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Effects of Parasitism on some Reproductive Indices in *Sarotherodon Galilaeus* (Linnaeus, 1758) in a Freshwater Habitat

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Abstract
The reproductive activities and parasitic infestation of Sarotherodon galilaeus were investigated between 2016 and 2018 using standard methods. The sex ratio was 0.94:1 (male: female) and the male grew longer than females at maturity. Five stages of gonadal maturity were observed in male and female sexes. The gonado-somatic index of female was higher than that of males. Multiple spawning of four times in a year that spread across rainy and dry seasons was observed. Generally, low fecundity (1711+176 eggs) and relative fecundity (9+1 eggs per gram body weight of fish) values were recorded. The egg diameter ranged from 0.4 mm to 2.10 mm. Parasite species diversity in S. galilaeus showed three species, which comprised of one Acanthocephalan; Neoechinorhynchus rutili, (Mueller, 1780), the metacercaria of a Trematode Clinestomum tilapiae (Leidy, 1856) and a nematode Procamallanus laevionchus (Wedl, 1862). There was no significant ($p \geq 0.05$) difference between the weights of infested and uninfested male fish. However, significant difference between the weights of infested and uninfested female fish in the two years was observed; which indicated that the female fish body weight was affected by the parasitic infestation. Therefore, the parasitic infestation which affected the body weight of the infested female fish could also affect the Gonado-somatic index value, egg production, fecundity and relative fecundity values; which would inadvertently affect the reproductive capability of the infested fish in the aquatic environment.

Keywords: Enteroparasites, Infestation, Intensity, Gonado-somatic, Sarotherodon galilaeus

Introduction
St Peter's fish {Sarotherodon galilaeus (Linnaeus, 1758)} is a dominant, endemic, and economically important tropical fresh water fish species, which belongs to the Cichlidae family. Sarotherodon galilaeus has been known to occur at 9°C; occasionally form schools; adults prefer open waters but juveniles and breeding adults are found inshore (Trewavas and Teugels, 1991). They are often associated with beds of submerged vegetation in Sudd lakes; feed on algae and fine organic debris; lacks marked sexual dichromatism when sexually active; forms temporary pair bonds (Stiassny et al., 2008).

Reproduction in fishes is one of the basic biological features enabling the maximum survival and continuation of their statutory roles in an ecosystem. Descriptions of reproductive strategies and the assessment of fecundity are fundamental topics in the study of the biology and population dynamics of fish species and also for the evaluation of the reproductive potentials of individual fish species (Costache et al., 2011). The availability of data based on reproductive parameters and environmental variations could lead to a better understanding of observed fluctuations in reproductive outputs and enhances our ability to estimate recruitment (Kraus et al., 2002). Reproductive activities in fish studies are carried out by the determination of certain reproductive parameters such as the Gonado-Somatic Index (GSI) which is the ratio of gonad weight to body weight and is used to estimate reproductive condition (Allison et al., 2005). The GSI is particularly helpful in identifying days and seasons of spawning, as the ovaries of gravid females swiftly increase in size prior to spawning; GSI is generally indicative of reproductive success and general water quality (Allison et al., 2005). The knowledge of fish breeding habits and fecundity helps in establishing its production potential and invariably its exploitation and management (Komolafe and Arawomo, 2007).

Fishes that are infested or infected with parasites are susceptible to stunted growth, low protein content and low reproductive abilities, since the parasites mostly feed on already digested food, blood, body fluids, and tissues. Different parasites have a variety of intermediate host and often

depend on trophic interactions for transmission; hence parasites within a vertebrate host may be excellent indicators of food-web structure and biodiversity. Mavuti et al., (2017) isolated a nematode (Paracamallanus spp.) from the intestines of farmed Nile tilapia in Kenya. Cestodes, nematodes and Acanthocephalans were also reported prevalent in wild and caged Nile tilapia in Kenya, Uganda and Ethiopia (Florio et al., 2009). Ajala and Fawole (2015) also recovered Neoechinorhynchus rutili (Mueller, 1780), Acanthocentius tilapia, Clinostomum tilapiae (Leidy, 1856), Procamallanus laevionchus (Wedl, 1862) and Paracamallanus cyathopharynx (Baylis, 1923) from the enteron of Sarotherodon galilaeus. Parasitic infection and infestation on fish production has largely remained an issue of concern to fish farming industry. Some parasites have been discovered to have zoonotic potential in mammalian host including man thereby making them of public health importance (Bichi and Yelwa, 2010).

This study intends to investigate parasitic species diversity, prevalence, intensity and the influence of parasitism on the process of reproduction in Sarotherodon galilaeus.

Materials and Methods

Study area: - The study area was Oba Reservoir in Ogbomoso, Oyo State, Nigeria. Oba Reservoir was impounded in 1964 and the tributaries are Idekun, Eeguno, Akanbi-Kemolowo, Omoogun, and Yakun streams. The main body of Oba Reservoir lies between Latitude 08° 3' N to 08° 12' N and Longitude 04° 6' E to 04° 12' E. The vegetation of the shoreline is dense with submerged macrophyte which decomposes in the rainy season. The substratum of the reservoir is mainly mud and sand. The reservoir sustains a thriving artisanal fisheries industry.

Procedure for collection of fish specimens: - Samples of the fish specimens were collected monthly from catches of local fishermen using traps, gill nets, and cast nets in the reservoir. Collection was done from November 2016 to October 2017 (2016/2017), November 2017 to October 2018 (2017/2018) between 06:00 - 08:00 am. The conventional period of dry season (months of October to March) and rainy season (months of April to September) that characterized the studied area were observed and used in this study. Efforts were made to ensure that most of the fish specimens were still alive as at the time of collection. Water from the reservoir was added to the samples at the point of collection before being transported to the laboratory in the Department of Pure and Applied Biology, Ladoke Akintola University of Technology, Ogbomoso, Nigeria for further investigations.

Identification was done according to Adesulu and Sydenham (2007); and Stiassny et al., (2008).
Reproductive parameters:- Reproductive activities in fish studies were carried out by the determination of certain reproductive parameters such as the gonado-somatic index (GSI) which is the ratio of gonad weight to body weight; it is used to estimate reproductive condition. Each specimen was weighed using a top loading Metler balance (model PN1200) to the nearest 0.1 g after they were blotted dry with filter paper, while total length (TL) was measured in centimeter (cm) using a measuring board. Total length was used because no evidence of cannibalism was observed during the pre-data and data collection periods. Numbers of males and female sexes harvested per year were counted and the ratio determined. The sex ratio was given as males: females (M: F), calculated using the formula: total number of males/total number of females (Vazzoler, 1996). Chi-square was used to verify the existence of significant differences between the sex ratio obtained and the commonly expected 1:1 sex ratio.

Dissection of collected specimens: - Euthanasia was carried out by physical method. Cervical dislocation was done by cervical transection using a knife inserted caudal to the skull, to sever the spinal cord and cervical vertebrae followed by pithing. Body cavity was opened ventrally with the aid of a sharp knife. The mesentery and connective tissues, connecting loops of the gut and the gonads were cut and the organs separated. The male and female gonads were placed in separate dishes and weighed. The data were used for reproductive studies. The mean of the weight of the gonads (total weight of right and left gonad) of all specimens were calculated for the males and females.

Determination of the gonado-somatic index: - The gonado-somatic index (GSI) of each fish was determined as described by King (1995). Monthly mean values (GSI) of male and female were computed and presented in graphical forms to ascertain monthly variations and detect the period of high reproductive activity represented by the peak(s) in the values.

Ovaries collected were weighed using an electronic Metler balance (model P1210) to the nearest 0.01 g. The ovaries were preserved separately in modified Gilson's fluid as described by Komolafe (2005). The preserved ovaries were periodically shaken to ensure the separation of eggs from ovarian tissues.

Fecundity is defined as the number of ripened eggs in the ovary, just before spawning. Sub samples of ovaries were obtained and weighed. The number of eggs in each sub-sample was enumerated manually. The absolute fecundity in the fish was estimated from the relationship established by Anene and Okorie (2008). A mean fecundity from all samples was calculated using direct summation procedure. The relationship between fecundity, total length, body weight, and gonad weight of fish was determined by exponential and linear regression using the formula of Bagenal (1967). The mean relative fecundity was calculated as described by Bagenal and Tesch (1978) and expressed in eggs/g body weight. The test for significant difference in the fecundity means between the two years was done using independent Student t test (2-tailed) at 95% confidence level.

Examination of Fish for parasites: - Examination of fish for parasites, handling and processing were done using standard procedure of Moravec (2004). Cestodes and nematode parasites recovered were stained using the procedure of Khalil (1991). Fixative used was formalin acetic acid (FAA). Cestodes were stained using acetocarmine; nematodes were stained with Horen's trichome stain; while acanthocephalans were preserved in weak Erlich's haematoxylin solution overnight and dehydrated, cleared in methyl-salicylate and mounted on a slide in Canada balsam.

Reproductive indices:- In this study, the minimum sizes of specimens in total length and weight, with observable matured gonads in male and female fish were taken as the maturity sizes (Fawole and Adewoye, 2004). The female and male gonad morphological descriptions were based on the descriptions of Olele (2010). Measurements of egg diameter were done based on Coleman and Galvani (1998).

Statistical analyses:- For the reproductive parameters, a regression graph was plotted between gonad weight and body weight of male and female specimens, the correlation coefficients r2 of good fit to the line of regression were determined using MS-Excel package. Differences between the means of GSI in the two years for both male and female fish were carried out using t test (2-tailed) at 95% level of confidence with SPSS version 15.0. Significant differences of parasitic infestation were tested using Kolmogorov-Smirnov K-S test at 95% level of confidence using SPSS version 15.0 for Windows. Difference between the means of body weight and total length of infested and uninfested fish specimens were carried out using t-test (2-tailed) at 95% level of confidence with SPSS version 15.0 for Windows. Regression analysis was carried out on the length-weights of infested and uninfested fish specimens as described by Hossain et al. (2006). The correlation coefficients r2 of good fit for infested and uninfested fishes were determined using MS-Excel package.

Results

Reproductive studies: - A total of 98 males and 108 females were investigated in 2016/2017, while 94 males and 110 females were investigated in 2017/2018. Sex ratio for the first year (2016/2017), was found to be 0.91:1, (male: female), while that of the second year (2017/2018) was 0.86:1 (male: female) given a general ratio of 0.88:1 (male: female). Size at maturity showed the smallest male with a mature gonad had a total length of 12.70 cm and the matured male fish with the smallest weight was 86.20 g. The smallest female with a mature gonad had a total length of 12.00 cm and the matured female with the smallest weight, weighed 126.00g.

Female gonadal development: - Five stages of gonadal development were observed in the female specimens examined. The observable characteristics of gonadal stages were:

Resting adult stage I: Ovaries were threadlike, and occupied a small portion of the body cavity. Developing stage II: Oogonia cells had advanced into the oocyte stage. Their nucleoli were not visible.

Maturation stage III: Cortical alveolus phase. The ovary wall was distended, occupying two third of the abdominal cavity. This stage was characterized by ring formation, with the presence of the cortical vesicles.

Ovulation/spawning stage IV: The ovary wall became thin, transparent and occupies the entire visceral region with visible egg globules.

Hydrated stage V: The ovary shrank with loose walls. There was the presence of degenerating corpora lutea and immature oocytes.

The number of observable matured female gonads stages III and IV were 50 (46.30%) in 2016/2017 and 38 (34.55%) in 2017/2018 respectively (Table 1).

Table 1: Gonad Maturity Stages of *Sarotherodon galilaeus* in Oba Reservoir.

		Year 2016/2017 Gonadal stages					Year 2017/2018 Gonadal stages				
Months	Sex	1	2	3	4	5	1	2	3	4	5
March	Male	1	3	1	2	1	2	-	3	2	1
	Female	-	-	5	6	2	-	2	3	5	3
April	Male	-	3	-	-	-	1	-	-	-	1
	Female	1	1	-	-	-	-	1	-	-	1
May	Male	1	3	2	2	1	3	2	4	4	3
	Female	1	-	3	4	4	1	3	5	2	2
June	Male	3	1	-	-	-	1	2	-	-	3
	Female	2	1	-	-	-	-	2	-	-	2
July	Male	3	1	3	2	1	2	2	2	1	-
	Female	-	-	3	2	2	1	2	2	4	3
August	Male	1	3	3	4	2	1	-	3	3	2
	Female	1	1	3	3	1	-	-	2	2	1
September	Male	1	2	1	1	3	1	-	1	1	-
	Female	-	-	2	1	1	1	-	1	-	2
October	Male	2	2	-	-	-	2	1	-	-	1
	Female	-	-	-	-	-	1	-	1	-	1
November	Male	1	-	-	-	-	1	1	-	-	2
	Female	1	-	-	-	1	1	1	-	-	-
December	Male	1	-	2	1	1	1	-	3	1	2
	Female	2	-	2	7	2	-	1	1	4	1
January	Male	2	1	-	-	-	1	1	-	-	-
	Female	1	2	-	-	2	-	2	-	1	-
February	Male	2	1	2	2	1	1	2	2	2	1
	Female	-	-	4	5	3	1	3	1	4	3

Male gonad morphological description: - Resting adult stage I: Testes were threadlike and invisible to the unaided eyes. They occupied an insignificant part of the body cavity.

Developing stage II: Cells were visible without aids, graduating into spermatocyte stage, with the presence of the melanomacrophage centres and lacanae cells.

Maturation stage III: Testis was turgid. This is the spermatid stage where the capillaries are prominent, giving a reddish colouration.

Spawning stage IV: The spawning stage characterized by agglutination of spermatozoa cells.

Hydrated stage V: Available Seminiferous tubule was empty, flabby, and characterized by irregularly shaped cell walls.

The number of observable matured male gonads stages III and IV were 28 (28.57%) in 2016/2017 and 32 (34.04%) in 2017/2018 respectively (Table 1).

Gonado-somatic indices (GSI):- The monthly GSI values for males: In 2016/2017, mean values ranged from 0.16 + 0.04% in April and November to 0.64 + 0.06% in March with a yearly mean of 0.39 + 0.0%. Reproductive activities were from November to August, with peak periods in December, March, May, and July (Figure 1). A regression graph plotted between gonad weight and body weight gave a correlation coefficient (R2) value of 0.708. In 2017/2018, the mean values ranged from 0.24 + 0.03% in November to 0.48 + 0.08% in July with a yearly mean of 0.33 + 0.05%. Reproductive activities were from December to July, with peak periods in April and July – (Figure 2). The regression graph plotted between gonad weight and body weight gave an R2 value of 0.798. The mean monthly GSI values

for the two years of study were 0.36 + 0.04%. No significant (p = 0.114) difference in the mean values of the GSI between 2016/2017 and 2017/2018 in male S. galilaeus.

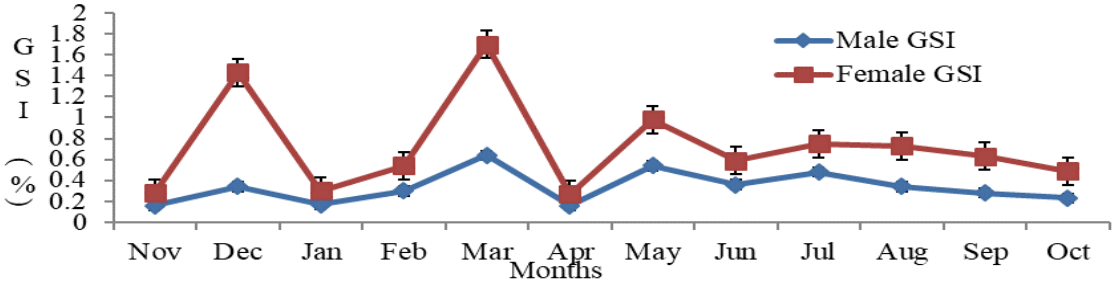


Figure 1. Monthly mean gonadosomatic indices for male and female *Sarotherodon galilaeus* showing peaks of reproductive activities in Oba Reservoir, 2016/2017.
Error bars represents standard error of means.

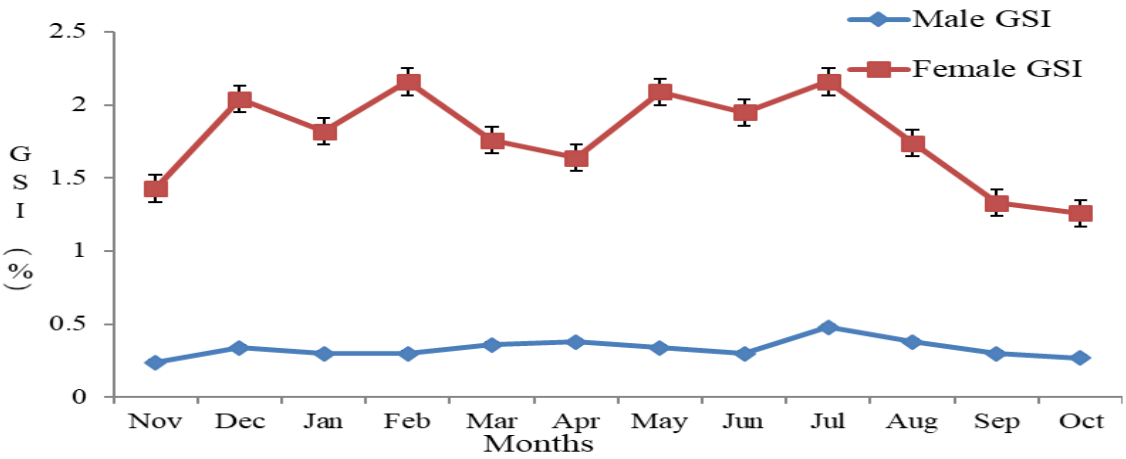


Figure 2. Monthly mean gonadosomatic indices for male and female *Sarotherodon galilaeus* showing peaks of reproductive activities in Oba Reservoir, 2017/2018.
Error bars represents standard error of means.

The monthly GSI values for females: - In 2016/2017, the mean values ranged from 0.27 + 0.01% in April to 1.70 + 0.03% in March with a yearly mean of 0.72 + 0.12%. Reproductive activities were from November to September, with peak periods in December, March, May, July and August, Figure 1. A regression graph plotted between gonad weight and body weight gave an R2 value of 0.899 while the one plotted for the observable matured females gave an R2 value of 0.765. In 2017/2018, the mean values ranged from 1.26 + 0.05% in October to 2.16 + 0.08% in February and 2.16 + 0.03% in July with a yearly mean of 1.78 + 0.21%. Reproductive activities in female in 2017/2018 were from November to August, with peak periods in December, February, May, and July, Figure 2. A regression graph plotted between gonad weight and body weight gave an R2 value of 0.051 while the one plotted for observable matured females gave an R2 value of 0.047. The mean GSI value for the two years of study was 1.25 + 0.15%. There was a significant difference in the mean values of the GSI between the two years in female the 'P' value was 0.01. The mean GSI values of 2016/2017 and 2017/2018 were significantly (0.001) different.

Matured female reproductive studies:- Gonads contain eggs of various sizes which ranged from 0.40 mm to 2.1 mm in diameter and a mean of 1.23 + 0.13 mm in 2016/2017; 0.40 mm to 2.0 mm with a mean of 1.40 + 0.10 mm in 2017/2018. Generally, the fecundity increased with gonad weight, total length and body weight. The mean fecundity for 2016/2017 was 1687+162 and 1735 + 119 for 2017/2018; for the two years, it was 1711 + 176 eggs. Student t - test carried out at 95% confidence level, for the difference between the mean fecundity values in 2016/2017 and 2017/2018 was significant; p = 0.047. The mean relative fecundity was 10 + 1.0 for 2016/2017 and 7 + 1 for 2017/2018; for the two years were 9 + 1 eggs per gram body weight of fish. The mean relative fecundity values of 2016/2017 and 2017/2018 were significantly, p = 0.01 different.

Parasitology

Diversity of parasites recovered in the stomach and intestine of the specimens: - The gastro - intestinal helminth parasites recovered were comprised of one Acanthocephalan; Neoechinorhynchus rutili, (Mueller, 1780), the metacercaria of a Trematode Clinestomum tilapiae (Leidy, 1856) and a nematode; Procamallanus laevionchus (Wedl, 1862). The metacercaria was found in the buccal cavity while the acanthocephalan and nematode were found in the intestine, nothing was found in the stomach.

Intensities of the parasite species in the enteron: - The intensities of the three parasites as distributed in the enteron were shown in Table 2.

Table 2: Intensities of Parasite Species in the Enteron

	2016/2017				2017/2018			
	Male		Female		Male		Female	
Parasite species	B.C.	Int.	B.C.	Int.	B.C.	Int.	B.C.	Int.
Neoechinorhynchus	0	6.5	0	7.20	0	3.2	0	4.07
Rutili		±0.55		±0.46		±0.22		±0.36
Clinestomum	8.6	0	7.6	0	4.7	0	4.8	0
Tilapiae	±1.64		±0.81		±0.46		±0.52	
Procamallanus	0	1.85	0	2.80	0	1.8	0	1.6
Laevionchus		±0.06		±0.05		±0.03		±0.07

B.C.= Buccal Cavity; Int. = Intestine

Prevalence of parasitic infestation: - In male specimen of 2016/2017 study, 34 were infested out of 98 giving a prevalence of 34.69% within sex and a general prevalence of 16.51% out of the total fish investigated in the year. In female, 52 were infested out of 108, giving a prevalence of 48.15% within sex and a general prevalence of 25.25% out of the total fish investigated in the year. In male specimen of 2017/2018, 41 were infested out of 94 giving a prevalence of 43.62% within sex and a general prevalence of 20.10% out of the total fish investigated in the year. In female 63 were infested out of 110, giving a prevalence of 57.27% within sex and a general prevalence of 30.88% out of the total fish investigated in the year.

Prevalence of parasitic infestation of S. galilaeus in seasons of each year: - The prevalence of parasitic infestation was found to differ with seasons in the two years of study. In 2016/2017 it was 19.25% in the dry season, 22.50% in the rainy season with a general value of 41.75% in the year. While in 2017/2018, it was 23.94% in the dry season, 27.04% in the rainy season and a general value of 50.98% in the year. However, a significant test (KS) at p=0.05 between the means of infested fish in the rainy and dry seasons in the two years was not significant.

Parasitaemia of species in relation to seasons and sex in the two years of study: - Seasonal level of parasitaemia for each species of parasite recovered in male and female fish in the two years of study was shown in Table 3. Significant tests (K-S tests at $p = 0.05$) of means of intensities of parasites between male and female fish in each of the two years were significant but not season dependent.

Relationship of parasitaemia and body weight: - In 2016/2017, a student t - test carried out to find the significant difference (at $p \geq 0.05$) showed that the means of the body weight of infested male (244.00+11.12 g) and uninfested male (256.23+10.64 g) was not significant. But in infested females (269.20+10.12 g) and uninfested females (297.76+17.82 g) it was significantly ($p = 0.043$) different. In 2017/2018, a student t - test carried out to find the significant difference (at $p \geq 0.05$) showed that the means of body weight of infested male S. galilaeus (227.82+14.22 g) and uninfested male (230.44+26.18 g) was not significant. In infested females of (275+14.59 g) and uninfested female (305.07+14.21 g) it was significantly ($p = 0.41$) different.

Relationship of parasitaemia and total length:- In 2016/2017, a student t - test carried out to find the significant difference (at $p \geq 0.05$) showed that the mean total length of infested male S. galilaeus (21.75+1.06 cm) and uninfested male (22.65+0.63 cm) was not significant. In infested females (22.60+1.03 cm) and uninfested female (22.88+0.35 cm) it was also not significant. In 2017/2018, the t - test between infested male S. galilaeus (18.93+1.05 cm) and uninfested male (18.60+0.72 cm) was not significant; in infested female (19.88+1.11 cm) and uninfested female (20.60+1.04 cm), the difference was not significant.

Table 3: Seasonal Level of Parasitaemia for Each Species of Parasite Recovered in Male and Female Sarotherodon galilaeus During the Years of Study

Female Sarotherodon galilaeus during the years of study																
Seasons	Rainy				Dry				Rainy				Dry			
	BC		Intestine		BC		Intestine		BC		Intestine		BC		Intestine	
Parasites	R.	TNP	R.	TNP	R.	TNP	R.	TNP	R.	TNP	R.	TNP	R.	TNP	R.	TNP
N. rutile	0	0	0-8	20	0	0	0-12	26	0	0	0-10	66	0	0	0-9	36
C. tilapiae	0-9	37	0	0	0-6	52	0	0	0-15	33	0	0	0-12	23	0	0
P. laevionchus	0	0	0-1	13	0	0	0-2	4	0	0	0-1	2	0	0	0-2	9
Total		37		33		52		30		33		68		23		45
		70				82				101				68		
		152								169					=301	
2017/2018																
N. rutili	0	0	0-5	19	0	0	0-5	22	0	0	0-6	22	0	0	0-5	19
C. tiapiae	0-4	15	0	0	0-3	14	0	0	0-9	22	0	0	0-6	19	0	0
P. laevionchus	0	0	0-1	3	0	0	0-2	5		0		2		0		8
		15		22		14		27		22		24		19		27
		37				41				46				46		
		78								92				=156		

Influence of parasitaemia on length – weight relationship: - Regression analyses were carried out between the length and weight of infested specimens and between the length and weight of uninfested specimens S. galilaeus. The correlation coefficient (R2) was found to determine if they had good fit. In uninfested male of 2016/2017, R2 value was 0.964, infested 0.912; uninfested female was 0.955, infested was 0.884. In uninfested male of 2017/2018, R2 value was 0.922, infested 0.877; infested female 0.804, uninfested 0.921.

Discussion

Reproductive activities: - The sex ratio obtained for Sarotherodon galilaeus in Oba Reservoir was 0.88:1 (male: female) which was not significantly different from the expected ratio of 1:1. This study showed that both sexes were available and for every male S. galilaeus in Oba reservoir, there was a female. This result was in consonance with those of other authors such as Fawole and Arawomo (2000) who reported a sex ratio of 1:1 for S. galilaeus from Opa Reservoir in Ile Ife; Olele (2010) reported a ratio of 1:0.9 (male: female) in Onah Lake, Delta state and El-Kasheif et al. (2013) reported 1:0.81 (male: female) from Damietta branch of River Nile in Egypt.

Size at maturity: - The smallest male with a matured gonad had a total length of 12.70 cm and the matured male fish with the smallest weight was 86.20 g. The smallest female with a matured gonad had a total length of 12.00 cm and the matured female with the smallest weight, weighed 126.00 g. This result was similar to that of Fawole and Arawomo (2000) who reported that in S. galilaeus, Length at maturity was 12.5 cm (males) and 11.7 cm (females). However, Olele (2010) reported that male specimens of S. galilaeus matured at a total length of 98.00 mm while the females matured at a total length of 89.00 mm. These variations may be as a result of different environmental factors that exist in the different localities. The sizes at maturity reported by Olele (2010) were lesser than the result obtained in this report and greater than that of Fawole and Arawomo (2000). However, in the three reports the trend remains constant; the male matured at a bigger size than the female.

Gonad development: - The study of gonad development in S. galilaeus from Oba Reservoir revealed five (5) developmental stages in males and females that were captured (Table 1). The occurrence of all the five (5) stages in all the months of study coupled with the observation of different stages of egg development in an ovary indicated that the fish species spawn all year round and a fish can spawn more than once in a year (multiple spawning). These observations were in agreement with Olele, (2010) and El-Kasheif et al. (2013) both of whom reported the observation of 5 developmental stages in the gonads of S. galilaeus from Onah Lake and River Nile respectively. They further reported the appearance of the five stages throughout the period of their investigations. However, Fawole and Arawomo

(2000) reported the observation of six maturity stages in S. galilaeus and their presence throughout the 27 months of study in Opa Reservoir, Ile-Ife. These differences arose because the sexual maturity is a function of the fish size, and may be influenced by the abundance and seasonal availability of food, temperature, photo - period and other environmental factors at different localities (Pen-Mendoza et al., 2005).

Five gonad developmental stages were recorded in S galilaeus of Oba Reservoir, with matured female gonad stages observed in stages III and IV (Table 1). The matured female gonad stages were found throughout the year, with the frequency of fish in which they were found high in the months of December, March, May, and August in 2016/2017 and the months of December, February, May, and July in 2017/2018. These months had a minimum gap of one month between them in which spawning could have probably occurred, which indicated multiple spawning by the fish species in a year. This observation was in agreement with those of Fawole and Arowomo (2000); Olele (2010) and El-Kasheif et al. (2013). Matured testes in stages III and IV were also observed all year round in males, which also complement the conclusion of multiple spawning.

The Gonado-somatic indices: - The GSI for males had a monthly mean ranged from 0.16 + 0.04% in April and November of 2017 to 0.64 + 0.06% in March of 2017 with a mean of 0.36 + 0.04%; while in females it ranged from 0.27 + 0.01% in April of 2017 to 2.16 + 0.08% in February of 2018 with a mean of 1.25 + 0.15%. It was observed that there was no significant difference in the mean values of the two years in males at $p = 0.05$, but in females the difference was significant, with the value of 1.78 % in 2017/2018 being higher than 0.724% in 2016/2017. The significant difference observed in the means of GSI of the two years could have resulted from a difference in the means of the gonad weight of the two years.

The result also showed that the GSI of female was higher than that of males. This result was in consonance with those of Fawole and Arowomo (2000) who reported 0.33 ± 0.21% (males) and 1.88 ± 1.01% (females) from Opa Reservoir, they opined that this observation was associated with the relatively heavier female gonad which was heavily laden with yolk deposits. Olele (2010) also reported a higher value in females than males. Generally, the GSI range recorded was from 0.16 + 0.04% to 2.16 + 0.08% with a mean of 0.79 + 0.02%. Olele (2010) reported 0.22% to 0.70% from Onah lake; Bala and Abdullahi (2011) 0.20% to 2.11% in Sabke Reservoir, Katsina State. The differences in GSI values recorded by various authors from different aquatic habitats might be as a result of different environmental factors like water temperature, day length, light intensity, and water level which influenced spawning period (El-Kashief et al., 2013).

Four (4) peaks were recorded in the GSI values in each of the two years of study in Oba reservoir (Figures 1 and 2). The peaks in 2016/2017 were in the months of December, March May and July. In 2017/2018, the months were December, February, May, and July. Most of these months were noted to be rainy months except December. This probably gave the fish ample opportunity to spawn several times (4) in a year in the reservoir. The presence of both immature and mature oocyte in the ovaries of fishes was also an indication of multiple spawning. Availability of food, together with some environmental factors like water temperature, photoperiodicity, water level, had been mentioned as conditions for a successful breeding in S. galilaeus. The presence of all these conditions in the reservoir will indicate that the wellness of the fish was good and this could have given rise to multiple spawning. Olele (2010) and El-Kasheif et al. (2013) were of the opinion that the fish species spawn more than once in a year. The GSI of the matured female fish ranged from 0.30% to 2.70% with a mean of 1.09 + 0.10 in 2016/2017 and in 2017/2018; it was from 0.46% to 0.91% with a yearly mean of 0.67 + 0.03%. The mean for the two years combined was 0.88 + 0.02%, which was higher than the 0.79 + 0.02% value obtained for all the females investigated. This also showed the importance of egg weight in determining the GSI value. Test for significant difference in the means of the GSI values of the two years was significant at $p \geq 0.05$. The significant difference may be as a result of multiple spawning and parasitism.

A regression analysis between gonad weight and body weight in males of the two years showed a positive linear relationship, and more than 70.00% of the data collated were well fitted to the regression line. This indicated that as the gonad weight increases in male the body weight increases. But in females, there was a difference in the R2 values of the two years; in 2016/2017 it was 0.765, in 2017/2018, it was 0.051, though a positive linear relationship between gonad weight

and body weight was still established. This means that in 2017/2018 only 5.1% of the data collated could fit the regression line, the remaining percentage (94.9%) belong to those factors militating against the relationship. This trend was also observed in the regression in matured female which gave an R2 values of 0.899 and 0.047 in 2016/2017 and 2017/2018 respectively. This resulted in the significant difference in the means of the GSI values of the two years recorded in females. The factors responsible for these are very diverse, which could be limnological, predation, parasitism, anthropological or celestial cues to mention a few. However, in this investigation the factor responsible was probably parasitism.

Fecundity:- The mean fecundity in the first year was 1687 ± 162 eggs per fish; the second year was 1735 ± 119 eggs per fish and in the two years 1711 ± 176 eggs. The low value of fecundity recorded in this study is a characteristic of fishes that exhibit either parental care for their offspring Anon (2003) and or prolonged breeding habit, Fawole and Arawomo (2000). This result agreed with the findings of Fawole and Arawomo (2000) who reported a range of 604 eggs to 2173 eggs and a mean of 1,048 ± 785 eggs from Opa Reservoir in Ile-Ife; Olele (2010) reported a range of 493 eggs to 1976 eggs in Onah Lake in Delta State, while Bala and Abdullahi (2011) reported a range of 265 eggs to 2467 eggs from Sabke Reservoir in Katsina State.

It was observed that the means of the fecundity values obtained for the two years were significantly different at p = 0.05. This could be as a result of many environmental factors like food availability, temperature, photoperiodicity, most important of all, the available space in the buccal cavity of the fish for incubation of eggs and protection of the fry. Sarotherodon galilaeus in Oba Reservoir had a relative fecundity range of 2 to 24 eggs per gram weight of fish with an overall mean of 9 eggs per gram weight of fish. Mohammed et al. (2014), showed that fecundity increases linearly with body weight and fish size. The mean values of relative fecundity, obtained in the two years were found to be significantly different from each other at p = 0.05. This was supported by the result of difference in mean of relative fecundity, which means physical factors like temperature, photoperiodicity, water level in the reservoir that affect fecundity may probably be major determinants of the results obtained for the relative fecundity.

In this study, there was a closer relationship between fecundity and body weight than what obtains between fecundity and length. Olele (2010) however was of the opinion that the number of eggs per gram of ovary was not influenced by either total length or body weight. Fawole and Arawomo (2000) reported a relative fecundity range of 2.88-17.97 eggs per gram body weight with a mean of 5.17eggs per gram body weight and Olele (2010) reported a range of 3.7 - 4.6 eggs per gram weight of fish.

Egg Size: The size (diameter) of the eggs of S. galilaeus in Oba Reservoir was observed to vary and the egg diameter varied in fish of same length and weight indicating multiple spawning. Throughout the study period, the egg diameter ranged from 0.4 mm to 2.10 mm with a mean of 1.30 ± 0.15 mm. The smaller egg size may be responsible for the high fecundity of 1711 ± 176 recorded in Oba Reservoir. Fawole and Arawomo (2000) reported a higher mean egg size of 2.2 mm and a lower fecundity value of 1048 ± 785 eggs; Bala and Abdullahi (2011) reported a range of 2.41 mm - 4.23 mm with a fecundity range of 265-2467 eggs. This showed that egg size may be inversely proportional to fecundity value.

Parasitology

Distribution of enteroparasites infesting S. galilaeus in Oba Reservoir: - The parasites recovered from the enteron of S. galilaeus were one Acanthocephalan; Neoechinorhynchus rutili, (Mueller, 1780), the metacercaria of a Trematode Clinestomum tilapiae (Leidy, 1856) and a nematodes; Procamallanus laevionchus (Wedl, 1862). The metacercaria was found in the buccal cavity while the remaining four parasites were found in the intestine. No parasite was found in the stomach.

Diversities of the parasite species in the enteron and their seasonal distribution: - The buccal cavity where there was high intensity of C. tilapiae is a region well supplied with blood capillaries which provide nutrients that the parasites feed on either through passive, active, or facilitated diffusion. Other species of the genus Clinostomum, like *C. cutaneum* were known to reside in the skin tissues of Cichlids, their presence in cyst form in the buccal cavity may be as a result of their affinity for oxygen and blood. According to Echi et al. (2012) *Clinostomatid metacercaria* had predilection for the mesenteries' of blood capillaries in the buccal cavity; this explained the high prevalence and abundance in the buccal cavity. *Clinestomum tilapiae* is known to use cichlids as intermediate host while the definitive hosts are piscivorous birds (Olurin et al., 2012).

The intensity of the acanthocephalans in the intestine was not as high as that of C. tilapiae in

the buccal cavity (Table 2) in both male and female of the two years and its restriction to the intestine may be attributed to the abundance of food supply in the gut; its proboscis also serve as an organ of attachment to the gut wall. Poulin and Morand (2004) were of the opinion that predatory fish species harbour a greater diversity and abundance of larval helminths than herbivorous and planktivorous species hence the feeding pattern of S. galilaeus is an important factor in their infestation with parasites.

Fresh water fishes are the definitive host of N. rutili while the Ostracod (*Cypria turneri*) which the fish feed on is the intermediate host. All acanthocephalan have an indirect life cycle that requires at least one intermediate host (FAO, 2006). Piscine acanthocephalans have aquatic insects and crustaceans (amphipods, isopods, copepods, and ostracods) as their foremost intermediate hosts (FAO, 2006). Adeosun (2016) reported that S. galilaeus in Oyan Lake (Nigeria) are euryphagous, opportunistic feeders, which can feed on a wide range of organisms, both on surface water and bottom sediments. They opined that their food includes diatoms, desmids, blue-green and green algae, protozoan, detritus and unidentified plants, but detritus is the most preferred food followed by filamentous blue-green algae. S. galilaeus had also been reported to feed on food items of animal origin like insects and copepods which may be the source of its infestation (Ajala and Fawole, 2015). Seasonally, infestation followed the same pattern in both male and female S. galilaeus in the two years with both N. rutili and C. tilapiae being higher in the rainy season. The decline in the amount of fish infested with C. tilapiae harvested in dry season may be due to the pisciverous birds that come to the reservoir to feed upon the infested fish when the water level was low.

Prevalence and Intensity of parasitic infestation in relation to sex:- The prevalence and intensity were observed to be higher in females than in males in the two years of study (Table 2), however, statistical test showed that there was significant difference (K.S.) $P = 0.041$ in the means of parasitaemia of male and female S. galilaeus. Although Olurin and Somorin (2006) and Olurin et al. (2012) observed that there was no difference between parasite intensity and sex in the parasitic infestation of C. guntheri, T. mariae and H. fasciatus in Owa stream and in S. galilaeus and T. zillii from Oshun River respectively. Ochieng et al. (2012) reported that male *O. niloticus* were more infested with C. tilapiae than female in Kenya. Poulin and Morand (2004) were of the opinion that these inconsistent results could be attributed to studies failing to control two important confounding variables, study effort and the influence of phylogenetic relationship among fish species. However in Oba Reservoir, during the period of this study, female S. galilaeus were more infested with parasites than male and there was a significant difference in the degree of intensity between the sexes in the two years of study.

Relationship between parasitaemia and body weight: - Result showed that there was no significant difference at $p = 0.05$ between the weights of infested and uninfested male fish. However, significant differences between the weights of infested and uninfested female fish in the two years were observed; which indicated that the female fish body weight was affected by the parasitic infestation. Ochieng et al. (2012) reported that the condition factor of the fish was not affected by the infestation of *O. niloticus* by C. tilapiae. Garacia et al. (1993) were of the opinion that clinostomids infection can have several effects on fish, among them being reduced growth, offset weight loss and prominent exophthalmia. C. tilapiae had the highest intensity of infestation in this investigation, and Ochieng et al. (2012) were of the opinion that the position to which the parasite attach is majorly determined by availability of resources it requires for optimum survival. Amlacher (1996) observed that adult trematode may not attack host organs by implanting in the tissues, but only affix to well-situated sites where all required nutrients may be acquired with ease. Hence the high infestation of C. tilapiae in this investigation probably resulted in the difference in body weights of infested and uninfested female fish, coupled with the reproductive demand on the female fish.

The body weight is an important denominator used in the determination of the value of GSI. The index is an expression of the percentage of body weight used for egg production. Hence, there is a high probability that the parasitic infestation which affects the body weight of the infested female Fish will also affect the GSI value and by implication affects the quantity of egg produced. This will inadvertently affect the reproductive capability of the infested fish. This is also supported by the significant differences obtained between (i) the fecundity and relative fecundity values of the two years of investigation in which values in 2017/2018 were higher (ii) the parasitic prevalence and intensity of the two years of investigation in which values obtained in 2017/2018 were higher than 2016/2017.

Relationship between parasitaemia and total length: - The tests of significant difference between the means of the total length of infested and uninfested S. galilaeus in both sexes of the two years were not significant. This showed that parasitaemia had no effect on the total length of S. galilaeus in Oba Reservoir. Echi et al. (2009) were of the opinion that the larger the fish, the lower the infestation, they adduced decrease in the prevalence of infection in the larger fish to increase in mortality of infested fish, increase in the built up humoral and non-specific immunity against the parasite; they opined that as the small size fish survives the infection, it grows to occupy new niches and acquire better microhabitat against parasitic infestation. Olurin et al. (2012) worked on helminthes parasite of S. galilaeus and Tilapia zillii; they reported that there was no relationship between parasite burden and fish size.

Influence of parasitaemia on length-weight regression values: - The regression results showed that parasitic infestation of S. galilaeus in Oba reservoir had some little effects on the length weight relationship. The correlation coefficient (R2) value obtained for uninfested and infested male and female of the two years were high showing that the relationship had a good fit to the line of regression. However lower values were recorded for the infested specimens in both sexes, especially in female which was lower than 0.90 in the two years. This is an indication that the low R2 values obtained for infested fishes of both sex showed that the parasite probably had an effect on the weight or length of the fish.

Conclusion and Recommendation

Sarotherodon galilaeus was found to spawn all year round and exhibit multiple spawning in a year in Oba reservoir. The fish was infested with one Acanthocephalan; Neoechinorhynchus rutili, (Mueller, 1780), the metacercaria of a Trematode (Clinestomum tilapiae) and a nematodes; Procamallanus laevionchus (Wedl, 1862). The metacercaria was found in the buccal cavity while the acanthocephalan and nematode were found in the intestine. Parasitic prevalence and intensity was higher in females than males and was found to negatively affect the weights of infested females. It is concluded that there is a high probability that the parasitic infestation which affects the body weight of the infested female Fish will also affect the Gonado-somatic index value and by implication affects egg production; which will inadvertently affect the reproductive capability of the infested fish.

It is recommended that continuous monitoring of causes of parasitic infestation and infection are carried out, because of its adverse effect on reproductive capability of the fish species, which may result in depletion of the fish population in the aquatic environment.

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