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Population Dynamics of the Fish Species *Brama brama* (Bonnaterre, 1788) in the Central-eastern Atlantic Ocean, Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

To find out more about the exploitation status of the fish species *Brama brama* in Côte d'Ivoire, population dynamics were undertaken with Logiciet FiSAT II (FAO-ICLARM Stock Assessment Tools) software (version 1.2.2). Samples were collected from artisanal marine fishermen landing at the Abobodoumé pirogue wharf, Abidjan. The study of this population dynamics is the first of its kind in the central-eastern portion of the Atlantic bordering Côte d'Ivoire. A total of 505 individuals were collected. Most were small, ranging in size from 18 to 36 cm, and weighing 95.6 to 523.4 g respectively. Von Bertalanffy growth was deployed using FiSAT II to determine the growth parameters of this Atlantic pomfret. The asymptotic length is L_∞ = 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 = -

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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: Brama brama; growth parameters; fishing mortality; exploitation status; Côte d'Ivoire.

1. INTRODUCTION

Population growth is increasing humanity's overall need for food, materials and energy (FAO, 1996). As far as food is concerned, more than a billion people today depend on fishery resources as their main source of animal protein (FAO, 2018). Under-nourishment is a major problem in Africa, especially when it comes to animal protein intake (Van E. Hecke & Vanderleenen, 2023). This increased need is one of the main causes of the unsustainable exploitation of natural resources, leading to the degradation of entire ecosystems and disrupting their overall functioning. Today, while many resources are overexploited, around 11% of the world's population remains under-nourished (FAO, 2018). In addition to the fish species targeted by artisanal fishing and the subject of several studies (tuna and related species), some are considered by-catch. This is precisely the case for the Atlantic pomfret *Brama brama* (Bonnaterre, 1788), which has so far not been the subject of any study in Côte d'Ivoire, despite being on the IUCN red list since 2013 (Iwamoto et al., 2015). This species of perciform fish is found in the Atlantic, Indian and South Pacific oceans, as well as in the Mediterranean (Figueiredo et al., 2002). Although this species has little commercial value at local level, it plays a vital role in the functioning of food webs. It is therefore important to monitor the stock of these non-target species, in order to preserve biological diversity and the proper functioning of fishing ecosystems. With this in mind, we have undertaken a study of the population dynamics of this fish species through the FAO-ICLARM Stock Assessment Tools II software (FiSAT II), in order to inform fisheries managers of its status in Côte d'Ivoire.

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 (Chavance et al., 2004). Côte d'Ivoire's Exclusive Economic Zone (EEZ), which extends over a length of around 600 km (N'goran et al., 2001), 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. (Fig. 1).

2.2 Sampling

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 the Abobodoumé wharf, Abidjan 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 the other two at the ends (Soro et al., 2009). These centimeter-long fragments are preserved in pillboxes with physiological liquid (ethanol 70%), then sent to the laboratory Oceanological Research Center (CRO) for histological studies.

2.3 Total Length Measurement

The total length (TL) of 505 fish of the *Brama brama* species was measured to the nearest 0.1 cm with a centimeter tape measure, following (Mainguy et al., 2023) model. 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 Von Bertalanffy model (Von Bertalanffy, 1938) 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. The theoretical age (t_0) was calculated according to the following relationship elaborated by (Von Bertalanffy, 1938):

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

TL: fish length at age t (cm), $L\infty$: 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 ($L\infty$ 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 (Pauly & Munro, 1984) 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 Gulland (Gulland, 1971) 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 equation of Beverton (1992):

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

$L\infty$ 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.

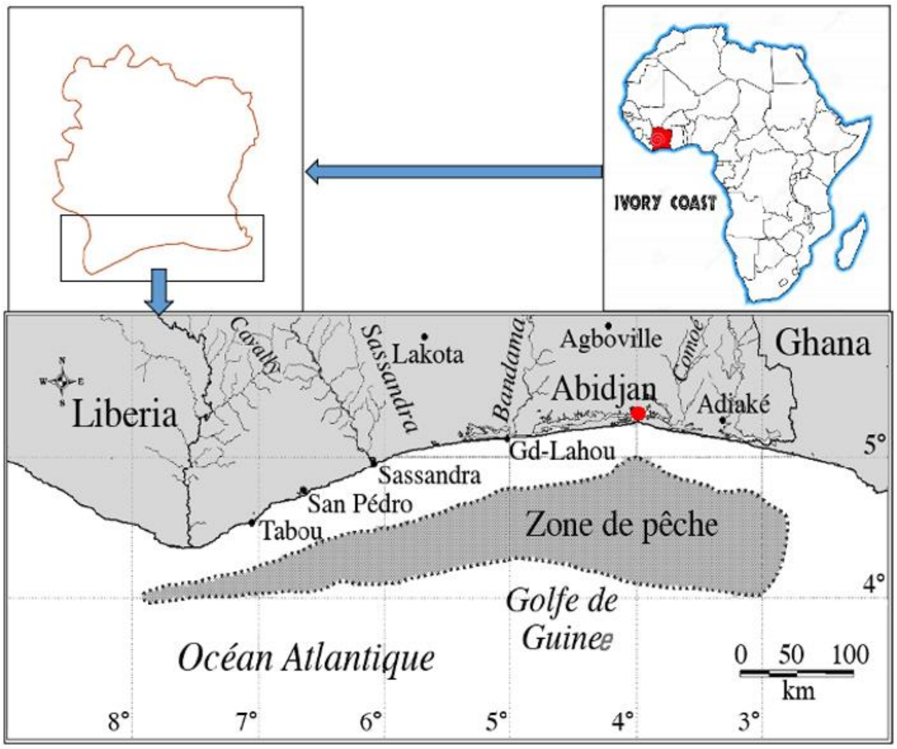

Fig. 1. Fishing zone of artisanal marine fishermen in Côte d'Ivoire EEZ (SORO et al.,2009, modifiée)

3. RESULTS AND DISCUSSION

3.1 Length-Frequency Distribution

During this period, the maximum length of *Brama brama* caught was 36 cm TL (523.4 g) and the minimum, 18 cm TL (95.6 g) (Fig. 2). The greatest number of individius caught was between 22 cm and 28 cm, and the mode was observed in the size class (Francis et al., 2007; Barrios, 2017; Lederoun et al., 2015).

the smallest size encountered (18 cm) is larger than that encountered by Nasir, (2016) in Iraqi waters (6.5 cm TL). The smallest size encountered by Ghosh et al., (2009) in the waters of Veraval, India (6 cm TL). As for the largest size encountered in our catches (36 cm TL), there is no significant difference between those observed by Nasir, (2016) and Ghosh et al., (2009), 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 Lobo & Erzini, (2001). The peak of our catch abundance is observed between 22 cm and 28 cm, compared with 13.8 and 20.8 cm (Nasir, 2016) and between 22.5 and 26.5 cm TL (Ghosh et al., 2009). Elsewhere, the size of pomfret caught in the waters of Tarakan, East Kalimantan, ranges from 9 cm to 35 cm FL (Prihatiningsih et al., 2015), in the Persian Gulf, from 9.5 to 31.2 cm FL (Amrollahi et al., 2006).

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. Also, the use of drift gillnets, which have a shallow drop-off depth, cannot capture the larger sizes of *Brama brama*, because according to Morales-Nin, (1991), the largest fish of this species are found at greater depths.

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 Fig. 3.

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, (Narges et al., 2011) obtained an asymptotic length of 33.90 cm with a growth rate of 0.55 yr^{-1}. In India, in the Veraval locality, (Barrios, 2017) 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 region 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 (Al-Nahdi et al., 2009). 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 Watanabe et al., (2006) 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 (Shimazaki, 1989).

3.3 Mortality Parameters

The catch curve for *Brama brama* is shown in Fig. 4. The values obtained with a mean surface temperature of 28.6°Care 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.

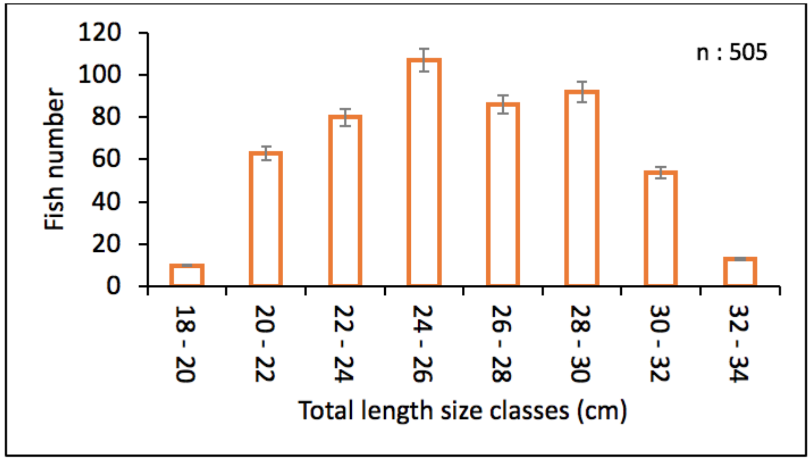

Fig. 2. Length frequency distribution of *Brama brama* by size-class in ZEE Côte d'Ivoire (November 2021 - April 2023)

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

Natural mortality of *Brama brama* (M = 2.14 yr^{-1}) is lower than fishing mortality (F = 4.01 yr^{-1}). 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 Al-Nahdi et al., (2009), 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. 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 (Ghosh et al., 2009).

3.4 Recruitment and First-Capture Size

Fig. 5 illustrates the variation in the probability of *Brama brama* capture as a function of individual size. 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 juveniles over the months of a whole year (Fig. 6), with a curve showing a single peak. This recruitment, which occurs throughout the year with values below 20%, is most pronounced in June and July, at around 18%.

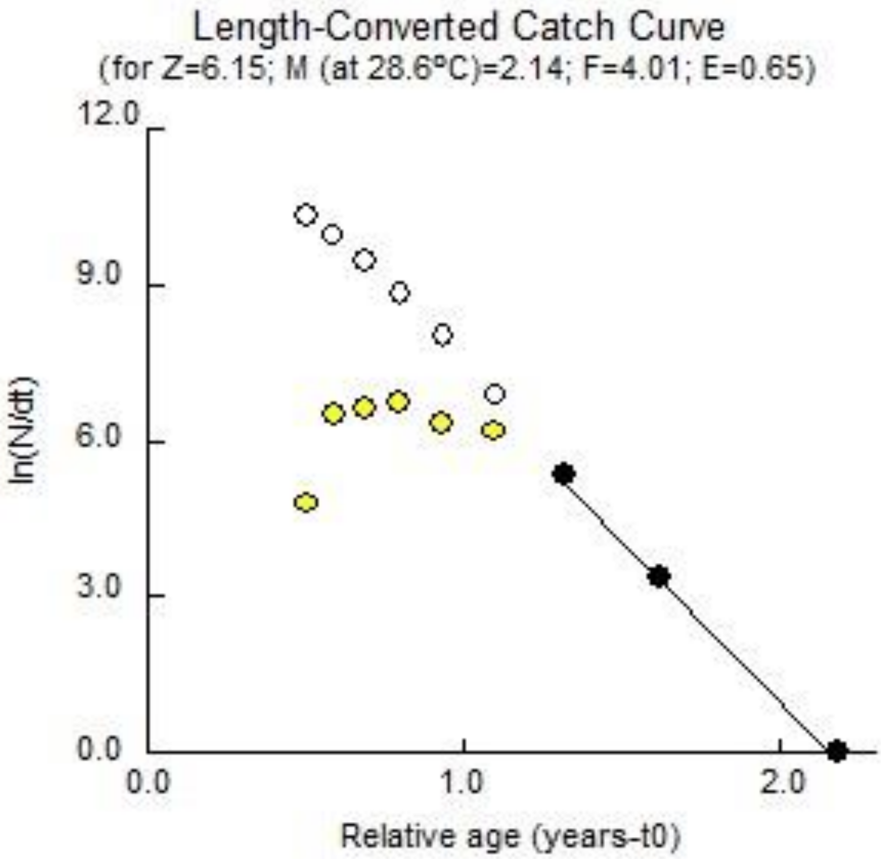

Fig. 4. Capture curve based on total length of *Brama brama* in EEZ waters of Côte d'Ivoire from November 2021 to April 2023

The implementation of the Beverton and Holt model (Barrios, 2017) in the FiSAT II software has made it possible to obtain results for the yield per recruit of the *Brama brama* fish population. In 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 (Francis et al., 2007) have stated that this species is said to be overexploited when the exploitation rate exceeds the critical threshold (Emax).

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 (Lederoun et al., 2015).

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 L50) 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. 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 (Soro et al., 2009), are thought to be favorable for young fish feeding, thanks to the planktonic proliferation during this period.

Compared with the tuna and tuna-like species landed by artisanal marine fishermen, the by-catch of *Brama brama* fish is insignificant from an economic point of view. So, to date, neither the Ivorian authorities nor the fishermen themselves have made any effort to enable individuals of this species to escape capture gear. However, the extinction of this species at local level would cause an imbalance in food webs, as *Brama brama* would be a potential prey for many fish living in the present study area. For optimal management of *Brama brama*, it would be advisable to identify the breeding seasons, as well as the ecosystems of ecological interest frequented by individuals of this species, including spawning grounds, nurseries and biological resting places.

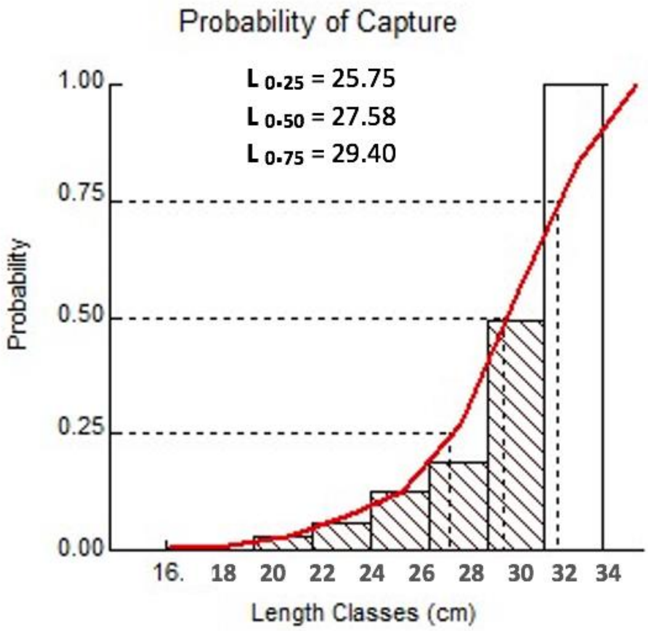

Fig. 5. Selectivity curves showing the probability of catching *Brama brama* in EEZ waters of Côte d'Ivoire from November 2021 to April 2023

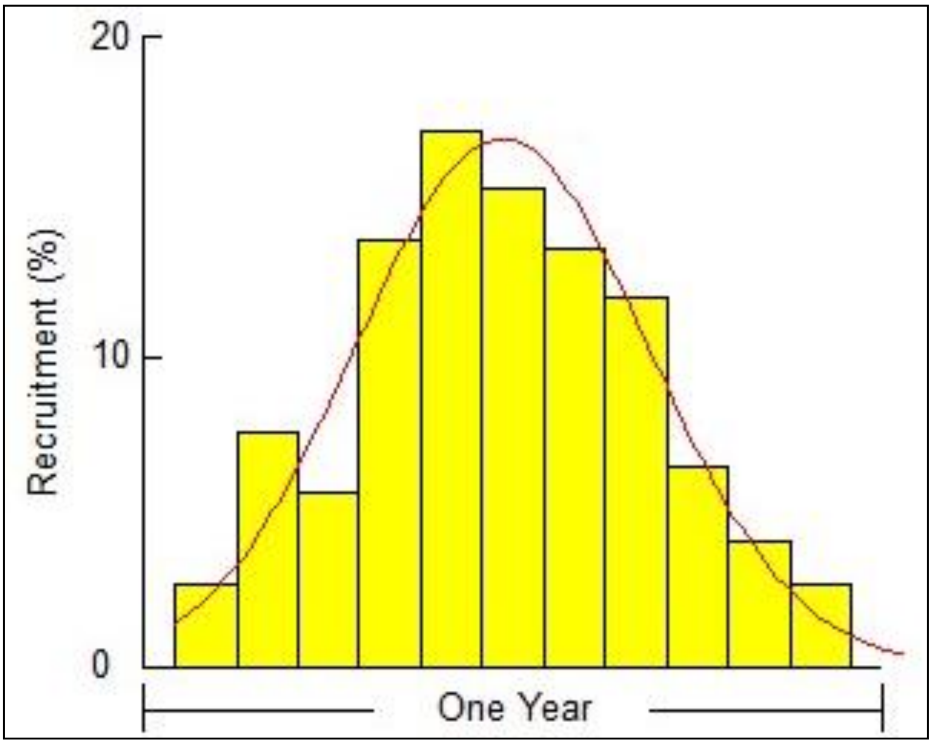

Fig. 6. *Brama brama* juvenile fish recruitment in EEZ waters of Côte d'Ivoire from November 2021 to April 2023

4. CONCLUSION

Population dynamics of *Brama brama* fish were studied using FiSAT II software, to find out more about the level of exploitation of this species in Côte d'Ivoire waters. The results showed that this species is overexploited in Côte d'Ivoire. This assertion is supported by the fishing mortality coefficient, which is higher than the natural mortality coefficient. The same applies to the exploitation rate, which is higher than the exploitation rate of the maximum yield per recruit. As the size of the first catch is greater than the size of the first sexual maturity, we can say that this fishery is focused on the spawning stock. Under these conditions, recruitment rates will fall, which will necessarily lead to lower catches. The protection of spawning grounds, nurseries and biological resting places, once identified, would make it possible to rebuild the stock of this species in Ivorian waters, if only to maintain the proper functioning of local food webs, given the low economic contribution of this fish.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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