Journal of Bioscience and Environment Research 2 (3): 3-7

Content available at Genesis Publishing Consortium Limited

Journal of Bioscience and Environment Research

Journal homepage: www.genesispcl.com/journals/jber

Original Research

Population parameters and the stock status in *Sardinella maderensis* (Lowe, 1838) in the coastal waters of Côte d'Ivoire (West Africa)

Coulibaly Bakari[1*], Joanny Tapé Gnahoré Toussaint[1], Sylla Soumaïla[1], Koné Tidiani[2], Kouamelan Essetchi Paul[3]

[1] *Centre de Recherches Océanologiques, 29 rue des pêcheurs- BPV 18 Abidjan, Côte d'Ivoire*
[2] *UFR Environnement, Université Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire*
[3] *Laboratoire des Milieux Naturels et de Conservation de la Biodiversité, UFR Biosciences, Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire*

Article info

Article history
Received: 22 March 2025
Revised: 12 April 2025
Accepted: 25 April 2025
Published: 16 June 2025

Keywords
Sardinella maderensis
Growth
Mortality
Exploitation rate
VPA analysis

Abstract

In West Africa, many fisheries are fully exploited or overexploited. The primary challenge in addressing this issue is often the lack of data to inform management policies. Since 2011, the production of *Sardinella maderensis* has been declining, and data on the species' population dynamics are scarce. This study aims to examine the population dynamics of *S. maderensis* and provide preliminary data on the state of its stock within the coastal waters of Côte d'Ivoire. Such data are essential for the sustainable management of these fisheries. To achieve this objective, a total of 2,112 samples of *S. maderensis* were collected from April 2022 to March 2023. These samples were measured for total lengths and analyzed using FiSAT II software. The length frequency distribution ranged from 12 to 41 cm, with an average of 23.03 ± 19.09 cm. The asymptotic length (L∞) was 31.50 cm, the growth rate (K) was 0.68 year^{-1}, the growth performance index (Φ') was 2.82, and the theoretical age (t0) was -0.105 year, indicating that this species is fast-growing. *S. maderensis* in the coastal waters of Côte d'Ivoire reaches sexual maturity before being caught by fishing gear, suggesting that the catches predominantly consist of mature individuals. The exploitation rate (E) was recorded at 0.47, slightly higher than the E max value. The study concludes that *S. maderensis* is overexploited in the coastal waters of Côte d'Ivoire. These findings should inform the adoption of appropriate measures for the sustainable management of this species, particularly by reducing fishing effort through regulating this fishery.

© 2025 Bakari et al. This is an open access article distributed under the **Creative Commons Attribution 4.0 International License** (www.creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Fish accounts for about 17% of global animal protein consumption (Benett *et al.*, 2018). In addition to this benefit, fishery products serve as a primary source of animal protein and provide many direct and indirect jobs worldwide. Efforts must be combined to ensure the sustainability of both the resource and the activity. Furthermore, in countries and regions where fishing may not be the primary source of employment, fishery products can help alleviate poverty in low-income households (Melnychuk *et al.*, 2020). The balance between fish production capacity and the fishing effort applied to it is crucial for sustainable fisheries management. When fishing effort becomes excessive, the pressure on fish stocks increases, leading to a reduction in their abundance. The status of fish stocks, as indicated by their abundance and fishing pressure relative to management targets, is primarily estimated using two broad categories of methods (Melnychuk *et al.*, 2020). First, stock status can be scientifically assessed by applying mathematical models to data collected from the fishery. Second, the status of stocks is often determined by qualitative expert opinion, drawing on the knowledge of those familiar with the fishery regarding trends in catch, fishing effort, and potentially the size of the fish.

Small pelagic fish play a crucial role in marine ecosystems due to their intermediate position in food webs and significant biomass (Jehid, 2016). Global production of small pelagic fish is approximately 39 million tons, accounting for more than one-third of the total catch, making these fish the most widely fished in the world (FAO, 2002). The situation in West Africa, particularly in Côte d'Ivoire, mirrors this global trend. In Côte d'Ivoire, small pelagic fish, notably *Sardinella aurita* and *S. maderensis*, serve as the primary coastal fishing resource (Weigel, 1999). The flat sardinella can be distinguished by a black spot located behind the operculum, while in *S. aurita*, the black spot is found on the operculum itself (Jehid, 2016). *S. maderensis* is characterized by a somewhat sedentary lifestyle and can be found in both superhaline and desalinated environments. This adaptability allows it to be fished by both marine fisheries and those in lagoons and estuaries, making it a relatively accessible and popular species. The International Union for Conservation of Nature (IUCN) lists this species on its red list of overexploited and threatened species (Tous, 2015). Due to its accessibility, *S. maderensis* has experienced significant exploitation over the past decade in Côte d'Ivoire, with landings of the species declining from 7,031 to 3,984 tons (DP, 2020).

Sustainable and effective fisheries management relies on fundamental tools, including stock assessments. However, in most cases, many fish stocks in commercial catches have not yet been assessed. This lack of assessment raises significant issues regarding the availability of crucial data, particularly biological reference points (Hilborn and Branch, 2013). Any exploitation of fish resources must be coupled with knowledge of the population dynamics of the stock. Additionally, population dynamics drive changes in the abundance or biomass of a stock over time, contributing to a better understanding

***Corresponding authors**
Email address: coulibaly.bakari@cro.edu.ci (Coulibaly Bakari)

doi: https://doi.org/10.69517/jber.2025.02.03.0002

ISSN: 3079-5346

of the stock and the processes that influence its current state and future evolution. Data on the population dynamics of a stock are vital for its management. Research on the status of the *S. maderensis* stock has been conducted in neighboring countries, including Liberia and Ghana (Ampossah *et al.*, 2019; Wehya *et al.*, 2017). However, in Côte d'Ivoire, data on the stock status of this species are very limited, which is necessary for the sustainable management of the resource. The present study aims to address this gap by providing data on the population dynamics of the species, particularly the stock's exploitation level, to assist managers in making informed decisions for sustainable resource management.

2. Materials and methods

2.1 Ethical approval statement

No ethical approval was required for this study.

2.2 Study area

Four landing stations were selected based on their accessibility and the intensity of fishing activities: Azuretti (Grand-Bassam) at 5°12'23.68"N, 3°47'57.89"W; Ossibissa (Abidjan) at 5°16'44.90"N, 4°03'14.58"W; Lahou Kpanda (Grand-Lahou) at 5°08'11.47"N, 5°01'33.77"W; and Fresco at 5°05'53.85"N, 5°34'46.38"W (Figure 1).

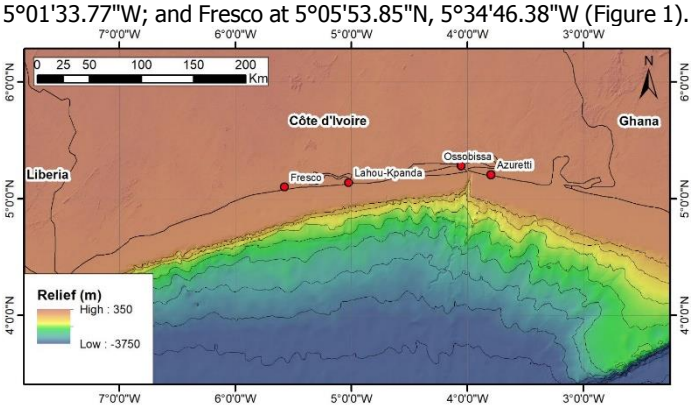

Figure 1. Map showing the sampling stations (●).

2.3 Data collection

Fish samples were collected monthly from landing sites using beach seines, purse seines, and gill nets during the sampling period from April 2022 to March 2023. Length frequency data were gathered for approximately 2,112 specimens of *S. maderensis*, and individuals were identified to the species level (Schneider, 1999). Each individual was measured for total length (TL) to the nearest millimeter using a measurement board, and their weight was recorded with an electronic scale.

2.4 Analytical methods

2.4.1 Growth parameters

The Von Bertalanffy Growth Function (VBGF) which best describes the fish growth as: $Lt = L\infty (1-e^{-k(t-t0)})$ (Pauly, 1979). The theoretical age at zero length (t0) was determined following this equation: $\log_{10}(-t_0) = -0.3922 - 0.275 \times \log_{10}L_\infty - 1.038 \times \log_{10}K$ (Pauly, 1979). The Longevity (T_{max}) was estimated (Pauly, 1983). The estimated values of L∞ and K were used to calculate growth performance Phi-prime (Φ') value (Pauly and Munro, 1984).

2.4.2 Mortality parameters

The length-converted catch curve method implemented in Fisat II software was used to estimate the instantaneous rate of total mortality. The instantaneous rate of natural mortality (M) was estimated using length-growth data from empirical equations, with a mean water temperature of 27.5 °C (Pauly, 1980). The instantaneous rate of fishing mortality (F) was estimated using the relationship F = Z - M, where Z and M are defined as above. To assess the state of the stock based on mortality rates, the exploitation ratio (E) was calculated using the formula E = F / (F + M). This provides a rough estimate of whether the stock is overfished (E > 0.5) or not (E < 0.5) (Pauly, 1983). The optimal value of E is approximately 0.5, assuming that sustainable yield is maximized when F is roughly equal to M (Gulland, 1971).

2.4.3 Length and age at first capture

The lengths at first capture, Lc_{50}, Lc_{25}, and Lc_{75}, for *S. maderensis* were derived from the length-converted catch curve. The probability of capture was determined using a graph of cumulative probability plotted against mid-length. Consequently, Lc_{50} corresponds to the cumulative probability at 50%, while Lc_{25} and Lc_{75} are linked to cumulative probabilities at 25% and 75%, respectively. The estimation of age at first capture (tc50) was conducted following the method of Beverton and Holt (1957).

2.4.4 Length and age at first sexual maturity

Both the length at first maturity (Lm_{50}) and the age at first maturity (tm_{50}) were determined (Hoggarth *et al.*, 2006; Goonetileke and Sivasubramania 1987).

2.4.5 Recruitment pattern

Recruitment pulse was reconstructed using a time series of length-frequency distribution to identify the annual pulses and the relative strength of each pulse (Amin *et al.*, 2009). The length at first recruitment (Lr) was defined as the midpoint of the smallest length class (Gheshlaghi *et al.*, 2012), and the age at first recruitment (tr50) was determined (Beverton and Holt, 1957).

2.4.6 Relative yield per recruit (Y/R) and relative biomass per recruit (B/R)

Relative yield per recruit (Y/R) and relative biomass per recruit (B/R) were calculated as functions of exploitation. Additionally, the exploitation rate at maximum (E_{max}), which corresponds to the exploitation value correlating with maximum yield production ($E_{0.1}$), was determined for a marginal increase of Y'/R at 10% of its virgin stock. Furthermore, $E_{0.5}$, the exploitation rate at which the stock is reduced to 50% of its unexploited biomass, was computed using the procedure that incorporates the knife-edge option fitted in the Fisat II tool.

2.5 Statistical analysis

The length frequency data were pooled into groups with 2 cm length intervals, and the estimation of population parameters was conducted using the FAO-ICLRAM Stock Assessment Tool (FISAT) (Gayanilo *et al.*, 1996; Pauly, 1987).

3. Results

3.1 Length frequency distribution and growth parameters

The length frequency distribution of *S. maderensis* shows a minimum length of 12 cm, a maximum observed size of 41 cm, and an average length of 23.03 ± 19.09 cm during the study period (Figure 2). Figure 3 presents the restructured length frequency data superimposed with the estimated growth curve. Growth parameters, including asymptotic length (L_∞), growth coefficient (K), theoretical age (t_0), T_{max}, and Phi-prime, were estimated (Table 1). The linear growth length equation of von Bertalanffy was established as: $Lt = 31.50\ (1-e^{-0.68(t+0.105)})$.

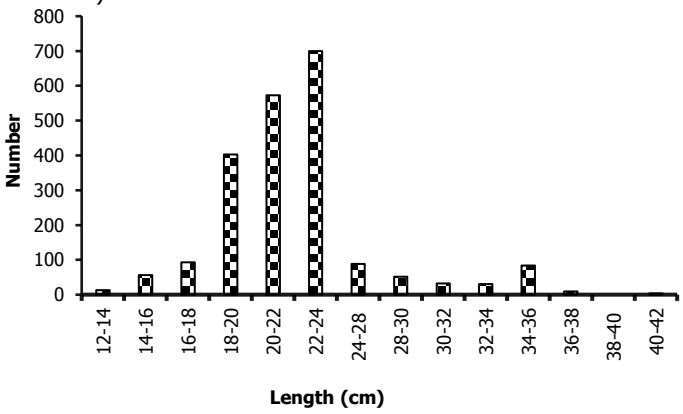

Figure 2. Length frequency distribution in *Sardinella maderensis* in the coastal waters of Côte d'Ivoire from April 2022 to March 2023.

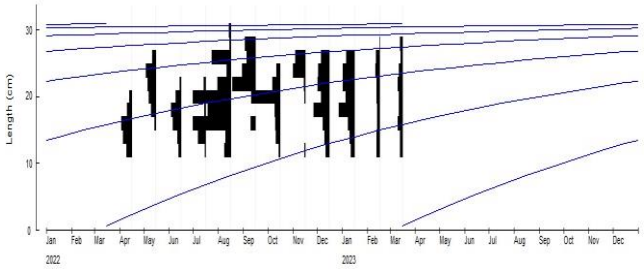

Figure 3. Reconstructed length frequency distribution superimposed with growth curve.

Table 1. Growth parameters in *Sardinella maderensis* of the coastal waters of Côte d'Ivoire from April 2022 to March 2023.

Parameters	L_∞ (cm)	K (year^{-1})	Φ'	t_0 (year)	T_{max} (year)
Values	31.50	0.68	2.82	-0.10	4.31

L_∞= Asymptotic length; K= growth rate; t_0= theoretical age; (Ø') = growth performance index; T_{max}= life-span or longevity.

3.2 Instantaneous mortality coefficients (Z, M and F) and current exploitation rate (E)

Total mortality (Z), natural (M) and Fishing (F) mortalities were estimated at 2.56, 1.30 and 1.20 year $^{-1}$ respectively (Figure 4). The current exploitation rate of the species was 0.47.

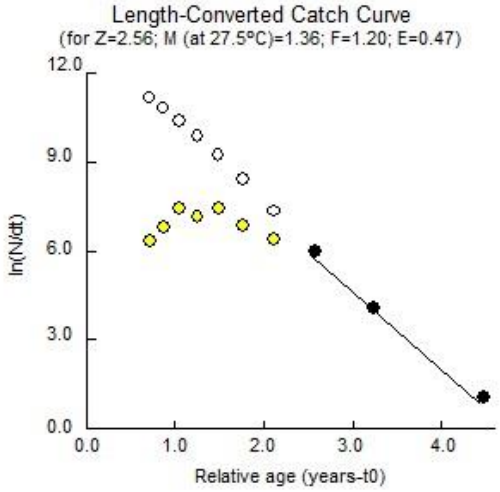

Figure 4. Length-converted catch curve in *Sardinella maderensis* of the coastal waters of Côte d'Ivoire during from April 2022 to March 2023.

3.3 Probability of capture and age at first capture

The Lc_{50} was estimated to be 23.75 cm, while the Lc_{25} and Lc_{75} were 21.88 cm and 25.65 cm, respectively. The age at first capture was estimated to be 1.95 years (Figure 5; Table 2).

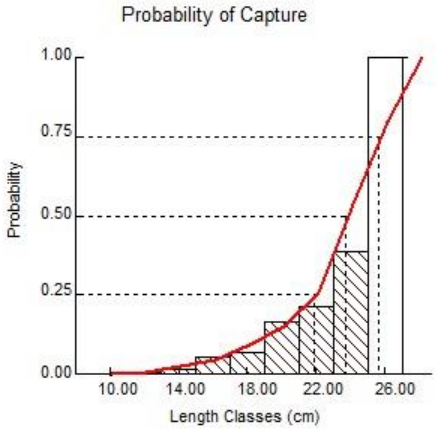

Figure 5. Probability of capture in *Sardinella maderensis* in the coastal waters of Côte d'Ivoire during from April 2022 to March 2023.

3.4 Length and age at first sexual maturity

The length and the age at first sexual maturity were 21 cm and 1.478 year respectively (Table 2).

3.5 Recruitment trend

Recruitment in *S. maderensis* in the coastal waters of Côte d'Ivoire is illustrated in Figure 6. This phenomenon occurs throughout the year, with two major peaks in June and October. The length at first recruitment (Lr_{50}) is 12 cm, corresponding to an approximate age at first recruitment of 0.59 years, or about six months (Table 2).

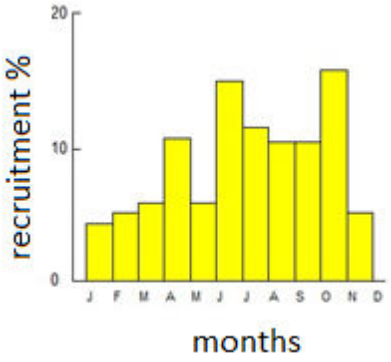

Figure 6. Recruitment pattern in *S. maderensis* of the coastal waters of Côte d'Ivoire during from April 2022 to March 2023.

Table 2. Length and age at first capture, first sexual maturity and first recruitment in *Sardinella maderensis* of the coastal waters of Côte d'Ivoire.

Parameters	Lc_{50}	tc_{50}	Lm_{50}	tm_{50}	Lr_{50}	tr_{50}
Values	23.75	1.95	21.00	1.47	12.00	0.59

t_{c50} (year) = age at first capture; L_{m50} (cm) = length at first sexual maturity; t_{m50} (year) =age at first sexual maturity; Lr_{50} (cm) = length at first recruitment; index, tr_{50} (year) = age at first recruitment.

3.6 Stock status

The current exploitation rate of *S. maderensis* is estimated at E = 0.47, which is lower than the threshold value of 0.5 but higher than the maximum exploitation rate (E_{max}=0.42). Additionally, this exploitation rate exceeds both the marginal exploitation rate ($E_{0.1}$) and the economic exploitation rate ($E_{0.5}$) (Figure 7). Furthermore, natural losses and the survivability of the fish population decrease with increasing length and fishing mortality (Figure 8).

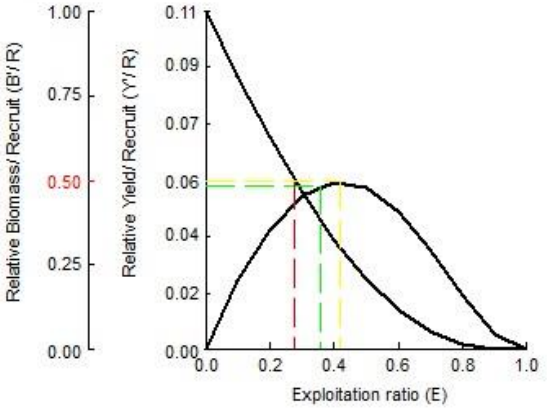

Figure 7. Relative yield (Y'/R) and relative biomass (B'/R) per recruit in *Sardinella maderensis* from April 2022 to March 2023.

4. Discussion

Size-related aspects, notably the maximum size observed in catches and the asymptotic length in this study, differed from previous studies conducted in the coastal waters of Côte d'Ivoire. These differences

can likely be attributed to the fishing location, sampling methods, and, most importantly, the fishing gear used. The significance of the sampling method cannot be overstated, as it can result in catches that are not representative of the exploited population. The fish size range observed in a study is influenced by the sampling methods employed (Van Den Avyle *et al.*, 1995). This variation is primarily due to the diversity of fishing gear used in the current study. Population estimates based on single-gear catches may lead to biased estimates of length–frequency or abundance in certain species (Clavero *et al.*, 2006).

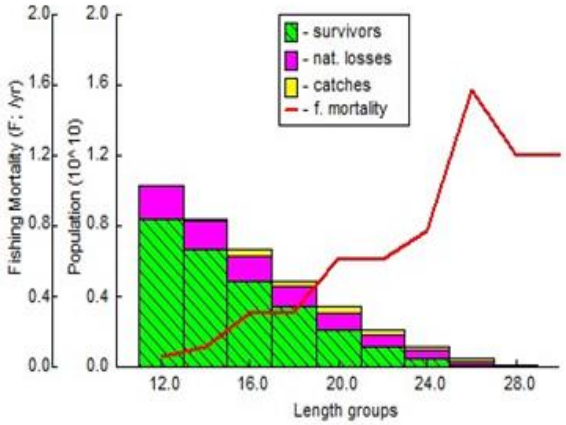

Figure 8. FISAT II output for length-structured virtual population analysis in *S. maderensis* from April 2022 to March 2023.

The asymptotic length recorded in this study was higher than the values reported for the species in Ghana and Nigeria (Amponsah *et al.*, 2019; Olopade *et al.*, 2019). However, it was lower than the value documented in Liberia (Wehye *et al.*, 2017). The maximum observed length in catches was approximately similar in both Côte d'Ivoire and Liberia. The growth performance index phi-prime was comparable to the value recorded in Liberia but higher than those noted in Ghana and Nigeria, respectively (Amponsah *et al.*, 2019; Olopade *et al.*, 2019). The growth rate K identified in this study was higher than those reported in Liberia, Ghana, and Nigeria (Amponsah *et al.*, 2019; Olopade *et al.*, 2019; Wehye *et al.*, 2017). The K value obtained indicates that *S. maderensis* in Côte d'Ivoire's coastal waters is a fast-growing species. Generally, slow growth in fish species is linked to inadequate environmental conditions, characterized by high density and limited resources (Allen and Hightower, 2010).

The length at first capture observed in this study was higher than the values reported in Liberia and Ghana (Amponsah *et al.*, 2019; Wehye et *al.*, 2017). The differences in the length at first capture could be attributed to the variety of fishing gears used, variability in authorized mesh sizes, and particularly the fishing zones. If fishing occurs in a nursery area, the catches will predominantly consist of juveniles, which may not be the case when fishing takes place far from such nurseries.

Table 3. Estimated growth parameters of *Sardinella maderensis* of Côte d'Ivoire's waters compared to those of other countries.

Country	References	TL∞ (cm)	K(year^{-1})	Φ'
Côte d'Ivoire	Current study	31.5	0.68	2.82
Libéria	Wehye *et al.* (2017)	44.63	0.38	2.88
Ghana	Amponsah *et al.* (2019)	23.63	0.61	2.53
Nigeria	Olopade *et al.* (2019)	23.31	0.54	2.46
Cameroon	Gabche and Hockey (1995)	27.24	0.48	1.76

S. maderensis reaches sexual maturity at an age of 5 months and a length at first capture one month earlier, both occurring before the second year of their life. The calculated length at first sexual maturity is lower than the length at first capture, indicating that the fish mature before being caught by fishing gear. This information is essential for stock renewal, as *S. maderensis* in Côte d'Ivoire's coastal waters has the opportunity to procreate before capture. Fish should have an Lc_{50} value greater than the length at first sexual maturity (Lm_{50}) (Snedecor and Cochran, 1980). This allows fish to contribute to the sustainability of the species through procreation. The study shows year-round recruitment trends with two peak periods, which aligns with the double recruitment patterns exhibited by most tropical species (Pauly *et al.*, 1982). The current exploitation rate is higher than the E_{max} value, indicating that the species is overexploited. Such results necessitate urgent management measures to maintain the sustainability of the fishery.

5. Conclusions

The length of the species ranged from 12 to 41 cm. *Sardinella maderensis* in Côte d'Ivoire's coastal waters is a fast-growing, long-lived species with year-round recruitment. Individuals of this species have the opportunity to reproduce before being captured by fishing gear, based on the sizes at first capture and first sexual maturity. Biological reference points E, E_{max}, $E_{0.1}$, and $E_{0.5}$ indicate a level of exploitation that requires special attention from fisheries managers.

Acknowledgements

We would like to sincerely thank everyone who directly or indirectly contributed to improving the quality of this work. We do not forget the fishing communities for the welcome they kindly gave us during the sampling period.

Source of funding

This research was conducted without any financial support from governmental, non-governmental, or private funding agencies. The study was entirely self-funded by the authors, and no specific grants were received for this research, authorship, or publication.

Data availability

Data will be available upon request from the corresponding author.

Informed consent statement

No informed consent was required to conduct the study.

Conflict of interest

The authors declare no conflict of interest.

Authors' contribution

Conceptualization, methodology, data curation, formal analysis, writing original draft: Coulibaly Bakari; **Data collection:** Coulibaly Bakari; **Data analysis:** Coulibaly Bakari and Sylla Soumaïla; **Figure preparation and supervision:** Kouamelan Essetchi Paul, Koné Tidiani and Joanny Tapé T.G. All authors critically reviewed the manuscript and agreed to submit final version of the manuscript.

References

Allen MS and Hightower JE, 2010. Fish population dynamics: mortality, growth, and recruitment. In: Hubert WA and Quist MC (Eds.), Inland Fisheries Management in North America (pp. 43–79). American Fisheries Society.

Amin SMN, Arshad A, Siraj SS and Japar-Sidik B, 2009. Population structure, growth, mortality and yield per recruit of sergestid shrimp, *Acetes japonicus* (Decapoda: Sergestidae) from the coastal waters of Malacca, Peninsular Malaysia. Indian Journal of Geo-Marine Sciences, 38: 57-68.

Amponsah Samuel KK, Patrick K Ofori-Danson, Francis KEN and Ameyaw GA, 2019. Estimates of Population parameters for *Sardinella maderensis* (Lowe, 1838) in the coastal waters of

Ghana. Greener Journal of Agricultural Sciences, 9: 23-31. http://doi.org/10.15580/GJAS.2019.1.011719017

Bennett A, Patil P, Kleisner K, Doug R, Virdin J and Basurto X, 2018. Contribution of fisheries to food security: Current knowledge, policy and research. NI Report 18-02, Duke University, Durham, NC, USA.

Beverton RJH and Holt SJ, 1957. On the dynamics of exploited fish populations. Beverton RJH and Holt SJ (Eds.). Springer Dordrecht. pp. 538. https://doi.org/10.1007/978-94-011-2106-4

Clavero M, Blanco-Garrido F and Prenda J, 2006. Monitoring small fish populations in streams: a comparison of four passive methods. Fisheries Research, 78: 243–251. http://doi.org/10.1016/j.fishres.2005.11.016

DP, 2020. Directory of fishing statistics. Directorate of Fisheries Production. Statistics Department Report Côte d'Ivoire. pp. 10.

FAO, 2002. World agriculture towards 2015/2030. Summary Report. Food and Agriculture Organization of the United Nations (FAO), pp. 97.

Gabche CE and Hockey HUP, 1995. Growth, mortality and reproduction of *Sardinella maderensis* (Lowe, 1841) in the artisanal fisheries off Kribi, Cameroon. Fisheries Research, 24(4): 331-344. https://doi.org/10.1016/0165-7836(95)00371-7

Gayanilo FCJ, Sparre P and Pauly D, 1996. FAO-ICLARM stock assessment tools (FiSAT) user's guide. FAO computerized information series fisheries, 8: 12.

Gheshlaghi P, Vahabnezhad A and Motlagh SAT, 2012. Growth parameters, mortality rates, yield per recruit, biomass, and MSY of *Rutilus frisii* kutum, using length frequency analysis in the Southern parts of the Caspian Sea. Iranian Journal of Fisheries Sciences, 11: 48-62.

Goonetilleke H and Sivasubramaniam K, 1987. Separating mixtures of normal distribution: basic programs for rates, Bhattacharya`s method and their application for fish population analysis. Colombo Sri Lanka, FAO UNDP. pp. 59.

Gulland JA, 1971. The fish resources of the Ocean West Polyfleet. Gulland JA (Eds.). Survey Fishing News (Books) Ltd. FAO Technical Paper No. 97. pp. 428.

Hilborn R and Walters CJ, 1991. Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Hilborn R and Walters CJ (Eds.). Springer New York, pp. 570. https://doi.org/10.1007/978-1-4615-3598-0

Hoggarth DD, Abeyasekera S, Arthur RI, Beddington JR and Burn, 2006. Stock Assessment for fishery management-A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP). Fisheries Technical FAO, Rome, pp. 261.

Jehid MAA, 2016. Thèse de doctorat, Ecole doctorale 438 Sciences de la matière, du rayonnement et de l'environnement. Université du Littoral Côte d'Opale, France. pp. 202.

Melnychuk MC, Baker N, Hively D, Mistry K, Pons M, Ashbrook CE, Minto C, Hilborn R and Ye Y, 2020. Global trends in status and management of assessed stocks: achieving sustainable fisheries through effective management. FAO Fisheries and Aquaculture Technical Paper No. 665. FAO, Rome. https://doi.org/10.4060/cb1800en

Olopade OA, Dienye HE and Bamidele NA, 2019. Some Population Parameters of the *Sardinella maderensis* (Lowe, 1838) in the Sombreiro River of Niger Delta, Nigeria. Acta Aquatica Turcica, 15(3): 354-364. https://doi.org/10.22392/actaquatr.53228

Pauly D and Munro JL, 1984. Once more on the comparison of growth in fish and invertebrates. ICLARM Fishbyte, 2: 1–21.

Pauly D, 1979. Gill Size and temperature as governing factors in fish growth: A generalization of von Bertalanffy's growth formula. Berichte Institut Für Meereskunde. pp. 156.

Pauly D, 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. Journal du Conseil, 39(2): 175-192. https://doi.org/10.1093/icesjms/39.2.175

Pauly D, 1983. Length-converted catch curves. A powerful tool for fisheries research in the tropics. Part 1. ICLARM Fishbyte, 1(2): 9-13.

Pauly D, 1987. A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrate. In: Pauly D and Morgan GR (Eds.), Length-Based Models in Fisheries Research. ICLARM Conference Proceedings. Manila, Philippines, and Kuwait Institute for Scientific Research, Safat, Kuwait. pp. 7-34.

Pauly D, David N and Ingles J, 1982. ELEFAN II: User's instruction and program listings. ICLARM, Manila. Mimeo, pag.var.

Schneider W, 1990. 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. pp. 268.

Snedecor GW and Cochran WG, 1980. Statistical Methods. Snedecor GW and Cochran WG (Eds.). The Iowa State University Press. pp. 477.

Tous P, Sidibé A, Mbaye E, de Morais L, Camara K, Munroe T, Adeofe TA, Camara YH, Djiman R, Sagna A and Sylla M, 2015. *Sardinella maderensis* (Lowe, 1838). The IUCN Red List of Threatened Species 2015. https://doi.org/10.2305/IUCN.UK.2015-4.RLTS.T198582A15543624.en

Van Den Avyle MJ, Boxrucker J, Michaletz P, Vondracek B and Ploskey GR, 1995. Comparison of catch rate, length distribution, and precision of six gears used to sample reservoir shad populations. North American Journal of Fisheries Management, 15: 940–955. https://doi.org/10.1577/1548-8675(1995)015<0940:COCRLD>2.3.CO;2

Von Bertalanffy L, 1938. A quantitative theory of organic growth (inquiries on growth laws II). Human Biology, 10: 181-213

Wehye A, 2017. Growth, Mortality and Exploitation of *Sardinella maderensis* (Lowe, 1838) in the Liberian coastal waters. Fisheries and Aquaculture Journal, 8: 189.

Weigel JY, 1999. Dynamiques d'exploitation et de valorisation des petits pélagiques marins en Afrique de l'Ouest. FAO Document technique sur les pêches. FAO, Rome. pp. 59.

GENESIS PUBLISHING CONSORTIUM LIMITED

Publisher's note

Genesis Publishing Consortium Limited pledges to maintain a neutral stance on jurisdictional claims shown in published maps and institutional affiliations.