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Original Article

Growth and exploitation parameters of the West African ladyfish *Elops lacerta* Valenciennes, 1847 in the Ivorian's exclusive economic zone, Côte d'Ivoire

Angelina Gbohono Loukou*[1,2], Soumaïla Sylla[1], Olivier Assoi Etchian[1], Ida Akissi Konan[1], Célestin Boua Atse[2]

[1]University Nangui Abrogoua, Formation Unit and Research of Nature Sciences, Laboratory of Biology and Animal Cytology, 02 BP 801 Abidjan 02, Côte d'Ivoire
[2]Centre of Oceanological Research, B.P.V 18 Abidjan, Côte d'Ivoire.

Abstract: West African ladyfish, *Elops lacerta* is a pelagic fish present in the coastal waters of West Africa from Mauritania to Angola. This study is conducted to provide data on the growth and exploitation parameters of *E. lacerta* important for the management and conservation of this species in the Ivorian's Exclusive Economic Zone (EEZ). These parameters were estimated by the indirect method using length frequency data collected in the Ivorian's EEZ during January 2019 to December 2020. Monthly length frequency data were analyzed by FiSAT II software. A total of 865 specimens were examined. The growth parameters from von Bertalanffy growth function (VBGF) estimations were $L\infty = 60.38$ cm fork length, $K = 0.39$ year^{-1}, and $t_0 = 0.46$ year. The estimated potential longevity (t_{max}) was 7.69 years. The exploitation parameters showed that the total mortality rate (Z), natural mortality rate (M) at 28.35°C and fishing mortality rate (F) were 1.57 year^{-1}, 0.80 year^{-1} and 0.77 year^{-1}, respectively. The exploitation rate (E = F/Z) was 0.49. This value is lower than the optimal exploitation value (E_{50}), thus expressing a case of under-exploitation of the species in the Ivorian's EEZ. The size of first capture (Lc) below the size of first sexual maturity (FL_{50}) and the optimal size of capture (L_{opt}) requires the implementation of an adequate mesh size management policy to allow fish to reproduce several times before being captured.

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Introduction

Studies on the growth and exploitation parameters of fishes are received a major impetus in recent years owing to the need to provide an adequate scientific basis for conservation of the resources. Several methods are used to determine the growth of fish, methods direct by the mark-recapture technique using chemical marks or external or internal implants (Dortel et al., 2014; Hamel et al., 2014; Eveson et al., 2015) and direct reading of hard structures (spines, otoliths, scales and vertebrae (Campana, 2014; Kumbar and Lad, 2016; Heimbrand et al., 2020; Izzo et al., 2021). The method indirect estimate based of length distribution data over time (Gayanilo et al., 2002; Panfili et al., 2002). Growth is an important aspect of the biology and life history of fish. Information on biology and population dynamics are essential for monitoring the rational exploitation and management of the stock.

Elops lacerta is a teleost fish of the family Elopidae. It is pelagic species found in the East Atlantic, precisely in the West African coastal waters, from Mauritania to Angola (IUCN, 2019). It lives at depths between 1 and 50 m in marine environment and it is a migratory species whose biological cycle is divided into three phases. The larval and juvenile phases take place in brackish water or in estuaries (marine, intermediate and freshwater estuary). Then, individuals in early sexual maturity migrate to the marine environment to continue growing and reproducing (Hie-Daré, 1982; N'Dour, 2007; Lawson and Aguda, 2010; Abdul et al., 2015). Most of the works on *E. lacerta* have been done in lagoon environments (Hie-Daré, 1982; Ikomi, 1994; Ecoutin and Albaret, 2003; Konan et al., 2007; Niyonkuru et al., 2007; Lawson and Aguda, 2010; Adams et al., 2013; Abdul et al., 2015; Abdul et al., 2016; Eyi et al., 2016; N'Dour et al., 2017; Coulibaly et al., 2018;

*Correspondence: Angelina Gbohono Loukou
E-mail: loukouangelinna@gmail.com
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Dienye et al., 2021). In Côte d'Ivoire, few studies have been carried out in the lagoon environment i.e. there are none in the marine environment. Therefore, the objective of this study is to provide data on the growth and exploitation parameters of *E. lacerta* for its management and conservation in the ivorian's Exclusive Economic Zone (EEZ) using length frequency data.

Materials and Methods

Study area: Côte d'Ivoire is located in West Africa in the intertropical zone belonging to the vast Gulf of Guinea ecosystem (Bassou, 2016). The Ivorian fishing area is located between latitudes 4°N and 5°N and longitudes 2.30°W and 8°W (Fig. 1). Fishing zone concerns the Exclusive Economic Zone (EEZ) with a limit of 200 nautical miles (370.4 Km). The study area has four marine seasons (Assan et al., 2018): a short cold season (SCS) in January to February (minor upwelling), a long warm season (LWS) between March to June, a long cold season (LCS) from July to October (major upwelling) and a short warm season (SWS) in November to December. The variation of salinity at the surface of the Ivorian Gulf is influenced by the intensity of freshwater inflow and rainfall. Two periods of high desalination are recorded, the first from February to March and the second from May to June (Gougnon et al., 2018).

Data collection: The specimens were obtained during January 2019 to December 2020 from the commercial catches at Abidjan fishing harbour from the industrial trawlers operating in the EEZ. Once a month, at least 30 individuals were collected and rapidly transported to Center of Oceanological Research laboratory (CRO). The fork lengths were measured on the 865 specimens were grouped by month. After measurements, dissection of each specimen was performed in the laboratory. The sex was determined and the different stages of sexual maturity were identified according to the macroscopic scale of Fontana (1969), based on color, consistency, volume, shape, vascularity, oocyte size and the presence or absence of milt in the gonads. The class interval was determined according to Sturge's rule (Scherrer, 1984). Mature individuals were grouped by size class and the percentage of the mature individuals for each size class calculated. The size of first sexual maturity (FL_{50}) was determined by sex and for the whole population (sex combined) according to Ghorbel et al. (1996).

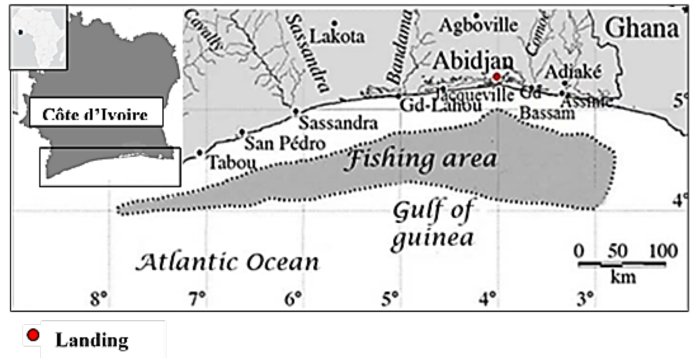

Figure 1. Fishing zone of Côte d'Ivoire.

Data Analysis: The size frequencies were used to create a dynamic cross-tabulation table using Excel software. The data were analysed using FiSAT II software (FAO-ICLARM Stock Assessment Tools) (version 1.2.2) (Gayanilo, 1996).

Growth parameters: The parameters of the von Bertalanffy Growth function (VBGF), asymptotic length ($L\infty$) and growth coefficient (K) were estimated by means of ELEFAN-I (Electronic LEngth Frequency ANalysis). Growth in length was studied using the Von Bertalanffy model (1938). This model describes the growth in length by the function:

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

Where $L\infty$ = asymptotic length (cm), K = growth coefficient ($year^{-1}$), t; t_0 = age at zero length (year) and t = age (year). Pauly (1979) empirical equation for the theoretical age at length zero (t_0) was used to obtain this parameter as:

$$Log(-t_0) = 0.392 - 0.275\ LogL\infty - 1.038\ LogK$$

Where t_0 = age at zero length (year), $L\infty$ = asymptotic length (cm) and K = growth coefficient ($year^{-1}$). The maximum age was calculated by the formula of Pauly (1980a):

$$t_{max} = \frac{3}{K}$$

Where tmax = maximum age (year) and K = growth coefficient ($year^{-1}$). The asymptotic weight ($W\infty$) was determined using the values of the intercept, the asymptotic length and the allometry coefficient in the following formula:

$$W\infty = aL\infty^{b}$$

Where W∞ = asymptotic weight (g), a = intercept, L∞ = asymptotic length (cm) and b = allometry coefficient. The Growth performance index (Ø') population in terms of length was determined using the index of Pauly and Munro (1984) and compared the index of Baijot and Moreau (1997):

$$Ø' = \text{Log}\ (\text{K}) + 2\ \text{Log}\ (\text{L}\infty)$$

Where Ø' = growth performance index, K = growth coefficient ($year^{-1}$) and L∞ = asymptotic length (cm).

Exploitation parameters: The natural mortality (M) was calculated as a function of asymptotic length (L∞), growth constant (K) and mean environmental temperature (T°C) (Pauly, 1980b):

$$Log\ M = -0.0066 - 0.279 Log\ L\infty + 0.6543\ \text{Log K} + 0.4634\ \text{Log T}$$

Where M is natural mortality, L∞ = asymptotic length (cm), K = growth coefficient ($year^{-1}$) and T = the mean habitat water temperature (°C). Total mortality rate (Z) and the fishing mortality (F) was computed using the relationship:

$$\text{Z} = \text{F} - \text{M}$$

According to Barry and Tegner (1989), the ratio of total mortality to the growth coefficient is an indicator of the state of the population. If, Z/K < 1: There is a predominance of growth over mortality in the population. If, Z/K > 1: mortality predominates over growth. If, Z/K = 1: the population is in a state of equilibrium. Therefore, the M/K ratio should be between 1.5 and 2.5 (Beverton and Holt, 1959). The catch probability provides a direct estimate of the length at which 25, 50 and 75% of fish would be vulnerable to the fishing gear (Pauly, 1984) through analysis of the catch curve converted to length. The optimal catch size is estimated for a given cohort according to the following equation Beverton (1992):

$$L_{opt} = L\infty \frac{3}{3 + M/K}$$

Where L_{opt} = optimal catch size (cm), M = natural mortality ($year^{-1}$) and K = growth coefficient ($year^{-1}$). The annual recruitment pattern was produced from routine of Moreau and Cuende (1991). This routine reconstructs the recruitment pulses from time series of length-frequency data to determine the number of pulses per year and the relative strength of each pulse (Gayanilo et al., 2005). The exploitation rate (E) was quotient between fishing mortality and total mortality (Beverton and Holt, 1966):

$$E = F/Z$$

Where F = fishing mortality ($year^{-1}$) and Z = total mortality ($year^{-1}$). The ratio between natural mortality (M) and fishing mortality (F) corresponds to a level of exploitation of the species stock. Three types of categories defined the level of exploitation of a species. According to Gulland (1971), when the exploitation rate (E) is equal to 0.5, the exploitation of the stock is optimal (F = M). An exploitation rate below 0.5 describes a level of under-exploitation of the species (F<M). On the other hand, when the exploitation rate is less than 0.5, it indicates overexploitation (F>M). From the analysis, E_{max}, $E_{0.1}$ and $E_{0.5}$ were also estimated from the modified form of Beverton and Holt (1964) relative yield per recruit (Y'/R) analysis by Pauly and Soriano (1986). Relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) values were carried out using the FISAT II software.

Results

Growth parameters of *E. lacerta:* A total of 865 specimens (494 males and 371 females) were analysed. The size of first sexual maturity size was 26.56 cm (FL_{50}) for males, 33.11 cm ($FL_{.}$) for females and 27.75 cm for population in the Ivorian's Exclusive Economic Zone (Fig. 2). The smallest mature individual is 23.4 cm. The fish sampled were classified into three groups, juveniles (sizes < 23.4 cm), sub-adults (23.4 cm < sizes < FL_{50}) and finally adult (sizes ≥ FL_{50}).

The restructured Von Bertalanffy growth curve and length frequency plot (Fig. 3) and the estimation growth coefficient have made it possible to determine the values of the asymptotic length and the growth coefficient. The von Bertalanffy growth model for *E. lacerta* in the Ivorian's Exclusive Economic Zone is described as $Lt = 60.38\ (1 - e^{(-0.39\ (t - to))})$. The values

Table 1. Growth parameters of *Elops lacerta*.

Growth Parameters	FL min-max	L∞	K	Rn	t_0	t_{max}	Ø'	W∞
Population	20-57	60.38	0.39	0.176	0.458	7.69	3.153	2269.86

FL: Fork length (cm); L∞: asymptotic length (cm); K: growth coefficient ($year^{-1}$); Rn: Response surface; t_0: age at zero length (year); t_{max}: maximum age (year); Ø': growth performance index; W∞: asymptotic weight (g).

Table 2. Exploitation parameters of *Elops lacerta*

Exploitation Parameters	M	F	E (F/Z)	Lc	L_{opt}	E_{10}	E_{50}	E_{max}
Population	0.80	0.77	0.49	25.28	35.86	0.57	0.34	0.673

M: Natural mortality; F: Fishing mortality; E: Exploitation rate; Lc: size at length at first capture; L_{opt}: Optimal catch size; E_{10}: Exploitation level at 10%; E_{50}: Exploitation level at 50%; E_{max}: Exploitation level maximal.

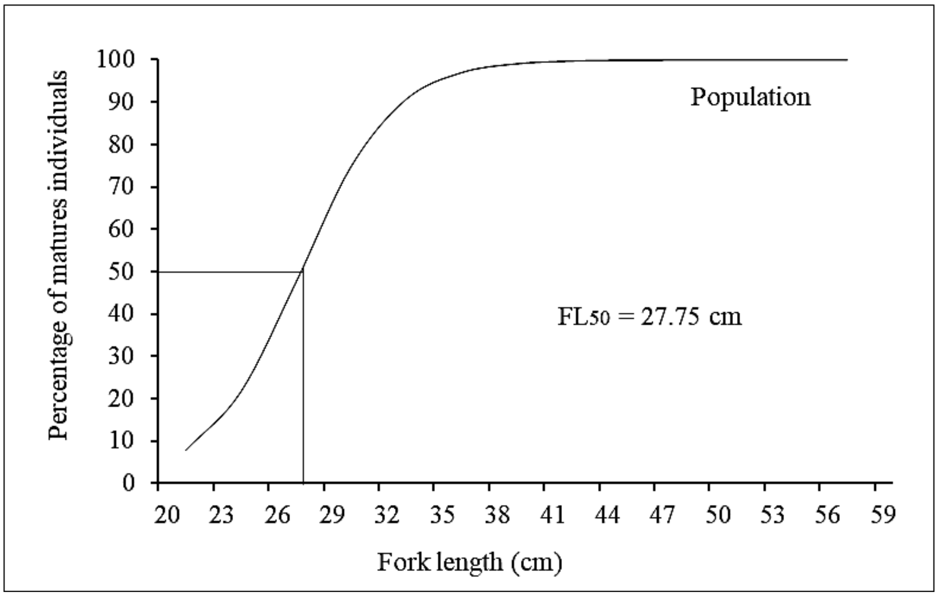

Figure 2. Size of the first sexual maturity (FL50) of *Elops lacerta* population in the Ivorian's Exclusive Economic Zone.

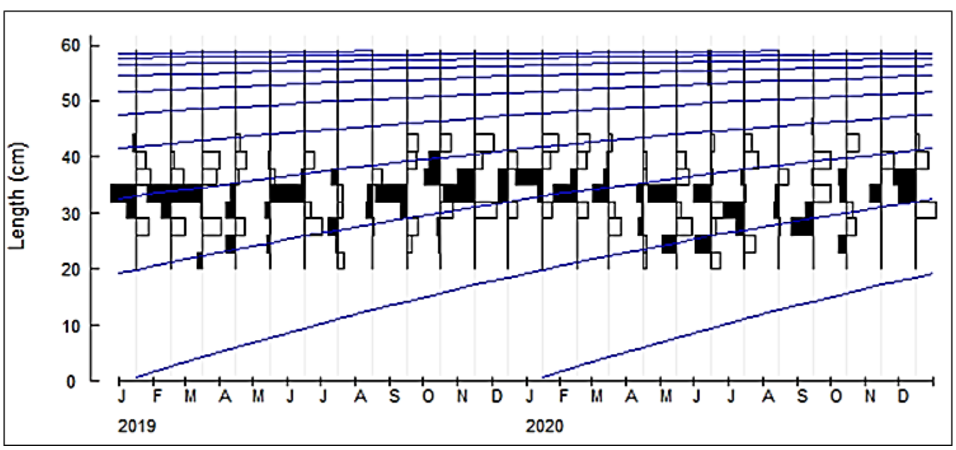

Figure 2. Restructured Von Bertalanffy growth curve and length frequency plot of *Elops lacerta*.

of the growth parameters of *E. lacerta* are presented in Table 1. The number of oblique curves representing the number of generations of *E. lacerta*. The start of the growth curve approximates the breeding period of the species. This allows the time or month of birth for any individual length surveyed to be located at a well-known date. The breeding of *E. lacerta* takes place from January.

Table 3. The relative yield per recruit and relative biomass per recruit predicted at different rate of exploitation in *Elops lacerta*.

E	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Y'/R	0.008	0.015	0.02	0.023	0.024	0.024	0.023	0.02	0.016	0.013
B'/R	0.816	0.65	0.502	0.373	0.263	0.174	0.104	0.053	0.020	00

E: Exploitation rate; Y'/R: Yield per recruit; B'/R: Biomass per recruit.

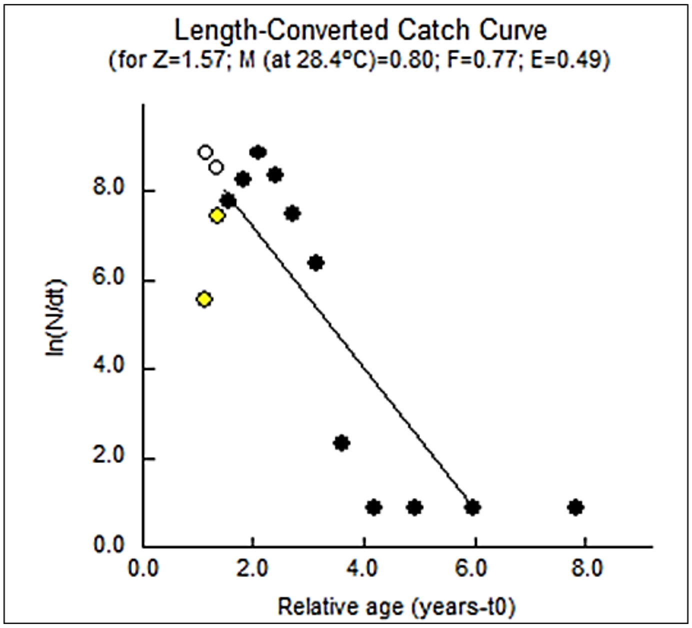

Figure 4. Length-converted catch curve of *Elops lacerta*.

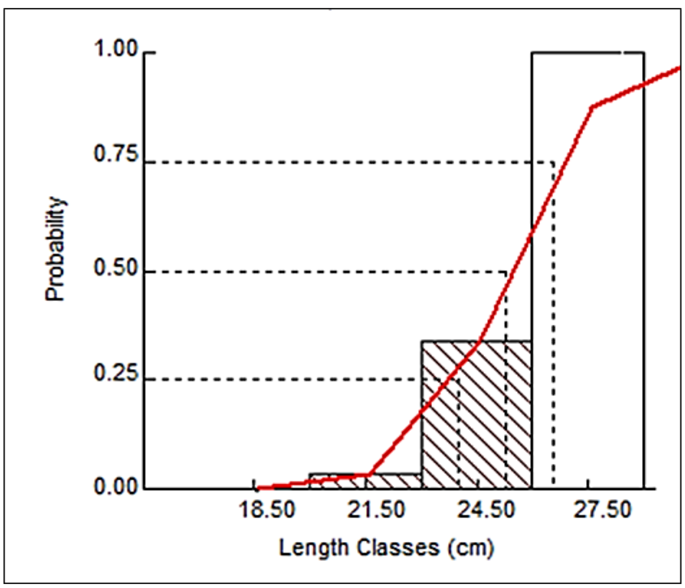

Figure 5. Probability of capture of *Elops lacerta*.

Exploitation parameters of *E. lacerta*: The total mortality (Z), the natural mortality (M) at 28.35°C and the fishing mortality (F) were respectively 1.57, 0.80 and 0.77 year^{-1}. Exploitation level is estimated as 0.49 (Fig. 4). The size at first capture (Lc), obtained from the probability of capture was 25.28 cm. The lengths

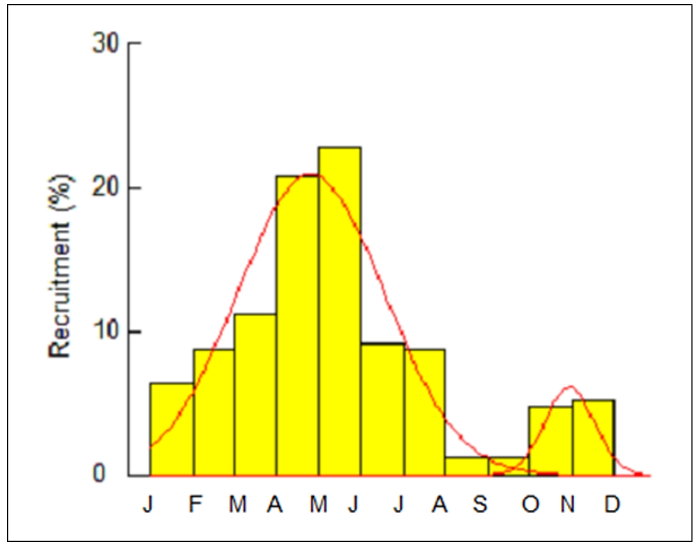

Figure 6. Recruitment pattern of *Elops lacerta*.

at which 25 and 75% of fish are captured were respectively 24.01 and 26.56 cm (Fig. 5). The optimal catch size is 35.86 cm.

The recruitment pattern's continuously throughout the year. The percent recruitment varied from 1.15 at 22.75% (Fig. 6). The size distribution of the catches suggests two peaks of recruitment, the first in May (22.75%) and the second in November (5.21%) belonging to the long and short marine warm seasons, respectively. The histogram of the virtual population analysis (Fig. 7) indicates that natural mortality is highest in juveniles and sub-adults. It decreases as the size of the individual's increases. Smaller individuals survive the most in this environment. Fishing mortality is more pronounced in adult individuals (sizes ≥ 27.75 cm).

Figure 8 shows the evaluation of yield and biomass per recruit as a function of fishing mortality. The curves for yield and biomass per recruit are on the x axis and fishing mortality on the y axis. The exploitation rate (Fig. 9) at different levels as E_{10}, E_{50} and E_{max} have been determined using the reports of Lc/L∞ and M/K. The exploitation parameters of

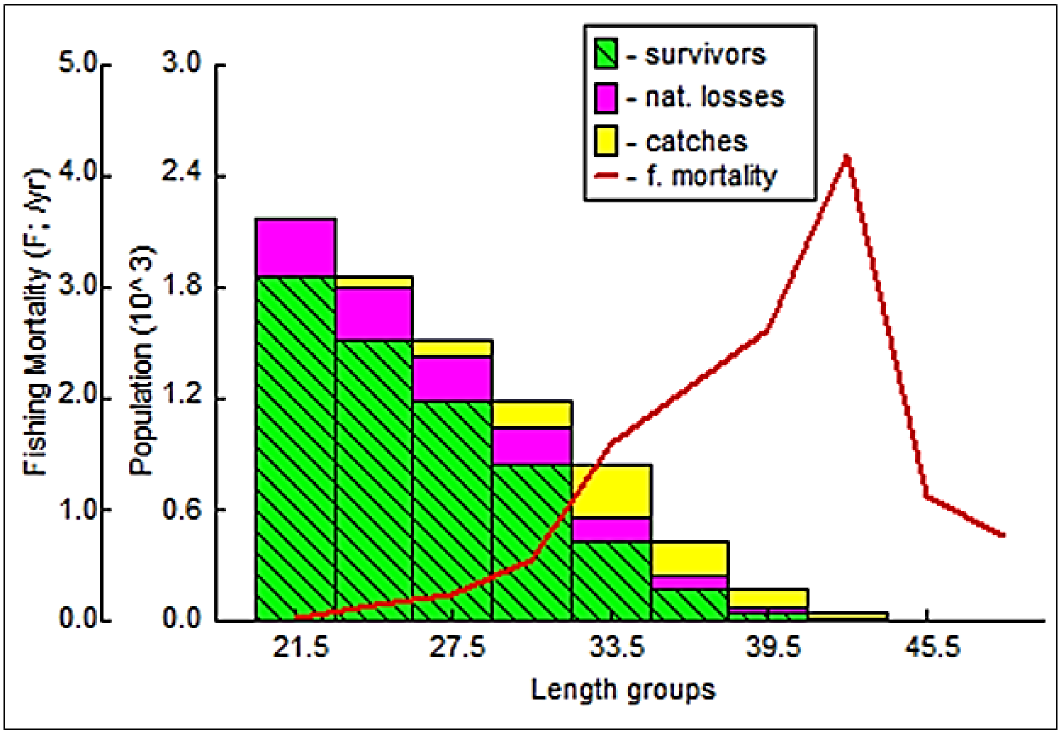

Figure 7. Virtual population analysis of *Elops lacerta*.

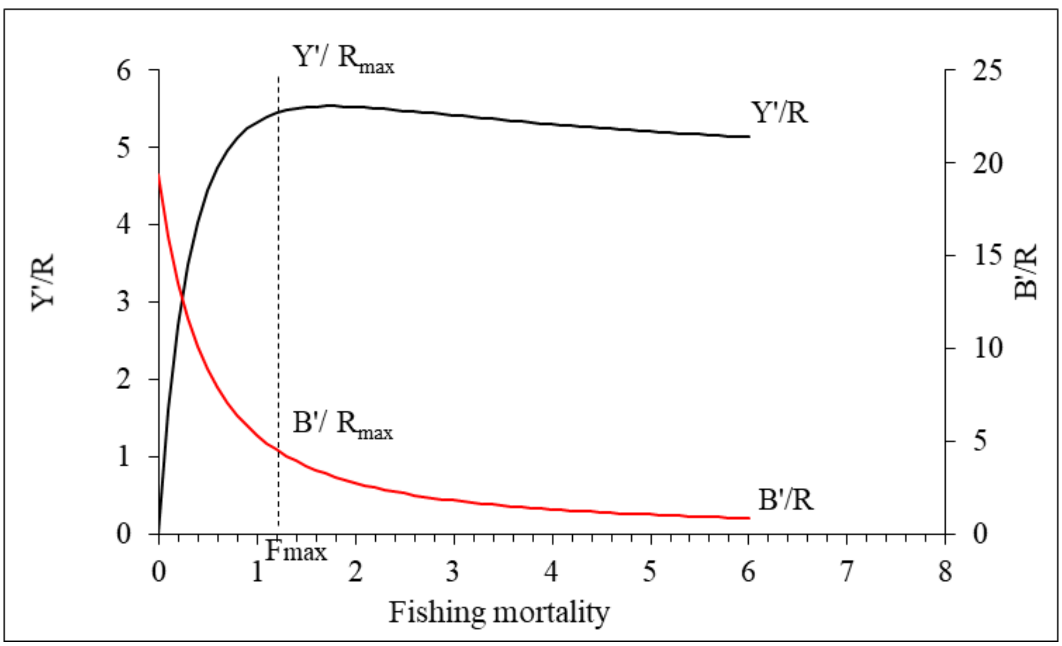

Figure 8. Yield per recruit (Y'/R) and biomass per recruit (B'/R) of *Elops lacerta* in function of the fishing mortality rate (F). (F_{max}: value of F which gives the maximum possible yield).

E. lacerta are presented in Table 2. The yield per recruit reached a maximum at an exploitation rate of 0.6 and decrease as it goes along the exploitation rate increased (Table 3).

Discussions

The Ivorian fishing area is located in the tropical region characterized by warm waters and abundant light that favors the growth of phytoplankton, which

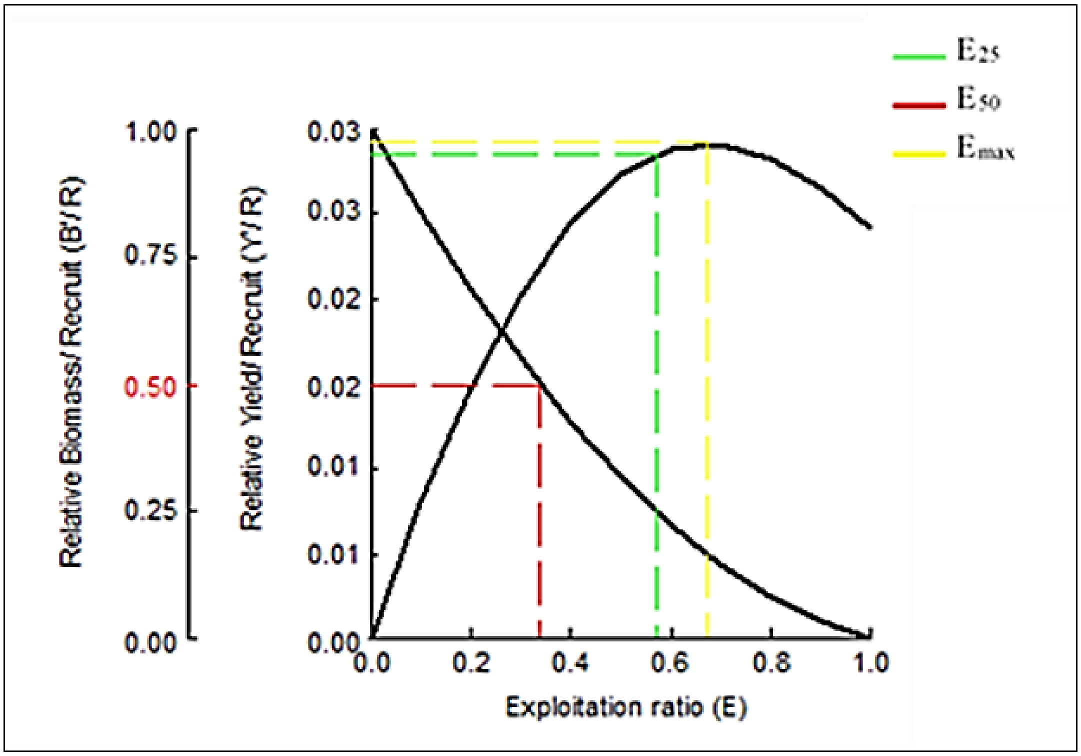

Figure 9. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) of *Elops lacerta*.

provides most of the primary production on which marine food webs depend. The asymptotic length obtained in this pelagic fish would be linked on the one hand to an important availability of food in our studied environment necessary for the essential functions of the organism. The protein and energy requirements of a fish depend on the size, age, physiological condition and environment of the animal. Thus, as an individual grows, its needs increase and needs to feed more. On the other hand, the high temperature of the environment would lead to an increase in the length of the fish. Indeed, when the temperature of the environment is high, the organism undergoes a rapid digestion accelerating the process of anabolic which induces a rapid growth to the increase of the voluntary ingestion and the conversion index. High temperatures would have a positive influence on the asymptotic length.

Climate change influences living conditions in the oceans. However, many fish species developed adaptive strategies to varying environmental temperatures. The warming of the water would cause an increase in metabolic rates which would lead to a regression of growth rates. Moreover, the growth rate of *E. lacerta* is relatively low compared to those reported by Niyonkuru et al. (2007), Abdul et al. (2015) and Dienye et al. (2021). The growth coefficient obtained would be related to the sexual maturation of the gonads. Indeed, the migration of these individuals to the marine environment to continue their growth and reproduction leads to a predominance of adult individuals in the environment. In addition, Wagué and Papaconstantinou (1997), explain that sexual maturation is probably one of the most important factors in the fall of the growth rate in fish. Thus, the growth rate would be high if the population is composed of more juveniles and low when there are more old individuals. Hie-Daré (1982), also indicated that immature *E. lacerta* in lagoon has a rapid growth in this environment.

The calculated size growth performance index (Ø') is higher than that reported by Niyonkuru et al. (2007) and Dienye et al. (2021). The results of Abdul et al. (2015) are slightly higher than our results. This difference can be explained by the methods for estimating the L∞ and K parameters. Similar observations have been made by Pauly (1991). Baijot and Moreau (1997), also reported that the mean values of the size growth performance index of several African fish species are between 2.65 and 3.32 are considered low. *Elops lacerta* can be considered as having a low growth performance.

The maximum life span in our study differs from that those of Niyonkuru et al. (2007) and Abdul et al. (2015). It is important to mention that better living environment conditions significantly impact the life expectancy of any organism; this could justify the longer lifespan found in this species in the Ivorian zone. The recorded mortality parameters indicate that natural mortality is higher than fishing mortality. This predominance of natural mortality over fishing mortality would be related to environmental conditions, diseases, interspecific responses such as predation and pollution.

The size at first capture is lowest than the size of first sexual maturity and the optimum size of capture. This species living at depths between 1 and 50 m in marine environment, would not escape the different fishing gears. the individuals of *E. lacerta* caught have not had the opportunity to reproduce several times. The sustainability of the *E. lacerta* population is threatened in the Exclusive Economic Zone.

The recruitment of *E. lacerta* marked by important peaks observed during the long and short marine warm season would be explained by a preference of warm waters of the species. The massive arrival of individuals in the exploitable stock at these times of the year would be explained by the fact that the environmental conditions are more favorable for these individuals, which would also be strategy to provide more opportunities of individual to survive in at environment. In addition to temperature, salinity is an abiotic factor that can influence the biological cycle of the recruits.

Our work revealed that fishing mortality is more pronounced in adult individuals. Indeed, the majority of juveniles and sub-adults would escape the various fishing gears, unlike the larger and more robust adult individuals. Thus, the continuous fishing pressure on adult individuals could lead to a low rate of spawning stock in the environment, hence the inability to ensure the sustainability of the species.

Conclusion

This study provides the first information on the growth and exploitation parameters of *E. lacerta* in the marine environment. It appears that the stock of *E. lacerta* exploited in the Exclusive Economic Zone is dominated by large individuals. However, the implementation of a management policy for this resource prohibiting the capture of specimens of *E. lacerta* at sizes below the optimum catch size.

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