Comparison of brackish water growth performances of *Sarotherodon melanotheron* (Cichlidae) from three West African populations

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Introduction

Tilapia are common in tropical freshwater aquaculture, not only in Africa where they originated, but also in Asia and South America (PULLIN, 1988). Red tilapia, which are hybrids between *Oreochromis mossambicus* or *O. hornorum*, and *O. niloticus* or *O. aureus* are sometimes raised in sea water (WATANABE *et al.*, 1989). Culture of tilapia in lagoon and estuarine environments remains poorly developed because few of the species have both rapid growth and the ability to withstand marked variations in salinity (PAYNE, 1983). *Sarotherodon melanotheron* is a paternal mouthbrooding tilapia, which inhabits salt, brakish and freshwaters in West Africa (PAULY, 1976; PRUNET and BORANCIN, 1989;

TEUGELS and THYS VAN DEN AUDENAERDE, 1992). The growth rates of populations that inhabit lagoons in Côte d'Ivoire (LEGENDRE, 1986; LEGENDRE and ECOUTIN, 1989) are low (0.4 to 0.5 g/day for 100g fish). Therefore this species have never been inventoried as a good candidate for aquaculture in brackish or salt waters (STICKNEY, 1986). TREWAVAS (1983) showed that populations of *S. melanotheron* are morphologically differentiated and described five subspecies: *S. m. heudelotii* (DUMERIL, 1859), from Senegal to Guinea; *S. m. paludinosus* (TREWAVAS, 1983), in certain freshwaters near Dakar, Senegal; *S. m. leonensis*, (THYS VAN DEN AUDENAERDE, 1971), from Sierra Leone to Liberia; *S. m. melanotheron* (RUPPEL, 1853), from Côte d'Ivoire to Cameroon; *S. m. nigripinnis* (GUICHENOT and DUMERIL, 1859), from Equatorial Guinea to Angola. Recent genetic studies made on populations of *S. melanotheron* (POUYAUD, 1994; POUYAUD and AGNESE, 1996,) show that this species is composed of genetically well differentiated populations, and three genetic groups can be defined: (1) populations from Cameroon Senegal and Guinea, (2) populations from Sierra Leone to and (3) populations from Gabon and Congo. This level of differentiation may also imply that populations have physiological and behavioural differences. Consequently, comparisons of growth performance were made between three genetically and morphologically differentiated populations, from Senegal (*S. m. heudelotii*), Côte d'Ivoire (*S. m. melanotheron*), and Congo (*S. m. nigripinnis*), with the aim of assessing aquaculture potential.

Material and Methods

Test Fish

Fish from three populations of *S. melanotheron* were tested under intensive culture conditions in brackish water. The fish which were hatched in captivity were the offspring of wild parents. *S. m. heudelotii* (S) were collected from the Niayes of Thiaroye in the suburbs of Dakar, Senegal during April 1993 (32 individuals, mean weight 63g, 16 males and 16 females). Broodstock *S. m. melanotheron* (I) were obtained from Layo experimental station in Ebrié Lagoon (Côte d'Ivoire) in October 1993 (40 individuals, mean weight 70g, 20 males and 20 females) and broodstock *S. m. nigripinnis* (C) (16 individuals, mean weight 53g, 8 males and 8 females) were collected at Bas Kouilou (lower Kouilou drainage in Congo) during May 1993.

Imported broodstocks were held in quarantine for six months and were then transferred to Layo aquaculture station. Fish were held under conditions which prevented the release of exotic fish into the natural environment.

First experiment

The wild parental fish were kept in tanks (1m*1m*1m) for 21 days, and on day 22, all brooders were removed and fry sorted.

Triplicate groups of 100 fry (between one and three weeks old) from each population were stocked into concrete tanks (33 fish/m^3).

Each group was labelled C1, C2 and C3; originating from the Congo; S1, S2 and S3 for population from Senegal; and I1, I2 and I3 for population from Côte d'Ivoire.

The fry had mean initial weights varying from 0.22 to 3.79g (Table 1). The growth trial was conducted in 4m^3 (2m*2m*1m) concrete tanks, and water was renewed (3m^3/h) with brackish water pumped from the lagoon.

The 176-days experimental period (4 January to 30 June 1994) coincided with the dry and then the rainy seasons so the physical and chemical characteristics of the water varied with time: salinities from 6 (February) to 0 (June), temperatures from 31.5°C (April) to 29°C (June).

Dissolved oxygen, maintained by mechanical agitation, varied from 4.4 mg/l at 5:00 PM to 4.5mg/l at 8:00 AM. Turbidity also varied, with Secchi disc values ranging from 70 cm (February) to 10 cm (June).

measures	C1	C2	C3	S1	S2	S3	I1	I2	I3
IMW (g)	0.35	0.36	0.32	0.22	2.72	3.79	0.55	0.77	0.62
SE	0.11	0.11	0.11	0.09	0.94	0.39	0.24	0.39	0.29
FMW (g)	44.3	31.9	29.1	74.5	106.7	116.1	40.8	37.9	40.8
SE	10.1	6.9	4.7	8.9	9.6	12.8	7.3	4.5	7.8
SR %	22	60	70	55	77	72	84	91	87
SLOPE * 10^2	1.41	1.26	1.10	1.81	1.85	1.84	1.35	1.25	1.26
SE * 10^2	0.07	0.04	0.03	0.04	0.01	0.02	0.04	0.03	0.05
INT	1.39	1.25	1.25	1.31	1.74	1.94	1.37	1.39	1.47
R^2	97.7	98.9	99.3	99.6	99.9	99.8	97.7	98.9	99.3

Table 1
Growth performances of all groups in the first experiment. IMW and SE: initial mean weights and standard errors; FMW and SE: final mean weights and standard errors; SR%: survival rates percentages; SLOPE *10^2 and SE *10^2: slopes of the regression lines of the growth curves and standard errors multiplied by 10^2; INT: intercepts of the regression lines; R^2: the R-squared.

The fish were fed with crumbles (0.5 to 1.5mm; containing 30% protein, 6% lipid, 7% cellulose, Vit.A 8000 I.U./kg, Vit.D3 2000 I.U./kg, Vit.E 100mg/kg, Vit.C 130mg/kg), twice every day. Every 15 days, the total weight of each tank of fish was monitored to adjust the daily feeding rate wich corresponded to 5% of the total biomass. Fish were individually weighed at the beginning and at the end of the experiment. During the experiment the total weight of each group, the number of individuals, the presence of mating individuals (individuals with sexual coloration) and the presence of mouthbrooding males were noted.

Second experiment

In the second experiment two populations originating from Senegal and Côte d'Ivoire were compared. Parental fish were held in tanks

(1m*1m*1m) for 56 days, and on day 57, all adults were removed and fry sorted. Three replicates of 50 fish from each population were placed in 1.6m^3 cages (31 fish/m^3), and labeled Sx, Sy, Sz and Ix, Iy, Iz. for Senegal and Côte d'Ivoire populations respectively.

Mean weights of the fish in all six replicates were similar (Table 4), weights (around 10g) corresponding to 6-week old fish in the Senegalese population and 8-week old fish in the Côte d'Ivoire population.

The 1.6m^3 (1.5m*1.5m*0.7m) cages, made of 6mm (side) mesh net, were held in place with stakes and rested on the bottom of a 1ha pond pump-fed with brackish or sea water. The 168-day experimental period (3 November 1994 to 20 April 1995) coincided with the dry season. Salinity varied over time: from 18 (November) to 35 (April). Water temperatures ranged from 29 to 31°C. Dissolved oxygen varied little during the experiment, averaging 6.0 mg/l at 8:00 AM and 12.5mg/l at 5:00 PM. The water was light green in colour and there was little suspended mineral matter.

The feeding and sampling protocols were as in the first experiment.

Data analysis

The survival rate was noted for each experiment. The different values observed were tested using a Chi^2 test (SNEDECOR and COCHRAN, 1957)

In order to compare growth rates, cube roots of weigths were taken, and a linear model applied: $Y=aX^{1/3}+b$, where Y is time in days and X the mean weight in g.

Growth rate equations were calculated from day 14 onwards to account adaptation of the fish to their new rearing environment.

Regression equations were compared for differences of slopes using ANCOVA F-test on mean squares (SNEDECOR and COCHRAN, 1957).

Results

First experiment

The results are summarized in Table 1.

Survival rates were not statistically different (Chi^2 Test, 5%) except for C1 replicate which showed the lowest survival rate (22%). Fish of the Côte d'Ivoire population showed the best survival (mean of 87%) whereas cumul was lowest in the Congo fish (mean of 51%), this value was caused by the low survival noted for the C1 replicate. Most mortalities occurred early in the experiment at a time when the fish were smallest and the salinity of the water highest.

The slopes and intercept of the growth rate equations for each replicate are shown in Table 1.

Cube roots transformation of the data enabled growth rates (slopes of the equations) to be compared. Table 2 summarizes the results of the statistical comparison (F test on mean squares) of the different slopes observed. Despite there being differences in initial weights in the three S groups, the corresponding slopes were not significantly different ($p>0.05$). During the experiment the growth of these groups followed the same model. This observation enables us to compare the slopes of the three S population groups with those of the C and I populations. In I population the slopes of the three groups were not significantly different ($p>0.05$). In C population, C3 group show a significantly lower slope than C1 group ($p>0.01$). Slopes observed in population S were statistically higher ($p<0.001$) than those observed in populations C and I while these two populations have not statistically different slopes except C3 group which had a statistically significant lowest slope with I1 group ($p>0.001$). In all groups there was no difference in weight between males and females.

Replicates	S3	S2	S1	I3	I2	I1	C3	C2
C1	***	***	***	~	~	~	*	~
C2	***	***	***	~	~	~	~	
C3	***	***	***	~	~	**		
I1	***	***	***	~	~			
I2	***	***	***	~				
I3	***	***	***					
S1	~	~						
S2	~							

Table 2
Statistical comparison (F test on mean squares) of the different slopes of the equations of the growth rates curves observed in the first experiment, with ~: P>0.05, *: 0.05>P>0.01, **: 0.01>P>0.001 and ***: P<0.001.

	First experiment			Second experiment	
Sexual characters	C	S	I	S	I
Appearence of first sexual colorations					
mean age of fishes (day)	70	91	70	154	154
Mean Weight (g)	8	26	7	93	47
Appearence of first spawn					
mean age of fishes (day)	98	133	98	168	168
Mean Weigh (g)t	9	56	13	107	52

Table 3
Mean age (days after hatching) and mean weigth of fish at the appearances of the first sexual colorations and the first spawns in both experiments.

Sexual dimorphism in body coloration of mature individuals of the three populations differed in both expression and time:

- mature males of Côte d'Ivoire Population permanently have metallic yellow opercula, whereas females have transparent opercula which show the red colour of the gills;

- when fish of the S population are spawning both sex have a black coloration on the edge of the caudal fin and at the throat;
- mature fish of both sex in the Congo population permanently display numerous black spots concentrated under the throat.

Table 3 summarize the observations. The appearence of sexual coloration and first spawn were simultaneous in both C and I population while it occured later in S population.

Second experiment.

The results are summarized in Table 4. The differences observed in survival rates (from 78 to 90%) was not significative (Chi^2 Test, 5%) despite the fact that I groups showed the highest values. In I population there was no initial mortality, but a slight morbidity appeared after the 50th day and continued through the end of the experiment. In the S population mortalities were noted during the first 30 days and disappeared thereafter.

Measures	Sx	Sy	Sz	Ix	Iy	Iz
IMW (g)	10.1	7.9	8.8	8.9	10.2	9.3
SE	1.2	0.8	0.9	1.2	1.4	1.4
FMW (g)	152.2	146.8	156.2	76.2	83.4	83.1
SE	24.3	19.1	20.3	19.0	23.3	22.4
SR %	82	78	80	86	90	88
SLOPE*10^2	1.73	1.75	1.80	1.36	1.39	1.43
SE*10^2	0.04	0.08	0.05	0.06	0.04	0.04
INT	2.78	2.74	2.71	2.28	2.32	2.27
R^2	99.4	98.1	99.2	98.3	99.2	99.1

Table 4
Growth performances of all replicates in the second experiment.
IMW and SE: initial mean weights and standard errors; FMW and SE: final mean weights and standard errors; SR%: survival rate percentages; SLOPE *10^2 and SE *10^2: slopes of the regression lines of the growth curves and standard errors multiplied by 10^2;
INT: intercepts of the regression lines; R^2: the R-squared.

The equations of the growth rate curves are shown in Table 4 (slope, intercept and R^2). Table 5 summarize results of the statistical comparison (F test on mean squares) of the different slopes observed. No significant differences were found between the intrapopulation slopes ($p>0.05$) whereas the interpopulation slopes were significantly different ($p<0.05$). In all groups, there was no difference in weight between males and females.

The appearance of secondary sexual characteristics and spawns (Table 3) occurred simultaneously for both populations when fish were 154 and 168 days old respectively.

Replicates	Sz	Sy	Sx	Iz	Iy
Ix	***	**	***	~	~
Iy	***	***	***	~	
Iz	***	**	***		
Sx	~	~			
Sy	~				

Table 5
Statistical comparison (F test on mean squares) of the different slopes of the equations of the growth rates curves observed in the second experiment, with ~ : P>0.05, *: 0.05>P>0.01, **: 0.01>P>0.001 and *** P<0.001.

Discussion

In both experiments, though survival rates were not statistically different (except for C1), the I groups always had the lowest mortalities. It can also be noted that this survival was characterized by a high initial mortality for population S and C. This could be due to the non-indigenous status of these two populations, rendering them more sensitive to the stress of manipulations. In these conditions, the densities of I groups were always higher than those of S. groups. This could affected their growth rates. LEGENDRE *et al.* (1989) showed that rearing densities varying from 20 to 150 fishes/m^3 do not affect growth rates of *S. melanotheron* from Côte d'Ivoire. Our results also showed that the S1 group in the first experiment which had a low survival rate did not have a higher growth rate value. For these raisons, it is likely that survival rates and the final densities observed in both experiments (25 fish/m^3 for S, and 30 fish/m^3 for I) did not affect the growth performances of each S and I group. In C population, C1 group had the higher growth rate and the lowest survival rate. Final density in C1 was 7 fishes/m^3. This density is far from those used in LEGENDRE *et al.* (1989) and the others observed in this study. Then we can conclued that population S had significantly higher growth rates than population I and C.

Comparison of the growth rates within each population for both experiments showed no statistically significant differences ($p>0.05$).Therefore fish from this species had the same growth rate at salinity varying from 0 to 35g/l. On the contrary, reproductive behaviors were different in both experiments. The first sexual coloration and first spawn occurred earlier in the first experiment (Table 3). In this experiment fish from S population reproduced later than those of two other populations. No differences were observed between S and I populations in the second experiment. LEGENDRE and ECOUTIN (1996) have shown that the time of the first appearence of sexual coloration and fecundity were different in wild, intensive and extensive captive conditions. Our results showed that salinity could also affect the reproductive behavior of this species. From these results it clearly apears that population from Senegal is a potential candidate for aquaculture, especially in waters such as lagoons or estuaries where the salinity varies. More studies are necessary to know if this growth capacities are consistent throughout the subspecies *Sarotherodon melanotheron heudelotii* or specific only to those populations living in the marshy areas of Dakar. It would therefore be useful to sample this subspecies throughout its distribution, which extends from Senegal to Guinea, and then to compare the zootechnical performances of the different populations.

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