SUSTAINABLE FISHERIES MANAGEMENT PROJECT (SFMP)

Status of the Small Pelagic Fish Stock in Ghana 2019.

Scientific and Technical Working Group

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ACRONYMS

B_{msy}	Biomass level that will produce the Maximum Sustainable Yield
CCM	Centre for Coastal Management
CECAF	Fisheries Committee for the Eastern Central Atlantic
CEWEFIA	Central and Western Region Fishmongers Improvement Association
CPUE	Catch-Per Unit Effort
CRC	Coastal Resource Center
DAA	Development Action Association
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
HM	Hen Mpoano
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

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

This report provides an update of the status of the small pelagic fish stocks of Ghana through 2019. It was led by the Fisheries and Scientific and Survey Division (FSSD) of Ghana's Fisheries Commission, and reviewed and validated by the Science and Technical Working Group (STWG) in August of 2019. The data used in this assessment were provided by FSSD and the Government of Norway's Fridjoft Nansen[1] survey program.

Previous assessments conducted by STWG (Lazar et al. 2016, Lazar et al. 2017 and Lazar et al. 2018) 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. Stock assessment reports provided detailed fisheries and biological background and established target biological reference points for the small pelagic stocks Two reference points were selected: fishing mortality (F), a mathematically calculated measure of the annual or instantaneous rate at which fish die from fishing, and biomass (B), defined as the entire weight of the in-water part of a fishable population, i.e., that part of a population (also called 'stock') that is exposed to fishing gears. Targets for the small pelagic stocks in Ghana were set 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.

Annual landings of small pelagic species in 2019, consisting of round sardinella (*Sardinella aurita*), flat sardinella (*Sardinella maderensis*), anchovies (*Engraulis encrasicolus*) and mackerel (*Scomber colias*), declined to the lowest level in the time series between 1990 and 2019. The total landings recorded in 2019 represented about 41% of the highest recorder landings in 1993. The catch per-unit of effort (CPUE), expressed in catch per per-seine canoe, declined to the lowest level in 2019 and represented about 25% of the highest CPUE recorded in early 1992 and 1995 (Figure 1). With a declining CPUE, the economic profitability of fishing is also declining.

Target Reference Points are Biological Reference points defined as the level of fishing mortality or of the biomass, which permit a long-term sustainable exploitation of the stocks, with the *best possible catch*. For this reason, these points are also designated as Reference Points for Management. They can be characterized as the Fishing level F_{target} or by the Biomass, B_{target}. The targets can be set at levels to achieve Maximum Sustainable Yields (MSY, or Fmsy or Bmsy).

FAO Fish Stock Assessment Manual, 2003

Biological reference points, such as the biomass needed to provide maximum sustainable yield (B_{MSY}). have been used by fisheries scientists for over 50 years to evaluate stock status. Reference points are emerging as one of the most widespread and effective bases for modern fisheries management.
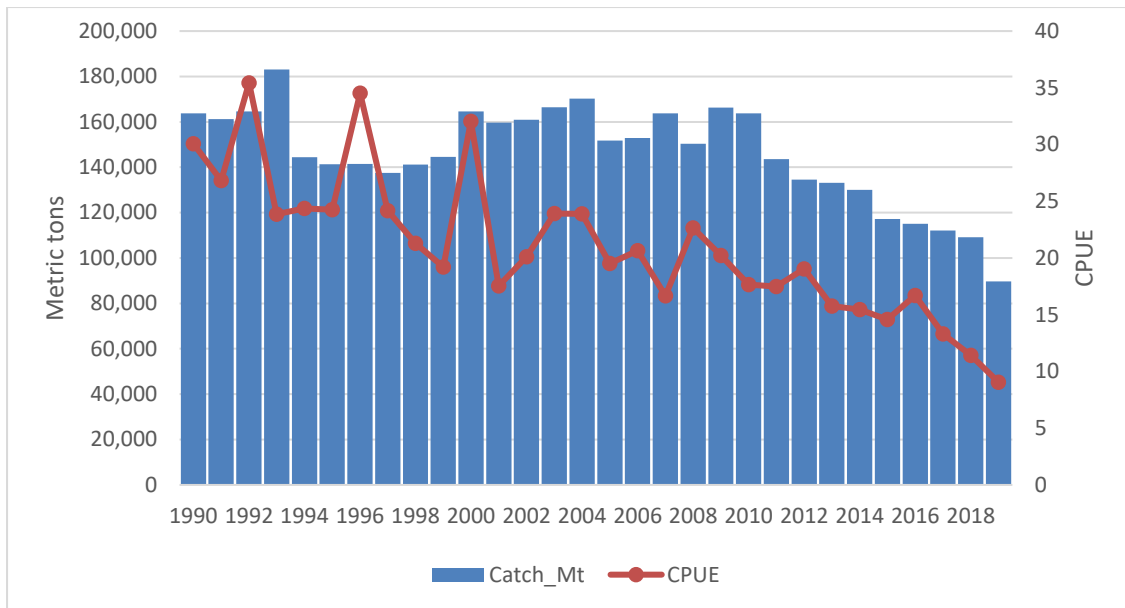
Pew Charitable Trusts 2016

Figure 1 Landings and CPUE of small pelagics (sardinella, mackerel and/ anchovies) in Ghana from 1990 to 2019

Annual landings of *Sardinella aurita* have declined from 119515 tonnes. in 1992 to 11,834 tonnes in 2019. This represented only 9.9% of the highest recorded landings (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 regime. Since the artisanal fishing fleet makes up the largest percentage of the recorded small pelagic landings annually and the declining catch and catch per unit of effort, and the significant increase in numbers of canoe fishing vessels over the last two decades point to the canoe sector as the main cause. While the illegal "saiko" landings by the industrial trawl sector may also be a significant factor, as this illegal catch is unrecorded, there are no adequate data to use in these stock assessments at this time or to assess its contribution to the fisheries decline.
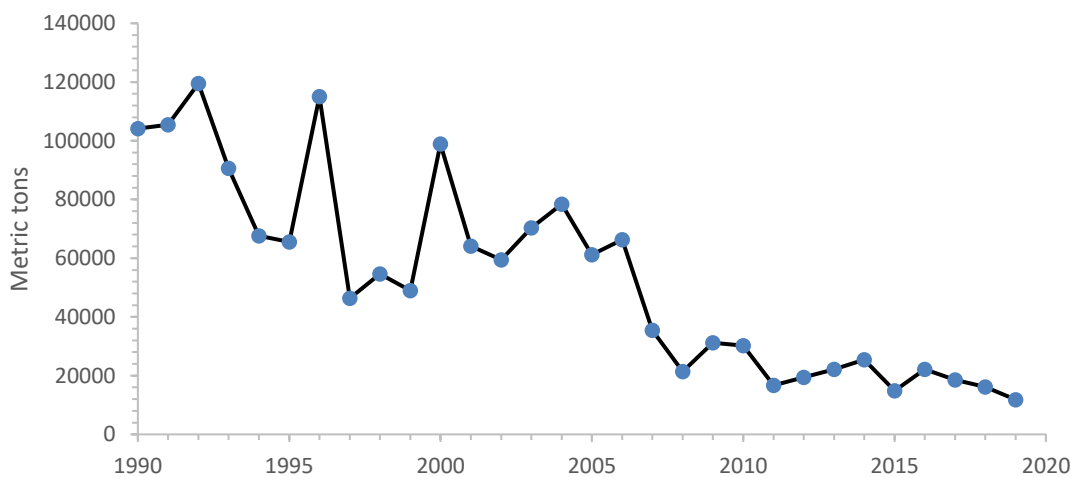

Figure 2 Trends of Sardinella aurita landings in Ghana (1990-2019)

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 (Lazar et al., 2018).

The trends of the annual landings by sub-sector shows the dominance of the landings by the artisanal sub-sector, taking about 80% of the landings in 1990s but declined in its share to 61% in recent years. The landings recorded in 2018 were the lowest in the time series (Figure 3). A slight increase was observed in 2019 due to increased landings of Atlantic bumper (*Chloroscombrus chrysurus*). Landings from the trawler fleet has remained relatively flat but has increased in recent years. The true size of the annual "saiko" landings still remains unknown as it is not part of the official landing statistics in Ghana. However, illegal saiko landings have only come about in the past decade, and the decline in landings of Sardinella has been occurring since the early 1990s. Independent surveys from the R/V Fridjoft Nansen (Fig 5) also corroborate the declines documented in this report using the Fisheries Commissions fisheries dependent data collection.
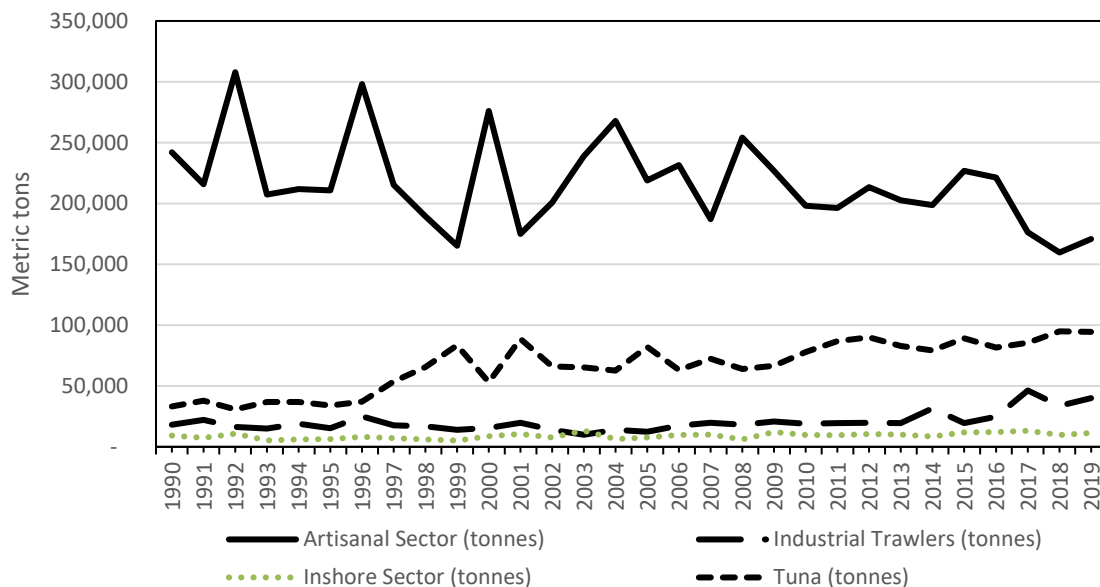
Figure 3 Trends in marine fish landings by sector in Ghana (1990-2019)

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 (1990-2019) by species and fishing sector (artisanal, semi-industrial and industrial) were provided by FC/FSSD. Fishing effort in number of purse seine canoes (1990-2019) 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 (Lazar et al., 2016). 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 <u>fishing power</u> 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 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).

Based on interviews conducted by SFMP with fishermen to collect catch and effort data as part of the fisheries profile of Ghana, it was reported that the fishing power increased by 40% since 1980s (Asare et al., 2015). 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

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[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.

hydroacoustic surveys conducted by R/V Fridjoft Nansen. The survey information can 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) measurements at artisanal landing sites 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 and Berg, 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

      B_{t+1}= population biomass of year t+1 (next year)

      B_t = population biomass of this year (t)

      r = intrinsic rate of biomass increase

      $\mathcal{E}$= lognormal process error

     K = carrying capacity

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*), that constrains the growth of the population to where the overall biomass no longer grows and remains constant in an unexploited population, 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 (*Bmsy=K/2*) and be subject to a fishery removal rate no greater than *Fmsy*. 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 ($r \le Fmsy$) 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:

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

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 Bannerman and Quartey (2016) 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.

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 4). The trends are consistent with observed landings and CPUE. The relative biomass estimated in 2018 is the lowest ever recorded since the beginning of these surveys in mid-1980s.
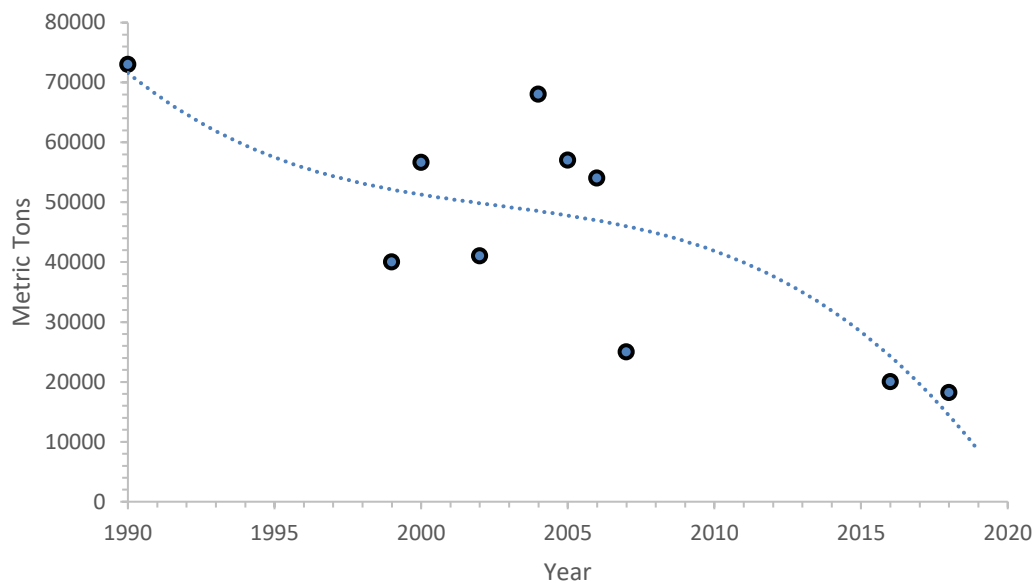

Figure 4 Hydroacoustic estimates of relative biomass of sardinella in Ghana (1990-2018)

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[4] of 36%. Estimates of total biomass of small pelagic species showed a sharp decline following the CPUE trends (Figure 5). The 2019 biomass estimates were the lowest recorded during this time series, well below the B_{msy} level. The biomass continued its decline as a result of effort increase. The biomass in 2019 was only at 54% of B_{msy} needed to maintain the long-term sustainable exploitation of the stocks (Figure 5). The stock is considered severely overfished and overfishing continue to occur, making this stock in a state of collapse. According to the 2019 landings figures of *Sardinella aurita*,

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[4] The coefficient of variation (CV) is defined as the ratio of the standard deviation to the mean. It shows the extent of variability in relation to the mean of the population. It is a standardized measure of dispersion of a probability distribution or frequency distribution and often expressed as a percentage.

representing less than 10% of the highest recorded landings, this stock is also considered collapsed.
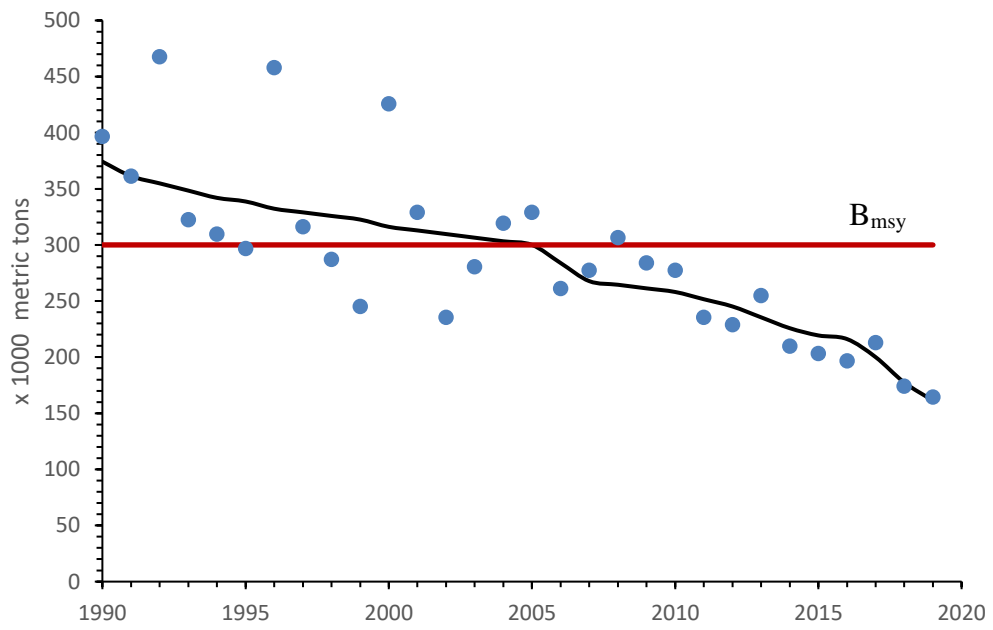

Figure 5 Estimates of relative biomass of small pelagics in Ghana (1990-2017)

Fishing mortality continued to increase as fishing effort increased and stock biomass declined. The current level of fishing mortality estimated at $F=0.81$ is well above $F_{msy}=0.4$ (the exploitation level at which the stock should maintain a sustainable biomass. Fishing mortality has gradually increased in the past 29 years reaching high and unsustainable levels since 2001 (Figure 6). Fishing mortality should not be confused or viewed as identical to fishing effort as it is the rate at which fish are killed or extracted from the ocean from fishing. As the instantaneous fishing mortality is used here, $F=0.81$ means that about 65% of the small pelagic fish is removed annually and $F=0.4$ means about 32% removal annually.
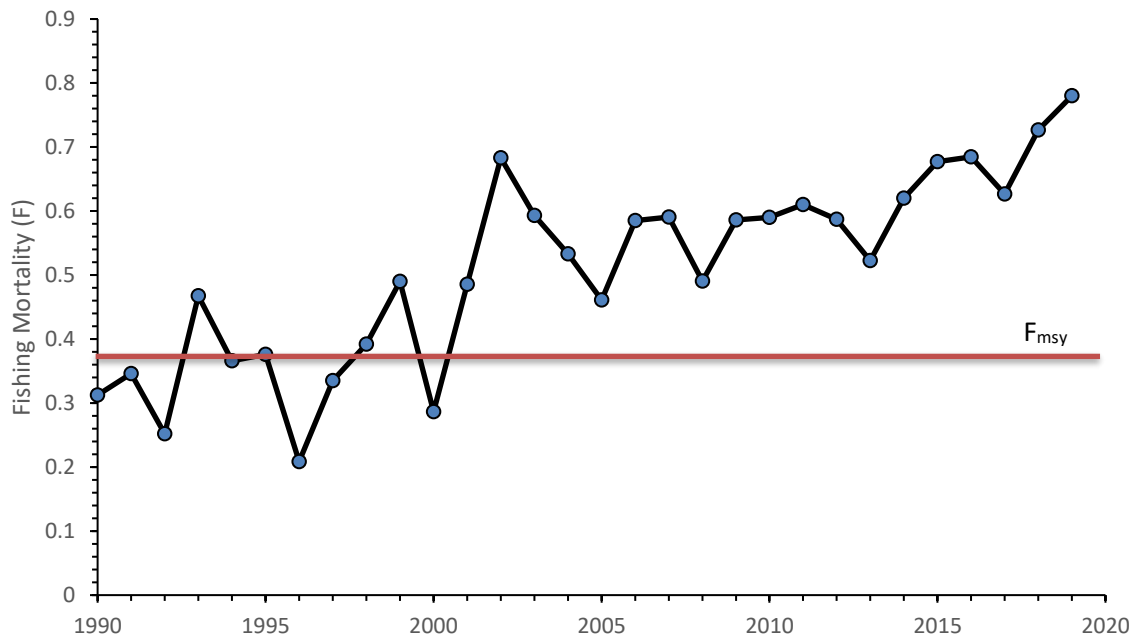
Figure 6 Estimates of fishing mortality of small pelagics in Ghana (1990-2017)

For small pelagic fish stocks, we select two types of biological reference points (biological indicators): fishing mortality and biomass. The fishing mortality rate needed to achieve maximum sustained annual yields, 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). The biomass of fish in the sea needed to achieve maximum sustained annual yields is 300,000 tonnes.

For management purposes, a "Kobe plot" was plotted to show temporal changes of the status of the stock from 1990 to 2019 (Figure 7).
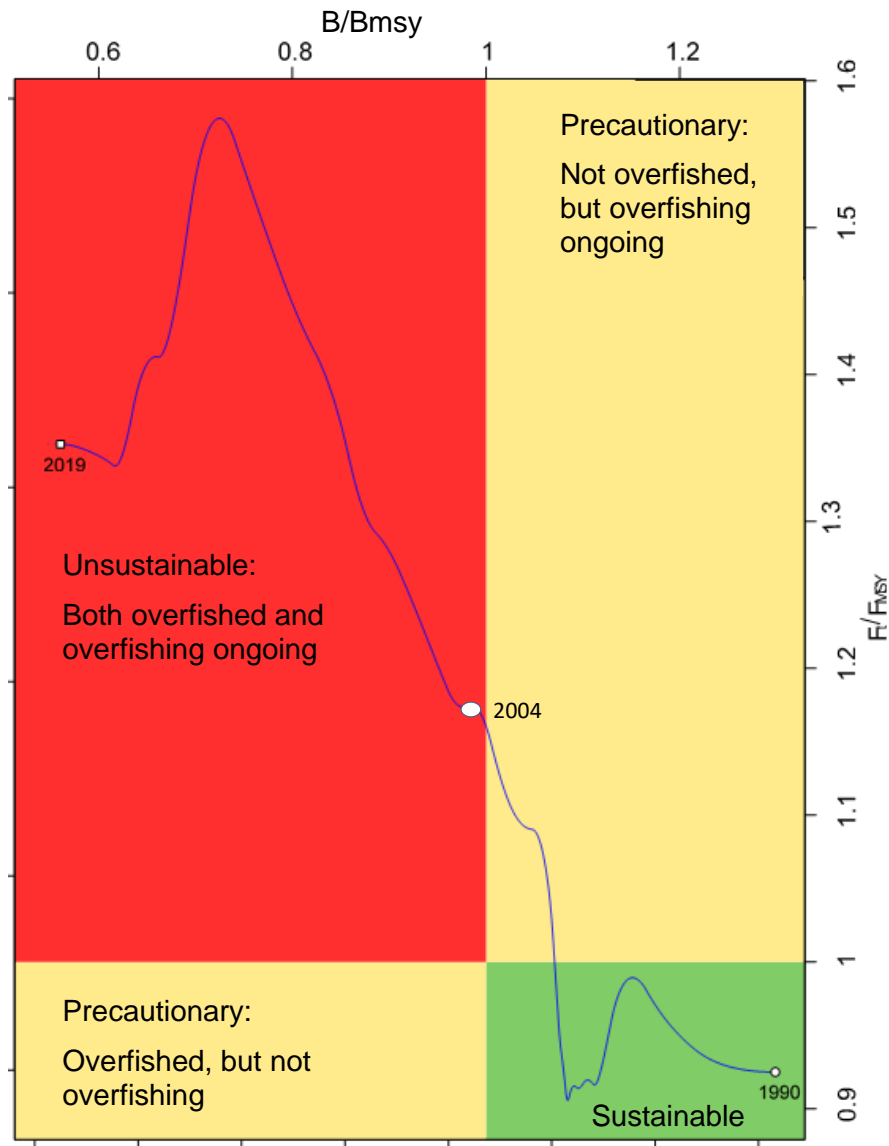
Figure 7 Kobe plot of fishing mortality and biomass relative to Fmsy and Bmsy

This plot is divided into four panels which correspond to the state of the fisheries (F/Fmsy) and the state of the stock (B/Bmsy). The green panel represents a healthy biomass and acceptable fishing mortality levels while the red panel represents a fishery where biomass is too low and fishing mortality is too high, meaning the fishery is overfished an (relative to biomass and where overfishing(relative to fishing mortality) is also occurring . The yellow

panels represent the area of transition. The trends are represented by the ratios of B/B_{msy} and F/F_{msy} over the period between 1990 and 2019. For each year, B or biomass of the stock is calculated for that year, and F or fishing mortality is calculated yearly (see Figures 5 and 6 annual figures.). These numbers are then divided by the Fmsy and B msy numbers mentioned above to get the ratio that is plotted in Figure 7.

The current biomass and fishing mortality have been in the red (overfished and overfishing occurring) panel since 2004 and continue in the direction of lowest level of biomass.[5] In order for the small pelagic fishery to recover and move into the preferred sustainable green zone, overfishing must be reduced via a reduction in fishing effort. In many countries where a fishery such as this one in Ghana has this type of plot, a full closure of the fishery is put in place (zero fishing mortality, no fishing effort) or effort is reduce to a ratio of F/Fmsy of below 1, which moves the plot into the bottom left quadrant, and fishing is kept low until the biomass ration B/Bmsy increases above 1.

MANAGEMENT RECOMMENDATIONS

The current state of the small pelagic stocks is severely overfished (very low biomass levels well below the point need for maximum sustained yields) and overfishing is still occurring (fishing mortality and effort well above what can produce maximum sustained yields). The Sardinella aurita fishery is considered collapsed[6] due its low landings recorded in 2019. The current level of effort and catches are not sustainable. Effort will have to be reduced to avoid future depletion of the stock. The Fishery Committee for the Eastern Central Atlantic (CECAF) working Group and the STWG recommended that small pelagic fisheries of Ghana should be closed to avoid a total collapse of the stock in 2017 and 2018 (CECAF, 2017). It was predicted by previous STWG's stock assessments that concluded without serious interventions to end overfishing and avoid the further deterioration of the *Sardinella aurita* stocks, this stock was expected to collapse by 2020.

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 snapshot 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, 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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[5] Note: A Kobe plot is divided into four panels: red (upper left) corresponds to the "overfished and overfishing phase", with spawning biomass inferior to MSY spawning biomass (SB MSY) and fishing mortality superior to MSY fishing mortality (FMSY). The green panel (lower right) is the "no risk" area where fishing mortality is below FMSY and the spawning biomass is above SB MSY. The two yellow panels (overfishing and overfished) characterize intermediate situations. (Dragon, A., Senina, I., Titaud, O., Lehodey, P., Calmettes, B., Conchon, A., Arrizabalaga, H., 2015). See also: https://issuu.com/wpcouncil/docs/what_is_a_kobe_plot

[6] There are many definitions of what constitutes a collapsed fishery – an abrupt change in biomass by 70% over a decade and remains low for years (Yletyinen, et at., 2018) https://doi.org/10.1101/329979 ,or, When the increasing proportion of the annual catch time series falls below 10% of the maximum catch. (Worm et al, 2006) https://doi.org/10.1126/science.1132294.

Based on the findings of the 2019 stock assessment and the prior assessments, the STWG recommends:

1) Current effort towards ending open access and reducing fishing effort should be intensified in the artisanal and semi-industrial sub-sectors.
2) Yield for the industrial sub-sector is in excess of the sustainable level (Maximum sustainable Yield- MSY) and therefore it should be reduced, via a reduction in number of days fishing per the national marine fisheries management plan and a reduction in in fleet size (see point 3 below)
3) Align the current levels of fishing effort and capacity with Maximum Sustainable Yield (MSY). The number of trawlers should be reduced by at least 44%.
4) A closed season should be implemented concurrently for all fleet except tuna. This should be institutionalized over the next five years to coincide with the peak breeding season of small pelagics (July-August).
5) Early announcement (minimum of 6 months) for future closed seasons in order to give fishers adequate time to prepare for the closure.
6) The closed season should be implemented in combination with effective enforcement of existing laws including but not limited to mesh size control, and of bans on light fishing, dynamite, chemicals, Saiko fishing etc. before and after the closure.
7) Trawl gears should be regulated; and as a matter of urgency, ensure that industrial trawlers target demersal fish only.
8) Formalize the STWG to serve as a scientific advisory body to the Fisheries Commission for the management of fisheries.
9) Consider investments and linkages to social intervention programs (e.g. school feeding and the Government of Ghana's Livelihood Empowerment Against Poverty LEAP - Program) to offset the socioeconomic impact of the closed seasons.

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