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Growth, Mortality and Stock Status of the Atlantic bumper *Chloroscombrus chrysurus*, Linnaeus 1766, from the Coastal Waters of Côte d'Ivoire

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ABSTRACT

The present study aimed to assess the stock of *Chloroscombrus chrysurus* in the Ivorian coastal waters to support its sustainable management. Approximately 2,520 specimens were collected between July 2022 and June 2023. The fish were captured using beach seines and gillnets, then measured and weighed to the nearest millimeter and gram, respectively. Stock assessment was conducted using the Fisat software, which analyzed pooled length-frequency data. The estimated growth parameters for *Chloroscombrus chrysurus* were as follows: asymptotic length (L_∞) of 22.05cm, growth rate (K) of 0.82 year^{-1}, growth performance index (ϕ') of 2.59, theoretical age (t_0) of -0.084 years, and life-span (T_{max}) of 3.57 years. Instantaneous fishing mortality (F) was estimated at 0.81 year^{-1}, while natural mortality (M) was 1.70 year^{-1}. The exploitation rate (E) was 0.32. The length at first capture (L_{o50}) was 13.32cm, which is slightly lower than the length at first sexual maturity (13.42cm).The findings indicate that the *Chloroscombrus chrysurus* population in Côte d'Ivoire's coastal waters is at moderate risk of overexploitation. To mitigate this risk, it is crucial to monitor the fishery and to implement immediate measures, such as increasing the mesh size of the nets and the cod-end or bag of beach seines.

INTRODUCTION

Carangidae family adult individuals are generally solitary and near the bottom to depths of at least 50 young usually pelagic and drifting. The family distribution extends from Morocco to southern Angola **(Carpenter & De-Angelis, 2016)**. Fishery resource represents a significant proportion among natural animal resource worldwide. Fish is a vital source of food for people, and it is estimated that about one billion people world-wide rely on fish as their primary source of animal protein **(FAO, 2014)**. In addition, fish consumption per capita per year estimated at 16kg **(Faillere*t al*., 2014)** in Côte d'Ivoire, increased to reach approximately 24.9kg. People interest in fish could be due to its contribution to food hygiene and its accessibility in terms of coast and quantity available.

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Chloroscombrus chrysurus Linnaeus 1766, also called the Atlantic bumper is known as a typical, economically and ecologically dominant species in the fish community species of the Carangidae family in the studied area. This species is caught by a range of fishing gear including gillnets, purse seines, beach seines and trawls. A stock assessment is best done when cumulative data from all fisheries are available. Given the available data, it was essential to conduct this study to ensure the sustainable management of the *Chloroscombrus chrysurus* stock along Côte d'Ivoire’s coastal waters.

MATERIALS AND METHODS

1. Sampling

Sampling zones were chosen based on the intensity of fishing activity (Abidjan, Grand-Bassam, Fresco and Grand-Lahou) (Fig. 1).

Data were collected from commercial fisheries, and fishermen were chosen randomly. These fishermen applied various fishing gear notably gillnets, purse seines and beach seines. Fishes in their catches were analyzed, and the identification of each specimen was made to the species level with the identification key of **Schneider (1990)**. Then, each collected individual was measured for its standard length (LS) to the nearest 0.1cm by using a fish ruler. The fish specimens were individually weighed to the nearest 0.01g using an electronic scale model FEL-500S. A total of 2,520 samples of *Chloroscombrus chrysurus* were analyzed from July 2022 to June 2023 (i.e 12 months).

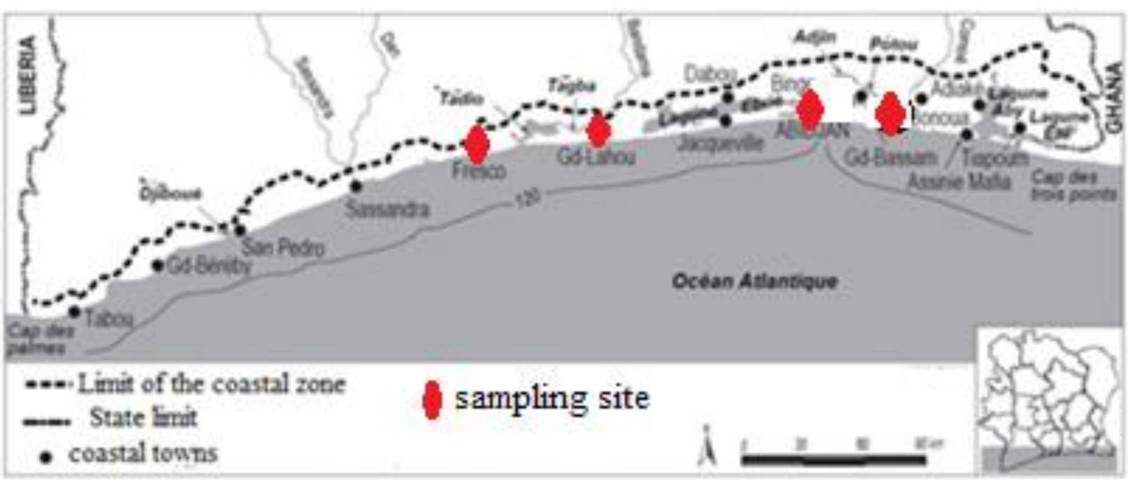

Fig. 1. Map showing sampling stations

2. Methods

2.1. von Bertalanffy growth parameters

All data were analyzed using FiSAT II (FAO-ICLARM Stock Assessment Tools) software **(Gayanilo *et al*., 2003)**. In addition, size frequency data were pooled into groups with 2cm length intervals.

It is assumed that frowth follows **Von Bertalanffy (1938)** model described by the following equation: $\mathbf{L(t) = L\infty * (1-(e^{(t-t0)}))}$. The theoretical age ($t_0$) was determined following the equation below:

$\mathbf{Log_{10}(-t_0) = -0.3922 - 0.275 \log_{10} L\infty - 1.0381 \log_{10} K}$ **(Pauly&Munro, 1984)**. Moreover, the longevity (T_{max}) in *Chloroscombrus chrysurus* was determined as followed:

$\mathbf{T_{max} = 2.9957/K + t_0}$**(Pauly, 1983)**.

2.2. Growth performance index (φ') *and lopt*

Two values notably the asymptotic length (L∞) and the growth coefficient (K) were used to estimate φ' as follows: $\mathbf{2 \,Log_{10} L\infty + Log_{10} K}$**(Munro &Pauly, 1983)**.

According to **Froese and Binolhan (2000)**, the size l_{optl} at which the maximum biomass is obtained was estimated as follows: $\mathbf{\log Lopt = 1.0421 * \log_{10} L\infty - 0.2742}$

2.3. Mortality parameters

The total mortality coefficient (Z) was estimated as the geometric mean of two methods: the catch curve method as described in **Ricker (1975)** and the converted catch curve of **Pauly (1983)**. The natural mortality coefficient (M) was computed as the geometric mean of three different methods **(Taylor, 1960; Hoenig, 1984)**.

The empirical equation proposed by **Pauly (1983)** for estimating natural mortality (M) using the asymptotic length (L∞) the growth coefficient (K), and the temperature (TTT) is given by:

$$\mathbf{\log_{10} M = 0.0066 - 0.279 \log_{10} L\infty + 0.6341 \log_{10} K + 0.4634 \log_{10} T}$$

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

Fishing mortality (F) was estimated by deducting natural mortality (M) from total mortality (Z). **F = Z- M**

2.4. Length at first capture Lc 50

The length at first capture is the length at which 50% of the fish are vulnerable and retained by the fishing gear. The length converted catch curve was used for the estimation of the probabilities of capture at 50, 75, and 25 **(Pauly, 1984)**.

The age at first capture was then determined as follows:

$tc_{50} = -1/K * \ln(1 - Lc50/L\infty) + t_0$(Beverton and Holt, 1957)

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

$\log_{10} Lm = 0.8979 * \log_{10} L\infty - 0.0782$(Froese and Binolhan, 2000)

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

$tm_{50} = -1/K * \ln(1 - Lm50/L\infty) + t_0$(Goonetileke&Sivasubramania, 1987).

2.5. Recruitment patterns

The basis of this part is consisted to identify the annual pulse and the relative strength of each monthly pulse. Indeed, this is possible by the use of size frequency series over a period which will allow to reconstruct the recruitment pulse. Hence, one or two pulses can be obtained. The age at first recruitment (tr) was obtained with the following formula:

$tr = -1/K * \ln(1 - Lr/L\infty) + t_0$(Beverton& Holt, 1957).

2.6. Stock status

The status of a fish stock which is an important indicator of sustainable management is made possible through its assessment. From the knife-edge selection incorporated into the Fisat II program, a prediction of the relative yield and biomass per recruit was made. In addition, the values of the $Lc/L\infty$ 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 will then be 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 ($Lc50/L\infty$). Yield isopleth was plotted to identify the impact of changes in exploitation ratio (E) on yield (critical length ratio **$(Lc) = Lc50/L\infty$**.

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 **(Jenning *et al*., 2001)**.

RESULTS

1. Length frequency distribution

The length frequency distribution of *Chloroscombrus chrysurus* revealed that the fish lengths ranged from 7 to 22cm. The dominant length classes were 12 and 13cm (Fig. 2).

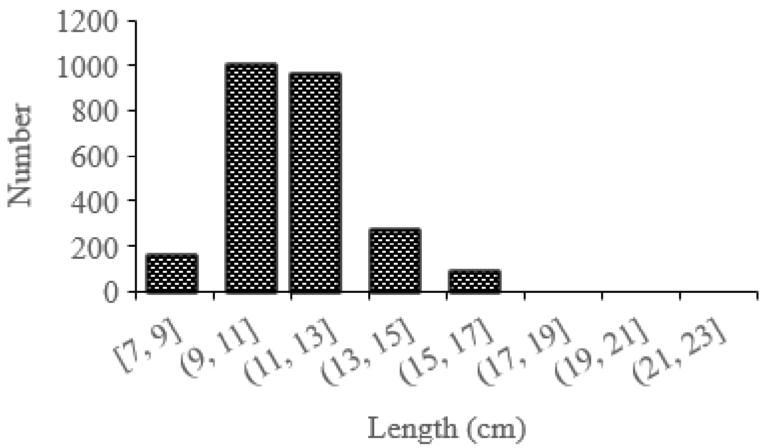

Fig. 2. Length frequency distribution of *Chloroscombrus chrysurus*

2. Estimation of growth parameters

Fig. (3) shows the restructured length frequency data superimposed with the estimated growth curve. The result of FiSAT routine showed the estimation of parameters such as $L\infty$, K, t_0, (Ø') and T_{max} at 22.05cm, 0.82year$^{-1,}$ -0.084 year and 3.57 year, respectively (Table I). The von Bertalanffy growth function equation (VBGF) for *Chloroscombrus chrysurus*was as follows:

$$Lt = 22.05\{1 - \exp[-0.82(t+0.084)]$$

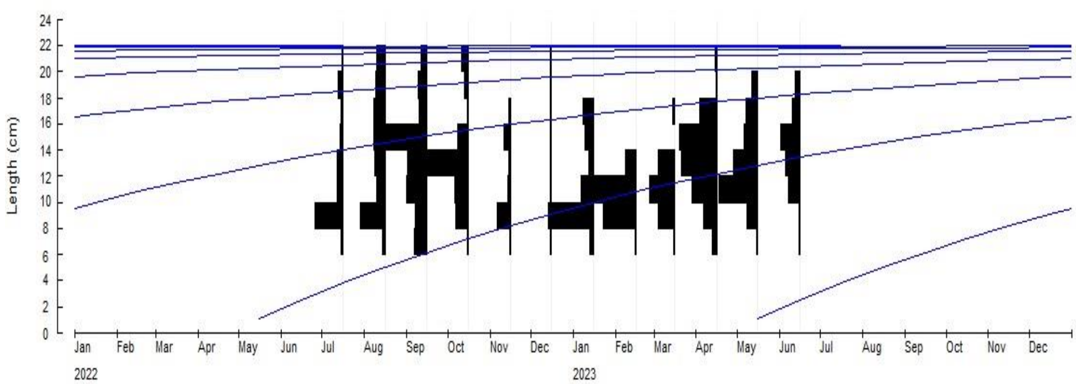

Fig. 3. Reconstructed length frequency distribution superimposed with growth curve

Table 1. Growth parameters of *Chloroscombrus chrysurus* along Côte d'Ivoire's coastal waters. L∞: Asymptotic length, K: Growth rate, t_0: Theoretical age, (Ø'): Growth performance index, Tmax: Life-span or longevity

Parameter	**L∞ (cm)**	**K (year^{-1})**	**t_0 (year)**	**(Ø')**	**Tmax (year)**
Values	22.05	0.82	-0.084	2.59	3.57

3. **Estimation of mortality parameters (M, F, Z) and exploitation rate (E)**

Fig. (4) shows estimates of mortality parameters and the exploitation rate of the species. Thus, the total mortality rate, Z, estimated from the linearized length-converted catch curve was 2.51 year^{-1}. The natural and fishing mortalities obtained were 1.70 and 0.81 year $^{-1}$, respectively. The exploitation rate was estimated at 0.32.

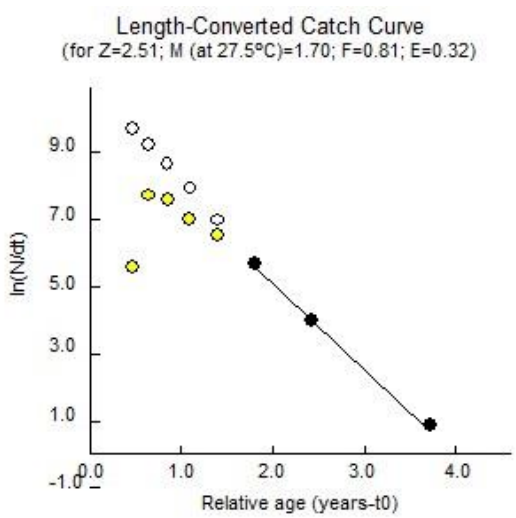

Fig. 4. Length-converted catch curve for *Chloroscombrus chrysurus* covering Côte d'Ivoire's coastal waters from July 2022 to June 2023

4. **Probability of capture and length at first sexual maturity (Lm50)**

The estimation of the length at first capture (Lc50%) was found to be 13.69cm, corresponding to an age of 1.03 years, as illustrated in Fig. (5) and detailed in Table (2). Additionally, the length at first sexual maturity was determined to be 13.42cm, corresponding to an age of 1.059 years, also presented in Table (2).

5. Recruitment pattern

Recruitment in *Chloroscombrus chrysurus* is represented in Fig.(6). Indeed, recruitment runs from March to October with a peak in August. The length at first recruitment (Lr50) was 7cm with a corresponding age at first recruitment of 0.380 year.

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

Parameter	**Lc50**	**Lm50**	**Lr50**	**tc50**	**tm50**	**tr50**
Values	13.32	13.42	7	1.032	1.059	0.380

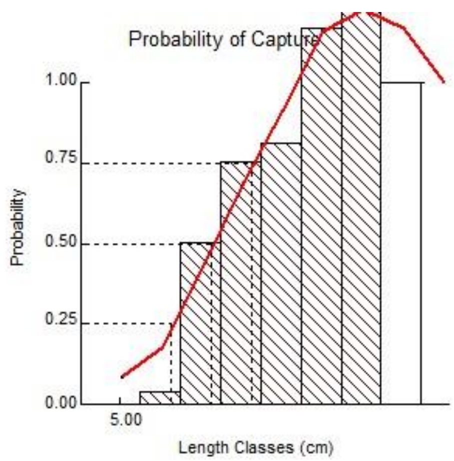

Fig. 5. Probability of capture analysis for *Chloroscombrus chrysurus* along Côte d'Ivoire's coastal waters from July 2022 to June 2023

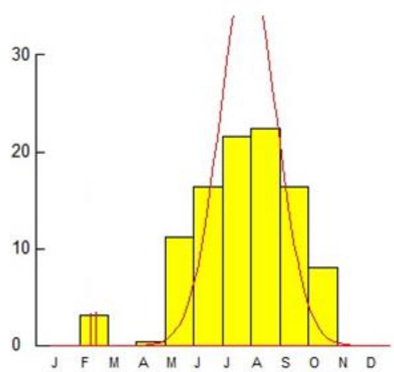

Fig. 6. Recruitment pattern in *Chloroscombrus chrysurus* covering Côte d'Ivoire coastal waters from July 2022 to June 2023

6. Stock prediction

6.1.Yield and biomass per recruit (Y/R, B/R)

The Beverton and Holt relative yield per recruit model showed that the indices for sustainable yield 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. 7a). The yield isopleths placed the fishery of *C. chrysurus* of Côte d'Ivoire's coastal waters in quadrant A depending on the interception of Lc50/L∞ = 0.60 and E= 0.32 (Fig. 7b).

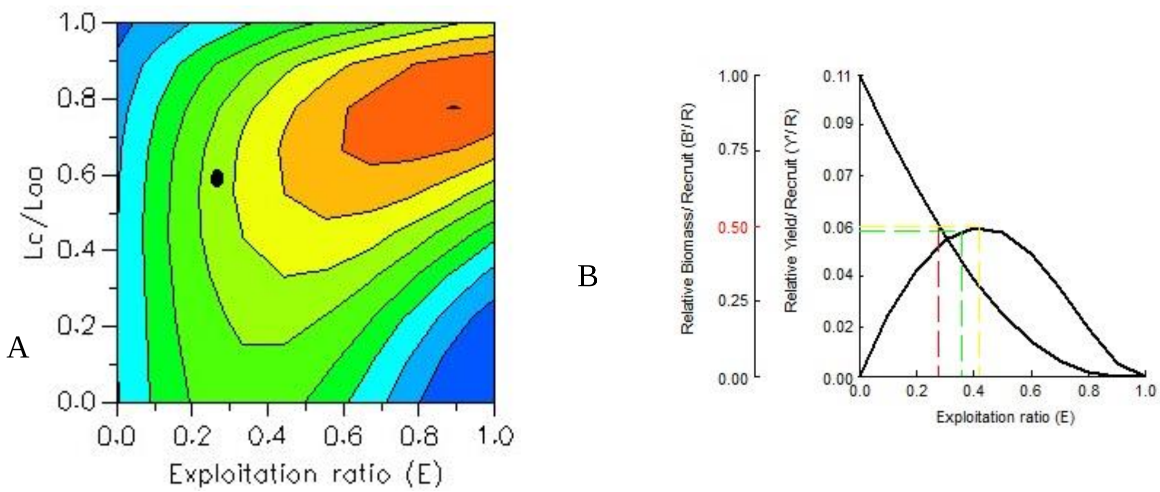

Fig. 7. Beverton and Holt relative yield per recruit model (7a) and yield isopleth diagram (7b) in *Chloroscombrus chrysurus* of coastal waters of Côte d'Ivoire

6.2.Length structured virtual population analysis

The trends in natural losses, survivors, catches and fishing mortality were shown in Fig. (8). The natural losses and survivors decreased with an increase in length and fishing mortality. The catch value increased with increasing of fishing mortality and then decreased. The highest value of fishing mortality was estimated at 1.2 per year.

Table (3) demonstrates the results of the virtual population analysis (VPA) of *Chloroscombrus chrysurus*. The catches of the species occurred from size 7cm, and the peak was obtained at 10cm. The recruitment of the species into the fishery was estimated at 1844569728. Then, the population decreased with increased length classes. The maximum steady state biomass (27.01 tons) was obtained in size groups of 13-14cm.

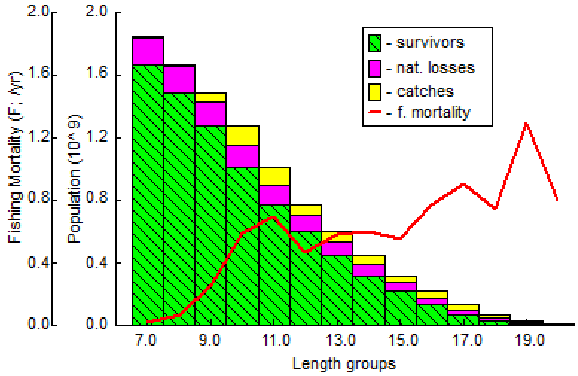

Fig. 8. Length-based virtual population analysis in *Chloroscombrus chrysurus* along Côte d'Ivoire's coastal waters from July 202 to June 2023

Table 3. Survivors, catches and biomass in *Chloroscombrus chrysurus* from VPA output in FiSAT II routine

Mid-length	Catch in number	Population (N)	F	Steady-state biomass (tons)
7	4000000	1844569728	0.016	8.55
8	15000000	1666904704	0.062	12.26
9	57000000	1484963584	0.254	16.40
10	118000000	127094484	0.587	20.13
11	11900000	1022358912	0.695	22.81
12	68000000	773634816	0.468	25.14
13	71000000	603989632	0.578	27.01
14	60000000	447061536	0.599	27.51
15	44000000	316980288	0.550	26.96
16	46000000	217132288	0.770	24.49
17	36000000	129321608	0.907	19.51
18	18000000	65551108	0.743	14.14
19	15000000	30594504	1.297	7.94
20	4000000	7499999	0.800	4

DISCUSSION

Knowledge on the current state and the future trends of a fish stock is a critically important key and provides essential information to fisheries managers. Growth parameters estimated in this study varied from those obtained from other areas and also other species. The L∞ and K parameters are correlated with each other **(Pauly & Morgan, 1987)**.

Furthermore, the higher K values are usually associated with the lower $L\infty$ values and vice versa. The differences of those values among localities may be related to the sampling strategy, different data sets and differences of their life pattern and ecological characters **(Adam, 1980)**. Indeed, **Sparre and Venema (1992)** had reported that growth parameters may vary, depending from species and the stock even within the same species. According to these authors environmental conditions could be responsible of these results.

The observed negative t_0 value indicates that the fish grow faster during juvenile stage as mentioned by **Sparre and Venema, 1998)**.

The growth performance index of 2.59 was relatively high. Growth performance index compares the growth performance of different population of fish species. In an optimally exploitation stock, F should be about equal to M with a fixed $E_{opt} = 0.5$ **(Gulland, 1971)**.

The result of the present study shows an exploitation rate (E) of 0.32 which is lower than the result mentioned in Ghana by **Amponsah *et al*. (2021)**. The difference observed in the exploitation rate values of the species could be explained by the fishing effort deployed in terms of the number of fishing trips and also the types of fishing gear used. Although the current exploitation value is lower than the optimal value (0.5), it is worth noting that the current exploitation value exceeds the estimated sustainable value of E0.5, the value of E for which the stock has been reduced to half its virgin biomass, which is equal to 0.275 but remains close to E0.1 and slightly lower than the maximum allowable exploitation rate (Emax). *Chloroscombrus chrysurus* population in Côte d'Ivoire stand the risk of moderate over exploitation if urgent measures are not undertaken in terms of monitoring the fishing effort. Urgent measures will also have to be taken regarding the gillnets mesh size in view of abundance of juvenile individuals in the catches.

The estimated value for the length at first capture Lc50 was lower than the length at first sexual maturity lm50. The estimated age at first capture (tc50) was also below the age at first sexual maturity (tm50). The results are in agreement with those revealed by a study on the same species in the Ghanaian coastal waters carried out by **Amponsah*et al*. (2021)**. This result indicates that, young and immature fish of the species were fished before they could reach the maturity. These facts could deprive many females from participating in breeding activities and thus limit the recruit numbers, the resource availability and its sustainability.

Moreover, the virtual population analysis (VPA) derived from the present study (Table 3) showed that the greatest harvest of *Chloroscombrus chrysurus* was obtained from individuals below the mid-length and the age at first maturity, thus pointing out the essential duty to take a look at the mesh size of fishing gears. The mesh size authorized in relation to the size at first sexual maturity should allow juveniles to escape from the net, so that only mature individuals are retained.

CONCLUSION

The study shows that *Chloroscombrus chrysurus* is a fast-growing species with a K value of 0.82 per year. Furthermore, the species presents a year-round recruitment, a short life-span. The study revealed a significant number of juveniles in the catches. The Lc_{50} value of 13.32cm was slightly lower than the length at first sexual maturity (13.42 cm). *Chloroscombrus chrysurus* stands at risk of moderate over-exploitation, necessitating effective fisheries management measures, including increasing the mesh size of fishing gear to ensure sustainable harvesting.

REFERENCES

Adam, P. (1980). Life history pattern in marine fishes and their consequences for fisheries management. Fish. Bull., 78: 1-12.

Amponsah, S.K.K.; Commey, N.A.; Asiedou, B. and Fazli, H. (2021). Assessing the stock status of Atlantic bumper, Chloroscombrus chrysurus, Linnaeus 1766, from the coastal waters of Ghana. Int. J Aquat. Biol, 9(4):248-253. DOI: https://doi.org/10.22034/ijab.v9i4.1174

Bertalanffy, V.L. (1938). *A Quantitative Theory of Organic Growth. Human Biology.* Baltimore, *10: 181- 213.*

Beverton, R.J.H. and Holt S.J. (1957). On the dynamics of exploited fish populations. U. K. Min. Agr. Fish. Food, Ish. Invest, 19: 533 pp.

Carpenter, K.E. and De-Angelis, N. (2016). The Living Marine Resources of the Eastern Central Atlantic**.** Bony Fishes (Tetradontiformes to Perciformes) and Sea Turtles, Rome, FAO, 4(2): 2351-3131.

Failler, P.; El-Ayoubi, H. and Konan, A. (2014). Industrie des pêches et de l'aquaculture. Rapport n°7 de la revue de l'industrie des pêches et de l'aquaculture dans la zone de la COMHAFAT, 100 pp.

FAO. (2014). The State of World Fisheries and Aquaculture: Opportunities and challenges. FAO. Rome, 213 pp.

Froese, R. and Binohlan, C. (2000). 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, 56: 758-773

Gayanilo, F.C.; Sparre, P. and Pauly, D. (2003). FAO ICLARM Stock Assessment Tool (FiSATII). User's Guide FAO Computerized Information Series (Fisheries), FAO, Rome, 266 pp.

Gulland, J.A. (1971). The *Fish Resources* of the *Ocean* ***West*** Polyfleet, ***Survey Fishing*** *News (**Books**)* Ltd, 255 pp.

Hoenig, J. M., (1983). Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898–903

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, 59 pp

Jennings, S.; Kaiser, M.J. and Reynolds, J.D. (2001). Marine Fisheries Ecology. Blackwell, Oxford 417 p.

Munro, J.L. and Pauly, D. (1983). "A simple method for comparing the growth of fishes and invertebrates," Fishbyte, The World Fish Center, 1(1): 5-6.

Pauly, D., (1983). Some Simple Methods for Assessment of Tropical FishStocks. 234 52; FAO Fisheries Technical Paper, 33p.

Pauly, D. and Munro, J.L. (1984). Once More on the Comparison of Growth in Fish and Invertebrates. Fish Byte, 2: 21-23.

Pauly, D. and Morgan, G.R. (1987). Length-based methods in fisheries research. International Center for Living Aquatic Resources Management, Manila. 467 pp

Pauly, D. (1984). 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, 325; 28 pp.

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, 268 pp

Sparre, P. and Venema, S.S. (1992). Introduction to Tropical Fish Stock Assessment, part 1. Manual FAO fish tech paper no .306, 1, Revue.1; Rome FAO, 376 pp.

Sparre, P. and Venema, S. C. (1998). Introduction to the tropical fish stock assessment. Manual. FAO Fish. Tech. Rep., 306, Rev. 2, Rome, pp 407

Taylor, C. C. (1961). Temperature, growth and mortality – the Pacific cockle. J. Cons. CIEM, 26: 117-124.