A Study of age, sex ratio, gonado-somatic index, fecundity, andbreeding season, of Nile tilapia (*Oreochromisniloticus* Linnaeus, 1758) from Khashm El-Girba reservoir and Atbara River, Eastern Sudan

Abstract

This study aims to investigate some reproductive aspects of Nile tilapia, *Oreochromis niloticus* in the Khashm El-Girba reservoir and Atbara River, eastern Sudan. The study was conducted during December 2015 to November 2016. Samples were collected bi-monthly basis from three localities, namely; Um Aswad (Atbara River), El-Remila, and El-Monaba (Khashm El-Girba reservoir), using beach seine nets of 1.2 cm 4.0 cm and 7.0 cm stretched mesh. A total of 1595 *O. niloticus* specimens were collected from all sampling sites.The age of *O. niloticus*was estimated using five anterior vertebrae of fish body; The results indicate that the age ranged between 0+ to 4+ years.Most of the collected fish specimens were of age 1+, withfemales most dominant at this age. Sex ratio was 1:1(M: F). Gonado-somatic index (GSI) of femalesof *O. niloticus* ranged between 1.965 – 2.620, and from 0.434 – 0.439 for males.Two periods of increase of GSI were observedreflecting two breeding seasons of this species. Used gravimetric method to estimate the average fecundity of *O. niloticus*ranged between 481 eggs in Um Aswad sampling site, and 638 in El-Remila site.The fecundity of *O. niloticus* has a high correlation with gonadal weight (r=0.82708) but a low correlation with standard length (r=0.47612) and total weight (r=0.50874).

The results of this investigation on *O. niloticus*indicate that the age of the fish ranged from 0+ to 4+ years, with a sex ratio of 1:1. The Gonado-somatic Index (GSI) indicated two spawning seasons, and fecundity was found to be strongly correlated with gonad weight, and moderately correlated with total length and standard length.This resultscan be used formulate management policies and procedures for protecting and conserving the fisheries resources and to regulate and improve the catches of the most important commercial fish species in that region.

Keywords

Age, Atbara River, Breeding season, Fecundity, Gonado-somatic index, Khashm El-Girba reservoir, Nile tilapia, Sex ratio.

Introduction

In the Republic of Sudan, the main freshwater capture fisheries are centered around the river Nile and its tributaries, man-made lakes anddamreservoirs, covering an estimated area of 3075 km²[1]. The Atbara River is the only northern tributary that joins the main Nile after the confluence of the Blue and White Nileat Khartoum. It represents one of the five sub-basins of the Nile system within Sudan [2]. Khashm El-Girba Dam is a gravity and embankment composite dam constructed on the Atbara River, about 4 km south of Khashm El Girba town in Eastern Sudan in 1964. Though the primary purpose of the dam is for irrigation purposes, yet, it supports seasonal artisanal fishery activities [2].

Fishes belonging to the family Cichlidae are represented by only three species in Sudan inland waters. These comprise Nile tilapia, *Oreochromis niloticus*(L. 1758);Galilaeus tilapia, *Sarotherodon galilaeus (*Artedi, 1758) and Redbelly tilapia, *T. zillii* (Gervais, 1848). *O.niloticus* comprises about 92% of the total "bulti" population found in the stretch of the White Nile [3]. Nile tilapia is the most popular fish species in Sudan and occupies a wide range of habitats, including rivers, man-made lakes, dam reservoirs, irrigation canals, haffirs (storage dams), rain pools, sewage canals and weed beds [4 and 5]. Moreover, Nile tilapia possess positive qualities that make it suitable for aquaculture; Tilapia can grow and reproduce in a wide range of environmental conditions and tolerate handling stress and lower management requirements; Tilapia has become a popular with increased global consumption[6].

Proper management and rational utilization of the fishery resource require knowledge of various aspects of fish biology. Hence, collection and assessment of basic biological data in the field, such as age, sex ratio, gonado-somatic index, fecundity, breeding season, recruitment,and mortality rate, etc. of fishes are important tools for sound management and exploitation of the fish stock [7]. Determination of age of a fish species is vital fordeterminingage at sexual maturity, growth, reproduction, and change in fish population due to fishing rate [8]. Age is usually determined by counting the number of annual rings present on the hard parts of the fish body, such as scales, otolith,opercular bone, vertebrae, fin rays etc.,[8 and 9];Tropical fish species seldom show clear annual rings in their otolith or scales, because of the lack of the strong seasonality which characterizes temperate zones, where age can be easily determined by counting the number of annual rings on the scales and otolith of fish [10].

Sex ratio of a fish species typically expresses the number of males compared to the number of females. (i.e. ratio of males to females), and provide information not onlyabout how many males and females are present in a population but also shows the breedingpotential and growth of the fish in the population. The gonado-somatic index (GSI), on the other hand, is used to follow and identify the seasonal development of gonads and spawning season, as the ovaries of gravid females steadily increase in size just prior to spawning in both sexes. However, the number of eggs produced by a female fish differs in different species and depends on the size and age of the fish. Knowledge of the fecundity and breeding habits of a fish helps in determining the reproductive potential of the individual fish species, its spawning seasons, breeding habits, life history, exploitation rate, and management of the fish stock [11-12, 38-39]. The fecundity of a fish species can be expressed as absolute fecundity or relative fecundity.

Fewstudies were carried out on the biology of*Oreochromis niloticus*from Atbara River and Khashm El-Girba reservoir, despite the high socio-economic importance and nutritious value of this species. Previous investigations included somebiological aspects of *Oreochromis niloticus*and *Labeo niloticus* from Khashm El-Girba reservoir and Atbara River, study ofLength-weight relationship, condition factor, sex ratio, and reproductive aspects of Nile tilapia [13 and 14]. On the other hand,while[15] investigated theimpactof the flushing of Khashm El-Girba reservoir on fisheries resources.[16] studied the fishing, flushing, and fish behavior from the seasonal Khashm El Girba reservoir. [17] reported on theproductivity and the fisheries of Khashm El-Girba reservoir, and [6] she studiedsome aspects of Khashm El-Girba reservoir fisheries.

The present investigationwas undertaken to study age, sex ratio, gonado-somatic index, fecundity, and breeding of Nile tilapia **(***Oreochromisniloticus*)from Khashm El-Girba reservoir and Atbara River, with the aim to establish base-line data to be used for the protection and conservation of this popular fish species and to establish soundmanagement measures which may lead toimproving the production of popular food fish species in the two freshwater resources in the eastern region of Sudan.

Materials and methods

Study Area

Three fishing sites were selectedfor collection of fish samples fromAtbara River (Um Aswad) and Khashm El-Girba reservoir (El-Remila and Al-Monaba).The coordinatesof these sites were determined using GPS (Garmin 62sc) as shown in Table 1 and Fig.1.

Table 1:Coordinates of sampling sites and estimated distance from Khashm El-Girba Fisheries Research Station.

Site	location	Distance	Coordinate (GPS)	Elevation
Um Aswad	Downstream	2.77 km	14°85´23.03´´ N - 35°45´48.86´´ E	1440 ft.
El-Remila	Upstream	6.57 km	14°45´3.89´´ N - 35°52´42.69´´ E	1549 ft.
Al-Monaba	Upstream	10.10 km	14°51´85.17´´ N - 35°52´37.27´´ E	1550 ft.

Fig. 1: Map of Khashm El-Girba reservoir (Atbara River, Sudan) and the sampling sites (source Google earth programmers, 2016).

Table 2: shows the abbreviations and their meanings.

Abbreviations	Meaning
M:F	Sex ratio Male to Female
GSI	Gonado-somatic index
TL	Total length
SL	Standard length
TW	Total body weight
GW	gonad weight

GW	Total weight of the gonads
TW	Total weight of fish
Av., fecd.	Average of fecundity
a	Intercept in length-weight relationship equation
b	Slope of liner length-weight relationship equation

Collection of fish samples

A total number of 1595 samples of fish were collected during the period of investigation. Samples of fish (*Oreochromis niloticus*) were collected bi-monthly basis fromDecember 2015 to November 2016, from three sampling stations, using beach seine nets of 1.2, 4.0 and 7.0 cm stretched mesh, and of length 32.0 m; 78.0 m and 88.0 m, and depth of 1.7 m; 2.20 m and 4.7 m. respectively.Collection of fish was made possible with the assistance of the staff of the Fisheries and Aquatic Life Research Station in Khashm El-Girba. Identification of the collected samples of fish was made to the species level according to [18 and 4].

Morphometric and measurement

All measurements of fish samples were taken at the sampling sites. Total length (TL)was measured to the nearest 0.1 cm, from the tip of the snout to the tip of the upper lobe of the caudal fin, and standard length (SL) from the tip of the snout to the flexure between the caudal peduncle and base of the caudal fin, using an ordinary measuring board. Total body weight (TW) and gonad weight (GW) were recorded to the nearest 0.1g, using a digital balance (SF-400A).

Age determination

In the present study, the anterior-most five vertebrae of fish body were used to determine age,as they were found to be well developed, and most suitable for age determination,compared to other methods, such as otolith, opercular bone, and fin ray [19]. Annual ringson the vertebrae can be easily read under the microscope and /orunder hand lens.The vertebrae were dissected,removed, boiled in tap water, cleaned using a plastic brush, dried for 3 days, and then kept in paper envelopes with relevant data (e.g. date and area of capture of fish specimens, total and standard length and total weight), for later reading of the annuli.

Determination of Sex and maturity stage

Large-size specimens of the collected samples of *O. niloticus* were sexually differentiated by examining the shape and structure of the genital papillae, while the gonads of small-size fish samples were identified through macroscopic examination of the gonads. The maturity stage of each fish was determined following the classification of maturity stages described by [20, 21 and 22].Samples of ripe ovaries of stage IV (ovary yellow color, with distinct large oval, about ⅓ of the visceral cavity; while testes creamy colored, thickened, enlarged and distended and extended full length of visceral cavity) and spawningstage V (ovary dull yellow, flaccid, with numerous large yellow oocytes; while testes creamy colored, extended full length of visceral cavity) were preserved in 5% formalin solution for fecundity estimation.

Sex ratio, on the other hand, was determined according to the following:

Sex ratio= number of males/number of females present in the collected samples.

Gonado-somatic Index (GSI)

The gonado-somatic index (GSI) is the ratio of fish gonad weight to body weight.It is used as an indicator parameter for reproduction. The GSI of *O. niloticus*was calculated for each specimen as the percentage of gonad weight of the fish against its total weight [23] using the following equation:

GSI = GW/ TW of fish, or

GSI (%) = Gonad weight (g)/Body weight (g) ×100 [24].

Where,

GW is the total weight of the gonads (ovary or testes) in gram, and TW is the total weight of fish in gram.

Breeding season

The breeding season of the fishwasassessed monthlyfrom the percentage of ripe females to the total number ofexamined females offish,following the gravimetric method [25]. The breeding season wasalso determined by an association of the GSI and the frequency distribution of the maturity stages of the gonads.

Estimation of fecundity

Fecundity was estimated using the gravimetric method. The ovaries were removed from ripe females, weighed to nearest 0.1 g using digital balance (SF-400A), and preserved in 5% formalin solution. Fecundity was estimated in the laboratory by taking sub-samples (one gram each) from the anterior and posterior right and left parts of the ovaries, and fecundity was calculated according to the following equation [25].

Fecundity = ½ (N1/ W1+ N2/ W2) /W

W1and W2= weight of two sub-samples.

N1= number of eggs in W1.

N2= number of eggs in W2.

W = total weight of ovaries from which sub-samples were taken.

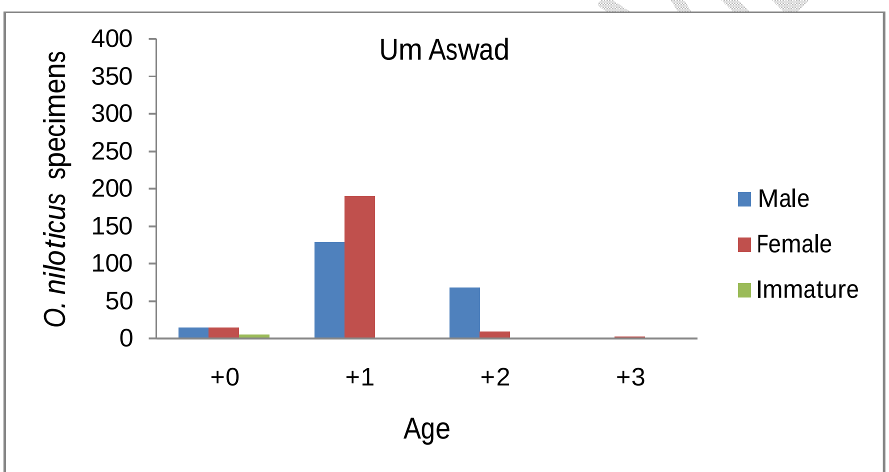
Data analysis

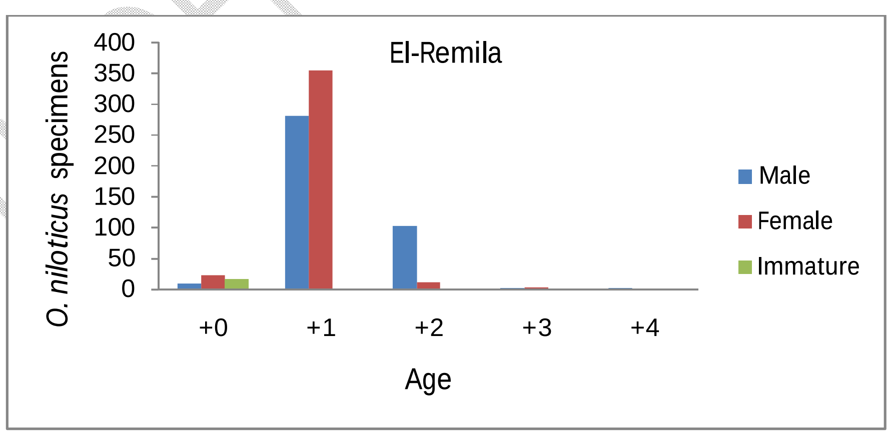
Data was analyzed using statistical package: Past statistical package version 3.14 and Microsoft Office Excel 2007, [13 and 14].

Results:

Age:

A total number of 240 specimens of *O. niloticus* were used to determine age. Although females of age 1+ yearwere more dominant in the examined samples, yet, malesof age 2+ were more abundant thanfemales in the three sampling sites. Immature stages of age 0+ year and age 3+ years formed only a small proportion of the examined specimens inUm Aswad andEl Monaba sampling sites, and were virtually absent from El- Remila site (Fig.2).





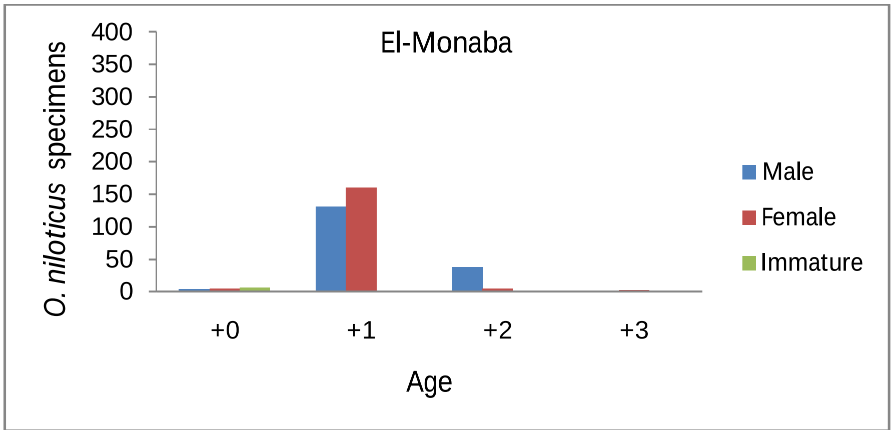


Fig.(2): Age distribution of *O. niloticus* during the study period (Dec. 2015 – Nov.2016).

Sex ratio:

Males and females of *O. niloticus*were present in nearly equal numbersin the study area,with sex ratio of 1:1 (M: F), except in El-Remila sampling site where high sex ratios of 1: 3 and 1: 2 (M: F) were recorded in September and October respectively. Table3.

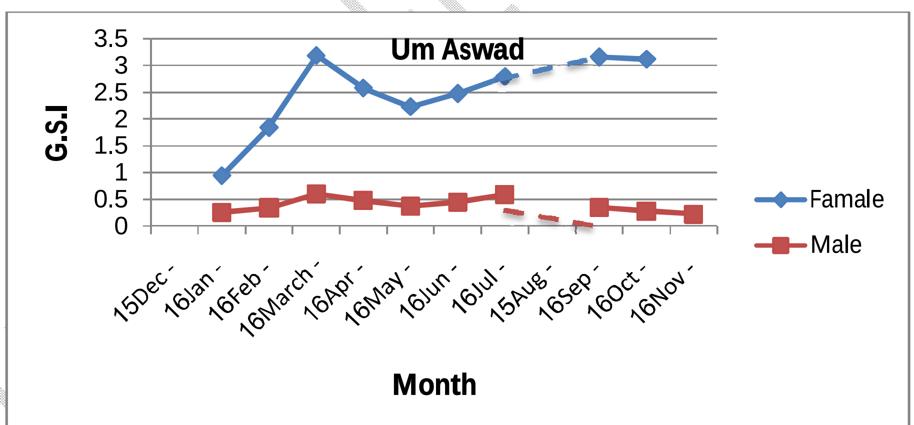
Table 3: Sex ratio of *O. niloticus* in Khashm El-Girba reservoir and Atbara River during the study period (Dec.2015 –Nov.2016).

months	Um Aswad	No. of Samples	El-Remila	No. of Samples	El-Monaba	No. ofSamples
Dec-15	-	0	1.0:1.0	28	1.0 :1.0	4
Jan-16	1.0:1.0	24	1.0:0.5	59	1.0 : 1.0	23
Feb-16	1.0 :1.0	34	1.0:1.0	70	1.0 : 1.0	12
Mar-16	1.0 :1.5	47	1.0:1.0	95	1.0 : 1.0	50
Apr-16	1.0 :1.0	84	1.0:1.0	125	1.0 :1.0	51
May-16	1.0 :1.0	98	1.0: 1.0	126	1.0 :1.0	53
Jun-16	1.0 : 1.0	68	1.0 : 1.0	122	1.0 : 1.0	62
Jul-16	1.0:1.0	45	1.0 : 1.0	92	1.0 : 1.0	53

Aug-16	-	0	-	0	-	0
Sep-16	1.0 :0.5	6	1.0 :3.0	26	1.0 :0.5	13
Oct-16	1.0 : 1.0	14	1.0 :2.0	36	1.0 : 1.0	21
Nov-16	1.0 : 1.0	15	1.0 :1.0	26	1.0 : 1.0	13
Mean sex ratio	1.0 : 1.0	435	1.0 : 1.0	805	1.0 :1.0	355

Gonado-somatic index:

In the present study,thegonado-somatic index ranged between 1.965 – 2.620 for females and 0.434 – 0.439 for males.Two peaks of gonado-somatic index were observedfor *O. niloticus*during the study period. The GSI started to increase during February and reached ahigh value in March- April. This is followed by a marked decrease in May. The GSI then showed a gradual increase in June, followed by a rapid rise at the beginning of July, and reachedahighpeakby the end of July and continued until the end of Octoberin bothsexes(Table 4 and Fig. 3).



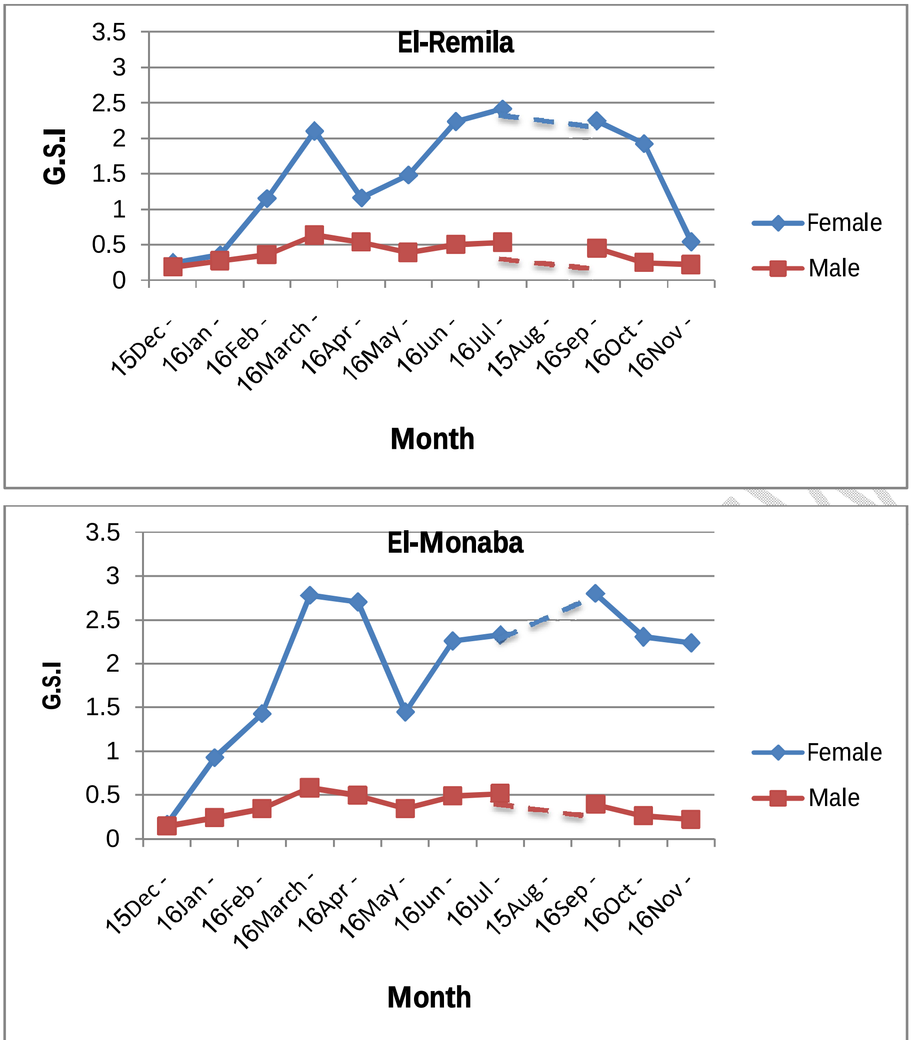


Fig.(3).Average monthly GSI of male and female *O. niloticus* during the study period (Dec.2015 – Nov.2016).

Table 4: Average monthly GSI of *O. niloticus*at Khashm El-Girba reservoir and Atbara River during the period of investigation (Dec, 2015 –Nov. 2016).

Months	Um Aswad		El-Remila		El-Monaba	
	female	male	female	male	female	male
Dec-15	-	-	0.243±0.076	0.187±0.073	0.165	0.142±0.028
Jan-16	0.947	0.259±0.307	0.357±0.102	0.271±0.100	0.171	0.238±0.195
Feb-16	1.851	0.342±0.245	1.151±0.498	0.354±0.233	1.428	0.339±0.095
Mar-16	3.194±0.847	0.604±0.186	2.100±0.525	0.632±0.231	2.278±0.569	0.578±0.285
Apr-16	2.587±0.55	0.480±0.166	1.162±0.474	0.536±0.231	2.704±0.492	0.493±0.198

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May-16	2.237±0.333	0.372±0.227	1.483±0.985	0.387±0.229	1.446±0.493	0.341±0.159
Jun-16	2.481±0.670	0.450±0.146	2.239±0.462	0.498±0.161	2.261±0.657	0.487±0.148
Jul-16	2.802±0.782	0.595±0.222	2.417±0.629	0.531±0.256	2.324±0.695	0.511±0.140
Aug-16	-	-	-	-	-	-
Sep-16	3.167	0.347±0.167	2.247±0.587	0.448±0.111	2.804±1.767	0.387±0.306
Oct-16	3.123	0.279±0.098	1.929±0.509	0.247±0.184	2.304±0.301	0.261±0.128
Nov-16		0.225±0.069	0.546±0.193	0.218±0.187	2.239	0.217±0.023
General	2.680±0.540	0.434±0.243	1.965±0.433	0.439±0.246	2.199±0.477	0.438±0.223

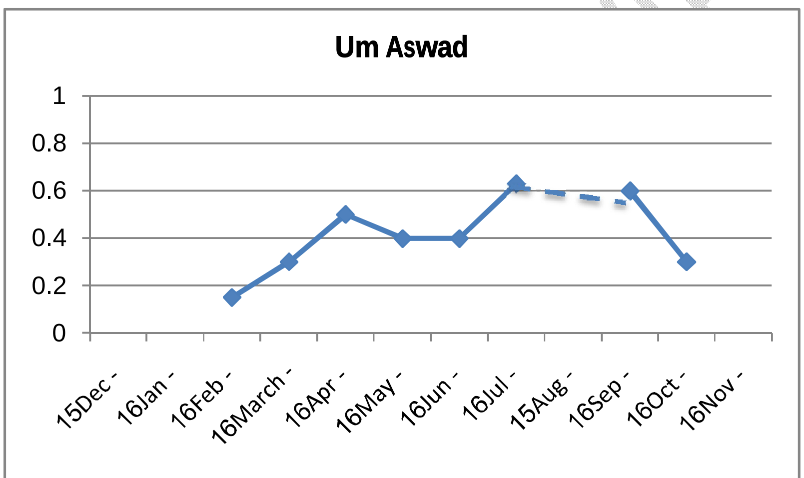
Breeding season:

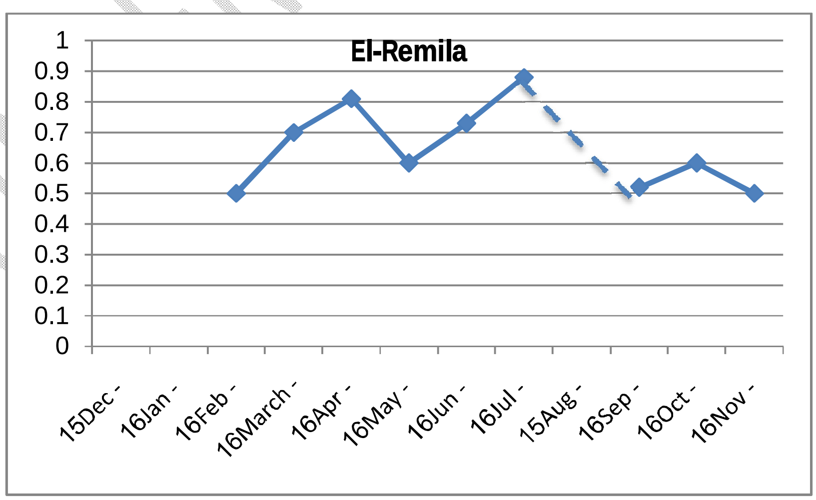
The breeding season of *O. niloticus* was determined from the frequency of ripe gonads of fish. In the present investigation, two breeding seasons were observed to occurat two different times of the year. At El Remila and El Monaba sites (Khashm El-Girba reservoir), the number of ripe females started to increase during February-March and reached a peak in April, followed by a slight decrease in May, then a sudden increase in June, then reaching a peak in July until October. However, at Um Aswad sampling site (River Atbara), the number of ripe ovaries reached relatively high levels in April, followed by a marked decrease in May - June, and reached a high-levelduring July- September.It is observed that *O. niloticus* breeds most of the year, except in December and January**,** and that mostripe females were of age1+ year (Fig 4&5, Table 5).

Table 5: Percentage of ripe females of *O. niloticus* atKhashm El-Girba reservoir and Atbara River during the study period (Dec. 2015 – Nov.2016).

month	Um Aswad	El-Remila	El-Monaba
Dec-15	0.00%	0.00%	0.00%
Jan-16	0.00%	0.00%	0.00%
Feb-16	6.25%	20.59%	14.29%

Mar-16	20.69%	44.23%	34.62%
Apr-16	40.91%	62.75%	65.38%
May-16	30.00%	28.57%	25.93%
Jun-16	30.43%	54.39%	52.94%
Jul-16	55.00%	76.47%	76.92%
Aug-16	- %	- %	- %
Sep-16	50.00%	15.79%	0.00%
Oct-16	20.00%	30.00%	44.44%
Nov-16	0.00%	22.22%	14.29%





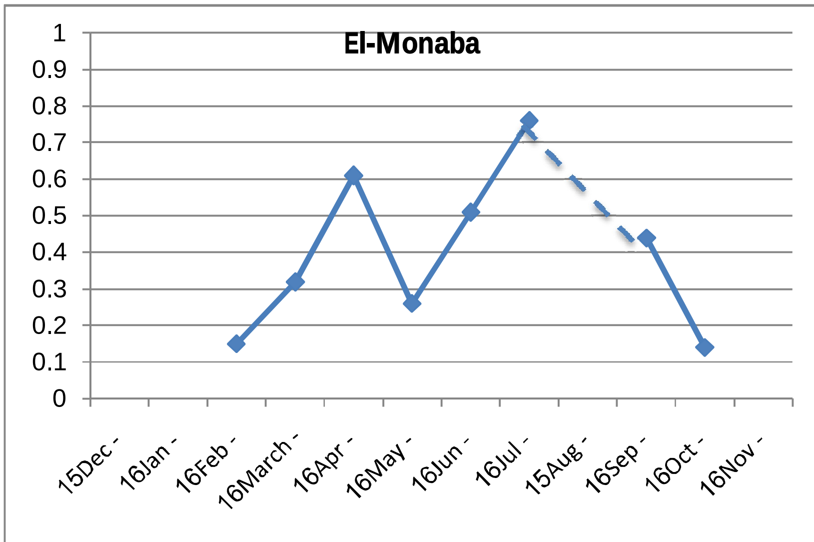


Fig.(4). Percentage of ripe females of *O. niloticus*during the study period (Dec. 2015 – Nov. 2016).

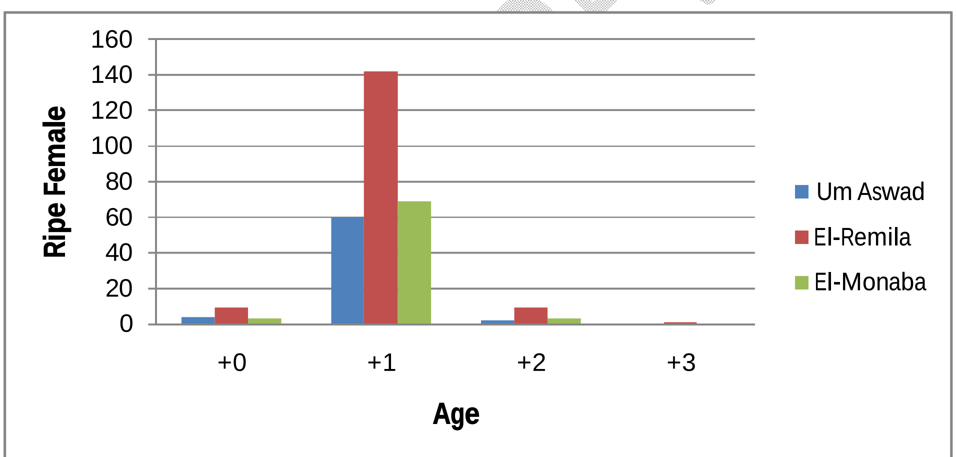


Fig.(5): Number of ripe females of *O. niloticus*according to age groups in the three sampling sites during theperiod (Dec. 2015- Nov. 016).

Fecundity:

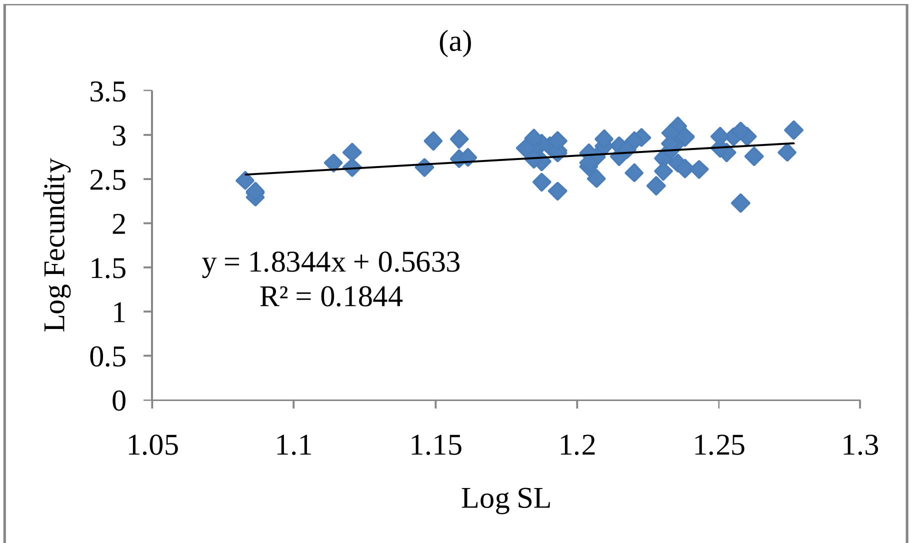
In the present study, total fecundity of *O. niloticus* varied with the breeding time and sampling locality. It rangedfrom 432±0 -812.454 (average of 481.715) eggs;to272.8-725.138 (average of 638.712 eggs), and 227±0 -729.23 (average of 633.724 eggs) in Um Aswad, in El-Remila and El- Monaba sampling sites respectively (Table 6). The estimated mean fecundity of the smallest ripe female*O. niloticus* (10.1 SL and 50.0 g TW) was253 eggs at El-Remila site, and301 and 227 eggs per ripe female (12.1 SL and 70– 76 g TW)atEl- Monaba and Um Aswad sites respectively, revealing that *O. niloticus* reached sexual maturity in the first year of life.

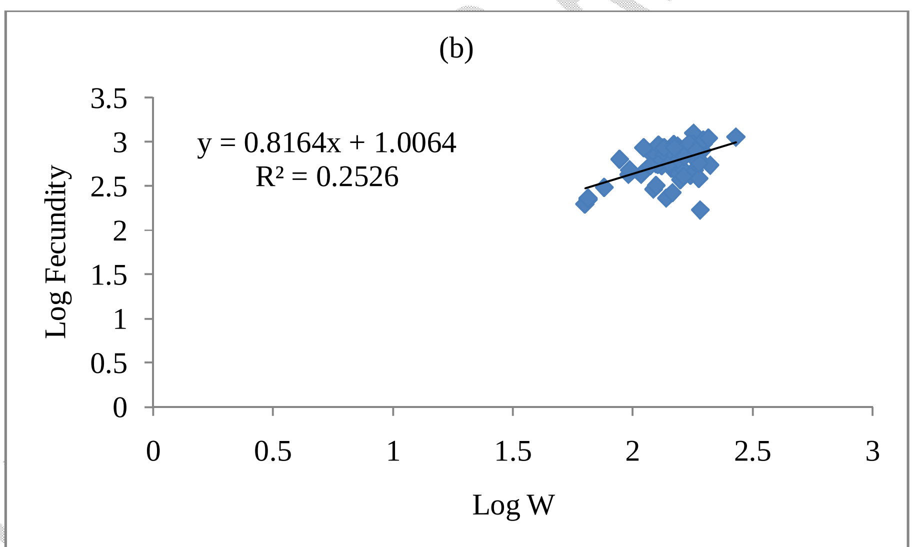
Fecundity of *O. niloticus*showed strong correlation with gonad weight, and weak correlation with standard length and total weight of the fish, with values ranging from (r =0.78288); to (r =0.77153) and (r=0.82707) in Um Aswad, El-Remila and El-Monaba sites respectively. Table (7); and Figs. 6(a, b and c); 7 (a, b and c) and 8 (a, b and c).

Table (6): Average monthly fecundity of *O. niloticus* in Khashm El-Girba reservoir and Atbara River during the study period (Dec.2015 –Nov. 2016).

Months	Um Aswad		El-Remila		El-Monaba	
	Av, fecd.	No. examined females	Av.fecd.	No. examined females	Av.fecd.	No. examined females
Dec-15	-	-	-	-	-	-
Jan-16	-	-	-	-	-	-
Feb-16	432±0	1	317.5±185.969	2	227±0	1
Mar-16	414.333±255.807	6	661.652±168.149	23	644.556±401.985	9
Apr-16	662.294±255.379	17	674.8±262.912	30	729.235±207.631	17
May-16	565.857±180.964	14	524.3±325.557	20	332±180.363	7
Jun-16	675.786±199.478	14	725.138±302.361	29	675.4±234.378	18
Jul-16	812.454±229.441	11	678±219.409	39	644.842±178.747	20
Aug-16	-	-	-	-	-	-
Sep-16	423±0	1	550.364±255.436	11	-	-
Oct-16	476±0	1	272.8±126.391	5	545.25±262.402	4
Nov-16	-	-	-	-	618±0	1

Ave. fecd.	481.715±217.422	65	638.712±171.819	159	633.724±178.186	77





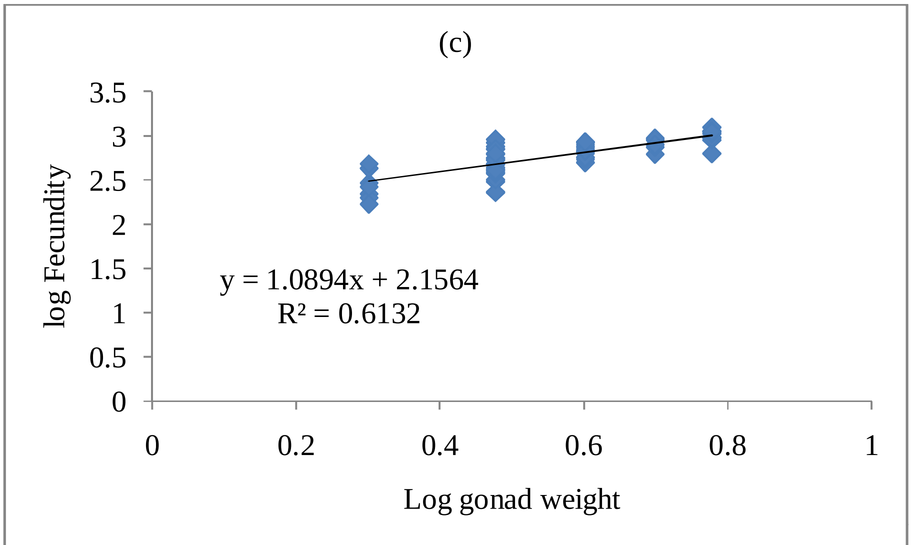
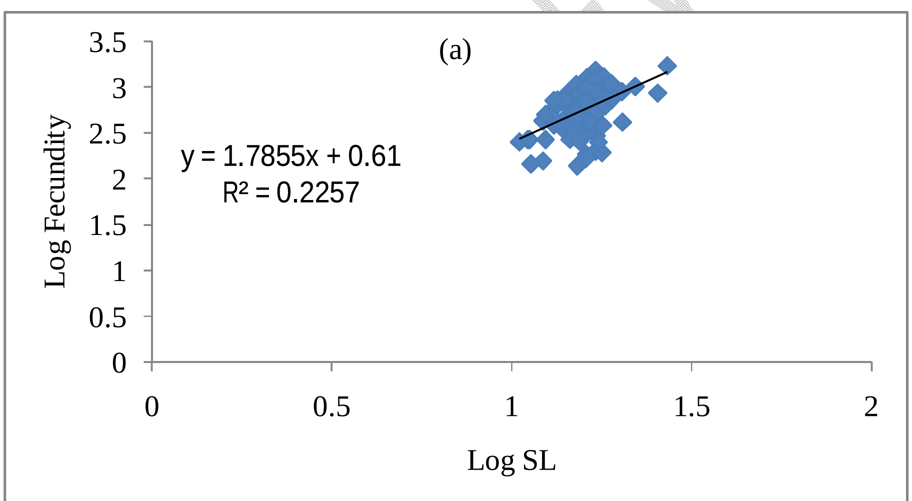
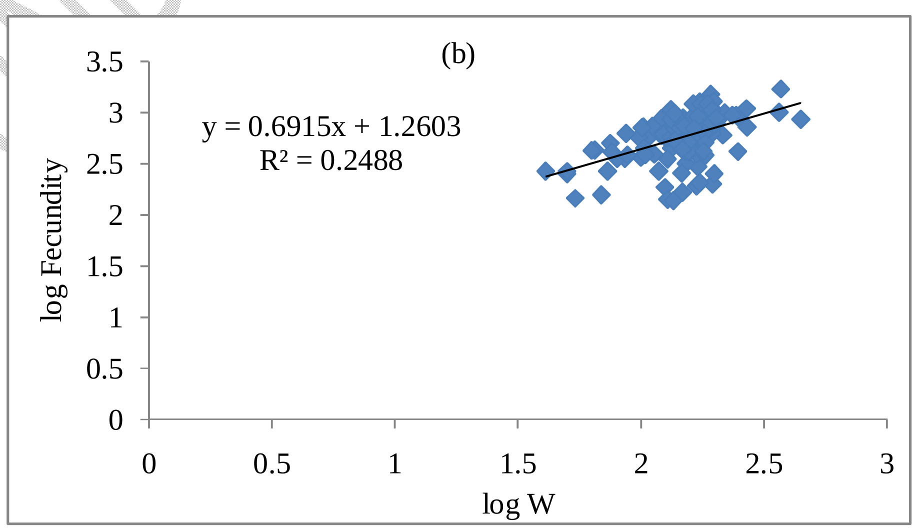


Fig. (6): Correlation of fecundity of *O. niloticus* withstandard length (a), body weight (b) and gonad weight (c) atUmAswad sampling site.





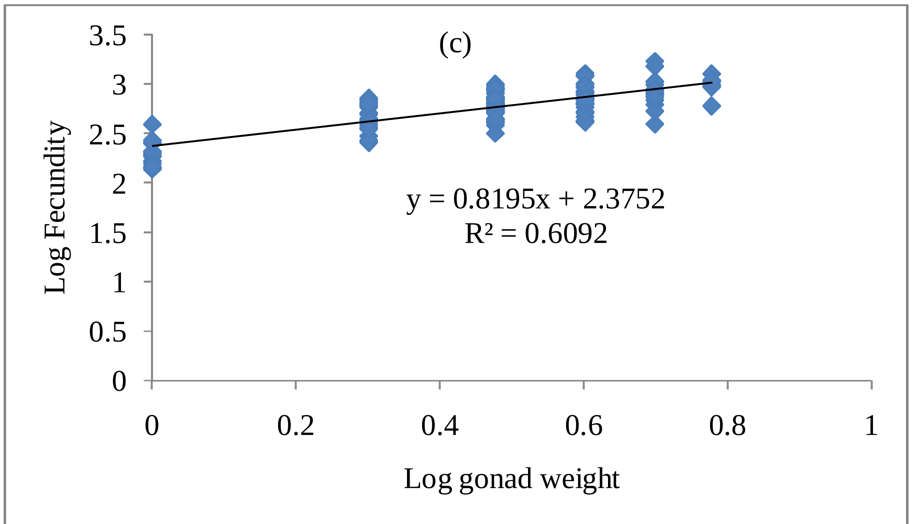
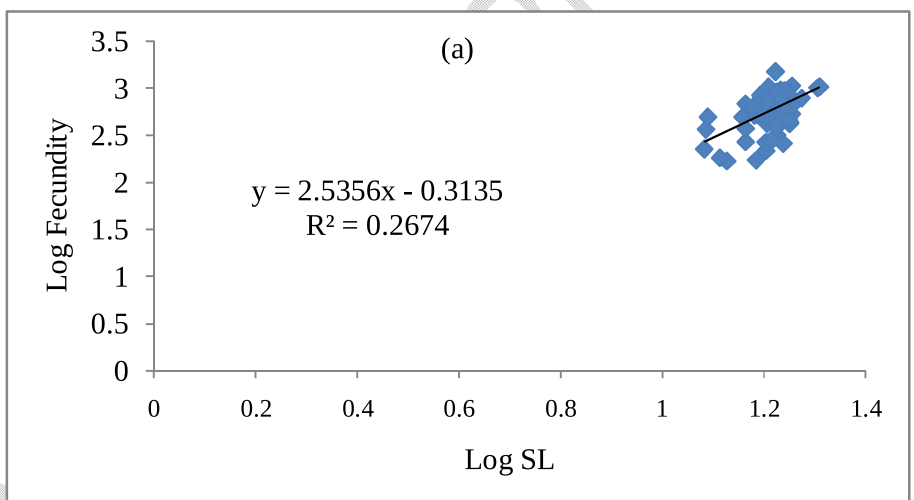


Fig. (7): Correlation of fecundity of *O. niloticus*with standard length (a), bodyweight(b) and gonad weight (c) at El-Remila sampling site during the study period



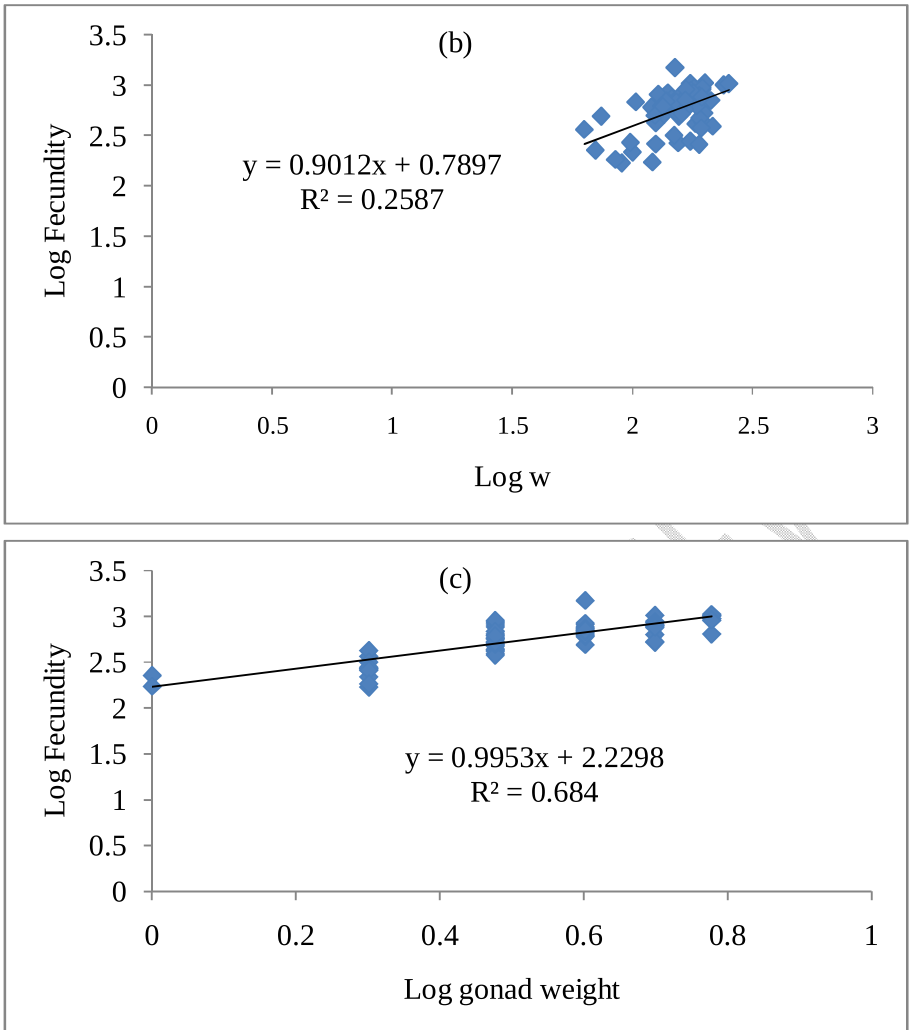


Fig. (8): Correlation of fecundity of *O. niloticus*with standard length (a), body weight (b) and gonad weight (c) at El-Monaba sampling site during the study period.

Table 7: Correlation of fecundity of *O. niloticus*at Khashm El-Girba reservoir and Atbara River sampling locations during the study period

site	Relation	b	a	R^2	N
Um Aswad	Fecundity tostandard length	0.563	1.834	0.184	65
	Fecundity to total weight	1.006	0.816	0.253	65
	Fecundity to gonad weight	2.1564	1.089	0.613	65

El-Remila	Fecundity tostandard length	0.61	1.785	0.226	159
	Fecundity to total weight	1.2603	0.691	0.249	159
	Fecundity to gonad weight	2.3752	0.819	0.609	159
El-Monaba	Fecundity tostandard length	0.3135	2.536	0.267	77
	Fecundity to total weight	0.7897	0.901	0.259	77
	Fecundity to gonad weight	2.2298	0.995	0.684	77

Discussion

In the present study, it was found that the most dominant ages of males and females*O. niloticus*were those of age 1+ year followed by age 2+ years. Immature fishes (age 0+) and older fishes of age 3+ years representedonly a small proportion of the examined fishes in Um Aswad and El-Monaba sites, and were virtually absent from El-Remila site. This may due to the selectivity of the fishing gear used for collecting the samples (beach seine nets of very small mesh size of 1.2 cm and 4.0 cm) and the seasonal flushing of Khashm El-Girba reservoir carried out during August 2015[26 and 27].

The overall sex ratio of *O. niloticus* remainedfairly constant throughout the study period at 1:1 (M: F), except in El Remila site where sex ratio of 1: 3 and 1:2 (M: F) was recorded in September and Octoberrespectively. This agrees with the results obtained for *O. niloticus*by different authors at different locations[11, 28, 29, 30, 31 and 32].Analysis of sex ratio of the examined samples showed that immature and maturing females of *O. niloticus* dominated the population of the examined fish, while older fishes were dominated by males.[21]found that the sex-ratio of females to malesof O. *niloticus*varied inversely with length of small fish of about 8-10 cm length(2.94: 1);and 0.39: 1 forlarger specimens of 36-38 cm length, and a ratio of 1:1for fish of length 26-28 cm. According to [32], the two sexes of *O. niloticus* did not occur in the same proportion during different seasons of the year, whereas females predominate during spring and winter and males were more abundant during summer and autumn,with an overall sex ratio of males to femalesof 1:1.37. The variation of sex ratio may be related to inaccurate sexing of the immature stages of the fish, and / or inadequate collection of fish samples.

Two peaks of gonado-somatic index were observed, suggesting two breeding seasons of this fish species; ashort breeding season during March-April, followed by a longer and main breeding season during July and October.In the present investigation**,** the two peaks of high GSI coincided with the periods of low and high-water levels in Khashm El-Girba reservoir and Atbara River.[21] reported high levels of ripe females of *O. niloticus*in Jebel Aulia Dam reservoir early in September until October, then in December- February, and reached a peak in late March and April.[32] also recorded high values of GSI of for *O. niloticus* females during March- April, and June–September. However, [33], working in Lake Tana, Ethiopia, reported that *O. niloticus* spawns throughout the year with a peak during June- July, and[30]stated that most tilapia species breed continuously throughout the year, with increased breeding rate during periods of intense sunshine or rainfall.

In the present study, fecundity of *O. niloticus*varied with locality, length and weight of the fishrather than not with age. Hence,at El-Remila sampling site, the youngest ripe female *O. niloticus* (SL 10.1 cm, and TW 50 g), had an estimated mean fecundity of 253 eggs, while fishes of 12.1 SL and 70– 76 g TW had mean fecundities of 301 and 227 eggs at El- Monaba and Um Aswad sites, respectively. This confirms that*O. niloticus* reached sexual maturity in the first year of life in the study area. This agrees withthe findings ofseveral investigators[11, 31, 32, 33 and 34].The variations in fish fecundity may be due to different adaptations toenvironmental factors, and increased feeding levels [20], or may result from different reproductive strategies of the fish species [37].

Moreover,analysis of fecundity with gonad weight and body length and weight showedthat a strong correlation existed between fecundity and gonad weight, but weak correlation between fecundity and standard length and total body weight of *O. niloticus*. However, [32] reported that fecundity of *O. niloticus*was better correlated with length (r= 0.9236) and weight (r= 0.9399) than with gonadal weight (r= 0.7651).

Two peaks of ripe ovaries were observedfor *O. niloticus* females during the period of investigation, suggesting two breeding seasons for this species;The first peak occursin March- April(during dry season); while the second season (main)peakcoincided with rainy season;in downstream site, peak occurs during July to late Octoberand extended to November in upstream sites. This finding agrees with those of [11, 31, 33, 34, 35].

However, [36],reported two breeding seasons for *O. niloticus* in Lake Beseka, Ethiopia, one from March-April and the second during August- September. He added that the lowest frequency of ripe fishes was recorded between October- February and May- July. These differences in the breeding seasons of *O. niloticus* may be related to different type of species, geographic regions, and environmental factors, and breeding strategies of the fish.

Conclusion

The results of the present investigation showed that sex ratio of *Oreochromis niloticus*was almostsimilar in the study area (1.0:1.0 of M: F).Two peaks of ripe females, coinciding with low and high levels of gonado-somatic index were observed during March-April and July- October, revealing two spawning seasons ofthis species.Fecundity of *O. niloticus*varied with the sampling locality, length and weight of the examined fish, andwas generally low in the studyarea. On the other hand,fecundity showed a high correlation with gonad weight, but low correlation with standard length and body weight in Um Aswad, El-Remila and El-Monaba respectively.Two breeding seasons were observed *O.niloticus*; a short one in dry season(March- April), and a long main breeding season during rainy season (July – October).

The results of this investigation carried outon *Oreochromis niloticus*in Atbara River and Khashm El-Girba reservoir are expected to be used by the concerned fisheries authorities in order toestablish sound management policies aimed at developingand conserving the fisheries of these two ecosystems. Such measures should include determination of mesh size of fishing nets, conservation of the resource by prohibiting catching under-sized fishes, determination of closed fishing season especially during the breeding seasons of commercially important fishes, and prevention of fishing by using harmful fishing gear.

Recommendation

Carry out further biological studies, especially on reproductive biology of the most important foodfish species in Khashm El-Girba and Atbara River to provide reliable basic data for better understanding and exploitation of the fishery resources of the two ecosystems.

Implement management policies and procedures for the protection and conservation of the fisheries resources in the eastern part of Sudan, including determining the mesh size of fishing nets, closed fishing seasons, prohibiting catching fish during the breeding seasons, prohibiting catching under-sized fishes, preventing fishing with harmful fishing gear, protect the environment from different sources of pollution.

It is strongly recommended to carry out research programs to evaluate the potential impacts of the two newly constructed Upper Atbara and Sittait dams.

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