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Situational Analysis of *Chrysichthys nigrodigitatus* Exploitation by Artisanal Fisheries in the Aghien Lagoon (South-East of Côte d'Ivoire)

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Abstract **Original Research Article**

Chrysichthys nigrodigitatus exploitation in the Aghien lagoon, Côte d'Ivoire, were analyzed by applying growth and mortality parameters, exploitation rate, relative yield and relative biomass per recruit. Fish population were sampled monthly during one year between June 2014 and May 2015 from artisanal and experimental captures. All the parameters determined during this study were done by the FiSAT II software. Concerning growth parameters, results indicated that the asymptotic length ($L\infty$) has been estimated at 380.76 mm SL, growth coefficient (K) was 0.48 year $^{-1}$ and growth performance index (Φ') was 2.84. Growth modelization revealed 4 cohorts for *Chrysichthys nigrodigitatus*. The estimates of the total (Z), natural (M) and fishing (F) mortalities were 2.11, 0.55 and 1.56 year $^{-1}$ respectively. The exploitation rate obtained ($E = 0.74$) is higher than E_{max} ($E_{max} = 0.41$), thus indicating that the *C. nigrodigitatus* stock is in a state of overexploitation.

Keywords: Artisanal fisheries, *Chrysichthys nigrodigitatus*, Aghien lagoon, Côte d'Ivoire, FiSAT II software.

INTRODUCTION

Over the past two decades, there has been an increase of anthropogenic activities that could threaten the biodiversity of aquatic ecosystems. Fishing appears according to (Katoussan J, 2007) as one of the most worrying threats. Indeed, fishing can affect the diversity, species composition, size structure of a fish population or even cause the collapse of the stock of certain target species (Pet-Soede C *et al.*, 2001). Yet in some developing countries, fishery products are the main source of animal protein (Ticheler A, 2000). In Côte d'Ivoire, the Aghien lagoon, due to its geographical proximity to the large urban area of Abidjan, is subject to strong fishing pressure (Bédia A *et al.*, 2009; Traoré A *et al.*, 2014). In addition, the Aghien lagoon management in terms of artisanal fisheries is the chiefdom business (Anoh K, 2010). This chiefdom authorizes access to the resource against payment of a fee without taking into account the regulation and control of the number of fishermen, fishing gear and techniques, fishing effort as well as monitoring and evolution of the stock of target species. However, the strong pressure of this artisanal fishery threatens the target fish stock (Assi S *et al.*, 2018; Assi S *et al.*, 2019; Konan K *et al.*, 2019). The species *Chrysichthys nigrodigitatus* is one of these fish species appreciated by the communities surrounding the Aghien lagoon because of its high market value. Therefore, it's specially targeted by fishermen. Consequently, water resources and biodiversity managers should be much more involved in monitoring and organizing fishing activities around the Aghien lagoon in order to find a balance between fishing effort and the fish stocks available in this lagoon. Face this threat, the establishment of a management system is necessary for the preservation of these fishery resources. These measures are mainly based on the state of knowledge of fishery resources and catch levels compatible with sustainable exploitation (Abowei J *et al.*, 2010; Tia C *et al.*, 2017).

The objective of this study is to provide information on the growth and exploitation parameters of the species *Chrysichthys nigrodigitatus* population with a view to rational exploitation and management of this fishery resource in the Aghien lagoon.

MATERIAL AND METHODS

Study site and samples collection

The Aghien lagoon is located in the north of the Ebrié Lagoon between latitudes 5°22' N and 5°26' N and longitudes 3°49' W and 3°55' W (Figure 1). 19 km long, with a watershed of 340 km^2, the Aghien lagoon is separated from the rest of the Ebrié Lagoon by the Potou Lagoon. The Aghien and Potou lagoons communicate via a natural channel. The Aghien Lagoon is subject to a hydrographic network composed of 03 rivers: Mé, Bété and Djibi. The watershed of those rivers are respectively (4020 km²), (220 km²) and (80 km²). The Bété and Djibi rivers open directly into the Aghien Lagoon, while the Mé river opens into the natural channel separating the Aghien and Potou lagoons (Ettien B, 2010). Located in an estuarine zone, the ichthyological diversity of this lagoon is strongly influenced by species of marine and continental origin.

Samples relating to the species *Chrysichthys nigrodigitatus* are from artisanal and experimental fisheries at the Aghien lagoon. These samples were obtained from a monthly samplings carried out during the period from June 2014 to May 2015. Fishes were collected using gill nets (10 to 40 mm stretch mesh). The identification of collected specimens was performed at species level, based on the keys proposed by (Paugy D *et al*., 2003a, 2003b), (Sonnenberg R *et al.*, 2009), (Fricke R *et al.*, 2019), as well as those of (Froese R *et al.*, 2019). For all individuals caught, the standard length (SL) was measured to the nearest millimetre. The parameter (SL) was used to avoid errors due to tail fins accidentally damaged during intra or interspecific fighting during capture and specimen conservation (Chikou A, 2006).

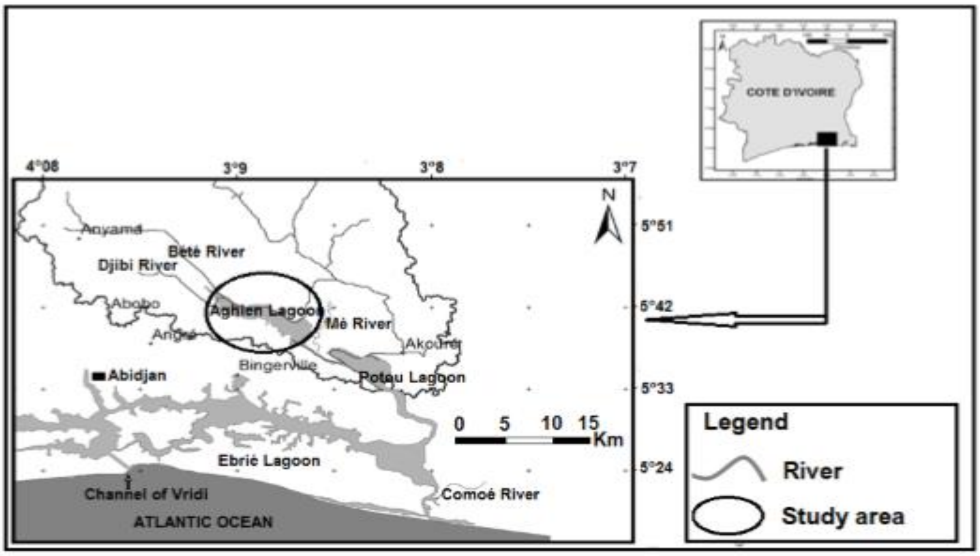

Figure 1: Location of the Aghien lagoon (South-East, Côte d'Ivoire)

Determination of growth parameters

The growth parameters of the species were assumed to follow the Von Bertalanffy's growth function (VBGF). The estimate of the Von Bertalanffy growth parameters, the asymptotic length ($L\infty$) and the growth coefficient (K) were derived using FiSAT II (Gayanilo F *et al.,* 2002).

(Pauly D, 1979) empirical equation for the theoretical age at length zero (t_0) was used to obtain this parameter as $Log_{10}\ (-t_0) = -\ 0.392 - 0.275\ Log_{10}\ L\infty - 1.038\ Log_{10}\ K$.

The reliability of these growth parameters was tested applying the growth performance index (Φ') which was computed from the equation (Pauly D, 1998):

$$\Phi' = Log\ K + 2\ Log\ L\infty.$$

Potential longevity, t_{max}, was worked out of the following formula (Pauly D, 1980):

$t_{max} = 3/K.$

Determination of mortality parameters and exploitation rate

The parameters $L\infty$ and K were used as input to length-Converted catch curve analysis to obtain estimates of the total annual instantaneous mortality (Z) following (Ricker W, 1980):

$N(t) = N_0\ e^{-Z\ t}$;

$N\ (t)$ is the number of survivors at time t; N_0 is the initial number of individuals at time t_0 taken as origin; Z is the total mortality.

Natural mortality (M) was estimated using the empirical formula of (Pauly D, 1980):

$Log\ (M) = -0.0066 - 0.2790\ Log\ (L\infty) + 0.6543\ Log\ (K) + 0.4634\ Log\ (T)$;

With "T" as the mean environmental temperature (°C). In this study, the mean annual habitat temperature used was 28.40°C.

The fishing mortality rate (F) was calculated as: $F = Z\text{-}M$ (Abowei J *et al.*, 2010).

The exploitation rate (E) was computed as: $E = F/Z$ (Pauly D, 1985).

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 (Gulland J, 1971).

Relative yield and relative biomass per recruit determination

(Beverton R *et al*., 1966) method as modified by (Pauly D, 1986) were used to predict the relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) of the species to the fisheries. Y'/R was computed following the formula below:

$Y'/R = E\ U^{M/K}\ (1 - (3U/1+m) + (3U^2/1+2m) - (U^3/1+3m))$.

Where $U = 1 - (Lc / L\infty)$ 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 fraction of mortality of the fish caused by the fishermen.

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

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

Yield per-recruit (Y'/R) and biomass per-recruit (B'/R) analysis to obtain reference points and evaluate the exploitation status of the specie was conducted. From the analysis, the maximum allowable limit of exploitation (E_{max}) giving maximum relative yield-per-recruit was estimated. The exploitation rate ($E_{0.1}$) at which the marginal increase in relative yield-per-recruit is 10% as well as the exploitation rate corresponding ($E_{0.5}$) to 50% of the unexploited relative biomass per-recruit were estimated.

Evaluation of all parameters during this study was done using the FiSAT II software. This software is the most frequently used to estimate fish population parameters (Al-Barwani S *et al.*, 2007), because of relatively simple application, requiring only length frequency data. In addition, the only necessary and sufficient condition for the use of the FiSAT II software, for a species, is to have data of frequency distributions of lengths of at least 100 fish distributed over 10 to 20 length classes (Ahouanssou M, 2011).

RESULTS AND DISCUSSION

RESULTS

Growth parameters

During this study, 189 specimens of *Chrysichthys nigrodigitatus* were analyzed. The standard length (SL) varied between 35 and 270 mm. The graphical representation of the K-Scan routine used to determine the values of the asymptotic length (L∞), the growth coefficient (K) and the growth performance index (Φ') selected as correct is presented at Figure 2. The value of the adjustment index Rn used for the validation of the growth parameters was 0.36.

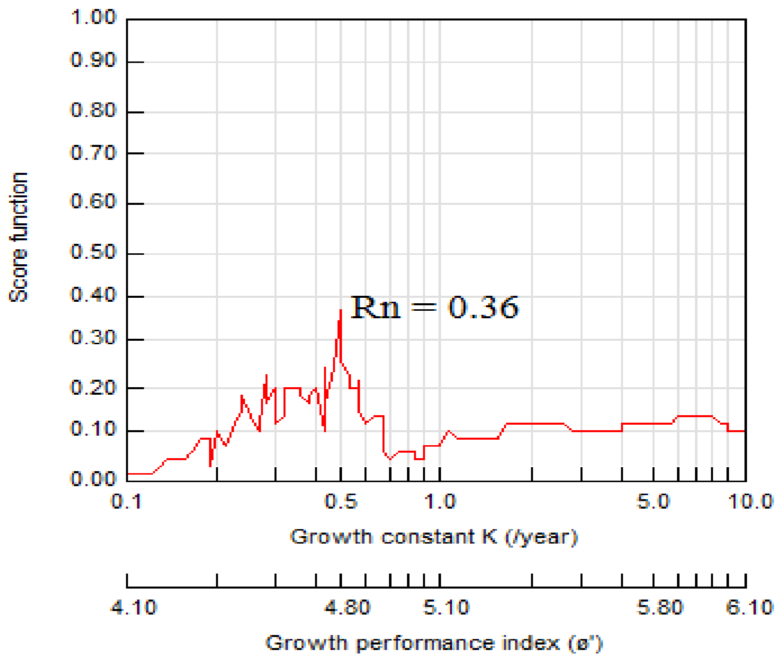

Figure 2: Curve from the K-scan routine for the determination of the best value of the asymptotic length and growth coefficient of *Chrysichthys nigrodigitatus* in the Aghien lagoon

The asymptotic length of *C. nigrodigitatus* (L∞) was 380.76 mm Ls with a growth performance index (Φ') of 2.84. The growth coefficient (K) and longevity, (t_{max}) were 0.48 year^{-1} and 6.24 years, respectively. The theoretical age (t_0) was - 0.46 years. Analysis of the graphical representation of the growth curve of the population of *C nigrodigitatus* following the Von Bertallanfy model reveals the existence of 4 cohorts within this population (Figure 3).

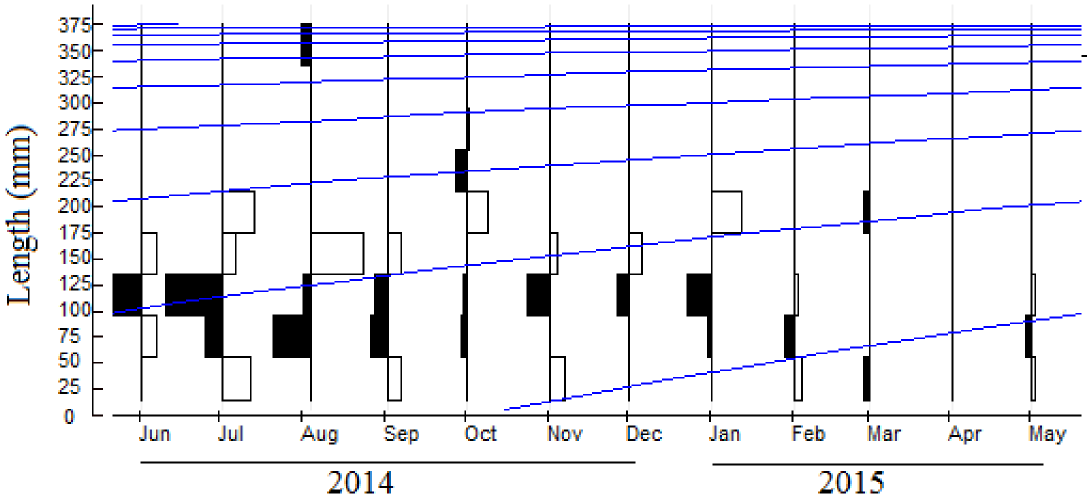

Figure 3: Modeling the growth of *C. nigrodigitatus* according to Von Bertalanffy at the Aghien lagoon

Mortality parameters and exploitation rates

Figure 4 illustrates the determination of total mortality (Z). The total mortality (Z) obtained was 2.11 year^{-1}. The natural mortality (M) for a temperature of 28.39 °C was 0.55 year -1 with a fishing mortality (F) of 1.56 year^{-1}. The corresponding current exploitation (E) was 0.74 for *Chrysichthys nigrodigitatus* at the Aghien lagoon.

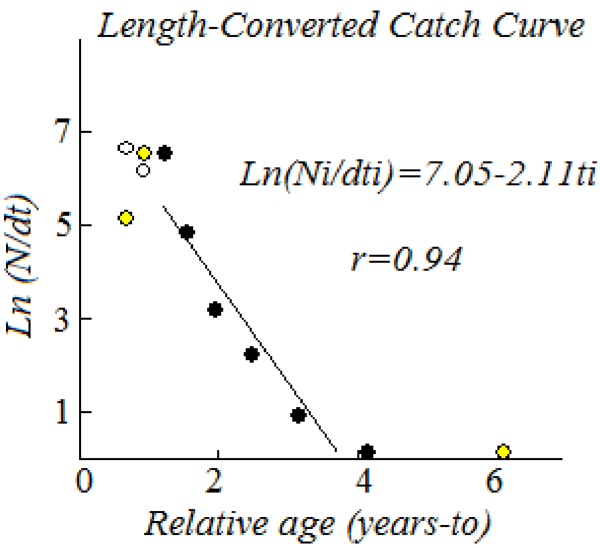

Figure 4: Determination of the total mortality (Z) of *C. nigrodigitatus* according to the linearized catch curve

Relative yield and relative biomass per recruit

The relative yield per recruit (Y'/R) increases to a maximum and then decreases. On the other hand, the relative biomass per recruit (B'/R) gradually decreases with the increase in the exploitation rate (Table 1).

Table 1: Relative yield and relative biomass per recruit according to exploitation rate of *Chrysichthys nigrodigitatus* in the Aghien lagoon

E	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Y'/R	0.019	0.033	0.041	0.043	0.040	0.033	0.022	0.011	0.002	0.000
B'/R	0.793	0.606	0.441	0.301	0.188	0.102	0.044	0.012	0.001	0.000

The current exploitation rate (E = 0.74) of *C. nigrodigitatus* is greater than the value of the maximum exploitation rate (E_{max} = 0.41) and the value of E below which the stock has been reduced by 50% of its unexploited biomass $E_{0.5}$ = 0.27).

DISCUSSION

Concerning growth parameters, the theoretical mean size that *C. nigrodigitatus*, which could live and grow indefinitely in Aghien Lagoon, would reach is greater than the maximum size observed. This result shows that large specimens could be captured if the stock of this population was not in exploitation. Analysis of the growth coefficient (K = 0.48 year $^{-1}$) indicates that *C. nigrodigitatus* grows more quickly towards asymptotic length. Indeed, (Branstetter S, 1987) indicates that the range of K values (0.20-0.50 year^{-1} and more) is characteristic of fast-growing species. In addition, the value of K shows that, the species studied is a long-lived fish species at the Aghien lagoon. Indeed, according to (Jutagate T *et al.*, 2003), for this coefficient, the interval 0 - 1 year^{-1} is characteristic of long-lived species. However, for (Niyonkuru C *et al.*, 2007) and (Ofori-Danson P *et al*, 2002), this growth is less rapid for the same species in lake Nokoué (K = 0.70 year^{-1}) in Benin and lake Volta (K = 0.65 year^{-1}) in Ghana, with a maximum longevity (t_{max} = 4.3 years in lake Nokoué; t_{max} = 4.62 years in lake Volta) lower than that obtained in the Aghien lagoon in Côte d'Ivoire. (Bédia A, 2017) have shown that the growth of *C. nigrodigitatus* in the Potou lagoon (K = 0.33 year^{-1}) in Côte d'Ivoire is lower with a maximum longevity (t_{max} = 9.9 years) greater than that observed in the Aghien lagoon in Côte d'Ivoire. Concerning the growth performance index, its estimated value (Φ' = 2.84) is relatively in the same order of magnitude as those obtained in the literature: Φ'= 2.95 in Lake Nokoué (Niyonkuru C *et al.*, 2007), Φ'= 2.96 in Potou lagoon (Bédia A *et al.*, 2017). According to (Moreau J *et al.*, 1986), the family fish species must have similar performance index (Φ') values.

For mortality parameters and exploitation rates in Aghien Lagoon, the fishing mortality (F) of *C. nigrodigitatus* was higher than the natural mortality (M). Therefore, in this lagoon, the species may have fewer predators. (Bédia A *et al.*, 2017) also reported this situation in the Potou lagoon (F = 1.73 year $^{-1}$ and M = 0.73 year $^{-1}$) in Côte d'Ivoire. However, in Lake Nokoué (Bénin), natural mortality of *C. nigrodigitatus* is higher than fishing mortality (F = 0.3 year $^{-1}$ and M = 1.3 year $^{-1}$) (Niyonkuru C *et al.*, 2007). Furthermore, at the Aghien lagoon, the Z/K ratio of *C. nigrodigitatus* was 4.39, thus showing that mortality largely predominates over growth in this fish species, as observed by (Barry J *et al.*, 1989) in their classification of Z/K ratio values. This intense mortality of the species could be due to high fishing pressure. Indeed, because of the high economic value of this species, it has become one of the preferential fishing targets in the Aghien lagoon. The predominance of mortality over growth has also been highlighted in the Aghien lagoon (Z/K = 2.92) [37] (Bédia A, 2015) and Potou lagoon (Z/K = 5.24) (Bédia A *et al.*, 2017) in Côte d'Ivoire as well as in lake Nokoué in Bénin (Z/K = 2.28) (Niyonkuru C *et al.*, 2007).

Concerning the relative yield and relative biomass per recruit, the exploitation rate (E) recorded in this lagoon is higher than the optimum exploitation rate (E_{op} = 0.50) recommended by (Gulland J, 1971). This observation indicates that the species *C. nigrodigitatus* stock in Aghien lagoon is in a state of overexploitation. This result is confirmed while considering the analysis of the relative production per recruit model based on (Beverton R *et al.*, 1966) model using the selection ogive. Moreover, this result could be justified by the fact that fishing mortality (F = 1.56 year $^{-1}$) is higher than natural mortality (M = 0.55 year $^{-1}$). In addition, stock renewal is compromised for *C. nigrodigitatus* in the Aghien Lagoon.

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