Comparative study of the growth of *Oreochromis niloticus* and *Sarotherodon galilaeus* in sewage ponds

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Abstract: Tilapia is a delicacy and of economic importance among freshwater capture fisheries. Some of these tilapia species are *Oreochromis niloticus* and *Sarotherodon galilaeus*. *O. niloticus* has better growth rate in fresh water culture than other tilapine species such as the *S. galilaeus* . However, due to pollution risk, sewage water might not support the growth of *O. niloticus* or any other tilapia species. The method used in this study was to assess the quality of physio-chemical parameters of sewage water in each of the sewage treatment ponds alongside the growth of *O. niloticus* and *S. galilaeus* in the ponds. The aim of this researech was to compare the growth of *O. niloticus* and *S. galilaeus* cultured in 1 m3 by volume of 1 mm net size mounted in the sewage treatment ponds in Tamale (Ghana) without supplementary feeding. The water quality was monitored every 2 weeks for six months to assess the levels of temperature, pH, turbidity, dissolved oxygen and ammonia. The overall mean weight of *O. niloticus* (19. 8 g) was higher than that of *S. galilaeus* (14. 0 g). The average growth rate of *O. niloticus* was higher (0. 13 g/day) than that of *S. galilaeus* (0. 12 g/day). Both *O. niloticus* and *S. galilaeus* in the aerobic pond showed a superior average growth rate of 0. 21 g/day and 0. 20 g/day respectively than fishes in the other ponds. Mean Dissolved Oxygen remained high (5. 9-7. 6 mg L^{-1}) in all the ponds throughout the study. Biological oxygen demand values between 3. 2 mg L^{-1} and 18. 9 mg L^{-1} were observed in the ponds between January and September. Ammonia-nitrogen or ionized Ammonia ranged from 1. 1 mg L^{-1} to 10. 0 mg L^{-1}. The minimum and maximum turbidity values in the ponds ranged from 32-480 NTU. High concentrations of toxic (un-ionized) ammonia exceeding 2. 0 mg L^{-1} occurred in all the ponds at certain times of the study and led to the death of *O. niloticus* and *S. galilaeus*.

Keywords: Hapa; *Sarotherodon galilaeus*; Omnivorous; *Oreochromis niloticus*; Phytoplankton; Sewage; Tilapia; Zooplankton

1 Introduction

Much attention has been focused on fish farming in Ghana to ensure the supply of protein levels required by the population. Research has been carried out to compare information on the culture performance of *Oreochromis niloticus* and *Sarotherodon galilaeus* in fresh waters using similar management strategies. However little work has been done on the culture of these species in sewage water. *S. galilaeus* and *O. niloticus* are two readily available fish species in Ghana and most parts of Africa. The choice of *O. niloticus* in Ghana is based on the widely recognized attractive culture attributes of the species (Popma and Lovshin, 1996), rather than on local experience and conditions such as in sewage water.

A limitation in natural food production in ponds reduce the growth rate of individuals (Brocksen et al., 1970). Because these two species are often cultured in Ghana, it is necessary to study and compare their growth development in sewage water to provide information on their performance using similar nutrient loadings without supplemental feed in the same waste water medium. The use of these species for the study is not an assumption that the other tilapia species are not cultured in Ghana or are not important; rather, these species were readily available at the time of the research.

Sewage consists essentially of urban residues as water, faecal material, bacteria and garbage (Ronald, 1995). Fish production in sewage-fed ponds is a common practice around the world, especially in Asia (Khalil and Hussein, 1997). Sewage-fed ponds contain high levels of N, P, Ca, and K (Pacey, 1978) and can produce as high as 7^{-10}Mg/ha/yr of fish depending on the sewage retention time (Kalbermatten et al., 1982). Environmental factors in sewage ponds that affect survival and growth of fish are both physico-chemical and biological (Zhou, 1986). To achieve fast growth and efficient performance the ponds should have optimal levels of these environmental parameters (Colt and Armstrong, 1981).

The objective of the study was to determine and compare the growth of two cichlid (tilapia) species: *O. niloticus* and *S. galilaeus* in sewage treatment ponds for six months without supplemental feeding and make some suggestions for production and management of sewage ponds.

2 Study area and methodology

The Tamale Metropolitan Assembly (TAMA) sewage treatment plant is located at Gbalahi, a village about 5 km away east from Tamale, Ghana with coordinates 9°24.45'N, 0° 51.00' W. The sewage treatment plant consists of two units of three ponds: a 2432 m^2 anaerobic pond (pond 2), a 1216 m^2 primary facultative pond (pond 3) and a 1216 m^2 secondary facultative pond (pond 4) in series, which are

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connected to a common 4464 m^2 aerobic pond (pond 5). One of the anaerobic ponds not in operation, was used as a control (pond 1).

The ponds are designed such that wastewater from the solid waste is drained into the control pond 1. Excreta are discharged into the anaerobic pond 2. Water becomes cleaner as it moves from pond to pond through controlled valves.

2.1 Measurement of temperature and pH of the ponds

Both pond temperature and pH were measured three times at different locations directly from a boat with a thermometer and a digital pH Meter (Model CG818) respectively at a depth of 20 cm.

2.2 Turbidity

Turbidity was measured immediately without altering the original sample conditions such as temperature and pH using the nephelometric method (APHA, AWWA, WEF, 1998) from three portions of the same sample. The average turbidity of each was calculated to represent the entire pond. Air and other gases trapped in the sample were removed by adding non-foaming type surfactant before the measurement. The sample was then agitated gently and allowed some time for the bubbles to disappear. The sample was poured into a cell and the turbidity was determined by the turbidimeter (Model 210p).

2.3 Determination of dissolved oxygen

Dissolved oxygen was determined by Azide modification of Winkler's method (APHA, AWWA, WEF, 1998). Water samples were collected in 1 L plastic bottles and transported at 10 ^oC to the laboratory in an ice chest. However, because Dissolved Oxygen (DO) was determined along Biological Oxygen Demand (BOD), dilution was done to the samples with a factor of 1:10 as pollution levels were high in all samples. Distilled water for dilution was collected in a 5 L plastic bottle and circulated before buffers of $MgSO_4$ (1 mL per litre of water) was added. DO was determined by collecting diluted samples in BOD bottles and adding 2 mL MnSO4, followed by 2 mL alkali-iodate-azide solutions to the samples and inverted several times to allow precipitation.

After the precipitate had settled, 2 mL concentrated H_2SO_4 were added to dissolve the precipitate, which gives an intensive yellow colour. A sample of the solution 100 mL was titrated with sodium thiosulphate solution (M/80 i. e. 0. 0125 M) to a pale yellow colour after which a 2 mL starch indicator solution was added and the titration was continued until the blue/black starch disappeared. The titration was repeated three times to determine the average value. DO content was calculated from the following formula (APHA, AWWA, WEF, 1998):

$$\text{Mg/L } O_2 = \text{Volume of titre} \times 101 \,/\, \text{Volume of sample use}$$

2.4 Determination of ammonia-nitrogen

The Nesslerization Method (APHA, AWWA, WEF, 1998) was used to determine ammonia in the samples after the addition of the Nessler's reagent. The yellow to brown colour produced was read in the range of 410 nm in a 1 cm light path inside a spectrophotometer. Turbid samples were filtered before the analysis. 1 mL of the supernatant was diluted to 50 mL with ammonia free water. Rochelle salt and Nessler reagent (2 drops each) were added and mixed. Samples were allowed to stand for 10 minutes to develop the colour before the absorbance was determined. The procedure was repeated three times to obtain the mean ammonia nitrogen.

2.5 Un-ionised ammonia (NH_3)

Un-ionised ammonia (NH_3) was calculated by multiplying conversion factor and ionized ammonia (NH_4^+) values obtained from ponds (Emerson et al., 1975).

2.6 Installation of nets in the ponds

Three replicates of 1. 0 m^3 nylon net (mesh size 1. 0 mm) were installed 10 m apart and 75 cm deep in each of the five ponds by means of nylon ropes and stones tied to the ends of the upper and lower corners.

2.7 Stocking of nets

O. niloticus and *S. galilaeus* were harvested from an experimental breeding pond at the CSIR Water Research Institute in Tamale. The fingerlings (9g ± 0. 2 g each) and (7cm ± 0. 2 cm each) were packaged in double transparent plastic bags (one inside the other) containing sufficient water and placed inside two insulated boxes built by the Institute for live fish transport. Temperature in the transport medium in the inner bag holding the fingerlings was reduced to 19 ^oC by adding ice chips to the water in the outer bags to calm the fish. Fish and bags were transported to the laboratory immediately. Before releasing the fingerlings into the nets, the bags were floated in the ponds until temperature of the transport water was equal to that of the ponds. The conditioning process was necessary to avoid death due to temperature shock. Each net was stocked with a mixture of 30 fingerlings of 50% each species and left in the nets for six months.

2.8 Fish sampling

Every two weeks, samples of ten *O. niloticus* and ten *S. galilaeus*individuals were collected from each net with a hand net on each sampling day for length and weight measurements.

2.9 Measurement of fish growth rate

The total length (cm) and weight (g) of ten specimens of each species sampled monthly from each 1 mm net size were measured individually with a measuring board and an electronic balance respectively.

Growth rate was determined from the equation (Bagenal, 1978): Gain in weight (g)/Time interval.

2.10 Relationship between weight and length of fishes

Relationship between weight and length of fishes and their condition factors were determined using the general equation log $W = a \times Lb$(Ricker, 1975), where W = weight of fish (g), L= length of fish (cm), $a$is a constant which can be positive, negative or zero and b is an exponent usually between 2 and 4, often close to 3. The weight and length of ten specimens of both *O. niloticus* and *S. galilaeus* was measured to determine the Weight-Length relationship in each pond.

2.11 Data analysis

Duncan's multiple-range test was used to test the differences in ponds quality and growth rate of tilapia species using Statistical Package for Social Scientist (SPSS for Windows, version 16. 0, Chicago SPSS Inc.).

3 Results and discussion

There was no difference in water temperature between the ponds ($p< 0. 5$). Mean monthly temperatures varied from 17 ºC in January to 29 ºC in November. The overall mean temperature over the study period was 24.3 ºC. The lowest temperature was recorded in January and corresponds with the low temperatures of the savanna region of northern Ghana. Chapman (1992) has reported that the temperature of a water body is influenced by the season, among other factors. The observed temperature range in this study did not adversely affect fish culture. BOD varied monthly in ponds, but no distinct pattern of variation was established. In general, low BOD (<8.0 mg L^{-1}) occurred in January while high BOD (> 12.0 mg L^{-1}) occurred in September. The lowest BOD was 3.2 mg/L in Pond 4 and the highest was 18.9 mg L^{-1} in Pond 3. The overall mean BOD was 7.4 mg L^{-1} over the study period. Wastewater normally showed BOD values up to 10 mg L^{-1}or more (European Inland Fisheries Advisory Commission Working Party on Water Quality Criteria for European Freshwater Fish, 1973) and a high BOD indicates oxygen depletion (Carla, 1992).

Ammonia-nitrogen or ionized Ammonia (NH_4^+) varied from pond to pond. The respective minimum and maximum NH_4^+ concentrations ranged from 1.1-1.8 mg L^{-1} and 2.6-10.0 mg L^{-1}. The lowest concentration occurred in the aerobic pond and the highest in anaerobic pond.

Mean turbidity recorded in Pond 3 (138 NTU) and pond 5 (139 NTU) was similar and significantly different from turbidity in each of the remaining ponds. The minimum and maximum turbidity values in the ponds ranged from 32-480 NTU. The variations in turbidity were very significant between ponds.

DO varied significantly between ponds. Mean DO remained high (5.9-7.6 mg L^{-1}) in all the ponds throughout the study. The lowest DO (3.3 mg L^{-1}) was recorded in Pond 2 and the highest (10.1 mg L^{-1}) was recorded in Pond 4. According to Baird (2000), dissolved oxygen levels help to determine how polluted a water body is as a result of contamination by organic substances. During the study, DO exceeded 5 mg L^{-1} and implied that the ponds were suitable for the culture of *O. niloticus* and *S. galilaeus* (EPA, 1998).

The depth of water in ponds averaged 1.1 to 2.5 m in the course of the study. In general, pond depth was directly related to the distance from the sewage discharge point (pond 2). Water levels in the ponds were adequate for fish culture.

High concentrations of toxic (un-ionized) ammonia (NH_3) exceeding 2.0 mg L^{-1} occurred in all the ponds at certain times of the study. The lowest (0.05 mg L^{-1}) and highest (3.04 mg L^{-1}) concentrations were recorded in pond 2 in December and pond 5 in January, respectively. In general, Pond 2 showed the lowest overall mean monthly concentration (0.95 mg L^{-1}), while Pond 5 showed the highest (2.15 mg L^{-1}) (Table 1).

Toxicity by ammonia is the result of the presence of the un-ionized ammonia (NH_3) in water (Palmer, 2001). Ammonia (unionized) concentrations between 0.05 and 2.0 mg L^{-1} would normally damage fish and concentrations above 2.0 mg L^{-1} would kill fish (Emerson et al., 1975).

Significant differences in pH were observed between ponds. The pH was generally high and ranged from 8.0 to 10.3 in all the ponds. High pH is a threat to fish life because it corresponds to high concentrations of un-ionized ammonia, which is toxic. Low pH upsets oxygen uptake and ion regulation, which can lead to skin degeneration whereas high pH is fatal (Shepherd and Romage, 1992) since it leads to a corresponding increase in Un-ionized ammonium (NH_3).

Table 1. Monthly un-ionized ammonia (NH_3) concentrations (mg L^{-1}) in the treatment ponds from August 2006 to February 2007.

Months	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
September	1.78	1.25	1.27	0.91	0.54
October	1.52	2.94	0.78	1.77	1.91
November	2.53	0.1	1.8	2.07	2.87
December	0.68	0.05	2.15	1.35	1.77
January	0.71	0.47	2.16	2.02	3.04
February	1.49	0.91	1.97	1.92	2.75

3.1 Weight and length growth

O. niloticus and *S. galilaeus* fingerlings were of uniform size (average weight 9.0 ± 0.2 g and average total length7.0 ± 0.2 cm) at the time of stocking. After six months of culture in hapas without supplemental feeding the minimum average size of *O. niloticus* was 37.0 g and the maximum was 54 g, while *S. galilaeus* had a minimum average of 25 g and a maximum of 45 g. The highest growth was obtained in the aerobic ponds. Table 2 shows the absolute growth rate of both species during the period of culture from all the ponds.

In general, both species grew at a similar rate in all the ponds, except that *O. niloticus* grew comparatively faster than *S. galilaeus* at least in ponds 1 to 3 (Table 1) and agree with literature that *O. niloticus* grows faster than *S. galilaeus*.

The overall mean weight gained by *O. niloticus* (19.8 g) from all the ponds was higher than that of *S. galilaeus* (14.0 g), which seems to indicate superior growth of *O. niloticus* than *S. galilaeus*. For each species, growth varied from pond to pond, with Pond 5 showing the highest growth rates for both species because both physico-chemical and biological parameters were more suitable 1n the aerobic pond than other ponds. Growth in total length (TL) showed a similar pattern.

Table 2. Absolute growth rate of *O. niloticus*and *S. galilaeus* in hapas inside sewage treatment ponds.

	Sewage	Initial	Final	Gain	Growth rate (%)
O. niloticus	Pond 1	9	25	16	64
	Pond 2	9	19	10	52.6
	Pond 3	9	32.7	23.7	72.5
	Pond 4	9	29.9	20.9	69.9
	Pond 5	9	37.4	28.4	75.9
S. galilaeus	Pond 1	9	24.8	15.8	63.7
	Pond 2	9	18.8	9.8	52.1
	Pond 3	9	23.9	14.9	62.3
	Pond 4	9	30.1	21.1	70.1
	Pond 5	9	37.4	28.4	75.9

Table 3. Summary of the relationship between total length and weight for *O. niloticus*and *S. galilaeus*.

Species	Pond	a	b	Growth
O. niloticus	1	0.06	2.5	Allometric
	3	0.02	3	Isometric
	4	0.03	2.8	Allometric
	5	0.02	3.1	Isometric
S. galilaeus	1	0.04	2.7	Allometric
	3	0.03	2.9	Allometric
	4	0.02	3.1	Isometric
	5	0.02	3	Isometric

3.2 Length-weight relationship

Growth in weight and the length showed strong positive correlation ($R^2 = 0.8$, $p \leq 0.5$) both species. The constants (a) and (b) were obtained from the equation log W = log a+b log L where a is the weight at the time of stocking and b was the growth rate of the species. It was observed that the smaller the value of a the bigger the value of b. Growth for *S. galilaeus* and *O. niloticus*were generally isometric (Table 3).

4 Conclusions

In conclusion both *O. niloticus* and *S. galilaeus* grew at similar rates in sewage ponds with a maximum weight gain of 28.4 g in the aerobic ponds. Comparatively, *O. niloticus* performed better in terms of growth at least in ponds 1 to 3 than *S. galilaeus*. However, fish culture in aerobic ponds is much desirable because growth in aerobic ponds was higher and the physico-chemical parameters in good quality than discharge and facultative ponds.

For effective management of sewage fish culture, the species should be allowed to move freely for both animal and plant food and not confined as in this experimental fish culture. Supplemental feeding may also be done to enhance fish growth. Sewage should be diluted to reduce toxicity of ammonia to reduce fish mortality. There is also the need for a collaborative effort between various national and municipal agencies since sewage fish culture has the capacity to reduce urban environmental pollution and the pollution of water bodies.

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