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SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP)

Status of the Small Pelagic Fish Stock in Ghana in 2018

DECEMBER, 2018

Ministry of Fisheries and Aquaculture Develoment (MOFAD)

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ACRONYMS

B_{msy}	Biomass level that will produce the Maximum Sustainable Yield
CECAF	Fisheries Committee for the Eastern Central Atlantic
CPUE	Catch-Per Unit Effort
CRC	Coastal Resource Center
EAF-Nansen	Ecosystem Approach to Fisheries-Nansen
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization
FC	Fisheries Commission
$F_{collapse}$	Fishing mortality rate that will lead to a collapse of the stock
F_{msy}	Fishing mortality rate which will produce the Maximum Sustainable Yield
FSSD	Fisheries Scientific and Survey Division
GoG	Government of Ghana
MFD	Marine Fisheries Division
MOFAD	Ministry of Fisheries and Aquaculture Development
MSY	Maximum Sustainable Yield
MT	Metric Tons
RV	Research Vessel
SFMP	Sustainable Fisheries Management Project
STWG	Scientific and Technical Working Group
URI	University of Rhode Island
USAID	United States Agency for International Development

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INTRODUCTION

This report provides an update of the status of the small pelagic fish stocks of Ghana through 2017. It was led by the FSSD, reviewed and validated by the Science and Technical Working Group (STWG) in June of 2018. The data used in this assessment were provided by Fisheries Commission/'s Fisheries Scientific and Survey Division (FC/FSSD) and the Fridjoft Nansen[1] survey program.

Previous assessments conducted by STWG (Lazar et al. 2016, Lazar et al. 2017) indicated a steep decline of the pelagic stocks caused primarily by continuous open access in the artisanal and semi-industrial fisheries, and increasing share of the landings being taken by trawlers via illegal fishing and transshipment (called "*saiko*") of catch that consists of a high proportion of juveniles (EJF and Hen Mpoano, 2019), weak enforcement and noncompliance with the current fisheries management measures. The USAID/Ghana Sustainable Fisheries Management Project (SFMP) is supporting the Ministry of Fisheries and Aquaculture Development (MOFAD) to reverse these trends and contribute to the socio-economic development and food security of the coastal communities in Ghana. Stock assessment reports provided detailed fisheries and biological background and established a biological reference points for fishing mortality (F) and biomass (B) at F_{msy}=0.4 and B_{msy}=300,000 tonnes. These management indicators were computed and validated by the STWG in 2016 and were set as targets for stock rebuilding of small pelagic species in Ghana.

Pelagic fish stocks extend beyond the borders of Ghana's Exclusive Economic Zone (EEZ), we assume, for management purposes only, that the landings from Ghana form a single small pelagic stock. A genetic study based on double-digest restriction-site associated DNA (ddRAD) sequencing (Takyi, 2019) demonstrated low level of genetic differentiation and lack of population structure of *Sardinella aurita* and *Sardinella maderensis* between Mauritania and Benin. Other small pelagic species such as anchovies (*Engraulis encrasicolus) and* mackerel (*Scomber colias)* were not included in this study. The results indicated that the biological range of sardinella stock extends from the Canaries to the Gulf of Guinea (Figure 1). Since the scope of the SFMP project is limited to Ghana's EEZ and for the purpose of management, it is valid to consider landings realized in Ghana to represent a single management unit. The large share (> 80%) of the Gulf of Guinea's small pelagic species are fished and landed in Ghana, therefore the status of the stocks and stock trends are indicative of the entire stock beyond Ghana's maritime boundaries.

Annual landings of sardinella have declined from 100,000 tonnes. in mid-1990s to 19,000 tonnes. in 2017 as fishing effort increased from 8,000 in 1990 to 13,650 canoes in 2017 (Figure 2). This drastic decline in landings is caused largely by the artisanal fishing fleet, which operates without proper management controls in an open access. In addition, the unit of effort of a canoe is more efficient today than in the past due to advanced technologies, modern fishing nets, powerful engines and big capital investments. For example, the average size of a purse seine was about 200-300 meters long in the 1970s but today it is 3 times larger - between 600-1000 meters in length and the average crew members on a canoe doubled from 10 to 20 fishermen. Canoe gross tonnage and capacity increased by 2.5 fold (from 2 to 5 metric tons) while the Catch per Unit Effort (CPUE) declined dramatically and the cost and timing of a fishing trip increased as fishermen spend more time searching for fish offshore.

[1] http://www.fao.org/in-action/eaf-nansen/en/

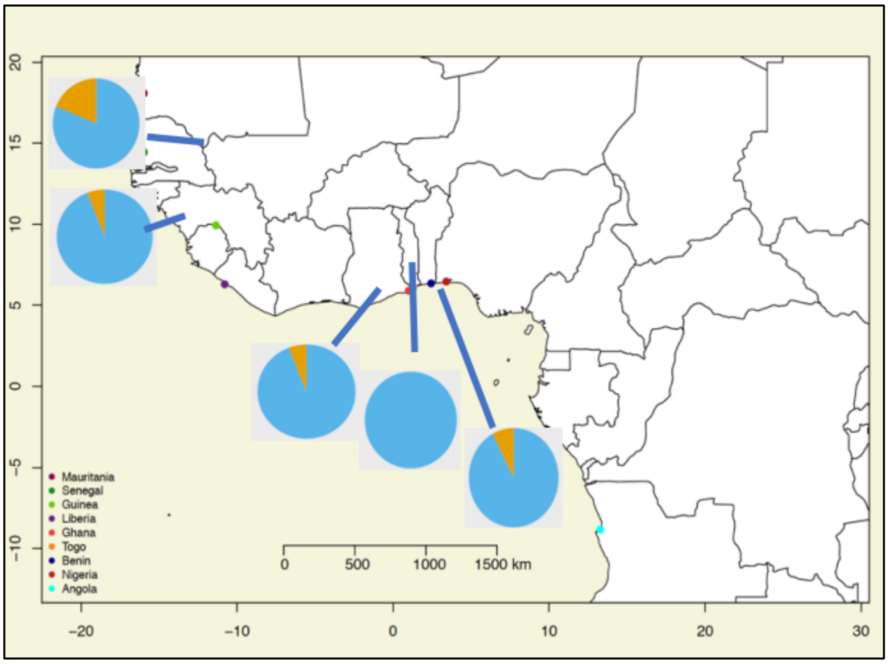

Figure 1. Graphical summary of structure-like plot of samples of Sardinella aurita and Sardinella maderensis from five countries – Blue color indicates level of genetic similarities (Takyi et al. 2019)

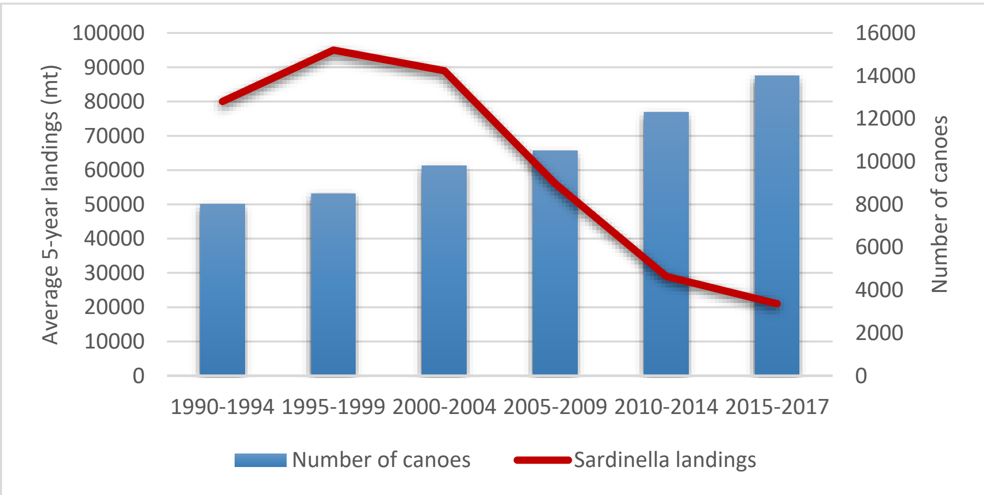

Figure 2. Trends of the average 5-year landings of sardinellas (bars) and effort (Line) trends in Ghana

SMALL PELAGIC STOCKS

The small pelagic fish stocks considered in this assessment consist of round sardinella (*Sardinella aurita)*, flat sardinella (*Sardinella maderensis)*, anchovies (*Engraulis encrasicolus)* and mackerel (*Scomber colias)* (Figure 3). The four species represent more than 80% of the total small pelagic fish landings and about 60% of the total landings in Ghana (all species combined). They have common biological and ecological traits and constitute the main source of protein for a large portion of the coastal communities in Ghana. They are also fished and processed using same techniques and commonly consumed by local populations.

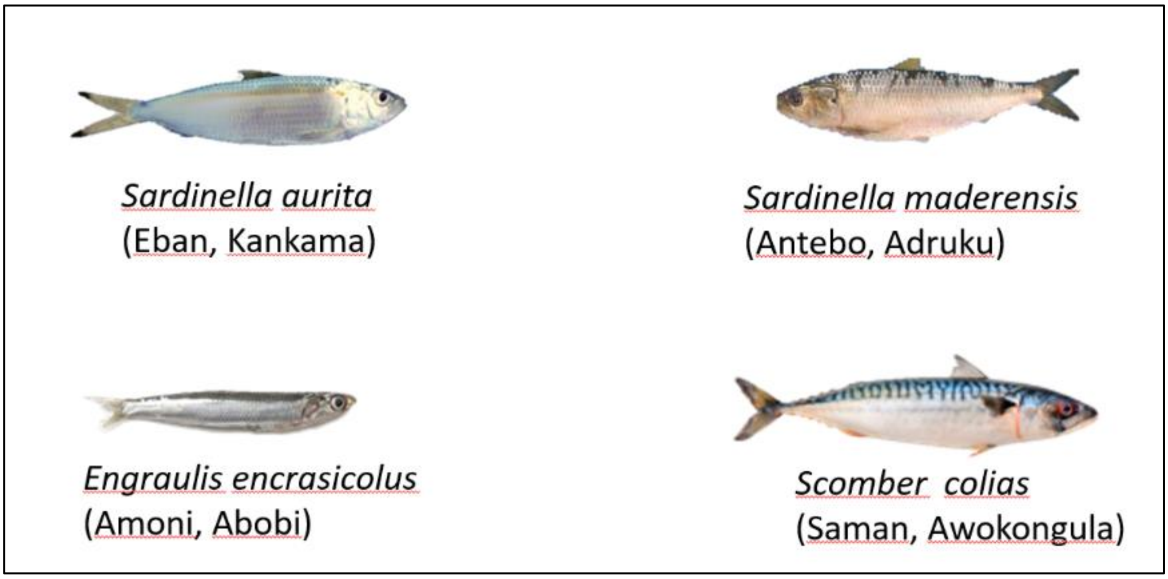

Figure 3. Small pelagic species considered in the assessment with scientific and local names

DATA SOURCE

The artisanal purse seine, encircling gillnets and beach seines are the main fishing gear used for the exploitation of small pelagics. There are two types of artisanal purse seine gear, and the difference is in the mesh size. The purse seine with a 25 mm mesh size is locally called "*watsa*," while the one with a 10 mm mesh is called "*poli*". The beach seine has a mesh size of 10 mm and is common in Volta and Western Region, mainly along estuaries. Purse seines are operated from canoes ranging between 10 to 20 meters in in length. The legal mesh size for all seine nets is 25 mm (Fisheries Regulation, 2010)[2]. There are over 3000 artisanal purse seiners and over 1,400 beach seines operating along the coast of Ghana.

The data for landings (1990-2017) by species and fishing sector (artisanal, semi-industrial and industrial) were provided by FC/FSSD. Fishing effort in number of purse seine canoes (1990-2017) targeting small pelagics were provided by the Marine Fisheries Resources Division of the Fisheries Commission. This observed fishing effort was calibrated to adjust for hyperstability[3] using field survey results conducted by SFMP in 2015 (Table 1). Catch and effort data are typically analyzed in the form of catch-per-unit-effort (CPUE), which expresses the quantity of fish caught (in number or weight) by a given fishing effort. It represents the best proxy for an indirect measure of fish abundance at sea. However, the standard unit of fishing effort is not always stable as equipment and fishing operations change overtime to maximize efficiency in the absence of harvest control measures. Fishermen increase their knowledge and competency using advanced technology and modern fishing means (nets, motors, winches, etc.) and invest more capital to adapt at longer, farther and multi-day fishing trips. In this case the fishing trip, which used to be half a day in 1970s, has now increased to two days on average. Therefore, the standard measurement of the efficiency of the fishing effort is referred to as the fishing power or also known as the corrected index of abundance $CPUE_{corrected(t)}$. This is often used to describe the fishing power of the fleet for catching fish, corrected for improvements in canoe structure, size, operation and technology. Fishing power is then defined as the product of the area of influence of the fishing gear

[2] https://www.mofad.gov.gh/wp-content/uploads/2016/05/Fisheries-Regulations-2010.pdf

[3] Hyperstability is where observed CPUE declines much slower than real abundance.

during a unit of operation and the efficiency of the gear during that operation. As a consequence of its definition it is shown that fishing power is the effective area covered by the gear during a unit operation (Sanders and Morgan, 1976).

Table 1. Average characteristics of artisanal fishing effort in Ghana from 1970s to 2015

	1970-1980	1980-1990	1990-2000	Present
TOTAL LOA – Canoe (meters)	10	13	15	22
HP	15	25	40	55
KW (HP/1.34)	11	19	30	41
VCU(Vessel Capacity Unit) = (LOA*BR)+045*kw	50	109	201	406
Crew-carrying unit	10	12	15	25
Net-length (m)	275	500	550	800
Net-depth (m)	30	25	25	55
mesh size (cm)	2.5	2.5	1	0.5
Carrying capacity (mt)	23	29.9	34.5	50.6
CPUE (# of boxes=30 kgs/canoe)	50	40	30	10
Days at sea per trip	1	1	1	1
Power of the canoe (LOA*KW)/1000	4.72	5.49	6.1	6.81
Power of the seine (L*D*Crew size)/1000	11	12	12	14
Total Unit power	53.41	65.45	74.7	94.67
Percent Change (70-80 as reference)	0	18.39	32.53	55.24
Percent change (1980 as reference)		0	12	39

Based on interviews conducted by SFMP with fishermen to collect catch and effort data as part of the fisheries profile of Ghana (Asare et al., 2015), we found that the fishing power increased by 40% since 1980s. Using the same procedure in Senegal in a sister project Collaborative Management for a Sustainable Fisheries Future in Senegal (USAID/COMFISH), the fishing power of artisanal purse seiners increased by 34% since 1980s (COMFISH, 2018). A major implication of the adjustment of the fishing power is that it estimates a low value for Maximum Sustained Yield (MSY), when used as a harvest control measure. It is therefore highly desirable to measure changes in fishing effort in a such a way as to record changes in fishing power as they occur overtime.

A supplemental data source on fish abundance were provided by the research vessel "R/V Fridjoft Nansen". The research vessel conducted a series of acoustic surveys in Ghana's EEZ and provided relative estimates of biomass of small pelagics in 1990, 1999, 2000, 2002, 2004, 2005, 2006, 2007 and 2016. The estimation of relative biomass is based on an expansion estimator, where mean fish density observed over an area covered by the echo-sounder is multiplied by the total area (EEZ). The acoustic surveys are complex and can be imprecise, but the time series estimates provide unbiased trends of abundance and spatial distribution of fish.

STOCK ASSESSMENT MODEL

The Surplus Production Model

A surplus production model was used to estimate annual fishing mortality and biomass using observed landings and effort data of small pelagics (sardinellas, anchovies and mackerel). Landings of these four major small pelagic species represent 80% of the total landings of small pelagic recorded by FC/FSSD. The assessment of this group of species reflects on the status of other small pelagic species, not considered in this assessment.

Fishing effort is represented by the number of purse seine canoes which was corrected to account for changes in fishing power.

A tuning index of fish biomass was used from the hydroacoustic surveys conducted by R/V Fridjoft Nansen. The survey information is able to reliably capture the trends signal in biomass and recruitment. However, they cannot provide absolute abundance estimates, but only relative values on an arbitrary scale. The combination of fisheries-dependent (CPUE) and the fisheries independent hydroacoustic estimates of relative abundance provides an unbiased estimate of biomass and fishing mortality.

The model used is a surplus production model. It is a mass balance approach in which stock biomass each year is the biomass of the year before plus new production minus the catch removed. Estimates of the new production is the net difference between additions from growth and recruitment and mortality losses. Surplus production modelling has a long history as a method for managing data-limited fish stocks. Recent advancements have cast surplus production models as state-space models in continuous time that separate random variability of stock dynamics from errors observed in fisheries-independent indices of biomass (Pedersen et al., 2017). The population dynamics represented by surplus production models builds on principles of logistic growth. It is widely recognized that the model structure of surplus production models is too simple to adequately describe the population dynamics of a real-world stock but it does not take into account the variability in size-structure, species interactions, recruitment or environmental conditions. However, the model measures these effects as a random error term in the equation governing the biomass dynamics.

The stock growth is assumed to follow the familiar logistic curve.

$$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{K}\right) - C_t + \in$$

Where:

t= Year
Bt+1= population biomass of year t+1 (next year)
B_t = population biomass of this year (t)
r = intrinsic rate of biomass increase
Ɛ= lognormal process error

The (*r*) parameter is a measure of population growth rate at very low abundance when density dependent factors are inoperative. The term in parentheses is the density dependent feedback mechanism that reduces stock growth when abundance is high. The average catch rates (CPUE) is expressed as the product of biomass (*B*) and the catchability coefficient (proportion of the total stock taken by one unit of effort) represented by (*q*). The relationship between the catchability q and the CPUE is:

$$\overline{CPUE} = \frac{Catch}{Effort} = qB$$

Where:

q = catchability coefficient
CPUE = Catch-Per-Unit-Effort
B = Biomass in metric tons

The model is then fit iteratively by minimizing the sum of square residuals between observed CPUE and predicted CPUE in the form of:

$$\sum (CPUE - \overline{CPUE})^2$$

Where *CPUE*, represents the observed index of abundance from which to subtract the predicted or expected $\overline{CPUE}$ from the model.

The management quantities for sustainable fisheries can be derived from the logistic model parameters as follows:

$$MSY = \frac{rK}{4}$$

$$F_{msy} = \frac{r}{2}$$

$$B_{msy} = \frac{K}{2}$$

Maximum sustainable yield (*MSY*) is the maximum yield that a stock can produce as a surplus to harvest on a long term basis. It is a function of both carrying capacity (*K*) and stock productivity (*r*). In order to produce *MSY* on a long-term basis, a stock needs to be at a biomass level equal to one-half carrying capacity ($B_{msy}=K/2$) and be subject to a fishery removal rate no greater than F_{msy}. The latter is equal to one-half the maximum rate of stock growth. A fishing mortality rate that approaches the maximum rate of stock growth ($r \leq F_{msy}$) will lead to stock collapse ($F_{collapse}$).

Fishing Effort Calibration

The abundance indices for CPUE were calibrated based on fishermen's interviews on historical trends of catch, effort and gear efficiency. The data collected were used to correct the observed CPUE summarized in Table 1 above as follows:

$$CPUE_{corrected(t)} = \frac{CPUE_{observed\ (i)}}{(1+\propto)^{i-io}}$$

Where $CPUE_{observed(i)}$ is the observed number of canoes targeting small pelagics estimated by the frame surveys over the period from 1990-2016; $CPUE_{corrected(i)}$ is the corrected index of abundance for the period of years i, and α is the annual rate of increase of fishing power of the artisanal canoe fishery.

The increase in efficiency is linked to modernization of the canoes, increased horsepower of outboard engines, and increase in net size. The use of light fishing is another factor having an effect on the efficiency. A report by FSSD demonstrated that the use of light had a significant effect on fishing power and identified a non-linear relationship between light fishing efficacy and fish density. In other words, light fishing increased fishing power as abundance of fish went down (Bannerman and Quartey, 2004). Fishermen believe that light fishing is a significant tool for attracting fish into the fishing circle of the purse seine, increase its efficiency and reduce time for searching for fish. This report demonstrated that herring, sardines, anchovies, squids, mackerels and small tuna were attracted by light.

LANDING TRENDS AND HYDROACOUSTIC SURVEY RESULTS

Total Landings of sardinella have been in sharp decline since 2000 reaching the lowest level in 2017 at 19,023 tonnes (Figure 4). This represents only about 14% of the highest recorded landings of 1996 (139,955 tonnes). The CPUE followed similar trends (Figure 5). The average catch/canoe/day declined from 4 tonnes to 0.2 tonnes per canoe/day. average zero catch (vessel spending more than 20 hours searching for fish and returning with no catch) has increased. Preliminary estimates show more than 25% of vessels in Tema returned to harbor without catch. This has resulted in declining catch per unit effort (CPUE).

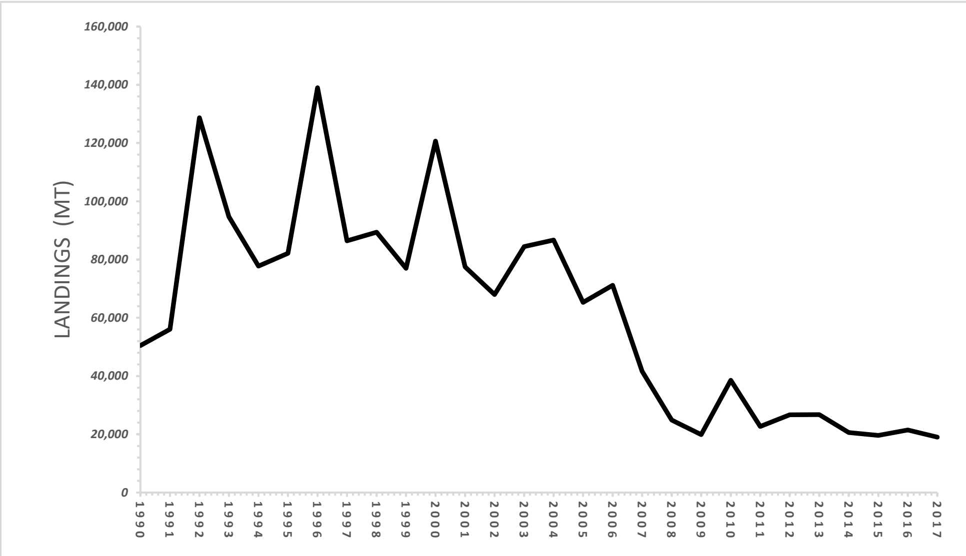

Figure 4. Total landings of sardinella in Ghana (1990-2017) Source: FC/FSSD, 2017

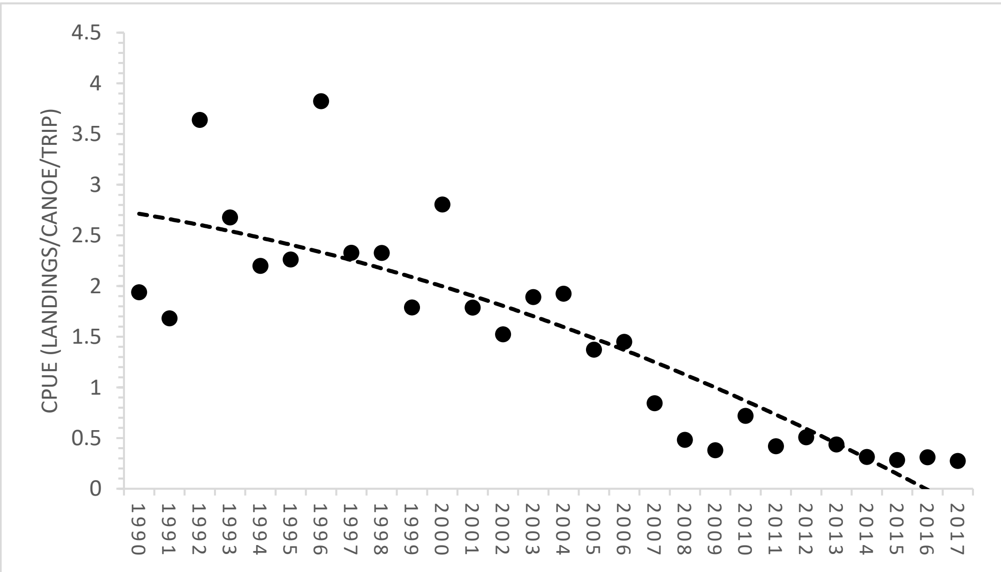

Figure 5. Catch Per Unit Effort (CPUE) of sardinella in Ghana (1990-2017) Source: FC/FSSD, 2017

The FC and the EAF-Nansen program have collaborated since 1980s to conduct a number of research cruises on board the R/V Fridjoft Nansen. It is one of the most advanced marine research vessel of its kind in the world, whih is operated by the Norwegian Institute of Marine Research with suppport from Food and Agriculture Organization (FAO) and the government of Ghana. They are conducted when funding becomes available. The survey addressed abundance and distribution of pelagic resources, environmental conditions within which they are encountered, and aspects of their early life history. The survey also offers an opportunity for local researchers to join cruises to address other research topics of high interest locally and regionally. The hydroacoustic surveys provides estimates of relative biomass of small pelagic species in Ghana's EEZ (Figure 6). The trends are consistent with observed landings and CPUE. The relative biomass estimated in 2016 is the lowest ever recorded since the beginning of these surveys in mid-1980s. Another hydroacoustic survey was conducted recently but the results were not available for this assessment. However, the estimates of the relative biomass were lower than those recorded in 2016 (personal communication).

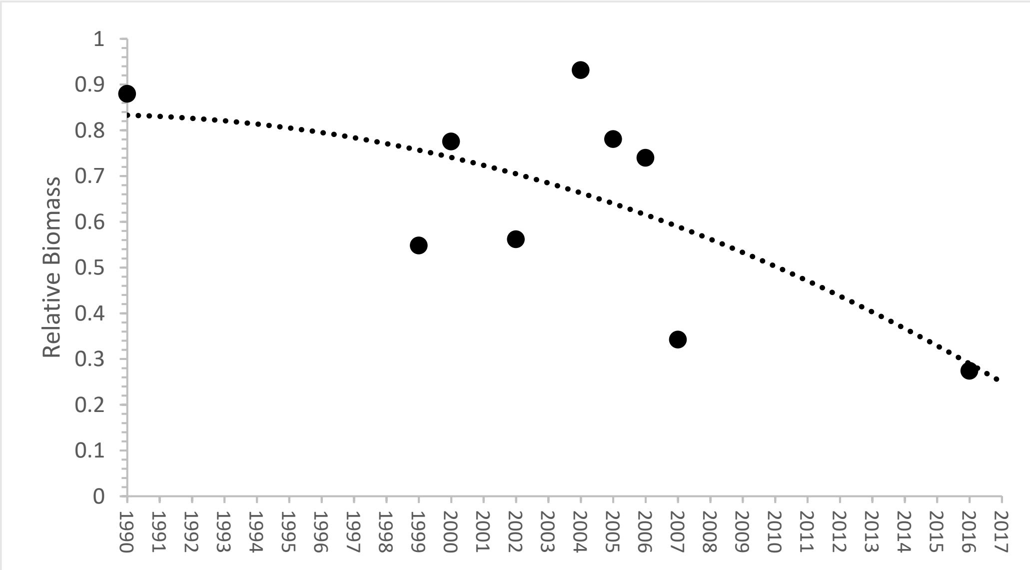

Figure 6. Hydroacoustic estimates of relative biomass of sardinella in Ghana (1990-2017)Source: EAF-Nansen Program, R/V Fridjoft Nansen

STATUS OF THE STOCK

The model estimated three parameters: (1) Initial Biomass (B_0), (2) intrinsic population growth rate (r) and (3) catchability (q) with equal weight associated with each parameter. The model fit had a coefficient of variation of 43% (CV=0.43). Estimates of total biomass of pelagic species showed a sharp decline following CPUE landing trends. Recent levels have reached the lowest point over the period between 1990 and 2017. Biomass in 2017 was only at 9.6% of the biomass needed to maintain a long-term sustainable exploitation of the stocks (Figure 7).

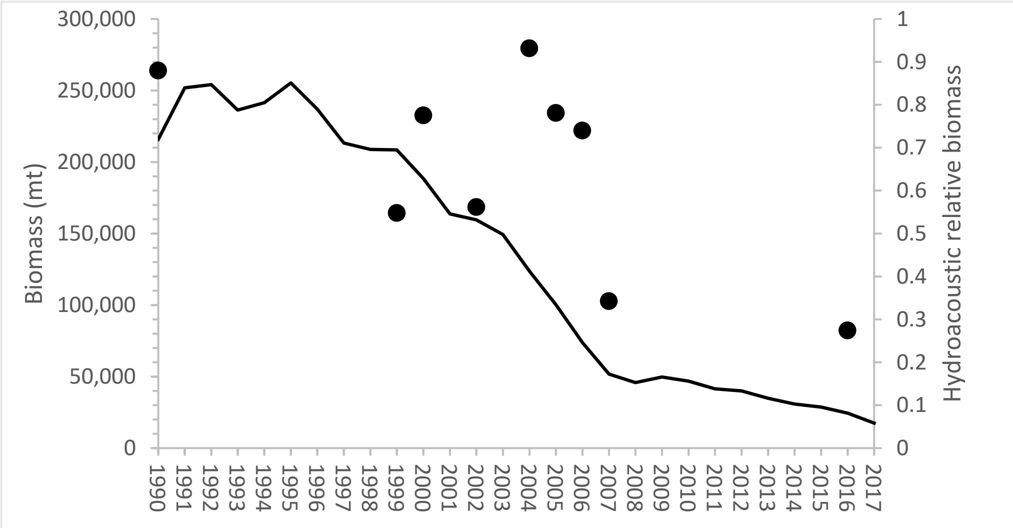

Figure 7. Hydroacoustic estimates of relative biomass of sardinella in Ghana (1990-2017) Source: EAF-Nansen Program, R/V Fridjoft Nansen

According to this assessment, the small pelagic fish stocks of Ghana are considered severely overfished. Fishing mortality has gradually increased in the past 25 years reaching high and unsustainable levels since 2004. The fishing mortality in 2017 (F_{2017}) was estimated at F=0.89 (Figure 8). The recent Fridjoft Nansen research acoustic survey conducted in September 2016 in Ghana estimated a low biomass for small pelagic stocks, noting a possible collapse of the sardinella stocks (personal communication).

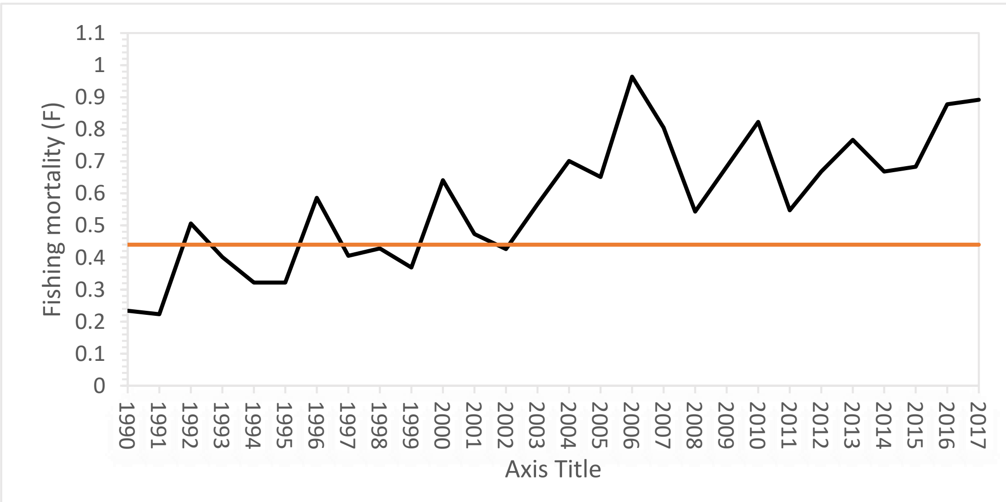

Figure 8. Fishing mortality estimates (F) from 1990 to 2017. The line refers to the sustainable fishing mortality rate (F_{msy}).

For small pelagic fish stocks, we select two types of biological reference points (biological indicators) measuring fishing mortality and biomass. The biological reference point relative to harvest levels, F_{msy}, is the level of harvest needed to achieve sustainability in the long term based on a sustainable growth and reproductive rates.

The F_{msy} for the small pelagic stock in Ghana was estimated by this model at F_{msy}=0.38, compared to F_{msy}= 0.4 estimated using the initial baseline data assessment in 2015 (Lazar et al., 2016). For management and consistency purposes, the STWG decided that the long-term target for stock rebuilding should be maintain at a fixed level (F_{msy}=0.40). This reference point is consistent with estimates applied for harvest control measures of small pelagics in the area of the Fishery Committee for the Central Eastern Atlantic (CECAF) region (Morocco to Angola) (CECAF, 2017). The B_{msy} for the small pelagic stock in Ghana was estimated by the model at 312,200 tonnes compared to the target rebuilding biomass (300,000 tonnes) estimated by the STWG in 2015 (Lazar et al., 2016). The current biomass is the lowest recorded during this period (1990-2017) and is well below the levels to rebuild this stock.

The status of the small pelagic fish stocks in Ghana are considered severely overfished. Fishing mortality has gradually increased in the past 28 years reaching high and unsustainable levels in 2017. The recent Fridjoft Nansen hydroacoustic survey conducted in 2016 and September 2017 confirmed this sharp decline of biomass. In addition, the average size of sardinella landed in 1998 was 16 cm compared to 9.5 cm measured in Tema in 2016 (FSSD, 2016). This is evidence of heavy recruitment and growth overfishing on these stocks.

MANAGEMENT RECOMMENDATIONS

Populations of short-lived species, such as small pelagic species, can grow or decline quickly in response to fishing pressure, and that this rapid decline in productivity often requires rapid interventions by fisheries managers to maintain sustainability. For a long time, the government of Ghana failed to control excessive fishing effort due to open access policy for the artisanal and industrial fisheries. The current state of the small pelagic stocks is severely overfished. The current level of effort and catches are not sustainable. Effort will have to be reduced to avoid future depletion of the stock. The CECAF’s working Group recommended that small pelagic fisheries should be closed to avoid a total collapse of the stock (CECAF, 2017).

The STWG presented a proposal to the Fisheries Commission to end overfishing and begin the rebuilding process in 2016 (Lazar et al., 2017). This proposal suggested a closed fishing season for one month for all fleets during the peak spawning season (August) to allow spawning stock to reproduce and juveniles replace lost biomass.

As a basis for providing scientific advice for fisheries management, there is generally a need for information on the status and development of the various fish stocks. The data used in this assessment is based on a sampling scheme and does not cover the entire fisheries. It is a snap shot of the landings time series used to capture trends of harvest rates and standing biomass. The absolute values of biomass estimates presented here need more reliable data and knowledge on the development of the fishing pressure on the different fish stocks. Based on the historical reconstruction of fish catches in Ghana conducted by the Sea Around Us project estimated that total landings were estimated at 20.8 million tonnes between 1950 and 2010 compared to 11.8 million tonnes reported by FSSD to the FAO (Nunoo et al. 2014).

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