Journal of Biology and Nature

Volume 16, Issue 2, Page 28-36, 2024; Article no.JOBAN.12302
ISSN: 2395-5376 (P), ISSN: 2395-5384 (O), (NLM ID: 101679666)

Population Dynamics and Stock Status of the Round Sardinella (*Sardinella aurita*, Valenciennes, 1847) in the Coastal Waters of Côte d'Ivoire (West Africa)

Coulibaly Bakari [a*], Aliko N'Guessan Gustave [b], Joanny Tapé Gnahoré Toussaint [a], Sylla Soumaila [a] and Kone Tidiani [b]

[a] Centre de Recherches Océanologiques (CRO), 29 Rue des Pêcheurs- BP V 18 Abidjan, Côte d'Ivoire.
[b] Laboratoire de Biologie et Ecologie Tropicale, UFR Environnement, Université Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire.

Authors' contributions

This work was carried out in collaboration among all authors. Author CB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ANG and SS managed the analyses of the study. Authors KT and JTGT did the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/joban/2024/v16i28830

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.ikprress.org/review-history/12302

Original Research Article

Received: 10/06/2024
Accepted: 13/08/2024
Published: 26/08/2024

**Corresponding author: E-mail: Coulibaly.bakari@cro.edu.ci, nanan84@yahoo.fr;*

***Cite as:** Bakari, Coulibaly, Aliko N'Guessan Gustave, Joanny Tapé Gnahoré Toussaint, Sylla Soumaila, and Kone Tidiani. 2024. "Population Dynamics and Stock Status of the Round Sardinella (Sardinella Aurita, Valenciennes, 1847) in the Coastal Waters of Côte d'Ivoire (West Africa)". Journal of Biology and Nature 16 (2):28-36. https://doi.org/10.56557/joban/2024/v16i28830.*

ABSTRACT

This work was carried out to fill for a short time the lack of available data on the dynamic of *Sardinella aurita* within Côte d'Ivoire's coastal waters. A total of 2000 samples *of S. aurita* were collected from May 2022 to April 2023, measured for total lengths and examined using FiSAT II. The asymptotic length ($L\infty$) and growth rate (K) were 31.50 cm and 0.78 $year^{-1}$ respectively implying that this species is a fast-growing and a shot live species. The lengths at first maturity and first capture were estimated at 18.49 cm and 23.42 cm respectively. The natural mortality rate (M=1.49 $year^{-1}$) was higher than the fishing mortality rate (F=0.61$year^{-1}$). The recruitment trend was continuous throughout the year with two major peaks showing the presence of strong recruitment into the stock. However, the exploitation rate (E=0.29) was lower than the 0.5. Furthermore, using the Quadrant rule, the investigated stock was categorized as underexploited. However, the current exploitation rate is higher than E0.5 inviting us to be more careful and to take appropriate measures.

Keywords: Growth; mortality; pelagic fisheries; Sardinella aurita; Côte d'Ivoire.

1. INTRODUCTION

Pelagic fish can be categorized as coastal and oceanic fish based on the depth of the water they inhabit. *Sardinella aurita* known as the round sardine is a coastal pelagic species with a preference for saline waters. It is a cold-water species preferring temperatures between 18-25°C [1]. Indeed, the concentration of the species near the surface is highly variable and relies on the variability of the coastal upwelling intensity [2]. The round sardinella is found along the West African Coast from the Mediterranean to Cape Frio (18°S). In the Eastern Central Atlantic, the species is found abundantly in the Gulf of Guinea [3] where its feeds on zooplankton particularly copepods and mysid larvae, but sometimes phytoplankton especially by juveniles [4]. Fish stocks in many parts of the world is declining. Unfortunately, the stock of *Sardinella aurita* in the coastal waters of Côte d'Ivoire, is not exempt from this sad reality. In addition, catches of the species decreased from 50000 tons 1979 to around 6349,54 tons in 2023 [5]. Despite this reduction in total catches, *Sardinella aurita* remains very important because it is ranked among the main ones for purse seines fisheries [6], beach seines and gillnets fisheries [7]. Its importance is also justified by both an economic point of view and a purely food security point of view. Consequently, *S. aurita* fisheries like other commercial fisheries have for sometimes been subject to intense fishing pressures to meet increasing demands. In addition, within the coastal waters of Côte d'Ivoire, the publish limited information available on the population parameters of the species which is crucial to the issue of food security slows down for a while any measure of sustainable management of this resource. Thus, the present study aims to estimate the population parameters of the species with a view to its sustainable management.

2. MATERIALS AND METHODS

2.1 Study Area

Sampling zones were chosen based on the fishing activity intensity Grand-Bassam/Azureti (5°12´23.68''N; 3°47´57.89W), Abidjan/Ossibissa (5°16´44.90N; 4°03´14.58W), Grand-Lahou /Lahou kpanda (5°08´11.47''N; 5°01´33.77''W) and Fresco (5°05´53.85''N; 5°34´46.38''W) (Fig. 1).

2.2 Data Collection

Data were collected from fishermen chosen randomly and using various fishing gear notably gillnets, purse seines and beach seines. Each specimen in the catches was identified to the species level using [8] identification key. Then each individual was measured for its total length (Lt) to the nearest 0.1 cm by using a fish ruler and weighed to the nearest 0.01g using an electronic scale model FEL-500S. In all, a total of 2000 samples of *Sardinella aurita* were assessed from May 2022 to April 2023 (i.e 12 months).

2.3 Data Analysis

FiSAT II software [9] was used for data analysis. In addition, for the sake of harmonious processing, the size frequency data were grouped into intervals of 2 cm in length.

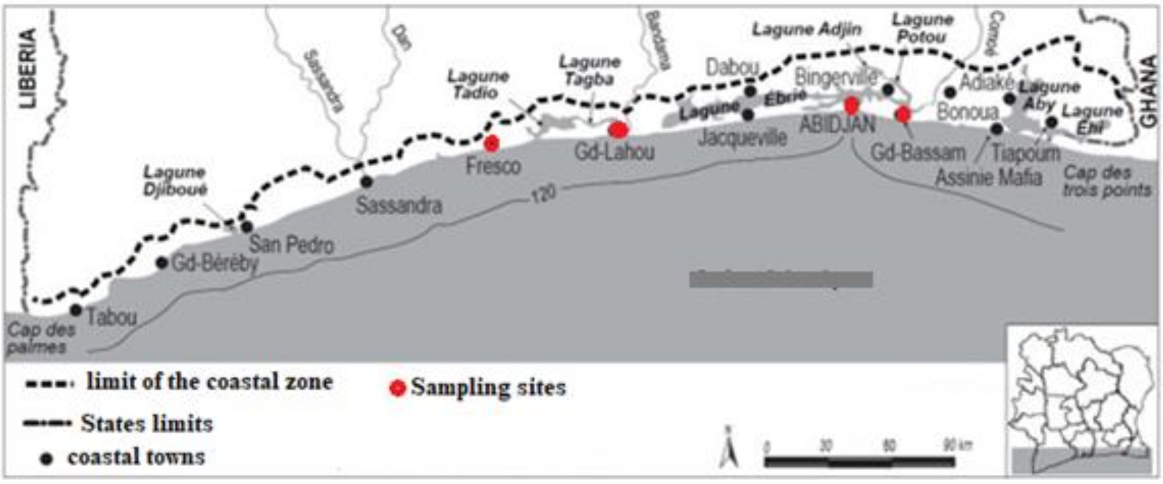


Fig. 1. Map showing the fish landing locations (●) (Anoh & Pottier, 2008) modified and adapted to the present work

2.3.1 Growth parameters

In a large number of fish, growth occurs according to the [10] and is described by the following equation: $L(t) = L_\infty *(1-(e^{(t-t_0)}))$.

The theoretical age (t_0) was calculated using the following equation:

$Log_{10}(-t_0) = -0.3922 - 0.275\ log_{10}\ L_\infty - 1.0381\ log_{10}\ K$ [11]

Then the longevity (T_{max}) of *Sardinella aurita* was determined as follows:

$T_{max} = 2.9957/K + t_0$ [12]

The growth performance index (ϕ') was determined with this equation: $(\phi') = 2\ Log_{10}\ L_\infty + Log_{10}$ [13].

2.3.2 Mortality rates

Several methods are used to evaluate total mortality from size distributions. The catch curve method is widely used and gives satisfaction [12]. Indeed, the history of catch curve technique in determining mortalities dates back to the late nineteenth century. The technique relies on assumptions that, recruitment and mortalities are constant over the years.

The natural mortality (M) was determined by the following equation:

$log_{10}\ M = -0.0066 - 0.279\ log_{10}\ L_\infty + 0.6541\ log_{10}\ K + 0.4634\ log_{10}\ T$ [12]

with T: the mean water temperature in (°C).

Fishing mortality (F) was estimated by the equation below

$F = Z - M$

2.3.3 Length at first capture (Lc50) and first sexual maturity (Lm50)

The determination of the size at first capture was made par the probability of capture curve and corresponds to the length Lc at which 50% of the individuals are retained by the fishing gear. The left ascending part of the length converted catch curve was used to estimate the probabilities of capture at 50, 75, and 25 which correlates with the cumulative probability at 50, 75 and 25 percent, respectively [14]. The age at first capture was then determine as:

$tc_{50} = -1/K * \ln(1 - Lc50/L_\infty) + t_0$ [15]

The length at first sexual maturity (lm50) was given by the following equation:

$Log_{10}\ Lm = 0.8979 * log_{10}\ L_\infty - 0.0782$ [16]

The age at first sexual maturity was estimated using the following equation:

$tm_{50} = -1/K * \ln(1 - Lm50/L_\infty) + t_0$ [17]

2.3.4 Recruitment pattern

Automatically, the recruitment pattern was decomposed and reconstructed through FiSAT II routine by the backward projection of the length frequency data. So, one or two pulses can be obtained [18]. The age at first recruitment (tr) was obtained using the following formula:

$$tr = -1/K * \ln(1-Lr/L\infty) + t_0$$ [15].

2.3.5 Stock assessment

The purpose of fish stock assessment is to provide estimates of the state of a given stock. The prediction of the relative yield and biomass per recruit of the species was made by analyzing the knife-edge selection incorporated into the FiSAT II program. In addition, the values of the Lc/ L∞ and M/K ratios were used as input data in the estimation of the reference points $E_{0.1}$, $E_{0.5}$ and E_{max}. These reference points were afterward used to assess the state stock of the studied species.

Yield isopleth contours which show the stock status were identified as the interception of the exploitation rate (E) and critical length ratio (Lc50/L∞). Yield isopleth was plotted to identify the impact of changes in exploitation ratio (E) on yield (critical length ratio (Lc)=Lc50/L∞.

A virtual Population Analysis (VPA) was used to determine the current and historical abundances and the fishing mortality rates by analyzing the catch of cohorts over time to generate an estimate of year-class over time [19]

3. RESULTS

3.1 Estimation of Growth Parameters

The ELEFAN routine allowed the estimation of growth parameters such as L∞ and K at 31.5 cm and 0.78 respectively. Fig. 2 shows the restructured Length frequency data superimposed with the estimated growth curve which revealed approximately four cohorts. The others growth parameters the theoretical age, (t_0), the lifespan (T_{max}) and the growth performance index (ϕ') wereestimated as -0.0259, 3.81 year and 2.81 respectively (Table 1). The Von Bertalanffy growth model equation was: Lt = 31.5{1– exp [-0.78(t+0.025)].

3.2 Estimation of Mortality Parameters (M, F, Z) and Exploitation Rate (E)

Fig. 3 shows estimates of mortality parameters and the exploitation rate of the species. Thus, (Z): the total mortality rate, estimated from the linearized length-converted catch curve was 2.10 $year^{-1}$. The natural (M) and fishing (F) mortalities were 1.49 $year^{-1}$ and 0.61 $year^{-1}$ respectively. The exploitation rate was estimated at 0.29.

3.3 Probability of Capture and Length at First Sexual Maturity (Lm50)

The estimation of the length at first capture L50%, 23.42 cm corresponding to age 1.03 years is shown in Fig. 4a and Table 2. Further, the length at first sexual maturity obtained was 18.49 cm corresponding to age 1.10 years (Table 2).

3.4 Recruitment Pattern

Recruitment in *S. aurita* within the Coastal waters of Côte d'Ivoire is represented by Fig. 4b. Indeed, recruitment runs all year round with two pulses in February and June. The length at first recruitment (Lr50) was 8cm with a corresponding age at first recruitment of 0.347 year (Table 2).

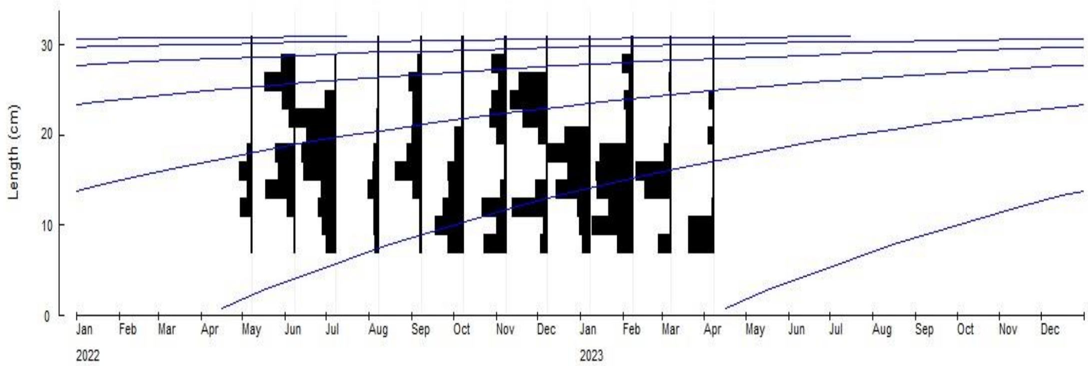


Fig. 2. Reconstructed length frequency distribution superimposed with the growth curve

Table 1. Growth parameters in *Sardinella aurita* within Côte d'Ivoire's coastal waters

Parameters	L∞ (cm)	K (year^{-1})	t_0 (year)	(ϕ')	T_{max} (year)
Values	31.5	0.78	-0.025	2.88	3.81

L∞: Asymptotic length, K: growth rate, t_0: theoretical age, (ϕ'): growth performance index, T_{max}: life-span or longevity

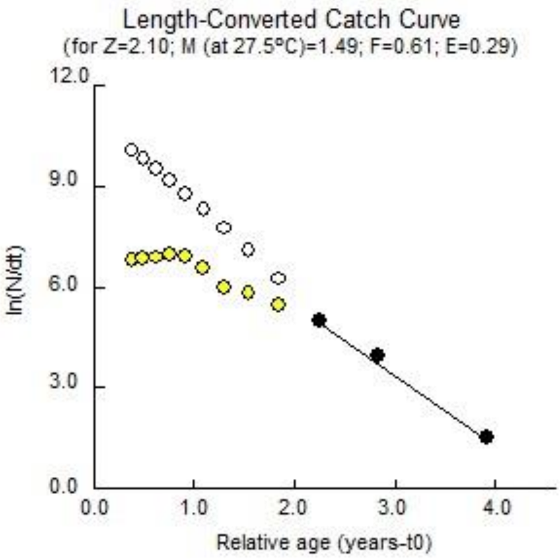
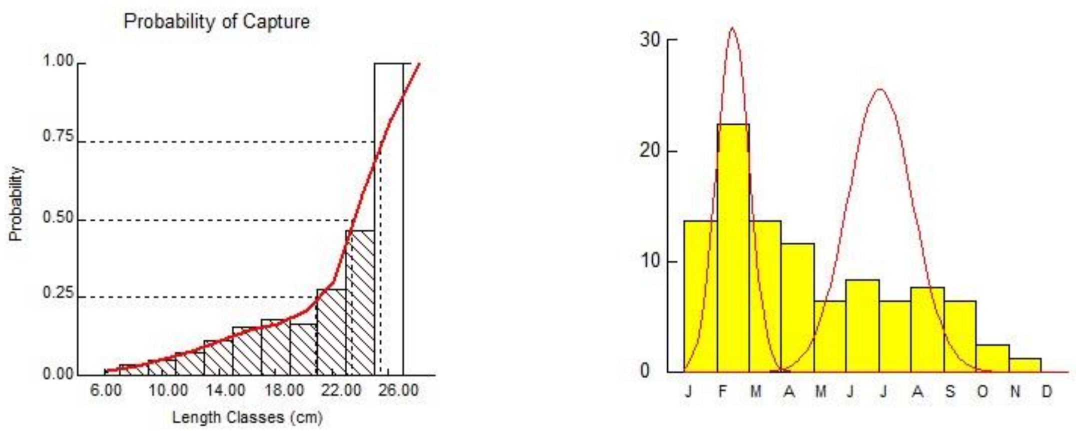


Fig. 3. Length-converted catch curve in *Sardinella aurita* within Côte d'Ivoire's waters from May 2022 to April 2023

Table 2. Length and Age at first capture sexual maturity and recruitment in *Sardinella aurita* within the coastal waters of Côte d'Ivoire

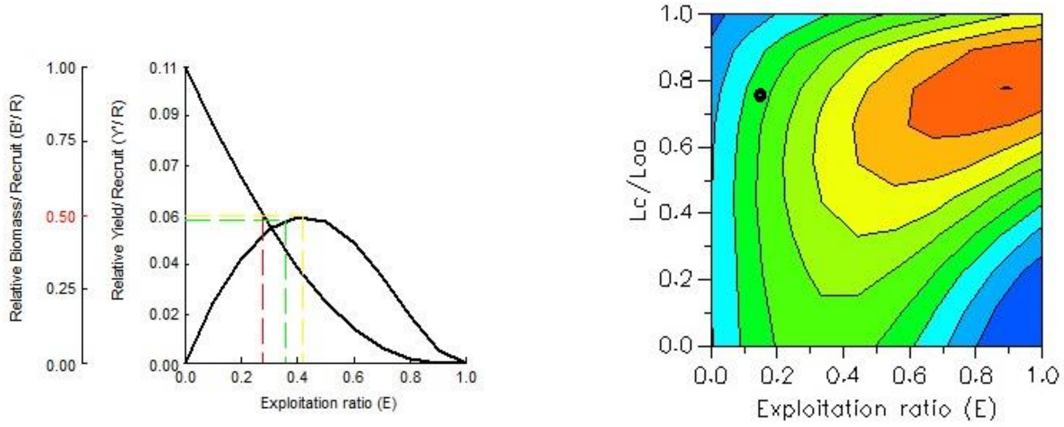
Parameters	Lc50	Lm50	Lr50	tc50	tm50	tr50
Values	23.42	18.49	8	1.78	1.10	0.347

Lc50 (cm): Length at first capture; Lm50 (cm): Length at first sexual maturity; Lr50 (cm): Length at first recruitment. tc50 tm50 and tr50 (year): age at first capture, age at first maturity and age at first recruitment respectively



4a **4b**

Fig. 4. Probability of capture (4a) and Recruitment pattern (4b) in *S. aurita* within Côte d'Ivoire's coastal waters from May 2022 to April 2023



5a 5b

Fig. 5. Beverton and Holt relative yield per recruit model (5 a) and Yield Isopleth diagram (5 b) in *S. aurita* within Coastal waters of Côte d'Ivoire

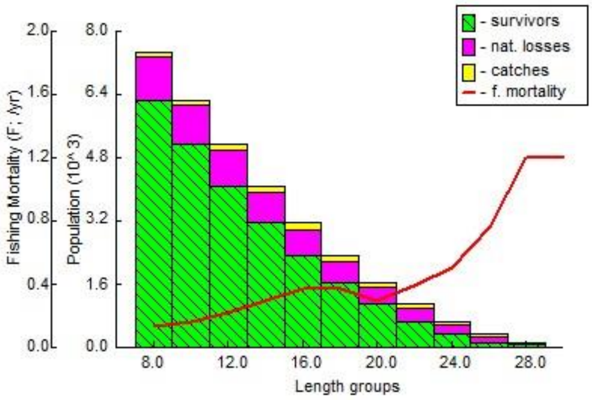


Fig. 6. Length-based virtual Population analysis in *Sardinella aurita* within Côte d'Ivoire's coastal waters from May 2022 to April 2023

3.5 Stock Prediction: Yield and Biomass Per Recruit (Y/R, B/R

Fig. 5 shows the Beverton and Holt relative yield per recruit model and indicates the indices which were 0.278 for optimum sustainable yield (E0.5), 0.421 for the maximum sustainable yield (Emax) and 0.355 for economic yield target (E0.1) (Fig. 5a). The yield isopleths placed the fishery in *S. aurita* within Côte d'Ivoire's coastal waters in quadrant A depending on the interception of ($Lc50/L\infty$ = 0.74) and E (0.29) (Fig. 5b).

3.6 Length Structured Virtual Population Analysis

Fig. 6 indicates the evolution of several parameters notably natural losses, survivors, catches and fishing mortality over time. The survivors and the natural losses decreased with an increase in length.

4. DISCUSSION

The present work gives values of growth parameters notably the length at infinity, the growth coefficient and the theoretical age different and especially higher than the values obtained by other studies [20]. The role of the growth rate K is central in determining the sustainable optimum body size for capture [21] and its measures the rate of approach to the asymptotic length. Thus, the growth coefficient (K) in fishery science is important because it characterizes a given fish stock. The growth coefficient (K) and other parameters vary significantly between different studies, likely due to differences in sampling methods and fishing gears. K, asymptotic length and the growth performance index can differ from stock to stock or from species to species. Indeed, the conditions of aquatic environment and especially the availability of adequate food can make it possible to obtain such results. *S. aurita* has a fast-growing and short life status within Côte d'Ivoire's coastal waters. *Sardinella aurita* has a fast growth rate and a short lifespan, which may make the population more vulnerable to overfishing and environmental changes. Generally, the growth rate is high in short-lived species. The length of fish is the best indicator of the fishing pressure, because Increased fishing pressure can reduce the average size of the fish, which in turn can affect the reproductive capacity and sustainability of the stock. The length at first capture (Lc_{50} = 23.50cm) was higher than the length at first sexual maturity (18.49 cm) indicating that *S. aurita* within Côte d'Ivoire's coastal waters reaches sexual maturity before being captured. This constitutes a best alternative for renewing the fish stock. According to [22], fish should reach sexual maturity before exploitation which allows them to procreate at least once before being captured. The size at first capture mentioned by [20] within Ghana's coastal waters was 5.99 cm, which was much lower than our result. This significant difference between the results could be due to two essential factors including the fishing pressure and the mesh sizes of the fishing gears used. The estimated age at first recruitment (tr50) shows that juveniles of *Sardinella aurita* enter into the stock shortly after birth, approximately three months suggesting the possibility of the presence of small size individuals in the catches. The study shows two peaks of recruitment as suggested by [23] for tropical fish species [24]. Regarding the intercept of the ratio ($Lc_{50}/L\infty$) and the exploitation rate (E), *S. aurita* falls into quadrant A corresponding to underexploited stock. According to [25], quadrant A represents underexploited fish with large fish caught at low fishing effort levels and the interception of $Lc/L\infty$ with (E) ratio from 0.5 to 1, and (E) from 0 to 0.5. All these indicators indicate that the species is underexploited, but a look at the value of the Beverton and Holt relative yield per recruit model gives a value of E0.5 (exploitation rate of reducing the stock to half of its virgin biomass), lower than the current exploitation rate implying that measures must be taken to contain the species exploitation for sustainable management of the resource. Such sustainable management measures should take into account fishing effort and the mesh size of fishing gears.

5. CONCLUSION

Regarding the results of the study *Sardinella aurita* is a fast-growing and short live species within Côte d'Ivoire's coastal waters. The recruitment pattern exhibit two peaks with a continuous phenomenon all year round. Despite being classified as underexploited, the current exploitation rate exceeds the sustainable rate (E0.5), which suggest that the stock is close to full exploitation and could reach the stage of overexploitation if not managed properly.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

We should like to sincerely thank all the people who directly or indirectly contributed to improving this work. We do not forget the fishing communities for the welcome they kindly gave us.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bianchi G, Carpenter KE, Roux JP, Molloy FJ, Boyer, Boyer HJ. FAO species identification guide for fishery purposes. Field guide to the living marine resources of Namibia. FAO, Rome; 1999.
2. Lett C, Ro, C, Levasseur AEA. Simulation and quantification of enrichment and retention processes in the southern benguela upwelling ecosystem. Fish Oceanogr. 2006;15 :363–372.
3. Brainerd TR. The sardinella fishery off the coast of West Africa: The case of a common property resource. Paper presented at the Second Annual Conference of the International Association for the Study of Common

Property (IASCP), September 26-29, 1991, University of Manitoba, Winnipeg, Canada; 1991.

4. Witehead F, Bianchi G, Scott WB. Scott FAO species identification sheets for fishery purposes. Eastern Central Atlantic; fishing areas 34, 47 (in part). Ottawa, Department of Fisheries and Oceans Canada, by arrangement with the Food and Agriculture Organization of the United Nations,1981; 46: I-7.
5. DAP. Directory of fishing and aquaculture statistics. Directorate of Fisheries Production. Statistics Department Report; 2023.
6. Coulibaly B, Tah L, Allico G, Sylla S, Koné T, Kouamelan EP. Fishing effort, catch per Unit Effort and fish production of purse Seines operating at the Boulay Island (Ossibissa, Côte d'Ivoire, west Africa). International Journal of Current Research. 2023 ;15(12):26749-26752.
7. Ecoutin JM. Chaînes de traitement des statistiques de pêche artisanale Annexes et codages. Arch. Scient. Centre Rech. Océanogr, Abidjan; 1979 (à paraître).
8. Schneider W. FAO Species Identification sheets for fishery purposes. Field guide to the commercial marine resources of the Gulf of Guinea. Prepared and published with the support of the FAO Regional Office for Africa. Rome, FAO. 1990; 268.
9. Gayanilo FC, Sparre P, Pauly D. FAO ICLARM stock assessment tool (FiSAT II). user's guide FAO computerized information series (Fisheries), FAO, Rome. 2003; 266.
10. Von Bertalanffy L. A quantitative theory of organic growth. Human Biology, Baltimore. 1938; 10:181- 213.
11. Pauly D. Munro JL. Once more on the comparison of growth in fish and invertebrates. ICLARM Fishbyte. 1984; 2(1):1–21.
12. Pauly D. Some simple methods for assessment of tropical fish stocks. 234 52; FAO Fisheries Technical Paper. 1983;33.
13. Munro JL, Pauly D. A simple method for comparing growth of fishes and invertebrates. ICLARM Fish byte. 1983; 1:5-6.
14. Pauly D. Fish population dynamics in tropical waters: A manual for use with programmable calculators. International Center for Living Aquatic Resources Management, Studies and Reviews, 8, Manila. 1984;325;28.
15. Beverton RJH, Holt JS. On the dynamics of exploited fish populations. Fish Invest London Ser. 1957; 2:533.
16. Froese R, Binohlan C. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fisheries and Biology. 2000; 56:758-773.
17. Goonetilleke H, Sivasubramaniam K. Separating mixtures of normal distribution: Basic programs for rates, Bhattacharya`s method and their application for fish population analysis. Colombo Sri Lanka, FAO UNDP. 1987;59.
18. Bougis P. Océanographie biologique appliquée. Exploitation de la vie marine. Edition Masson, Paris. 1976; 320.
19. Jennings S, Kaiser MJ, Reynolds JD. Marine fisheries ecology. Blackwell, Oxford. 2001;417.
20. Amponsah SKK, Ofori-Danson PK, Nunoo FKE, Ameyaw AGA. Population dynamics of *Sardinella aurita* (Valencienne, 1847) within Ghana's coastal waters. Agricultural, Livestock and Fisheries. 2016d;4(3):237-248.
21. Froese R, Winker H, Gascuel D, Sumaila UR, Pauly D. Minimizing the impact of fishing. Fish and Fisheries. 2016;17(3): 785–802.
    Available:https://doi.org/10.1111/faf.12146
22. Snedecor GW, Cochran WG. Statistical methods. USA:The Iowa State University Press. 1980; 232-237.
23. Pauly D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES Journal of Marine Science. 1980;39(2): 175–192.
24. Pauly D, Soriano ML. Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In: Maclean JL, Dizon LB, Hosillos LV. (Eds.) The First Asian Fisheries Forum, Asian Fisheries Society, Manila, Philippines. 1986;491-496.

25. Madkour FF. Feeding ecology of the round sardinella, *Sardinella aurita* (Family: Clupeidae) in the Egyptian Mediterranean waters. International Journal of Environmental Science and Engineering (IJESE). 2011; 2:83-92.

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.ikprress.org/review-history/12302