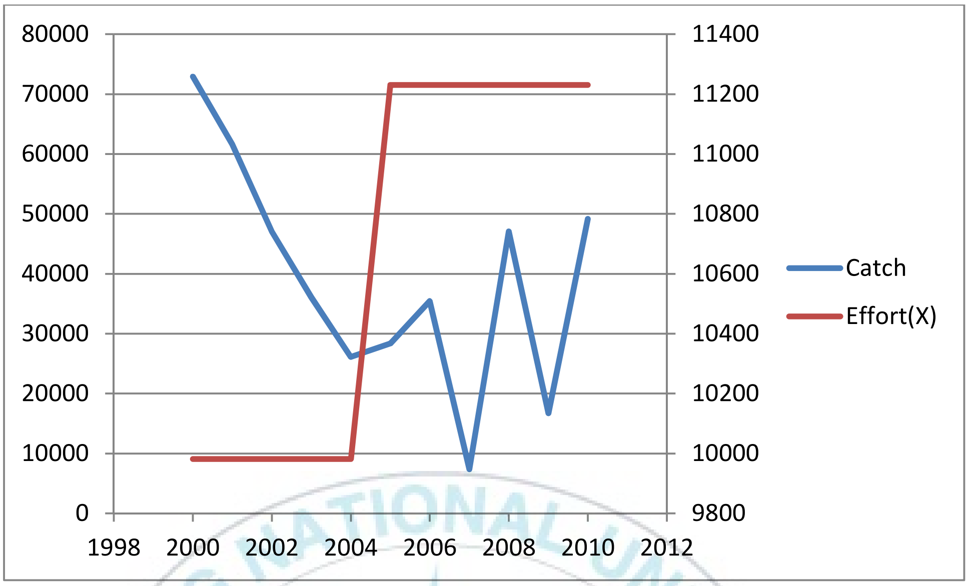

Fig. 2c Catch and Effort of *Engraulis encrasicolus* in the small pelagic fishery of Ghana, 2000-2014

1.1 *Sardinella aurita*

The estimation of F_{MSY} of the small pelagic fishery by the application of the Schaefer surplus production model statistics for the period of 2000 to 2013 from the coast of Ghana revealed an F_{MSY} of 6394.56 canoes and a MSY of 98161.74t (Fig. 3b).

1.2 *Sardinella maderensis*

The F_{MSY} for flat sardine by the application of Schaefer model was 6,328.68 canoes and the MSY is 15,687.17t from the time period of 2000 to 2013 (Fig.4b)

1.3 *Engraulis encrasicolus*

It was revealed by the application of Schaefer production model that the F_{MSY} was 6409.799 canoes and the MSY was 70,687.65t from the time period of 2000 to 2010(Fig.5b)

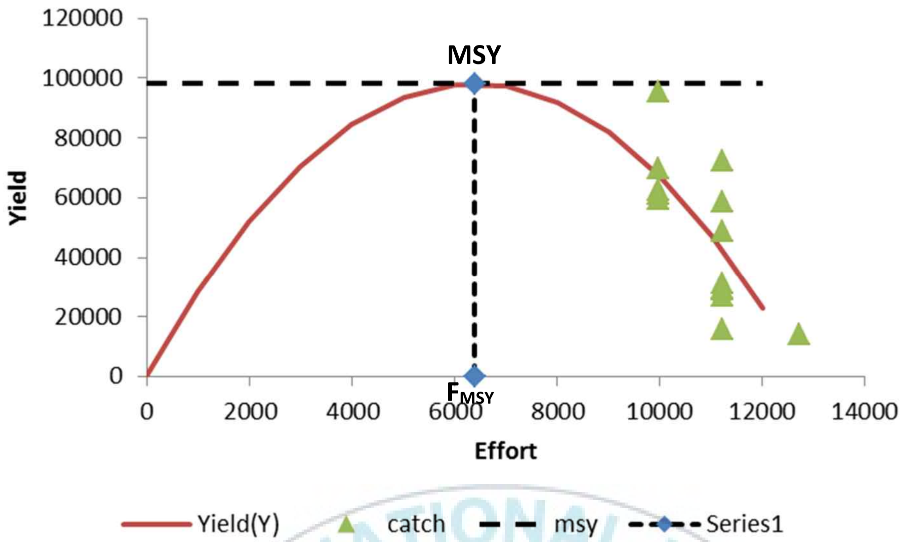

Fig. 3a Maximum Sustainable Yield (MSY) and F_{MSY} of *Sardinella aurita* in the small pelagic fisheries of Ghana, 2000-2013, and catch, represented with shady triangle during same time.

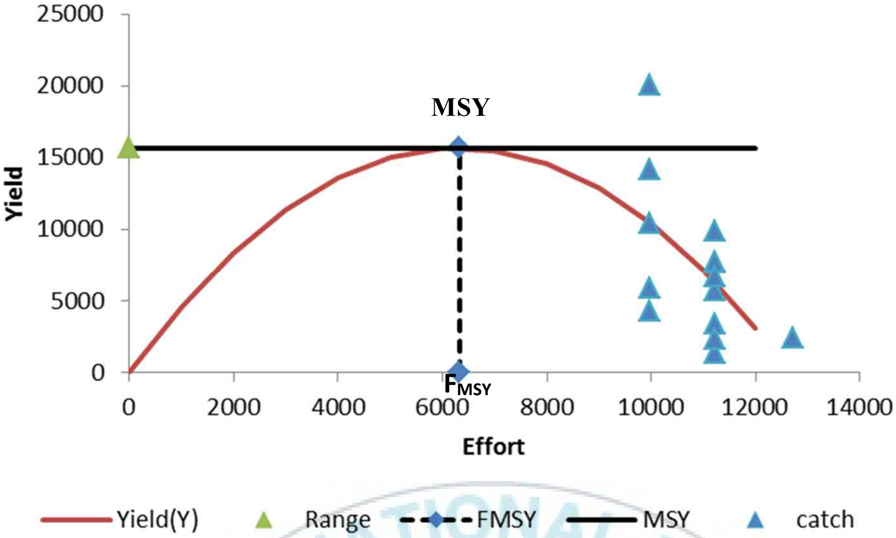

Fig. 3b Maximum Sustainable Yield (MSY) and F_{MSY} of *Sardinella maderensis* of the small pelagic fisheries of Ghana, 2000-2013,

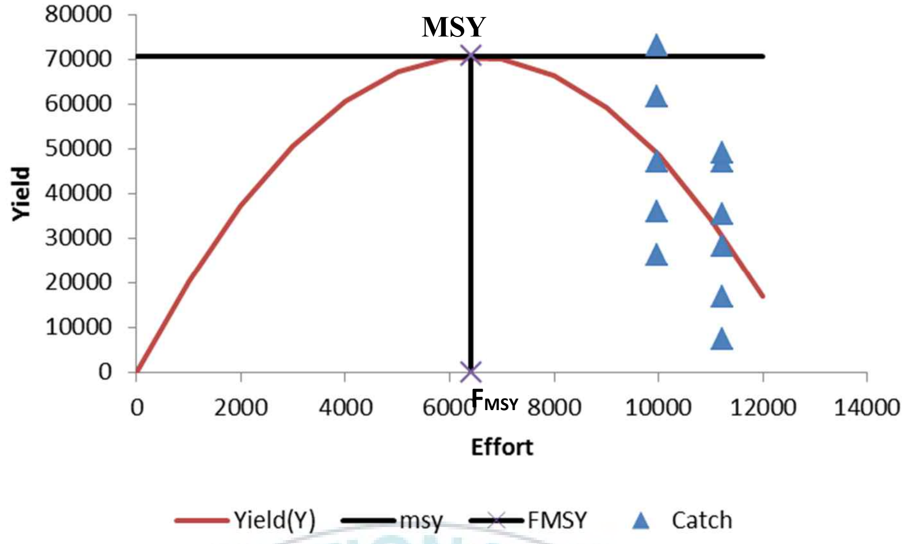

Fig. 3c Maximum Sustainable Yield (MSY) and F_{MSY} of *Engraulis encrasicolus* in the small pelagic fisheries of Ghana, 2000-2013,

DISCUSSION

Maximum Sustainable Yield (MSY)

Making decisions to manage fisheries are commonly directed by the stock assessment results. Hence, it is essential that scientists provide a reliable description of stock dynamics and stock status to the managers (Lynch *et al*. 2012). The main purpose of the paper was to estimate the MSY of small pelagic fishery of Ghana by Surplus Production models. The objective of the application of "surplus production models" is to determine the optimum level of effort that is the effort that produces the maximum yield that can be sustained without upsetting the long-term productivity of the stock, the MSY. Catch-per-unit-effort (CPUE) was considered to be proportional to the fish biomass abundance. The surplus production models can determine the level of effort at which a fishery produces a maximum yield of a fish stock in a sustainable manner without changing the long term productivity termed as MSY (Sparre and Venema 1998).

The concept or understanding of MSY has played a significant role in the fishery science over the decades and often regarded as the target Biological Reference Point (BRPs) (Smith and Punt 2001), thereby serving as a standard of measurement of stock status from a biological point of view. These reference points are generally summarized under the three main fish stock dynamic models, i.e., stock-recruit, dynamic pool and production models (Gabriel and Mace 1999).

FAO, 2007 reported in the Fishery Country Profile on Ghana that the estimated maximum catch the small pelagic fishery can sustain is 180,000t. However, no work has previously been reported on the MSY and the F_{MSY} of sardines (*Sardinella aurita* and *S. maderensis*) and anchovy (*Engraulis encrasicolus*) separately of the Ghana coastal waters. To our knowledge, this is the first study to investigate the MSY and F_{MSY} of sardines and anchovy fisheries of Ghana coastal waters.

From the period of 2000 to 2013, the year 2000 had the highest catch record of *S. aurita* but also the lowest effort. Thus the CPUE listed at that time was also the highest. When the effort increased, the catch and CPUE is reduced continuously. The *S. maderensis* for the same period had the highest catch record (but also the lowest effort which reflected the CPUE, highest and reduced as the effort increased continuously). *E. encrasicolus* had its highest catch in 2002 and lowest in 2007. The stock seemed to be recovering form 2008 as the catch increased although the effort kept increasing. This can partly be attributed to enforcement of fisheries laws of Ghana.

According to the production model assumptions, biomass should be increased when the catch is less than the surplus production and be decreased when the catch exceeds the MSY (Walsh and Colbourne, 2007). In figure 3, the results showed that the catches exceeded the MSY, reaching almost the double quantity and suddenly, the effort was more than the F_{MSY} estimated with the Schaefer model. Then, during the period of time throughout 2000 to 2013, the fishing effort was exceeded about 50%, 49%, and 57% of the F_{MSY} for *S. aurita*, *S. maderensis* and *E. encrasicolus* respectively. Thus, the fishing activity contributes to the declining of the CPUE which is the relative Biomass. The MSY and its F_{MSY} were estimated as shown in Fig. 3 where the MSY for the period was 98161t with an F_{MSY} of 6394 canoes, 15687.17t with an F_{MSY} of 6329 canoes and 70687.65t with an F_{MSY} of 6410 canoes respectively. These estimates indicate that the fishing intensity had already passed the F_{MSY} level for the *Sardinella aurita*, *Sardinella maderensis* and *Engraulis encrasicolus* of the small pelagic fishery of Ghana during the years from 2000 to 2013. The fishing effort for *Sardinella aurita* is 50.24008% higher than the estimated $F_{MSY,\ for}$ *Sardinella maderensis* it is 49.72254% higher and for *Engraulis encrasicolus* it is 57.07238% higher than the estimated $F_{MSY.}$

Therefore, it is strongly recommended to implement fisheries management policies of reducing effort by taxing fishing effort, introducing fishing seasons, quota systems and establishing common ownership of the fishery to bring down the fishing effort on the fishery.

One of the apparent failures in fisheries estimation model failures are, in fact, data failures. The quality of fisheries data has a significant impact on the quality of stock assessment, and thus fisheries management (Chen, 2003 in Wang 2011), therefore, fisheries management institutions of Ghana have to develop a plan and strategies to collect data with quality and representative enough for this fishery and others.

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