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Status of the Small Pelagic Fish Stock in Ghana 2019.

Scientific and Technical Working Group

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For more information on the Ghana Sustainable Fisheries Management Project, contact:

USAID/Ghana Sustainable Fisheries Management Project
Coastal Resources Center
Graduate School of Oceanography
University of Rhode Island
220 South Ferry Rd.
Narragansett, RI 02882 USA
Tel: 401-874-6224 Fax: 401-874-6920
Email: info@crc.uri.edu

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Detailed Partner Contact Information:
USAID/Ghana Sustainable Fisheries Management Project (SFMP)
10 Obodai St., Mempeasem, East Legon, Accra, Ghana
Telephone: +233 0302 542497 Fax: +233 0302 542498

Raymond Babanawo	Chief of Party	Email: raybabs.sfmp@crcuri.org
Enoch Appiah	Deputy Chief of Party	Email: eappiah.sfmp@crcuri.org
Kofi Agbogah	Senior Fisheries Advisor	Email: kagbogah@henmpoano.org
Perfectual Labik	Communications Officer	Email: perfectual.sfmp@crcuri.org
Mary Asare	M&E Officer	Email: mary.sfmp@crcuri.org
Brian Crawford	Project Manager, CRC	Email: bcrawford@uri.edu
Mark Newton	USAID AOR	Email: mnewton@usaid.gov

Hen Mpoano
38 J. Cross Cole St. Windy Ridge
Takoradi, Ghana
+233 312 020 701
Kofi Agbogah
kagbogah@henmpoano.org

Resonance Global
(Formerly SSG Advisors)
182 Main Street
Burlington, VT 05401
+1 (802) 735-1162
Nick
McClurenmcclure@resonanceglobal.com

Friends of the Nation
Parks and Gardens
Adiembra-Sekondi, Ghana
+233 312 046 180
Donkris Mevuta
Kyei Yamoah
info@fonghana.org

CEWEFIA
B342 Bronyibima Estate
Elmina, Ghana
+233 024 427 8377
Victoria C. Koomson
cewefia@gmail.com

Centre for Coastal Management (CCM)
University of Cape Coast, Cape Coast,
Ghana
+233 242910056
Denis Aheto: daheto@ucc.edu.gh

Development Action Association (DAA)
Darkuman Junction, Kaneshie Odokor
Highway
Accra, Ghana
233 302 315894
Lydia Sasu
daawomen@daawomen.org

For additional information on partner activities:

CCM/UCC	https://ccm.ucc.edu.gh/
CEWEFIA	http://cewefia.weebly.com/
CRC/URI	http://www.crc.uri.edu
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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

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INTRODUCTION

This report provides an update of the status of the small pelagic fish stocks of Ghana through 2019. It was led by the FSSD, reviewed and validated by the Science and Technical Working Group (STWG) in July 28-29, 2020. 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 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 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.

Annual landings of small palgic species, 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).

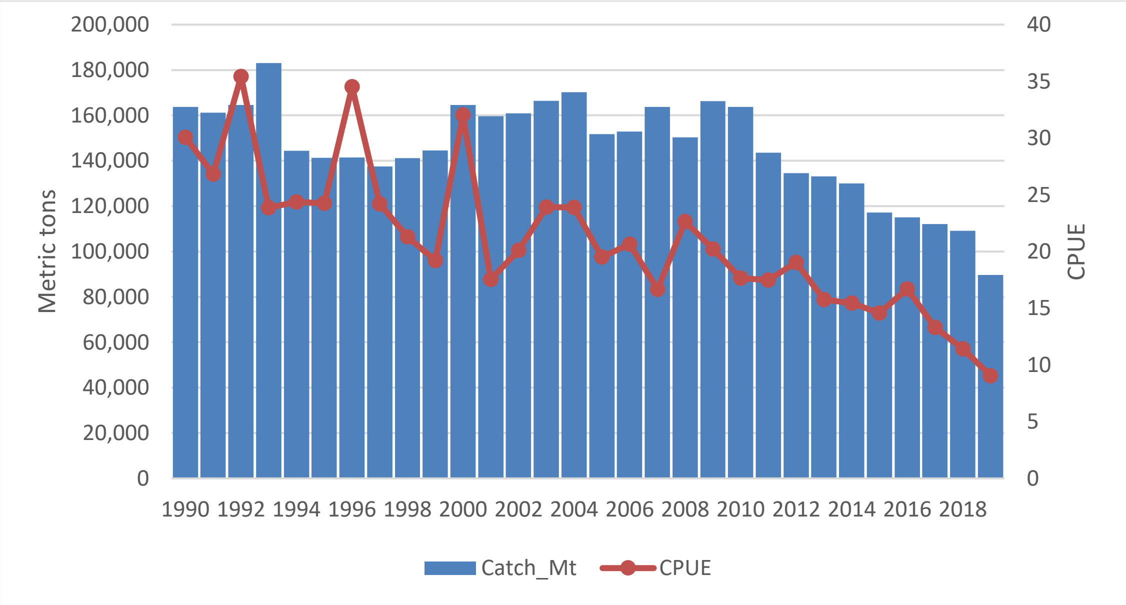

Figure 1 Landings and CPUE of small pelagics (sardinella, mackerel and/ anchovies) in Ghana from 1990 to 2019

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

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. 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).

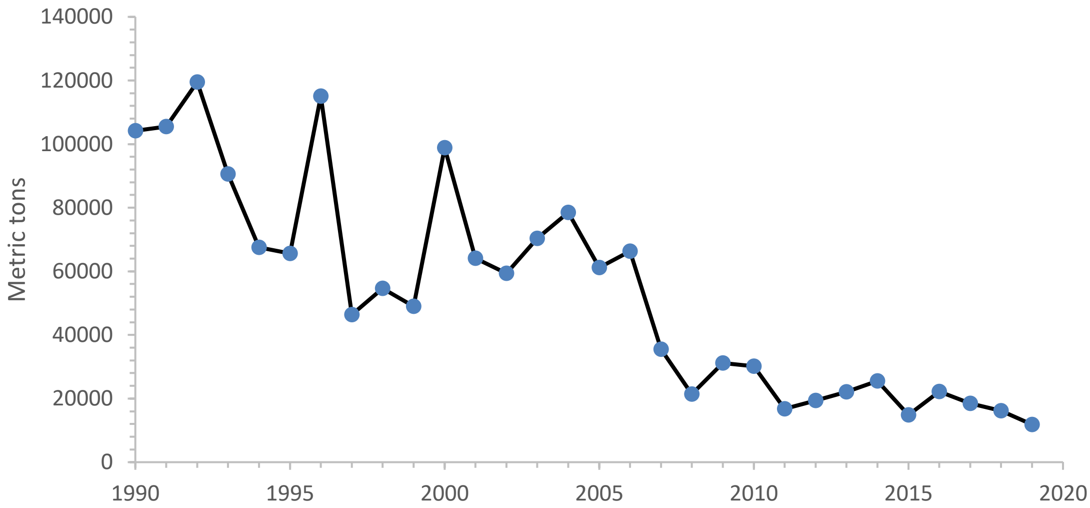

Figure 2 Trends of Sardinella aurita landings in Ghana (1990-2019)

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)*.

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.

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

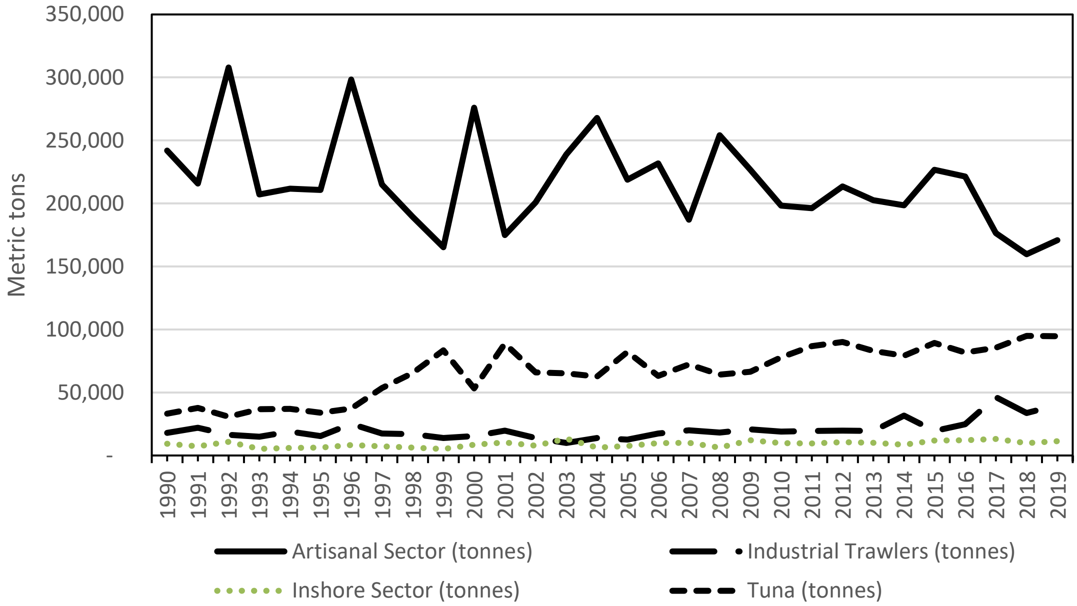

Figure 3 Trends in marine fish landings by sector in Ghana (1990-2019)

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 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 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

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

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 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) 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

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 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 2016 is the lowest ever recorded since the beginning of these surveys in mid-1980s.

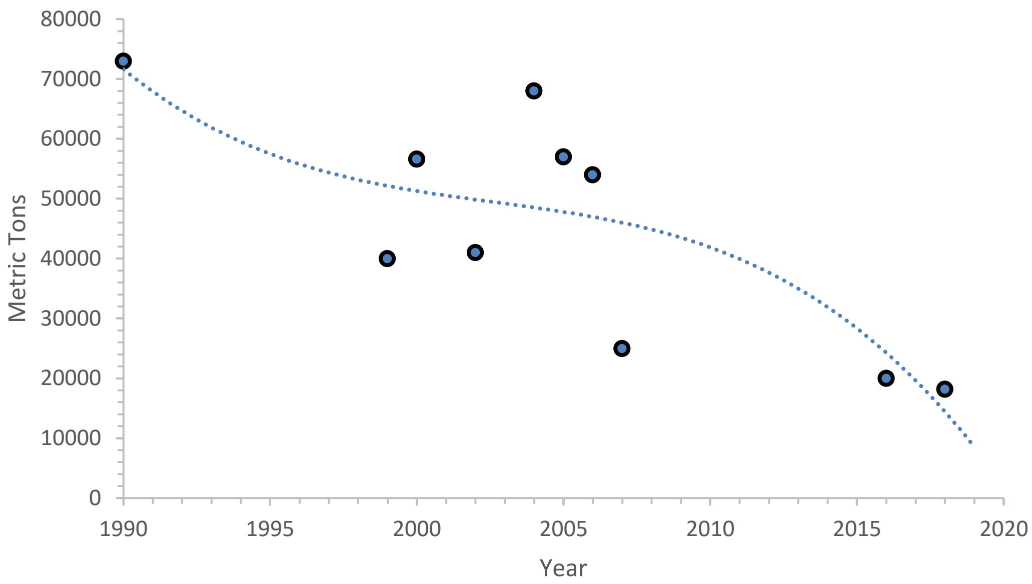

Figure 4 Hydroacoustic estimates of relative biomass of sardinella in Ghana (1990-2018)

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 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 results of effort increase. The biomass in 2019 was only at 54% of B_{msy} needed to maintain a 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*, representing less than 10% of the highest recorded landings, this stock is also considered collapsed.

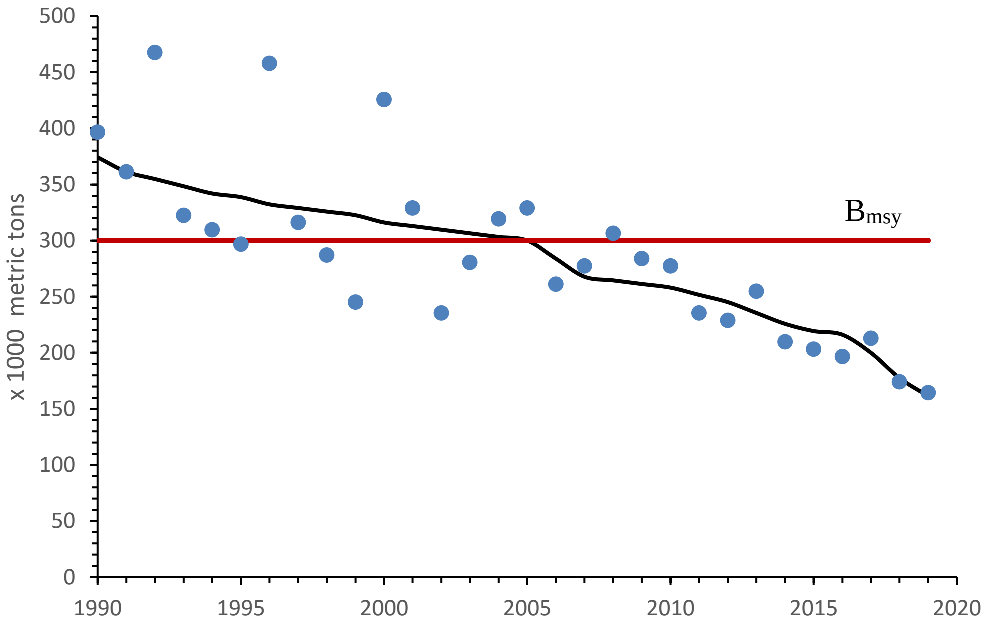

Figure 5 Estimates of relative biomass of small pelagics in Ghana (1990-2017)

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 exfoliation 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).

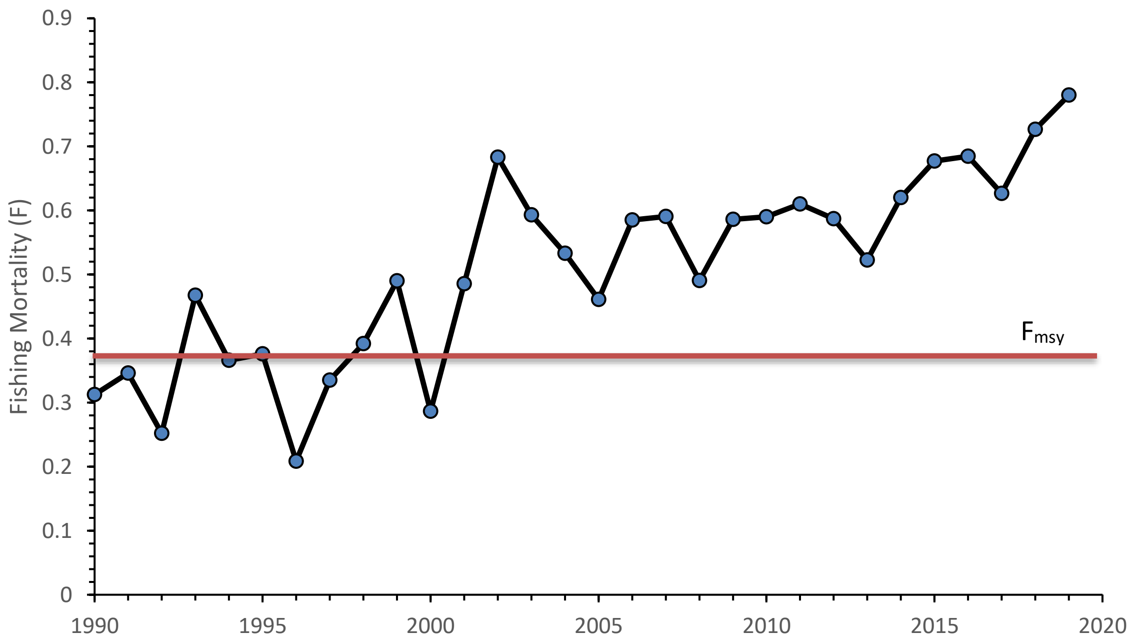

Figure 6 Estimates of fishing mortality of small pelagics in Ghana (1990-2017)

For small pelagic fish stocks, we select two types of biological reference points (biological indicators) 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 purposes, a “Kobe plot” was plotted to show temporal changes of the status of the stock from 1990 to 2019 (Figure 7). This plot is divided into four panels which correspond to the state of the fisheries and the state of the stock. The green panel represent the healthy biomass and acceptable fishing motility level while the red panel represent the overfished state of the stock in terms of biomass and fishing mortality. The yellow panels represent the area of transition. The trends are represented by the ratios of B_t/B_{msy} and F_t/F_{msy} over the period between 1990 and 2019.

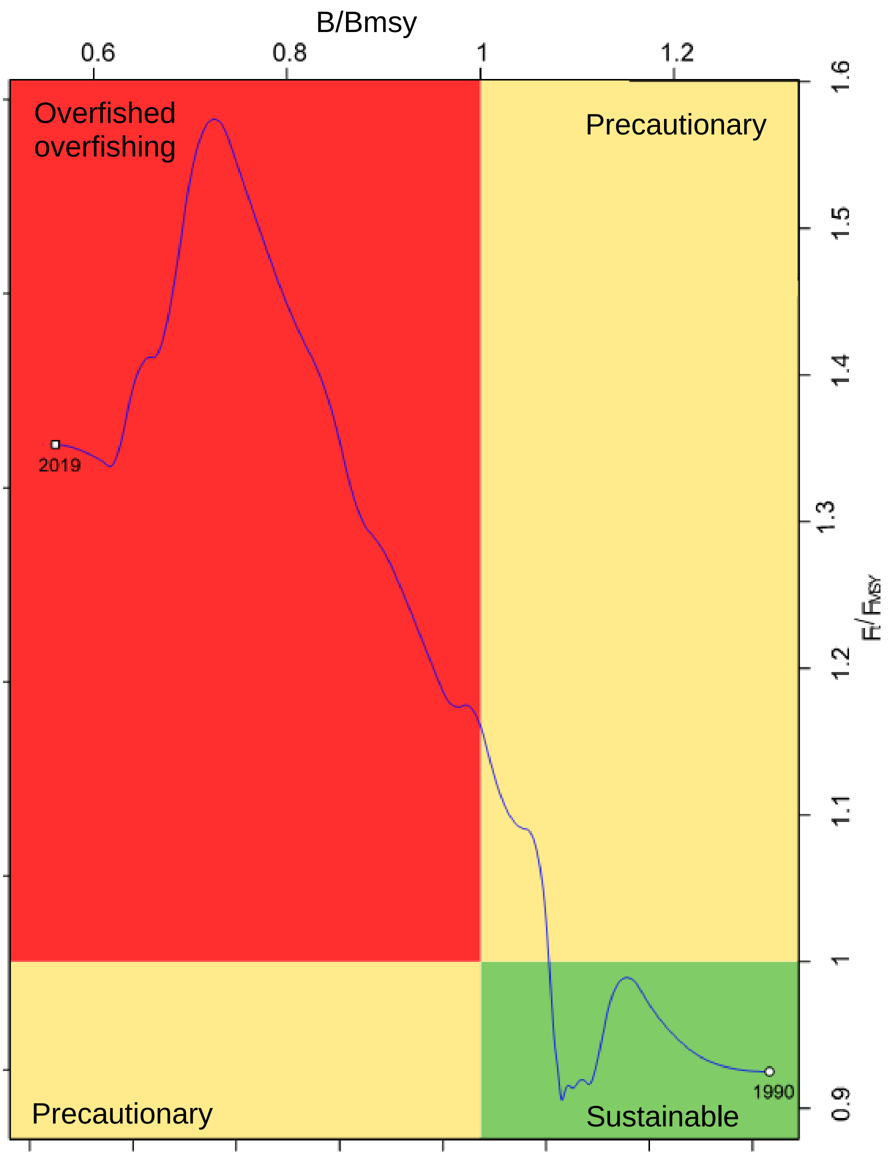

Figure 7 Kobe plot of fishing mortality and biomass relative to Fmsy and Bmsy

The current biomass and fishing mortality have been in the red (overfished) panel since 2004 and continue in the direction of lowest level of biomass.[4]

MANAGEMENT RECOMMENDATIONS

The current state of the small pelagic stocks is severely overfished. The stock of Sardinella aurita is considered collapsed 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 CECAF's 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).

The STWG made the following recommendations:

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.
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.

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[4] 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

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.

REFERENCES

Asare, C., Nortey, D.D.N., Lazar N, Kankam, S. and Agbogah, K. (2015). Results of field survey for the small pelagic fisheries profile. The USAID/Ghana Sustainable Fisheries Management Project (SFMP), Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island and Hen Mpoano, Windy Ridge – Takoradi. GH2014_ACT020_HM 52 pp. https://www.crc.uri.edu/download/GH2014_ACT020_HM_FIN508-1.pdf

Bannerman P., Quartey, R. (2004). Observations of the commercial light fishing operation in Ghana. Report of the Fisheries Scientific and Survey Division, Fisheries Commission. 9 pp.

CECAF. (2017). Status summary for small pelagic stocks in the southern area of the Eastern Central Atlantic – FAO/CACAF/SSCVIII/2017/3. 16 pp.

Dragon, A., Senina, I., Titaud, O., Lehodey, P., Calmettes, B., Conchon, A., Arrizabalaga, H. (2015). An ecosystem-driven model for spatial dynamics and stock assessment of North Atlantic albacore. Canadian Journal of Fisheries and Aquatic Sciences. 17 February 2015. https://doi.org/10.1139/cjfas-2014-0338. .

EJF and Hen Mpoano (2019). Stolen at sea. How illegal 'saiko' fishing is fueling the collapse of Ghana's fisheries. A report produced by the Environmental Justice Foundation and Hen Mpoano, 32 pp. https://ejfoundation.org/resources/downloads/Stolen-at-sea_06_2019.pdf

FSSD (2016). Marine Fisheries Research Annual Report, 2016. Fisheries Commission, Ministry of Fisheries and Aquaculture Development.

Lazar, N., Yankson K., Blay, J., Ofori-Danson, P., Markwei, P., Agbogah, K., Bannerman, P., Sotor, M., Yamoah, K. K., and Bilisini, W. B. (2016). Status of the small pelagic stocks in Ghana 2015. Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography. GH2014_ACT093_CRC http://www.crc.uri.edu/download/GH2014_ACT093_CRC_FIN508.pdf

Lazar, N., Yankson K., Blay, J., Ofori-Danson, P., Markwei, P., Agbogah, K., Bannerman, P., Sotor, M., Yamoah, K. and K., Bilisini, W. B. (2017). Status of the small pelagic stocks in Ghana and recommendations to achieve sustainable fishing 2016. Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. GH2014_ACT150_CRC https://www.crc.uri.edu/download/GH2014_ACT150_CRC_FIN508.pdf

Lazar, N., Yankson K., Blay, J., Ofori-Danson, P., Markwei, P., Agbogah, K., Bannerman, P., Sotor, M., Yamoah, K. K., and Bilisini, W. B. (2018). Status of the small pelagic stocks in Ghana 2017. Scientific and Technical Working Group. USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal Resources Center,

Graduate School of Oceanography. GH2014_SCI042_CRC
https://www.crc.uri.edu/download/GH2014_SCI042_CRC_FIN508.pdf

Lazar, N., Yankson,K., Blay, J., Ofori-Danson, P., Markwei, P., Agbogah, K.,Bannerman, P., Sotor, M., Yamoah, K. K., Bilisini, W. B. (2018). Status ofthe smallpelagic stocks in Ghana in 2018. Scientific and Technical Working Group.USAID/Ghana Sustainable Fisheries Management Project (SFMP). Coastal ResourcesCenter, Graduate School of Oceanography, University of Rhode Island.GH2014_SCI_082_CRC.16 pp. https://www.crc.uri.edu/download/GH2014_SCI082_CRC_FIN508.pdf

Nunoo F.K.E.,, B. Asiedu, K. Amador, D. Belhabib, V. Lam, R. Sumaila and D. Pauly (2014) Marine Fisheries Catches in Ghana: Historic Reconstruction for 1950 to 2010 and Current Economic Impacts, *Reviews in Fisheries Science & Aquaculture*, 22:4, 274-283, https://www.tandfonline.com/doi/abs/10.1080/23308249.2014.962687

Pedersen M., and Berg C.W. (2017). A stochastic surplus production model in continuous time. *Fish and Fisheries*, 18, 226-243.

Sanders M.J. and Morgan A. J. (1976) Fishing power, fishing effort, density, fishing intensity and fishing mortality. *ICES journal of Marine Science*, Volume 37, Issue 1, 63-40. https://doi.org/10.1093/icesjms/37.1.36