Original Research Article

Stock assessment with Virtual population Analysis (VPA) and population dynamic of the blue runner *Caranx crysos* (Mitchill,1815) within Côte d'Ivoire's coastal waters

ABSTRACT

Background and objectives

The blue runner *Caranx crysos*is exploited by artisanal marine fisheries but the knowledge on their population dynamic is still sketchy. The study was carried out to estimate population parameters and the stock status within Côte d'Ivoire's coastal waters**.**

Methodology

Fish were caught using gill nets in several sampling sites and then measured to the nearest mm and weighted to the nearest g. Data on fish length measurement were recorded during the period from April 2022 to May 2023, followed by the analysis of the recorded values using FiSAT software.

Results

The asymptotic length (L∞), the growth rate (K), the growth performance index (Ø'), the theoretical age (t0) and the maximum age (tmax) obtained from length frequency data were 38.85 cm, 0.70 per year, 3.02, -0.12 year and 4.18 year respectively. From the study the total mortality rate (Z) estimated was 2.33 year^{-1}, the natural mortality rate (M) was 1.75 year^{-1} and fishing mortality (F) was 0.58 year^{-1}. The current level of exploitation rate (E) and the maximum exploitation rate (E max) were estimated as 0.25 and 0.42 respectivelyindicating a low exploitationof*Caranx crysos* within Côte d'Ivoire's coastal waters.

Conclusion

Although the assessed fish species was underfished, there is the need to ensure continuous monitoring of fishing effort and adherence to mesh size regulations in order to sustain the fishery.

Keywords: population dynamic, stock assessment, Caranx crysos, marine, fishery, Côte d'Ivoire.

1. INTRODUCTION

The fishes of the family carangidae commonly known as Jacks inhabit marine and estuarine waters in tropical, subtropical and temperate regions [1].

The family Carangidae forms one of the largest families of bony fishes comprising various marine fishes that are ecologically and commercially important species [2]. From the total of about 140 species belonging to 32 genera around the world, 39 species occur in the Eastern central Atlantic [3]and twenty-two on the mainland coast of tropical west Africa [4]. The blue runner is a species of marine fish. Relatively large, 70 cm was the highest length ever recorded. Its colour varies from bluish green to olive green [5]. Its body is elongated, and compressed with top and bottom arched equally. Adipose eyelid covers the posterior section of the eye, with the jaw's posterior extremity located directly under the eye. The first part of the dorsal fin is made up of 8 spines while the second part consists of one spine with around 25 soft rays. the blue runner feeds on crabs, shrimps, copepods, prawns and jellyfish [6]. The blue runner usually moves in small schools [7]. They are mostly found in coastal marine and brackish waters to at least 100 m depth. The blue runner *Caranx crysos* (Mitchill, 1815) is a coastal pelagic species found in the Eastern central Atlantic, from Senegal to Angola [8]. This species is reported within Caranx species and are mainly caught in the inshore fishery using trawl fleet in industrial fisheries and purse-seines in artisanal fisheries in Côte d'Ivoire with an annual landing of approximately 824 tons [9]. Recently, there has been increasing interest in this relatively unexploited species and landings increased substantially with 2053.4 tons [10]. Often, it is harvested by small scale fishermen who deploy small mesh sized purse seine and beach seine fishing gears. However, fairly good catches are made during July to September, yearly. Locally, the blue runner is marketed fresh or smoked. Nonetheless, the absence of adequate information on its stock status and population parameters from the coastal waters of Côte d'Ivoire, threatens the exploitation status and sustainability of the species with regards to meeting the needs of future generations without compromising the needs of the present generation. In view of this, the aim of the present work was to assess the stock status and estimate the various populations parameters of *Caranx crysos* within Côte d'Ivoire's coastal waters. Information acquired from this study will enable sustainable effective management of the resource.

2. MATERIAL AND METHODS

2.1. Study area

This study focused on the Ivorian coastline with 550 long and an estimated surface area of 23253 km^2.Indeed, the coastline extends from the cape palmas (7° W) to the cape three points (2° W). The landing sites used were located at the eastern part of the country (Abidjan, Grand-Bassam)(Figure 1).

2.2. Data collection

Fish samples were purchased from local fishers at the selected landing sites operating mostly with beach and purse seine fishing gears for 10 months (once every month), from May 2022 to June 2023. Moreover, fishermen were chosen by random and fishes in their catches were analyzed. Each specimen was identified to the specie level using [3] manual. Then each individual collected was measured for its standard length (LS) to the nearest 0.1 cm by using a fish measuring

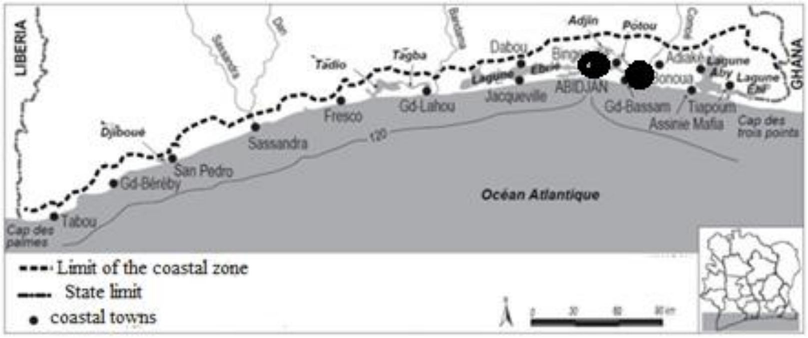

Fig. 1. Map showing the delimitation of the Ivorian coastline with landing sites ●/ source: Pottier and Anah (2008)

board. The fish specimens were individually weighed to the nearest 0.01g using an electronic weighing balance model FEL-500S. In all a total of 568 samples of *Caranx crysos* were assessed.

2.3. Data analysis

The length frequency data were pooled into groups with 2cm length intervals. Then the data were analyzed using the FiSAT II (FAO-ICLARM Stock Assessment Tools) software [11].

2.3.1. Growth parameters

The von Bertalanffy growth function and length frequency distribution were plotted based on the ELEFAN I routine of the FiSAT II software, which is used to understand the seasonal oscillation along with the estimation of the $L\infty$, K, and Rn. The predicted maximum length from extreme values was computed. The estimate of theoretical age at length zero (t0) was obtained by using the empirical equation [12].

$$\log10\ (-t_0) = -0.3922 - 0.275\ \log10 L\infty - 1.0381\ \log10 K$$

The longevity of individuals (Tmax) was estimated using the equation: Tmax =3/K + to [12] .

The growth performance index was generated as: (ϕ) =2logL∞ + log K [13]. The growth performance index (ǿ) for the species was computed based on the length data using the following equation [14]

$$Ø' = \log10 K + 2\ \log10 L\infty$$

2.3.2. Mortality rates

The length-converted catch curve method incorporated in the FiSAT package estimated the instantaneous total mortality (Z), and the natural mortality (M) for the species calculated using [15] empirical equation relating M, t0, L∞, and K, and mean water temperature (T) where T= °C

$$\log10\ M = -0.0066 - 0.279\ \log10\ L\infty + 0.6543\ \log10\ K + 0.463 \log10\ T$$

Fishing mortality (F) was derived from the difference between

Fishing mortality (F) was derived from the difference between Z and M. The exploitation ratio (E) was obtained from the ratio of fishing mortality and total mortality.

2.3.3. Length at first Capture (Lc50)

The ascending left arm of the length-converted catch curve was used to analyze the probability of capture of each length class as fitted in the FISAT II. By plotting the cumulative probability of capture against mid-length a resultant curve was obtained from which the length at first capture (Lc50) was taken as corresponding to the cumulative probability at 50%. Additionally, the length at both 25 and 75 captures were taken as corresponding to the cumulative probability at 25% and 75% respectively

2.3.4. Recruitment pattern

The recruitment pattern was determined by backward projection on the length axis of the set of available length–frequency data as described in FiSAT. This routine reconstructs the recruitment pulse from a time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse [17]. Input parameters included L_∞ and K. Normal distribution of the recruitment pattern was determined by NORMSEP [18] in Fisat. The midpoint of the smallest length group in the catch was estimated as the length at first recruitment (Lr) [19].

2.3.5. Length at first maturity (Lm50)

The length at first sexual maturity (Lm50) is the maiden length at which the fish is capable of contributing to the stock population. The length at first maturity (Lm50) was estimated using the expression: $Lm50 = (2 * L_\infty)/ 3$ [20]

2.3.6. Stock size assessment

The model of [21], as modified by [22] was followed to predict the relative yield per recruit (Y´/R) of the species, using the knife-edge analysis incorporated in FiSAT software. The data of Lc/L_∞ and M/K values were used to estimate E0.1 (exploitation point at which the related increase in yield per recruit reached 1/10 of the related increase computed at a very devalued value of E), E0.5 (the exploitation rate corresponding to 50% of the unexploited relative biomass per recruit (B‟ /R)) and Emax (exploitation point that gives maximum relative yield-per-recruit). The current exploitation rate (E) and the biological target reference points (E0.1and Emax) were used to indicate the stock status [23].

The length-frequency data also were used to carry out virtual population analysis (VPA) for the species using a routine modified from [23]and incorporated in the FiSAT package to reconstruct the population from size-wise total catch data in the length-frequency samples raised to the total catch [24]. VPA allows for reconstruction of population from total catch data by age or length. The initial step was to estimate the terminal population (Nt), followed by the successive estimation of F values, and finally, the population sizes are computed for each length class (midpoint).

Yield isopleth contours which show the stock status was 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)=$Lc50/L_\infty$.

3. RESULTS AND DISCUSSION

3.1. RESULTS

3.1.1. Length frequency distribution

The length range of *Caranx crysos* in the catches was from 9 to 39 cm with a mean of 20,91cm. The length frequency distribution showed more than one modal class with the major peak ranged in the interval 15-17 cm.

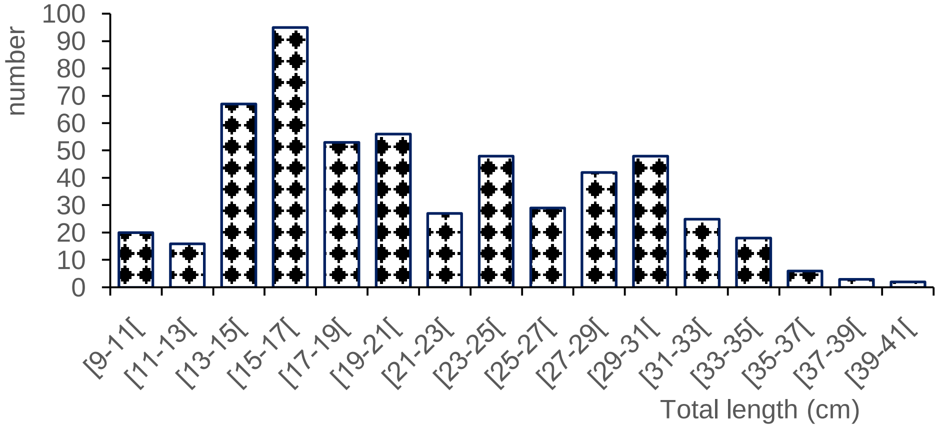

Fig. 2. Length-frequency distribution of *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023

3.1.2. Growth parameters

From ELEFAN I routines, the best estimates of growth parameters obtained were; asymptotic length (L∞) =38.85 cm total length and growth rate (K) = 0.70 per year. Figure (2) shows the restructured Length frequency data superimposed with the estimated growth curve which revealed approximately six cohorts. The estimated theoretical age at birth (t0) and longevity (Tmax) were -0.12 and 4 years respectively (Table 1). The Von Bertanlaffy Growth Function (VBGF) for *Caranx crysos* was calculated as $Lt=38.85(1-e^{-0.70(t-(-0.12))})$. The growth performance index (Ø') of 3.02 was estimated for the *Caranx crysos*. The estimated Z/K ratio was 2.58 indicating that the *Caranx crysos* in Côte d'Ivoire is slightly mortality dominated (Table 1).

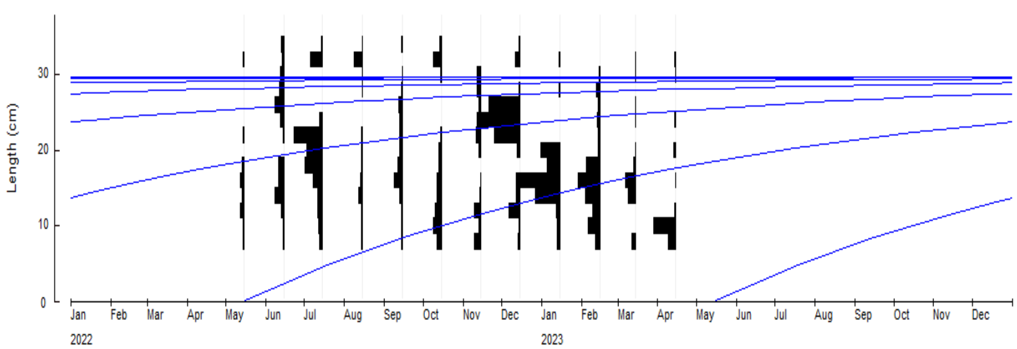

Fig. 3. Reconstructed length frequency distribution superimposed with growth curve

Table 1. population parameters of the *C. crysos*within Côte d'Ivoire's coastal wate

Parameters	Unit	Values

Asymptotic length (L∞)	cm	38.85
Growth rate (K)	year	0.70
Growth performance index (Ø')		3.02
longevity (t max)	year	4.18
theoretical age (t0)		-0.12
length at first maturity	(cm)	25.9
length at first recruitment	(cm)	10

3.1.3. Probability of capture and Length at first maturity (Lm50)

The probability of capture routine gave an estimate of L50% at 26.43 cm (Figure 3). Further, the estimates for L25% and L75% were 23.53 cm and 29.05 cm respectively. The length at first maturity obtained was 25.9cm (table 1)

3.1.4. Mortality parameters

From the linearized length-converted catch curve (Figure 4), total mortality (Z) was estimated at 2.33 per year, while natural mortality (M) of 1.75 per year was obtained. By subtracting the value of natural mortality from the total mortality, the fishing mortality (F) of 0.58 per year was obtained. The optimum fishing mortality rate was 0.7 per year. The exploitation rate (E) was estimated at 0.25.

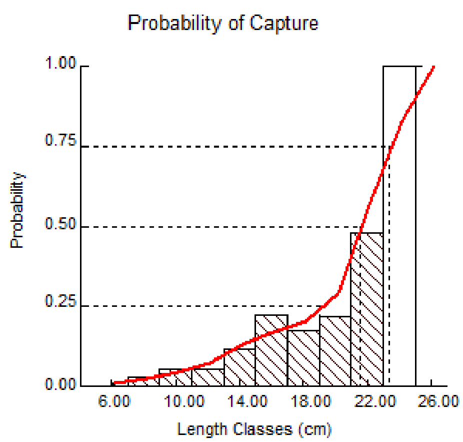

Fig. 4. Probability of capture analysis for *Caranx crysos*within Côte d'Ivoire's coastal waters from April 2022 to May 2023

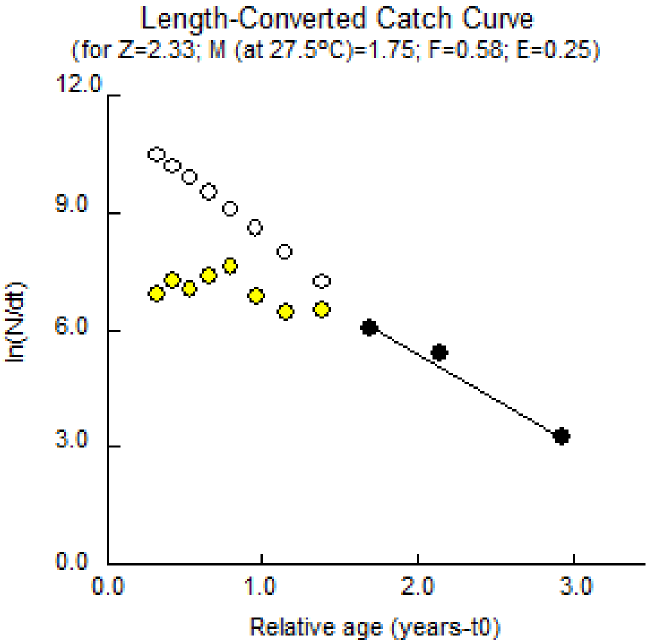

Fig. 5: Length-converted catch curve for *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023.

3.1.5. Recruitment pattern

The recruitment pattern established in (Figure 6) indicated a year-round recruitment for *Caranx crysos* with one peak of in march. The length at first recruitment (Lr50) obtained was 10 cm.

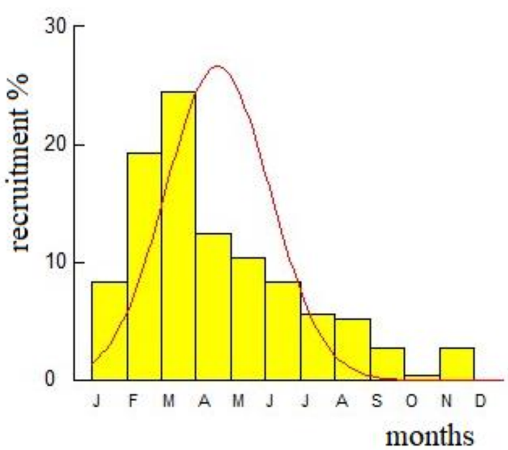

Fig.6: Recruitment pattern for *Caranx crysos*within Côte d'Ivoire's coastal waters from April 2022 to May 2023.

3.1.6. Relative yield per recruit

The plot of relative yield per recruit against exploitation ratio showed that the indices for sustainable yield were 0.27 for the optimum sustainable yield (E0.5), 0.42 for the maximum sustainable yield (Emax), and 0.35 for the economic yield target (E0.1) as indicated in Figure 7.

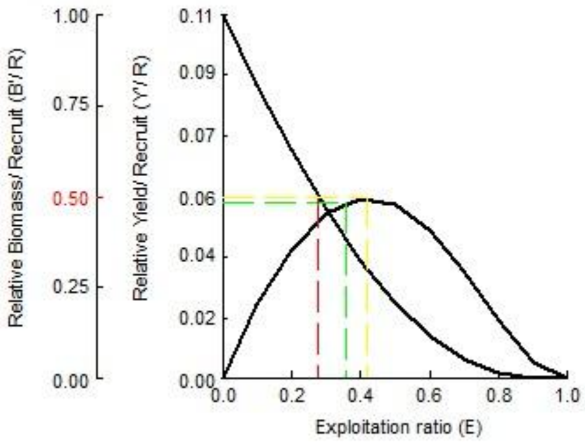

Fig. 7 : The relative yield plot for *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to may 2023. Yellow line: Emax; red line: E50; green line: E10.

3.1.7. Yield isopleth

The yield isopleths shown in Figure 8 envisage the response of Lc/L∞=0.68 and E=0.25. As a result, the stock status of the investigated fish species fell in quadrant A (underfishing stage).

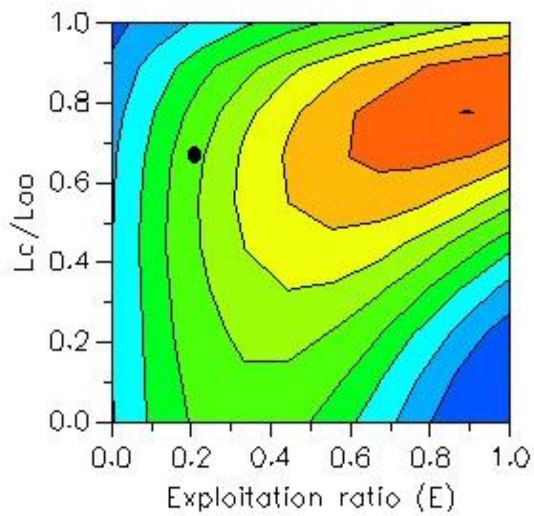

Figure 8: Yield isopleth diagram for *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023.

3.1.8. Virtual population analysis

Figure 9 shows the virtual population analysis of *Caranx crysos*.Individuals within the range of 10 to 15 cm experienced the highest level of exploitation. Natural losses were highest among individual within the length range of 9 to 12 cm. Surviving individuals in the stock exhibited adeclining trend with an increased rate of fishing pressure. The highest number of survivors in the stock was observed in the length range of 9 to 12 cm, whereas the lowest number of survivors was observed for individuals at a length range of 25 to 30 cm. Fishing mortality was higher on individuals within the length range of 27 to 35 cm and lower on individuals at length range of 9 to 11 cm. Recruit estimated into the population was $63.63.10^4$ with the highest harvesting intensity occuring within length 13 cm to 15cm with fishing mortality rate of 0.24 per year Table 2. Peak of fishing mortality rate 0.85 ensued within length range of 33 to 35 cm

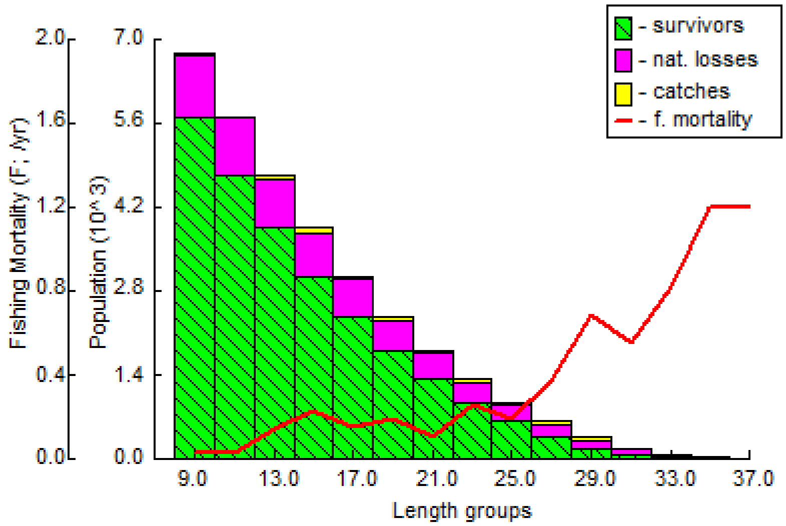

Fig. 9: Length-based virtual population analysis of *Caranx crysos*within Côte d'Ivoire's coastal waters from April 2022 to may 2023.

Table 2: Survivors and catches of *Caranx crysos* from VPA output in FISAT II

Mid - length	Catch in numbers	survivors (N)	Fishing mortality	Steady-state Biomass (tons)
9.0	190000	63636964	0.0339	0.82
11	160000	53644520	0.0318	1.35
13	670000	44679056	0.1504	196
15	930000	36210812	0.2408	2.61
17	530000	28523302	0.1605	3.25
19	570000	22214100	0.2044	3.83
21	260000	16763142	0.1120	4.31
23	520000	12439004	0.2765	4.58
25	300000	8628273	0.2045	4.59
27	440000	5761169.50	0.4054	4.27
29	530000	3421938	0.7489	3.45
31	250000	1653439	0.6177	2.41
33	180000	695155.50	0.9499	1.36
35	60000	183638.50	0.8500	1.66
37	0	0.00	0.8500	0.00

3.2. DISCUSSION

The length at infinity and the growth rate (K) of the present study were higher than estimated by [25]. However the present work showed a greather values of the growth rate (K) and the growth performance index (Ø') indicating a more conducive environment to the well-being of fish. The differences observed in growth parameters compared with other authors could be due to several factors notabily variations in environmental conditions from one area to another which affect the growth of the species as well as the genetic characterization of the species. The difference in the size range sampled could also significantly influence the growth model parameter estimates. According to [26], the growth parameters varied from species to species, even in the same species and also from different stocks due to differing environmental conditions such as temperature, water quality, food availability, etc. The length at first capture (Lc50) estimated from this study was lower than estimates by other researchers [26]. The size at first capture was very close to the size at first sexual maturity but remained higher, which showed that individuals have the opportunity to reproduce before being captured. This help ensure the sustainability of the species. According to [27], fish should be allowed to reach sexual maturity pior to exploitation. The natural mortality rate estimated from the present study was 1.75 per year higher than estimate of mortality rate by [26] within Ghana's coastal waters. This value was also higher than the obtained fishing mortality of the present study. This observation could suggest that *Caranx crysos* in tropical coastal waters of Côte d'Ivoire, was more prone to natural mortality-induced conditions than to fishing gears. Again, it is plausible to suggest that natural mortality is the most important form of mortality confronting this species, as such these species are not under intense fishing pressure. Indeed, fish can die naturally from predation, illness, aging and environmental reasons. According to [28], natural mortality and water temperature are related. The natural mortality of a given fish will rise as the water temperature rises. However, in case of such studies with higher natural mortality relative to fishing mortality, it would be interesting to conduct research in order to determine the main causes of fish deaths. Recruitment into the stock of *Caranx crysos* was continuous throughout the year indicating a continuous presence of mature female species. In addition, the unimodal recruitment curve may indicate that the assessed species spawns once in their lifetime. The length at first recruitment from this work was below the estimated length at first capture (i.e 26.43 cm). such situation suggests that individuals of the assessed fish species have the opportunity to rejoin the stock before becoming vulnerable and captured by any available fishing gear.

The *Caranx crysos* stock from the current study has not been subjected to overfishing as the exploitation rate (E = 0.25) was below the optimum level of 0.5. However, the exploitation ratio was slightly lower than the E0.5, and Emax which indicates that the investigated species is heavily fished. The interception of the L_c/L_∞ (proportion of the length at first capture to the length at infinity) (L_c/L_∞ =0.68) and the exploitation rate (E=0.25) of the species fell in quadrant A, implying underfishing of the *Caranx crysos*'s stock. For this species large fish are caught at low effort level. [22], used four-quadrant models to describe fish yield related to fish size. Quadrant A represents underfishing where large fish are caught at low effort level and the ratio of fish length at first capture (Lc) to the asymptotic length (L_∞) is 0.5 to 1, and the exploitation rate (E) is 0 to 0.5. Quadrant B represents eumetric fishing, developing fishery where small fish are caught at low effort level and L_c/L_∞ = 0 to 0.5; E = 0 to 0.5. Quadrant C represents eumetric fishing, developed fishery where large fish are caught at high effort level and L_c/L_∞ = 0.5 to 1; E = 0.5 to 1. Quadrant D represents overfishing where small fish are caught at high effort level and L_c/L_∞ = 0 to 0.5; E = 0 to 0.5. the high number of survivors and of C*aranx crysos* indicated that, the species stock is not within the reach of recruit failure in the future and subsequently the imminent collapse of the fishery is unlikely. The high number of survivors of *Caranx crysos*indicated that, the species stock was safe from future recruitment failure.

4. CONCLUSION

Caranx crysos, within Côte d'Ivoire's coastal waters was found to be a fast-gowing species with continuous recruitment. The species stock was safe from future recruitment failure and exhibits high natural mortality rate. The exploitation rate (E=0.25) was below the optimum level of 0.5 implying that the stock of *Caranx crysos* was underexploited. This calls for continuous monitoring and sustainable exploitation to meet food security and nutrient needs of the peoples

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