E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2022; 10(1): 46-55

www.fisheriesjournal.com
Received: 26-11-2021
Accepted: 22-12-2021

Kouakou Zoumana Séraphin
University of Nangui Abrogoua, Department of Sciences and Environment Management, Environmental and Aquatic Biology Laboratory, 02 BP 801 Abidjan 02, Côte d'Ivoire

Doumbia Lassina
University of Nangui Abrogoua, Department of Sciences and Environment Management, Environmental and Aquatic Biology Laboratory, 02 BP 801 Abidjan 02, Côte d'Ivoire

Konan Koffi Mexmin
University of Nangui Abrogoua, Department of Sciences and Environment Management, Environmental and Aquatic Biology Laboratory, 02 BP 801 Abidjan 02, Côte d'Ivoire

Ouattara Mamadou
University of Nangui Abrogoua, Department of Sciences and Environment Management, Environmental and Aquatic Biology Laboratory, 02 BP 801 Abidjan 02, Côte d'Ivoire

Ouattara Allassane
University of Nangui Abrogoua, Department of Sciences and Environment Management, Environmental and Aquatic Biology Laboratory, 02 BP 801 Abidjan 02, Côte d'Ivoire

Corresponding Author:
Kouakou Zoumana Séraphin
University of Nangui Abrogoua, Department of Sciences and Environment Management, Environmental and Aquatic Biology Laboratory, 02 BP 801 Abidjan 02, Côte d'Ivoire

Reproductive biology of the main fish species in lakes Taabo, Kossou and Faé (Côte d'Ivoire) with a view to rational fishing

Kouakou Zoumana Séraphin, Doumbia Lassina, Konan Koffi Mexmin, Ouattara Mamadou and Ouattara Allassane

DOI: https://doi.org/10.22271/fish.2022.v10.i1c.2635

Abstract
This study was carried out in order to find out the sizes of first sexual maturity and the reproduction period of the main fish species (*Chrysichthys nigrodigitatus, Hemichromis fasciatus, Pelloluna leonensis, Oreochromis niloticus, Sarotherodon galilaeus, Sarotherodon melanotheron, Coptodon zillii, Coptodon zillii x Coptodon guineensis, Distichodus rostratus, Aucheglanis occidentalis, Hepsetus odoe, Parachanna obscura* and *Schilbe mandibularis*) targeted by the fishery in three lakes (Taabo, Kossou, Fae). The sizes at first maturity recorded in Lake Kossou are larger than those obtained in the other two lakes. However, the sizes at first capture (Lc_{50}) for all species in the three lakes are smaller than the sizes at first sexual maturity (L_{50}). Monthly monitoring of the gonadosomatic index (GSI) showed that breeding activities took place during two seasons (wet and dry). The breeding activity during the rainy season is longer than during the dry season. For a sustainable supply of fish, the fishery could be closed during the period when most fish spawn (rainy season).

Keywords: First maturity size, first capture size, gonado-somatic index, spawning period

1. Introduction

Fishing is one oldest activity which have allowed human beings to survival. Fishing is a source of economic income and employment. It can improve nutritional health through the providing of halieutic protein. The man-made lakes are the main fishing grounds in Côte d'Ivoire. Fishing activities take place on all twelve months of the year in the man-made lakes of Taabo, Kossou and Faé. This long fishing period leaves these water bodies overexploited [1, 2, 3]. This over-exploitation is reflected in particular in the decrease of the average size of the fish species compared to the size of the same species found in the other pools, the disappearance of large individuals, and in the sharp decline in daily catches despite the increased performance of the fishing gear used [4, 5]. According to Gourène *et al.* [6], over-exploitation due to fishing and pollution of various origins in continental African aquatic environments endanger aquatic fauna, particularly the fishes, and therefore the sustainability of fishing. Reservoirs are the sites of the main continental fishing activities in Côte d'Ivoire [7].

The abusive exploitations of these lake ecosystems constitute serious obstacles that could have a deep impact on the normal biological functions of species such as growth and reproduction. In response to stresses, due to overexploitation, certain fish populations develop adaptive strategies, notably the regulation of growth and reproduction. The reproductive strategy used by fish species is a set of characteristics that the specie must exhibit in order to reproduce successfully [8]. Reproductive strategy is also an overall model of species-specific reproduction and covers a range of life cycle characteristics including age, size at first sexual maturity, gonadal development, fecundity, oocyte size, reproductive period and oviposition period. Some life cycle characteristics can be influenced by the amount of food, fishing pressure, and environmental conditions [9, 10]. Therefore, knowledge of these life cycle characteristics of fish species is an essential tool that can provide relevant information for the design of fisheries management regulations to enable sustainable exploitation of fisheries and the conservation and preservation of fish and biological stocks [11, 12]. After several years of exploitation, it would therefore be important, both ecologically and managerially, to control the reproduction

Period of the fish species targeted by fishing, in order to improve the management and sustainable exploitation of the fishery resources of these lakes (Taabo, Kossou and Faé). So this study aims to assess some reproductive characteristics of the main fish species caught in Taabo, Kossou and Faé lakes. More specifically, the aim is to determine (1) the sizes of first sexual maturity and first capture and (2) the period of reproduction. Secondly, these first results will allow us to propose a plan of management of the three lakes for a sustainable fishing.

2. Materials and methods

2.1. Study area

The study focuses on samples collected from the Taabo and Kossou hydroelectric man-made lakes and the Faé agri-electric dam lake (Figure 1). Taabo and Kossou dams are both built on the Bandama River. The man-made lake Taabo is downstream of the Kossou man-made lake. The Faé dam is built on the San Pedro River.

Lake Taabo is located between 5°07' and 5°33' West longitude and 6°25' and 6°56' North latitude and covers an area of 69 km² with a water volume of 625,106 m^3. Its average annual flow is 128.7 m^3/s [13]. There are two rainy seasons. The main season goes from April to June and the short one runs from September to November. There are two dry seasons. The main one is situated between December and February. The short runs season from July to September [14].

Lake Kossou is located between 6° 58' and 8° 08' North latitude and 5° 27' and 5° 45' West longitude, with a surface area of 770 km² [15]. The climate contains four seasons: a long rainy season from February to June; a short dry season from July to August; a short rainy season from September to October and a long dry season from November to February [16].

Lake Faé is located between 4°58' - 5°02' north latitude and 6°38' - 6°42' west longitude and covers an area of 16.28 km² of water and 11.24 km² of floodable areas [1]. There are four seasons including two rainy seasons and two dry seasons. The first rainy season takes place between April and July, with maximum rainfall in June and the second, very irregular, extends from September to November or December.

2.2. Sampling

Fish samplings has taken place from September 2017 to October 2018 from experimental and commercial fisheries. The fishing gear consisted in two (2) sets of multi-filament and mono-filament gillnets. Each set was composed of 10 nets with mesh size of 10, 15, 20, 25, 30, 35, 40, 50, 60 and 70 mm respectively. Fishes caught were identified using the identification key of Paugy *et al.* [17]. Each specimen was measured at total and standard lengths to the nearest millimetre and weighed to the nearest thousandth of gram. After dissection, the gender was determined by gonad examination. The stage of sexual maturity was equally determined after macroscopic examination. Sexual maturity scale of Legendre and Ecoutin [18] was used to describe the structure of the gonads.

A survey was carried out on all fishermen operating on lakes Taabo, Kossou and Faé. We have identified 199 fishers in Taabo, 3457 fishers in Kossou and 120 fishers in Faé. Each fisherman was asked to provide the following information: fishing gear used, periods when they stopped working and the reason, alternative activities to fishing.

2.3. Data analysis

2.3.1. Choice of fish species

This study was carried out on of 13 fish species. Four (4) of them were common to the three lakes and seven (7) to two lakes (Taabo and Kossou). The species *Distichodus rostratus* has been funded only in Lake Taabo while *Auchenoglanis occidentalis* was only found in Lake Kossou. Four species (*Sarotherodon melanotheron, Parachanna obscura, Hepserus odoe and Schilbe mandibularis*) were only caught in Lake Faé (Table 1). These species are important in the market

2.3.2. Gonado-somatic Index (GSI)

Gonado-somatic index (GSI) expressed in percent, is the calculation of the gonad mass as a proportion of the total body mass [19]. It is used to determine the degree of maturation of the gonads and the reproduction period based on the variation in gonad mass during the sexual cycle [20]. When this ratio is low, the species is in a state of sexual rest or is immature. A very high ratio reflects an advanced state of gonad maturation and indicates the proximity of gamete emission [21]

The GSI formula used is as follows

$$GSI = \frac{W_g}{W_{ev}} \times 100 \qquad (1)$$

GSI : Gonado-somatic index;

W_g: Weight of gonad (g);

W_{ev}: eviscerated weight (g)

2.3.3. Size at first maturity (L_{50})

The size at first sexual maturity (L_{50}) is the length at which 50% of the individuals are mature. It was estimated by fitting a non-linear logistic function regression linking the proportions of mature individuals and the standard length of the fish. This sigmoid shape function enables L_{50} to be determined accurately [22]. The formula is written as follows

$$P = \frac{e^{(a+bSL)}}{1+e^{(a+bSL)}} \qquad (2)$$

$$L_{50} = -\frac{a}{b} \qquad (3)$$

The logistic model of the size at first sexual maturity was determined using Statistica 7.1 software.

2.3.4. Size at first capture (Lc_{50})

The size at first catch (Lc_{50}) is the length at which 50% of the fishes are caught by fishing. It was determined using the general equation of Von Bertalanffy [23] incorporated in the FISAT II software [24].

2.3.5. Estimated fishing effort

The fishing effort corresponds to the quantification of the exploitation of a stock during a given time interval [25]. It indicates the fishing pressure exerted by fishermen on a stock. Fishing effort remains the only index applicable to the structural heterogeneity characterising tropical artisanal fisheries [26].

2.4. Statistical Analysis

The Chi-square test was used to compare the first maturity sizes (L_{50}) of male and female individuals. The Chi-square test was also used to compare the size at first maturity (L_{50}) with the size at first capture (Lc_{50}). The non-metric multidimensional scale (nMDS) [27] was used to gather the months in which reproduction occurs using the reproductive period of the fish species in each lake. This analysis is based on the Bray-Curtis similarity measure using the group linking procedure. The similarity analysis (ANOSIM) determined whether the gather of months formed were significantly different. The values of the R statistic are an absolute measure of the degree of separation of the groups, ranging from 0 (indistinguishable) to 1 (well separated) [28]. The software programme PAST (Paleontological Statistic) version 2.15 was used for the multivariate analyses (nMDS, ANOSIM). The Chi-square test was carried out using R software.

3. Results and Discussion
3.1. Results
3.1.1. First sexual maturity and first caught size
First sexual maturity sizes, first capture sizes and the results of the Chi-squared test are shown in Table 2 and 3. The sizes of first sexual maturity obtained in Kossou Lake are larger than those recorded in the other two lakes (Taabo and Faé). In all three lakes, in the majority of species the first reproductive size of the females is smaller than that of the males. In the species *Chrysichthys nigrodigitatus* (all lakes), *Distichodus rostratus* (Taabo), *Coptodon zillii x Coptodon guineensis* (Faé) and *Hepsetus odoe* (Faé) the size of first sexual maturity of females is greater than that of males. The Chi-square test indicates that the difference between the sizes of first sexual maturity is not significant in all fish species in the three lakes. The sizes at which 50% (Lc_{50}) of the individuals are caught vary from 25.07 mm (*Pelloluna leonensis*) to 92.32 mm (*Distichodus rostratus*) at Taabo, from 42.72 mm (*Pelloluna leonensis*) to 114.14 mm (*Auchenoglanis occidentalis*) at Kossou and from 55 mm (*Sarotherodon melanatheron*) to 130.37 mm (*Hepsetus odoe*) at Faé Lake. These first capture sizes are smaller than the first sexual maturity sizes (L_{50}) for of all species (Table 3). The comparison of the two sizes shows that the size at first sexual maturity is significantly larger than the size at first capture, except for *Pelloluna leonensis* in which there is no significant difference between the two sizes in the three lakes.

3.1.2. Fishing effort
Knowledge of the number of fishing units or fishermen can give an idea of the fishing effort. In this study we used the number of fishermen per km² to express the fishing effort. The number of active fishermen on the different lakes is 199, 3457 and 120 respectively in Taabo, Kossou and Faé. The fishing effort determined is 2.88 anglers/km² in Taabo, 4.48 anglers/km² in Kossou and 7.37 anglers/km² in Faé.

3.1.3. Gonado-somatic index (GSI) and Reproductive period
The monthly variations of the Gonadosomatic index (GSI) in each lake are shown in figures 2, 3 and 4. The variations in GSI show that in each month at least two species reproduce in each lake. High values of the Gonadosomatic index indicate months when a majority of the individuals are reproducing. The breeding period ranged from three to six months.

The percentage of fish species that spawn in each month in lakes Taabo, Kossou and Faé is shown in Figure 5. In Taabo Lake, the reproduction of 37.5% of the species takes place in the months of November, January, February and April. In the months of June, July, September and October at least 60% of the species reproduce in each of these months. In Kossou Lake, 37.5% of the species reproduce in November, January and February. Half of the species, i.e. 50%, have their breeding period in June and September. In the months of April, July and October at least 60% of the species carry out their reproductive activity. In Faé Lake, 25% of the species collected reproduce in January and September and 40% in February and October. In the months of November, April, June and July at least 60% of the species are reproducing.

The nMDS ordination showed a separation into two groups of the months in which the fish species reproduce in each lake (Taabo, Kossou and Faé) (Figure 6). In Taabo the first group (G1) is composed of the months of January, February, April and November and the second group (G2) includes the months of June, July, September and October. In Kossou, G1 includes the months of January, February and November. G2 includes the months of June, July, September and October. In Faé, G1 includes the months of January, February, September and October. G2 includes the months of April, June, July and November. In general, G1 contains the dry season months (November, January and February) and G2 the wet season months (April, June, July, September and October). According to the ANOSIM results (Table 4), there are significant differences between the groups of months formed in each lake (Taabo $R = 0.62$, $P < 0.05$, Kossou $R = 0.46$, $P < 0.05$, Faé $R = 0.64$, $p < 0.05$). G1 is significantly different from G2 in all three lakes (Taabo, Kossou and Faé). The reproduction of fish species is more accentuated in the rainy season than in the dry season.

3.2. Discussion
Knowledge of the size of first sexual maturity in fish is essential to determine the minimum size of spawners for the purpose of rational stock management [29, 30]. Analysis of maturity indicates that male and female individuals reach sexual maturity at different sizes. This difference in size could be attributed to the differential growth of individuals observed in most teleosteans [31]. In many cases, size differences are associated with sexual differences related to the relative distribution of energy for gametes production [32]. The values of size at first sexual maturity obtained in *Coptodon zillii x Coptodon guineensis, Coptodon zillii, Hemichromis fasciatus, Sarotherodon galilaeus, Oreochromis niloticus, Pelloluna leonensis* and *Chrysichthys nigrodigitatus* in this study vary from one lake to another for the same species. These differences according to the basins can be explained by the fact that the first maturity size of individuals depends on biological and/or ecological factors in the environment such as variations in environmental parameters and the availability of food resources [30, 33]. According to Albaret [34], these variations are different strategies developed by, fishes in different environments to better adapt and benefit from their ecosystem. In the natural environment, the size at sexual maturity is linked to the size of the water body, the density of fish and the various states of stress existing within fish populations [35, 36]. Thus Baijot *et al.* [37] indicate that the larger the lakes are the greater the size of first maturity. The large size of first maturity in Kossou Lake would be explained by its greater surface area (770 km²) than that of Taabo Lake (69 km²) and Faé Lake (16.28 km²). In our study females of *Chrysichthys nigrodigitatus, Oreochromis niloticus, Sarotherodon galilaeus, Sarotherodon melanotheron, Parachanna obscura, Auchenoglanis occidentalis, Schilbe*

mandibularis and *Distichodus rostratus* reached sexual maturity at smaller sizes than in the observations of Albaret [38] (*Chrysichthys nigrodigitatus* 195 mm, *Oreochromis niloticus* 160 mm, *Sarotherodon galilaeus* 145 mm), [39] (*Parachanna obscura* 245 mm), [40] (*Auchenoglanis occidentalis* 270mm), [41] (*Sarotherodon melanetheron* 136 mm), [42] (*Schilbe mandibularis* 181 mm) and [43] (*Distichodus rostratus* 463 mm). Indeed, Welcomme [44] and Rutaisire and Booth [45] reported that fish respond to fishing pressure by reducing the size at first maturity [46] also indicates that fishing pressure leads to a reduction in the age at first spawning, and therefore the size at first sexual maturity. Thus the fishing effort of 3 fishers/km² in Taabo, 4.48 fishers/km² in Kossou and 7.37 fishers/km² in Faé exceeds the FAO standard of 2 fishers/km² [37]. This mode of exploitation practiced on these lakes could be one of the reasons for the reduction in the size of the first reproduction. The fecundity of a species is most often a function of the size of the female, as larger sizes result in more eggs being laid [47, 48]. This reduction in the size of first sexual maturity could cause a decrease in fecundity in these species.

Gonado-somatic index (GSI) of the fish species showed different reproductive intensities in the different seasons. Fish reproduces more in the rainy season than in the dry season in the three lakes (Taabo, Kossou and Faé). Our results corroborate with those of Kwarfo-Apegyah and Ofori-Danson [49] who indicated that the breeding period of fish in the Bontanga Reservoir in Ghana takes place during the rainy season. The reproductive biology of tropical freshwater fish species is influenced mainly by the rainfall regime and/or water level fluctuations [47]. The breeding periods of fish species in the three Lakes followed the general breeding pattern of tropical freshwater fish species, in that they coincide with the rainy season and the associated high-water level. This synchronisation of the reproduction period with the rainy or flood season, well known in many tropical fish species, appears to be a very advantageous strategy for juveniles [50]. Indeed, during the rainy season, submerged areas provide shelter for fish and they find food resources in abundance [51].

We have found that the sizes of first capture (Lc_{50}) are below the size of first maturity (L_{50}) for all species studied [52] made the same observation for six catfish species caught in the Ouémé delta in Benin. Fish harvesting patterns in the three lakes tend to reduce the fecundity of the stocks as most of the fish caught do not have the chance to reproduce at least once before being removed from the environment. This fishing practice would reduce the stock of fish available in the environment. In front of reduction of the available fish resource, it would be interesting to propose various alternatives for a sustainable management of fishing in lakes Taabo, Kossou and Faé. The main reproduction periods take place during the rainy season. So, we could propose a fishing closure in June, July, September and October in Taabo Lake; in April, June, July, September and October in Kossou Lake and finally in April, June, July and November in Faé Lake. We know that fishing is the main source of livelihood for artisanal fishermen. Thus, the closure of the fishery during these periods will leave fishermen without work, making them very vulnerable. This possibility is unlikely to guarantee their full cooperation. So fishermen can carry out their activity but with a reduced rate of fish exploitation. This can be done in two ways. The first is to reduce fishing effort [53]. Fishing gear and water trips need to be reduced. Each fisherman, for example, could have a battery of gillnets and be allowed to go out once a day. Beach seining should be prohibited. The second is to increase the mesh size of the nets to allow spawners to reproduce at least once in their lifetime before being caught. Therefore the mesh size must be increased to 100mm. The challenges associated with these two management options are monitoring and surveillance to ensure fishermen's compliance.

To gain the support and cooperation of fishermen, the Ministry of Fisheries Resources should delegate management authority to fishermen and other stakeholders, in order to compel them to assume greater responsibility for the conservation of fisheries resources. This could be achieved through the adoption of a community-based fisheries management system [54, 55].

This option involves the formation of fisheries co-management committees with fishers and other stakeholders from the riverside community. The committee can ensure responsible fishing practices by formulating relevant regulations for the sustainable exploitation of fishery resources. According to Pinkerton [56], fishing communities or organisations should be involved as partners in the planning, design and implementation of fishing regulations. Indeed, when these communities or fishermen's organisations are involved in habitat protection and are part of the process of drafting management policies, they give full legitimacy to the regulations, being the strongest advocates, controllers and implementers of management decisions. Consequently, a community co-management committee would ensure that a closed period, reduced fishing effort and regulations on minimum mesh size for gillnets are respected, in the interest of protecting fish stocks and ensuring sustainable exploitation of the resource.

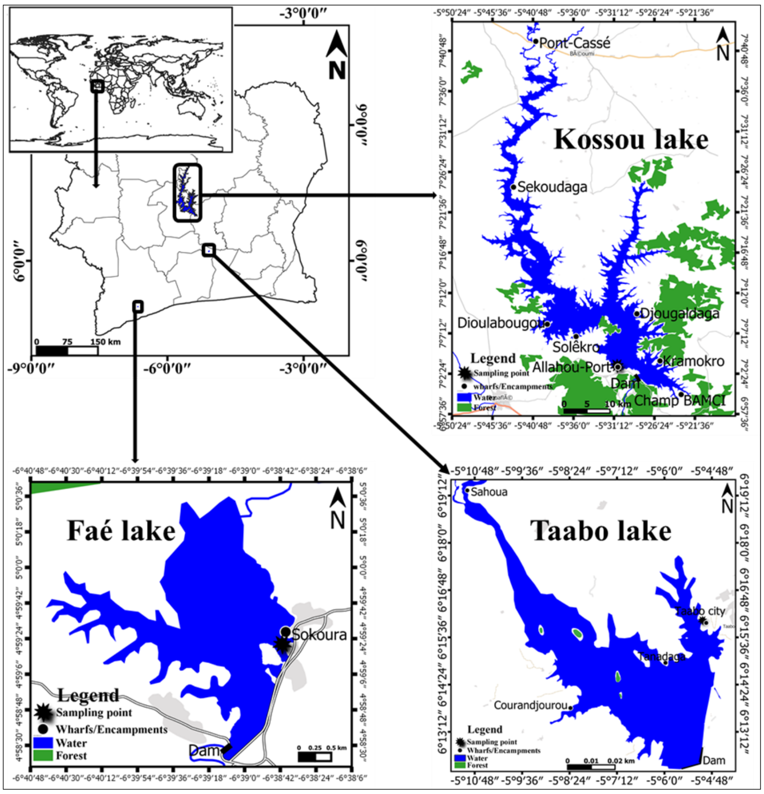

Fig 1: Geographical situation of the studied areas: Taabo, Kossou and Faé lakes (Côte

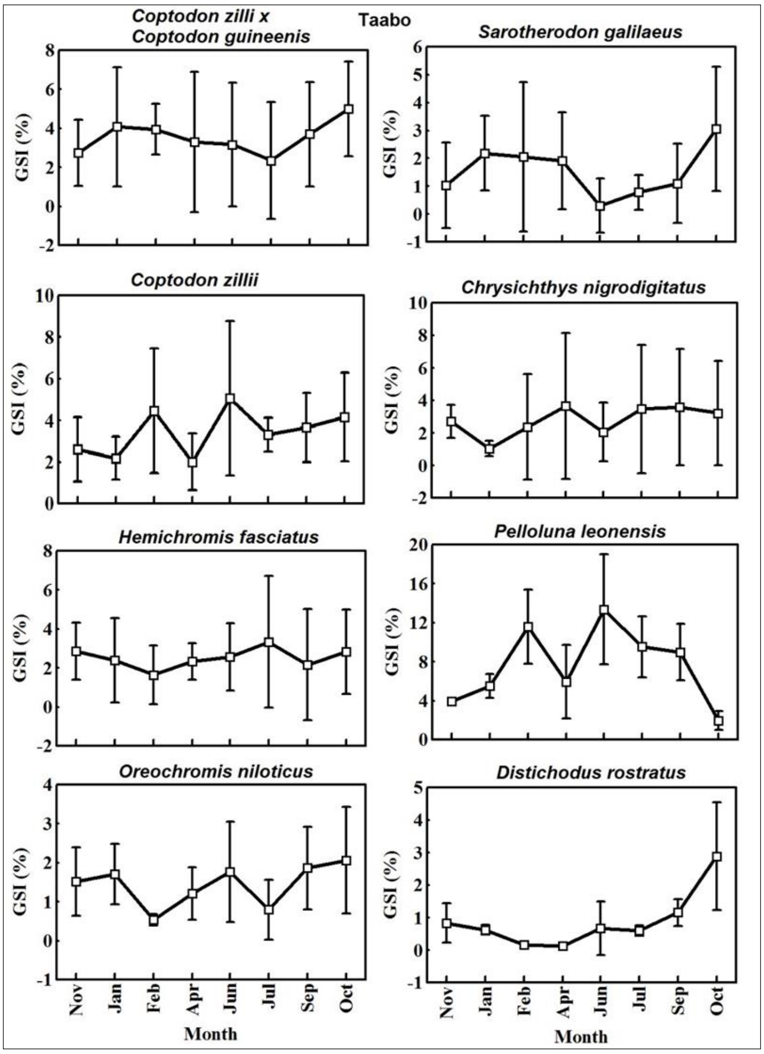

Fig 2: Monthly variation in the Gonado-somatic index (GSI) of female fish species in Taabo Lake

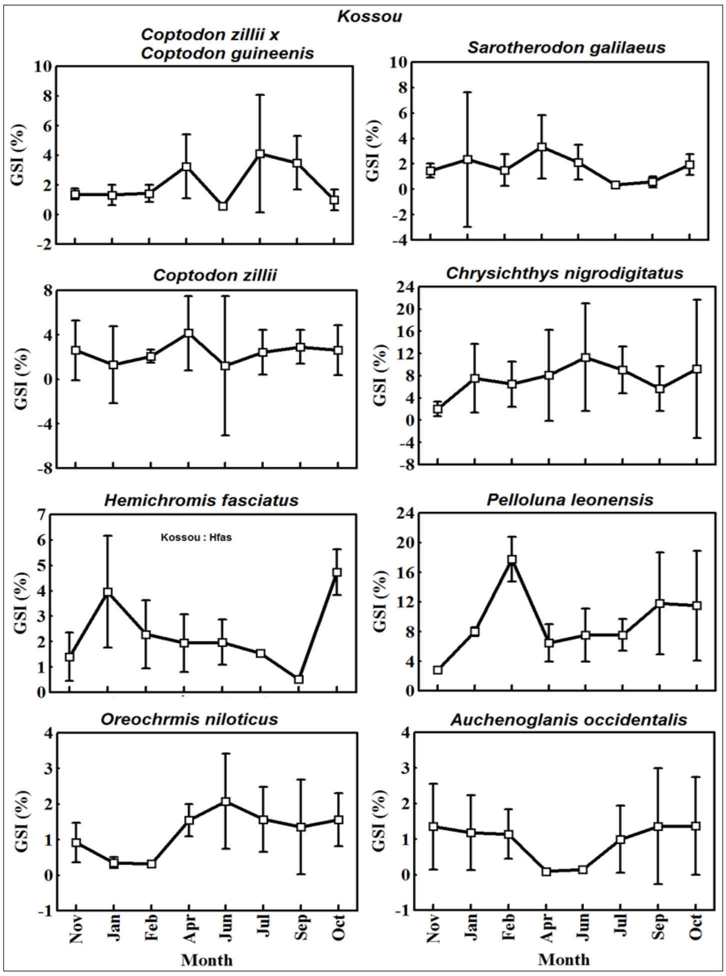

Fig 3: Monthly variation in the Gonadosomatic index (GSI) of female fish species in Kossou Lake

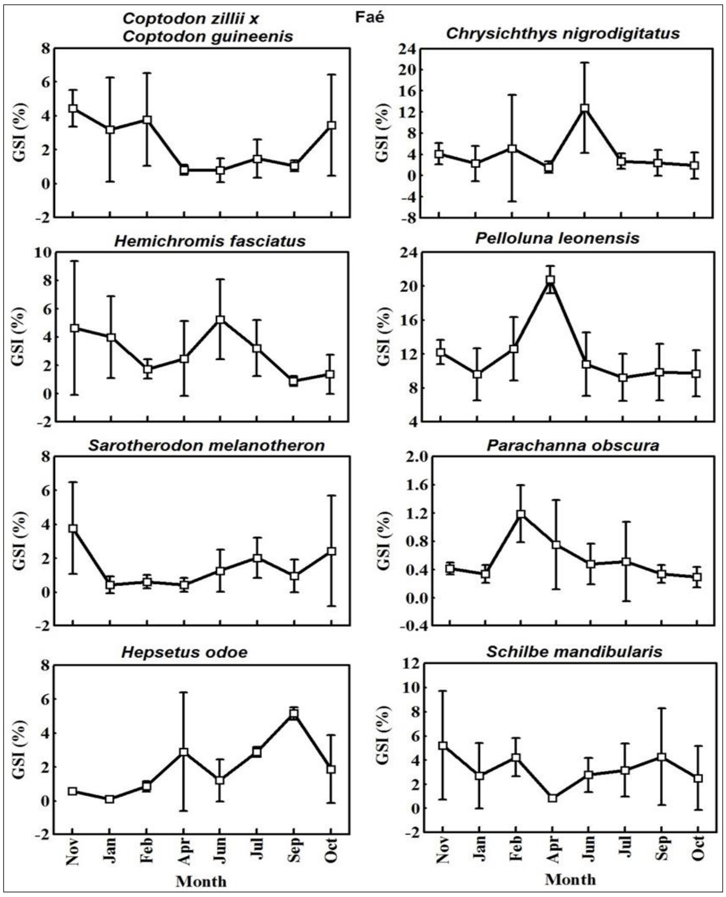

Fig 4: Monthly variation in the Gonadosomatic index (GSI) of female fish species in Faé Lake

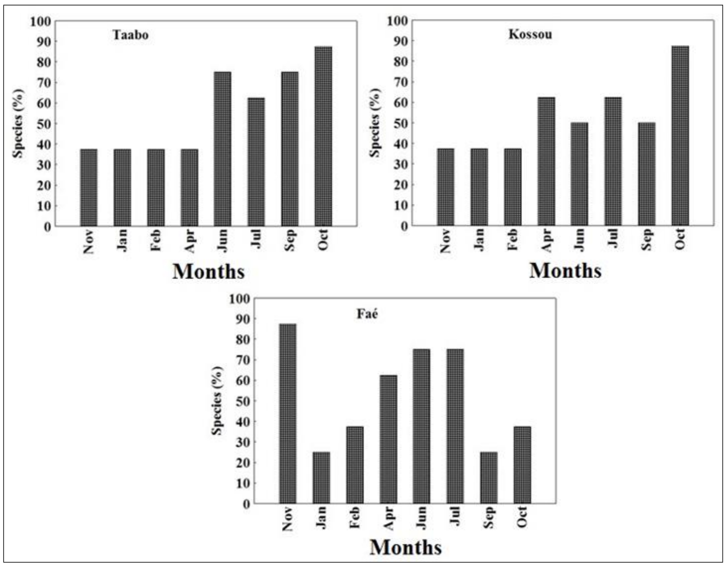

Fig 5: Percentage of the breeding population by month

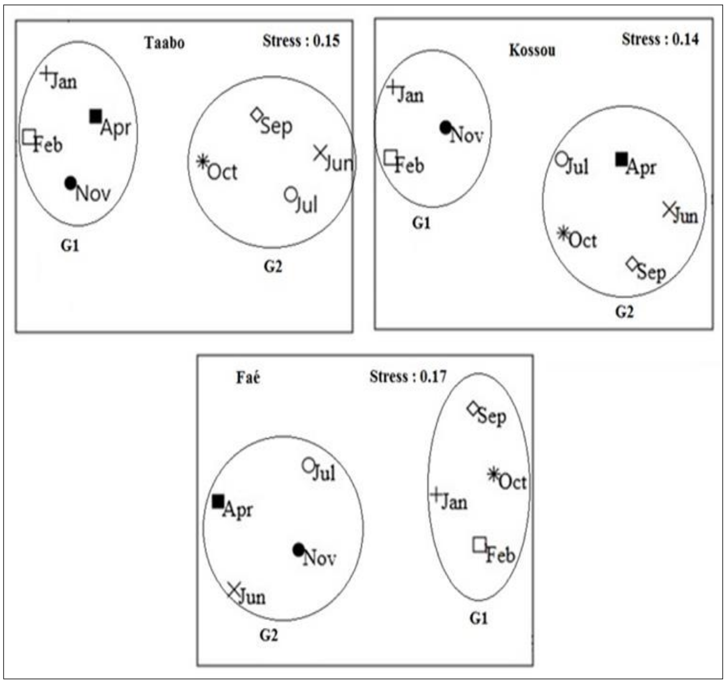

Fig 6: Non-metric multidimensional scaling (nMDS) plot of months of reproduction of fish species in Lakes Taabo, Kossou and Faé

Table 1: List of fish species studied in the three lakes

Species	Lacs		
	Taabo	Kossou	Faé
Coptodon zillii x Coptodon guineensis	+	+	+
Hemichromis fasciatus	+	+	+
Chrysichthys nigrodigitatus	+	+	+
Pelloluna leonensis	+	+	+
Coptodon zillii	+	+	
Oreochromis niloticus	+	+	
Sarotherodon galilaeus	+	+	
Distichodus rostratus	+		
Auchenoglanis occidentalis		+	
Sarotherodon melanotheron			+
Parachanna obscura			+
Hepsetus odoe			+
Schilbe mandibularis			+

Table 2: Comparison of the sizes at first sexual maturity (L_{50}) between the two sexes of fish species caught in lakes Taabo, Kossou and Faé.

Species name	Taabo			Kossou			Faé		
	L_{50} (mm)		χ^2	L_{50} (mm)		χ^2	L_{50} (mm)		χ^2
	Male	Female		Male	Female		Male	Female	
Coptodon zillii x Coptodon guineensis	111.7	106.13	0.14	129.22	120.19	0.32	86.38	91.23	0.13
Coptodon zillii	99.96	97.31	0.035	120.62	111.4	1.14			
Hemichromis fasciatus	96.63	85.17	0.47	103.85	91.39	0.88	91.3	82.09	0.63
Oreochromis niloticus	123.69	106.22	1.32	133,39	125.66	0.27			
Sarotherodon galilaeus	124.22	120.4	0.059	134.95	129.31	0.001			
Chrysichthys nigrodigitatus	143.95	154.12	0.32	159.81	167.81	0.19	138.74	145.60	0.15
Pelloluna leonensis	27.34	26.43	0.015	70.47	66.65	0.66	59.23	57.07	0.025
Distichodus rostratus	377.47	428.68	3.25						
Auchenoglanis occidentalis				268.97	249.88	0.702			
Sarotherodon melanotheron							110.91	117.62	0.19
Parachanna obscura							214.07	183.01	2.42
Hepsetus odoe							170.77	178.63	0.17
Schilbe mandibularis							112.07	109.04	0.04

Table 3: Comparison of first sexual maturity sizes (L_{50}) and first catch sizes (L_{c50}) of fish species caught in Lake Taabo, Kossou and Faé. (* : Significant P < 0.05 difference)

Species	Taabo					Kossou					Faé				
	Lc_{50} (mm)	Male		Female		Lc_{50} (mm)	Male		Female		Lc_{50} (mm)	Male		Female	
		L_{50} (mm)	χ^2	L_{50} (mm)	χ^2		L_{50} (mm)	χ^2	L_{50} (mm)	χ^2		L_{50} (mm)	χ^2	L_{50} (mm)	χ^2
Coptodon zillii x Coptodon guineensis	47.04	111.7	26.33*	106.13	22.79*	53.16	129.22	31.72*	120.19	25.91*	61.32	86.38	4.28*	91.23	5.90*
Coptodon zillii	59.89	99.96	10.04*	97.31	8.90*	56.79	120.62	12.2*	111.4	4.37*					
Hemichromis fasciatus	48.41	96.63	1.81*	85.1	4.13*	43.72	103.85	18.26*	91.39	11.34*	59.56	91.3	11.71*	92.09	6.97*
Oreochromis niloticus	66.12	123.69	6.72*	106.22	2.1*	72.43	133,39	9.03*	129,66	6.20*					
Sarotherodon galilaeus	61.91	124.22	20.85*	120.4	18.75*	64.58	134.92	21.95*	129.31	21.61*					
Chrysichthys nigrodigitatus	83.08	143.95	21.19*	154.12	26.56*	49.95	159.81	57.53*	167.81	63.79*	60.10	138.74	37.62*	145.66	42.32*
Pelloluna leonensis	25.07	27.34	0.09	26.43	0.03	42.75	70.47	0.66	66.65	1.02	56.95	59.23	1.56	57.07	1.19
Distichodus rostratus	92.32	377.47	173.08*	428.68	217.16*										
Auchenoglanis occidentalis						114.14	268.97	62.57*	249.88	50.62*					
Sarotherodon melanotheron											55	110.91	18.841*	117.62	22.71*
Parachanna obscura											75.43	214.07	68.58*	183.01	44.78*
Hepsetus odoe											130.37	170.77	5.41*	178.77	7.57*
Schilbe mandibularis											74.22	112.07	7.69*	109.04	6.61*

Table 4: Statistic results of ANOSIM and their significance levels (P < 0.05) for pairwise comparisons of fish reproductive period among the two groups in each locality

Locality	Groups	ANOSIM	
		Global-R	P
Taabo	1 and 2	0.61	0.027
Kossou	1 and 2	0.46	0.020
Faé	1 and 2	0.64	0.028

4. Conclusion

This study showed that in the fish species studied, male and female individuals reach sexual maturity at different sizes. The large sizes of first sexual maturity are reached in Lake Kossou only. The fish are caught before their first reproductive size. The majority of the fish reproduce during the rainy season in the three lakes: Taabo (June, July, September and October), Kossou (April, June, July, September and October) and Faé (April, June, July and November).

5. Acknowledgements

This document was produced as part of a project entitled "Scientific studies for the purpose of proposing national regulations for the rational exploitation of inland water fishery resources: Bandama, Comoé and Faé river basins", financed by the European Union (EU) and the Directorate of Aquaculture an^{2}d Fisheries (DAP).

6. References

1. Da Costa KS, Dietoa YM. Typologie de la pêche sur le lac Faé (Côte d'Ivoire) et implications pour une gestion une gestion rationnelles des ressources halieutiques. BFPP/Bull.fr. Pêche pisciculture. 2007;384:1-14.
2. Blé AKSR. Rentabilité de la pêche pratiquée sur le lac de Taabo couvert partiellement par les végétaux aquatiques envahissants sur la période 2002-2005. Revue de Géographie Tropicale et d'Environnement, 2008, 13 pp.
3. Diarra A. Kossou: Un pôle de production halieutique en décadence. Revue Espace, Territoires, Sociétés et Santé. 2020;3(5):79-91.
4. Montchowui E, Chikou A, Kogbeto MJ, Laleye P. Biodiversité et structure des communautés de poissons du lac Hlan au Bénin. International Journal Biological Chemical Sciences. 2008;2(2):196-206.
5. Kraidy LAB, Kone N, Berte S, N'zi KG, Yao SS. Kouamelan PE. Pêche et paramètres de reproduction de *Pellonula leonensis* Boulenger 1916, dans le lac de Taabo (Fleuve Bandama, Côte d'Ivoire): implications pour une

exploitation durable du stock. International. Journal of Biological and Chemical Sciences. 2014;8(1):75-88.
6. Gourène G, Teugels GG, Hugueny B, Thys Van Den Audenaerde DFE. Evaluation de la diversité ichtyologique d'un bassin ouest-africain après la construction d'un barrage. Cybium. 1999;23(2):147-160.
7. Tah L, Da Costa KS, Kouassi JN, Moreau J. Effort de pêche et production piscicole au lac d'Ayamé I (Bassin de la Bia; Côte d'Ivoire) après le départ des pêcheurs « bozos ». Agronomie Africaine. 2009;21(1):103-115.
8. Ouattara M, Diomandé D, Boussou KC, Gourène G. Stratégies de reproduction de *Marcusenius ussheri* (Pisces, Mormyridae) en fonction des conditions hydrologiques créées par la construction du barrage hydroélectrique d'Ayamé I sur le cours principal de la rivière Bia (Côte d'Ivoire). Belgian Journal of Zoology. 2010;140(1):11-19.
9. Duponchelle F, Legendre M. Oreochromis niloticus (Cichlidae) in Lake Ayame, Côte d'Ivoire: life history traits of a strongly diminished population. Cybium. 2000;24:161.
10. Pathak BC, Ali R, Serajuddin M. Comparative Analysis of Reproductive Traits in Barred Spiny Eel, *Macrognathus pancalus* (Hamilton, 1822) from Lotic and Lentic Ecosystems of Gangatic Basin, India. World Journal of Fish and Marine Sciences. 2012;4(5):470-479.
11. Lima JTAX, Fonteles-Filho AA, Chellappa S. Biologia reprodutiva da Serra, *Scomberomorus brasiliensis* (Osteichthyes: Scombridae), emáguas costeiras do Rio Grande do Norte. Arquivos de Ciências do. 2007;40(1):24-30.
12. Oliveira MR, Costa EFS, Chellappa S. Ovarian development and reproductive period of white mullet, *Mugil curema* in the coastal waters of Northeastern Brazil. Animal Biology Journal. 2011;2(4):222-237.
13. Aliko NG, Da Costa KS, Konan KF, Ouattara A, Gourène G. Fish diversity along the longitudinal gradient in a man-made lake of West Africa, Taabo hydroelectric reservoir, Ivory Coast. Ribarstvo. 2010;68(2):47-60.
14. Kouassi KL, Goné DL, Meledje NH, Wognin AV, Aka K. Hydrologie et évolution spatio-temporelle des charges solides en suspension dans le lac du barrage hydroélectrique de Taabo (Côte D'Ivoire). European Journal of Scientific Research. 2007;18(3):464-478.
15. Kouassi N. Données écologiques et biologiques sur les populations d'*Alestes baremoze* (Joannis, 1835), Poissons Characidae du lac de barrages de Kossou. Thèse de Doctorat d'Etat ès sciences. Université Nationale de Côte d'Ivoire, 1978, 278.
16. Iltis A, Lévêque C. Caractéristiques physico-chimiques des rivières de Côte d'Ivoire. Revue d'Hydrobiologie Tropicale. 1982;15(2):115-130.
17. Paugy D, Leveque C. Teugels GG. Faune des poissons d'eaux douces et saumâtres d'Afrique de l'Ouest. IRD/MRAC, Publications scientifiques du Museum, 2003, 1272.
18. Legendre M, Ecoutin JM. Suitability of brackish water tilapia species from the Ivory Coast for lagoon aquaculture: Reproduction. Aquatic. Living Resources. 1989;2:71-79.
19. Fermond Y. Les *Haplochromis spp*. (Teleostei, Cichlidae) des zones rocheuses du Mwanza Gulf, lac Victoria, Tanzanie; Structures des communautés et écomorphologies. Thèse de Doctorat. Laboratoire d'Ichtyologie générale et Appliquée, Muséum National d'Histoire Naturelle. ORSTOM, Paris, 1996, 270.
20. Bougis P. Recherches biométriques sur les Rougets (*Mullus barbatus* L. et *M. surmulatus* L.). Archives de Zoologie Experimentale et Générale. 1952;89(2):57-174.
21. Konan YL, Ouattara S, Koné T, Bamba M, Koné I. Caractéristiques de la reproduction de *Thysochromis ansorgii* (Pisces, Cichlidae) dans la forêt des marais Tanoé-Ehy (Côte d'Ivoire), Journal of Applied Biosciences. 2013;71:5715-5727.
22. Barbieri LR, Chittenden JME, Lowere-Barbieri SK. Maturity, spawning and ovarian cycle of Atlantic croaker, *Micropogonias undulatus*, in the Chesapeake Bay and adjacent coastal waters. Fish Bulletin. 1994;92:671-685.
23. Von Bertalanffy L. A quantitative theory of organic growth (inquiries on growth laws II.). Human. Biology. 1938;10(2):181- 213.
24. Niyonkuru C. Etude comparée de l'exploitation et de la démographie des poissons Cichlidés dans les lacs Nokoué et Ahémé au Bénin. Thèse de Doctorat, Université d'Abomey-Calavi, Bénin. 2007, 199.
25. Laurec A, Le Guen JC. Dynamiques des populations marines exploitées. Tome1 : Concepts et Modèles. Centre National pour l'Exploitation des Océans. Rapports scientifiques et techniques. 1981, 45.
26. Laë R. Estimation des rendements de pêche des lacs africains au moyen de modèles empiriques. Aquatic Living Resources. 1997;10:83-92.
27. Clarke KR, Warwick RM. Change in Marine Communities: An Approach to Statistical Analysis and Interpretation. Natural Environment Research Council, UK. 1994, 144.
28. Clarke KR, Gorley RN. Primer v. 5: User manual/ tutorial. Plymouth, UK: Primer-E. 2001, 91.
29. Dadebo E, Ahlgren G, Ahlgren I. Aspect of reproductive biology of *Labeo horie* Heckel (Pisces: Cyprinidae) in lake Chamo. African Journal of Ecology. 2003;41:31-38.
30. Atse BC, Konan KJ, Kouassi NJ. Biologie de la reproduction du Cichlidae *Tylochromis jentinki* dans la lagune Ebrié (Cote d'Ivoire). Cymbium. 2009;33(1):11-19.
31. Poulet N. Le sandre *Sander luciperca* (L.): Biologie, comportement et dynamique des populations en Camargue (Bouches du Rhône, France). Thèse de Doctorat. Université Toulouse III-Paul Sabatier (France). 2004, 286.
32. Weatherley AH, Gill HS. The biology of fish growth. London: Academic Press. 1987, 443.
33. Koné N, Berte S, Kraidy ALB, Kouamelan EP, Koné T. Biologie de la reproduction du Clupeidae *Pellonula leonensis* Boulenger, 1916 dans le lac de barrage de Kossou (Côte d'Ivoire). Journal of Applied Biosciences. 2011;41:2797-2807.
34. Albaret JJ. Les poissons, biologie et peuplement. *In*: Environnement et ressources aquatiques de Côte d'Ivoire. Tome II. Les milieux lagunaires. DURAND JR, DUFOUR P, GUIRAL D & ZABI SGF (eds), ORSTOM. 1994, 239-279.
35. Legendre M, Ecoutin JM. Aspect de la stratégie de reproduction de *Sarotherodon melanotheron*: comparaison entre une population naturelle (Lagune Ebrié, Côte d'Ivoire) et différentes populations. *In*: Le Troisième Symposium International sur le Tilapia en Aquaculture (Pullin R.S.V., Lazard J., Legendre M.,

Amon Kothias J.B. & Pauly D., eds) ICLARM Conference Proceedings. 1996;41:375-386.
36. Lowe-McConnell RH. Ecological studies in tropical fish communities. Cambridge University Press. Cambridge, United Kingdom, 1987, 382.
37. Baijot E, Moreau J, Bouda S. Aspects hydrobiologiques et piscicoles des retenues d’eau en zone soudano-sahélienne. Centre Technique de Coopération Agricole et Rurale (CTA) Commission des Communautés Européennes (CCE). Bruxelles, 1994, 250.
38. Albaret JJ. Reproduction et fécondité des poissons d'eau douce de Côte-d'Ivoire. Revue d'Hydrobiologie Tropicale. 1982;15(4):347-371.
39. Adebisi AA. The relationships between the fecundities, gonado-somatic indices and egg sizes of some fishes of the Ogun River, Nigeria. Hydrobiologia. 1987;111:151-156.
40. Benech V. Contribution à la connaissance de la reproduction de quelques espèces d'intérêt halieutique dans le delta central du Niger. Atelier IER/ORSTOM "études halieutiques dans le delta central du Niger, Bamako, 1990, 17.
41. Koné T, Teugels GG. Données sur la reproduction d’un tilapia estuarien (Sarotherodon melanotheron) isolé dans un lac de barrage ouest africain, Aquatic Living Resources. 1999;12:289-293.
42. Ouattara M, Doumbia L, Yao K, Gourène G. Reproduction du poisson-chat africain Schilbe mandibularis (Günther 1867) (Siluroidei ; Schilbeidae) en mileix lacustre et fluviatile (Côte d’Ivoire). Livestock Research for Rural Development. 2008;20(1).
43. Berté S, Kouamélan EP, Ouattara NI, Koné T, Goore BG, N’Douba V, *et al*. Cycle de reproduction et fécondité de Distichodus rostratus (Characiformes, Distichodontidae) dans un bassin ouest africain (fleuve Bandama, Côte d’Ivoire). Tropicultura. 2008;26(2):104-107.
44. Welcomme RL. The conservation and environmental management of fisheries in inland and coastal waters. Netherlands Journal of Zoology. 1992;42(2-3):176-89.
45. Rutaisire J, Booth AJ. Reproductive biology of ningu, *Labeo victorianus* (Pisces: Cyprinidae), in the Kagera and Sio Rivers, Uganda. Environmental Biology of Fish. 2005;73:153-162.
46. Laë R. Réponses adaptatives des populations et des peuplements de poissons aux pressions de l’environnement. Proposition UR (Unité de Recherche) RAP/IRD, 1999, 33.
47. Wooton RJ. Ecology of Teleost Fishes. Ist edtn. Chapman and Hall, London, 1990, 344.
48. Montchowui E, Lalèyè P, Poncin P, Philippart J-C. Reproductive strategy of *Labeo senegalensis* Valenciennes 1842 (Teleostei: Cyprinidae) in the Ouémé basin, Benin. African Journal of Aquatic Science. 2010;35(1):81-85.
49. Kwarfo-Apegyah K, Ofori-Danson PK. Spawning and recruitment patterns of major fish species in Bontanga Reservoir, Ghana, West Africa. Lakes & Reservoirs: Research and Management. 2010;15:3-14.
50. Issa EA, Olufeagba SO, Raji A. Effects of some environmental factors on the fecundity of tilapia species (Family Cichlidae) in Kigera Reservoir, New Bussa. 19th Annual Conference of the Fisheries Society of Nigeria. Ilorin Nigeria, 2005, 861-868.
51. Oso JA, Idowu EO, Fagbuaro O, Olaniran TS, Ayorinde BE. Fecundity, condition factor and gonado-somatic index of *Hepsetus odoe* (African Pike) in a tropical reservoir, Southwest Nigeria. World Journal of Fish and Marine Sciences. 2011;3(2):112-116.
52. Chikou A, Laleye PA, Bonou CA, Vandewalle P, Philippart JC. Tailles de première maturité et de capture de six espèces de poisson-chat dans le delta de l’Ouémé au Bénin (Afrique de l’Ouest). International Journal of Biological and Chemical Sciences. 2011;5(4):1527-1537.
53. Garcia SM. The precautionary approach to fisheries. Progress review and main issues: 1995–2006. FAO Fish. Tech. Paper N°487, 261 pp. United Nations Food and Agriculture Organization (FAO), Rome, 2006.
54. Yamamoto T. Development of a community-based fishery management system in Japan. Marine Resource Economics. 1995;10:21-34.
55. Pomeroy RS, Pollnac RB, Predo CD, Katon BM. Impact evaluation of community-based coastal resource management projects in Philippines. Naga, ICLARMQ. 1996;19:9-11.
56. Pinkerton E. Partnership in management. A fishery manager’s guide book. Management measures and their application (ed. K. L. Cochrane). Fish. Technical Paper FAO, Rome, 2002;42:159-75.