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Reproductive biology of the fish *Liza dumerili* (Steindachner, 1870) in the Ebrié lagoon (South-Eastern Côte d'Ivoire, West Africa)

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Abstract
The reproductive features of the fish *Liza dumerili* were studied for one annual period in the sector III of the Ebrié lagoon from south-eastern Côte d'Ivoire. Overall, an annual population comprising 141 males, 232 females, and 74 unsexed immatures were collected. The sex ratio was 1:1.64 in favour of females. The theoretical sex ratio (1:1) and the observed sex ratio within the population of *L. dumerili* differed significantly ($X^2 = 5.974$; $p<0.05$). At the level of the first sexual maturity, the mean of male fork lengths reached 242 mm while measurements of this morphological character in females were 245 mm. The monthly evolution of the gonado-somatic index (GSI) associated with sexual maturation stages are a hint that *L. dumerili* mainly reproduces in the rainy season, in particular between April and June. The absolute fecundity in females varied from 112 095 to 920 356 oocytes and corresponded to individuals having their fork lengths comprised between 209 and 335 mm. Meanwhile, the relative fecundity weighed between 1156 and 1247 oocytes/g.

Keywords: Fecundity, Mugilidae, reproductive features, Ebrié lagoon, Côte d'Ivoire

Introduction
Fishes of the family Mugilidae are abundant and largely widespread in estuaries of tropical and temperate regions where they represent a major commercial resource [5]. In West Africa, only the genera *Mugil* and *Liza* are known from this family. These pelagic and coastal vertebrates are particularly encountered in brackish waters and do well in high salinity conditions [3]. They have been bred for many years in countries namely Italy, Japan, Taiwan, Hawaii (USA), Egypt and Tunisia [33]; because of their organoleptic quality and the therapeutic properties of by-products such as: salted and dried ovaries and oil of the head and triples [28].
In Côte d'Ivoire, these two genera are represented by six species, namely *Mugil cephalus*, *Mugil curema*, *Mugil bananensis*, *Liza falcipinnis*, *Liza grandisquamis* and *Liza. dumerili* [24]. Moreover, the availability of these species in lagoon systems, their very high growth potential [3, 23], their ecology and dietary [3, 31] and their organoleptic quality [3] make most of them appropriate animals for aquaculture. Breeding a fish species requires knowledge of its feeding habits as well as its reproductive biology in the wild. If the reproductive biology of *M. curema*, *L. falcipinnis* and *L. grandisquamis* in the Ebrié lagoon [3] and that of *M. cephalus* in the Ebrié and the Grand-Lahou lagoons [10] are known, that of *L. dumerili* has so far not been studied in the country. However, *L. dumerili* colonizes the three lagoon systems (Aby, Ebrié and Grand-Lahou).
It is a species with high aquaculture potential because of its rapid growth and its organoleptic qualities [23]. In addition, it feeds on inexpensive food [31].
The aim of this study is to determine the reproductive parameters of *L. dumerili* in the Ebrié lagoon through the knowledge of the sex ratio, the size of the first sexual maturity, the reproduction period and the fertility.

Materials and methods
Study site
The Ebrié lagoon is located between 3 ° 47 'and 5 ° 29' West longitude and between 5 ° 02 'and 5 ° 42' North latitude. With a total area of 566 km2, it stretches 130 km from the Azagny Canal

to the west, which connects it with the Bandama river and the Grand-Lahou lagoon. In the East, it merges with the offshore outlet of Comoé river [41] and is connected to the Aby lagoon via the Assinie canal (Figure 1). The Ebrié lagoon communicates with the Atlantic Ocean throughout the Vridi canal. It has been subdivided into six sectors [12, 11] including the sector III, (study site).

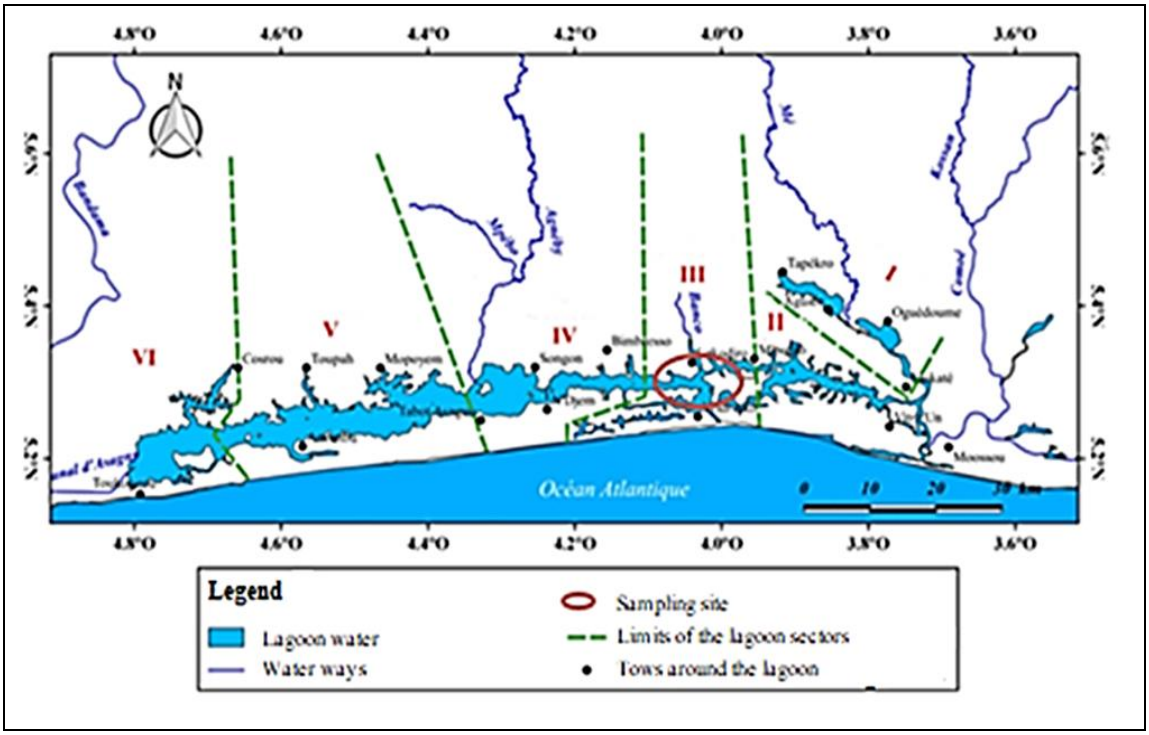


Fig 1: Map of Ebrié lagoon with different sectors (I, II, III, IV, V, VI) and sampling site.

Sampling and measures of breeding parameters

Monthly samples of *Liza dumerili* were collected in sector III of the Ebrié lagoon from September 2017 to August 2018. The experimental fisheries were carried out with a 70 m long gillnet for a fall of 2 m and 20 mm mesh side. The net was laid at 7 pm and raised at 2 am. In parallel, physico-chemical parameters such as pH, salinity, dissolved oxygen, temperature, conductivity and turbidity were determined. The captured fish were kept in the ice and transported to the laboratory. Once in the laboratory, they were identified using the keys of Albaret [2], Harrison [19] and Konan *et al*. [24]. On each individual, the total *(Lt)*, fork (*Lf*) and standard (*Ls*) lengths to the nearest millimeter and the total mass to the nearest 0.1 g were measured. The fish were subsequently dissected to collect the gonads and the liver. These organs were weighed. The weight of eviscerated fish was determined. Sex and stage of sexual maturity is identified using the macroscopic scale of EL Housni [13].

The sex ratio (M: F), expressing the proportion of males or females in a sampled population, was determined according to the following formula:

$$SR = \frac{M}{F}$$

where M is the number of males and F the number of females.

The study of the size of first sexual maturity was made by determining the proportions of mature individuals per size class of 1 cm interval. The size of first sexual maturity that corresponds to the length at which 50% of the individuals are mature [17] was determined using a logistic function that links the proportions of mature individuals to the total length of the fish [36]. This feature tracks the degree of sexual maturity by size. It is computed with the following equation:

$$P = \frac{1}{1+e^{-(a+bLf)}} \text{ with } Lf_{50} = -\frac{a}{b}$$

P = proportion of mature fish;
Lf = fork length of fish;
a and *b* a re constants.

In this study, fish with gonads reaching a stage ≥ 4 are considered mature.

In order to establish the sexual cycle and to determine the laying period, the gonado-somatic index (GSI) which reflects the mass evolution of the gonads with respect to the mass of the eviscerated fish and the hepato-somatic index (HSI), thus reflecting the evolution in mass of livers compared to the mass of eviscerated fish; males and females were calculated monthly with the formulas:

$$GSI = \frac{M_g}{M_{év}} \times 100 \quad \text{and} \quad HSI = \frac{M_f}{M_{év}} \times 100$$

with Mg representing gonads mass (in g), M_f being the mass of livers (in g) and $M_{év}$ being the eviscerated mass of the fish (in g).

The condition factor reveals the physiological state of fish of the same species. It provides information, among other things, on the storage of the reserves necessary for gametogenesis [16], and therefore on the fish's ability to reproduce. It has been determined with the following formula:

$$K = \frac{M}{Lf^3} \times 100$$

with M being the live weight of fish and *Lf* = fork length of fish.

Absolute fertility (number of oocytes in one ovary) and relative (number of oocytes per unit of body weight) were determined by counting oocytes at the advanced maturation stage (stage 5). These indices were calculated to evaluate the reproductive potential of *Liza dumerili* females.

Data Analysis

The Chi-square (X^2) test was used to compare the percentages of sex ratios calculated for the different hydrological seasons with the theoretical sex ratio (1:1). This test was also used to compare the size of first sexual maturity between males and females. The analyses were performed using the R software.

Results

Sex-ratio

A total of 447 specimens of *Liza dumerili* were caught (141 males, 232 females and 74 immature fishes). The results of sex ratio for all individuals captured in the Ebrié lagoon indicate the female dominance (1:1.64; Table 1). The X^2 test shows that there is a significant difference between observed sex ratio and theoretical sex ratio 1:1 (X^2 = 5.974; P = 0.00914).

Whereas the sex ratio observed in dry season was more favorable for females (1:1.83), this, in rainy season, was in contrast in favour of males (1:0.6). Likewise, during the flood season, the sex ratio was in favor of the females (1:2.28). The observed sex ratio and the theoretical sex ratio (1:1) differed significantly these three seasons.

Table 1: Monthly and seasonal variations of the sex ratio of *Liza dumerili* fished in the Ebrié lagoon.

Season	Month	M	F	M : F	G
Dry season	January	8	12	1:1,5	4,027*
	February	1	0	----	----
	March	0	2	----	----
	April	4	10	1:2,5	18,960***
	Total	13	24	1:1,85	8,785**
Rainy season	May	16	6	1:0,38	21,444***
	June	10	4	1:0,4	18,978***
	July	4	6	1:1,5	4,027*
	August	20	14	1:0,7	3,128
	Total	50	30	1:0,6	6,316*
Flood season	September	40	112	1:2,8	23,354***
	October	14	30	1:2,14	13,528***
	November	16	20	1:1,25	1,239
	December	8	16	1:2	11,331***
	Total	78	178	1:2,28	15,671***
	Annually	141	232	1:1,64	5,974*

M: number of males; F: number of females; *: significant difference at α= 0.05; **: significant difference at α= 0.01; ***: significant difference at α=0.001. G = χ^2 observed Chi-square value of the two-sided test.

Size of first sexual maturity

The sizes of first sexual maturity in males and females of *Liza dumerili* were obtained from the percentage curves of mature individuals (Figure 2). The analysis of these curves revealed that in this species, the sexual maturity is reached at a larger size in the female than in the male, respectively 245 mm and 242 mm. However, the chi-square tests revealed no significant difference (X^2 = 0.004, p > 0.05) between the size of first sexual maturity of males and females.

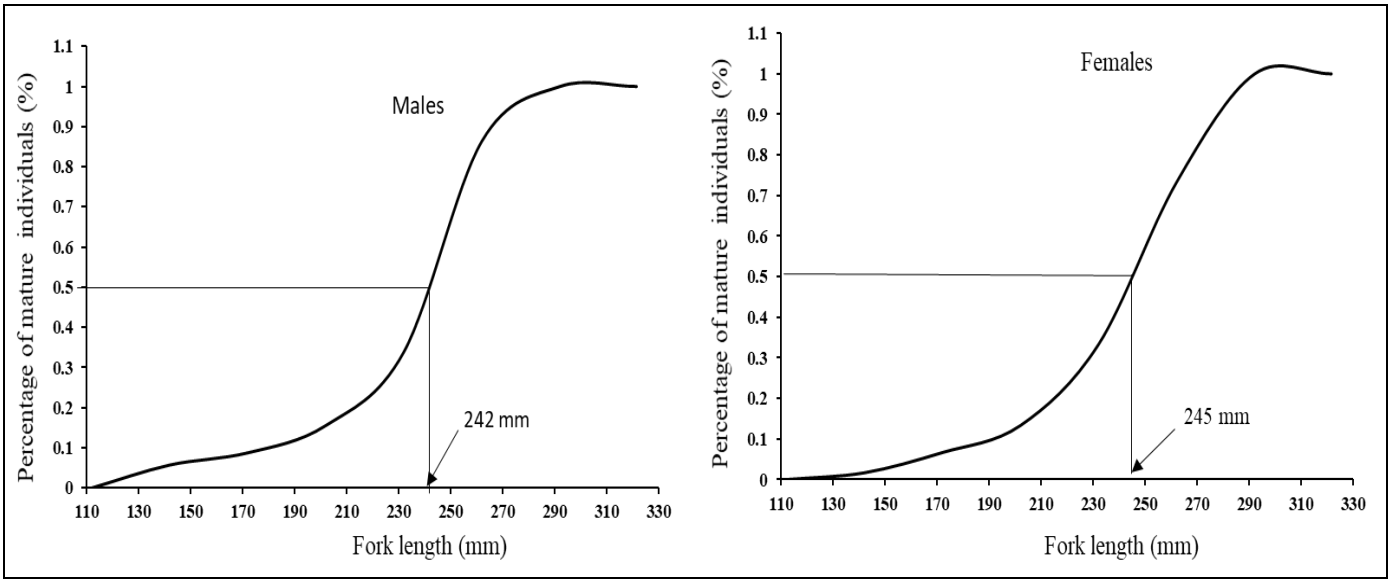


Fig 2: Size of first sexual maturity (L_{50}) according to the fork length (*Lf*) of males and females of *Liza dumerili* in the Ebrié lagoon.

Monthly variation of the stages of sexual maturity

Six stages of sexual maturity were defined in *Liza dumerili*. These six stages were observed although at variable proportions in males and females during the 12 months of sampling. This variation in the percentage of maturity in both sexes showed a progressive replacement of stages during the year (Figure 3). This indicates that the maturation of the gonads of this fish is evolutionary. The analysis of the sexual maturity evolution in *L. dumerili* showed that the stage 1 appears from November or December up to February to March when the proportion was important between sexes. However, the stage 2 was less important in catches except in June when it was dominant. Concerning the stage 3, it was very abundant in males in the month of July. In November, the stage 4 dominated catches in males and females. Meanwhile the stage 5 occurred between March to April and August to September for both sexes. Males in a sexual rest (stage 6) were present in April, May and September while females of this stage were observed in January, June and September.

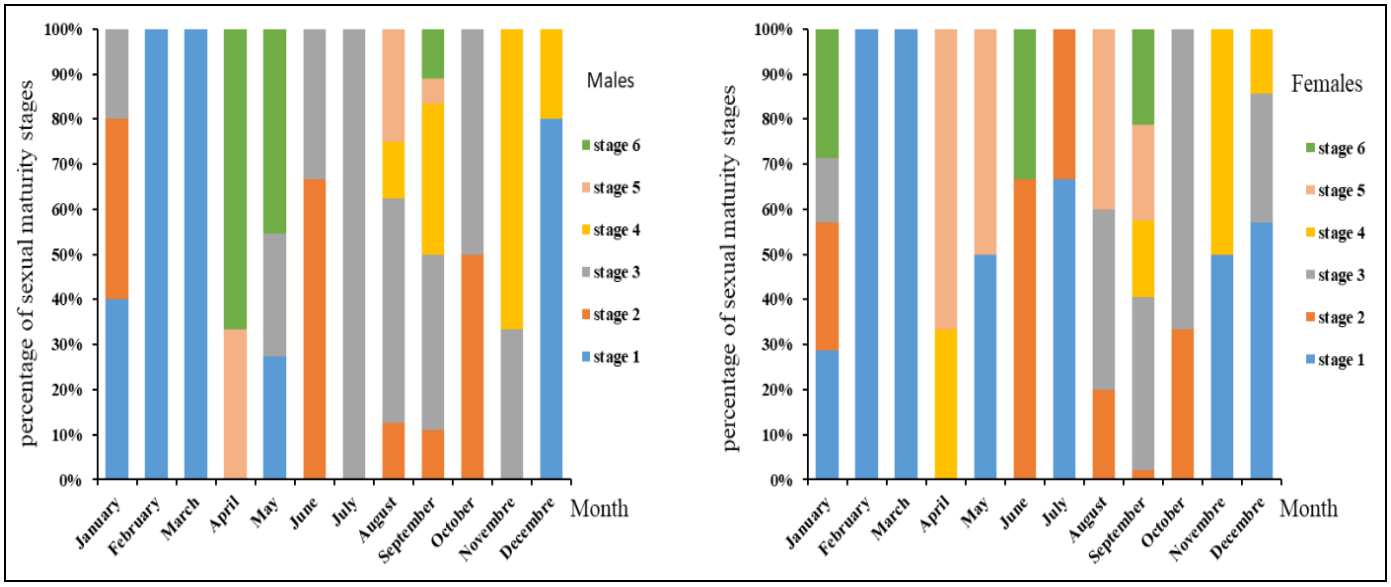
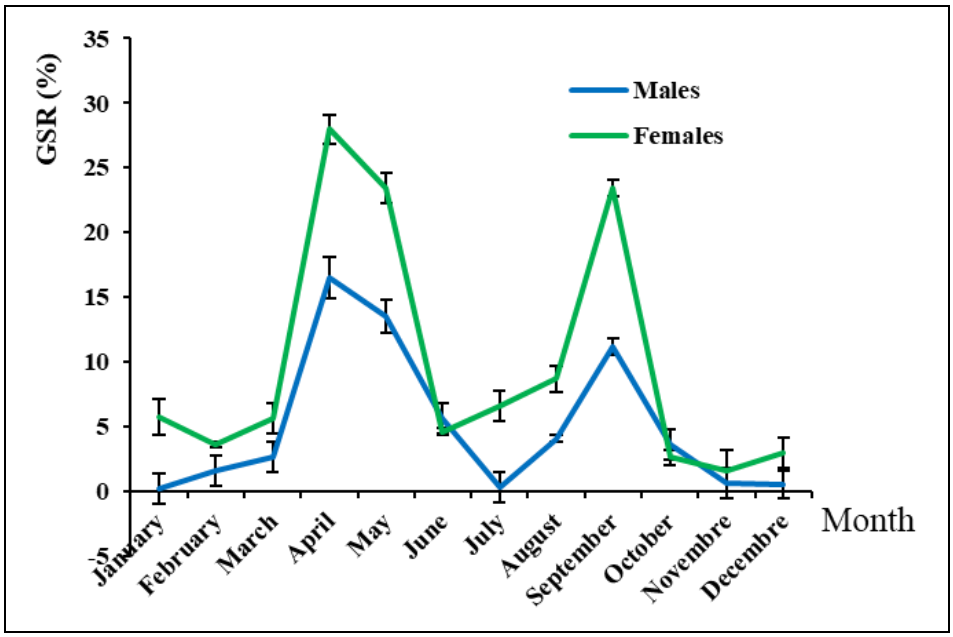


Fig 3: Monthly variation in percentages of sexual maturity stages in males and females of *Liza dumerili* caught in the Ebrié lagoon

Monthly change in gonado-somatic index (GSI), hepato-somatic index (HSI) and condition factor (*K*)

The monthly variations of GSI, HSI and *K* in males and females of *Liza dumerili* showed similar patterns (Figure 4). The GSI of the females was on the whole higher than that of the males. The two curves evolved in a similar way. Thus, the GSI increased from February to April when a peak is observed in both sexes. It increased from 1.19 ± 1.63% to 16.47 ± 1.59% in the male and from 3.59 ± 0.25% to 27 ± 1.10% in the female. It fell thereafter, in both sexes from May to reach a low value in July in the male (0.32 ± 1.16%) and in June (4.59 ± 0.25%) in the female. In contrast, HSI fell in males and females when the GSI reached its peak. As for the *K* factor, the maximum has been recorded in April for males and females and 0.023 ± 0.001% and 0.044 ± 0.001% respectively.



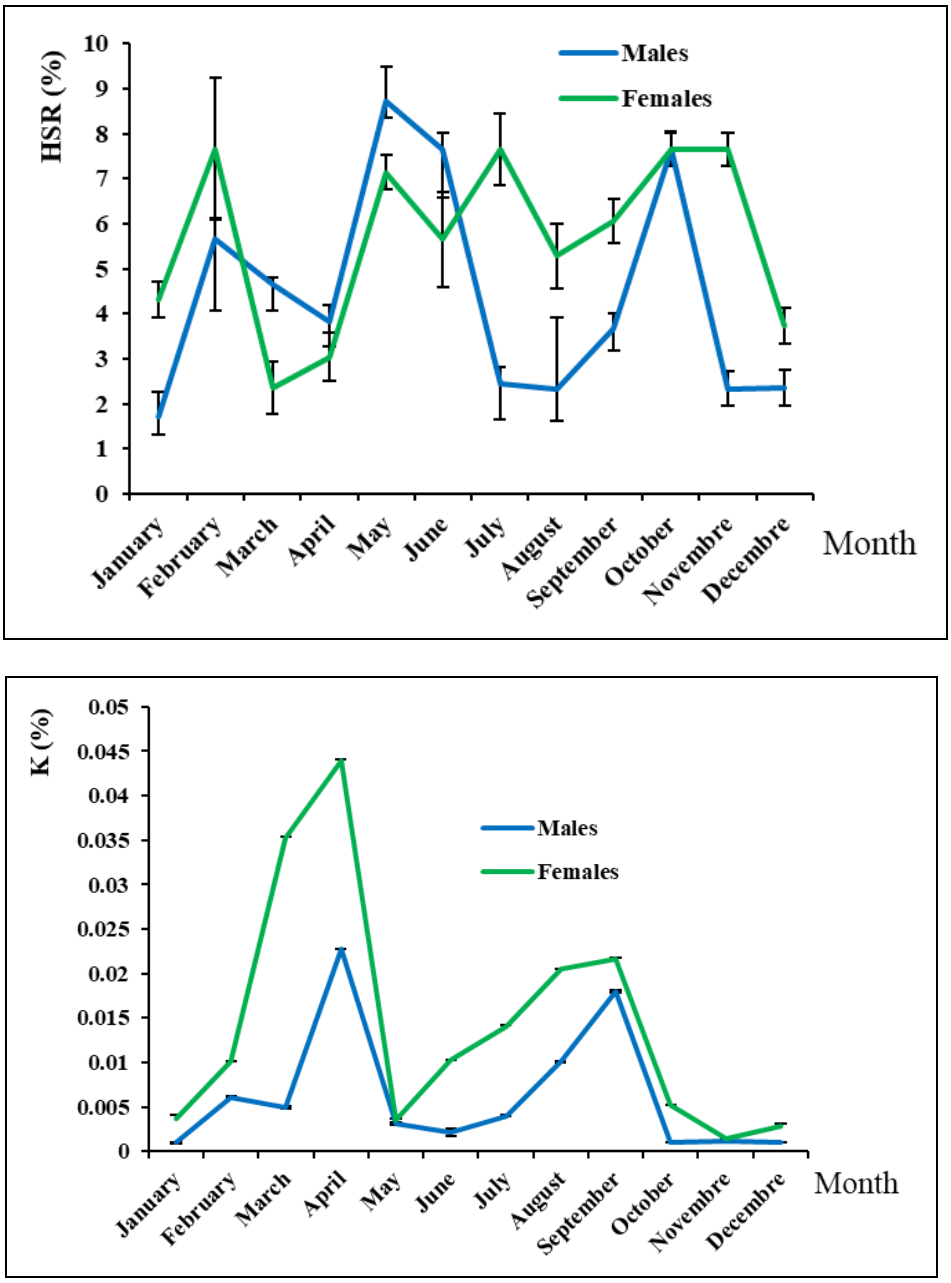


Fig 4: Monthly variations of gonado-somatic index (GSI), hepato-somatic index (HSI) and condition factor (*K*) in males and females of *Liza dumerili* fished in the Ebrié lagoon.

Fecundity

The absolute fertility ranged from 112 095 to 920 356 oocytes with an average value of 628 992 ± 4697 oocytes in the female whose fork length is between 209 and 335 mm. Regarding relative fertility, it ranged from 1156 to 1247 oocytes/g body weight with an average value of 1191 ± 516.16 oocytes/g body weight.

Discussion

The sex ratio observed for all *Liza dumerili* catches in the Ebrié lagoon was marked by the preponderance of females (1:1.64). This predominance of one sex is a frequent phenomenon in many teleosts, including *Sarotherodon melanotheron* [25], *Mullus barbatus* [29], *Trachinotus teraia* [39], *Tylochromis jentinki* [22] and *Heterotis niloticus* [26]. Several hypotheses would explain this imbalance of the sex ratio in favour of one sex or another; among others, displacement for foraging, reproduction, gregarious behaviour strongly related to sex. The variation in the sex ratio also depends on the physiological state of fishes [1]. In teleosts in general, males are more abundant during reproduction periods, while during periods of sexual rest, females are predominant [37] [10]. In fact, during reproduction, males gather around females. This would explain the considerable increase in the number of males compared to females during this period. Chemmam-Abdelkader *et al.* [7] and Kraidy *et al.* [27] reported the same facts. Within the family Mugilidae, there is segregation by sex and age group during their movement [40]. As a result, the most accessible fishing gear bank would have a predominance of one sex in the catch. The imbalance of the sex ratio is much observed in mules. Some authors, Vall [40], Ilkyaz *et al.* [20] and Patimar [35] reported a predominance of females. Authors such as Albaret and Legendre [3], Fehri-Bedoui *et al.* [16] and Katselis *et al.* [21] related a preponderance of males.

Knowledge on the size of first sexual maturity in fish is appropriate and necessary for determining the minimum size of first captures [34]. This size is closely related to the extent of the water body [18], fish density [30] and stress conditions in fish populations [32]. The size of *Liza dumerili* at sexual maturity was slightly larger in females (245 mm) than in

males (242 mm). This could be attributable to the differential growth observed in most teleost fishes [37]. According to Bruslé [6], Albaret and Legendre [3], this morphological feature is generally typical to the family Mugilidae. Within the same age, height and weight are greater in females than in males [4]. Our results are similar to those of Albaret and Legendre [3], Diaby [8] on the same species, and Konan [22] and Kouakou [26] respectively on *Tylochromis jentinki* and *Heterotis niloticus.* Similar results have been reported in other species from the family Mugilidae such as, *L. ramada* [15, 14], *L. aurata* [20] and *L. saliens* [35].

The presence of male and female individuals at the advanced sexual maturation stage (stage 5) may suggest that *L. dumerili* spawns its eggs in the lagoon. The same observations were communicated by Albaret & Legendre [3] about the reproductive behaviour of *L. grandisquamis* and *L. falcipinnis* in the Ebrié lagoon and by Djadji [9] concerning the latter species in the Ebrié and Grand-Lahou lagoons. The evolution of the gonado-somatic ratio coupled with the macroscopic stages of sexual maturation indicated that the reproduction of *L. dumerili* in the Ebrié lagoon is likely to occur at very specific periods of the year. The gonad maturation period was from February to April and the spawning period was from April to June. However, the observation of a low decrease of the GSI from September to October for *L. dumerili* has been made. It would be therefore likely that during these months, there is also spawning in the environment. This observation may be a hint that the majority of females spawn between April and June. In the meanwhile, the highest proportions of males and females of stages 5 and 6 are observed in that period. The spawning peak was more pronounced at the rainy season (April to June) where the environmental and trophic conditions were favorable to ensure the larval development and the survival of fry. During the period of gamete release (reproduction), the HSI decreased while, in contrast, the GSI increased. On the other hand, the GSI and the *K* factor evolved in the same way. This could suggest that females and males of *L. dumerili*, may stock their reserve energy necessary for gonad maturations in their livers. Similarly, the spawning period corresponds to the period when the *K* factor is the lowest [16]. This results in a loss of weight of the fish indicating that the latter would also use their reserve energy contained in the muscles and viscera to ensure reproduction. Similar observations have been found in *L. aurata* and *Dentex maroccanus* on the Tunisian coasts [16, 7]. *Liza dumerili* is therefore a lean fish since the peak of its GSI preceded that of the HSI.

The absolute fecundity of *L. dumerili* varied between 112 095 and 920 356 oocytes. According to Albaret and Legendre [3], fertility is very high among the family Mugilidae. *Liza dumerili* could be considered as a species belonging to fish groups having a very high fertility. This high fertility could be a strategy to maximize offspring survival in fish groups that do not practice parental care [39]. Fecundities similar to that obtained in *L. dumerili* have been reported by other authors. This is the case of the congener *L. falcipinnis* having a fecundity comprised between 119 738 and 833 145 oocytes in the lagoon Ebrié [9]. In the same lagoon, Djadji *et al.* [10] related in *Mugil cephalus* an absolute fertility ranging from 135 136 to 2844 890 oocytes, and varying between 126 681 and 2 789 869 oocytes in the Grand-Lahou lagoon. Similarly, Bernardon and Vall [4] reported for this same species an absolute fertility ranging from 5 to 7 million eggs on the Mauritanian coasts.

Conclusion

This study showed that in the Ebrié lagoon, the *Liza dumerili* species reproduced mainly in April and May. The size of first sexual maturity (Lf_{50}) is reached at a fork length of 242 mm in the male and 245 mm in the female. Absolute fecundity in the female varied from 112 095 to 920 356 oocytes with an average value of 628 992 ± 4697 oocytes.

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