International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 7 No. 1 July 2014, pp. 382-392

http://www.ijias.issr-journals.org/

Dynamics of the exploited population of *Istiophorus albicans* (Latreille, 1804, Istiophoridae) by marine artisanal fishing in Côte d'Ivoire (West Africa)

Jean-Paul Aka AGNISSAN, Abdoulaye KONE, Sylvain Kouassi KONAN, and Konan N'DA

Laboratory of Biology and Cytology Animal,
Nangui Abrogoua University,
Abidjan, Côte d'Ivoire, 02 BP 801 Abidjan 02, Côte d'Ivoire

ABSTRACT: The dynamics of the exploited population *of Istiophorus albicans* (Atlantic sailfish) from artisanal gillnet fishery was investigated based on length frequency data, using FiSAT software. Specimens were sampled from the artisanal fishery captures in the coastal waters near Abidjan (Côte d'Ivoire), from October 2009 to October 2010. Growth parameters of *I. albicans* were estimated using ELEFAN I method. The asymptotic length (L_∞), the growth rate constant (K) and the theoretical age at length zero (t_0) were estimated to be 231.6 cm fork length, 0.48 yr^{-1} and 0.49 yrs, respectively. The estimated growth performance index (Φ') of *I. albicans* was 4.41. Instantaneous of total mortality coefficient estimated by non seasonalized length converted catch curves (Z) was 1.56 yr^{-1}. Natural mortality (M) estimated by Pauly's empirical equation was 0.63 yr^{-1} and the estimated fishing mortality (F) was 0.93 yr^{-1}. The current rate of exploitation *(E)* was given as 0.60, indicating that the sailfish stock is over fished. From the analysis of probability of capture of each length class we estimated the length at first capture L_c (length at 50 % capture) to be 158.23 cm. The relative yield per recruit analysis incorporating probabilities of capture predicted the maximum exploitation rate E_{max}= 1, confirming that *I. albicans* is being overexploited.

KEYWORDS: asymptotic length, sailfish, exploitation rate, length-frequency.

1 INTRODUCTION

A major challenge facing the sustainable management of fish stocks is to ensure that stock assessments are based on accurate information and identify relevant sources of quantitative and qualitative uncertainty [1]. A few studies have investigated the population structures of some billfishes in Côte d'Ivoire. Sailfish, *Istiophorus albicans*, is a pelagic istiophorid species [2] that is fished by the artisanal technical in Côte d'Ivoire since 1988 [3]. This species is widely distributed in the tropical and temperate waters of the world [4]. In the Atlantic Ocean, sailfish occurred throughout in subtropical and tropical waters, and occasionally in Atlantic temperate waters [5]. Geographical limits based on commercial catches is approximately 40°N in the western North Atlantic, 50°N in the eastern North Atlantic, 40°S in the western South Atlantic, and 32°S in the eastern South Atlantic [5]. Sailfish are a member of the billfish family Istiophoridae that also includes marlins and spearfishes, and are highly regarded by recreational fishers for their spectacular gamefish characteristics [6]. Some reports of age and growth of sailfish caught in the Atlantic Ocean are: [7] analyzed size-frequency distribution; references [8], [9] used spines; [10], [11] analyzed otoliths; [6] used spines to estimate age and describe growth of sailfish caught in the Gulf of Arabia. Some investigations of sailfish age and growth in the Pacific Ocean are: [12] estimated sailfish growth through the size frequency of specimens caught by longline vessels in the eastern China Sea from 1952 to 1955. Reference [13], [14], [15] used the fourth spine of the dorsal fin to determine age and describe growth of fish caught in the southern part of the Gulf of California, along the Taiwan coast and Mazatlan coast, Sinaloa (Gulf of California), respectively.

Istiophoridae hold an important place among the fish caught by the artisanal fishery with drift gillnets in Ivorian coastal waters [16]. Despite the fisheries importance of *I. albicans*, its life-history parameters needed for stock assessment and management are unknown in Ivorian Exclusive Economic Zone (EEZ). The capacity of exploited populations to sustain yields is a function of their demographic characteristics such as longevity, growth and mortality rates. Quantitative estimation of these parameters, therefore, is paramount to understanding the population dynamics and associated status of exploited species [17]. For the management of fish resources, knowledge of various population parameters and exploitation level (*E*) of that population is required. Growth and mortality model parameter estimates are required for analytical fisheries management. Age determination of fish is needed in order to complete the knowledge about the abundance and fluctuations of any species [18]. Knowledge of these parameters is important in fishery management in determining whether an area is heavily fished or under-exploited to allow possible management measure to be taken [19]. Traditional methods of studying the dynamics of exploited fish stocks were mostly based on age-structured data. However, use of computers and theoretical advantages of analytical methods based on length-frequency data led to their development during the 1980s ([20], [21], [22] and widespread use in recent years (e.g. [23], [24], [25], [26]). Length-frequency data is easier to obtain than age-structured data, and correctly ageing fishes in tropical waters may be difficult due to reduced seasonal growth contrast [27] or problems in interpreting otolith growth increments [28]. Thus, length-frequency methods were used to overcome such difficulties [26].

The objective of the present study was to estimate the population parameters and exploitation level of *I. albicans* to assess the stock position of the species from ivorian coastal waters.

2 MATERIAL AND METHODS

There are many tools for assessing exploitation levels and population dynamics of a stock. Of those, FiSAT II (FAO-ICLARM Fish Stock Assessment Tools) package (http://www.fao.org/fi/statist/fisoft/fisat/index.htm) has been most frequently used for estimating population parameters of fish [29] because it needs only length–frequency data. The advantage of this technique is that within 1 year it is possible to assess any fish stock if sufficient length–frequency data is available [30]. Parameters estimates were based on length-frequency analyses (LFA). Sailfish are caught daily by an artisanal gillnet fishery and landed at the port of Abidjan. This study was carried out from October 2009 to September 2010. For each specimen, the lower jaw fork length (LJFL to the nearest centimetre) was measured. The data were then grouped into fork length classes by 10cm intervals. Subsequently the data were analyzed using the FiSAT software as explained in detail by [31]. Asymptotic length (L_∞) and growth coefficient (*K*) of the von Bertalanffy growth function (VBGF) were estimated by means of ELEFAN (Electronic LEngth Frequency ANalysis) routine using the FAO–ICLARM Package FiSAT II [31], by modal progression analysis using NORMSEP (Normal Separation) method [32]. K-scan routine [24] was conducted to assess a reliable estimate of the *K* value. ELEFAN routine of FiSAT using a non-parametric, was preferred over more sophisticated approaches, because it makes less demand on the underlying data, and especially because it can accommodate any unknown number of cohorts originating of the same year [33]. To find the best growth curve passing through the maximum number of peaks, different starting samples and starting lengths were subjected to the goodness-of-fit tests by assessing the ratio ESP/ASP. The standard version of the VBGF is defined by the equation:

$$L_t = L_\infty\left(1 - e^{-K(t-t_0)}\right)$$

where L_t is the mean length at age *t*, L_∞ the asymptotic length, *K* the growth coefficient, *t* the age of the *I. albicans* and t_0 is the hypothetical age at which the length is zero [34]. According to reference [35], empirical equation for the theoretical age (t_0) at length zero was used to obtain this parameter:

$\log_{10}(-t_0) = -0.392 - \log_{10} L_\infty - 1.038 \log_{10} \mathrm{K}$. This parameter is not calculated by the ELEFAN method.

The estimates of L_∞ and *K* were used to estimate the growth performance index (Φ') [36] of *I. albicans* using the equation:

$$\Phi' = 2\log_{10} L_\infty + \log_{10} K$$

Mortality estimates were obtained as described in reference [37]. The total mortality coefficient, *Z* (year^{-1}) was estimated by a length-converted catch curves (LCC) [31]. This method consists in pooling all the distributions while maintaining their relative importance for a single frequency distribution, which reduces the part of the sampling biases [22]. *Z* is then calculated on the descending part of this single global distribution. As *Z* is determined in a given age or size range, the estimation makes sense only within this range.

Natural mortality rate, *M* (year^{-1}) was estimated using Pauly's equation [22] based on L_∞, *K* and the mean annual environmental temperature of the species concerned, as implemented in the FiSAT II package:

$$\log_{10} \mathrm{M} = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} \mathrm{K} + 0.4634 \log_{10} \mathrm{T}$$

where *M* is the natural mortality, L_∞, the asymptotic length, *K* refers to the growth coefficient of the VBGF and *T* is the mean annual habitat temperature (◦C) of the water in which the stocks live. Here it is 28 ◦C. Once *Z* and *M* were obtained, then fishing mortality *F* (year^{-1}) was estimated using the relationship:

$F = Z - M$ where *Z* is the total mortality, *F* the fishing mortality and *M* is the natural mortality. The exploitation level (*E*) was obtained by the relationship according to reference [21]: $E = F/Z$. The parameter *E* expresses the proportion of a given cohort/population that ultimately dies due to fishing given existing exploitation pressure [38]. We used the ascending left part of the length-converted catch curve to analyse the probability of capture of each length class i [39]. This entails dividing the numbers actually sampled by the expected numbers (obtained by backward extrapolation of the straight portion of the catch curve) in each length class of the ascending part of the catch curve. The lengths at 50% capture (L_c) were estimated by plotting probabilities of capture against the mid-lengths.

The recruitment patterns of *Istiophorus albicans* were also estimated by analysis of pooled length frequency data. Restructured samples were used [40]. Recruitment pattern was presented in terms of the percentage of recruitment vs. time (months).

Length-based Virtual Population Analysis was performed on the pooled annual length frequencies of *I. albicans* from the system to estimate the mean number in the population and the overall fishing mortality by length group. Virtual population analysis (VPA) is still commonly used for assessing freshwater and marine fisheries resources because of its moderate data requirement and simple algorithm [41].

Our relative yield per recruit (*Y'/R*) and relative biomass per recruit (*B'/R*), reference [38] method as modified by [42] were executed using knife-edge selection procedure. This method assumes that fishes smaller than L_c are not captured by the gear. The predicted values were obtained by substituting the input parameters of L_c/L_∞ ($L_c$is the minimum length captured; obtained from the extrapolation of length converted catch curve) and M/K in the FiSAT II package and according to the model,

$$Y'/R = EU^{M/K}\,[1 - (3U/1 + m) + (3U^2/1 + 2m) - (U^3/1 + 3m)],$$

where $U = 1 - (L_c/L_\infty)$ is the fraction of growth to be completed by the fish after entry into the exploitation phase, $m = (1 - E)/(M/K) = (K/Z)$, and $E = F/Z$ is the exploitation rate, i.e., the fraction of mortality of the fish caused by the fishermen, *F* the instantaneous fishing mortality coefficient and L_c is the length at first capture.

The relative biomass-per-recruit (*B'/R*) was estimated from the relationship:

$$B'/R = (Y'/R)/F.$$

The *M/K* ratio was calculated with the formula according to reference [42]:

$$Ln(M/K) = -0.22 + 0.3\ Ln\ (T)$$

Then we computed E_{max} (the value of exploitation rate *E* giving the maximum relative yield-per-recruit), $E_{0.1}$ (the value of E at which marginal increase in *Y'/R* is 10% of its value at *E*=0), and $E_{0.5}$ (the value of *E* at 50% of the unexploited relative biomass-per-recruit) through the first derivative of the function according to reference [38]. All these methods were provided by the FiSAT II package.

3 Results

3.1 Growth parameters

The growth parameters L_∞ and K were obtained for the best fit with L_∞ = 231.60 cm and *K*= 0.48 year^{-1}. For these estimates through ELEFAN I the response surface (Rn) was 0.235 for the curve from the K-scan technique (fig. 1). The estimated value for the growth performance index (Φ') of *Istiophorus albicans* during the present investigation was 4.41. The estimated values for theoretical age (t_0) at length zero were - 0.491 years. Length-frequency histogram and corresponding VBGF curve are presented in fig. 2. The LJFL varied from 90 to 220 cm for females and from 80 to 200 cm for males. For females, L_∞ = 231 cm, *K*= 1 year^{-1} and score=0.318, Φ'= 4.73, $t_0$was calculated as – 0.35 years. For males, the parameters were: L_∞ = 210 cm, *K*= 0.45 year^{-1} and score=0.346, Φ'= 4.30, t_0 = - 0.51 years. Females had a better growth than males as indicated by the calculated LJFL at age (Table).

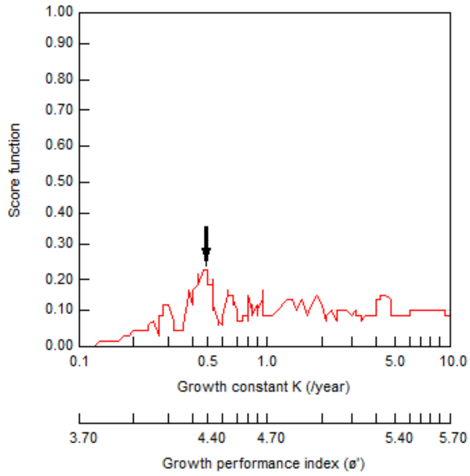

Fig. 1. K-scan routine for determining best growth curvature giving best value of asymptotic length with growth performance indices in Istiophorus albicans

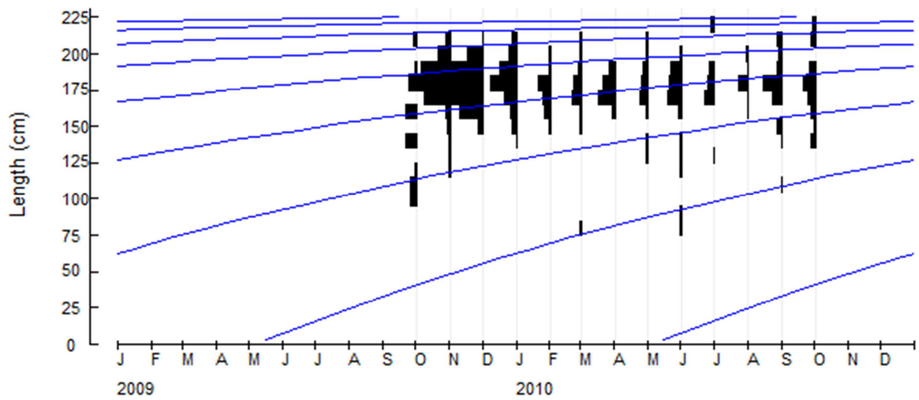

Fig. 2. Lower jaw fork length (LJFL) frequency histograms and the corresponding curves for unsexed individuals combined von Bertalanffy growth function of Istiophorus albicans in the Coastal Zone of Côte d'Ivoire

Table 1. Lower jaw fork length (LJFL) at age for females, males and combined sex calculated from the VBGF

Age (Years)	LJFL at age (cm)		
	Females	Males	Combined sex
1	171.22	103.56	118.33
2	208.97	142.13	161.51
3	222.90	166.72	188.23
4		182.41	204.76
5		192.41	214.99
6		198.78	221.32

3.2 MORTALITY PARAMETERS AND EXPLOITATION

In this study, the temperature used was 28 ◦C, the average water temperature in the 12 months in coastal waters. Using L_∞ and K estimates from ELEFAN 1 (L_∞ = 231.6 cm, K = 0.48 year^{-1}), the calculated values of the instantaneous rates of natural mortality are M = 0.63 year^{-1}.

The instantaneous rates of total mortality obtained by the length converted catch curve (LCC) was Z = 1.56 year^{-1} for 4–6 years of age (fig. 3).

This value come from the growth parameters estimated from ELEFAN routine.

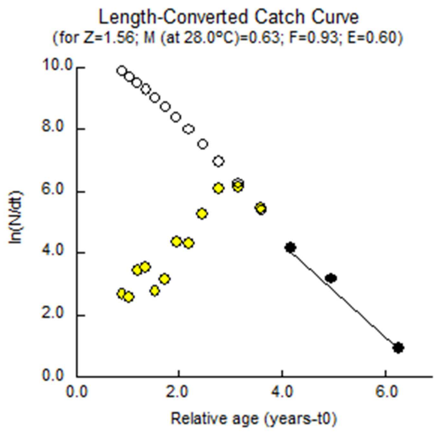

Fig. 3. Lower jaw fork length (LJFL) converted catch curve and mortality estimates for unsexed individuals combined, calculated from the parameters of the von Bertalanffy growth function of Istiophorus albicans at a mean temperature of 28◦C. Z, instantaneous rate of total mortality; M, instantaneous rate of natural mortality; F, instantaneous rate of fishing mortality; E, exploitation rate (E = F.Z^{-1}).

Based on our *Z* from the LCC, the fishing mortality (*F*) was 0.93 year^{-1}.

From the estimates of the instantaneous of fishing and total mortalities, an exploitation rate (*E*) of 0.60 was obtained for *I. albicans* from artisanal gillnet fishery, which is highest than the optimum level of exploitation (*E*=0.50). According the sex, LCC resulted in higher mortality estimates for females (Z = 1.54 year^{-1}, *M* = 1.01 year^{-1} and *F* = 0.53 year^{-1}) than for males (Z = 0.93 year^{-1}, *M* = 0.61 year^{-1} and *F* = 0.32 year^{-1}).

3.3 PROBABILITIES OF CAPTURE

The size of fish at various probabilities was presented by the fig. 4. The estimated sizes at 25, 50 and 75% probabilities of capture of *I. albicans* were respectively 149.35, 158.23 and 167.10 cm.

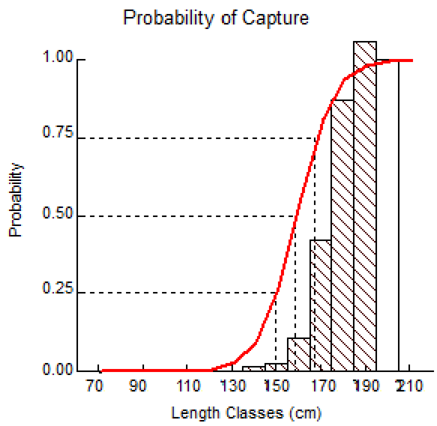

Fig. 4. Figure 4 Logistic selection curve for probability of capture of each length class of Istiophorus albicans in the Exclusive Economic Zone of the Côte d'Ivoire, L_{25}=149.35 cm, L_{50}=158.23 cm (=length at first capture Lc), L_{75}=167.10 cm

3.4 RECRUITMENT PATTERN

The recruitment patterns of *Istiophorus albicans* to the ivorian coastal waters is presented in fig. 5. This graph shows that there is one major and one minor pulsed recruitment peak in a year, both of which overlap in time to give one continuous recruitment pattern. The percentage recruitment values for the different months were: 7.08 % (January), 5.63 % (February), 8.25 % (March), 11.63 % (April), 16.80 % (May), 11.85 % (June), 10.23 % (July), 13.60 % (August), 6.36 % (September), 4.76 %

(October), 3.08 % (November) and 0.0 % (December). The highest recruitment period occurred from March to August with a large peak in May, accounting for 16.80 %.

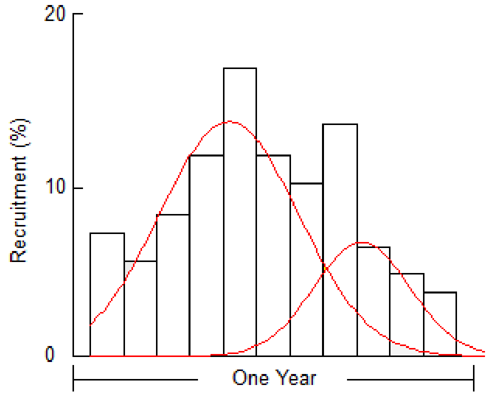

Fig. 5. Recruitment pattern of Istiophorus albicans from the artisanal fishery captures in the coastal waters near Abidjan (Côte d'Ivoire)

3.5 VIRTUAL POPULATION ANALYSIS

Virtual Population Analysis performed of *I. albicans* indicated that the minimum and the maximum fishing mortalities were recorded for the mid-lengths 80 and 190 cm, respectively (fig. 6). At first, fishing mortality was inconsiderable and constant. The peak was obtained with 1.188 year^{-1}.

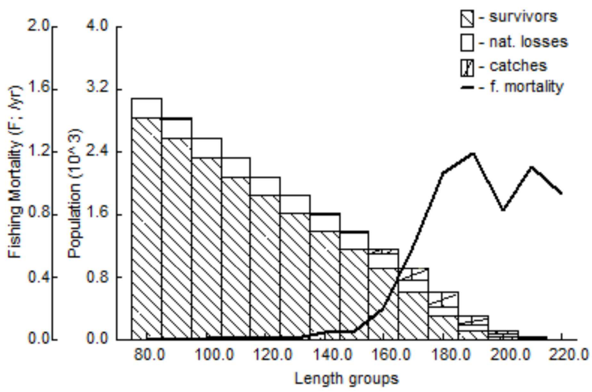

Fig. 6. Length-based Virtual Population Analysis Istiophorus albicans

4 RELATIVE YIELD PER RECRUIT AND RELATIVE BIOMASS PER RECRUIT

The fraction of growth to be completed by the fish after entry into the exploitation phase (*U*) was 0.32. Two dimensional relative yields per recruit prediction models incorporating probabilities of capture are given in fig. 7 and the isopleths diagram are given in fig. 8. The relative yield per recruit (*Y'/R*) increases up to maximum and then stabilizes. The knife edge selection procedure for the analysis of relative yield per recruit (*Y'/R*) gave a predicted value of 1.00 (E_{max}). The computed current exploitation rate (*E*) of 0.60 is slightly lower the predicted $E_{max}$of 1.00. The exploitation rate at which marginal increase occurred in the relative yield per recruit was 10% of its value at *E*=0, whereas ($E_{0.1}$) was 1.00. The exploitation rate ($E_{0.5}$), which, corresponds to 50% of the virgin (i.e., the unexploited stock) relative biomass per recruit was 0.42. The mean ratio of length at first capture (L_c) and asymptotic length (L_∞) was 0.68, while that of natural mortal (*M*) and growth rate (*K*) was 2.18.

According to the isopleths diagram (fig. 8), the optimum values of L_c/L_∞ to obtain optimum exploitation rate was between 0.50 and 0.70. It is a simulation of the response of yield per recruit of *I. albicans* in the sea to changes in length at first capture L_c and exploitation rate *E* over a wide range of values.

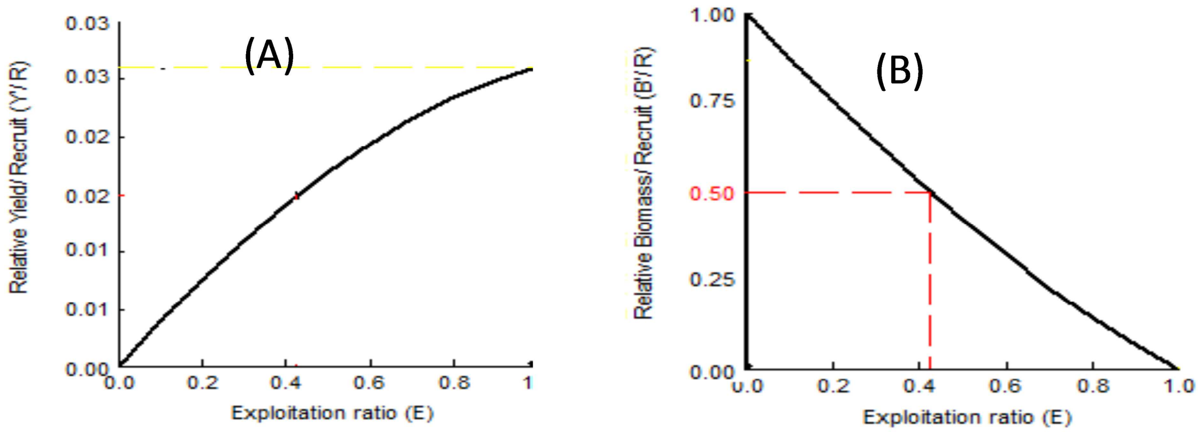

Fig. 7. ***(A) Relative yield per recruit and (B) relative biomass per recruit for Istiophorus albicans as computed using knife edge recruitment method. Input parameters: L_c/L_∞=0.683, M/K=2.18. Output parameters: E_{max}=1.00, $E_{0.1}$=1.00, $E_{0.5}$=0.42***

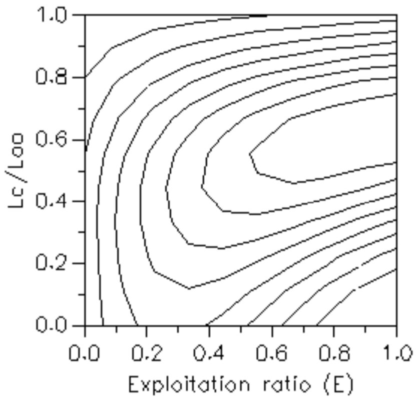

Fig. 8. ***Yield isopleths for Istiophorus albicans. The yield contours predict the response of relative yield-per-recruit of the fish to changes in L_c (length at first capture) and E (exploitation rate). L_c/L_∞ values represent varying scenarios equivalent to a change in mesh size and E corresponds to changing levels of F/Z. The dotted line is the actual computed value of the critical ratio L_c/L_∞ =0.68***

5 DISCUSSION

In tropical and sub-tropical waters, despite the difficulty in determining age of fish, unfortunately the dynamic pool models have been under-utilized for defining management strategies in fisheries. However, with the development of the length-based stock assessment methodologies, it is possible to investigate population dynamics of fish stocks in tropical waters [24].

The asymptotic length L_∞ calculated by the ELEFAN routine was 231.6 cm. The ranges of L_∞ with a wide range of K parameters were analysed to determine the optimum pairs of growth constants with best fit (maximum Rn, score). Usually, the Rn value range between 0 and 1 in the ELEFAN-FiSAT package. The oscillation parameter (C) and winter point (WP) were assumed to be 0 as it is a tropical species. L_∞ is the largest theoretical mean length that a species could attain (granted it grows throughout life) in its habitat given the ecological peculiarities of that environment, and K is the speed it grows towards this final size. Fin spine ageing is the most common technique used to estimate age and growth parameters of large pelagic billfishes from the families Istiophoridae and Xiphiidae [43], [15]. Although, our tool for the calculation of growth parameters is based on the analysis of length-frequency data (FiSAT II), ours computed values of *K* = 1.0 year¯1 for females, 0.45 $year^{-1}$ for males and 0.48 $year^{-1}$ for combined sex for *I. albicans* in the ivorian EEZ were greatly higher than the K values recorded in the literature (0.145 $year^{-1}$ for females and 0.115 $year^{-1}$ for males, [14]; 0.29 $year^{-1}$ for females and 0.42 $year^{-1}$ for males, [6]; 0.18 $year^{-1}$ for females and 0.16 $year^{-1}$ for males, [15]). This difference could be due to spatial differences in growth, the range of ages and sizes used in the analysis, or the form of the growth model applied [14]. Comparisons of growth rates of populations and species are important in fisheries science and ecology for a range of management and academic reasons [23]. However, there is no straight forward way to undertake such comparisons. One stock can grow faster than the other when young and slower than the other when older. Thus, growth comparison is a multivariate problem that must take into consideration both the growth rate (K) and the asymptotic size (L_∞). The index of growth performance (Φ') is a useful tool for comparing the growth curves of different populations of the same species and/or of different species belonging to the same order [44]. The growth performance index (Φ') calculated in this study was equal to 4.41 for combined sex, 4.73 for females and 4.30 for males. Despite the diverse source of data (length frequency data and spines) and the different computational methods used for obtaining $L_\infty$and K, the overall growth performance indices are very similar to each other ([14], Φ'=3.99 for the females and 3.86 for the males; [6], Φ'=4.02 and 4.03 respectively for the females and for the males; [15], Φ'=4.05 for the females and 4.02 for the males). All fish of a given length, including the law of growth in length is known, can be assigned a theoretical age t and therefore a date of birth. The month in which births were the most abundant is May. Length converted catch curve for Istiophorus albicans from Ivorian Exclusive Economic Zone (EEZ) suggested short life expectancy (6 years). Reference [7] estimated age and growth of western Atlantic sailfish and suggested rapid growth and short (4 year) life expectancy. Also, [7], [12] used length frequency analysis and concluded that sailfish are a very fast growing and short-lived species. Reference [8] reported age classes (without validation) up to 8 years by enumerating incremental circuli (bands) in dorsal fin spines, but indicated that enlargement of the spine's vascular spongy core eroded the early growth bands in older individuals. For the same area, [9] indicated differences in size, mostly when fish were 2 years old; females grew faster than males and had greater variation in size and weight. [13] reported no difference in growth between sexes in the southern Gulf of California. Along the coast of Taiwan, [14] mentioned size differences between genders, females (80–232 cm LJFL) being significantly larger than males (78–221 cm LJFL). In the Arabian Gulf, [6] specifies that females were larger (129–199 cm LJFL) than males (125–177 cm LJFL). [15] observed differences in the growth between sexes and in observed lengths. Female sailfish showed a faster growth rate than males. In the present study, females were larger (90–220 cm LJFL) than males (80–200 cm LJFL). The length-at-age estimates presented in Table confirmed that females had a better growth than males.

Seasonal growth does not appear to be an adequate description of growth of I. albicans stocks, in spite of the presence of a seasonal upwelling phenomenon in the area [23]). The instantaneous natural mortality coefficient M, apart from indicating the fraction of death caused by all possible causes except fishing, is a necessary input in the computation of many models in fish population dynamics study. However, direct and reliable estimate of M in an exploited population is difficult to obtain. Among fish, natural mortality is found to be correlated with reproductive success [45]. Generally M/K is used as an index for checking the validity of M and K values estimated by different methods and it is known to range from 1.5 to 2.5 [38]. The M/K ratio obtained in the present study (2.18) was well known within this range. The higher fishing mortality (0.93 year^{-1}) versus natural mortality (0.63 year^{-1}) observed for I. albicans indicates that the fisheries are developed. The model of [22] for M estimation was derived from data obtained from 175 different fish stocks distributed in 84 species, both freshwater and marine, and ranging from polar to tropical waters. Ipso facto, the model should yield reliable results. As a rule of thumb, if Z/K ratio < 1, then the population is growth-dominated; if it is > 1 then it is mortality-dominated; if it is 1 then mortality balances growth in such population according to reference [46]. Thus in this investigation, the Z/K value of 3.25 that implies this population is highly mortality-dominated. Also, this result suggested a high level of exploitation.

The recruitment pattern established in this study revealed an all year round recruitment with two peaks (one major and the other secondary).

Virtual population analysis (VPA) has been widely applied to estimate the abundance of commercial fish stocks since its development [47]. This method is an estimation technique that reconstructs the historical abundance of a fish stock by accounting for the catch and natural deaths accruing each year to the cohorts comprising the stock. The peak of fishing mortality (1.2 / year) observed (fig. 6) indicates fishing pressure on individuals lengths 160 cm and 200 cm.

The maximum exploitation rate (E_{max}), which gives maximum relative yield per recruit, is estimated at 1 and greatly differs from the exploitation rate (0.60) estimated in this study. This further suggests that the stock of *I. albicans* is probably being over fished both in terms of yield per recruit and biomass per recruit as implemented by [48]. This is based on the assumption that in an optimally exploited stock, natural and fishing mortalities should be equal or E = 0.5 [48]. This implies that the fisheries are developed and the fishing is eumetric with large fish being caught at high effort level. However, the ratio L_c/L_∞ according to reference [49], 0.68 > 0.5 indicates that captures dominated by tall length fishes.

In the relative yield per recruit and biomass per recruit prediction models the descending curves showed decrease in biomass / recruit (*B'/R*) as exploitation ratio increased. The other curve showed increase in yield / recruit (*Y'/R*) with increase in exploitation ratio (*E*) up to E_{max}. $E_{0.5}$ is the value of *E* associated with a 50 % reduction of the biomass (per recruit) in the unexploited stock. The present current estimated exploitation rate (*E*) of 0.60 is slightly lower than the predicted maximum value of 1.00, computed yield per recruit (knife edge selection procedure) analysis. The implication is that the stock is overexploited. A stock assessment provides decision makers with much of the information necessary to make reasoned choices. A fishery stock assessment describes the past and current status of a fish stock.

6 CONCLUSION

This study aims at to estimate the growth parameters and to highlight the effect of fishing on the stock of Atlantic sailfish EEZ Ivorian using the FiSAT software. Females had a better growth than males. Recruitment is continuous throughout the year and is marked by a large peak in May. A large predominance of mortality on growth in the species and fishing mortality on natural mortality exists. The fisheries are developed and fishing is eumetric with large fish being caught at high effort level. The sailfish stock is overfished.

Management recommendations: This study recommends that the current exploitation rate be reduced. It is so necessary to reduce fishing mortality. Also, it is important to create policies for Atlantic sailfish.

REFERENCES

[1] R. J. Marriott, D. J. Adams, N. D. C. Jarvis, M. J. Moran, S. J. Newman and M. Craine, "Age-based demographic assessment of fished stocks of *Lethrinus nebulosus* in the Gascoyne Bioregion of Western Australia," *Fisheries Management and Ecology*, vol. 18, pp. 89–103, 2011.

[2] Schneider W., *FAO species identification sheets for fishery purposes. Fields guide to the commercial marine resources of the Gulf of Guinea*. FAO Regional Office for Africa, Rome, 1992.

[3] K. N'Da and G. R. Dédo, *Exploitation du voilier Istiophorus albicans (Istiophoridae, Latreille, 1804) par la pêcherie artisanale maritime en Côte d'Ivoire*, SCRS, 2008.

[4] Beardsley, Jr. G. L., Merrett, N. R., and Richards, W. J., *Synopsis of the biology of the sailfish Istiophorus platypterus* (Shaw and Nodder, 1791), In: R. S. Shomura, and F. Williams (Eds.), Proceedings of the International Billfish Symposium, Part 3. Species Synopses, Kaliua-Kona, Hawaii, NOAA Technical Report, pp. 95–120, 1975.

[5] Nakamura I., *FAO Species Catalogue, Billfishes of the World.* FAO Fisheries Synopsis, vol. 5, no. 125, 1985.

[6] J. P. Hoolihan, "Age and growth of Indo-Pacific sailfish, *Istiophorus platypterus*, from the Arabian Gulf," *Fisheries Research*, vol. 78, pp. 218–226, 2006.

[7] D. P. de Sylva, "Studies on the age and growth of the Atlantic sailfish, *Istiophorus americanus* (Cuvier), using length–frequency curves," *Bulletin of Marine Science of the Gulf and Caribbean*, vol. 7, pp. 1–20, 1957.

[8] J. W. Jr. Jolley, "The Biology and Fishery of Atlantic Sailfish *Istiophorus platypterus*, from Southeast Florida," *Florida Marine Research Publications*, vol. 28, pp. 1–31, 1977.

[9] Hedgepeth, M. and Jolley, J. W. Jr., *Age and growth of sailfish Istiophorus platypterus, using cross sections from the fourth dorsal fin spine*, In: E. D. Prince, and L. M. Pulos (Eds.), Proceedings of the international workshop on age determination of oceanic pelagic fishes: Tunas, billfishes and sharks, NOAA Technical Report, pp. 131–136, 1983.

[10] R. L. Radtke and J. M. Dean, "Morphological features of the otoliths of the sailfish, *Istiophorus platypterus*, useful in age determination," *Fishery Bulletin*, vol. 79, 360–367, 1981.

[11] E. D. Prince, D. W. Lee, C. A. Wilson and J.M. Dean, "Longevity and age validation of a tag-recaptured Atlantic sailfish, *Istiophorus platypterus*, using dorsal spines and otoliths," *Fishery Bulletin*, vol. 84, pp. 493-502, 1986.

[12] T. Koto and K. Kodama, "Some considerations on the growth of marlins, using size-frequencies in commercial catches. I. Attempts to estimate the growth of sailfish,"*Fisheries Research Laboratory*, vol. 15, pp. 97-108, 1962.

[13] R. M. Alvarado-Castillo and R. Felix-Uraga, "Growth of *Istiophorus platypterus* (Pisces: Istiophoridae) from the mouth of the Gulf of California," *Revista de Biología Tropical*, vol. 46, pp. 115–118, 1998.

[14] W. C. Chiang, C. L. Sun and S. Z. Yeh, "Age and growth of sailfish (*Istiophorus platypterus*) in waters off eastern Taiwan," *Fishery Bulletin*, vol. 102, no. 2, pp. 251–263, 2004.

[15] J. S. Ramírez-Pérez, C. Quiñonez-Velázquez, L. A. Abitia-Cardenas and F. N. Melo-Barrera, "Age and growth of sailfish *Istiophorus platypterus* (Shaw in Shaw and Nodder, 1792) from Mazatlan, Sinaloa, Mexico," *Environmental Biology of Fishes*, vol. 92, no. 2, pp. 187–196, 2011.

[16] Y. N. N'Goran and J. B. Amon Kothias, *Captures des Istiophoridés par la pêcherie artisanale ivoirienne et effort de pêche de 1988 à 2004*. SCRS, 2006.

[17] E. Grandcourt, T. Z. Al Abdessalaam, F. Francis and A. Al Shamsi, "Age-based life history parameters and status assessments of by-catch species (*Lethrinus borbonicus*, *Lethrinus microdon*, *Pomacanthus maculosus* and *Scolopsis taeniatus*) in the southern Arabian Gulf," *Journal of Applied Ichthyology*, vol. 26, pp. 381–389, 2010.

[18] A. El-Haweet, M. Hegazy, H. Abuhatab and E. Sabry, "Validation of length frequency analysis for *Boops boops* (Bogue) growth estimation," *Egyptian Journal of Aquatic Research*, vol. 31, no. 1, pp. 399–408, 2005.

[19] N. Niamaimandi, A. B. Arshad, S. K. Daud, R. C. Saed and B. Kiabi, "Population dynamic of green tiger prawn, *Penaeus semisulcatus* (De Haan) in Bushehr coastal waters, Persian Gulf," *Fisheries Research*, vol. 86, pp. 105–112, 2007.

[20] R. Jones, *Assessing the effects of changes in exploitation pattern using length composition data (with notes on VPA and cohort analysis)*. FAO Fisheries Technical Paper, 1984.

[21] Gulland J. A., *Length-based methods in fisheries research: from theory to application*, In: D. Pauly, and G. R. Morgan (Eds.), Length-based methods in fisheries research, ICLARM Conference Proceedings, Manila, Philippines, pp. 335–342, 1987.

[22] Pauly D. and Morgan G. R., *Length-based methods in fisheries research*, ICLARM Conference Proceedings, Manila, Philippines, 1987.

[23] C. B. García and L. O. Duarte, "Length-based estimates of growth parameters and mortality rates of fish populations of the Caribbean Sea," *Journal of Applied Ichthyology*, vol. 22, pp. 193–200, 2006.

[24] S. Dadzie, F. S. Abou-Seedo and J. Moreau, "Population dynamics of *Parastromateus niger* in Kuwaiti waters as assessed using length–frequency analysis," *Jounal of Applied Ichthyology*, vol. 23, pp. 592–597, 2007.

[25] A. García Vásquez, J. C. Alonso, F. Carvajal, J. Moreau, J. Nuñez, J. F. Renno, S. Tello, V. Montreuil and F. Duponchelle, "Life-history characteristics of the large Amazonian migratory catfish *Brachyplatystoma rousseauxii* in the Iquitos region, Peru," *Journal of Fish Biology*, vol. 75, pp. 2527–2551, 2009.

[26] Y. J. Lin and W. N. Tzeng, "Vital population statistics based on length frequency analysis of the exploited Japanese eel (*Anguilla japonica*) stock in the Kao-Ping River, southern Taiwan," *Journal of Applied Ichthyology*, vol. 26, pp. 424–431, 2010.

[27] S. E. Campana, "Accuracy, precision and quality control in age determination, including a review of the use and abuse of age validation methods," *Journal of Fish Biology*, vol. 59, pp. 197–242, 2001.

[28] B. Morales-Nin and J. Panfili, "Seasonality in the deep sea and tropics revisited: what can otoliths tell us?" *Marine and Freshwater Research*, vol. 56, pp. 585-598, 2005.

[29] S. M. N. Amin, M. A. Rahman, G. C. Haldar, M. A. Mazid and D. Milton, "Population dynamics and stock assessment of *Hilsa shad*, *Tenualosa ilisha* in Bangladesh," *Asian Fisheries Science*, vol. 15, pp. 123–128, 2002.

[30] S. M. Al-Barwani, A. Arshad, S. M. Nurul Amin, S. B. Japar, S. S. Siraj and C. K. Yap, "Population dynamics of the green mussel *Perna viridis* from the high spat-fall coastal water of Malacca, Peninsular Malaysia," *Fisheries Research*, vol. 84, no. 2, pp. 147–152, 2007.

[31] F. C. J. Gayanilo, P. Sparre and D. Pauly, *FAO-ICLARM Stock Assessment Tool II (FiSAT II), User's Guide, revised version*, Rome, 2005.

[32] V. Hasselblad, "Estimation of parameters for a mixture of normal distributions," *Technometrics*, vol. 8, pp. 431–444, 1966.

[33] M. L. D. Palomares and D. Pauly, "The growth of jellyfishes," *Hydrobiologia*, vol. 616, pp. 11–21, 2009.

[34] S. J. Newman, "Growth, age estimation and preliminary estimates of longevity and mortality in the moses perch, *Lutjanus russelli* (Indian ocean form), from continental shelf waters off north-western Australia," *Asian Fisheries Science*, vol. 15, pp. 283–294, 2002.

[35] D. Pauly, *Theory and management of tropical multispecies stocks*. ICLARM Studies and Reviews, 1979.

[36] D. Pauly, "Tropical fishes: patterns and propensities," *Journal of Fish Biology*, vol. 53(Suppl A), pp. 1–17, 1998.

[37] J. Moreau and B. Nyakageni, "*Luciolates stapperssi* in Lake Tanganyika. Demographical status and possible recent variations assessed by length frequency distributions," *Hydobiologia*, 232, 57–64, 1992.

[38] R. J. H. Beverton and S. J. Holt, *Manual of methods for fish stock assessment*, Part 2, Tables of yield functions, FAO Fisheries Technical Paper, vol. 38, 1966.

[39] P. Sparre, *Computer programs for fish stock assessment: Length-based Fish Stock Assessment (LFSA) for Apple II Computers*. FAO Fisheries Technical Paper, vol. 101(Suppl 2), 1987.

[40] J. Moreau and F. X. Cuende, "On improving of resolution of the recruitment pattern of fishes," *ICLARM Fishbyte*, vol. 9, pp. 45–46, 1991.

[41] Y. Chen, Y. Jiao, C. L. Sun and X. Chen, "Calibrating virtual population analysis for fisheries stock assessment," *Aquatic Living Resources*, vol. 21, pp. 89–97, 2008.

[42] Pauly, D.and Soriano, M. L., *Some practical extension to the Beverton and Holt's relative yield per recruit model*, In: J. L. Maclean, L. B. Dizon, and L. V. Hosillo (Eds.), The First Asian Fisheries Forum, Asian Fisheries Society, Manila, Philippines, pp. 491–496, 1986.

[43] R. K. Kopf, K. Drew and R. L. Jr. Humphreys, "Age estimation of billfishes (*Kajikia* spp.) using fin spine cross-sections: the need for an international code of practice," *Aquatic Living Resources*, vol. 23, pp. 13-23, 2010.

[44] P. Sparre, E. Ursin and S. C. Venema, *Introduction to tropical fish stock assessment*. Part 1. FAO Fisheries Technical Paper, vol. 306, pp. 1–376, 1987.
[45] D. R. Gunderson, "Trade off between reproductive effort and adult survival in oviparous and viviparous fishes," *Canadian Journal of Fisheries and Aquatic Sciences*, vol. 54, pp. 990–995, 1997.
[46] J. P. Barry and M.J. Tegner, "Inferring demographic processes from size-frequency distributions: simple models indicate specific patterns of growth and mortality," *Fishery Bulletin*, vol. 88, pp. 13–19, 1990.
[47] H. Yamaguchi and T. Matsuishi, "Effects of sampling errors on abundance estimates from virtual population analysis for walleye Pollock in northern waters of Sea of Japan," *Fisheries Science*, vol. 73, pp. 1061–1069, 2007.
[48] Gulland, J. A., *The fish resources of the oceans*. Fishing New Books, London, 1971.
[49] Pauly, D., and Moreau J., *Méthodes pour l'évaluation des ressources halieutiques*. Collection de l'INP de Toulouse. Cépaduès-éditions. Toulouse, France, 1997.