Population dynamics of the fish species *Brama bBrama* Bonnaterre (1788) in the central eastern of Atlantic Ocean, Côte d'Ivoire

ABSTRACT

The study of the population dynamics of the fish species *Brama brama* is the first of its kind in the central-eastern portion of the Atlantic bordering Côte d'Ivoire. The aim is to assess the level of exploitation of this species, through its population dynamics. Samples were collected from artisanal marine fishermen landing at the Abobodoumé pirogue wharf, Abidjan. A total of 505 individuals were collected. Most were small, ranging in size from 18 cm to 36 cm, and weighing 95.6 g toand 523.4 g respectively. Von Bertalanffy growth was deployed using FiSAT II (FAO-ICLARM Stock Assessment Tools) software (version 1.2.2) to determine the growth parameters of this Atlantic pomfret. The asymptotic length is $L\infty$ = 35.70 cm, with a growth performance Ø' = 3.25, justifying the high specific growth rate K = 1.4 yr^{-1}. Theoretical age (t_0 = - 0.97 yr^{-1}) and longevity or maximum age (t_{max} = 2.14 yr^{-1}) were determined. This maximum age obtained in Ivorian waters confirms that the fish caught are too young. Natural mortality for this species (M = 2.14 yr^{-1}) is lower than fishing mortality (F = 4.01 yr^{-1}). The exploitation rate (E = 0.65) is higher than the critical value (E = 0.5). These results suggest that this species is overexploited in Ivorian waters, even though the size of first capture is greater than the size of first maturity.

Keywords: population dynamic, Bramidae species *Brama brama*, marine fishermen

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place the common or local name of the captured species

1. INTRODUCTION

Population growth is increasing humanity's overall needs for food, materials and energy. As far as food is concerned, more than a billion people now depend on fisheries resources as their main source of animal protein [1]. This increased need is one of the main causes of the unsustainable exploitation of natural resources, leading to the degradation of entire ecosystems and thus disrupting their overall functioning. Today, while many resources are overexploited, around 11% of the world's population remains undernourished [1]. In addition to the fish species targeted by artisanal fishing and the subject of several studies (tuna and related species), some are considered bycatch. This is precisely the case for the Atlantic pomfret, whose scientific name is *Brama brama* Bonnaterre (1788). It is also important to monitor the stock of these non-target species, in order to preserve biological diversity and the

proper functioning of fishing ecosystems. It is with this in mind that population dynamics of this fish from the Bramidae family have been undertaken.

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2. MATERIALS AND METHODS

2.1 Sampling site

Sampling of the *Brama brama* fish species was carried out in an artisanal marine fishery operating in the Gulf of Guinea. This stretch of ocean belongs to the central-eastern zone of the Atlantic Ocean, which covers West Africa from Morocco to Congo [2]. Côte d'Ivoire's Exclusive Economic Zone (EEZ), which extends over a length of around 600 km [3], is a fraction of the central-eastern Atlantic Ocean. This Ivorian property extends from Cap of Palmes (8°W) in the west, to Cap of Tree Pointes (2°30'W) in the east. (Figure 1).

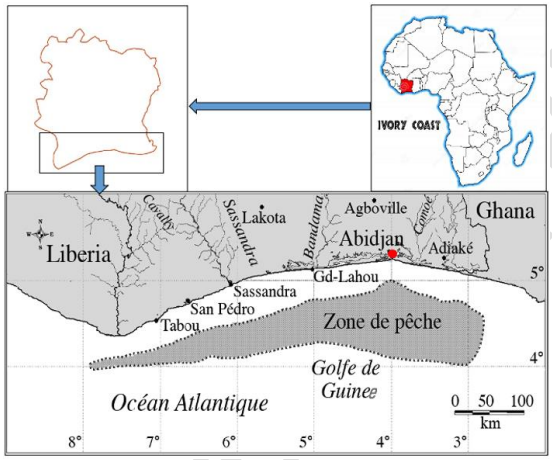

Fig 1: Fishing zone of artisanal marine fishermen in Côte d'Ivoire EEZ [4] ●**: ~~Landing (~~data collection site~~)~~

2.2 Sampling

- ~~This sampling involved~~ A total of 505 individuals of the *Brama brama* species were~~,~~ caught by the artisanal commercial fishery by drift gillnets in the Côte d'Ivoire EEZ, near ~~that lands at~~ the Abobodoumé wharf, Abidjan~~.~~. ~~These individuals were caught with drift gillnets in the Côte d'Ivoire EEZ~~, between November 2021 and April 2023. Data collection takes place weekly from Thursday to Saturday. When individuals of this species are landed, the main metric parameters (length and total mass) are sampled. Each fish is then opened on the flank with a pair of shears to identify the sex and determine the macroscopic stage of maturation. After sex identification, the gonads are recovered and weighed. Three fragments are then taken from each gonad, one in the middle and

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the other two at the ends. These centimeter-long fragments are preserved in pillboxes with physiological liquid (~~70° alcohol~~ ethanol 70%), then sent to the laboratory for histological studies.

2.3 Total length measurement

The total length (~~L~~TL~~t~~) of 505 fish of the *Brama brama* species was measured to the nearest 0.1 cm with a centimeter tape measure. The total weigh of each fish was also measured using an HD TECH electronic balance, precision 0.01 gram.

2.4 Growth and exploitation parameters

The [5] model has been deployed in the FiSAT II software (FAO-ICLARM Stock Assessment Tools II) (version 1.2.2) to determine growth parameters. It is one of the most widely used models for growth studies in fisheries biology. ~~Using this software, T~~the theoretical age (t_0) was calculated according to the following relationship:

$$log10(-t0) = -0.392 - 0.275 * log10(L\infty) - 1.038 * log10(K)$$

~~L~~TL~~t~~: fish length at age t (cm), L∞: asymptotic length (cm) at which growth is zero, K: growth rate (yr^{-1}), t_0: the theoretical age at which the fish has zero size.

On the basis of these parameters (L∞ and K) determined, the length-based index of growth performance (Ø') and maximum lifespan of these fish in our waters were calculated from the formulas proposed by [6] as follows:

$$Ø' = log10(K) + 2log10(L\infty)$$

$$-\text{tmax} = \frac{2.9957}{K}$$

A number of relationships exist between the total (Z), natural (M) and fishing (F) mortality coefficients, as well as with the exploitation rate (E):

$$\text{Z} = \text{M} + \text{F} \;;\; \text{E} = \frac{\text{F}}{\text{Z}} \;;\; \text{E} = \frac{\text{F}}{\text{M} + \text{F}}$$

When two of the mortality parameters are known, the third is automatically deduced.

Following [7] work on the exploitation rate (E) of a fishery resource, when E < 0.5, the stock is said to be underexploited, when E > 0.5 the stock is overexploited, and when E = 0.5 or F = M, the stock is optimally exploited.

2.5 Recruitment and first-capture size

The ogive selection method stipulates that the probability of a fish being caught is correlated with its length. On this basis, the size of first capture (Lc or L_{50}) is estimated, and the optimal length (Lopt) of capture is estimated for a given cohort according to the following equation from [8]:

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$$\text{Lopt} = L\infty \frac{3}{3+(\frac{M}{K})}$$

L∞ and K are function of Von Bertalanffy growth, while the value of M depends on the natural mortality rate. The recruitment period for Atlantic pomfret (*Brama brama*) was determined using FiSAT II's recruitment patterns method, based on individual size frequency data.

3. RESULTS AND DISCUSSION

3.1 Length-frequency distribution

The total number of individuals of this species caught with drift gillnets between November 2021 and April 2023 was 505 fish. During this period, the maximum length of *Brama brama* caught was 36 cm LTt (523.4 g) and the minimum, 18 cm ~~L~~TL~~t~~ (95.6 g) (Fig 2). The greatest number of individus caught was between 22 cm and 28 cm, and the mode was observed in the size class [24 - 26].

~~In this central-eastern portion of the Gulf of Guinea bordering Côte d'Ivoire,~~ the smallest size encountered (18 cm) is larger than that encountered by [9] in Iraqi waters (6.5 cm TL~~t~~). The same applies to the smallest size encountered by [10] in the waters of Veraval, India (6 cm TL~~t~~). As for the largest size encountered in our catches (36 cm TL~~t~~), there is no significant difference between those observed by [9] and [10], which are 35 cm and 38.5 cm TL respectively. The longest recorded length of this species, 100 cm, was observed in southern Portugal by [11]. The peak of our catch abundance is observed between 22 cm and 28 cm, compared with 13.8 and 20.8 cm [9] and between 22.5 and 26.5 cm TL [10]. Elsewhere, the size of pomfret caught in the waters of Tarakan, East Kalimantan, ranges from 9 cm to 35 cm FL [12], in the Persian Gulf, from 9.5 to 31.2 cm FL [13] and in the Arabian Sea from 10 to 32 cm FL [14]. The encounter of smaller individuals in Iraqi waters and in Veraval, India, would be linked to fishing carried out near spawning grounds, unlike the sites surveyed in Côte d'Ivoire. On the other hand, the absence of juveniles in our catches may be linked to the large mesh size of the drift gillnet used to target tuna. Several factors may also be responsible for differences in the frequency of each size class, including external factors such as food and temperature, as well as internal factors such as sex, age, heredity, parasites and diseases that influence fish growth. Also, the use of drift gillnets, which have a shallow drop-off depth, cannot capture the larger sizes of *Brama brama*, because according to [15], the largest fish of this species are found at greater depths.

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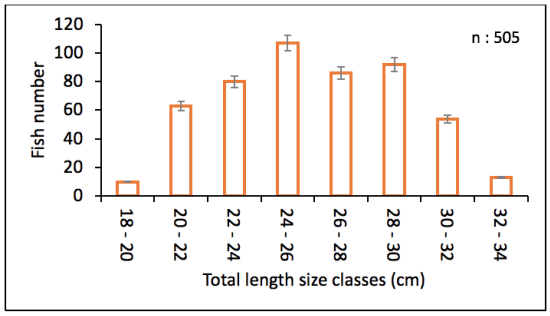

Fig 2: Length frequency distribution of *Brama brama* by size-class in ZEE Côte d'Ivoire (November 2021 - April 2023)

3.2 Growth parameters

Estimated growth parameters for *Brama brama* include asymptotic length ($L\infty$ = 35.70 cm), specific growth rate (K = 1.4 yr^{-1}), length-based index of growth performance (Ø' = 3.25), theoretical age (t_0 = - 0.97 yr^{-1}) and longevity or maximum age in Ivorian waters (tmax = 2.14 yr-1). The growth curve used to determine these parameters is shown in fig3.

In *Brama brama* fish, the asymptotic length is the theoretical maximum length that individuals of this species can reach in this fraction of Atlantic Ocean, in relation to the factors influencing their environment. The value of K corresponds to the speed at which these fish grow to reach this greatest length locally. The asymptotic length obtained is 35.70 cm. The growth rate obtained for this species is 1.4 yr^{-1}. In the Persian Gulf, [16] obtained an asymptotic length of 33.90 cm with a growth rate of 0.55 yr^{-1}. In India, in the Veraval locality, [10] obtained 41.57 cm as the asymptotic length, with a value of K= 0.64 yr^{-1}. The asymptotic length obtained in the present study is greater than that obtained in the Persian Gulf, and smaller than that observed in India. The growth rate obtained in the Ivorian región~~portion~~ is higher than in the other two localities. In general, variations in the growth rate of a species from one body of water to another could be due to ecosystem-specific factors and biological phenomena such as maturation phases and competition for food [17]. Also, variations in $L\infty$ and K between regions are due to ecological differences, variability of fish and to parasites and other diseases. The growth rate calculated for individuals of this species ranging in size from 32.8 cm to 51.5 cm was K = 0.342 yr^{-1}. This low growth rate in larger individuals compared with our samples is explained by [18] as meaning that this species grows rapidly during its first years of life. This corroborates the high growth rate observed in our individuals, all of which have an optimum lifespan of less than three years (tmax = 2.14 yr^{-1}). Several other authors have reported a period of rapid growth in the early years of the pomfret's life in Atlantic Ocean [19].

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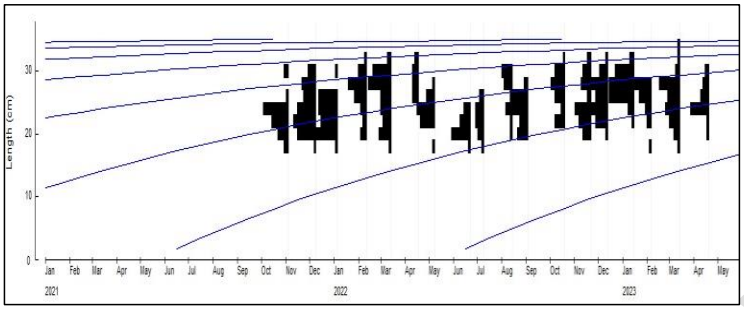

Fig 3: Von Bertalanffy growth curve of *Brama brama* in EEZ waters of Côte d'Ivoire from November 2021 to April 2023

3.3 Mortality parameters

The catch curve for ~~the fish species~~ *Brama brama* ~~in Côte d'Ivoire EEZ~~ is shown in fig 4. The values obtained with a mean surface temperature of 28.6°C are total mortality (Z = 6.15 yr^{-1}), natural mortality (M = 2.14 yr^{-1}), fishing mortality (F = 4.01 yr^{-1}) and exploitation rate (E = 0.65) in Côte d'Ivoire marine waters. In this case, the value of fishing mortality is higher than natural mortality, approaching double the latter. Also, the exploitation rate (E) of our species is higher than the reference exploitation rate (E = 0.5) which symbolize overexploitation.

Natural mortality of *Brama brama* (M = 2.14 yr^{-1}) is lower than fishing mortality (F = 4.01 yr^{-1}) ~~in the Côte d'Ivoire EEZ~~. This implies that the mortality of most of these fish is linked to fishing and not to predation or habitat and physicochemical characteristics. Human harvesting is therefore responsible for stock fluctuation in this ecosystem. The exploitation rate (E = 0.65), which is an anthropogenic action, confirms this fact, as the value of E is higher than the critical value (E = 0.5). According to [20], the maximum level of exploitation of a resource is reached, when the exploitation rate is greater than or equal to 0.5, or when fishing mortality (F) is equal to or greater than natural mortality (M). It is therefore possible to affirm that this fish species, considered as by-catch, is overexploited in Ivorian waters. In addition, the F/K ratio (2.86) greater than 2 again confirms high fishing-related mortality. ~~Elsewhere, I~~in India, cases of overexploitation of this species have been reported, notably in Veraval (India) where fishing mortality (F = 2.11 yr^{-1}) was higher than natural mortality (M = 1.20 yr^{-1}), with an exploitation rate (E = 0.64) above the critical value [10]. This was the case in Pangandaran (Indonesia), where fishing mortality (F = 3.04 yr^{-1}) also greater than natural mortality (M = 0.64 yr-1) resulted in a case of overexploitation with a value of E = 0.84 [21].

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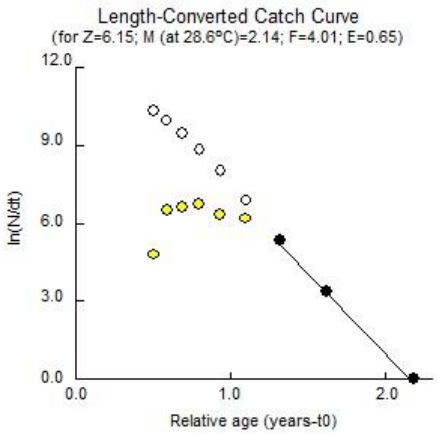

Fig 4 : Capture curve based on total length of *Brama brama* in EEZ waters of Côte d'Ivoire from November 2021 to April 2023

3.4 Recruitment and first-capture size

Fig 5 below illustrates the variation in the probability of *Brama brama* capture as a function of individual size. ~~Looking at the graph, T~~the average size of first capture (Lc or L_{50}) is 27.58 cm. This value is greater than the first maturity size for both males (18.11 cm) and females (17.78 cm).

The histogram obtained using ELEFAN I (FiSAT II) software shows the variation in the rate of appearance of juvenile fish over the months of an entire year (Fig 6) with a~~. Analysis of this figure reveals a~~ recruitment curve with a single peak. This recruitment, which occurs throughout the year with values below 20%, is most pronounced in June and July, at around 18%.

The exploitation rate (E) obtained from the ratio of fishing mortality (F) to total mortality (Z) is 0.65. This rate (E) is well above the maximum exploitation rate, as well as the optimum exploitation rate (Eopt = 0.5). Figure 7 shows that, after a growth phase, the yield per recruit of this species peaked at an exploitation rate of 0.42, and is now entering a phase of steady decline as the exploitation rate continues to increase.

The implementation of the Beverton and Holt model [22] in the FiSAT II software has made it possible to obtain results for the yield per recruit of the *Brama brama* fish population. In the Côte d'Ivoire EEZ, the exploitation rate (E = 0.65) is higher than the rate corresponding to the capture of 50% of the population (E-50 = 0.278). This value is also higher than the maximum exploitation rate (E-max = 0.421). Based on these results, the certainty of overexploitation of Atlantic pomfret in our study area is confirmed, since [19] have stated that this species is said to be overexploited when the exploitation rate exceeds the critical threshold (E_{max}). One of the reasons for overexploitation is that drift gillnet meshes are not designed to

avoid these individuals, as they are considered non-targeted. Also, the lack of control by fishermen in the field encourages the use of unapproved catching gear, which is a factor in the destruction of stocks. What's more, the Z/K ratio (4.39) of this species is well above 2, synonymous with total mortality predominating over growth [23]. This is bound to lead to very intense exploitation of this resource, as many of the young individuals have no chance of reaching optimum growth size. As the size of first capture (Lc or L_{50}) is greater than the size of first maturity, we can say that this is a case of biological overexploitation. A fishery focused on the spawning stock generally leads to such overexploitation.

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The recruitment histogram for this species shows continuous recruitment throughout the year, with a significant peak in the months of June-July. These months, included in the major upwelling [4], are thought to be favorable for young fish feeding, thanks to the planktonic proliferation during this period.

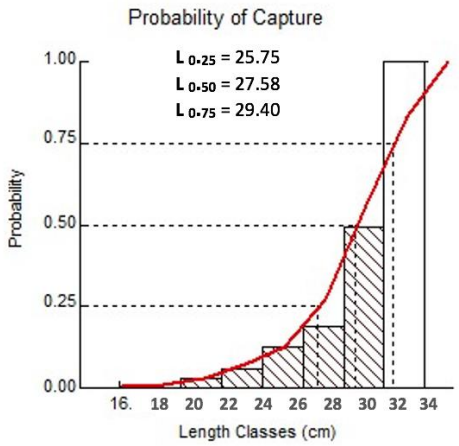

Fig 5 : Selectivity curves showing the probability of catching *Brama brama* in EEZ waters of Côte d'Ivoire from November 2021 to April 2023

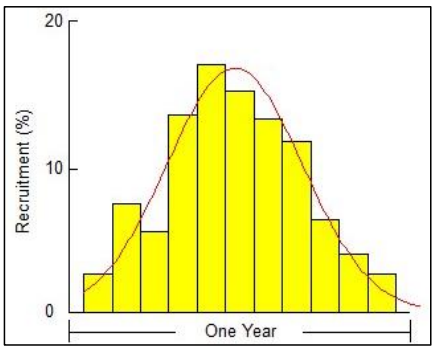

Fig 6 : ~~Histograms of~~ *Brama brama* juvenile fish recruitment in EEZ waters of Côte d'Ivoire from November 2021 to April 2023

4.Conclusion

~~This study of the dynamics of the Atlantic pomfret (*Brama brama*) is the first of its kind on this species in the marine waters of Côte d'Ivoire. The study involved 505 individuals caught with drift gillnets, ranging in size from 18 cm to 36 cm. All fish were between one and three years old.~~ The results showed that this fish species is overexploited in the Ivorian portion of the Atlantic Ocean. The fishing mortality coefficient is higher than the natural mortality coefficient. The exploitation rate of this species is higher than the exploitation rate of the yield per maximum recruit. The asymptotic length of this species is relatively low, compared with values obtained in other localities. In terms of growth coefficient, this size game caught in Côte d'Ivoire shows accelerated growth. Recruitment of young fish is continuous for this species, with a relatively high rate in June-July (upwelling period). As the size of first capture is greater than the size of first maturity, we say that this fishery is focused on the spawning stock. In such a fishery, recruitment rates will tend to fall, leading to local overexploitation of the resource. Closing fishing grounds during the upwelling period could be an alternative to replenish the stock of this species.

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