Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 9 – Issue 1, February 2021

Food and Feeding Habit of Two Mugilidae from Lagoon of Grand-Lahou (Côte d'Ivoire) : *Liza dumerili* (Steindachner, 1870) and *Liza falcipinnis* (Valenciennes, 1836)

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ABSTRACT---- ***Study of the diet and feeding habits of 104 specimens of Liza dumerili (Steindachner, 1870) and 113 specimens of Liza falcipinnis (Valenciennes, 1836) coming from the artisanal fishing of the Grand-Lahou lagoon was carried out over the period from September 2008 to August 2009. Analysis of stomach contents revealed that these two species of fish feed mainly on diatoms and detritus. It appears that these species are phytoplanktonophagous and detritivores. The diet of Liza falcipinnis does not vary according to the size of the individuals. These two species specialize in the consumption of diatoms, particularly pennate diatoms.***

Keywords---- Artisanal fishing, Stomach contents, Feeding, Phytoplanktonophagus, Côte d'Ivoire

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1. INTODUCTION

Mugilidae are coastal fish of tropical and temperate seas. Brackish, estuarine and lagoon environments are their favorite domain [1]. In Côte d'Ivoire, investigations focused on systematics [2], reproduction [2, 3, 4, 5] and ecology [2]. These fish, which are caught year round, are well represented in the fishery landings from the Grand-Lahou lagoon, although no statistics relating to this are available [4]. However, *Liza dumerili* (Steindachner, 1836) and *Liza falcipinnis* (Valenciennes, 1870), two species of this family of fish, are frequently encountered in the catches of the artisanal fishery of this lagoon. In addition, these species of fish are highly appreciated by the population for the quality of their flesh and are highly prized. Finally, their fishing plays an important socio-economic role [4]. To this end, it appears necessary to conduct a study on the food ecology of these fish species with a view to cultivating them for better management of stocks and meeting the fish needs of human populations.

1. MATERIAL AND METHODS

2.1. Study environment

The Grand-Lahou lagoon is located between 5 ° 07 and 5 ° 14 North latitude and between 4 ° and 5 ° 25 West longitude [6]. It is a lagoon system that runs from east to west over a length of 50 km [7]. This lagoon system includes the Tagba (57 km²), Mackey (28 km²), Tadio (90 km²) and Niouzoumou (15 km²) lagoons. It communicates with the sea through the Grand-Lahou pass at the level of the Tagba lagoon (Figure 1).

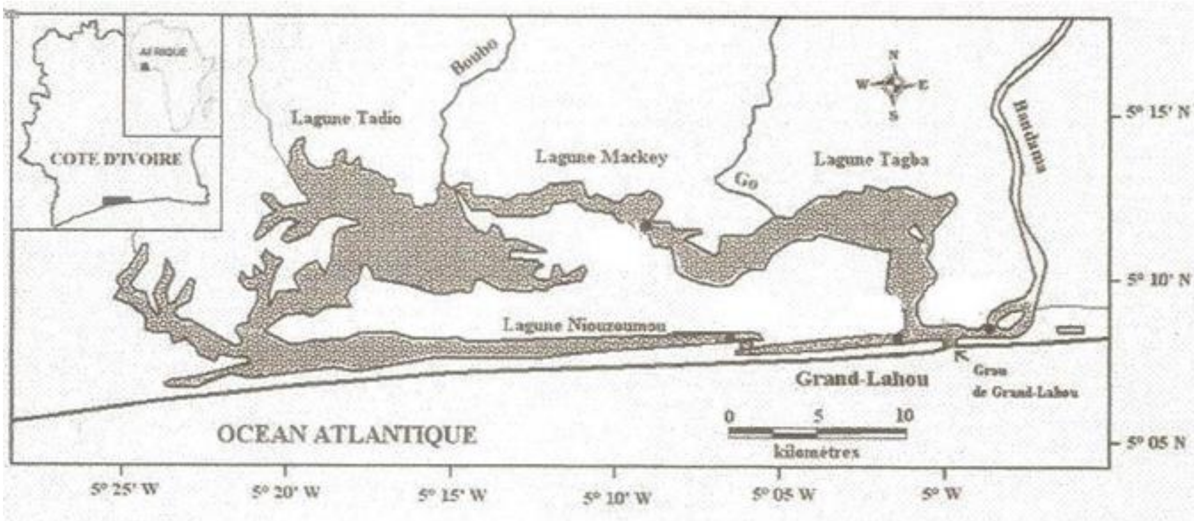

Figure 1: Grand-Lahou lagoon system [8].

2.2. Sampling and data analysis

The fish were harvested from artisanal commercial fishing during the period from September 2008 to August 2009 in the lagoon of Grand-Lahou. The boats used for fishing are small canoes. They are three to four meters in length with 0.5 m wide. The fishing gears consist of gill nets and cast nets. The gill nets used have a length between 25 and 100 m, a height of 2 to 3 m and meshes between 25 and 45mm. The cast nets are 50 to 200 m long, 0.5 to 2 m high and 20 to 25 mm mesh size. After identification of the fish species according to [1], the specimens were weighed to the nearest gram and measured to the nearest millimeter (fork length). The fish were dissected and each stomach was removed and stored in a pill box containing 5% formalin. In the laboratory, the stomach is taken out of the pill organizer and weighed after being rinsed with copious amounts of water, then wrung out on blotting paper. After incision and recovery of the stomach contents, a volumetric dilution was performed to facilitate the separation of the different foods at a rate of 10 to 30 ml of water depending on the size of the stomach. Next, the planktonic prey was observed using solutions of stomach contents mounted between slide and lamella. The identification of phytoplankton was made using the keys of [9, 10, 11]. Their count was carried out under a binocular microscope using a Bürker cell. Zooplankton was identified using the keys of [12, 13, 14], then counted under the microscope under the using a Dolfuss tank. The specimens were grouped into two size classes in *Liza falcipinnis* according [2]. The first class includes individuals smaller than 18 cm (juveniles) and the second class includes individuals having reached the size of first maturity (size ≥ 18 cm). The size class regrouping at *Liza dumerili* was not carried out due to insufficient number of full stomachs.

The coefficient of emptiness (Cv) which expresses the percentage of empty stomachs was calculated by the formula:

Cv = (Nv / Nt) x 100 with Nv being the number of empty stomachs and Nt the total number of stomachs examined.

the corrected percentage of occurrence making it possible to determine the food preferences of a given species, Fc = (Fi / ΣFi) x 100, where Fi = frequency of occurrence with Fi = Ne / Nt where Ne, the number of stomachs containing a category of prey and Nt, the total number of stomachs containing at least one prey [15, 16].

The percentage by number [17, 18] which represents the proportion of a prey category i in the total stomach contents was calculated. It is obtained by the equation: N = (Ni / Nt) x 100 where Ni = total number of a prey category i and Nt = total number of all prey.

The specific abundance index which is calculated on the basis of knowledge of the number, volume or weight of prey and expressing the proportion of each category of prey, only in the stomachs where it is encountered [19] is determined according to the equation: Si = ai / ati with ai, total abundance of prey i and ati, total abundance of all prey only in all stomachs containing prey i.

Comparisons of diet between maturity stages were made using the Schoener index [20]. It was used to assess the degree of similarity between the stages.

$$\alpha = 1 - 0{,}5\,(\sum_{i=1}^{n} \left| p_{xi} - p_{yi} \right|\,)$$

Pxi = proportion of prey i consumed by a stage of maturity or individuals of a season (x),

Pyi = proportion of a prey i consumed by a maturity stage individuals of a season (y).

Diets are considered significantly similar when the α value is greater than 0.6 [21]

2.3. Ethologie alimentaire

2.3.1. Feeding ethology

The graphic method of [22], modified by [19] is chosen to describe variations in diet by plotting the specific abundance of prey versus frequency of occurrence in a two-dimensional graph. This method relates the diet of a given species to its feeding strategy. It allows us to analyze the importance of prey, their contribution to the extent of the trophic niche and their feeding strategy.

2.3.2. Statistical analysis

The Costello diagram, modified by [19] is carried out using the STATISTICA 7.1 program [23].

2. RESULTS

3.1. General profile of the diet of *Liza dumerili*

A total of 104 stomachs were examined, 13 full stomachs were counted, for an emptiness percentage of 87.5%. The stomach contents consist of planktonic prey (phytoplankton and zooplankton), detritus, grains of sand and indeterminate elements (Table 1). The preys (phytoplankton and zooplankton) are divided into 6 groups. Phytoplankton is made up of cyanobacteria (chroococcaceae and oscillatoriaceae) and diatoms (centric and pennate). As for zooplankton, it includes copepods, rotifers, foraminifera, nematodes. Numerically, the most abundant foods are diatoms (67.89%) with a dominance of pennate diatoms (57.56%). They are followed by cyanobacteria (13.71%) then foraminifera (10.43%). The classification of foods based on the percentages of occurrence indicates that diatoms (25.5%), cyanobacteria (21.3%) are important, followed by detritus (16%). Among the diatoms, pennate diatoms (18.1%) are the most consumed prey, as well as chroococcaceae (16.9%) from the cyanobacteria group.

Table 1**:** Composition of the general diet of *Liza dumerili*; N: percentage by number, Fc: corrected percentage of occurrence, S: specific abundance.

FOOD ITEMS	**N (%)**	**Fc (%)**	**S (%)**
PHYTOPLANKTON	**81.6**	**46.8**	
CYANOBACTERIES	**13.71**	**21.3**	
Chroococcaceae	**8.74**	**16.9**	**8.28**
Chroococcus	2.1	4	7.94
Gomphosphaeria	0.76	1.1	3.82
Merismopedia	2.53	4	4.91
Microcystis	2.3	4.3	3.59
Myxosarcina	1.05	3.5	2.08
Oscillatoriaceae	**4,97**	**4,4**	**8.51**
Oscillatoria	1.91	1.1	10.41
Phormidium	3.06	3.3	16.66
DIATOMS	**67.89**	**25.5**	
Centric Diatoms	**10.33**	**7.4**	**26.85**
Actinoptychus	6.6	3.7	20.56
Terpsinoe	3.73	3.7	9.37
Pennate Diatoms	**57.56**	**18.1**	**71.02**
Amphora	15.6	7.4	18.88
Cymbella	0.19	1.1	2.94
Gyrosigma	5.4	2.4	19.34
Navicula	35.22	6.1	3.68
Nitzschia	1.15	1.1	5.74
ZOOPLANkTON	**15.9**	**18.7**	
COPEPODS	3.56	8.4	4.9
FORAMINIFERA	10.43	8.1	15.58
ROTIFERS	1.15	1.11	2.47
NEMATODES	0.76	1.09	1.11
UNDETERMINED	2.5	2.5	2.6
DETRITUS	**-**	**16**	

3.2. Feeding ethology of *Liza dumerili*

Analysis of the Costello diagram reveals that *Liza dumerili* has a general diet (Figure 2). The percent occurrence and specific abundance values for centric diatoms, oscillatoriaceae, copepods, rotifers, foraminifera and nematodes are low. As for pennate diatoms, their specific abundance is high (71.02%) while their percentage of occurrence is low (18.1%).

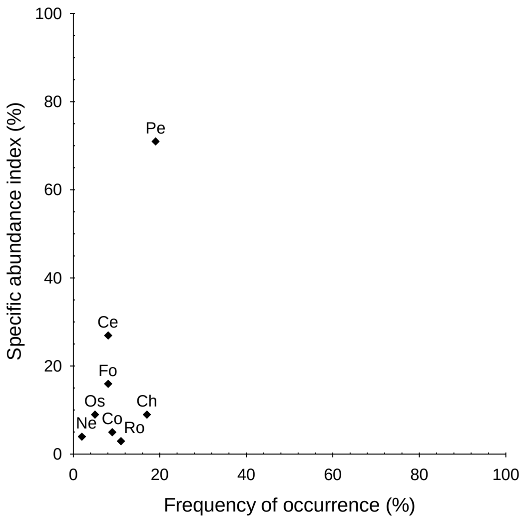

Figure 2: Costello diagram describing the feeding strategy of *Liza dumerili*.

Pe: Pennate diatoms; Ce: centric diatoms; Ch: Chroococcaceae; Os: Oscillatoriaceae;

Fo: Foraminifera; Co: Copepods; Ne: Nematodes; Ro: Rotifers.

3.3. General diet profile of *Liza falcipinnis*

113 fish stomachs were examined. 38 had full stomachs and 75 had empty stomachs, for an emptiness percentage of 66.4%. Two categories of prey (phytoplankton and zooplankton) divided into 6 groups have been identified. Phytoplankton includes cyanobacteria (14.49%) (chroococcaceae and oscillatoriaceae) and diatoms (83.18%) (centric diatoms and pennate diatoms). Among the diatoms, pennate diatoms (72.76%) are the most abundant. Zooplankton are made up of copepods (0.30%), rotifers (0.6%), foraminifera (0.99%) and nematodes (0.07%). Detritus, grains of sand and an undetermined component are noted (Table 2). Regarding the percentages of occurrence, diatoms are the most important with 42.11%, followed by cyanobacteria (32.84%). Diatoms are dominated by pennate diatoms with 33.33%.

Table 2**:** Composition of the general diet of *Liza falcipinnis*; N: percentage by number, Fc: corrected percentage of occurrence, S: specific abundance**.**

FOOD ITEMS	**N (%)**	**Fc (%)**	**S(%)**
PHYTOPLANKTON	**97.67**	**74.95**	
CYANOBACTERIES	**14.49**	**32.84**	
Chroococcaceae	**5.45**	**23.35**	**7.33**
Chroococcus	2.14	4.1	5.39
Gomphosphaeria	0.11	0.49	0.81
Merismopedia	0.8	5.1	1.6
Microcystis	0.8	4.1	1.48
Microcrocis	0.3	1.46	1.12
Myxosarcina	0.76	4.3	1.11
Synechocystis	0.6	3.8	1.43
Oxillatoriaceae	**9.04**	**9.49**	**11**
Lyngbya	0.13	0.49	1.16
Oscillatoria	3.1	3.3	5.36
Phormidium	0.46	1.14	1.74
Planctothrix	4.38	2.04	7.93
Pseudanabaena	0.97	2.52	1.81
DIATOMS	**83.18**	**42.11**	
Centric diatoms	**10.42**	**8.78**	**8.09**
Actinoptychus	4.85	4.9	7.32
Terpsinoe	5.46	3.5	8.12
Melosira	0.04	0.19	11.42
Odontella	0.07	0.19	1.16
Pennate diatoms	**72.76**	**33.33**	**78**
Amphora	21.6	7.6	23.77
Cymbella	0.76	1.18	3.82
Eunotia	5.74	4.9	8.33
Gyrosigma	13.5	6.2	14.55
Navicula	19.15	7.4	20.92
Nitzschia	2.71	1.45	20.87
Pinnularia	9.3	4.6	13.78
ZOOPLANkTON	**1.96**	**4.91**	
COPEPODS	0.30	0.98	1.13
FORAMINIFERA	0.99	2.06	6.05
ROTIFERS	0.6	1.7	2.82
NEMATODES	0.07	0.17	3.04
INDETERMINETED	0.37	1.25	1.78
DETRITUS	**-**	**9.2**	**-**

3.4. Feeding ethlogy of *Liza falcipinnis*

The Costello diagram shows that the species *Liza falcipinnis* has a generalist diet (Figure 3). The frequency of occurrence and specific abundance values of centric diatoms, chroococcaceae, oscillatoriaceae, foraminifera, copepods, rotifers and nematodes are low. Pennate diatoms show a high specific abundance (78%) compared to the percentage of occurrence (33. 33%).

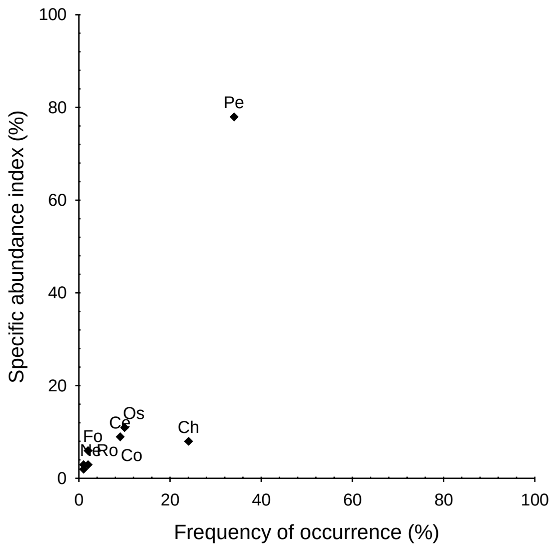

Figure 3: Costello diagram describing the feeding strategy of *Liza falcipinnis*.

Pe: Pennate diatoms; Ce: centric diatoms; Ch: Chroococcaceae; Os: Oscillatoriaceae;

Fo: Foraminifera; Co: Copepods; Ne: Nematodes; Ro: Rotifers.

3.5. *Liza falcipinnis* diet according to size

Based on the numerical percentage, diatoms with 83.18% are the most abundant prey in small individuals (<18 cm). Among these diatoms, pennate are the most abundant preys (80.18%). They are followed by cyanobacteria (13.12%), detritus (12.86%). In large individuals (> 18 cm), diatoms with 77.25% numerical percentage are the most important preys. They are dominated by pennate diatoms (69.08%). Cyanobacteria (17.13%) come second. Based on the occurrence, diatoms are the most important prey in both size classes with 43.83% for small individuals and 46.15% for large individuals. Then come the cyanobacteria with 23.99% for small sizes and 32.84% for large sizes (table 3). Regarding the feeding strategy, the analysis of the Costello diagram of each size class shows that the fish are generalists (Figure 4). Apart from the pennate diatoms which have a low percentage of occurrence and a high specific abundance, the values of percentage of occurrence and specific abundance of other prey (centric diatoms, chroococcaceae, oscillatoriaceae, foraminifera, copepods, nematodes and rotifers) are weak.

Table 3**:** Composition of the diet of *Liza falcipinnis* according to the size.

Fc: corrected percentage of occurrence, N: numerical percentage, S: specific abundance

FOOD ITEMS	**Small size** (size < 18 cm)			**Large size** (size ≥ 18 cm)		
	N (%)	**Fc (%)**	**S(%)**	**N (%)**	**Fc (%)**	**S(%)**
PHYTOPLANKTON	**96.3**	**67.82**		**94.38**	**78.99**	
CYANOBACTERIES	**13.12**	**23.99**		**17.13**	**32.84**	
Chroococcaceae	**4.9**	**13.52**		**5.94**	**18.19**	
Chroococcus	0.73	1.42	**8.83**	2.8	0.99	**15.33**
Gomphosphaeria	-	-	8.63	0.18	0.32	14.4
Merismopedia	1.71	2.84	-	0.75	3.16	1.79
Microcystis	1.9	5.6	3.05	0.64	4.26	1.33
Microcrocis	-	-	2.88	0.09	1.5	5.08
Myxosarcina	0.46	2.24	-	0.51	3.7	0.83
Synechocystis	0.1	1.42	1.28	0.97	4.26	6.33
			1.07			3.30
Oscillatoriaceae	**8.22**	**10.47**		**11.19**	**11.51**	
Lyngbya	0.2	1.42	**8.51**	0.18	0.45	**8.04**
Oscillatoria	5.22	4.27	0.66	3.86	2.63	1.14
Phormidium	-	-	7.1	0.1	1.54	0.04
Planctothrix	2.5	1.94	-	5.38	2.63	11.4
Pseudanabaena	0.3	2.84	5.25	1.67	4.26	2.33
			4.5			1.89
DIATOMS	**83.18**	**43.83**		**77.25**	**46.15**	
Centric diatoms	**2.46**	**7.1**	**26.85**	**8.17**	**10.62**	**19.01**
Actinoptychus	0.2	2.84	1.9	3.83	4.26	6.03
Terpsinoe	2.22	284	18.14	4.16	5.61	6.84
Melosira	-	-	-	0.05	0.30	0.08
Odontella	0.4	1.42	11.42	0.13	0.45	1.16
Pennate diatoms	**80.18**	**36.73**	**71.02**	**69.08**	**35.53**	
Amphora	30.05	11.4	38.17	17.42	6.29	**71.10**
Cymbella	1.03	1.42	2.14	1	1.54	32.7
Eunotia	3.4	2.84	55.4	6.36	5.8	3.68
Gyrosigma	8.3	5.6	9.57	12.4	6.35	34.84
Navicula	16	5.6	41.01	19.3	8.01	19.2
Nitzschia	16.1	4.27	43.27	4.45	0.99	22.04
Pinnularia	5.3	5.6	4.84	8.09	5.26	6.88
						14.85
ZOOPLANkTON	**2.5**	**5.44**		**5.37**	**7.3**	
COPEPODS	-	-	-	0.58	1.54	1.13
FORAMINIFERA	1.75	3.02	6.44	3.06	2.08	6.05
ROTIFERS	0.75	2.42	0.7	1.6	3.16	3.04
NEMATODES	-	-	-	0.13	0.52	2.82
INDETERMINED	1.2	1.02	4.4	0.25	0.45	1.78
DETRITUS	-	**12.86**	-	-	**7.9**	-

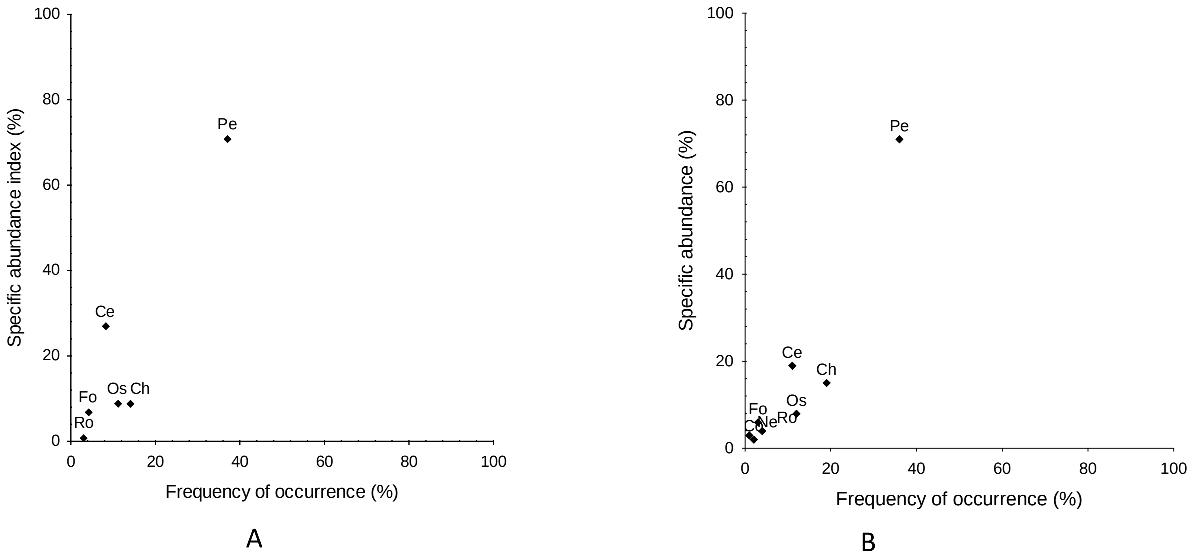

Figure 4: Costello diagram describing the feeding strategy of *Liza falcipinnis* according to size.

(A : small size ; B : large size)

Pe: Pennate diatoms; Ce: centric diatoms; Ch: Chroococcaceae; Os: Oscillatoriaceae;

Fo: Foraminifera; Ro: Rotifers.

3.5. Dietary overlap of the two species

The value of the food overlap index of the two species is: α = 0.75.

3.6. Dietary overlap of *L. falcipinnis* according to size

The food overlap index according to the size of *L. falcipinnis* is as follows: α = 0.84

3. DISCUSSION

The analysis of the diet of *Liza dumerili* from the Grand-Lahou lagoon shows that this species feeds on diatoms (67.89%) (pennate diatoms and centric diatoms), cyanobacteria (13.71%) (chroococcaceae and oscillatoriaceae), foraminifera (10.43%), copepods (3.56%), rotifers (1.15%) and nematodes (0.76%). These preys are planktonic. Phytoplankton, in particular diatoms, are the most abundant. Among the diatoms, the pennate diatoms are the most consumed preys. This species has a phytoplanktonophagous diet. The presence of detritus and grains of sand was observed in all stomachs. This indicates that this fish has a preference for diatoms, detritus and sand. It is also a detritivore. These results are consistent with those issued by [24] in the Sine Saloum estuary in Senegal and by [25] in the Pra and Volta estuaries in Ghana. [26-27] reports the presence of foraminifera in the South African estuary; which is consistent with this present study. On the other hand, [28] in Lagos Lagoon in Nigeria underline the absence of foraminifera in these fish. This absence could be due to his living environment. The presence of the sand particles in all the stomachs indicates that they could contribute to the digestion of the prey of these individuals. This hypothesis agrees with that put forward by [29] and [30] who assert that these particles of sand help the stomach to mechanically crush the diatoms. In addition, some authors have observed that *L. dumerili* has the particularity of ingesting larger grains of sand than do other Mugilidae species ([27, 31, 32, 25]. The presence of sand particles in all stomachs would indicate the presence of benthic life of *L. dumerili*. This would explain the food preference of pennate diatoms. The pennate diatoms are mainly benthic diatoms [33].

Moreover, the general diet profile of *Liza falcipinnis* from the Grand-Lahou lagoon shows that this fish consumes the same types of prey as *L. dumerili*. This species is therefore phytoplanktonophagous.

Indeed, the most abundant preys are the diatoms (83.18%) more particularly the pennate diatoms (72.76%). In addition to diatoms [34] in Nigeria in his work reports the presence of other algae (slime, rhodophyceae, chlorophyceae and dinophyceae) which was not observed in this study. This could be due to the unavailability of these algae in the Grand-Lahou lagoon. According to [8], the phytoplankton densities of this lagoon are seasonal. They are greater during the short dry season and the long rainy season, low in the long dry season and low in the short rainy season

This present study shows that diatoms and detritus constitute the bulk of the prey consumed by this species. This fish is a detritivore. Also, our results corroborate those of [28] and those of [31] in Sierra Leone; [25] in Ghana.

Studies carried out by [2], in the Ebrié lagoon in the Ivory Coast have presented results similar to ours. These authors indicate that in the Ebrié lagoon *L. falcipinnis* seems to be distinguished from the other species of mullet studied by a more opportunistic diet.

It has the possibility of including elements of zooplankton and macro-invertebrates in its diet and especially that of ingesting more and better assimilating cyanobacteria [2]. In the present study, the individuals examined did not consume macroinvertebrates. This could be due to the fishing area. Indeed, these authors attest that macro-invertebrates were observed in *L. falcipinnis* individuals from lagoon areas under strong marine influence. The Grand-Lahou lagoon communicates partially with the marine environment [36] while the Ebrié lagoon is permanently [37].

In the diet of *L. falcipinnis*, diatoms are the most important prey regardless of the size of this fish. However, small individuals did not consume copepods and nematodes. The diet according to the size of *L. falcipinnis* does not vary. This assertion is the same as that made by [25] in Ghana.

Liza dumerili and *Liza falcipinnis* are mainly phytoplankton and scavengers. [38] qualify them as limnivorous, that is to say that they swallow the mud and sift it through a gill apparatus developed to extract organic particles. Moreover, in our study, the coefficient of vacuité of the two studied species is high especially that of *L. Dumerili*. This could be due to the time of day fishing. [39] (2002) In [38] justify this situation by the fact that mules graze seagrass during the day, and at night, suck clay from mudflats to cleanse their stomachs. Which would explain the high number of empty stomachs. [25] state that in the Volta estuary mullets do not feed at night, which is not the case in the lagoons of Elmina and Cape cost in Ghana [32-40].

Regarding the feeding strategy of these two species, the Costello diagram of each species indicates that they are on a generalist diet. However, the majority of the population of each species specializes in the consumption of diatoms, especially pennate diatoms. This is explained by the fact that their specific abundance is high (71.02% for *L. dumerili* and 78% for *L. falcipinnis*) compared to their percentage of occurrence (18.1% for *L. dumerili* and 33. 33% for *L. falcipinnis*). Centric diatoms, oscillatoriaceae, copepods, rotifers, foraminifera, and nematodes show low values for specific abundance and percent occurrence in both species. These low values indicate that these prey are rare in the diet of these fish. This means that they are eaten by a small percentage of predators. In this case, the ecological niche of these species is said to be restricted [19]. Therefore, their position in the food web of the ecosystem is interesting in that they are the main primary consumers within the fish fauna. This could be beneficial for aquaculture. [25] support this assertion by the fact that their low trophic level is an asset for aquaculture because the establishment of these foods requires little means.

L. dumerili and *L. falcipinnis* have a high dietary overlap index ($\alpha = 0.75$) and greater than 0.6. This index shows that these two species have a similar diet. This similarity could lead to food competition between them if the availability of resources were to decrease [41].

Regarding the dietary overlap of *L. falcipinnis* according to size, the overlap index ($\alpha = 0.84$) of the two size classes exceeds the cut-off value. This could mean that there is food competition between individuals of the two size classes.

4. CONCLUSION

The stomach contents of *Liza dumerili* and *Liza falcipinnis* from the Grand-Lahou lagoon consist mainly of diatoms, detritus and sand particles. These fish are phytoplanktonophagous and detritivores. The diet of *Liza falcipinnis* does not vary with height. These two species specialize in the consumption of diatoms, particularly pennate diatoms.

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