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Growth, Mortality Parameters and Exploitation Rate of West African Ilisha (*Ilisha africana* Bloch, 1795, Clupeidae) off Benin Coastal Waters (West Africa): Implications for Management and Conservation

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Abstract

West African Ilisha was the third most abundant species of Clupeidae off Benin coastal waters after *Sardinella spp* and *Ethmalosa frimbriata*. The fishing effort of these fisheries increased with a dominance of small-sized specimens in the catches. This paper allowed updating some demographic parameters and the exploitation rate of *Ilisha africana* collected between July 2013 and June 2014 from the coastal waters of Benin for management and conservation of these fisheries. The growth pattern showed a negative allometric growth with an abundance of small-sized specimens. The von Bertalanffy growth function (VBGF) estimations were: L_∞ = 21.31 cm standard length; K = 1.20 year^{-1}; and $t_0 = -0.138$ year. The total mortality rate (Z), natural mortality rate (M) and fishing mortality rate (F) were 4.040 year^{-1}, 2.27 year^{-1} and 1.77 year^{-1} respectively. The Z/K ratio was 3.667 and the exploitation rate ($E = F/Z$) was 0.44 showing an under exploitation of this species. The estimated potential longevity (t_{max}) was 2.5 years. In addition, the fisheries management should be devolved from the state to the local level to compel fishermen to take greater responsibility for the sustainability and conservation of the fisheries such as size-limit regulation by gradually increasing fishing gears mesh size.

Keywords

Ilisha africana, Growth Parameters, Mortality, Exploitation Rate, Benin

1. Introduction

The direct consequence of maritime congestion caused by the presence of an important number of local and foreign fleets remains overfishing, one of the big threats on marine fauna and flora in West-Africa (Diouf, 1996 [1]). The decrease in capture generally noticed at the same time led to environmental degradation, and overexploitation has aroused the dynamic of studying the population (Villanueva, 2004 [2]). According to FAO estimates approximately 80% of the global fish stock are overexploited (FAO, 2006 [3]). The impact of over fishing is alarming in West Africa where countries are already very poor and depend on water resources for economic growth and food (FAO, 2006 [3]). 75% of artisanal marine fishing catches in Benin consisted of pelagic species which included 60% of the smallest coastal Clupeidae (Gbaguidi, 2000 [4]). These species are totally free and independent, of the substratum nature (Laloe and Samba, 1991 [5]; Collignon, 1991 [6]). The influence of the environment on their biology and their fluctuating availability and abundance had been highlighted in many fish pools around the world (Belvèze, 1984 [7]; Cury and Fontana, 1988 [8]; Freon, 1988 [9]; Pauly, 1997 [10]).

The small pelagic species of commercial importance for artisanal marine fishing in Benin are *Sardinella aurita, Sardinella maderensis* and *Ilisha africana* (FAO, 1991 [11]). They contribute between 30% - 47% of the total marine catch in Benin. Of this stock, *Ilisha africana* contributes between 27% and 82% (Senouvo and Gbaguidi [12]). This species is found along the West African coast from Northern Senegal to Angola. It is a typical representative of a group of small predatory Clupeids with a laterally flattened body, relatively small tail and a large up-turned mouth (Valiky and Cham, 2002 [13]).

Due to the high demand for these species, it is necessary to evaluate their population parameters to ensure proper management of this fishery.

Studies on the fish community are useful for a durable management of fishing activities (Aliko *et al*., 2010 [14]). Population parameters such as asymptotic length (L_∞) and growth coefficient (k), mortality rates and exploitation level were studied with the major objective of rational management and resource conservation (Tah *et al*., 2010 [15]; Nasser, 1999 [16]).

Growth information provides a lot of tools that are used in fishery management. The data on the age of a fish can provide tools in fishery management such as the general background information needed for management decisions. It aids in the diagnosis of management needs such as the recognition of overcrowding and stunting (Carlendar, 1955 [17]; Deekae and Abowei, 2010 [18]).

Mortality can be defined as the death of an organism. It is a very important aspect of population biology since it provides information about changes in the population. Mortality can be caused by fishing activity (fishing mortality) or by natural action (natural mortality) (Abowei and Hart, 2009 [19]; Abowei *et al*., 2010 [20]). According to Marshall, 1993 [21], mortality rates are of prime importance to fishery scientists in expressing the dynamics of fish population.

The present work is the first attempt to investigate growth rates, mortality coefficients and the exploitation rate of this species in the coastal waters of Benin to ensure the proper management of this fishery.

2. Materials and Methods

2.1. Study Area, Fish Sampling

Specimens of *I. africana* were sampled from catches off Benin's coastal waters (West Africa) landing at the artisanal fishing port of Cotonou (Figure 1). 1,356 specimens, including 683 males, 613 females and 60 unsexed were randomly sampled from July 2013 to June 2014. Each week at least 25 specimens were sampled from commercial catches. The total length (TL) of the fish was measured at nearly 0.1 cm from the tip of the snout (mouth closed) to the extended tip of the caudal fin. Standard length (SL) was measured from the tip of the snout (mouth closed) to the base or the joint of the caudal fin. The fork length of the fish (LF) was also measured. The body weight (W) and the eviscerate weight of individual fishes were measured at nearly 0.1 g after removing adhered water and other remains from the body surface. The sex was determined by macroscopic examination of gonads (King, 1995). The mean lengths and weights of the classes were used for data analysis using FiSAT (Gayanilo and Pauly, 1997 [22]).

2.2. Length-Frequency Distribution Structure and Sex Ratio

The analysis of the length-frequency distribution was used to determine the size modal distribution. Histograms were obtained from the distribution.

The sex ratio calculated as $\text{Sexratio} = 100\dfrac{\text{Number of males}}{\text{Number of females}}$ (Sossoukpe *et al*., 2013 [23]) provides a useful tool to assess the biological characteristics of the fish.

2.3. Length-Weight Relationship

The length-weight relationships were expressed as: $W = aL^b$ (Ricker, 1975 [24]), W and L were fish body weight and total length respectively, "a" and "b" were the intercept and slope of the regression curve of the length and weight of the fish, respectively. Differences between sexes were tested to consider the pooled sexes. The correlation (r^2) between length and weight was computed from the

(a) (b) (c)

Figure 1. Location of the sampling site. (a) Benin, acountry in West Africa; (b) Benin; (c) Artisanal Fishing Port of Cotonou.

regression curve. The value of b is a good indicator of the type of growth: the growth is isometric if $b = 3$ (Wootton, 1990 [25]); and the growth is allometric if $b \neq 3$ (negative allometric if $b < 3$ and positive allometric if $b > 3$) (Ricker, 1975 [24]). The paired sample t-test of Student was used to compare "*b*" to 3, and Pearson correlation was used to test the significance of all regressions. To appreciate the fish's well-being, "*b*" is compared to 3. When "*b*" is not significantly different from 3, the species shows a good adaptation to the dominant ecologic condition of the habitat. If "*b*" is significantly different from 3, there is less adaptation (Baijot *et al*., 1994 [26]).

2.4. Growth and Mortality Parameters

The asymptotic length (L_∞) is defined as the length that the species would reach if it lived indefinitely and the growth coefficient (K) is a measure of the rate at which the maximum size is attained (King, 1995 [27]; von Bertalanffy [28]). Monthly population length-frequency distribution data as input in FiSAT software (Gayanilo and Pauly, 1997 [22]) was used to determine L_∞ and K (We the rall, 1987 [29]; Silvestre and Garces, 2004 [30]; Pauly, 1987 [31]). The theoretical age at length zero (t_0) was estimated using Pauly's empirical equation (Pauly, 1979 [32]): $\text{Log}_{10}(-t_0) = -0.392 - 0.275\ \text{Log}_{10}L_\infty - 1.038\text{Log}_{10}K$.

To compare the growth *of Ilisha africana* from the study area with those from other studies, the growth performance index (φ') was calculated. The estimates of L_∞ and K were used to compute the φ' (in terms of length) of the species (Munro and Pauly, 1983 [33]; Pauly and Munro, 1984 [34]): $\varphi' = \text{Log}_{10}K + 2\text{Log}_{10}L_\infty$.

The annual instantaneous rate of total mortality, Z, was estimated from the linearized length-converted catch curves (Pauly and David, 1981 [35]; Sparre and Venema, 1992 [36]). The instantaneous natural mortality rate, M, was computed as: $\text{Log}_{10}M = -0.0066 - 0.279\ \text{Log}_{10}L_\infty + 0.6543\text{Log}_{10}K + 0.463\text{Log}_{10}T$ (Pauly, 1980 [37]). Where T is the annual average of habitat temperature. $T = 29.9^\circ\text{C}$ is considered in this study.

The instantaneous fishing mortality rate, F, was computed as $Z - M$, and the exploitation rate (E) was expressed as $E = F/Z$ (Pauly, 1980 [37]).

2.5. Longevity (t_{max})

The value of the mean coefficient of growth has been used to generate longevity as shown by the formula $\boldsymbol{t_{max} = 3/K}$ (Anato, 1999 [38]).

2.6. Probability of Capture and Length at First Capture (L_C or L_{50})

The probability of capture provides a clear indication of the estimated real size of fish in the fishing area that are vulnerable to a specific gear. This parameter is an important tool for fishery managers who, by regulating the minimum mesh size of a fishing fleet, can mostly determine what should be the minimum size of the target species of a fishery. The probability of capture was computed from the length-converted catch curve. A selectivity curve was generated using linear regression fitted which was used to estimate the final value of L_{25}, L_{50} and L_{75} (*i.e.*, lengths at which 25%, 50% and 75% of the fish will be vulnerable to the fishing gear, respectively). Estimates of at-first-capture length (L_{50}) were derived from the probabilities of capture generated from the catch curve analysis output by FiSAT.

2.7. Exploitation Rate

The exploitation rate (E) was generated by FiSAT. The exploitation rate indicates whether the stock is lightly ($E < 0.5$) or strongly ($E > 0.5$) exploited, based on the assumption that the fish are optimally exploited when $F = M$ or $E = 0.5$ (Guland, 1983 [39]).

3. Results

3.1. Length-Frequency Distribution Structure and Sex Ratio

A total of 1,296 sampled specimens were sexed comprising 683 males and 613 females (**Table 1**). The population size distribution structure of *I. africana* (**Figures 2-4**) was unimodal with a modal class at 11.0 - 13.0 cm. A pooled sample shows that males were slightly more numerous than females.

Table 1. Mean standard length (*SL*), mean total weight (*W*), number of specimens (*N*) and Sex ratio ($S - R$) of *I. africana* off Benin coastal waters.

	N (S – R)	Mean SL (cm) (range)	Mean W (g) (range)
Males	683	12.68 ± 0.05 (9.4.5 - 15.0)	17.33 ± 0.01 (8.7 - 27.1)
Females	613	12.85 ± 0.03 (10.5 - 16.0)	17.92 ± 0.02 (9.2 - 33.5)
Males + Females	1,296 (111.41%)	12.77 ± 0.01 (11.5 - 16.0)	17.63 ± 0.01 (8.7 - 33.5)

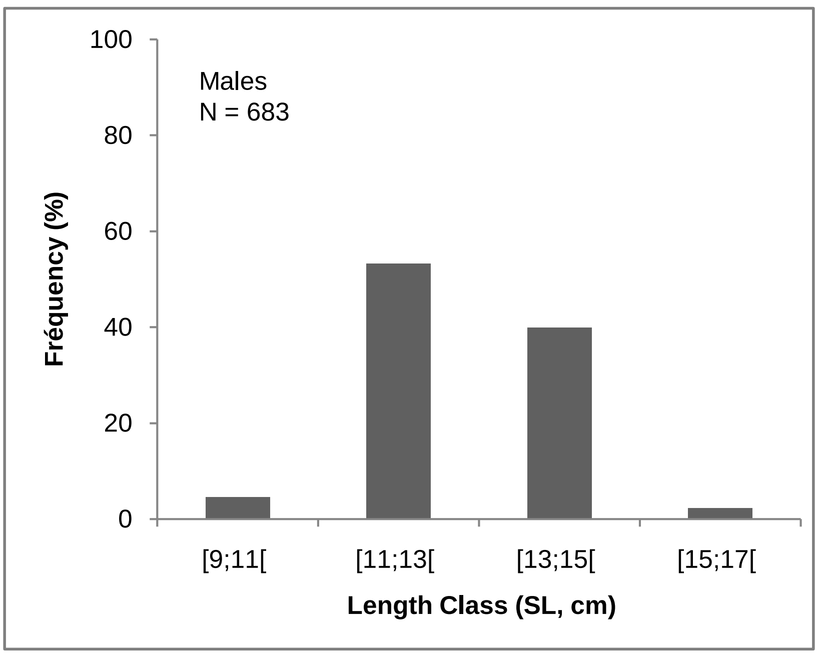

Figure 2. Population structure of male *I. africana*.

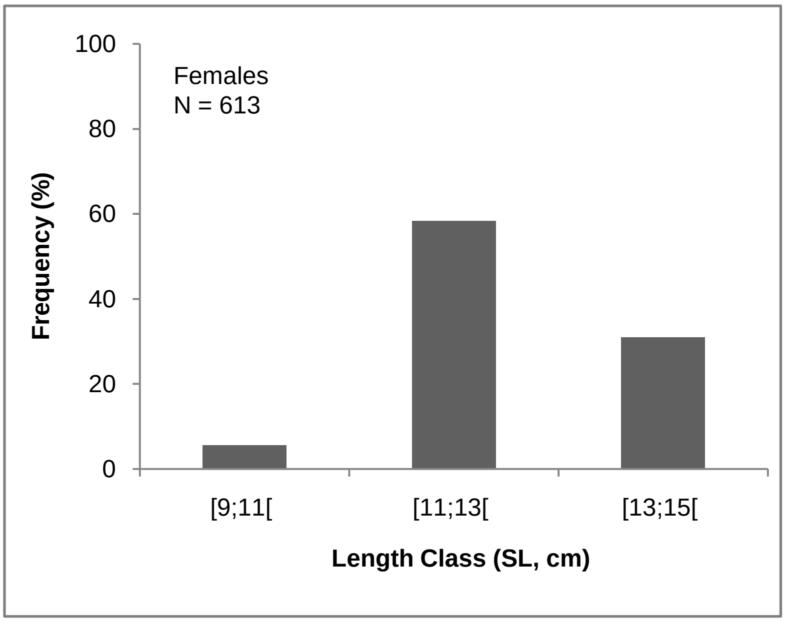

Figure 3. Population structure of female *I. africana.*

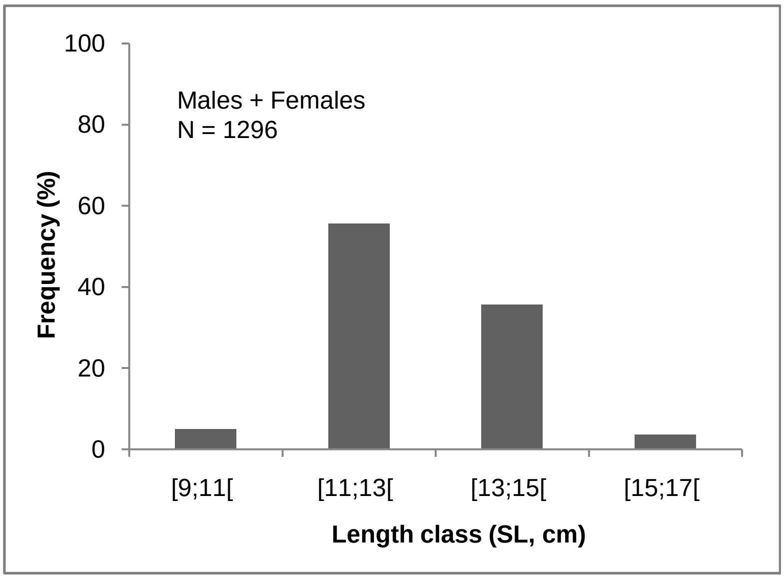

Figure 4. Population structure of pooled samples of *I. africana.*

3.2. Length-Weight Relationship ($L - W$)

The results of the $L - W$ relationship of *I. africana* by sex are consigned in Table 2. The $L - W$ regression in males was not significantly different from that of females ($p > 0.05$). The respective $L - W$ regressions for males, females and pooled samples are presented in Figures 5-7. The value of the Person correlation coefficient is close to 1; that means a positive correlation between the Total Weight (W) of the fish and its Total Length (TL). As well in males ($b = 2.355$) as in females ($b = 2.327$), b is significantly different from 3 ($p < 0.05$). The *I. Africana* exhibited a negative allometric growth (Table 3). It means that the fish grows relatively faster in length than in weight.

Table 2. Length-weight relationship parameters of *I. africana.*

Sex	Number	TL (cm)	W_t (g)	Equation	r^2
Males	683	11.3 - 18.5	8.7 - 27.1	$W_t = 0.028TL^{2.355}$	0.907
Females	613	11.6 - 20.2	9.2 - 33.5	$W_t = 0.030TL^{2.327}$	0.886
Males + Females	1296	11.3 - 20.2	8.7 - 33.5	$W_t = 0.026TL^{2.369}$	0.856

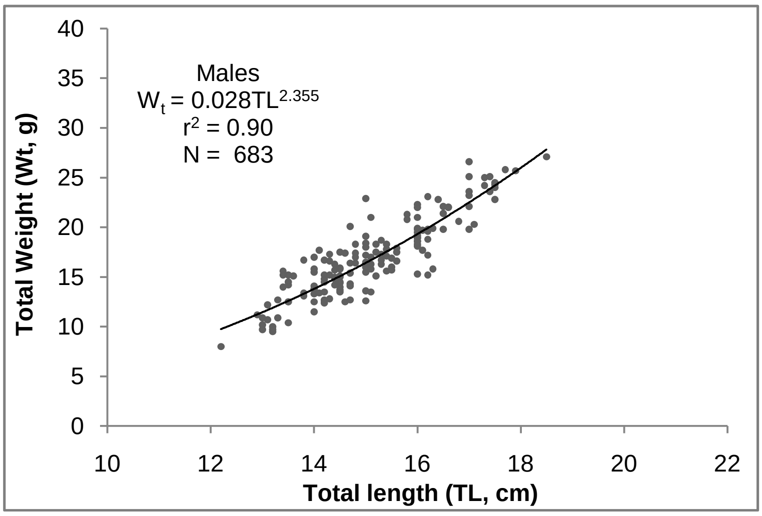

Figure 5. Length-weight relationship of males of *I. africana.*

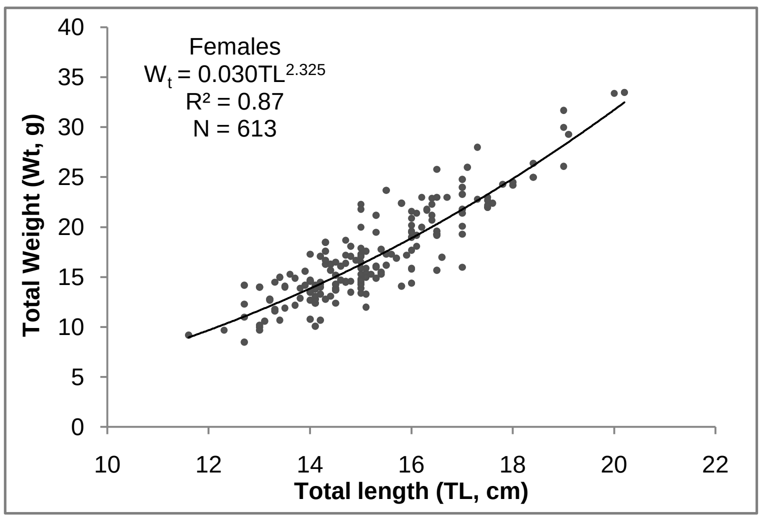

Figure 6. Length-weight relationship of females of *I. africana*.

3.3. Von Bertalanffy Growth and Mortality Parameters (L_∞, *K*, to and φ')

The asymptotic length output by FISAT L_∞ **(cm),** the Growth coefficient K **(year**$^{-1}$**)**, the Hypothetical age (t_0) and the Growth performance index φ' of *I. africana* in the coastal waters of Benin obtained are reported in Table 4.

The Von Bertalanffy growth equation is as follows:

$$TL = 21.31\left\{1-\exp\left[-1.20\left(t+0,138\right)\right]\right\}\text{cm}$$

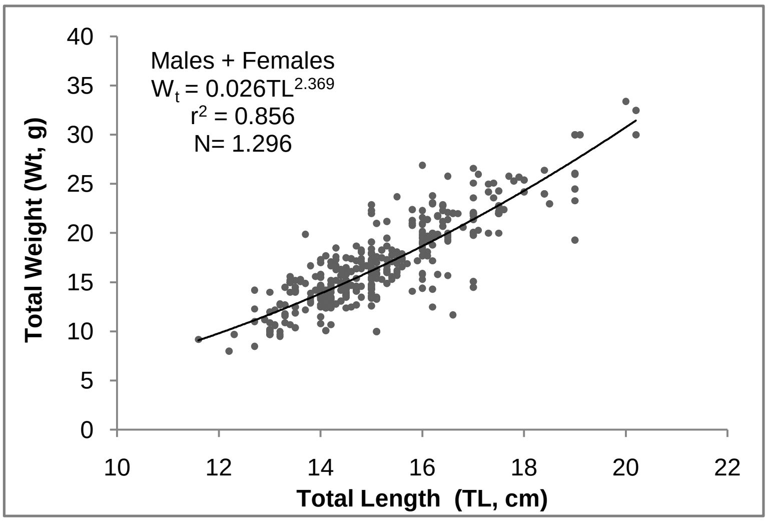

Figure 7. Length-weight relationship of both males and females of *I. africana*.

Table 3. Length-weight relationship of *I. africana* according to literature and in different areas.

Authors	Countries	Length-weight relationship
Current study	Benin	$W_t = 0.0684TL^{2.369}$
Fiogbe *et al.* (2003) [40]	Benin	$W_t = 0.0057TL^{3.6}$
King (1996) [41]	Nigeria	$W_t = 0.0078TL^{2.99}$
Anyangwa (1991) [42]	Sierra Leone	$W_t = 0.0038TL^{3.35}$
Stokholmand Isebor (1993) [43]	Benin and Nigeria	$W_t = 0.09287TL^{2.92}$
Valiky and Cham (2003) [13]	Sierra Leone	$W_t = 0.008TL^{2.94}$

Table 4. Estimated growth parameters of *Ilisha africana* of Benin coastal waters.

Parameters	Values
Asymptotic length (L_∞)	21.31 cm
Growth coefficient(K)	1.200 yr^{-1}
Hypothetical age (t_0)	−0.138 yr
Growth performance index φ'	2.736

The estimated values of asymptotic length (TL_∞) and growth coefficient (K) of the Von Bertalanffy growth equation were 21.31 (cm) and 1.200 ($year^{-1}$) respectively. Figure 4 shows the growth curves generated from ELEFAN I for *I. africana*. It was assumed in the ELEFAN I analysis that the value of the hypothetical age at length zero (t_0) was $t_0 = -0.138$.

3.4. Estimation of Mortality Parameters (M, F and Z)

The length-converted catch curve (Figure 8) showed that the total mortality Z (for fish ranging from 9.0 to 17.0 cm in standard length) estimated for *I. africana* was 4.04 per year. The natural mortality (*M*) at 29.5˚C was 2.27 per year while the fishing mortality (*F*) was 1.77 per year (Table 5).

3.5. Longevity (t_{max})

The longevity of *I. africana* in the Benin coastal waters is (t_{max}) = 2.50 yrs.

3.6. Probability of Capture and Length at First Capture (L_C or $L_{50\%}$)

The estimated length at first capture was 12.92 cm (Figure 9).

3.7. Exploitation Rate

The exploitation rate for *I africana* in the coastal waters of Benin was 0.44 (Figure 5). Using the E_{opt} = 0.5 criterion (Pauly and Munro, 1984 [34]), it could be concluded that the stock of this species was under exploited.

4. Discussion

4.1. Length-Frequency Distribution Structure and Sex Ratio

The asymptotic length for *I. africana* (TL_∞ = 21.31 cm) suggests that the *I. africana*

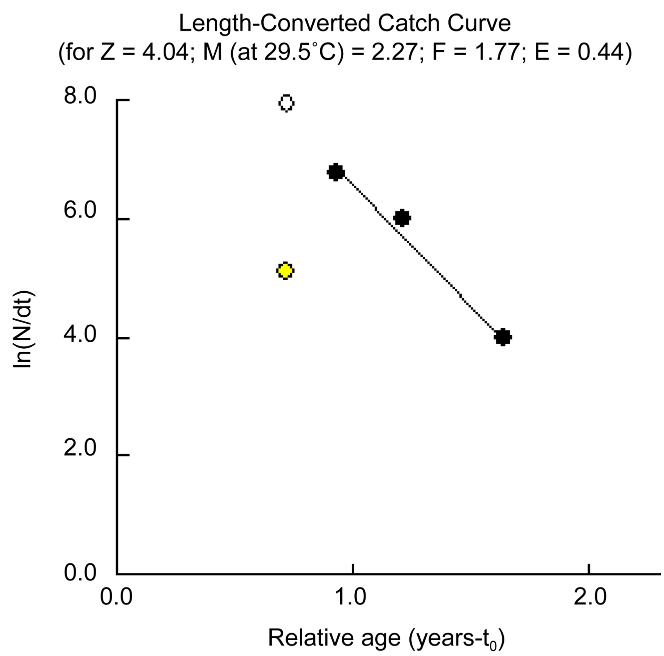

Figure 8. Total instantaneous mortality estimated from the length-converted catch curve.

Table 5. Mortality parameters of *I. africana*in different countries.

Authors	Regions	M (yr^{-1})	F (yr^{-1})	Z (yr^{-1})
Villanueva (2004) [2]	Ivory Coast	1.421	0.138	1.559
Villanueva (2004) [2]	Gambia	0.991	0.518	1.509
Valiky and Cham (2003) [13]	Sierra Leone	1.8	-	5.1
StokholmandIsebor (1993) [43]	Benin et Nigeria	-	-	3.66

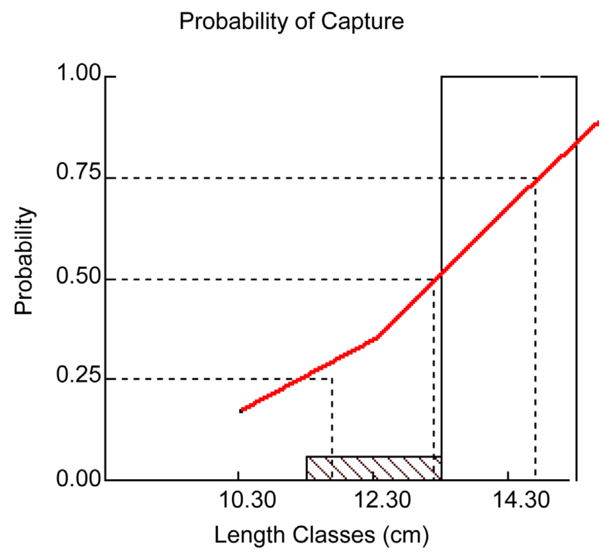

Figure 9. Capture probabilities of *Ilishaafricana*.

stock being exploited consists of relatively smaller-sized individuals. Larger specimens reaching *TL* = 34.54 cm have been reported in Ivory Coast where the modal length was 13.12 cm (range 13 - 15 cm) (Villanueva, 2004 [2]. This modal length is notably close to what was in this survey, implying the dominance of juveniles in these catches. The length-frequency distribution structure of this species was clearly unimodal indicating probably the existence of one cohort in the population. Males are more numerous than females in contrary to what was reported by in Nigeria (King, 1997 [44]), in Nigeria and Benin (Stokholm and Isebor, 1993 [43]) and in Sierra Leone (Valiky and Cham, 2003 [13]). An equally significant predominance of females especially was reported in the Baléares during the reproduction season of species (Andreu and Rodiguez-Roda, 1952 [45]). This variation could be explained by the migratory character of this species.

4.2. Length-Weight Relationship

The value of the Person correlation coefficient between the length and the weight was positive ($r = 0.856$, $N = 1296$, **Table 2**). The value of $b = 2.369$ (both sexes) indicated a negative allometric growth. However, many studies (**Table 2**) particularly in Benin (Fiogbe *et al.*, 2003 [40] ($b = 3.6$) and in Sierra Leone ($b = 3.35$) (Anyangwa, 1991 [42]) showed that **b** can be higher than 3 (majored allometric) and in this case the weight of the individual fish grows faster than its length. This difference of the **b** value could be attributed to environmental conditions. Kundsen, 1962 [46] supported this conception. In fact these fish length and weight variations can be shown in the course of a change in environmental factors. So it is obvious that the sample mood has influenced the weigh-length relationship.

4.3. Von Bertalanffy Growth Parameters (L_∞, K and to) and Growth Performance Index (φ')

Fish grows throughout its life. Fish growth is the result of the actions of specific endogen factors (genetic luggage) and exogenous factors that consist of abiotic characteristics (temperature, dissolved oxygen) and biotic characteristics (availability of food resources, feeding, intra- or interspecific competition) (Ezenwaji and Ikusemiju, 1981 [47]; De Merona *et al*., [48]; Panfili *et al*., [49]).

According to literature (**Table 6**) the estimated asymptotic length in this study (L_∞ = 21.31 cm) is close to what was found in Gambian estuary (Villanueva, 2004 [2]) and in Nigeria (East of Niger delta) (Stokholm and Isebor, 1993 [43]. In contrast, in Sierra-Leonean waters (Nasser, 1999 [16]), in Nigerian estuary (King, 1997 [46]) and in Ivory Coast coastal waters (Villanueva, 2004 [2]), high values of the asymptotic length were reported respectively. This can be explained by the diversity of methods used in the growth parameters evaluation, the sensibility of the von Bertalanffy models at the key length-ages used, and the quality of samples. Growth parameters analyses indicate that the adjustment curve is relative to small-sized specimens and the value of hypothetical age at length zero is t_0 = −0.138. Few studies inform on the value of φ' of *I. africana.* In this study, the value of φ' was 2.736. Growth performance indexes of *I. africana* in other countries are reported in **Table 6**. The φ' (2.90) values obtained in Nigeria's estuary (Stokholm and Isebor, 1993 [43], King, 1997 [44]) are slightly higher than what was found in the present study. The low values of growth performance indexes can be attributed to food unavailability, unfavorable environmental conditions. Specifically, getting maximal length (L_∞ = 21.31 cm) to a rate of K growth of 1.200 year^{-1} is coherent and close to those gotten in Gambian estuary (Villanueva, 2004 [2]). It corresponds to the maximal size of *I. africana*. The individual lengths which are 34.54 cm (for 0.75 growth rate) and 28.2 cm (for 1.0 growth rate) are respectively mentioned in Ebriélagun (Villanueva, 2004 [2]) off Ivory Coast, in Nigerian estuary (King, 1997 [44]) andin Sierra Leone (Valiky and Cham, 2003 [13]). Thus, the increase in L_∞ value results in the decrease of K value.

4.4. Mortality Parameters (Z, M and F) and Longevity (t_{max})

Mortality and growth parameters are antagonistic factors in the dynamic of populations (Ahouansou Montcho, 2011 [50]). Fishing mortality (F) and natural mortality (M) contribute to total mortality ($Z = M + F$). Their ratio is a good indicator of the prevalence of one or another. The relevance of the estimated natural mortality M value is established through M/K. As a general rule, if Z/K

Table 6. Growth parameters of *I. africana* in different countries.

Authors	Regions	TL_∞ (cm)	K (an^{-1})	φ'
This study	Benin	21.31	1.2	2.736
Villanueva (2004) [2]	Ivory Coast	34.54	0.75	-
Villanueva (2004) [2]	Gambia	22.75	0.38	-
Valiky *et* Cham (2003) [13]	Sierra Leone	28.2	1	-
Stockholm and Isebor (1993) [43]	East of Niger delta	22.0	2.33	2.90
King (1997) [44]	Nigeria (marine)	29.6	0.80	2.85

ratio < 1, the population is marked by the predomination of growth over mortality; if Z/K ratio > 1, then mortality predominates over growth; if Z/K ratio = 1, then the population is in an equilibrium where mortality balances growth (Barry and Tegner, 1989 [51]). In the present study, Z/K ratio = 3.667. Thus mortality predominated very largely over growth in *I. africana* off the coastal waters off Benin. The value of the instantaneous annual natural mortality (M = 2.27 yr^{-1}) obtained in this study is higher than the fishing mortality (F = 1.77 yr^{-1}). These results suggested a weak exploitation of the *I. africana* stock in the study area.

The instantaneous total mortality Z reported in this study is close to what was found (Z = 5.1 yr^{-1}) in Sierra Leone (Valiky and Cham, 2003 [13]) and slightly lower than what was reported in Niger Delta (Z = 3.66 yr^{-1}) [45]. In Ivory Coast the value of Z = 1.559 yr^{-1} found (Villanueva, 2004 [2]) was widely different from the current result. The difference between these estimates could be attributed to many factors such as diseases, food availability, environmental factors which affect the determination of mortality through the population structure (Gabche and Hockey, 1995 [52]). The longevity of this species is t_{max} = 2.5 yrs and the natural mortality M is 2.27 yr^{-1}. Based on these results and what was reported in Ivory Coast (t_{max} = 4 yrs, M = 1.421 yr^{-1}) (Villanueva, 2004 [2]), it could be concluded that the weaker the natural mortality, the greater the longevity.

4.5. Probability of Capture and Management

Fifty percent (50%) of fish specimens measuring at least 12.92 cm are vulnerable to the fishing gear. Comparing these results with the length-at-first-sexual-maturation (L_{50}) reported in Sierra Leone (Valiky and Cham, 2003 [13]), 19.10 cm for males and 17.43 cm for females, it could be concluded that *I. africana* off Benin's coastal waters widely reaches the length-at-first-sexual-maturation before its first capture. In these conditions individuals could contribute to a renewal of stock.

4.6. Exploitation Rate

The exploitation rate E = 0.44 yr^{-1} in this study is inferior to the value of the optimal exploitation rate E_{opt} = 0.5 (Pauly and Munro, 1984 [34]). The fact that the E obtained in the present study is inferior to E_{opt} = 0.5 indicates that the stock of *I. africana* is slightly underexploitated in the coastal waters of Benin. The fact that samples were dominated by small-sized specimens implies management measures such as size-limit regulation by gradually increasing fishing gears mesh size (Sossoukpe *et al*., 2013 [53]; 2016 [54]).

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