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Does light duration (photoperiod) have an effect on the mortality and welfare of cultured *Oreochromis niloticus* and *Clarias gariepinus*?

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Abstract: One hundred and eighty juveniles of *Oreochromis niloticus* with a respective smean total length and weight of 7.30 ± 0.5 cm and 7.05 ± 0.5 g and 180 fry of *Clarias gariepinus* with a mean total length and weight of 14.90 ± 0.1 cm and 32.10 ± 0.5 g were separately cultured in 3 replicates in 18 plastic tanks (1 × 1 × 0.5 m; 200 L), 9 for *O. niloticus* and 9 for *C. gariepinus*, for photoperiods of 24 L: 0 D, 0 L: 24 D, and 12 L: 12 D for 13 weeks. Mortality and welfare impairment were evaluated daily. Mortality was significantly higher ($P < 0.05$) for the 0 L: 24 D photoperiod among *O. niloticus* and significantly higher ($P < 0.05$) for the 24 L: 0 D photoperiod among *C. gariepinus*. In general, mortality was significantly higher ($P < 0.05$) among *O. niloticus* than in *C. gariepinus*, with mortality being very high in the first 5 weeks of culture in the 2 species in all 3 photoperiods. Mortality was probably due to stress in the tanks arising from poor acclimatization to the environmental conditions, feeding inhibition, cannibalism, and maladjustment to the light/dark rhythmic cycle. The 0 L: 24 D photoperiod had a profound effect on the welfare of the juveniles of *O. niloticus*, and 24 L: 0 D compromised the welfare of the juveniles of *C. gariepinus*, as shown by the nonintrusive welfare indicators. The 2 unfavorable photoperiods manifested in stress conditions that caused injuries and affected swimming activity, behavior, coloration, and growth. If welfare challenges arising from photoperiodism are taken into account during culture of the species with photoperiodic manipulation, the species' mortality will be decreased and the farmer's profits will increase.

Key words: *Oreochromis niloticus*, *Clarias gariepinus*, photoperiod, mortality, stress, welfare, water quality

1. Introduction

Most studies have concentrated on the effect of photoperiod on the growth and other body parameters of several species of fish, but very few studies have addressed the effect of different photoperiods on the mortality and welfare of tropical African fish species, especially highly cultured species such as the African catfish *Clarias gariepinus* and the Nile tilapia *Oreochromis niloticus*. Varying photoperiods have been used to increase the growth of different stages of fish species, reduce sexual maturation, and vary the time of spawning (Stevenson, 2007). The use of photoperiod manipulations for these purposes has been implicated in compromising the welfare of fish, as reviewed by the Fisheries Society of the British Isles (FSBI, 2002), Hastein (2004), Burgos et al. (2004), and Huntingford et al. (2006), among others, but with little research undertaken on the implications of photoperiod manipulations on fish welfare. Welfare of fish is linked to the fish being healthy, comfortable, well-nourished, safe, and able to express their innate behavior, and not suffering from unpleasant states such as pain, fear, or distress.

Different rates of mortality have been recorded in fish species cultured under different photoperiod regimes. For example, Giri et al. (2002) reported the lowest survival in a continuous 24-h dark/light regime (0 L: 24 D). Burke et al. (2005) recorded lower mortalities in Arctic char cultured under a 24-h continuous photoperiod (24 L: 0 D), while Aride et al. (2006) observed no mortality in tanbaqui (*Colossoma macroponum*) when cultured under 3 photoperiods of 24 h of light, 24 h of darkness, and 10 h of light and 14 h of darkness. Shan et al. (2008) and Freitals et al. (2009) showed that photoperiodism affected the mortality of Miiuy croaker larvae *Miichthys miiuy* and pejerry larva *Odontesthes argentinensis*, respectively. The highest mortality was recorded in African catfish *Clarias gariepinus* when cultured in 24 h of continuous light (Mino et al., 2008), while the best survival rate of fingerlings of *O. niloticus* occurred in the 0-h light group according to Bezerra et al. (2008). Appelbaum and Kamler (2000) also reported that continuous light increased mortality in *Clarias gariepinus* larvae, while Solomon and Okomoda (2012) linked increased mortality in *Clarias gariepinus* juveniles to a regime with a higher incidence of light.

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The aim of this work was to investigate the effect of 3 different light regimes (photoperiods) on the welfare and mortality of the Nile tilapia *Oreochromis niloticus* and the African catfish *Clarias gariepinus*, which are the 2 most important and highly cultured tropical African fish.

2. Materials and methods

One hundred and eighty juveniles of *O. niloticus* with an average mean weight of 7.05 ± 0.05 g were obtained from a private fish farm (Nefraday Nigeria Ltd.) in Ilorin, Nigeria, and 180 fry of *Clarias gariepinus* with an average mean weight of 1.00 ± 0.2 g were purchased from the hatchery of the Kwara State Ministry of Agriculture, Ilorin, Nigeria. The fishes were transported to the fish laboratory of the University of Ilorin, Ilorin, Nigeria, where they were acclimatized for 1 week in laboratory conditions set for the experiment in 6 plastic tanks of 200 L filled with borehole water before the start of the experiment. After the period of acclimatization, the fish were distributed randomly into 18 plastic tanks (1 × 1 × 0.5 m; 200 L), 9 for *O. niloticus* and 9 for *C. gariepinus*, corresponding to 3 replicates for each photoperiod of 24 h of continuous light (24 L: 0 D), 24 h of continuous darkness (0 L: 24 D), and 12 h of light and 12 h of darkness (12 L: 12 D). Each tank was stocked with 20 individual fish, and the inside of the tanks had black coloration. Fish in 0 L: 24 D were placed in a well-ventilated dark room, while fish in 24 L: 0 D were illuminated with a 40-W fluorescent lamp with a light intensity of 400 lx at the water surface. Fish in 12 L: 12 D were placed in natural daylight and darkness for 12 h each at the time the experiment was done. The fish were fed with commercial Coppens feed twice daily (0800 and 1800 hours) at 5% of body weight. The feed composition was 45% protein, 12% fat, 9.55% oil, 1.5% crude fiber, and 1%–2% total phosphorous. The experiment was conducted for 13 straight weeks (91 days).

Fish were sampled for survival and mortality daily by the use of a hand net to count the numbers of surviving and dead fish in each tank at each sampling time. Survival was calculated using the following formula:

$N_t - N_o$,

and survival percentage was calculated using the following formula:

$N_t - N_o \times 100$,

where N_t = number of fish stocked and N_o = number of dead fish.

Mortality was calculated as the initial number of fish stocked minus the number of surviving individuals, and percentage mortality was calculated as:

$$\frac{N_o}{N_t} \times 100.$$

Evaluation of fish welfare in each photoperiod tank was done visually daily through the use of nonintrusive signs and danger signals without involvement of complicated laboratory analysis. The signs and signals used include growth, behavior, morphological anomalies, swimming activity, injuries, color, and mortality.

Physicochemical parameters of the tank water such as dissolved oxygen, dissolved carbon dioxide, temperature, and pH were measured weekly with the aid of a Lamotte Aquaculture Lab Model SCL-08. The water in the tanks was changed weekly to reduce stress for the fish.

Data are expressed as means ± SE. One-way ANOVA and Duncan's multiple range tests were used to test significant differences between the photoperiod groups and between species at $P < 0.05$.

3. Results

The mortality and survival results for *O. niloticus* and *C. gariepinus* in the 3 photoperiods are presented in Table 1. In *O. niloticus*, mortality was significantly higher ($P < 0.05$) in total darkness (0 L: 24 D) than in the 24 L: 0 D photoperiod, while the 12 L: 12 D photoperiod had the least mortality. In *C. gariepinus*, mortality was significantly higher ($P < 0.05$) in total light (24 L: 0 D) than in total darkness (0 L: 24 D), while 12 L: 12 D had

Table 1. Survival and mortality rates of *O. niloticus* and *C. gariepinus* under 3 different photoperiods.

Photoperiod	Initial number stocked	Number of survival	Percentage survival	Number of mortality	Percentage mortality
24 L: 0 D *O. niloticus*	60	36	60	24	40
0 L: 24 D *O. niloticus*	60	14	23.3	46	76.7
12 L: 12 D *O. niloticus*	60	48	80	12	20
24 L: 0 D *C. gariepinus*	60	38	63.3	22	36.7
0 L: 24 D *C. gariepinus*	60	46	76.7	14	23.3
12 L: 12 D *C. gariepinus*	60	52	86.7	8	13.3

the least mortality. The survival rate of the 2 species in the 3 photoperiods is inversely proportional to the mortality rate, with the highest survival found in the photoperiod group with the lowest mortality, while the lowest survival rate was found in the group with the highest mortality. Between the 2 species, mortality was significantly higher ($P < 0.05$) in *O. niloticus* than in *C. gariepinus*. Mortality was significantly higher ($P < 0.05$) between the 2 species over time, particularly in the first 5 weeks of culture.

The nonintrusive welfare indicators used in assessing the welfare of the 2 species in the 3 photoperiods are presented in Table 2. There were no morphological anomalies observed in either species, but there were behavioral, swimming, color, and growth differences between the 2 species in the 3 photoperiods. Injuries on the body were also observed.

Water quality parameters of the tanks showed that dissolved oxygen and carbon dioxide contents of the tanks were 4.0–8.5 mg/L and 0.01–0.05 mg/L respectively, while temperature was in the range of 26.0–28.0 °C and pH varied between 6.5 and 7.5.

4. Discussion

Many studies have shown that light manipulation (photoperiodism) can be used to modulate fish growth and sexual maturation in fish culture. Photoperiodism has also been demonstrated to compromise fish welfare in aquaculture (FSBI, 2002; Hastein, 2004; Burgos et al., 2004; Huntingford et al., 2006; Stevenson, 2007), which often leads to mortality. Different species of fish at different stages of life respond to different photoperiods for their growth, gonadal maturation, spawning, and feeding rhythms. Different photoperiods will also impair the welfare of fish and cause mortality in different species of fish at different stages of their life.

This investigation revealed that continuous darkness (0 L: 24 D) had a significant impact on the mortality and welfare of the juveniles of *O. niloticus*, while continuous light (24 L: 0 D) had a significant impact on the mortality and welfare of the juveniles of *C. gariepinus*. The mortalities recorded in the 2 species were probably due to stress in the tanks. The stress factors arose from poor acclimatization to the environmental conditions (water quality) and responses in feeding time in the tanks. Giri et al. (2002) and Burke et al. (2005) gave a similar explanation of feeding inhibition and feeding-time responses for the mortality recorded during photoperiod treatment of fish species. Most of the deaths in the 2 species and in all 3 photoperiods were recorded in the first 5 weeks of the experiment, but those of *O. niloticus*, especially in the 0 L: 24 D photoperiod, were found throughout the 13 weeks of the experiment. Similar results were obtained by Cerqueira and Bagger (2001) in fat snook, Bast (2001) in *O. niloticus*, Burke et al. (2005) in Arctic char, Mino et al. (2008) in *C. gariepinus*, and Shan et al. (2008) in the larvae and juveniles of Miiuy croaker. The mortality recorded in *C. gariepinus* could also have come from the stressful effects of light and the cannibalistic tendency of the growing juveniles in the 24 L: 0 D tank. Kozlowski and Poczyczynski (1999) reported a similar scenario among European catfish larvae, while Almazán-Rueda (2005) observed that stress was the cause of mortality in *C. gariepinus* subjected to different photoperiods, with the lowest survival in the 18 L: 6 D photoperiod. Hecht and Appelbaum (1988) noted that cannibalism has been observed in fish species reared under controlled conditions and fed to satiation. The natural light/dark rhythm cycle to which the 2 species were accustomed in their natural habitat (innate behavior) was responsible for the low mortality noted in the 12 L: 12 D photoperiod. Stressful conditions in the tanks probably caused the mortality. Low mortality has also been observed in several species cultured under natural photoperiods (Kiyono and Hirano, 1981; Tuckey and Smith, 2001; Canavate et al., 2006).

Table 2. Welfare assessment of *O. niloticus* and *C. gariepinus* under 3 different photoperiods.

Welfare indicators	24 L: 0 D *O. niloticus*	0 L: 24 D *O. niloticus*	12 L: 12 D *O. niloticus*	24 L: 0 D *C. gariepinus*	0 L: 24 D *C. gariepinus*	12 L: 12 D *C. gariepinus*
Behavior	Active	Suppressed	Active	Suppressed	Active	Active
Morphological anomalies	None	None	None	None	None	None
Swimming activity	Very active	Suppressed	Active	Suppressed	Active	Active
Injuries	None	Found on the body	None	None	Found on the body	None
Color	Normal	Normal	Normal	Black	Dark	Normal
Growth	Highest	Moderate	Lowest	Moderate	Highest	Lowest
Mortality	Moderate	Highest	Lowest	High	Low	Lowest

In some other experiments on fish mortality and photoperiod treatments, Aride et al. (2006), Sampaio et al. (2009), Alvarez-Rosario et al. (2009), and Faramorzi et al. (2011) found very insignificant or no mortality in fish species cultured under different photoperiods. It could therefore be deduced that mortality of fish species under different photoperiods is related to the conditions in the tank, adaptation of the species to those conditions, age of the fish, and the fish species.

The nonintrusive welfare indicators used in this work showed that continuous darkness (0 L: 24 D) had profound effects on the welfare of the juveniles of *O. niloticus*, while continuous light (24 L: 0 D) compromised the welfare of the juveniles of *C. gariepinus*. The 2 unfavorable photoperiods manifested in stress conditions in the fish species. Although morphological abnormalities were not observed in the 2 species, their swimming activity, behavior, coloration, and growth were distorted, with injuries observed on the bodies of individuals of both species. The injuries in *O. niloticus* probably resulted from collisions while searching for food in the dark, since *O. niloticus* is a visual feeder and photophilic. According to Merighe et al. (2004), agonistic behavior in *O. niloticus* is affected by background color. The injuries in *C. gariepinus* could also be from cannibalism and aggression during feeding in the dark, as noticed by Almazán-Rueda et al. (2008). The injuries might even be responsible for mortality in both fish species. Chronic stress might have caused the welfare impairment, while acute stress might be responsible for mortality (Pickering, 1998; Damsgard et al., 2006). The unfavorable photoperiods could have also affected the immune systems of the species, resulting in the observed deviations in the normal welfare behavior of the species. Pottinger and Pickering (1992) and Burgos et al. (2004) reported that artificial photoperiods affect the immune system of rainbow trout, leading to mortality. The observed 'normal' welfare conditions in the 12 L: 12 D photoperiod in the 2 species were a result of their innate behavior being displayed in their natural photoperiod.

A direct relationship between welfare and mortality was found in this work. High mortality is indicative of serious welfare impairment. In order to reduce mortality to the barest minimum even in the best photoperiod such as 24 L: 0 D for *O. niloticus* and 0 L: 24 D for *C. gariepinus*, it is recommended to acclimatize the species for at least 4 weeks, as well as reduce the conditions in tanks that could bring stress in these photoperiods before the culture of the species. If photoperiod manipulations are to be used in modulating the growth of the species in aquaculture, it is best to consider the effects of the alteration in light regimes on the welfare of the fish. Smart-tag technology should be employed in production systems to monitor and document their welfare status, optimize production, and give early warning signs of welfare problems in the tanks and among the species. Welfare assessment systems, like the one developed for Atlantic salmon called 'Welfaremeter', could be developed for the species. Doing this will increase the species quality and acceptability and increase the profits of the farmers.

A combination of many welfare indicators, including intrusive signals such as measurement of cortisol, lactate, and glucose, as well as nonintrusive signals like ventilation rate, should be used in assessing the welfare of the fish species. However, further research is needed to determine the extent of alterations in light/dark rhythm cycles on the species' welfare so as to ascertain to the fullest the impacts of photoperiodism on the survival, immune system, behavior, biotic conditions, etc. of the species.

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