International Journal of Fauna and Biological Studies
Available online at www.faunajournal.com

IJFBS
International Journal of Fauna And Biological Studies

**E-ISSN 2347-2677**
**P-ISSN 2394-0522**
www.faunajournal.com
IJFBS 2022; 9(5): 38-44
Received: 26-07-2022
Accepted: 28-08-2022

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# Reproduction of five mullet fish (Mugilidae) in Grand-Lahou Lagoon, Côte d'Ivoire: Size at first sexual maturity, reproduction period and sex ratio

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**DOI:** https://doi.org/10.22271/23940522.2022.v9.i5a.932

## Abstract
This work provides information on Mugilidae fish reproduction in Grand-Lahou lagoon. From September 2009 to August 2011, for each specimen sampled, the total length in cm, the total mass and the eviscerated mass in g, the gonads mass in cg, the sex and the gonads maturity stages were recorded. Parameters studied were size at first sexual maturity, reproduction period and sex ratio. The sexual maturity is reached between 16.1 cm and 21.0 cm in four of the five species studied and at 41.6 cm in *Mugil cephalus* females. *Liza dumerili* and *Mugil curema* reproduce from September to November, *Liza falcipinnis* from July to October, *Mugil bananensis* from March to June and *Mugil cephalus* from August. These species reproduce in lagoon, except *Mugil cephalus*. During breeding season, the sex ratio is in favour of females in *Mugil curema* and *Mugil bananensis*. In *Liza dumerili* and *Liza falcipinnis*, sexes are rather balanced.

**Keywords:** Reproduction, Mugilidae, Grand-Lahou lagoon, Côte d'Ivoire

## 1. Introduction
In Côte d'Ivoire, artisanal fisheries provide 70% of national fish catches. Fishing is practised at sea, in lagoons and in continental waters (DPH, 2016) [15]. Lagoon fishing exploits an area of 1,180 km$^2$ including Aby, Ebrié and Grand-Lahou lagoon systems (Wango *et al*., 2011) [29]. This activity provides local populations with fish, which constitutes the main source of animal protein in their diet. In addition, it generates income for them (Anoh, 2010) [4]. So, rational management of these fisheries should be a priority.

In order to preserve exploited fish stocks, many traditional artisanal fisheries are self-governing. Measures taken include limiting fishermen's number, closing fishing during certain periods or banning the use some fishing gears or fishing techniques (Bravo-Olivas and Rosa, 2020) [7]. In Ivorian lagoons, there is a co-management model involving native families, traditional chieftainships and national fisheries service for this purpose (Anoh, 2010) [4]. However, optimal fisheries management should include biological objectives to ensure a sustainable exploitation of species, ecological objectives to minimise impact of fishing on the ecosystem, economic objectives to maximise fishermen's income and social objectives to ensure employment opportunities in the sector (Cochrane, 2005) [10].

The main cause of decline in fish populations is overfishing (Berkowitz, 2014) [5]. Closing fishing during the spawning season is often advocated as an effective conservation measure for fishery resources. However, population renewal also requires a minimum quantity of spawners to be present during the reproduction period, a fertilisation of eggs to be effective and finally a sufficient survival of the eggs and larvae to be ensured (Biseau, 2013) [6].

The present study was undertaken to provide information on the reproduction of mugilid fish in the Grand-Lahou lagoon. They are regularly caught by fishermen. They therefore have an economic role and are also highly valued for the quality of their flesh. These coastal fish from tropical and temperate seas also colonize lagoon and estuarine environments, so moving between these environments (Albaret, 1992) [1]. They therefore raise many questions about their life. The results obtained could be used for any conservation policy for mugilidae stocks in the Grand-Lahou lagoon.

## 2. Materials and Methods

### 2.1 Study area

The Grand-Lahou lagoon system (Figure 1), with an area of 190 km$^2$ and a length of fifty kilometres, is located between 5°05' and 5°15' north latitude and between 4°55' and 5°25' west longitude. It is made up of the Tadjo, Niouzoumou, Mackey and Tagba lagoons and receives continental waters from the Gô, Boubo and Bandama rivers (Laë, 1982). On the basis of water salinity, four sectors have been identified. These are:

- Zone of lagoon inlet, directly subject to marine influence;
- Zone close to inlet and under the influence of the Bandama river with unstable salinity;
- continental area (Mackey lagoon) where salinity is the lowest;
- Oceanic area (Tadjo Lagoon and the western part of Niouzoumou Lagoon) where water remains brackish throughout the year (Konan *et al*., 2008) [19].

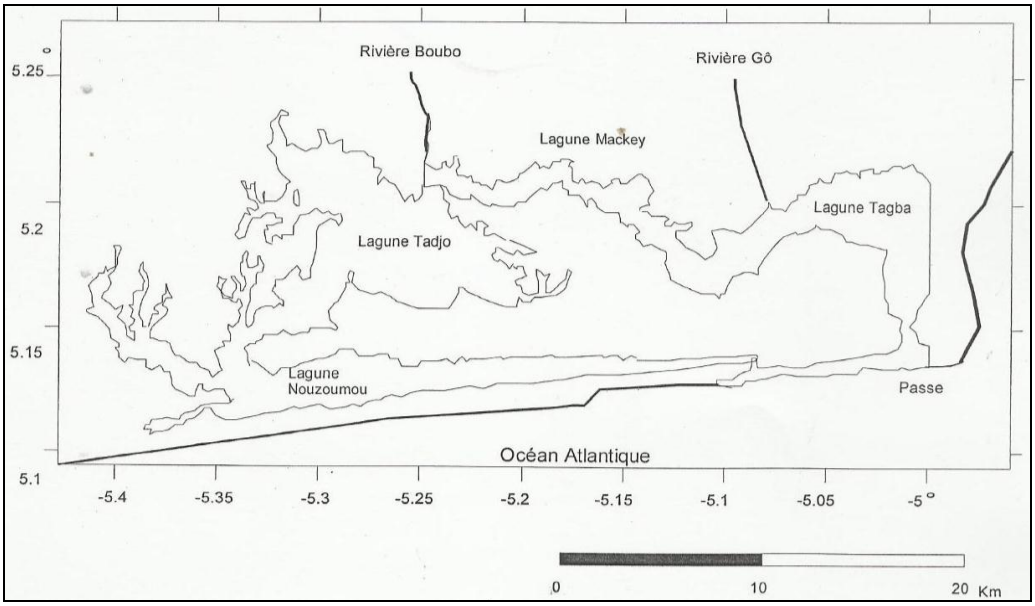



**Fig 1:** Map of the Grand-Lahou lagoon

### 2.2 Data collection

Samplings were conducted from September 2009 to August 2011 during the first week of each month. Mullet fish were identified using guides developed by Diouf (1991) [11]. Five of the six species identified have been studied because of their abundance in catches. These are *Liza falcipinnis*, *Liza dumerili*, *Mugil curema*, *Mugil bananensis* and *Mugil cephalus*. For each specimen sampled, the total length was recorded in cm using an ichthyometer, the total mass in g using an electronic balance with a precision of 1 g and a range of 5 kg, as well as an eviscerated mass after extraction of digestive tract and gonads. Gonads were weighed with an electronic balance with a precision of 0.1 g. Sex, gonads macroscopic appearance and gonads maturity stages were recorded using sexual maturity scale established in Mugilidae by El Housni (1988) [16].

### 2.3 Data processing

#### 2.3.1 Size at first sexual maturity

The size at the first sexual maturity corresponds to the size at which 50% of specimens are sexually mature (Djemali, 2005) [14]. The corresponding maturity stage is stage 4, at which oocytes are visible to the naked eye (El Housni, 1988) [16]. On this basis, proportions of mature specimens (P) in each 1 cm size class were calculated. These proportions are related to the length of the fish (L) according to an equation with a sigmoidal curve (Pope *et al*., 1983 in Amenzoui *et al*., 2004) [2]:

$$P = \frac{100}{1+e^{-[a+(b.L)]}}$$

With P: percentage of mature specimens per size class; L: total length of the fish; a and b are obtained after a logarithmic transformation of the previous expression:

$$-\ln\frac{100-P}{P} = a + b * L$$

#### 2.3.2 Reproduction period

The reproductive period was determined using a quantitative approach based on the calculation of the Gonado-Somatic Index (GSI). GSI was calculated using the formula (Lahaye, 1980) [22]:

$$GSI = 100 * \frac{\text{poids des gonades (g)}}{\text{poids éviscéré du poisson (g)}}$$

#### 2.3.3. Sex ratio

Sex ratio, proportion of males to females, was calculated during each month from the relationship (Kartas and Quignard, 1984) [18]:

$$\text{Sex} - \text{ratio} = \frac{\text{Nombre de mâles}}{\text{Nombre de femelles}}$$

Calculated proportions are compared to the theoretical one using a bilateral test at significance level 5%. Test is defined by relation

$$\varepsilon = \frac{P - P0}{\sqrt{\frac{P0\,(1-P0)}{n}}}$$

If ε >1.96, equality hypothesis is rejected.

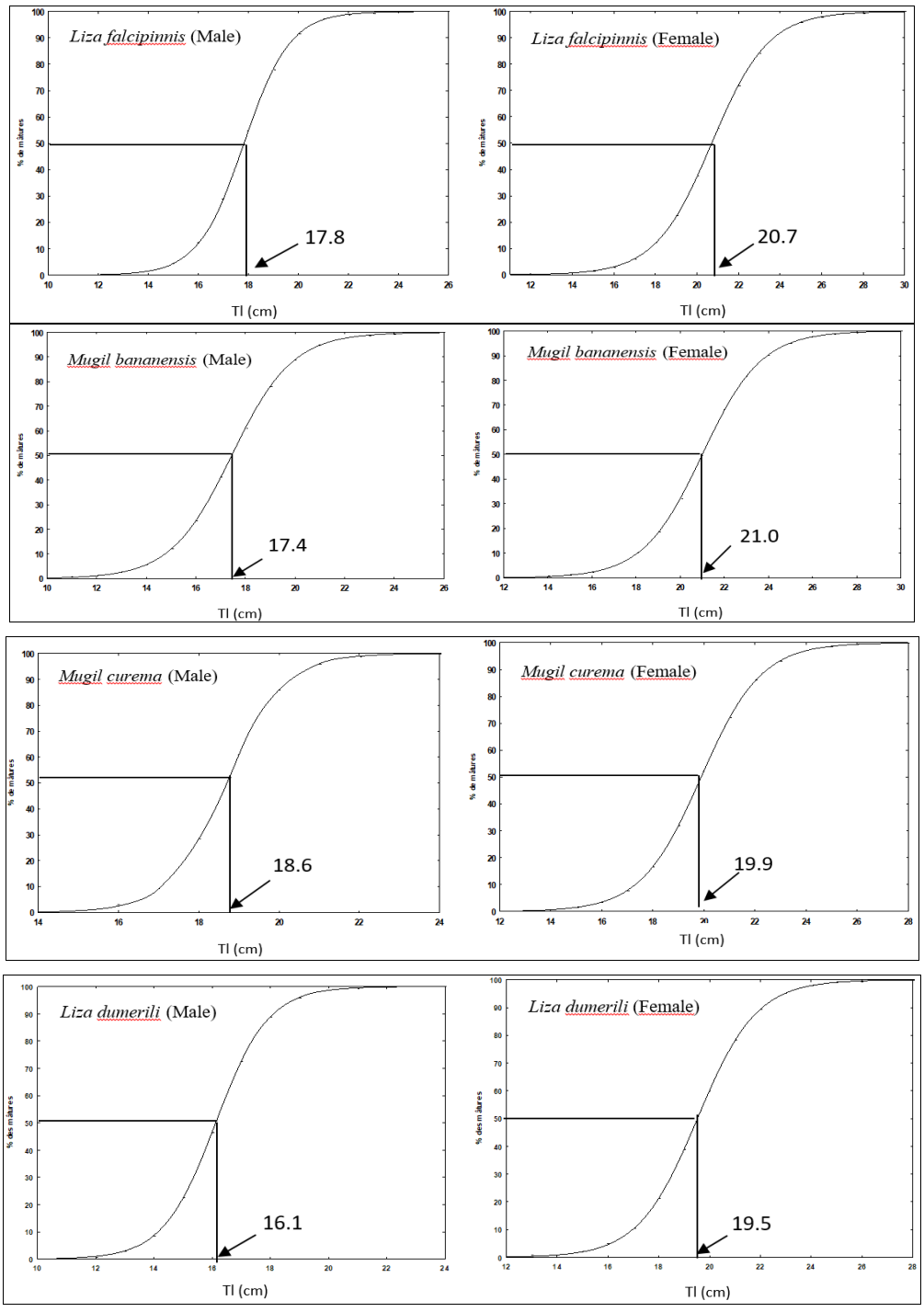
## 3. Results

### 3.1. Size at first sexual maturity

In Grand-Lahou lagoon, mugilidae species reach sexual maturity at different sizes (Figure 2). Those calculated for females are always larger within the same species. The smallest corresponding size is noted for male of *Liza dumerili* (16.1 cm) and the largest one for female of *Mugil bananensis* (21.0 cm). However, when considering sexes, differences between sizes at sexual maturity are smaller, with maximums of 2.5 cm and 1.5 cm between males and females respectively. The low number of *Mugil cephalus* males recorded did not allow the calculation of this parameter.

### 3.2. Reproduction period

Monthly Gonado-Somatic Index (GSI) variation curves show a single peak for all species (Figure 3). For *Liza dumerili*, *Liza falcipinnis*, *Mugil bananensis* and *Mugil curema*, peaks of GSI for males coincide with those of females. For *Liza dumerili* and *Mugil curema*, these values increase from February and peak in September with values of 18.0% and 14.7% respectively. They fall from September to November. For *Liza falcipinnis*, RGI increases from April-May to reach its peak in July (9.98%), then gradually decreases until October. For *Mugil bananensis*, RGI rises from September to reach its peak in March then falls until June. Finally, For *Mugil cephalus*, the peak of the RGI is reached a little earlier for males in July and for females in August (4.5%). Thereafter, RGI values fall until December.



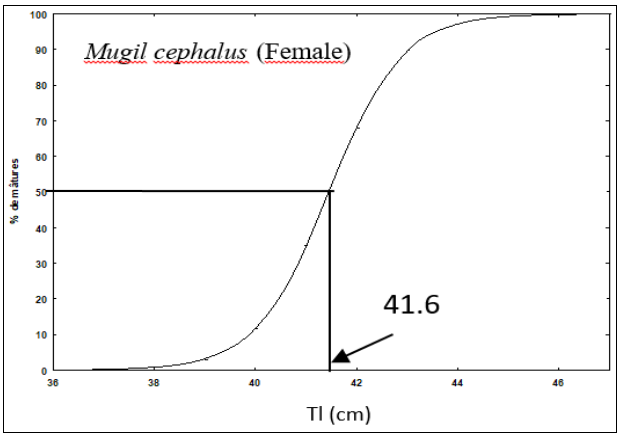



**Fig 2:** Diagrams for determining size at first sexual maturity for different species (*L.*, *Liza* et *M.*, *Mugil*).

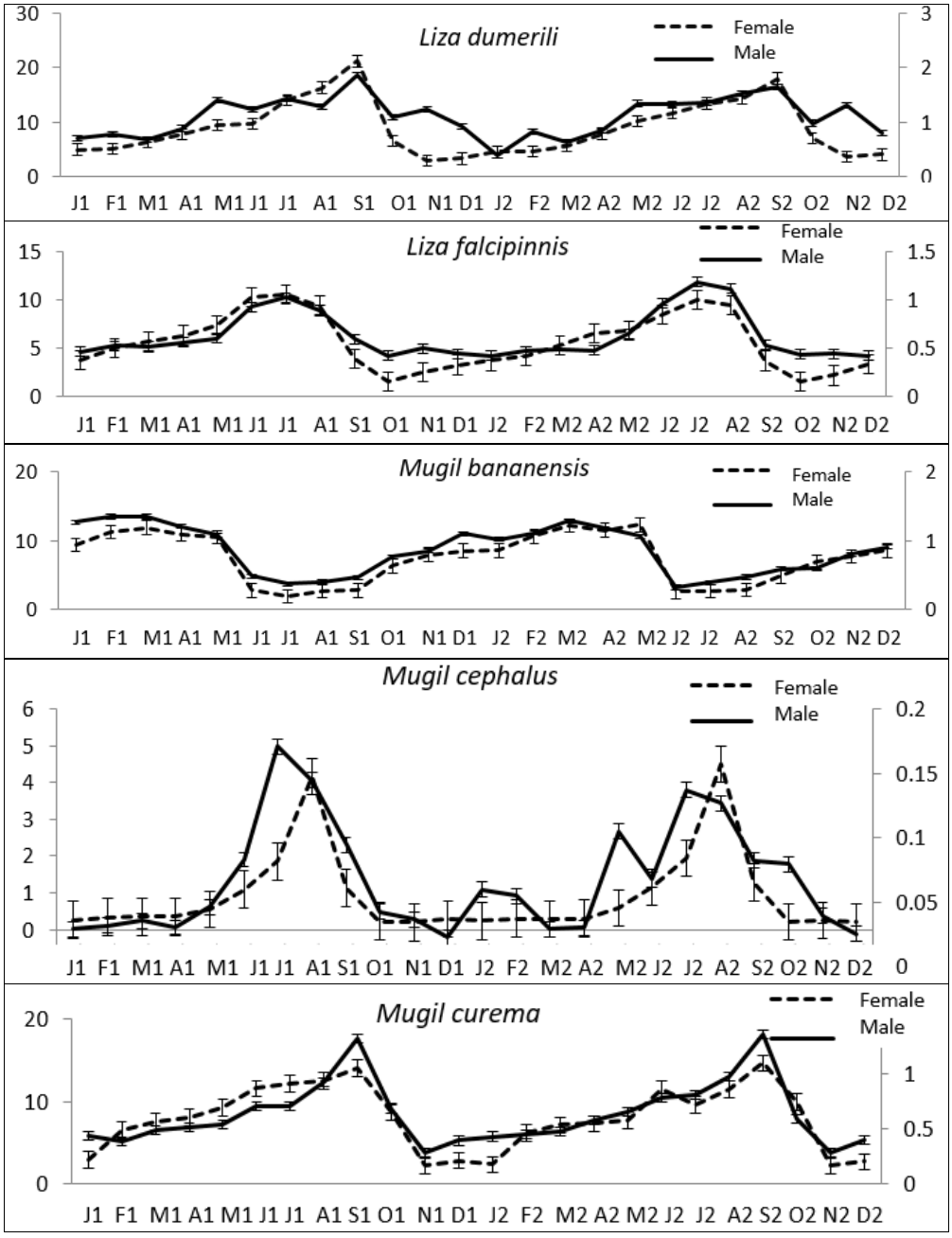



**Fig 3:** Monthly variation of Gonado-Somatic Index for females and males (monthly index 1 and 2 corresponding to sampling year 1 and 2 respectively).

### 3.3. Proportions of monthly sexual maturity stages

All sexual maturity stages have been observed for males and females of different species except for *Mugil cephalus* (Figure 4). For *Liza dumerili*, females at stage 5 appear from July to

October and those at stage 6 in October and November. Females of *Liza falcipinnis* at stage 5 are mainly observed in July and August and stage 6 from September to November, while females of *Mugil curema* reach stage 5 from June to October and even November and stage 6 from September to November. These advanced stages appear earlier for *Mugil bananensis* from February/March to May for stage 5 and from March to July for stage 6. Finally, for *Mugil cephalus*, stage 4 is the most abundant in females and stage 5 is rarely found from July to September. No stage 6 was observed for males and females.

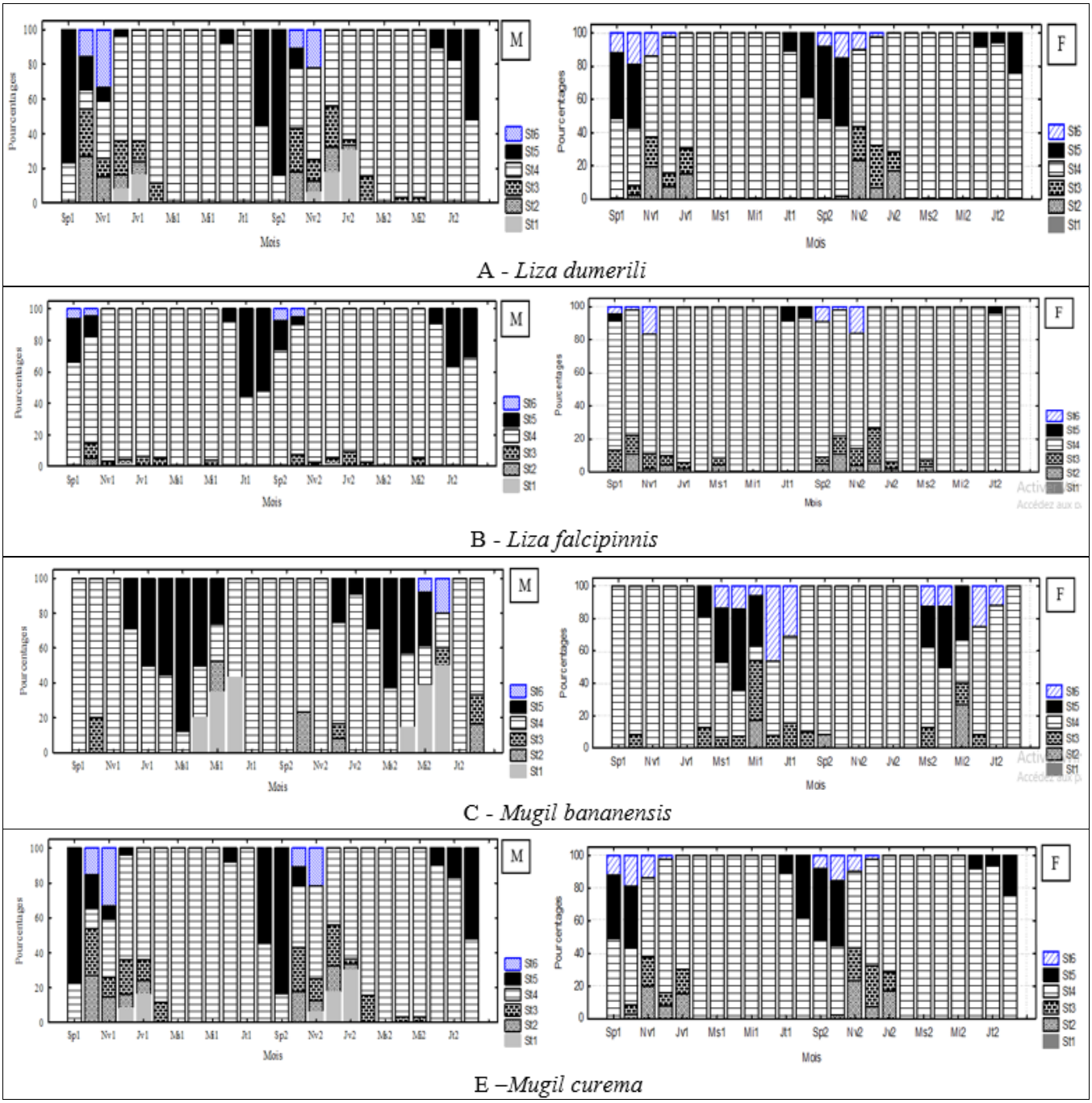



**Fig 4:** Monthly relative proportions of sexual maturity stages for different species

### 3.4. Sex ratio

For *Liza dumerili*, the sex ratio imbalance was only statistically significant three months during the two years of sampling, five months for *Liza falcipinnis* and six for *Mugil curema*. Conversely, sex imbalance is mostly observed for *Mugil bananensis* (13 months out of 24) and secondarily for *Mugil cephalus* (8 months out of 24). Considering periods of fall in the Gonado-Somatic Index (GSI), for *Mugil curema* and *Mugil bananensis*, sex ratio is more in favour of females. However, for *Liza dumerili*, *Liza falcipinnis* and *Mugil cephalus*, the predominance of one sex during this period is not observed over the two years of the study (Table 1).

**Table 1:** Monthly variation of sex ratio for different species: M, number of males; F, number of females; * significant difference; ε: value of the parameter of the two-sided test. Sex-ratio values at reproduction periods are highlighted

| Mois | | *Liza dumerili* | | | | *Liza falcipinnis* | | | | *Mugil bananensis* | | | | *Mugil cephalus* | | | | *Mugil curema* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **F** | **M:F** | **ε** | **M** | **F** | **M:F** | **ε** | **M** | **F** | **M:F** | **ε** | **M** | **F** | **M:F** | **ε** | **M** | **F** | **M:F** | **ε** |
| Sp | 12 | 12 | 1 :1.00 | 0.000 | 33 | 23 | 1 :0.70 | 1.383 | 12 | 13 | 1 :1.08 | 0.310 | 19 | 21 | 1 :1.11 | 0.387 | 13 | 49 | 1 :3.77 | 4.498* |
| Oc | 14 | 13 | 1 :0.93 | 0.287 | 42 | 50 | 1 :1.19 | 0.674 | 15 | 12 | 1 :0.80 | 0.861 | 13 | 13 | 1 :1.00 | 0.000 | 26 | 37 | 1 :1.42 | 1.352 |
| Nv | 14 | 12 | 1 :0.86 | 0.596 | 31 | 45 | 1 :1.45 | 1.427 | 9 | 11 | 1 :1.22 | 0.775 | 22 | 16 | 1 :0.73 | 1.223 | 27 | 51 | 1 :1.89 | 2.383* |
| Dc | 7 | 19 | 1 :2.71 | 3.575* | 65 | 29 | 1 :0.45 | 2.967* | 14 | 8 | 1 :0.57 | 2.113* | 14 | 8 | 1 :0.57 | 2.113* | 23 | 38 | 1 :1.65 | 1.905 |
| Jv | 10 | 22 | 1 :2.20 | 2.905* | 46 | 52 | 1 :1.13 | 0.474 | 8 | 12 | 1 :1.50 | 1.549 | 8 | 7 | 1 :0.88 | 0.516 | 21 | 33 | 1 :1.57 | 1.721 |
| Fv | 9 | 12 | 1 :1.33 | 1.107 | 27 | 46 | 1 :1.70 | 2.016* | 9 | 16 | 1 :1.78 | 2.169* | 14 | 5 | 1 :0.36 | 3.669* | 17 | 18 | 1 :1.06 | 0.221 |
| Ms | 10 | 11 | 1 :1.10 | 0.369 | 23 | 24 | 1 :1.04 | 0.165 | 8 | 15 | 1 :1.88 | 2.357* | 7 | 6 | 1 :0.86 | 0.596 | 17 | 17 | 1 :1.00 | 0.000 |
| Av | 9 | 16 | 1 :1.78 | 2.169* | 22 | 19 | 1 :0.86 | 0.567 | 8 | 14 | 1 :1.75 | 2.113* | 11 | 9 | 1 :0.82 | 0.775 | 25 | 17 | 1 :0.68 | 1.475 |
| Mi | 19 | 17 | 1 :0.89 | 0.430 | 26 | 35 | 1 :1.35 | 1.143 | 15 | 35 | 1 :2.33 | 3.098* | 11 | 14 | 1 :1.27 | 0.930 | 26 | 24 | 1 :0.92 | 0.310 |
| Jn | 10 | 9 | 1 :0.90 | 0.408 | 24 | 29 | 1 :1.21 | 0.731 | 4 | 13 | 1 :3.25 | 4.101* | 10 | 21 | 1 :2.10 | 2.749* | 25 | 26 | 1 :1.04 | 0.152 |
| Jt | 9 | 13 | 1 :1.44 | 1.408 | 20 | 23 | 1 :1.15 | 0.540 | 11 | 26 | 1 :2.36 | 3.140* | 5 | 23 | 1 :4.60 | 4.980* | 16 | 27 | 1 :1.69 | 1.982* |
| At | 15 | 13 | 1 :0.87 | 0.553 | 25 | 29 | 1 :1.16 | 0.574 | 7 | 10 | 1 :1.43 | 1.367 | 19 | 20 | 1 :1.05 | 0.199 | 22 | 31 | 1 :1.41 | 1.315 |
| Sp | 11 | 11 | 1 :1.00 | 0.000 | 27 | 22 | 1 :0.81 | 0.790 | 8 | 12 | 1 :1.50 | 1.549 | 12 | 22 | 1 :1.83 | 2.278* | 18 | 37 | 1 :2.06 | 2.676* |
| Oc | 9 | 12 | 1 :1.33 | 1.107 | 40 | 46 | 1 :1.15 | 0.540 | 13 | 9 | 1 :0.69 | 1.408 | 13 | 15 | 1 :1.15 | 0.553 | 28 | 45 | 1 :1.61 | 1.804 |
| Nv | 13 | 17 | 1 :1.31 | 1.033 | 37 | 50 | 1 :1.35 | 1.157 | 14 | 8 | 1 :0.57 | 2.113* | 18 | 14 | 1 :0.78 | 0.968 | 30 | 60 | 1 :2.00 | 2.582* |
| Dc | 14 | 21 | 1 :1.50 | 1.549 | 59 | 30 | 1 :0.51 | 2.524* | 12 | 6 | 1 :0.50 | 2.582* | 12 | 16 | 1 :1.33 | 1.107 | 28 | 43 | 1 :1.54 | 1.636 |
| Jv | 17 | 23 | 1 :1.35 | 1.162 | 44 | 50 | 1 :1.14 | 0.494 | 11 | 10 | 1 :0.91 | 0.369 | 13 | 11 | 1 :0.85 | 0.645 | 23 | 35 | 1 :1.52 | 1.603 |
| Fv | 12 | 16 | 1 :1.33 | 1.107 | 37 | 40 | 1 :1.08 | 0.302 | 7 | 11 | 1 :1.57 | 1.721 | 13 | 9 | 1 :0.69 | 1.408 | 19 | 21 | 1 :1.11 | 0.387 |
| Ms | 11 | 11 | 1 :1.00 | 0.000 | 24 | 28 | 1 :1.17 | 0.596 | 8 | 8 | 1 :1.00 | 0.000 | 8 | 9 | 1 :1.13 | 0.456 | 23 | 22 | 1 :0.96 | 0.172 |
| Av | 13 | 12 | 1 :0.92 | 0.310 | 18 | 23 | 1 :1.28 | 0.945 | 6 | 8 | 1 :1.33 | 1.107 | 10 | 7 | 1 :0.70 | 1.367 | 29 | 19 | 1 :0.66 | 1.614 |
| Mi | 17 | 12 | 1 :0.71 | 1.336 | 21 | 38 | 1 :1.81 | 2.232* | 8 | 15 | 1 :1.88 | 2.357* | 12 | 8 | 1 :0.67 | 1.549 | 29 | 18 | 1 :0.62 | 1.813 |
| Jn | 15 | 12 | 1 :0.80 | 0.861 | 32 | 55 | 1 :1.72 | 2.048* | 5 | 12 | 1 :2.40 | 3.190* | 10 | 18 | 1 :1.80 | 2.213* | 30 | 25 | 1 :0.83 | 0.704 |
| Jt | 10 | 12 | 1 :1.20 | 0.704 | 30 | 26 | 1 :0.87 | 0.553 | 10 | 17 | 1 :1.70 | 2.008* | 9 | 22 | 1 :2.44 | 3.248* | 18 | 34 | 1 :1.89 | 2.383* |
| At | 11 | 11 | 1 :1.00 | 0.000 | 23 | 23 | 1 :1.00 | 0.000 | 6 | 13 | 1 :2.17 | 2.854* | 11 | 20 | 1 :1.82 | 2.249* | 25 | 29 | 1 :1.16 | 0.574 |

## 4. Discussion

Monthly Gonado-Somatic Index (GSI) variation curves show a single annual peak, reflecting a single reproduction period for different species during a year. This period corresponds to the fall phase of GSI. Thus, *Liza dumerili* and *Mugil curema* reproduce from September to November, *Liza falcipinnis* from July to October, *Mugil bananensis* from March to June and *Mugil cephalus* from August. These periods are located in the rainy season in this locality. Indeed, the climatic regime there is bimodal with four seasons. The long rainy season begins in February and ends in July, and the short rainy season from September to November (Kouao *et al*., 2021) [20]. It is therefore generally noted that in most fish, rainfall appears to be the main environmental factor modulating spawning period (Chellappa *et al*., 2009) [8]. The pre-spawning maturity stage (stage 5) as well as the post-spawning stage (stage 6) have been observed for *Mugil curema*, *Liza dumerili*, *Mugil bananensis* and *Liza falcipinnis*, indicating that these species can reproduce in lagoons. Diouf (1996) [12] also reported the reproduction in the Sine Saloum estuary of *Mugil curema*, *Liza dumerili*, *Liza falcipinnis* and *Liza grandisquamis*. In contrast, for *Mugil cephalus*, stage 5 was rarely observed in some females and no post-spawning stage (stage 6) was observed. The latter species does not lay eggs in Grand-Lahou lagoon. Many authors have noted a migration of *Mugil cephalus* in the marine waters during for reproduction (Ameur *et al*., 2003; Ould Mohamed Vall, 2004; Djadji *et al*., 2013) [3, 26, 13]. This migration could be explained by the search for suitable sites favourable for egg fertilisation or larval survival. Embryonic development and hatching only occur at salinities between 10 and 15‰ for this species. However, the optimum for larval survival is between 30‰ and 40‰ (Lee and Menu, 1981) [24].

In the Grand-Lahou lagoon, mugilidae species reach sexual maturity at different sizes. The role of genetic factors in controlling growth in fish has been noted, each species having its own growth rate with some variability within a given range (Fontaine and Le Bail, 2004) [17]. In addition, sizes at the first sexual maturity of females are always larger than those of males. The latter therefore become sexually mature at a smaller size than females. The same observation was also made in mugilidae fish inhabiting freshwater in Iran (Coad, 2017) [19]. This could be related to the sex-related differential growth in fish. Indeed, in majority of fish, females grow faster than males (Pauly, 2019) [27]. Fontaine and Le Bail (2004) [17] provide an explanation for this phenomenon. According to these authors, variations in body growth are result of growth stimulation by certain anabolic hormones during first gametogenesis phase, and reduction of body growth during the second phase due to massive redirection of absorbed energy coupled with an inhibiting effect of high concentrations of sex steroids. So, differences in growth that can be observed among sexes are partly explained by these mechanisms. Indeed, when reproductive cycle starts earlier for one sex, this results in a body growth differential, often negative, with the other sex maturing later.

Sex imbalance observed during some months shows a temporal variation of this parameter within different populations. Such results have been noted by Lawson *et al*. (2010) [23] in *Liza falcipinnis* in Nigeria. During reproduction periods corresponding to the periods RGI falling, for *Mugil curema* and *Mugil bananensis*, sex ratio is more in favour of females. However, for *Liza dumerili*, *Liza falcipinnis* and *Mugil cephalus*, sexes are rather balanced. In fishes, the sex ratio shows great variability in species and in different localities. Oliveira *et al*. (2012) [25] reported different authors on reasons related to reproductive behaviour, food availability or environmental conditions. However, Radoslava and Galerida (2017) [28] noted a variation in the sex ratio within a population of *Mugil cephalus* as a function of age. Males are

dominant in juveniles up to two years old. In individuals from three to seven years of age, sexes are rather balanced and in favour of females in individuals older than seven years. Therefore, the structure of the sampled population has a strong influence on sex ratio calculated.

## 5. Conclusion

In the Grand-Lahou lagoon, mullet fish reach sexual maturity at different sizes. These fishes reproduce mainly during rainy season, *Liza dumerili* and *Mugil curema* from September to November, *Liza falcipinnis* from July to October, *Mugil bananensis* from March to June and *Mugil cephalus* from August. All these species reproduce in lagoon except *Mugil cephalus*. During reproduction periods, the sex ratio is more in favour of females in *Mugil curema* and *Mugil bananensis*, while in *Liza dumerili* and *Liza falcipinnis* sexes are rather balanced.

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