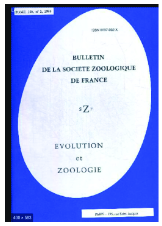
Bulletin de la Société Zoologique de France
2024, volume 149 (3), pages 49 à 62
ISSN : 0037-962X
http://societe-zoologique.fr/



Growth and reproduction of three fish species (*Clarias gariepinus, Oreochromis niloticus* and *Bagrus bajad*) in Foum-Gleita Lake (Mauritania)

Cheikhna Yero GANDEGA[1], Nassima EL OMRANI[2], Meriem BENSMIRA[3], Djimera LASSANA[1], Mariam SY[1], Ahmad AL-SHAMMARI[4], Adel Ali NASEEB[4], Mohammad ALI[4], Roger FLOWER[5] & Mohammed RAMDANI[6]

[1] Mauritanian Institute for Oceanographic Research and Fisheries, PO box 22, Nouadhibou- Mauritania; gandega_cheikhna@yahoo.fr

[2] Faculty of Sciences, University Ibn Zohr Agadir, Morocco, naelomrani007@gmail.com

[3] Département d'Agronomie, Faculté des Sciences de la Vie et de la Nature, Université Mustapha Stambouli, Mascara, Algérie, bensmiram@hotmail.com

[4] Environment & Life Sciences Research Center, Kuwait Institute for Scientific Research, Kuwait. mohalikisr@gmail.com, ahmad.alshammari1990@outlook.com , ajnaseeb@gmail.com

[5] University College London, Dept. of Geography, London, WC1E 6BT, United Kingdom rogerflower88@gmail.com

[6] Scientific Institute, Mohammed V University of Rabat, Morocco, ramdanimed@gmail.com

*Corresponding author : ramdanimed@gmail.com

Manuscrit reçu le 31/05/2024 ; accepté le 10/10/2024 ; mis en ligne le 30/10/2024 ; DOI : https://doi.org/10.60881/bszf149-3-1

Abstract

This study focuses on three fish species in Foum-Gleita Lake (Mauritania): *Clarias gariepinus*, *Oreochromis niloticus* and *Bagrus bajad*. Both growth and reproduction of these three species are investigated. Growth parameters are used to determine median sexual maturity size and the reproduction periods during an annual growth cycle. Knowledge of the population parameters of these fish is relevant to their exploitation, growth rate data is used to estimate size distributions and fishing impacts on each fish population. Catch seasons and the minimum catch size for populations of each species were obtained to assist in better stock management.

The studied species stocks were sampled and caught specimens were measured for total length, fork length, and total body weight. Evisceration of fish enabled the determination of sexual maturity by examining and weighing the gonads; food availability was assessed from prey in the alimentary bolus.

Male *Clarias gariepinus* growth rate (k=0.16) was higher than for females (k = 0.12). This growth difference was confirmed by the growth performance indicator, phi. The same scenario was observed in *Oreochromis niloticus*. However, the opposite scenario occurred in *Bagrus bajad* where female growth rate tended to out-perform that of males. *Clarias gariepinus* showed two well-marked seasonal growth modes with total lengths of about 40 cm during January to July and about 30 cm between September to December in males. But in females the two seasonal growth modes were around 43 cm from January to August and around 40 cm from September to December. For both sexes of *Oreochromis niloticus*, the two modes of seasonal growth were well marked at between 20 and 30 cm from August to December. *Bagrus bajad* did not show well marked seasonal growth modes at all; likely due to an artefact linked to the low numbers per size class of the male individuals sampled or to environmental factors. These results are compared to data from elsewhere and collectively they contribute useful biological indicator data relevant to supporting new policies for the rational management of freshwater fishery resources in Mauritanian lakes.

Keywords Freshwater fisheries, *Clarias gariepinus, Oreochromis niloticus, Bagrus bajad*, reproduction, sexual maturity, Foum-Gleita Lake, Mauritania.

Croissance et reproduction de trois espèces de poissons (*Clarias gariepinus*, *Oreochromis niloticus* et *Bagrus bajad*) dans le lac Foum-Gleita (Mauritanie)

Résumé

Cette étude porte sur trois espèces de poissons du lac Foum-Gleita (Mauritanie) : *Clarias gariepinus*, *Oreochromis niloticus* et *Bagrus bajad*. Les paramètres de croissance sont utilisés pour déterminer la taille médiane de maturité sexuelle et les périodes de reproduction au cours d'un cycle annuel de croissance. La connaissance des paramètres de population de ces poissons est pertinente pour leur exploitation et les données sur le taux de croissance sont utilisées pour estimer la répartition des tailles et les impacts de la pêche sur chaque population. Les saisons de capture et la taille minimale de capture pour les populations de chaque espèce ont été collectées pour contribuer à une meilleure gestion des stocks.

Chaque stock d'espèce étudiée a été échantillonné et les spécimens capturés ont été mesurés pour leur longueur totale, leur longueur à la fourche et leur poids corporel total. L'éviscération des poissons permettait de déterminer la maturité sexuelle par l'examen et la pesée des gonades ; la disponibilité de la nourriture a été évaluée à partir des proies contenues dans le bolus alimentaire.

Le taux de croissance des mâles *Clarias gariepinus* (k = 0,16) était plus élevé que celui des femelles (k = 0,12). Cette différence de croissance a été confirmée par l'indicateur de performance de croissance, phi. Le même scénario a été observé chez *Oreochromis niloticus*. Cependant, le scénario inverse s'est produit à *Bagrus bajad* où le taux de croissance des femelles avait tendance à dépasser celui des mâles. *Clarias gariepinus* a montré deux modes de croissance saisonniers bien marqués avec des longueurs totales d'environ 40 cm de janvier à juillet et d'environ 30 cm de septembre à décembre chez les mâles. Mais chez les femelles les deux modes de croissance saisonniers sont de 43 cm de janvier à août et d'environ 40 cm de septembre à décembre. Pour les deux sexes d'*Oreochromis niloticus*, les deux modes de croissance saisonnière étaient bien marqués entre 20 et 30 cm d'août à décembre. *Bagrus bajad* n'a pas montré de modes de croissance saisonniers bien marqués. Cela pourrait être dû à un artefact lié aux faibles effectifs par classe de taille des individus mâles échantillonnés ou à des facteurs environnementaux. Ces résultats sont comparés à des données provenant d'ailleurs et apportent des données d'indicateurs biologiques utiles pour soutenir de nouvelles politiques de gestion rationnelle des ressources halieutiques d'eau douce en Mauritanie.

Mots-clés Pêcheries d'eau douce, *Clarias gariepinus*, *Oreochromis niloticus*, *Bagrus bajad*, reproduction, maturité sexuelle, Lac Foum-Gleita, Mauritanie

Introduction

Currently the commercial importance of inland fishing in the national economy of Mauritania is small compared to that of sea fishing. Nevertheless, inland freshwater bodies have significant fisheries potential. Over-exploitation of marine resources and increasing human population growth in Mauritania are exerting strong pressures on resources generally. One freshwater lake with an already notable freshwater fishery is Foum-Gleita Lake. Here a high number of boats operate at various locations in the lake and currently serve a high demand for fish in local markets.

A first step in meeting the chain of challenges confronting improvement of inland fisheries performance is, according to the Blue Growth Initiative (ABABOUCH & CAROLU, 2015), enhancement of natural fisheries potential by imposing rational exploitation regulations. Improving the national economy (increasing GDP growth) by providing food, nutritional security and creating new jobs in rural areas are all part of this initiative. These aims need to be achieved for inland Mauritanian freshwaters by managing fisheries better within a well-integrated inland fisheries policy. At the present time, however, the fishery resources potential of Mauritanian continental freshwaters remains poorly assessed due to the scarcity of appropriate biological, socio-economic, and environmental status data. Such data are essential if UN Sustainability Goals (e.g., SDG 15) are to be achieved enabling sustainable exploitation of fishery resources.

For sustainable fisheries management, data on the biology and ecology, abundance and biomass (stocks), and occurrence (diversity) of fish populations are needed. Knowledge of population parameters, in particular growth rates, allows estimation of the impact of fish catches on age classes. Data concerning the limitation of catch seasons and imposition of minimum catch sizes (EL ZARKA, 1970**,** PHILIPPART, 1977; CLAY, 1979; MOHR, 1994; MUKANKOMEJE *et al.,* 1994; LALÈYÈ, 1995; DUPONCHELLE & PANFILI 1998**;** CHIKOU *et al.,* 2007; MALAMI & MAGAWATA, 2010**;** EDEA *et al.,* 2019; NIHOREYE *et al.,* 2019) are also required as a minimum to inform fisheries management. This study is focused on the three main fish species commonly caught in Foum-Gleita Lake, namely *Clarias gariepinus* (Burchell, 1822), *Oreochromis niloticus* (Linnaeus, 1758) and *Bagrus bajad* (Fabricius, 1775). These species are highly appreciated by the local and sub-regional populations because of the quality of their flesh. The study aims are to determine:

1. the growth parameters of each species in the lake

2. the median maturity size
3. the reproductive seasons for each species.

The collected data will provide relevant biological information aimed at supporting a new policy for the rational management of freshwater resources in Foum-Gleita Lake.

This lake was created in the large Gleita depression by damming the Black Gorgol River in 1981; it was inaugurated on November 26, 1985. This dam now supports the largest water reservoir in the country. It is a permanent water body with an average capacity of 500 million m^3 and a catchment area of ~160 km^2 (OMVS, 2010; SADEGH, 2021, GANDEGA *et al.,* 2020). Mean annual rainfall recorded at Foum-Gleita (1995-2018) was 240 $mm.y^{-1}$, with 120 $mm.y^{-1}$ as the minimum and 500 $mm.y^{-1}$ as the maximum. The humid period is from June to October.

The lake water is sourced from rain, springs but mainly river water. Twelve fishing villages are located around the lake. About 200,000 people inhabit these villages and most are devoted to fishing, agriculture and livestock farming according to the season. There are three main points for landing fishery catches from the lake, located near M'Bout (see Figure1).

The lake supports a large ichthyological biodiversity with more than twenty species (GANDEGA *et al.,* 2020), (Table 1).

Bagrus bajad, *Clarias garipeinus* and *Oreochromis niloticus* are highly appreciated in Mauritania. Consequently, all are highly valued by the fishermen and catches easily exceed other species caught in the lake. Catches are intended for local-consumption of both fresh and salted-dried fish; the latter facilitates marketing and increases the product value. According to estimates by competent authorities, this lake has an annual potential of around 800 tonnes of fish per year (SADEGH, 2021). Fishing has been practiced since 1986 by traditional fishermen living around the lake and fishing activity is open throughout the whole lake and during the whole year. At the dam, just a few families from Guidimakha specialize in fishing this area.

Table 1. List of the fish species in Foum-Gleita Lake and their commercial interest.
Tableau 1*. Liste des espèces de poissons du lac Foum-Gleita et leur intérêt commercial.*

Scientific names	English names	French names	Local names	Commercial
Alestes baremoze (Joannis, 1835)	Silversides	Silverside	Giccal	Minor
Alestes dentex (Linnaeus, 1758)	Characin	Characin	Selinthe	Minor
Bagrus bajad (Fabricius, 1775)	Bayad	Bayad	Dibbabe	High
Bagrus docmak (Fabricius, 1775)	Sumutondu		Safdu baleeru	Mnor
Brachysynodontis batensoda Rüppell, 1832	Upsidedown catfish	Poisson-chat	Gangue-Kala	Minor
Brycinus nurse (Rüppell, 1832)	Nurse tetra, Characin	Nurse tetra	Debbere	Minor
Clarias gariepinus (Burchell, 1822)	North African catfish	Poisson-chat nord-africain	Sellour, Baleewu	High
Heterobranchus bidorsalis Geoffroy St-Hilaire, 1809	African catfish	Poisson-chat africain	Samak	Minor
Hyperopisus bebe (Lacepède, 1803)	Ngai	Ngai	Fulfulde, Sauya	Minor
Labeobarbus bynni (Fabricius, 1775)	Niger barb	Barbus du Niger	Bouri	Minor
Lates niloticus (Linnaeus, 1758)	Nile perch	Perche du Nil	Diène wekh	High
Marcusenius senegalensis (Steindachner, 1870)	Trunkfish	Poisson-coffre	Samak	Minor
Mormyrus rume Valenciennes, 1847	Mormyrids	Poisson électrique	Samak	Mnor
Oreochromis aureus (Steindachner, 1864)	Blue tilapia	Tilapia bleu	Bolti azraq	High
Oreochromis niloticus (Linnaeus, 1758)	Nile tilapia	Tilapie du Nil	Bolti annil	High
Sarotherodon galilaeus (Linnaeus, 1758)	Mango tilapia	Tilapia de mangue	Bolti almango	Minor
Schilbe intermedius Rüppell, 1832	Silver catfish	Poisson-chat argenté	Sellour fidhi	Minor
Schilbe mystus (Linnaeus, 1758)	African butter catfish	Poisson-chat	Sellour ifriqi	Mnor
Synodontis membranaceus (Geoffroy St-Hilaire, 1809)	Catfish	Poisson-chat	Galabaya	Minor
Synodontis schall (Bloch & Schneider, 1801)	Wahrindi	Wahrindi	Wahrindi	Minor
Tilapia zillii (Gervais, 1848)	Redbelly tilapia	Tilapia à ventre rouge	Bolti	High

Materials and methods

Foum-Gleita Lake reservoir is located 120 km east of Kaédi town in the Gorgol region of southern Mauritania. This agro-ral pastoral region is supported by the Black Gorgol River which, below the lake confluences with the White Gorgol River and the Senegal River (Figure 1).

The total lake canoe fleet consisted of 36 boats (in 2021) and fishing intensity varies according to the seasons. The most intense period of fishing activity occurs from November to April. Fishermen use boats varying from 6 to 12 m in length and from 0.8 m to 1.5 m in width. They use three types of fishing gear: shore seine, gill net (40 – 70 mm stretched mesh) and 200 m long-lines) Around a hundred fishermen in 2021 who did not have canoes practiced shore fishing.

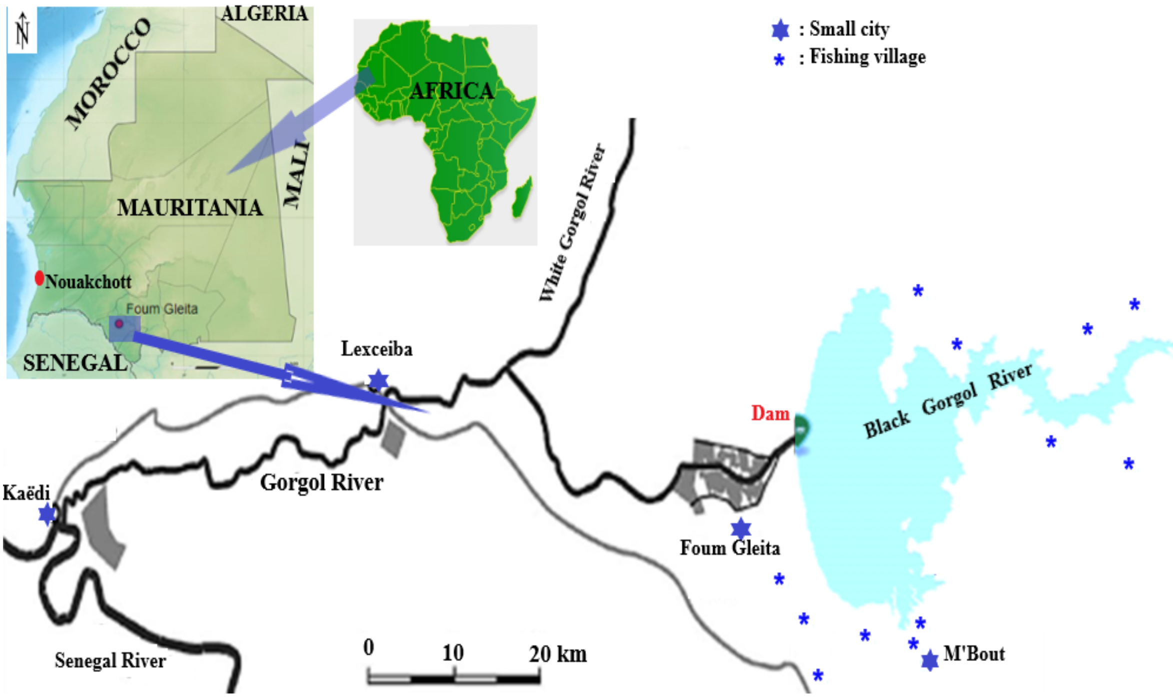


Figure 1. Foum-Gleita Lake is located in southern Mauritania and was formed after damming the Black Gorgol River inflow in 1981.

Figure 1. *Le lac Foum-Gleita est situé dans le sud de la Mauritanie et s'est formé après la construction d'un barrage sur l'affluent du fleuve Gorgol Noir en 1981.*

Preliminary lake water quality data were obtained on two occasions (January and June 2021) at two near-shore locations using standard techniques. Water samples were taken at 2 m depth using a depth sampling bottle (General Oceanics 02-13813 model). Water was conserved in 250 ml opaque glass bottles and stored in a cooler. Temperature, salinity, redox potential, and pH were measured in situ, using a field multi-parameter probe (PCE-PHD 1- HANNA model), calibrated before each site measurement. Water transparency was estimated using a Secchi disk (diameter 20 cm). Secchi disc depth is expressed in meters and corresponds to disappearance depth of the disk observation. Dissolved oxygen was determined by the chemical method (RODIER *et al.,* 1997).

The three species *Clarias gariepinus, Oreochromis niloticus* and *Bagrus bajad* were identified in catches made by artisanal fishermen using different fishing techniques and types of gear. Sample collection was carried out during January to December 2021. The most frequently used gear is the long-line. This is suspended above the lake bottom by buoys and weighted with stones used as sinkers at intervals of 50 to 60 cm and number 8 hooks are used. Most fishing operations take place at night. The gear is deployed at sunset, left submerged overnight and recovered at dawn. All fish caught are retained for sale and are transported directly to the fish market. Random sampling of fresh fish was carried out immediately upon return of fishermen and/or at the fish market.

A total of 2469 individuals of the three fish species were sampled, they are distributed as follows, 1106 individuals *Oreochromis niloticus*, 416 individuals *Clarias gariepinus* and 847 individuals *Bagrus bajad*.

Males were distinguished from females primarily by the possession of genital papillae just before the anal fin. Sex ratio was calculated as the number of females divided by the number of males (F/M); where: F= number of females and M = number of males. The chi-square test was used to determine whether the proportion of females differ from the proportion of males using the formula:

$$\chi^2 = \Sigma\,(O-E)/E$$, (OLOWO *et al.,* 2022).

Where:

χ^2 =Chi-square test; O = observed values, E = expected values.

The null hypothesis (HO) that there is no difference between the proportion of females and the proportion of males was tested at p (0.05).

For each individual fish the following data were collected:

The total length (TL) and the fork length (FL) were measured using an ichthyometer board and weighed (total weight TW) using a high precision electronic scale (0.01g), type (STB, 6202i).

All individuals were eviscerated to determine the state of sexual maturity, weight of the gonads and identify preys in stomach contents.

The maturity stage was determined by examining the gonads visually based on the maturity scale of LALÈYÈ (1995) (Table 2).

Table 2. Conventional scale for assessing the maturity stage (see LALÈYÈ, 1995).
Tableau 2. *Echelle conventionnelle d'évaluation du stade de maturité (voir LALÈYÈ, 1995).*

Stages	Females	Males
I	Undifferentiated ovaries with faint whitish filaments	Undifferentiated testes with barely visible transparent whitish filaments
II	Differentiated ovaries; very small but no free oocytes	Testes already developed but no sperm visible after incision
III	Differentiated ovaries; large and ± free oocytes but not yet expelled by manual pressure on the abdomen	Semen visible after incision of the testes but not expelled by manual pressure on the abdomen
IV	Eggs expelled by manual pressure	Semen visible after incision of the testes and expelled by manual pressure on the abdomen
V	Stage II Empty ovaries	Stage II Empty testes

Median size at sexual maturity (L50) was determined using R software according to the ''FSA'', ''FSAdata'' and ''CAR'' packages. This length L50 corresponds to the fork length at which 50% of individuals in the population are mature.
The sexual cycle of each species was monitored according to the gonado-somatic index (GSI) calculated using the formula: GSI = (Pg x 100)/Pe
where: Pg = Mass of gonad and Pe = Mass of gutted fish.
The development of the GSI over time allows the breeding period of each species to be identified.
Growth parameters (L_∞ and K) of two species were obtained by using size frequency data incorporated into R software (R CORE TEAM, 2021) and using the "TropFishR" package (MILDENBERGER *et al.,* 2017; TAYLOR & MILDENBERGER, 2017). This package follows the FISAT II technique, which uses the Electronic Length Frequency Analysis (ELEFAN) method (VAN WEERD, 1995; GAYANILO *et al.,* 1988; GAYANILO & PAULY, 1997; DUPONCHELLE & PANFILI, 1998); it is a system for stock assessment using Length Frequency (LFQ) data reconstructed from the LFQ data. This method is used to estimate the growth model parameters from the progression of LFQ modes over time according to the Von Bertalanffy growth function (VBGF) and is based on the use of the function available inELEFAN method (see above).

Results

Preliminary lake water quality (Table 3) shows some spatial variation but was broadly similar across the lake. Maximum temperature of the water surface near the dam was 30.7°C in June (summer) and minimum temperature was 21.0°C in January (winter) and this was only slightly higher at M'Bout. Water was circum-neutral in pH, and salinity/conductivity were relatively low. Water redox potential was also low indicating organic matter is relatively high. Dissolved oxygen (DO) varied between c. 13 and c. 5 $mg.L^{-1}$, with the higher value indicating good oxygenation and healthy conditions for aquatic life. However, the lower figure (summer value) is approaching stress conditions for many fish and is caused by high productivity and/or high organic loading, conditions that are exaggerated by warmer water and low light. Secchi disc depth was low notably in summer.

Table 3: Physicochemical parameters of the surface water of Foum-Gleita Lake as determined in January and June 2021 near the dam and near M'Bout area (see Figure 1).
Tableau 3 *: Paramètres physico-chimiques des eaux de surface du lac Foum-Gleita tels que déterminés en janvier et juin 2021 à proximité du barrage et à proximité de la zone M'Bout (voir Figure 1).*

Stations	Temperature (°C)	Secchi disc (m)	pH	Total Dissolved Solids ($mg.L^{-1}$)	Dissolved Oxygen ($mg.L^{-1}$)	Salinity (psu)	Redox Potential (mV)
Dam	21.0 - 30.7	0.16 - 0.49	7.2 - 7.7	222 – 250	5.10 - 14.4	0.21 - 0.48	132.8
M'Bout	21.1 - 32.8	0.21 - 0.46	6.98 -7.9	05 – 106	5.00 - 12.8	0.25 - 0.37	100.6

Sex ratio

In *Oreochromis niloticus*, the sample comprised 392 females, 709 males, and 5 individuals whose sex could not be determined macroscopically. The sex ratio shows a significant difference between the proportions of males compared to females which is 67.1% for males and 32.9% for females. The sex ratios are significantly different from the expected 1:1, where males significantly outnumbered females throughout the year. The sex ratios are low throughout the year, being between 0.4 and 0.7 (Table 4), with χ^2 = 1.22, less than the critical value 3.84.
In *Clarias gariepinus* the sample comprised 211 females, 196 males, and 9 individuals of undetermined sex. The

results give the proportions of 48.2% for males and 51.8% for females; the sex ratios are not significantly different, males and females occurred in almost equal proportions (Table 4). χ^2 = 0.14, less than the critical value 3.84.

In *Bagrus bajad,* the sample consists of 401 females, 437 males, and 9 individuals of undetermined sex. The proportions are 47.8% for females and 52.1% for males. Males outnumbered females and sex ratios between 0.8 and 1.2 were not significantly different at χ^2 = 0.14, less than the critical value 3.84.

Table 4. Sex ratio of the 3 studied species from Foum-Gleita Lake (January- December 2021).
Tableau 4. *Sex-ratio de 3 espèces étudiées dans le lac Foum-Gleita (janvier-décembre 2021)*

Month	No. of fish	No. of female	% of female	No. of male	Sex ratio	No. of fish	No. of female	% of female	No. of male	Sex ratio	No. of fish	No. of female	% of female	No. of male	Sex ratio
	Oreochromis niloticus					*Clarias gariepinus*					*Bagrus bajad*				
Jan	102	42	41.17	64	**0.6**	44	19	43.18	25	**0.8**	67	31	46.26	36	**0.9**
Feb	81	26	32.09	55	**0.5**	40	21	52.50	19	**0.9**	96	51	53.12	45	**1.1**
Mar	103	36	34.95	67	**0.5**	21	9	42.85	12	**0.7**	65	30	46.15	35	**0.8**
Apr	78	23	29.48	55	**0.4**	32	17	53.12	15	**1.1**	84	28	33.33	56	**0.5**
May	98	37	37.75	61	**0.6**	22	12	54.54	10	**1.2**	74	36	48.64	38	**0.9**
June	99	42	42.42	57	**0.7**	44	24	54.54	20	**1.2**	75	40	53.33	35	**1.1**
July	108	42	38.88	69	**0.6**	42	25	59.52	17	**1.5**	52	20	38.46	32	**0.6**
Aug	90	35	38.88	55	**0.6**	39	26	66.66	13	**2.0**	62	34	54.83	28	**1.2**
Sept	77	26	33.76	51	**0.5**	19	8	42.10	11	**0.7**	78	42	69.00	36	**1.2**
Oct	72	18	25.00	54	**0.3**	26	12	46.15	14	**0.8**	61	29	46.77	32	**0.9**
Nov	81	27	33.33	56	**0.5**	36	17	47.22	19	**0.9**	51	20	39.21	31	**0.6**
Dec	101	38	37.62	65	**0.6**	42	21	5.0.00	21	**1.0**	73	40	54.79	33	**1.2**
Year	1190	392	32.94	709	**0.5**	407	211	51.84	196	**1.1**	838	401	47.85	437	**0.9**

Sexual cycle

The sexual cycle of the 3 species is based on the observations data of the length classes of males and females (cf. Figures 4, 5, 6) and on data from GSI. Monthly GSI values for *C. gariepinus* shows that in males (Figure 2a) the pre-maturation period was from February to June. After maturation during in June, expulsion of sexual products was observed from July to September, followed by a sexual rest period from September to February. In females (Figure 2b), the pre-maturation period started from February to May, maturation extended from May to June and the spawning period lasted three months, June to August. Sexual rest was from September to February as for males.

Monthly GSI values for female *B. bajad* (Figure 2c) show that the pre-maturation period extended from February to April and maturation was from April to May. Spawning products took place from May to September and the sexual rest period extended from September to January. In males (Figure 2d), the pre-maturation period was from January to April and maturation extended from April to June. Expulsion of sexual products took place from June to October and the sexual rest period was from October to December. *B. bajad* GSI values showed a very extended spawning period which lasted for five months for both sexes with low precocity of females.

In *O. niloticus* GSI values for males (Figure 2e) shows that the pre-maturation period occurred from January to June, maturation from June to August, and release of sexual products took place from August to September. Sexual rest was from September to December. In females (Figure 2f) the pre-maturation period occurred from January to April and the maturation extended from April to July. The release of sexual products was observed from July to September with sexual rest from September to December.

Median sexual maturity size

Size at first maturity (L50) is the length at which 50% of the fish have reached maturity. In this study, the size at maturity in males and females was estimated during the maturation period. The large and whitish testes and yellowish orange ovaries were defined as matured (cf Figure 3).

Examination of *Clarias gariepinus* data shows that the size of the smallest mature male individual was 29 cm and 25 cm for the smallest female (Figure 3a). Median sexual maturity size is 27.7 cm in females and 35.9 cm in males (Figure 3b). In *Bagrus bajad*, results (Figure 3c) show median sexual maturity size was 38.7 cm (males) and 31.48 cm (females) (Figure 3d). The smallest individual females encountered measured 22 cm and 36 cm for males. The size of the smallest male individual of *Oreochromis niloticus* was 17 cm and 10 cm for the smallest female (Figure 3e). The calculated median sexual maturity size is 25.3 cm for males and 16.38 cm for females (Figure 3f).

Growth

The growth estimation parameters (K, L_∞, t_0 and φ) for *Clarias gariepinus*, *Bagrus bajad* and *Oreochromis niloticus* are shown in Table 5.

The analysis (Table 5) shows that male individuals of *Clarias gariepinus* (growth rate K = 0.16) tend to grow faster than females (K = 0.12). This growth difference was confirmed by growth performance (φ). The same scenario is observed in *Oreochromis niloticus*. However, the opposite scenario is seen for *Bagrus bajad* where females tend to grow better than males.

The analysis of restructured size frequencies (Figure 4.) made it possible to identify the phases for each distribution of monthly sizes.

For male C. *gariepinus*, the analysis shows the phases are well differentiated and size reached 40 cm in total length from January to July and reduced to around 30 cm from September to December. However, in females the modes occur at values greater than 40 cm (40 and 45 cm) from January to August and around 40 cm from September to December. Both sexes of *O. niloticus* show that the modes are well marked and occur at values between 20 and 30 cm (Figure 5). Analyses (Figure 6) make it possible to identify the modes for each distribution of monthly size data for *B. bajad*. This figure also shows that for females, the phases are well marked, at around 40 cm throughout the year. In the males the modes are not well marked throughout the year. This could be due to an artefact linked to the low numbers per size class of the male individuals sampled.

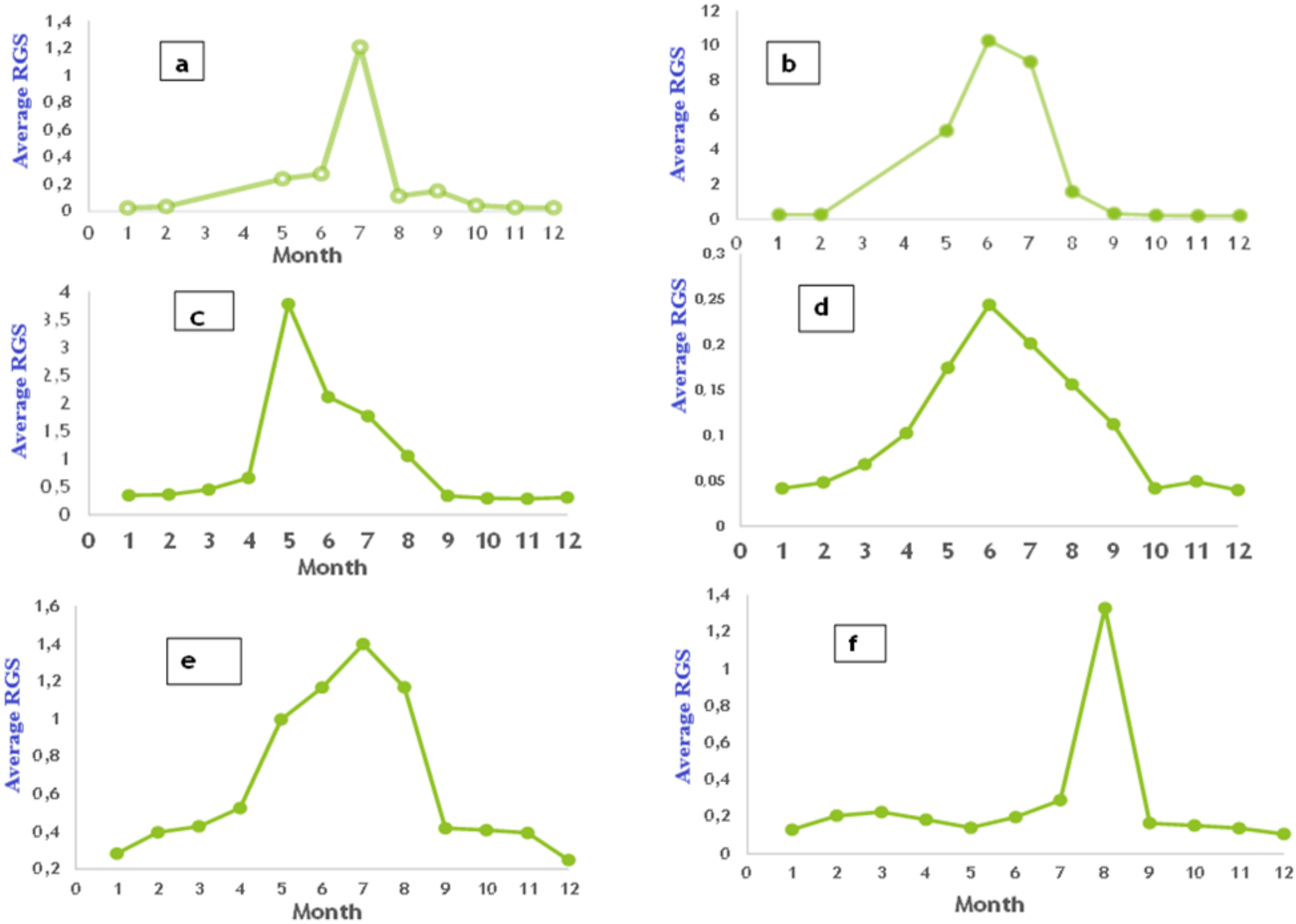


Figure 2. Monthly development of the gonado-somatic index (GSI) of *Clarias gariepinus* (a-b), *Bagrus bajad* (c-d) and *Oreochromis niloticus* (e-f), left column: female, right column: male in Foum-Gleita Lake.

Figure 2. *Développement mensuel rapport gonado-somatique (RGS) de* Clarias gariepinus *(a-b),* Bagrus bajad *(c-d) et* Oreochromis niloticus *(e-f) dans le lac Foum-Gleita, colonne gauche : femelle, colonne droite : male.*

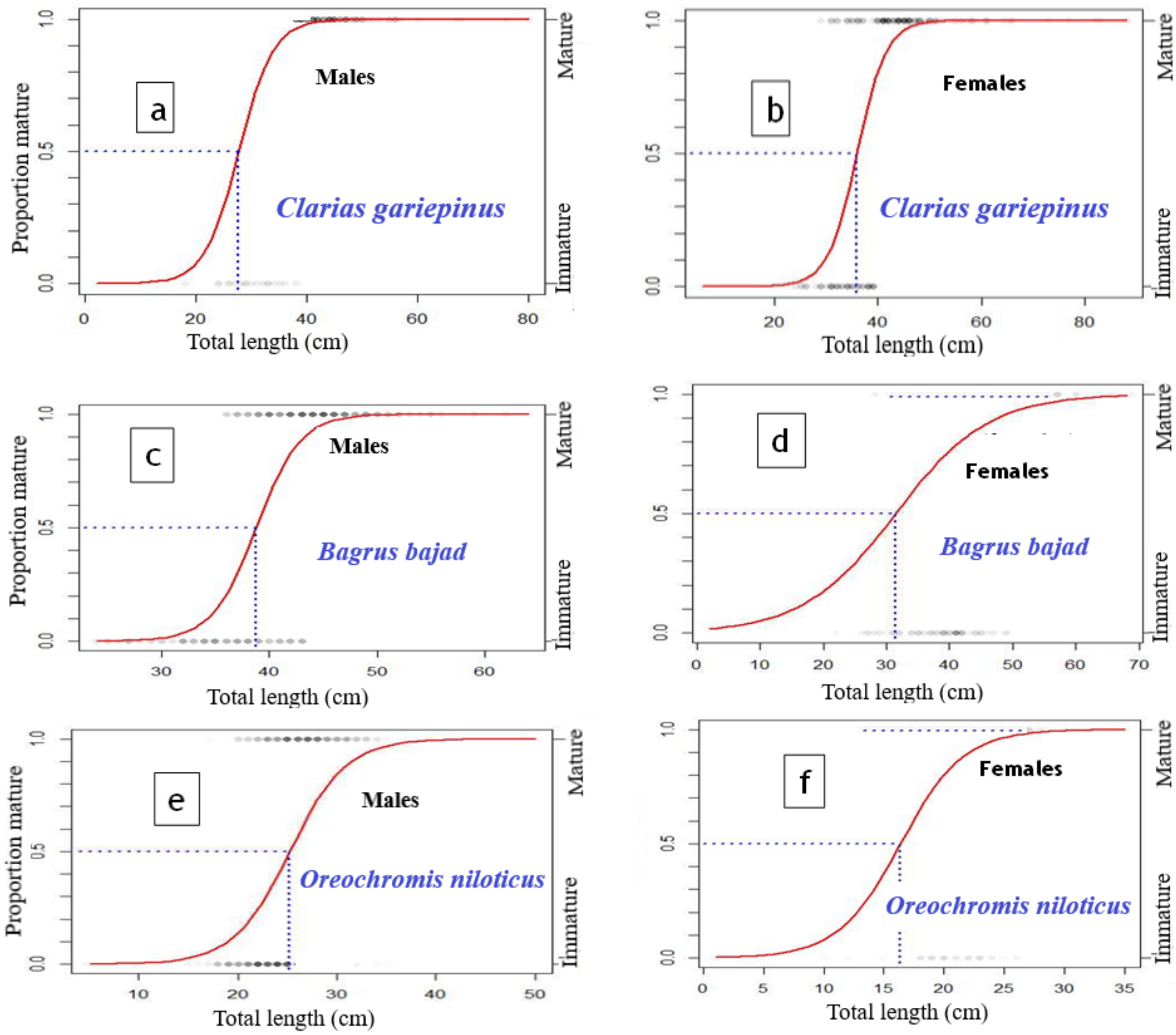
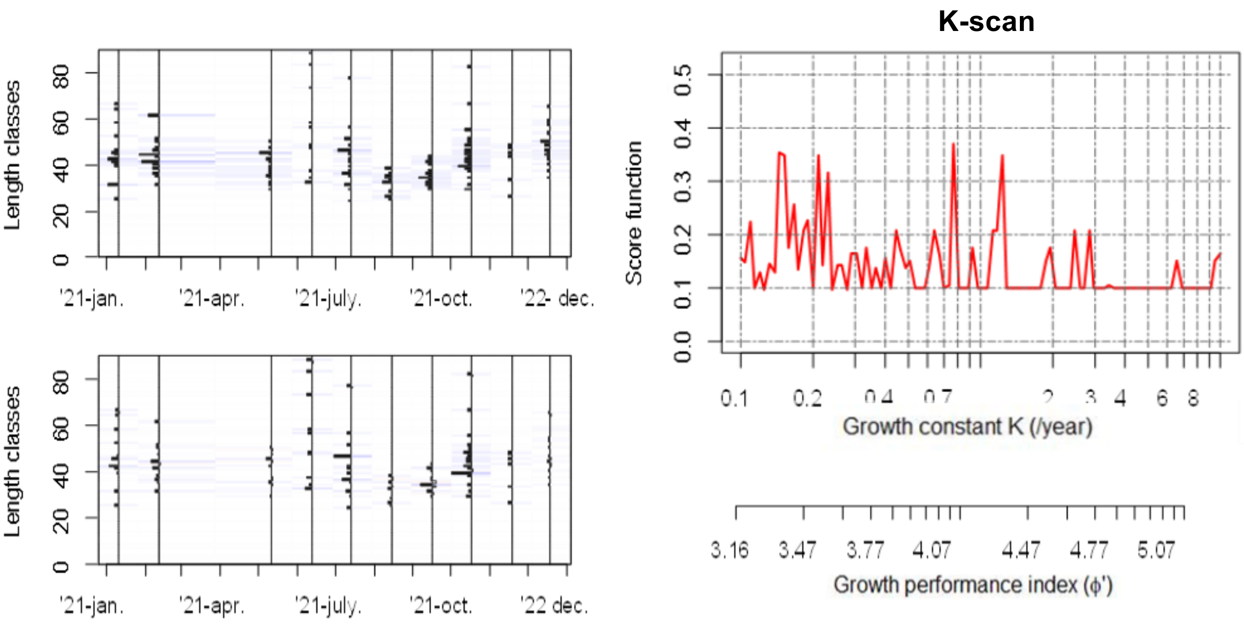


Figure 3. Size at first maturity of *Clarias gariepinus* (a-b), *Bagrus bajad* (c-d) and *Oreochromis niloticus* (e-f) in Foum-Gleita Lake.
Figure 3. *Taille à première maturité de* Clarias gariepinus *(a-b),* Bagrus bajad *(c-d) et* Oreochromis niloticus *(e-f) dans le lac Foum-Gleita.*

Table 5. Estimation of growth parameters (K, L∞, t0 and φ) of *Clarias gariepinus, Bagrus bajad* and *Oreochromis niloticus* in Foum-Gleita Lake.
Tableau 5. *Estimation des paramètres de croissance (K, L∞, t0 et ϕ) de* Clarias gariepinus, Bagrus bajad *et* Oreochromis niloticus *dans le lac Foum-Gleita.*

Species	Sex	L∞	K	t0	Phi (φ)
Clarias gariepinus	Males	134	0.16	0.70	3.45
	Females	101	0.12	0.24	3.08
Bagrus bajad	Males	73	0.47	0.32	3.39
	Females	71	0.90	0.80	3.65
Oreochromis niloticus	Males	44	3.76	0.11	3.86
	Females	41	5.10	0.48	3.90

Clarias gariepinus Males



Clarias gariepinus Females

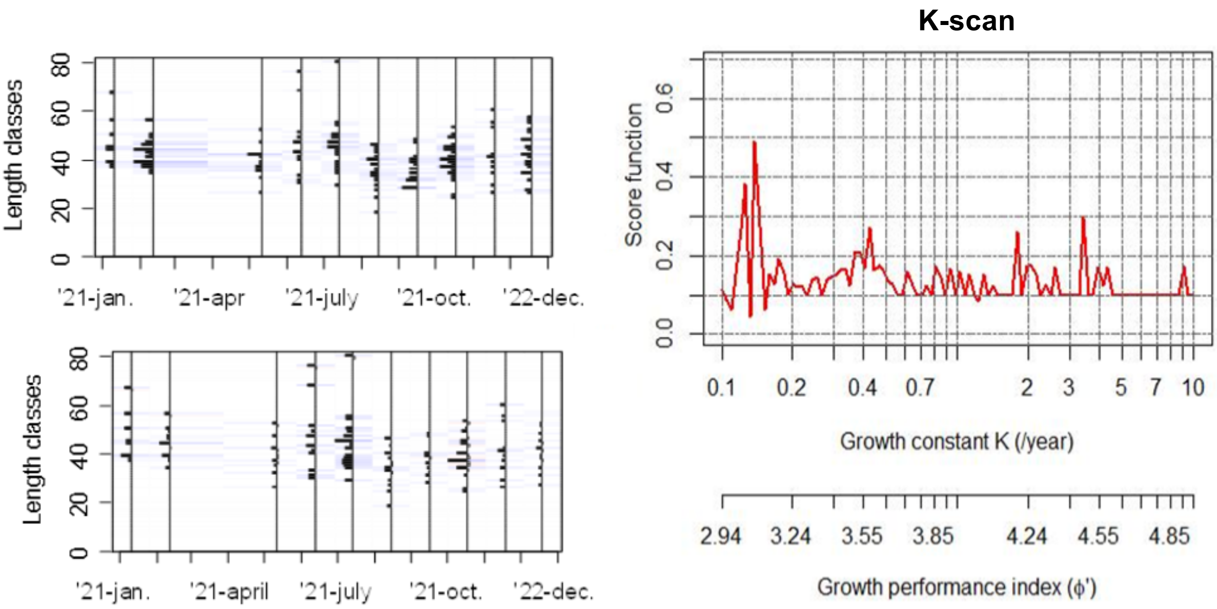
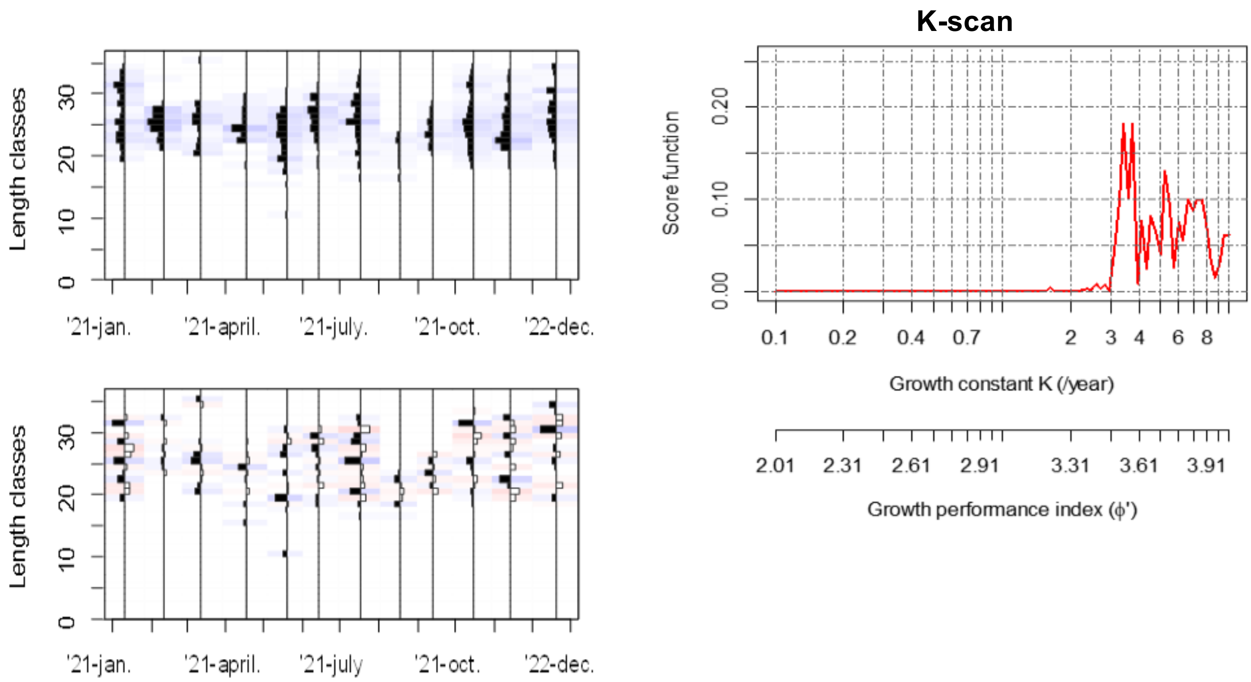


Figure 4. Monthly size frequency distribution and estimated K-Scan of *Clarias gariepinus.*
Figure 4. *Distribution mensuelle des fréquences de taille et K-Scan estimé de* Clarias gariepinus.

Oreochromis niloticus Males



Oreochromis niloticus Females

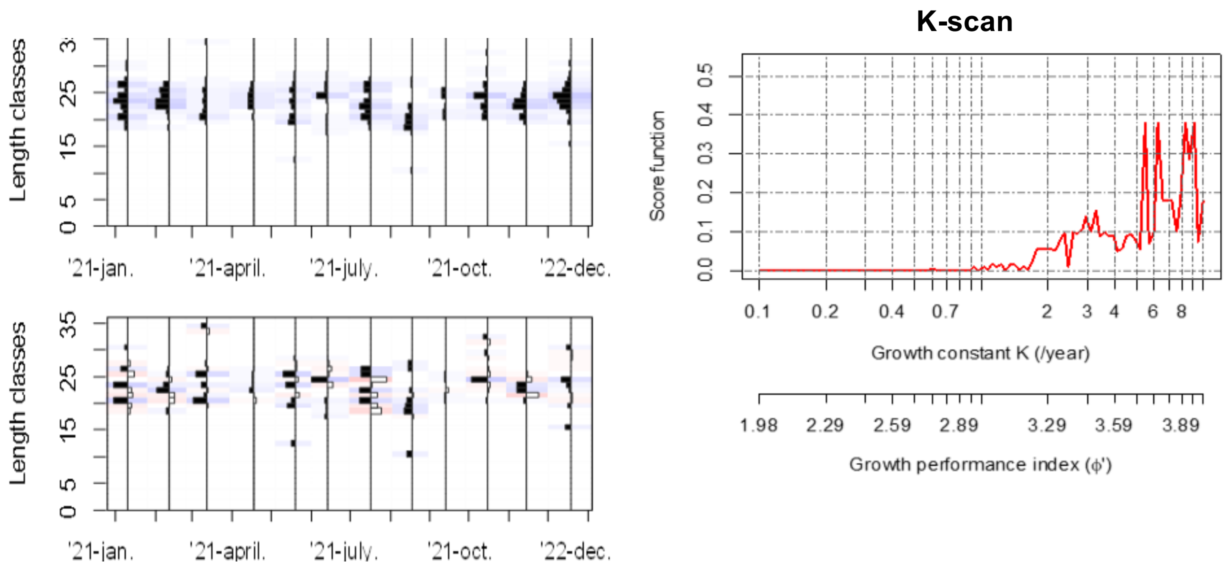


Figure 5. Monthly size frequency distribution and estimated K-Scan of *Oreochromis niloticus.*
Figure 5. *Distribution mensuelle des fréquences de taille et K-Scan estimé d'*Oreochromis niloticus.

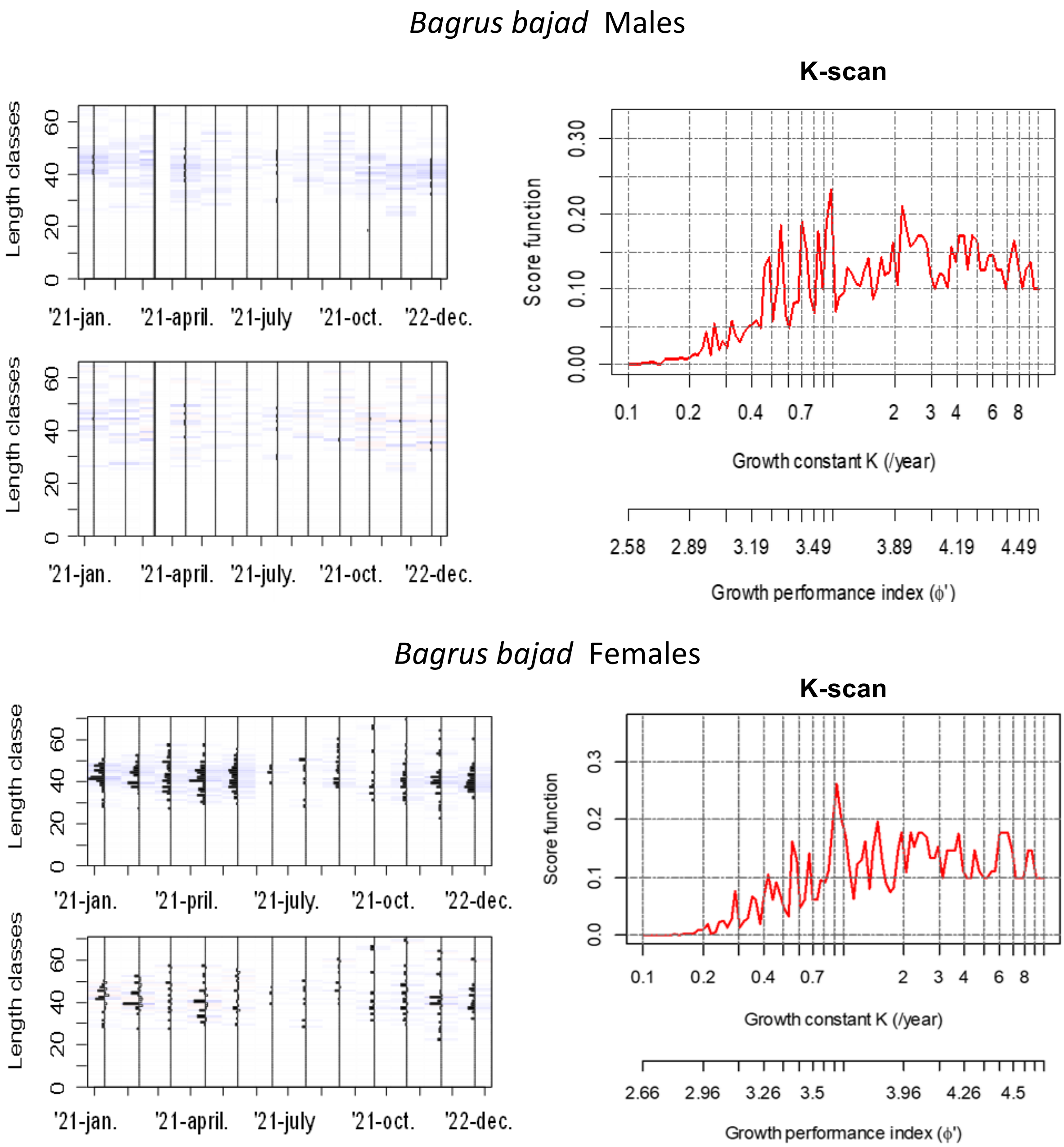


Figure 6. Monthly size frequency distribution and estimated K-Scan of *Bagrus bajad.*
Figure 6. *Distribution mensuelle des fréquences de taille et K-Scan estimé de* Bagrus bajad.

Discussion

Growth indice results for *Clarias gariepinus, Bagrus bajad* and *Oreochromis niloticus* (cf. Table 4) can be compared with those reported by other authors. Our analyses indicate individuals of *Clarias gariepinus* reach asymptotic sizes of 101 cm for females and 134 cm for males but are these contrary to the work of WILLOUGHBY & TWEDDLE (1978b) in Malawi. In the latter, females have a size FL∞ of 57.76 cm and the males have a size of 132 cm but the growth rate (K) value for females (0.31) is higher than that found in this study (0.12). Whereas our data indicate that *C. gariepinus* in Foum-Gleita Lake grow faster than the fish from Lake Malawi (WILLOUGHBY & TWEDDLE, 1978a,b).

According to studies by EL-DRAWANY & ELNAGAR (2015), *Bagrus bajad* from the Muess Canal, in Sharkia (Egypt), individuals of both sexes reach asymptotic sizes of 87 cm. However, our study shows that females reach 71 cm and males 73 cm. The growth rates K values are 0.90 for females and 0.47 for males in . These values for the Foum- Gleita Lake fish are higher than those recorded in Egypt (K = 0.16) for both and combined sexes.

The FL∞ size of *Oreochromis niloticus* male is 44 cm and 41 cm in females so males tend to grow slightly faster than females. Compared to results of KITIKLI (2010) in Togo, both sexes recorded lower mean lengths of 23.74 cm. The growth rate K (1.5) reported in Togo, is lower than that of females (K = 3.7) and males (K = 5.1) quoted in the present study, which suggests that this fish grows faster in Foum-Glieta than the Togo population.

Table 6. Summary of the growth parameters of *Clarias gariepinus*, *Bagrus bajad* and *Oreochromis niloticus* reported by different authors.
Tableau 6. *Résumé des paramètres de croissance de* Clarias gariepinus, Bagrus bajad *et* Oreochromis niloticus *rapportés par différents auteurs.*

Species	Authors	Areas	Methods	FL ∞ (cm)	K	t0
Clarias gariepinus	Present study	Foum-Gleita (Mauritanie)	Size frequency analysis with R	♀ = 101 ♂ = 134	0.12 0.16	0.24 0.70
	WILLOUGHBY & TWEDDLE (1978b)	Shire River Valley (Malawi)	Vertebrae	♀ = 57.76 ♂ = 132	0.31 0.09	- 0.38 - 0.73
Bagrus bajad	EL-DRAWANY & ELNAGAR (2015)	Muess Canal, Sharkia, (Egypt)	Vertebrae	♀+♂ = 87	0.159	-1.25
	Present study	Foum-Gleita (Mauritania)	Size frequency analysis with R	♀ = 71 ♂ = 73	0.9 0.47	0.8 0.32
Oreochromis niloticus	EL ZARKA *et al*. (1970)			♀+♂ = 42.59	0.46	0.541
	BLACHE (1964)	Lake of Tchad		♀+♂ = 45.17	0.31	0.1
	KITIKLI (2010)	Bagbé (South Togo)	Size frequency analysis with FiSAT and R	♀+♂=23.74	1.5	-0.11
	Present study (2021)	Foum-Gleita (Mauritania)	Size frequency analysis with R	♀= 41 ♂= 44	3.7 5.1	3.86 3.9

The determination of size at first sexual maturity of each species was carried out to aid control of the dynamics of populations by estimating developmental trends in the fishery stocks in Foum Gleita Lake. Our results are summarized and compared with those obtained by other authors reporting on the different water bodies (Table 7).

Table 7. Summary of the first sexual maturity in *Clarias gariepinus*, *Bagrus bajad* and *Oreochromis niloticus*, reported by different authors.
Tableau 7. *Résumé de la première maturité sexuelle chez* Clarias gariepinus, Bagrus bajad *et* Oreochromis niloticus, *rapportée par différents auteurs.*

Species	Authors	Area	L50
Clarias gariepinus	HOLL (1968)	Zimbabwe, (South Africa)	♀ = 38 cm ♂ = 38 cm
	BRUTON (1979)	Sibaya Lake (South Africa)	♀ = 35 cm ♂ = 35 cm
	Present study	Foum-Gleita (Mauritania)	♀ = 27.5 cm ♂ = 35.9 cm
Oreochromis niloticus	PEÑA-MENDOZA *et al.* (2005)	Emiliano Zapata Dam, Morelos, Mexico	♀ = 15.13 cm ♂ = 15.20 cm
	NIHOREYE *et al.* (2019)	Nyakabera (RD Congo)	♀ = 10.1cm ♂ = 13.5 cm
	SALIFOU (2000)	Comoé Lake (Burkina Faso)	♀ = 17.75 cm ♂ = 21.28 cm
	Present study	Foum-Gleita Lake (Mauritania)	♀ = 16.38 cm ♂ = 25.3 cm
Bagrus bajad	BENECH (1990)	Delta Central (Niger).	♀ = 33 cm ♂ = 25 cm
	Present study	Foum-Gleita Lake (Mauritania)	♀ = 31.48 cm ♂ = 38.7 cm

This comparison shows that the size (L50) of *Clarias gariepinus* is similar to that reported by BRUTON (1979) in Lake Sibaya in South Africa, but slightly lower than that reported by HOLL (1968) for Lake Rhodesia (Zimbabwe).
This is an indication of precocity of this fish in the Foum-Gleita Lake stock (where females are indicated to become sexually mature before males) in contrast to the Rhodesia Lake stock.
The size (L50) of *Oreochromis niloticus* is slightly greater than that mentioned in Lake Comoé in Burkina Faso (SALIFOU, 2000), and more so compared with the size reported in Lake Nyakabera (NIHOREYE *et al*. (2019). The precocity of females (L50 = 16.38 cm) compared to males

(L50 = 25.3 cm) was noted in the studied lake and this was also cited in Lake Comoé, Nyakabera and in Mexico (PEÑA-MENDOZA *et al.*, 2005).

Size (L50) of *Bagrus bajad* shows that the females are earlier than those from Niger (BENECH, 1990) in the Central Delta of Niger, but here males seem to be earlier than the males from Foum-Gleita Lake. Taken collectively, the growth and reproduction indices estimated for all the three fish species in Foum-Gleita Lake indicate that this fishery resource is currently relatively slightly/moderately underexploited by fishing activities.

In Foum- Gleita Lake differences in sex ratios amongst the studied species could be due to various factors: fishing gear selectivity during sampling, mortality and survival rate among species, migration of different sexes during feeding and spawning and age differences. Our results indicate that emission of male sexual products usually takes place in a shorter time and with approximately a one-month lag period compared to the spawning period of the females.

Conclusion

This study shows that the sex ratio is in favor of males for *Oreochromis niloticus* and *Bagrus bajad*, but of females for *Clarias gariepinus*. Analysis of the results of the sexual cycle shows that in *O. niloticus* the emission of male sexual products takes place quickly and with a lag of about one month compared to the egg-laying period of the females. In *C. gariepinus*, the spawning period lasts longer (three months) with early spawning by females as early as June. For *B. bajad* the spawning period is spread over five months for both sexes and with a low precocity of females. These sex cycle differences are thought be an adaption to reduce competition between the species for food resources.

Analysis of the data collected from all three fish species sampled in the lake show that the size of the smallest females is 10 cm for *O. niloticus* 25 cm for *C. gariepinus,* and 22 cm for *B. Bajard*. In *C. gariepinus* the males tend to grow faster than in the females and the same scenario is observed in the males of *O. niloticus*. These growth indicator differences could also be an adaption to reduce competition for food or to catch techniques.

Despite the initial results of this study indicating that the principal Foum-Gleita Lake fishery is rather under-exploited, the data refer to only one year and it is prudent to promote fishery stock sustainability by introducing regulations that allow larger males to be preferentially caught. Also, species catches should be regulated according to the information given concerning the growth and reproduction periods. Monitoring of annual total catch data and establishing year on year trends in fish size data is recommended to help refine maximum sustainable yield targets for the fishery.

Overall, based on current results on the reproduction of these three fish species, it is recommended that regulation of fishing in Foum- Gleita Lake is needed soon to help preserve biodiversity and enable rational and sustainable exploitation of the fishery resources.

References

ABABOUCH, L. & CAROLU, C. (2015).- Fisheries and Aquaculture in the Context of Blue Economy. United Nations Economic Commission for Africa. https://www.afdb.org.

BENECH, V. (1990).- *Contribution à la connaissance de la reproduction de quelques espèces d'intérêt halieutique dans le delta central du Niger.* Atelier ORSTOM "Etudes halieutiques dans le Delta Central du Niger", Bamako, novembre 1990, 17 p.

BLACHE, J. (1964).- *Les poissons du bassin du Tchad et du bassin adjacent du Mayo Kebbi : étude systématique et biologique.* ORSTOM Paris, 4, 483 p.

BRUTON, M.N. (1979).- The breeding biology and early development of *Clarias gariepinus* (Pisces: Clariidae) in lake Sibaya, South Africa, with a review of breeding in species of the subgenus *Clarias* (*Clarias*). *Transactions of the Zoological Society of London (UK)*, **5** (1), 1-45. https://doi.org /10.1111/j.1096-3642.1979.tb00056.x

CHIKOU, A., LALEYE, P., PHILIPPART, J.C. & VANDEWALLE, P. (2007).- Quelques aspects de la biologie de reproduction chez *Clarias ebriensis* Pellegrin (Siluriformes, Clariidae) dans le delta de l'Ouémé au Bénin (Afrique de l'Ouest). *Cybium*, **31**(2), 207-215. https://doi.org/10.260238/cybium/2007-312-015.

CLAY, D. (1979).- Sexual maturity and fecundity of the African catfish (*Clarias gariepinus*) with an observation on the spawning behaviour of the Nile catfish *(Clarias lazer*a). *Zoological Journal of the Linnean Society*, **65**, 351-365.

DUPONCHELLE, F. & PANFILI, P. (1998).- Variation in age and size at maturity of female Nile Tilapia (*Oreochromis niloticus*), populations from manmade lakes of Côte d'Ivoire. *Environmental Biology of Fishes*, **52**, 453-465.

EDEA, O.G., HINVI, L.C. & GBANGBOCHE, A.B. (2019).- Synthèse Bibliographique sur des Paramètres Biologiques et Zootechniques du Poisson-chat Africain *Clarias gariepinus* Burchell, 1822. *European Scientific Journal*, **15** (27), 54-88. https://doi.org/10.19044/esj.2019.v15n27p54.

EL-DRAWANY, M.A. & ELNAGAR, W.C. (2015).- Growth, Food and Feeding Habits of *Bagrus bayad* and *Bagrus docmac* Inhibiting Muess Channel, Sharkia Province, Egypt. *Journal Aquaculture Research and Development*, **6** (7), 1-8. DOI: 10.4172/2155-9546.1000348.

EL-ZARKA, S., SHAHEEN, A.H. & EL-ALEEM, A.A. (1970).- Tilapia fishery in Lake Mariut: age and growth of *Tilapia nilotica* L. in the lake. *Bulletin of the National Institute of Oceanography and Fisheries*, **1**, 149-182.

GANDEGA, C.Y., MAHFOUD, M., BAH, M. & BA, M.L. (2020).- *Rapport de synthèse sur le suivi des* *plans d'eau continentaux en Mauritanie*. INROP, 55 pp.

GAYANILO, F.C. & PAULY, D. (Eds.) (1997).- *FAO-ICLARM stock assessment tools: Reference manual*. Rome: Food and Agriculture Organization of the United Nations.

GAYANILO, F.C. JR, SORIANO, M. & PAULY, D. (1988).- *A draft guide to the complete ELEFAN*. Manila, Philippines: ICLARM.

HOLL, A.E. (1968). Notes of spawning behaviour of barbel *Clarias gariepinus* Burchell in Rhodesia. *Zoologica Africana*, **3** (2), 185-188.

KITIKLI, V. (2010).- *Étude de la croissance d'*Oreochromis niloticus *(Linné, 1758) en période d'inondation dans le village de Bagbé (Sud du Togo) à partir des données de longueur.* Diplôme de Master, Burkina Faso, 58 p.

LALÈYÈ, P.A. 1995. Écologie comparée de deux espèces de *Chrisichthys*, poissons siluriformes (Claroteidae) du complex lagunaire Lac Nokoué-lagune de Porto-Novo au Bénin. Tropicultura **13** (4), 153-154.

MALAMI, G.Z. & MAGAWATA, I. (2010).- Analysis of food and feeding habits of catfish (*Bagrus bajad*, *Macropterus* (Daget) in River Rima and Goronyo dam, in Sokoto State, Nigeria. *Nigerian Journal of Basic and Applied Science*, **18** (2), 277-284.

MILDENBERGER, T.K., TAYLOR, M.H. & WOLFF, M. (2017).- TropFishR: an R package for fisheries analysis with length-frequency data. *Methods in Ecology and Evolution*, **8** (11), 1520-1527. DOI: 10.1111/2041-210X.12791.

MOHR, E.W. (1994).- Age determination in tropical fish. *Naga*, **17** (2), 27-30.

MUKANKOMEJE, R., LAVIOLETTE, F. & DESCY, J.-P. (1994).- Régime alimentaire de Tilapia, *Oreochromis niloticus*, du Lac Muhazi (Rwanda). *Annals of Limnology*, **30** (4), 297-312.

NIHOREYE, F.J., NYONGOMBE, U.N., ALUNGA, L.G., AKONKWA, B.D., ISUMBISHO, M.P. & OKITAYELA, O.F. (2019).- Reproductive performance of female Nile Tilapia *Oreochromis niloticus* L. in South Kivu (DR Congo): Comparison of two strains differing in origin and history of domestication. *International Journal of Scientific Research and Management*, **7** (8),224-236. https://doi.org/10.18535/ijsrm/v7i8.mp02.

OLOWO, U.C., EGUN, N.K., EHIGIATOR, A.P., PRECIOUS, A. & OBOH, I.P. (2022).- Growth analysis and sex ratio of fish species from the Ovia River, Edo State, Nigeria. *Biologija*, **68** (2), 110-120.

OMVS (2010).- *Etude pour la caractérisation (état des lieux) de la pêche et de l'aquaculture continentales et élaboration d'un plan de développement pour les sites retenus dans les Wilayas de Gorgol et Trarza, République Islamique de Mauritanie*. Rapport définitif. Projet de gestion intégrée des ressources en eau et de développement des usages multiples dans le bassin du fleuve Sénégal. SONED-Afrique/SCET-Rim. 135 p.

PEÑA-MENDOZA, B., GOMEZ-MARQUEZ, J.L., SALGADO-UGARTE, I.H. & RAMIREZ-NOGUERA, D. (2005).- Reproductive biology of *Oreochromis niloticus* (Perciformes: Cichlidae) at Emiliano Zapata dam, Morelos, Mexico, *Revue de Biologie Tropicale*, **53** (3-4), 515-522. DOI: 10.15517/RBT.V53I3-4.14666.

PHILIPPART, J.C. (1977).- *Contribution à l'hydrologie de l'Ourthe. Dynamique et production des populations de quatre espèces de poissons Cyprinidae :* Barbus barbus *(L.),* Leuciscus cephalus *(L.),* Leuciscus leuciscus *(L.) et* Chondrostoma nasus *(L.).* Thèse de doctorat, Université de Liège, 225 p.

R CORE TEAM (2021).- *R: A language and environment for statistical computing.* R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

RODIER, J., BAZIN, C., BROUTIN, J.-P., CHAMBON, P., CHAMPSAUR, H. & RODI, L. (1997).- *L'analyse de l'eau: Eaux naturelles, eaux résiduaires, eau de mer* (8eme édition), Dunod. 1432 pages.

SADEGH, A.S. (2021).- *Étude de la biodiversité des cyanobactéries et leurs toxines dans le barrage de Foum-Gleita (Mauritanie).* Thèse Doctorat, Faculté des Sciences et Techniques, Nouakchott, 206p.

SALIFOU, O. (2000).- *Biologie de reproduction de Tilapia :* Oreochromis niloticus *du lac de barrage de la Comoé (Burkina Faso).* Mémoire d'Ingénieur du Développement Rural, Université Polytechnique de Bobo Dioulasso, p. 77.

TAYLOR, M.H. & MILDENBERGER, T.K. (2017).- Extending electronic length frequency analysis in R. *Fisheries Management and Ecology*, **24** (4), 330-338. https://doi.org/10.1111/fme.12232.aa.

VAN WEERD, J.H. (1995).- Nutrition and growth in *Clarias* species - a review. *Aquatic Living Resources*, **8**, 395-401.

WILLOUGHBY, N.G VAN WEERD VAN WEERD. & TWEDDLE, D. (1978a).- *The ecology of the commercially important species in the Shire Valley fishery, Southern Malawi*. In: Symposium on river and floodplain fishes in Africa, Bujumbura, Burundi, 21-23 November 1977. CIFA Tech. Pap. 5, p. 137-152.

WILLOUGHBY, N.G. & TWEDDLE, D. (1978b).- The ecology of the catfish, *Clarias gariepinus* and *Clarias ngamensis* in the Shire Valley, Malawi. *Journal of Zoology*, **186** (4), 507-534.