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MANIPULATING THE SPAWNING TIME OF THE AFRICAN CATFISH (*CLARIAS GARIEPINUS*) USING TEMPERATURE AND PHOTOPERIOD

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ABSTRACT

The possibility of manipulating the spawning time of the African catfish (*Clarias gariepinus*) was tested so that its fry could be produced and available all the year round.

A total number of 120 of *Clarias gariepinus* immature females with an average weight of 80.52 ± 4.58 g were randomly divided into 8 groups and accommodated in 8 glass aquaria & 170 x 70x 50 cm each, representing 3 treatments and control (two replicates each). The first two aquaria (control) were subjected to the natural light (10L: 14D) and room temperature (18 – 21 °C). The second two aquaria (treatment 1) were also kept under same photoperiod as the control, however water temperature was increased and maintained at (27 – 28 °C). The third two aquaria representing treatment 2 were subjected to a longer photoperiod (15L: 9D) and their water temperature was kept as low as the control. Water temperature of the last two aquaria (treatment 3) was adjusted and maintained as high as that of treatment 2 (27 – 28 °C), however the photoperiod was similar to that of the second treatment (15L: 9D). Fish were fed 6 days a week at a rate of 2% of the total biomass using 25% protein pelleted diet. Feeding quantity was adjusted according to the total biomass weekly. Samples of fish were taken regularly from the odd aquaria to follow growth rate and check for maturity. Five samples were taken during the experimental run. The first sample was taken after 16 days from the beginning of the experiment. The second one was after 30 days from the beginning of the experiment. The third was carried out after 45 days The fourth and fifth were after 55 and 70 days from the start of the experiment, respectively. The fish samples were scarified and ovaries were extruded carefully and weighed to calculate the gonadosomatic index. Whenever fish of any treatment reach maturity stage and become fully ripe, fish of the other aquaria of the same

selected when they were ready to spawn and were artificially reproduced using injection with suspension of pituitaries of males from the same aquaria.

After 30 days from the start of the experiment, treatment 1 (15L: 9D, & room temperature) reached the ripe stage earlier than the other ones, 40 days earlier than the control group. Thirteen females out of 15 with an average body weight of 95.4 ± 3.82g responded to the injection. After 45 days from the beginning of the experiment treatment 3 (15L:9 D & 27 – 28°C) followed Treatment 1. The spawning time of treatment 3 started 25 days earlier than the control. Twelve females with an average body weight of 96.0 ± 2.22 g were stripped successfully out of 15. After 55 days, treatment 2 (15L: 9 D & room temperature) was the third one to reach the ripe-egg stage 15 days earlier than the control. Number of responding females was 11 with an average body weight of 97.1 ± 6.74 g. The last treatment that reached egg-ripening stage was the control after 70 days from the beginning of the experiment. Twelve females with an average body weight of 99.0 ± 5.26 g were injected and stripped. The mean values of egg/weight index percentage, fertilization percentage, hatching percentage and percentage of deformed larvae in the three treatments were not significantly different. Moreover, the spawning time of first group extended to overlap with that of the third one that extended in its turn to overlap with the spawning time of the second. The spawning time of the second treatment also extended to overlap with that of the control. Accordingly, there was an artificial spawning time (additional 40 days) that prolonged the natural spawning season and extended the availability of Clarias fry for, a longer period. Growth, gonadosomatic index, artificial spawning indices were also discussed.

INTRODUCTION

In the intensive fish farming availability of eggs and fry all the year round is very important in order to optimize the profitability of fish farming process. Thus the artificial induction of spawning and the ability to control reproduction of cultivated species is the solution, especially when fish farms deal with species that do not normally spawn in captivity or when the fry is not available when required or scarce in the wild. The hatchery is therefore obliged to keep its own broodstock and to manipulate the reproductive cycle as an essential condition to extend the availability of seed out of the natural period of

reproduction. The role of photoperiod and temperature is not negligible. Both ultimate and proximate factors are able to trigger the endocrine events leading to the final maturation and spawning (Shepherd & Bromage, 1988). Thus the manipulation of photoperiod and temperature as main cues in gonadal regulation and spawning became one of the means to adjust the timing of spawning to offer eggs and fry when they are demanded by fish farms. In this concern, some authors studied the role of photoperiod and temperature in freshwater fish.

Bon *et al.* (1999) studied the effects of accelerated photoperiod regimes on the reproductive cycle of the female rainbow trout. He concluded that early spawning was achieved when accelerated photoperiod regimes were applied.

Nishi (1981) studied photosensitive development of the ovary in the Mosquitofish, *Gambusia affinis affinis*. In his experiment, stimulation of ovaries was induced in fish exposed to a 16L-32D or a 8L-28Dlight cycle, though it did not occur in the fish maintained under a short photoperiod of 8L-16D.

Shaikh and Hafeez (1993) on cyprinid fish, *Cyprinion watsoni* assessed different photoperiod-temperature regimes using gonadosomatic index and histological criteria in different seasons, prespawning, spawning and post spawning. Their results revealed that long photoperiod-warm temperature accelerated gametogenic progress in the prespawning season. Short photoperiod-warm temperature had inhibitory or regression effect in most seasons. In the spawning season, warm temperature stimulated spawning and low temperature inhibited it regardless of photoperiod. Low temperature in long and short photoperiod initiated gonadal recrudescence in both sexes

Marshall and Bielic (1996) investigated the Periodicity of reproductive behaviour by the blue tilapia, *Oreochromis aureus*. Their observations assured that shifting the light cycle by seven hours resulted in a corresponding shifting in time of spawning.

De-March (1977 & 1978) combined between temperature and photoperiod on the induction of reproduction and growth of freshwater amphipod *Hyalella azteca*. He considered the photoperiod as the main cue in the induction and termination of reproduction, however active reproduction did not take place unless temperature was within certain range. Optimum reproduction and growth rates occurred in this range.

Other authors were interested in manipulating the environmental factors to examine the optimum conditions of reproduction; Jobling *et al.* (1995)on Arctic charr, *Salvelinus alpinus;* Chang, *et al.*(1993) on female ayu, *Plecoglossus altivelis* and Poncin (1992) on barbel, *Barbus barbus.*

Carriillo *et al.* (1993) on Sea bass (*Dicentrarchus labrax*) reported that spawning time could be advanced by using a month of long days in an otherwise constant short photoperiod.

The aim of this work was to test different temperature-photoperiod regimes on the reproductive behavior and growth of the African catfish *Clarias gariepinus* to improve the production of fry.

MATERIALS AND METHODS

The experiment started on 15/1/2001. As shown in Table (1), a total number of 120 Nile catfish *Clarias gariepinus* immature females with an average weight of 80.52 ± 4.58 g were randomly divided into 8 groups and accommodated in 8 glass aquaria & 170 x 70x 50 cm each, representing 3 treatments and control (two replicates each). A number of 5 males was taken randomly from a group of males with an average body weight of 80.16 ± 5.27 g and placed with females of each aquarium. The rest of male group were kept under the same conditions of the experiment for later use. The first two aquaria (control) were subjected to the natural light (10L:14D) and room temperature (21 – 22 °C). The second two aquaria (treatment 1) were also kept under same photoperiod as the control, however water temperature was increased and maintained at (27 – 28 °C). The third two aquaria representing treatment 2 were subjected to a longer photoperiod (15L: 9D) and their water temperature were kept as low as the control. Water temperature of the last two aquaria (treatment 3) was adjusted as high as that of treatment 2 (27 – 28 °C) however the photoperiod was similar to that of the second treatment (15L: 9D). The four aquaria of treatment 2 & 3 were placed together separate from that of the other two treatments. The photoperiods were adjusted using an automatic light timer to be switch on before it becomes dark to prolong the natural photoperiod; that was (10L :14D) on January, fifteenth 2001 when the experiment started, for additional 4 hours. Water temperature of treatment 1 & 3 was adjusted using heaters. Fish were fed 6 days a week at a rate of 2% of the total biomass using

25% protein pellets. Feeding quantity was adjusted according to the total biomass weekly. Samples of fish were taken regularly from the odd aquaria to follow growth rate and check for maturity. Five samples were taken during the experimental run. The first sample was taken after 16 days from the beginning of the experiment. The second one was after 30 days from the beginning of the experiment. The third was carried out after 45 days.The fourth and fifth were after 55 and 70 days from the beginning of the experiment respectively. The fish samples were scarified and ovaries were extruded carefully and weighed to calculate the gonadosomatic index. Whenever fish of any treatment reach maturity stage and become fully ripe, the time of ripening was recorded and fish of the other aquaria of the same treatment were checked for maturity. The fully ripe ones were selected when they were ready to spawn and were artificially reproduced using injection with suspension of pituitaries of males from the same aquaria. The method described by Abdel-Nasser and El-Ghobashy (2000) for artificial propagation of *Clarias gariepinus* broodstock was adopted. The data of artificial propagation of each treatment were registered, number of responding females; egg weight index percentage; fertilization percentage; hatching percentage and percentage of deformed larvae. Egg weight index percentage was calculated according to Abdel-Hakim and Abdel-Nasser (2001).

RESULTS AND DISCUSSION

The significance of the mean values of body weight and gonadosomatic index was greatly affected among means of the same treatment in the different samples at different time intervals. Regarding average body weights of females in the first sample, there was no significant difference among means of the different treatments as shown in Table (2). While in the second sample, a significant difference was found between average body weight of females of the first treatment, 99.03 ± 4.06 g and that of females of the control group, 90.33 ± 3.72 g ($p<0.01$). Whereas no significant difference was noticeable between average body weight of females of treatment 2 and 3 (91.35 ± 1.61& 95.25 ± 4.37) g, respectively, and that of the control as indicated in Table (3). In the third and fourth sampling times as represented in Tables (4 & 5), there were no significant differences between the different treatments and the control. Table (6) shows the average body weight and GSI of females and males of

treatment 1 in the fifth sampling time. The gonadal development of females as well as males of treatment 1 started to respond to the high temperature earlier than the other treatments after 30 days from the beginning of the experiment (40 days earlier than the control). Therefore, some females of treatment 1 started to be fully ripe and were ready to spawn since the GSI of the second sample of GSI reached 11.2 ± 0.47 %. Subsequently, females of the same treatment in the other aquarium were taken out and then checked for maturity. The fully ripe ones were separated and artificially reproduced by injecting them with pituitary suspension of males from the same aquarium. The rest were returned to the aquarium. The state of ripening of the remaining females and males was monitored. Whenever some fish reached the full ripe stage, they were injected and stripped and the data of responding females to the injection, absolute weight of stripped eggs, egg weight index percentage, fertilization percentage, hatching percentage and percentage of deformed larvae were recorded. Some females from this treatment (treatment 1) became ripe and could be stripped after taking the third samples (after 15 days from the first sample). At this time females of the third treatment started to show signs of egg ripening when GSI averaged 12.6 ± 2.11 % 45 days from the beginning of the experiment (25 days earlier than the control. The same procedures were adopted with fish of treatment 3. The time taken for all fish in treatment 3 to enter the ripe-egg stage overlapped with the time interval taken for all females of treatment 2 to display ripening features of eggs. Ten days after the beginning of the spawning time of fish of treatment 3, ripening precursors of fish of treatment 2 appeared. Hence GSI of some fish reached 13.2 ± 1.4% after 55 days from the beginning of the experiment and could be injected and stripped successfully (15 days earlier than the control). The control group of fish was the last one whose fish started to respond after 70 days from the beginning of the experiment when their mean value of GSI was 12.8 ± 0.51 %. Overlapping occurred also with fish of treatment 2 and the control group.

According to the previous data, the first treatment whose fish reached the ripe stage earlier than the other ones, 40 days earlier than the control, was treatment 1 (natural light & 27 – 28 °C). Thirteen females out of 15 with an average body weight of 95.4 ± 3.82g responded to the injection, table (8).The egg/weight index percentage, fertilization rate, hatching rate and percentage of deformed larvae was

10.0 ± 1.18, 85.2 ± 4.75, 75.3 ± 8.56 and 3.10 ± 0.25, respectively. Treatment 3 (15L:9 D & 27 – 28°C) followed treatment 1 after 45 days from the beginning of the experiment (25 days earlier than the control).Twelve females with an average body weight of 96.0 ±2.22 g could be stripped successfully out of 15. The egg/weight index percentage, fertilization percentage, hatching percentage and percentage of deformed larvae was, 9.67 ± 1. 5; 86.0 ± 4.19; 74.9 ± 4.34 and 2.15 ± 0.42, respectively. Treatment 2 (15L: 9 D & room temperature) was the third one to reach the ripe-egg stage after 55 days (15 days earlier than the control). Number of responding females was 11 with an average body weight of 97.1 ± 6.74 g. The last group of fish that reached egg-ripening stage was the control group after 70 days from the beginning of the experiment. Twelve females with an average body weight of 99.0 ± 5.26 g could be injected and stripped. The egg/weight index percentage, fertilization percentage, hatching percentage and percentage of deformed larvae was 10.12 ± 2.15, 83.70 ± 5.5, 72.6 ± 5.33 and 3.0 ± 0.7, for treatment 2, respectively and 9.20 ± 0.45, 84.0 ± 3.21, 73.9 ± 6.24 and 2.40 ± 0.92, for the control, respectively.

As indicated in Table (7), statistical evaluation of data of each treatment in the different samples revealed that, the average body weight of fish of the control in sample 1, 2, 3, 4 and 5, 83.5 ± 4.24; *90.33 ± 3.72; 94.0 ± 5.94; 96.0 ± 5.53 and 97.0 ± 5.01 g; respectively,* was significantly higher than that of zero sample (initial body weight). Average body weights of treatment, 1 in the first and second sample, were 88.3 ± 3.89 & 99.03 ± 3.86 g, respectively, and were significantly higher than that of the initial stock sample, 79.88 ± 2.7 g. The same trend was observed regarding average body weight of treatment 2. It was significantly higher in sample1, 2, 3 and 4, 91.39 ± 1.61; 93.24 ± 6.29 and 94.94 ± 4.36 g, respectively, than that of the zero sample, 79.88 ± 3.3 g. In treatment 3, average body weight of females in sample 1 (82.93 ± 6.11), was not significantly larger than the initial average body weight, 80.21 ± 4.7 g. However in sample 2 and 3, it was significantly larger (95.25 ± 4.37) and 3 (99.0 ± 5.42) g, than that in the zero sample.

There was highly significant increase in the mean value of gonadosomatic index (GSI) of females of treatment 1, 2 and 3 of the first sample (7.07 ± 1.01, 1.19 ± 0.3 & 2.72 ± 0.84 %, respectively) than that of the control (0.74 ± 0.08 %) as represented in table 2. A highly significant increase in GSI of females of treatment 1 (11.2 ± o.47 %) and 3 (7.83 ± 4.49%) of the second sample than that of the

control group (5.03 ± 0.81%). In the third sample ovaries of females of the third treatment developed faster than that of females of the control. GSI of the former one (12.6 ± 2.11 %) was significantly higher than that of the later 5.93 ± 1.08 %. However GSI of treatment 2, 6.95 ± 1.04 %, did not display significant increase than the control. As for the fourth sample, GSI of group 3 of fish reached significantly higher value of GSI, 13.2 ± 1.4 %, than that attained in fish of the control group, 6.95 ± 1.08 %.

Comparing the average values of GSI of females of each treatment in the different samples demonstrated that GSI of control fish in sample 2, 3, 4 and 5 (5.03 ± 0.81, 5.93 ± 1.08, 6.95 ± 1.04 & 12.8 ± 0.5 %) was increasingly higher than that in sample 1 (0.74 ± 0.08 %). Also mean value of GSI in fish of treatment 1 (11.2 ± 0.47 %) increased significantly in the second sample than in control (7.07 ± 1.01 %). The mean values of GSI of the second treatment reached significantly higher values in sample 2 (4.61 ± 0.29), 3 (6.95 ± 1.04) and 4 (13.2 ± 1.4 %) than that was obtainable in sample 1 (1.19 ± 0.3 %). A significantly higher mean values of GSI among fish of treatment 3 in the second (7.83 ± 0.49) and third sample (12.6 ± 2.11 %) than that of fish of the first sample (2.72 ± 0.84 %).

The same trend was detected regarding males of the different treatments in different samples. Average body weight of fish of treatment 1, 2 and 3 was not significantly different than that of the control in the first sample, 83.7 ± 2.36; 83.7 ± 5.04, 82.4 ± 3.78 and 82.28 ± 2.77 g, respectively.

Males of treatment 1 and 2 in the second sample had significant larger average body weight than that of the control, 91.23 ± 3.1, 92.3 ± 3.02 and 85.7 ± 3.49 g, respectively. While average body weight of males of treatment 3, 86.03 ± 5.33 g, did not differ significantly than that of the control.

Non of any treatment in the third sample differed significantly in their average body weight values than the control.

The attainable average body weight of fish of treatment 2 and the control in the fourth sample (90.15 ± 5.4, 96.0 ± 5.21 g) did not differ significantly.

Males of control group in samples 1 & 4 did not differ significantly in their average body weight than those of the initial stock (zero sample). While those of treatment 1 in sample 2, 3 & 5 had significantly larger average body weight than that of the zero

sample, 80.18 ± 2.96; 82.28 ± 2.77; 85.7 ± 3.49; 93.14 ± 4.89; 90.0 ± 21 & 93 ± 3.31 g; for sample 1, 2, 3, 4 and 5 respectively.

Average body weight of treatment 1 in second sample was increasingly larger than that of the initial weight in the same treatment, 91.23 ± 3.1 & 81.48 ± 5.71 g, respectively. Whereas in sample 1, it did not show significance, 83.7 ± 2.36 g.

The average body weight of males of treatment 2 in sample 2 & 3 was significantly larger than that of the initial weight, 92.3 ± 3.02; 90 ± 2.1 & 83.08 ± 5.2 g respectively. However males of the first(83.7±5.04g)and fourth sample(92.3±3.02 g) was not significantly different than that of the initial stock.

Concerning average body weight of males of treatment 3 in the third sample, it was significantly higher than that of males of treatment 3 in the zero time(92.15±4.77&80.72±5.47) g, respectively. Average body weight of treatment 3 in the first and second sample was not significantly different than in the zero group (82.4 ± 3.78, 86.03 ± 5.33 g), respectively.

Mean values of GSI of males in the first sample differed significantly in the different treatments than in the control. It was significantly higher in treatment 1,0.58 ± 0.11%, and 3, 0.48 ± 0.07%, than that in the control, 0.13 ± 0.04%, while no significant difference appeared between treatment 2, 0.22 ± 0.09, and the control.

In the second sample, the average values of GSI in the three treatments, 0.57 ±0.07; 0,47 ± 0.07 and 0.59 ± 0.17% respectively, were not significantly different than that in the control, 0.49 ± 0.06. The same trend was noticed in sample 3. Treatment 2 & 3 (0.5 ±0.03&0.55±0.06 %, respectively) did not show significant difference with the control group (0.53 ± 0.1 %) regarding mean GSI values. In the last sample, GSI of males of treatment 2, 0.57 ± 0.13 % was not significantly different than that of the control, 0.5 ± 0.99 %.

Highly significant increase in the mean values of GSI of fish of the control in sample 2, 3, 4 & 5 than that in sample 1, 0.13 ± 0.04; 0.49 ± 0.06; 0.53 ± 0.1; 0.5 ± 0.09 & 0.53 ± 0.09 %, for all samples respectively.There was no noticeable difference between mean value of GSI of treatment 1 in sample 1 and 2 (0.58 ± 0.11 & 0.57 ± 0.07%. respectively).

There were significant increases in the mean values of GSI of males of treatment 2 in sample 2 (0.47 ± 0.07%) and 4 (0.57 ± 0.3%) than that in the first sample (0.22 ± 0.09%). While it was not significantly different in sample 3 (0.5 ± 0.03%) than in sample 1.

In samples 1, 2 & 3, average GSI of males in treatment 3 was not significantly different, 0.48 ± 0.07; 0.59 ± 0.17 & 0.55 ± 0.06 respectively.

The daily weight gain of females of the different treatments is represented in Table (9). It was 0.32, 0.25, 0.25, 0.23 and 0.17 for the control group during the five time intervals of the experiment respectively. For treatment 1 it was 0.77 and 0.49. As for treatment 2 and 3 it was 0.33, 0.31, 0.23 and 0.2 for the former and 0.47, 0.44 and 0.35 for the latter.

The spawning time of *Clarias gariepinus* in the wild extends from April to June. The bigger sizes start to spawn first before the intermediate sizes then comes the turn of the smaller ones at the end of the spawning season (Abd El-Nasser and El-Ghobashy, 2000). In the present study, the spawning time of three groups of fish from the same size-group kept under high temperature-natural photoperiod, high temperature-long photoperiod and long photoperiod-room temperature regimes was accelerated. Artificial heating as well as long daylight provoked advanced shifts in the spawning time. Fish became fully ripe at 40, 25 and 15 days, respectively earlier than the control group (room temperature-natural photoperiod). Moreover, the spawning time of first group extended to overlap with that of the third one that extended in its turn to overlap with the spawning time of the second. The spawning time of the second treatment also extended to overlap with that of the control. Accordingly there was an artificial spawning time (additional 40 days) that prolonged the natural spawning season and extended the availability of *Clarias*, fry for longer period, as represented in Figure (1). Therefore, this study suggests that by exposing different groups of breeders of different sizes to different natural phase-shifted photoperiods and temproperiods regimes, eggs could be obtained during the whole year. This opinion coincides with Marshall and Bielic (1996) and Bon *et al.*, (1999). Worth mentioning, in the present investigation long photoperiod did not play the expected role. It was supposed that the spawning time of the third treatment, that exposed to both long photoperiod and high temperature (15L: 9D & 27-28 °C), would be preceding that of the first treatment that exposed to high temperature only. De-March (1998) considered that the photoperiod is the main cue in the induction of gonadal development. Nevertheless, this contradiction may be explained by a previous investigation (De-March, 1997) who assured that photoperiod does not radically modify

the time of maturation unless it falls within an optimum range of temperature Therefore, further investigations are needed in order that successive levels of temperature could be employed with constant levels of photoperiod and vice versa to determine the optimum temperature range within which photoperiod could play its role.

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Table 1. Number, average initial body weight and total weight of fish exposed to different light and temperature regimes.

Treat.	Aqua. No.	No. of fish		Average initial body weight (g)				Total weight (g)	
				+		>			
		+	>	Mean	SD	Mean	SD	Female	Male
T1	Aqua. 1	15	9	80.42[a]	4.40	80.18[a]	2.96	1206.3[a]	721.6
	Aqua. 2	15	5	81.25[a]	4.30	80.80[a]	3.88	1218.8[a]	404.0
T2	Aqua. 3	15	9	79.88[a]	2.70	81.48[a]	5.71	1198.2[a]	733.3
	Aqua. 4	15	5	83.03[a]	4.30	79.73[a]	3.07	1245.5[a]	394.3
T3	Aqua. 5	15	9	79.88[a]	3.30	83.08[a]	5.20	1198.2[a]	747.7
	Aqua. 6	15	5	80.14[a]	4.12	82.52[a]	5.76	1202.1[a]	412.6
T4	Aqua. 7	15	9	80.21[a]	4.70	80.72[a]	5.47	1203.2[a]	726.5
	Aqua. 8	15	5	79.3[a]	5.78	81.10[a]	6.94	1189.5[a]	405.5

Numbers with similar alphabetic letters within the same column are not significantly different.

Table 2. Gonadosomatic index and final average body weight of *Clarias gariepinus* females after 16 days of exposure.

Treatment		Gonadosomatic index GSI %		Average body weight (g)	
		+	>	+	>
Control	natural light (10L:14D) Room temperature.	0.74 ± 0.08	0.13 ± 0.04	83.50 ± 5.24	82.28 ± 2.77
T1	natural light (10L:14D) 27-28 °C	7.07 ± 1.01****	0.58 ± 0.11 ****	85.30 ±3.86	83.7 ± 2.36
T2	15L:9D Room temperature.	1.19 ± 0.30 **	0.22 ± 0.09	84.25 ± 3.4	83.7 ± 5.04
T3	15L:9D 27-28 °C	2.72 ± 0.84 ****	0.48 ± 0.07 ****	82.93 ± 6.11	82.4 ± 3.78

* sig. different than the control (p <0.05),

** sig. different than the control (p <0.02) ,

*** sig.different than the control (p<0.01),

**** sig. different than the control (p <0.001).

Table 3. Gonadosomatic index and final average body weight of *Clarias gariepinus* females after 30 days of exposure.

Treat.	Gonadosomatic index GSI %		Average body weight (g)	
	+	>	+	>
Control	5.03 ± 0.81	0.49 ± 0.06	90.33 ± 3.72	85.7 ± 2.49
Treat. 1 [R]	11.2 ± 0.47****	0.57 ± 0.07	99.03 ± 4.77***	91.23 ± 3.1*
Treat. 2	4.61 ± 0.39	0.47 ± 0.07	91.35 ± 1.61	92.3 ± 3.02**
Treat. 3	7.83 ± 0.49****	0.59 ± 0.17	95.25 ± 4.37	86.03 ± 5.33

[R] Indicates reached ripe stage.
* sig. different than the control (p <0.05), ** sig. different than the control (p <0.02),
sig. different than the control (p <0.01), * sig. different than the control (p <0.001).

Table 4. Gonadosomatic index and final average body weight of *Clarias gariepinus* females after 45 days of exposure.

Treat.	Gonadosomatic index GSI %		Average body weight (g)	
	+	>	+	>
Control	5.93 ± 1.08	0.53 ± 0.1	94.00 ± 5.94	93.14 ± 4.89
Treat. 2	6.95 ± 1.04	0.50 ± 0.03	93.24 ± 6.29	90.0 ± 2.1
Treat. 3 [R]	12.6 ± 2.11****	0.55 ± 0.06	99.00 ± 5.52	92.15 ± 4.77

[R] Indicates reached ripe stage. * sig. different than the control (p <0.05),
** sig. different than the control (p <0.02), ***sig. different than the control (p <0.01),
**** sig. different than the control (p <0.001).

Table 5. Gonadosomatic index and final average body weight of *Clarias gariepinus* females after 55 days of exposure.

Treat.	Gonadosomatic index GSI %		Average body weight (g)	
	+	>	+	>
Control	6.95 ± 2.28	0.50 ± 0.09	96.00 ± 5.53	90.0 ± 5.21
Treat. 2 [R]	13.2 ± 1.4****	0.57 ± 0.13	94.94 ± 4.36	91.15 ± 5.4

[R] Indicates reached ripe stage
* sig. different than the control (p <0.05), ** sig. different than the control (p <0.02),
sig. different than the control (p <0.01), * sig. different than the control (p <0.001).

Table 6. Gonadosomatic index and final average body weight of *Clarias gariepinus* females after 70 days of exposure.

Treat.	Gonadosomatic index GSI %		Average body weight (g)	
	+	>	+	>
control [R]	12.8 ± 0.51	0.53 ± 0.09	97.6 ± 2.9	93.15 ± 3.31

Table 7. Average gonad weight and average body weight of the different treatments at different time intervals.

After (days)	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
	Ave. gonad wt. (g)	Ave. body wt. (g)	Ave. gonad wt. (g)	Ave. body wt. (g)	Ave. gonad wt. (g)	Ave. body wt. (g)	Ave. gonad wt. (g)	Ave. body wt. (g)
0		80.42 ± 4.4		79.88 ± 2.7		79.88 ± 3.3		80.21 ± 4.7
16	0.6[Y] ± 0.1	83.50 ± 5.42	6.04 ± 1.01	88.3 ±3.86***	1.0 ± 0.24	84.25 ± 3.4	2.27 ± 0.78	82.93 ± 6.4
30	4.55 ± 0 .52	90.33 ± 3.72**	10.13 ± 0.82	99.03 ± 4.06****	4.21 ± 0.36	91.35 ± 1.6****	7.48 ± 0.8	95.25 ± 4.37**
45	5.60 ± 1.28	94.0 ± 5.94***			6.49 ± 1.14	93.24 ± 6.29***	11.94 ± 2.1	99.00 ± 5.52****
55	6.71± 1.24	96.0 ± 5.53****			12.56 ± 1.82	94.94 ± 0.36****		
70	12.49 ± 0.47	97.60 ± 2.9****						

* sig. different than 0 samole (p <0.05),
** sig. different than 0 sample (p <0.02),
***sig. different than 0 sample (p <0.01),
**** sig. different than 0 sample (p <0.001).

Table 8. Spawning indices of the four groups of *Clarias gariepinus* females that were exposed to different light and temperature regimes.

Treat.	Fish No.	No. of responding females	Ave. body wt. (g)	Egg/ wt. * index %	Fertilization %	Hatching %	% of deformed larvae
Treat. 1	15	12	99.0 ± 5.26	9.20 ± 0.45	84.0 ± 3.21	73.9 ± 6.24	2.40 ± 0.92
Treat. 2	15	13	95.4 ± 3.82	10.0 ± 1.18	85.2 ± 4.75	75.3 ± 8.56	3.10 ± 0.25
Treat. 3	15	11	97.1 ± 6.74	10.12 ± 2.15	83.70 ± 5.5	72.6 ± 5.33	3.0 ± 0.7
Treat. 4	15	12	96.0 ± 2.22	9.67 ± 1.5	86.0 ± 4.19	74.9 ± 4.34	2.15 ± 0.42

Table 9. Daily weight gain of the different treatments at the different samplingtime.

Time	daily wt. gain (g)			
	T1	T2	T3	T4
15/1 – 1/2	0.32	0.77	0.33	0.47
2/2 – 15/2	0.25	0.49	0.31	0.44
16/2 – 30/2	0.25		0.23	0.35
1/3 – 10/3	0.23		0.20	
11/3 – 25/3	0.17			

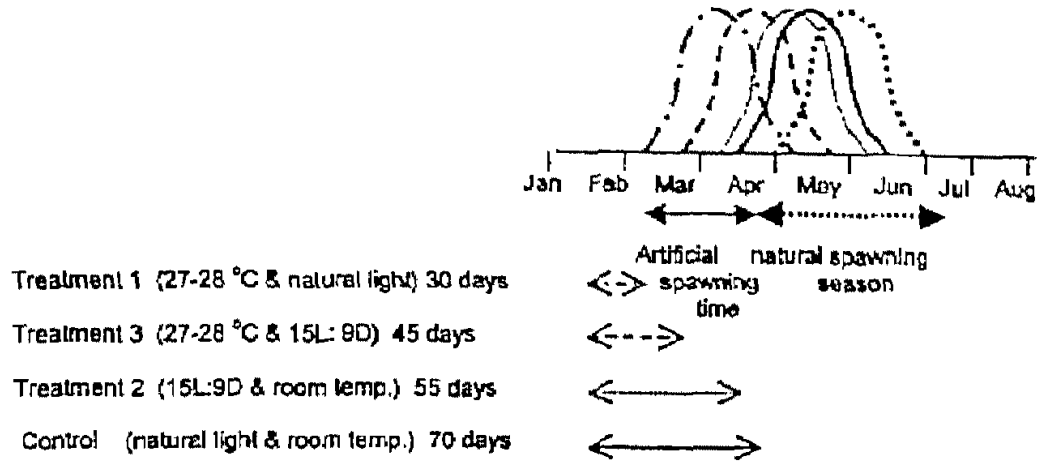

Figure 1. The natural spawning season could be extended for longer artificial spawning times by manipulating the phase- shifted photoperiod and temperature.