Annual Research & Review in Biology

Volume 38, Issue 10, Page 1-10, 2023; Article no.ARRB.110839
ISSN: 2347-565X, NLM ID: 101632869

Population Dynamics and Sustainable Management of the Blue Runner *Caranx crysos* (Mitchill,1815) within Côte d'Ivoire's Coastal Waters

Coulibaly Bakari [a*], Tah Léonard [a], Sylla Soumaila [a], Kone Tidiani [b] and Kouamelan Essétchi Paul [c]

[a] Centre de Recherches Océanologiques (CRO), 29 rue des pêcheurs- BP V 18 Abidjan, Côte d'Ivoire.
[b] Laboratoire de Biodiversité et Gestion Durable des Ecosystèmes Tropicaux, UFR Environnement, Université Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire
[c] Laboratoire des Milieux Naturels et de Conservation de la Biodiversité, UFR Biosciences, Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, 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 TL and SS managed the analyses of the study. 'Authors KEP and KT managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2023/v38i1030608

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://www.sdiarticle5.com/review-history/110839

Original Research Article

Received: 13/10/2023
Accepted: 19/12/2023
Published: 24/12/2023

ABSTRACT

Background and objectives: The blue runner *Caranx crysos* is exploited by artisanal marine fisheries but the knowledge on its population dynamic, is still sketchy. The present work was conducted to obtain information on population parameters and assess the stock of the species within Côte d'Ivoire's coastal waters.

**Corresponding author: E-mail: nanan84@yahoo.fr;*

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 with FiSAT.
Results: The asymptotic length ($L\infty$), the growth rate (K), the growth performance index (Ø'), the theoretical age (t0) and the maximum age (T_{max}) 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 the exploitation rate (E) and the maximum exploitation rate (E max) were estimated as 0.25 and 0.42 respectively indicating a low exploitation of *Caranx crysos* within Côte d'Ivoire's coastal waters.
Conclusion: Although *Caranx crysos* was underfished, fishing effort must be carefully monitored as well as a policy of adherence to conventional mesh sizes for responsible management of the fishery.

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

1. INTRODUCTION

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

"The Carangidae family 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 the trawl fleets in semi-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. Growth characteristics of fishes are an important part of population dynamics and allow to take serious decisions on the management issue of any fishery. Mortality either from fishing activity or natural mortality is a major cause of decline in any fish population" [11]. 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 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. MATERIALS AND METHODS

2.1 Study Area

This study concerns 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 used landing sites were located at the eastern part of the country (Abidjan, Grand-Bassam) (Fig. 1).

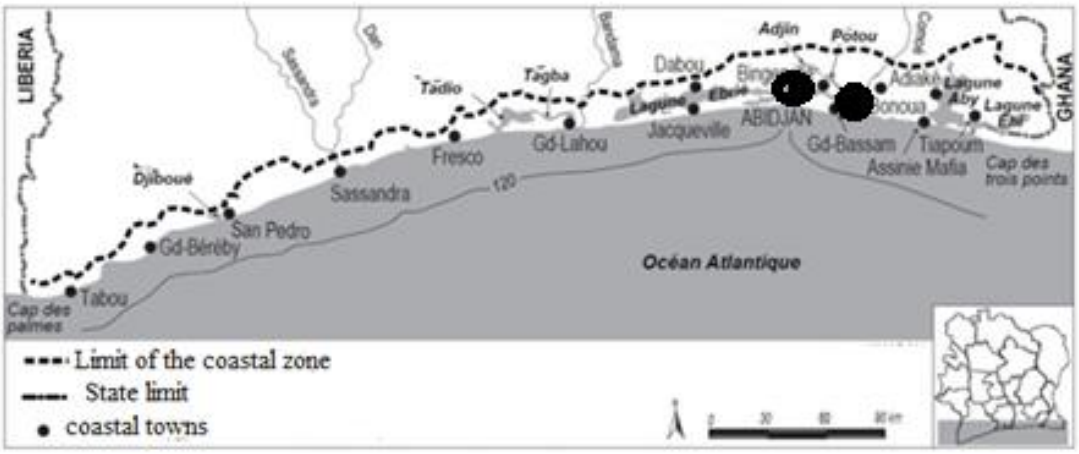

Fig. 1. Map showing the delimitation of the Côte d'Ivoire's coastline with landing sites (●)
source: Pottier and Anah (2008)

2.2 Data Collection

Fish samples were purchased from local fishers at the selected landing sites (Fig. 1) operating mostly with beach and purse seine fishing gears for 12 months (once every month) from April 2022 to May 2023. Moreover, fishermen were chosen by random and fishes in their catches were analyzed. Each specimen was identified to the species level using [3] manual. Then each collected individual was measured for its standard length (LS) to the nearest 0.1 cm by using a fish ruler. The fish specimens were individually weighed to the nearest 0.01g using an electronic scale model FEL-500S. In all, a total of 568 samples of *Caranx crysos* were assessed

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2.3 Data Analysis

"Length frequency data were pooled into groups with 2 cm length intervals. Then the data were analyzed using FiSAT II (FAO-ICLARM Stock Assessment Tools) software" [12].

2.3.1 Growth parameters

Growth parameters were determined through length frequency data using FiSAT II software and ELEFAN 1 routine. It is assumed that the growth follows the von Bertalanffy model represented as followed:

$$L(t) = L\infty * (1-(e^{(t-t0)}))$$

Using an empirical equation, we can thus determine the theoretical age (t_0) [11] which is the age of a given fish at length zero

$$Log_{10}(-t_0) = -0.3922 - 0.275\ log_{10} L\infty - 1.0381\ log_{10} K$$

The longevity (T_{max}) of *Caranx crysos* was determined by the following equation: $T_{max} = 3/K + t_0$ [11]
The growth performance index was given as (Ø') = $2\ Log_{10} L\infty + Log_{10} K$ [13].

2.3.2 Mortality rates

The slope of the catch curve according to the length frequencies allows to assess the total mortality (Z). The natural mortality (M) for the species was estimated with the following equation [14].

$$Log_{10} M = -0.0066 - 0.279\ Log_{10} L\infty + 0.6543\ Log_{10} K + 0.463\ Log_{10} T$$

T: the mean water temperature in (°C)

The fishing mortality (F) was obtained as followed: F = Z- M

The exploitation ratio (E) was obtained from this equation: E = F/Z.

2.3.3 Length at first Capture (Lc50)

The size at-first capture (Lc50) according to [15], is determined from a curve indicating a particular point corresponding to the horizontal axis (Lc50) at which the half part of individuals captured by the fishing gear escaped while the second half part of individuals remained prisoners.

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 [16].

2.3.5 Length at first maturity (Lm50)

The (Lm50) of the fish was expressed by the following formula: Lm50 = (2 * L∞)/ 3 [17].

2.3.6 Stock size assessment

The [18] model incorporated in FiSAT program was used to predict the relative yield per recruit (Y'/R) and the relative biomass per recruit (Y'/B). reference points such as $E_{0.1}$, $E_{0.5}$ and E_{max} were used to analyze the stock status [19]. A virtual population analysis was undertaken to get information on survivors, natural losses and impact of fishing mortality on different length class.

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∞.

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.

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. Fig. (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). 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).

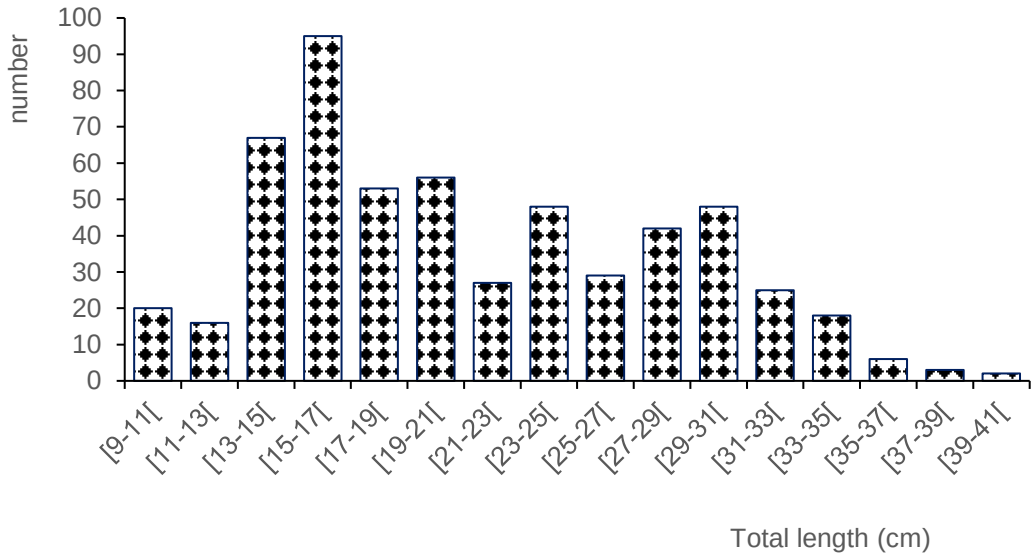

Fig. 2. Length-frequency distribution of *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023

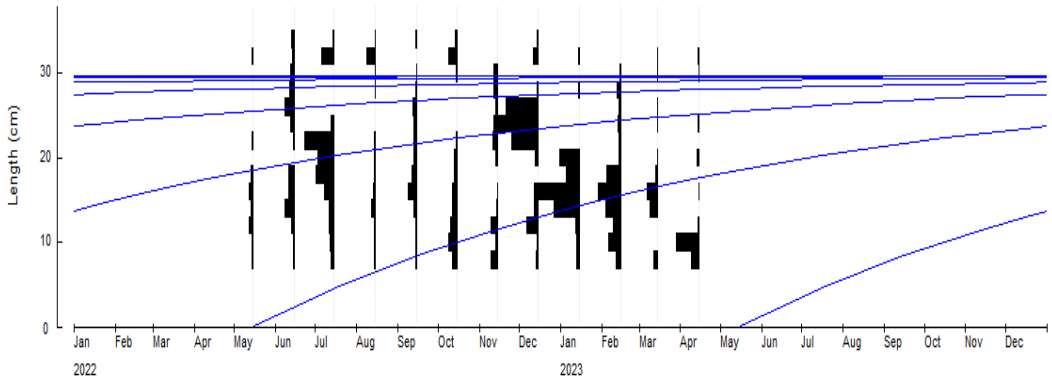

Fig. 3. Reconstructed length frequency distribution superimposed with growth curve

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

Parameters	Unit	Values
Asymtotic length (L∞)	cm	38.85
Growth rate (K)	year^{-1}	0.70
Growth performance index (Ø')		3.02
Longevity (T_{max})	year	4.18
Theoretical age (t_0)	year	-0.12
Length at first maturity	cm	29.5
Length at first recruitment	cm	10
Z/K		2.58

3.1.3 Probability of Capture and Length at first sexual maturity (Lm50)

The probability of capture routine gave an estimate of L50% at 26.43 cm (Fig. 4). 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 Estimation of mortality

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. 5).

3.1.5 Recruitment pattern

The recruitment pattern established in (Fig. 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.

3.1.6 Beverton and Holt yield (Y'/R) or Biomass (Y'/B)

Fig. 7 shows biological reference points such as $E_{0.5}$ (red dash), $E_{0.1}$ (green dash), and E_{max} (yellow da0.27, 0.35 and 0.42 respectively.

3.1.7 Yield isopleth

The yield isopleths (Fig. 8) show the response corresponding to the intercept point of Lc/L∞=0.68 and E=0.25. Thus, we observe that the stock status of the investigated fish species fell in quadrant A (underfishing stage).

3.1.8 Virtual population analysis

Fig. 9 shows the virtual population analysis of *Caranx crysos*. Natural losses were higher among juvenile individuals and declined among adults individuals. The number of survivors for small sizes decreased gradually. Fishing mortality was greather on adults of range size from 27 to 35 cm and lower on small size from 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 the fishing mortality rate 0.85 ensued within length range of 33 to 35 cm.

3.2 Discussion

The length at infinity and the growth rate (K) of the present study were higher than estimated by [20]. 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

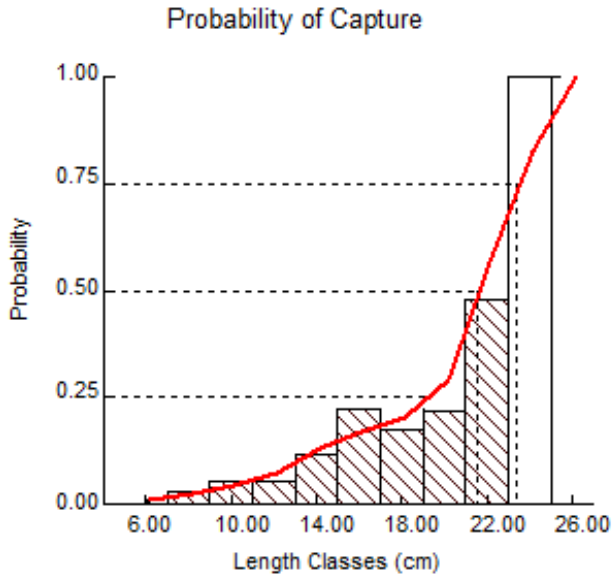

Fig. 4. Probability of capture analysis for *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023

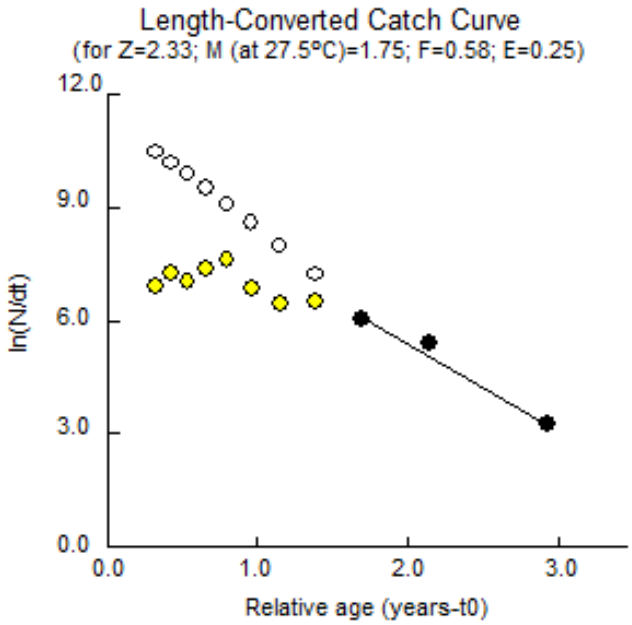

Fig. 5. Length-converted catch curve for *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023

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 [21], "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" [20]. 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 [22], fish should be allowed to reach sexual maturity prior to exploitation. For the present work, the Natural mortality (M) value was 1.75 year^{-1} and higher than the value obtained by

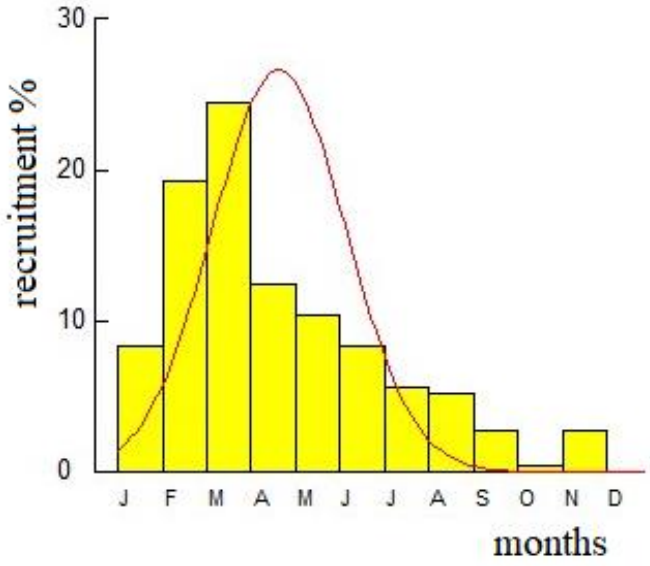

Fig. 6. Recruitment pattern for *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023

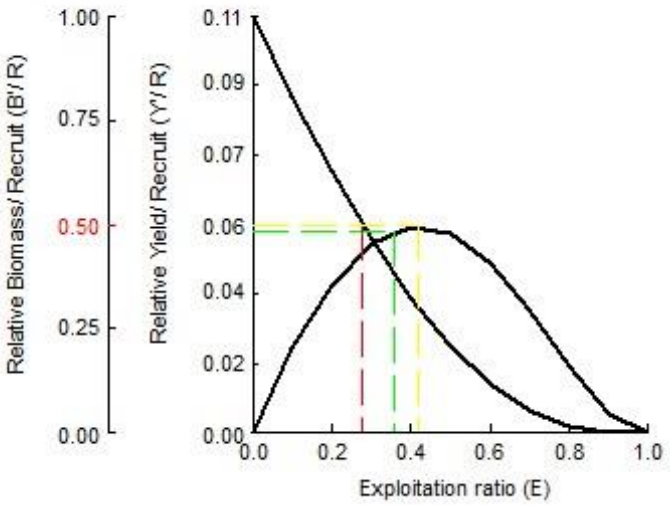

Fig. 7. The relative yield plot for *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023

[20] within Ghana's coastal waters. *Caranx crysos* within Côte d'Ivoire's coastal waters was more affected by natural mortality. Indeed, fish can die naturally from predation, illness, aging and environmental reasons. According to [23], natural mortality and water temperature are related. The natural mortality of a given fish will rise as the water temperature rises. However, in the 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. Regarding recruitment pattern of *Caranx crysos* throughout the year, we can confirm a continued presence of mature female individuals.

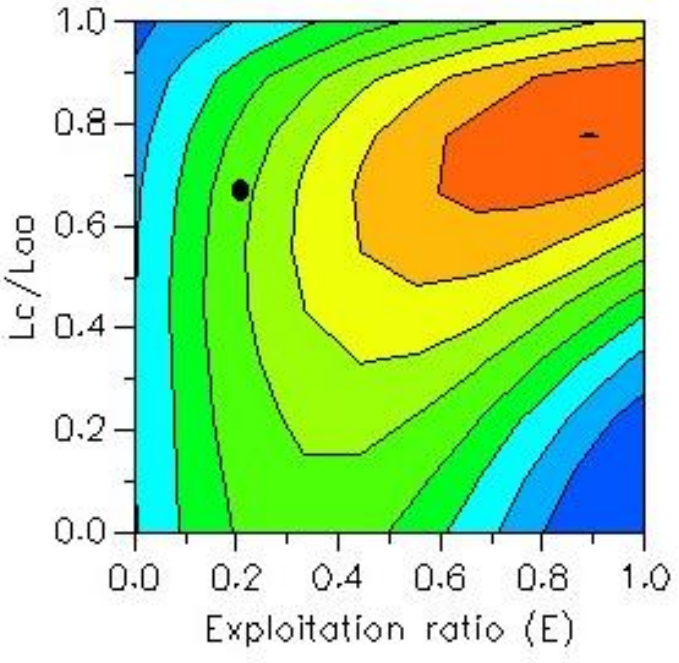

Fig. 8. Yield isopleth diagram for *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023

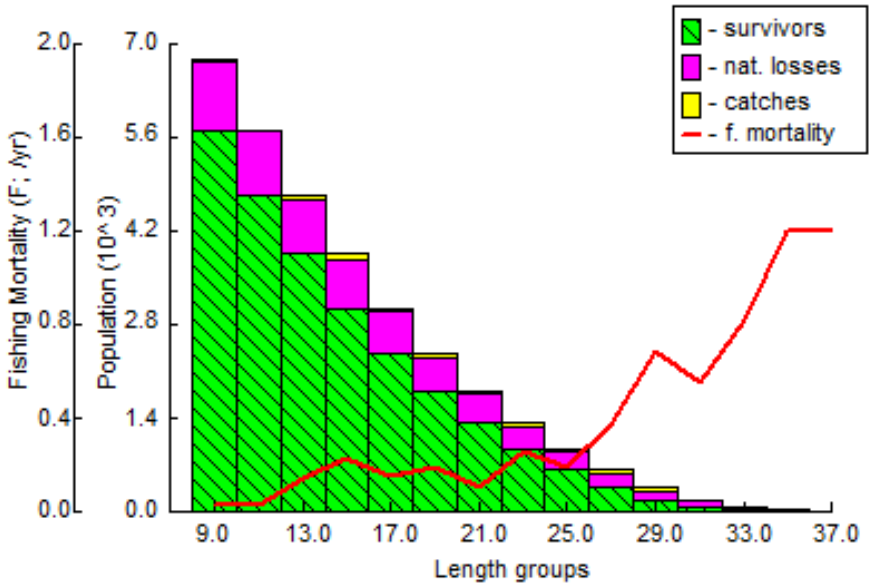

Fig. 9. Length-based virtual population analysis of *Caranx crysos* within Côte d'Ivoire's coastal waters from April 2022 to May 2023

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

The current exploitation ratio (E = 0.25) was lower than 0.5 which is the optimum level. The interception of the Lc/L∞ (0.68) and the exploitation ratio (E=0.25) of the species fell in quadrant A, implying underfishing of the stock. For this species, large fish are caught at low effort level. In order to describe fish stock status four quadrant models have been proposed by [24]. The first one is the quadrant A representing underexploited fish with large fish caught at low effort level and the interception of Lc/L∞ with (E) ratio from 0.5 to 1, and (E) from 0 to 0.5. The second is the quadrant B representing developing fishery with small fish caught at low effort level and Lc/L∞ = 0 to 0.5; E = 0 to 0.5. Afterwards, the quadrant C corresponding to eumetric fishing with large fish caught at high effort level and Lc/L∞ = 0.5 to 1; E = 0.5 to 1. Finally, the quadrant D corresponding to overexploitation with small fish caught at high effort level and Lc/L∞ = 0.5; E = 0 to 0.5. the high number of survivors of C*aranx crysos* indicated that, the stock is out of danger of any decline in the future. 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-growing species with continuous recruitment. The species stock was safe from future recruitment failure and exhibits high natural mortality rate. The exploitation ratio (0.25) was smaller than 0.5 implying that *Caranx crysos* was underexploited. These results call for a regular monitoring of the fishery

ACKNOWLEDGEMENTS

Our gratitude goes to all the fishermen at the various sampling stations for their support during data collection. We thank the anonymous reviewers for their relevant comments, which allowed us to improve an earlier version of this document.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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