

## Growth and Survival of Dorado *Salminus brasiliensis* (Pisces, Characidae) Post-larvae Cultivated with Different Types of Food and Photoperiods

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### ABSTRACT

The effect of food and photoperiod on dorado (*Salminus brasiliensis*) post-larvae growth and survival was investigated using the following treatments: LD (Light: Dark) 24:0 + *Artemia nauplii* (A), LD 24:0 + fish prey (F), LD 14:10 + A, LD 14:10 + F, LD 0:24 + A and LD 0:24 + F. *Prochilodus lineatus* larvae were used as fish prey. Higher survival rates were registered in fish prey treatments ( $P < 0.05$ ) and were not influenced by photoperiod whereas in *Artemia* treatments, the survival was very low, but directly proportional to light increase ( $P < 0.05$ ). The better growth in LD 0:24 was related to a safe-energy strategy that reduced energy consumption whereas in LD 24:0, the higher energy consumption reduced the growth. In intermediate photoperiod, the post-larvae did not define a strategy to capture preys, using alternatively the static safe-energy and the swimming consuming energy, which caused higher heterogeneity in growth.

**Key words:** Dorado, Food type, Larviculture, Photoperiod, *Salminus brasiliensis*

### INTRODUCTION

The dorado, *Salminus brasiliensis* (Cuvier, 1816), formerly classified as *Salminus maxillosus* (Valenciennes, 1849), is a freshwater fish of Characidae family that occurs in important South American rivers like the Paraná and the Uruguay (Paiva, 1983; Godoy, 1987). It is a large size piscivorous species that lives in lotic environments (Britski et al., 1999), whose males can weigh up to five kg and females up to 26 kg in nature (Morais Filho and Schubart, 1955).

The dorado spawns in the rainy hot season of the year in which food can be easily found even for adults (Esteves and Pinto Lôbo, 2001). In

captivity, the larvae hatch with a mean ( $\pm$  standard deviation) length of  $4.96 \pm 0.18$  mm (Zaniboni-Filho et al., 2004) and since the beginning of the exogenous feeding post-larvae present a very intense cannibalistic behavior, which can decimate the larviculture. Due to this behavior, strategies of management must be implemented within the first days of cultivation to minimize this potential damage. Usually, the post-larvae remain in the laboratory for one week where fish larvae are used as standard food source since the use of inert food is not efficient for the species. After this period, they are transferred to outdoor tanks to complete their growth. For *Salminus brasiliensis*, studies evaluating the standard procedure of post-larvae rearing during the first week in laboratory are not available.

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Despite the cannibalism observed in the larval stage in captivity species with that behavior grow fast and reach the market size in a time 30% shorter than those that do not present it (Zaniboni Filho, 2000). This rapid growth associated with high market prices, with species adaptation to sport fishing systems and with the reduction of dorado natural populations related to habitat degradation, justifies the growing interest for the cultivation of this species.

The factors that cause cannibalism can be divided in two general categories: genetic and behavioral (Hecht and Pienaar, 1993). Within the genetic category, the main cannibalism cause is the size variation among individuals due to different growth rates related to genotypical differences. Behavioral cannibalism may be induced by environmental or external factors, such as food availability, population density, turbidity, light intensity and the presence of shelter (Pienaar, 1990). Studies concerning behavior and feeding strategies were made using fish larvae and planktonic organisms as food source in order to minimize the mortality of larvae that occurs due to inadequate feeding in either natural environment (Kamler, 1991) or in laboratory. Accordingly to Bromage and Roberts (1995) and Qin et al. (1997), *Artemia* sp. nauplii can be used as an alternative for feeding fish carnivorous larvae.

Photoperiod, a very important issue for visual predators (Dabrowski and Jewson, 1984; Baras et al., 2000), acts on fish activity stimulating the food consumption (Tesch, 1975; Zavala Camin et al., 1991) and can significantly affect larvae growth and survival by improving the post-larvae skills in locating, capturing and eating preys. A long day usually favors the larvae culture and the synergistic effect of food availability in relation to the length of the day seems to be a determining factor in this stage (Boeuf and Le Bail, 1999).

As *Salminus brasiliensis* is considered a visual predator (Cecarelli, 1997), the present study aimed to investigate the simultaneous effect of light availability and food type on the growth and survival of dorado post-larvae using the standard rearing procedures and alternative ones, in order to identify mechanisms that influence the cultivation of this species during the phase where cannibalism is more intense.

## MATERIALS AND METHODS

The experiment was carried out in November at the São Carlos Fish Culture Station, Santa Catarina State, Brazil. Round cream colored plastic aquariums with 10 L of fresh water were used as experimental units in a closed water circulation system provided with mechanical aeration. Each aquarium was stocked with 15 randomly selected dorado post-larvae/L, the standard number used in the fish culture station that presented  $6.73 \pm 2.00$  mm,  $13.89 \pm 0.47$  mg and  $1.21 \pm 0.80$  mm mean ( $\pm$  standard error) of length, weight and height, respectively. *Salminus brasiliensis* larvae were obtained through induced reproduction of the same breeders. During incubation and after hatching, the individuals were maintained in the same funnel incubator until the beginning of the experiment. At that time, the larvae presented 21 h post-hatch (mean incubation temperature was 26°C) and had the mouth fully opened and functional. Individuals that presented those characteristics associated with the beginning of exogenous feeding were named post-larvae and could be used in the experiment.

The following treatments were used in a factorial model applied in a completely random design with four repetitions: Light:Dark (LD) 24:0 + *Artemia* nauplii (A), LD 24:0 + fish prey (F), LD 14:10 + A, LD 14:10 + F, LD 0:24 + A and LD 0:24 + F, where photoperiod (LD 0:24, 14:10 or 24:0) and food type (fish prey or *Artemia*) were the factors analyzed. Two 40 watt fluorescent lamp (turned on at 18:00 h and turned off at 08:00 h) were used to simulate a continuous photoperiod in the LD 24:0 treatment. A black plastic cover was used in experimental units allocated to LD 0:24 and to the dark hours of LD 14:10 treatments.

*Artemia* nauplii were obtained accordingly Lavens and Sorgeloos (1996) and offered in a proportion of 40 nauplii/dorado post-larvae/feeding at 03:00, 07:00, 11:00, 15:00, 19:00 and 23:00 h. Six fish larvae were offered once a day for each dorado post-larvae. Fish larvae prey were obtained by induced reproduction of *Prochilodus lineatus* Steindachner (1881), conducted two days before the beginning of the experiment. After hatching, the larvae were maintained in incubators until used as food throughout the experiment. Post-larvae swimming activity was visually monitored before and after each feeding session in *A. nauplii* treatments and a few minutes later in fish prey treatments. Dissolved oxygen concentrations and

temperature were obtained with an YSI-55 (12231 Industriplex Blvd, Suite A, Baton Rouge, LA 70809) oxygen meter, pH was measured with an YSI-60 digital pH meter and total ammonia and nitrite concentrations were measured using colorimetric methods. The analyses were performed once a day before the feeding procedures, except for temperature that was measured three times a day at 08:00, 14:00 and 20:00 h. Experimental units were siphoned daily to debris removal and a 30% water renewal was performed after water analyses in the late afternoon.

A total count of dorado post-larvae was carried out at the end of the sixth day of the experiment in order to establish the final survival rate. The dead dorado post-larvae collected during siphoning were used to quantify mortality. These post-larvae were stored in a 4% buffered formaldehyde solution for later laboratory analysis which included the individual measure of total length and height with a precision ruler, and wet weight with a 0.1 mg analytical balance. As dorado post-larvae did not feed on dead fish for cannibalism only dorado post-larvae that disappeared from the experimental units were considered. Length-weight relationships were constructed to identify the growth pattern of post-larvae, using the data from all repetitions for each treatment. Condition factor (Le Cren, 1951) coefficient of variation was used to measure the post-larvae heterogeneity among fish prey treatments. In *Artemia* treatments the reduced number of survivors did not allow the use of that approach.

Data were analyzed by two-way analysis of variance (Zar, 1996) or by trend comparison regression analysis applied to a two-way ANOVA (Gomez and Gomez, 1984). For the variables such as total length, total wet weight, height and mortality, that did not present interaction between photoperiod and food type the levels of the food qualitative factor were compared (fish prey versus *Artemia* sp. nauplii) by Tukey's test, whereas regression analysis was applied to the levels of photoperiod quantitative factor using data from each photoperiod pooled over all food type levels. For survival and cannibalism, as an interaction between photoperiod and food type was present, a trend comparison regression analysis applied to a two-way ANOVA was used. In this procedure a regression analysis was applied independently to each level of the food type factor, testing for linear or quadratic adjustments. All analyses used a 0.05

significance level and before being used percentage survival, cannibalism and mortality data were transformed to arcsine values (Zar, 1996).

## RESULTS

Water quality variables remained within the range considered suitable for fish survival and growth of dorado (Gazzola, 2003; Serafini, 2005). Mean ( $\pm$ standard deviation) temperature, pH and dissolved oxygen concentration were  $24.5 \pm 0.75^{\circ}\text{C}$ ,  $7.12 \pm 0.02$  and  $7.93 \pm 0.33$  mg/L, respectively. Total ammonia was not detected on the first three days but showed a gradual increase to 0.5 mg/L on the sixth day when nitrite was first registered at a concentration of 0.25 mg/L.

Photoperiod effect on survival and cannibalism were different when fish prey or *Artemia* were used, as demonstrated by the significant interaction ( $P < 0.05$ ) between these factors. The survival was much higher when fish preys (Table 1) were used but different photoperiods did not change it ( $P < 0.05$ ), whereas in *Artemia* treatments the very low survival was directly proportional to the increase of light period (Fig. 1).

In fish prey treatments, the cannibalism was much lower than *Artemia* treatments ( $P < 0.05$ ) and different photoperiods did not show influence ( $P < 0.05$ ). In *Artemia* treatments, cannibalism was reduced with the increase of light (Table 1 and Fig. 2). The mean ( $\pm$  standard error) mortality was low,  $1.7\% \pm 0.3\%$  and  $2.4 \pm 0.3\%$ , with the use of fish larvae or *Artemia* sp. nauplii, respectively. This difference was significant ( $P < 0.05$ ), but photoperiod did not influence this variable ( $P > 0.05$ ).

The growth in weight, length and height in dorado post-larvae was inversely proportional to the increase of light period despite of the type of food used (Fig. 3), but larvae fed with fish prey always showed a much better performance (Table 2) than those fed with *Artemia* nauplii ( $P < 0.05$ ), despite dorado post-larvae actively fed on them. Length-weight relationships (Fig. 4) showed that the growth of post-larvae in fish prey treatments were more heterogeneous in the intermediate (LD 14:10) photoperiods as demonstrated by its higher condition factor coefficient of variation (Fig. 5).

The visual observation of post-larvae swimming activity showed that a directly relationship

occurred with the increase of light period in either fish larvae or *A. nauplii* treatments. In LD 0:24, the post-larvae were distributed at random in water column and presented low swimming activity during most of the time whereas in LD 24:0 and in LD 14:10 light period an intense swimming activity was observed. In the dark period of LD 14:10, the post-larvae presented higher swimming activity than that observed in LD 0:24.

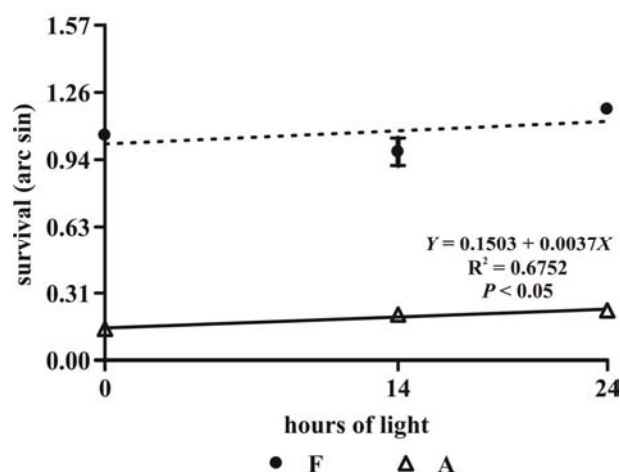
## DISCUSSION

The dorado post-larvae in LD 0:24 remained static waiting for preys, a safe-energy strategy that reduced the encountering with sibling post-larvae

and consequently the cannibalism. This strategy produced the better growth among treatments despite the fact that this species has been considered a typical visual predator. The results registered for dorado post-larvae survival and growth in LD 0:24 contrasted with other studies where better survival and growth were found with the increase of photoperiod, a response associated with various factors as the dependency of larvae visual abilities (Giri et al., 2002), the increase of predator-prey encounters (Puvanendran and Brown, 2002) and prey availability (Boeuf and Le Bail, 1999; Kestemont et al., 2003) and the insufficient time for the establishment of a robust rhythmicity plus the reduction of the standard metabolic rate (El-Sayed and Kawanna, 2004).

**Table 1** - Mean ( $\pm$  standard error) survival (%) and cannibalism (%) for dorado (*Salminus brasiliensis*) post-larvae, submitted to different photoperiods and fed with fish prey or *Artemia* nauplii after six-days of cultivation.

Food type	Photoperiod	Survival (%)	Cannibalism (%)
Fish prey	LD 0:24	75.67 $\pm$ 1.86	23.00 $\pm$ 2.12
	LD 14:10	68.33 $\pm$ 5.78	29.17 $\pm$ 5.58
	LD 24:0	85.17 $\pm$ 1.86	13.50 $\pm$ 2.12
<i>Artemia</i> nauplii	LD 0:24	2.17 $\pm$ 0.42	95.83 $\pm$ 0.69
	LD 14:10	4.50 $\pm$ 0.57	92.67 $\pm$ 0.54
	LD 24:0	5.33 $\pm$ 0.61	92.17 $\pm$ 0.69



**Figure 1** - Mean ( $\pm$  standard error) survival (arcsine transformed) of dorado (*Salminus brasiliensis*) post-larvae in different photoperiods with fish prey (F) or *Artemia* sp. (A) as food source after six days of cultivation. The slope in fish prey photoperiods was not different from zero ( $P > 0.05$ )

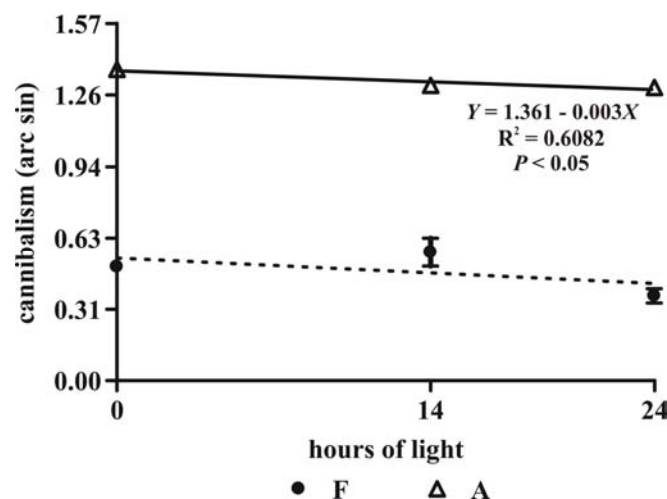
Therefore, in the absence of light, another sensorial function could be prevailing over dorado vision. Many studies have shown that preys could also be detected through electro-sensibility and sensorial functions (Bleckmann, 1992; Popper, 1996; Montgomery and Hamilton, 1997; Haine et al., 2001) and that the movements made by prey organisms were important in the locating strategies of predator species. As mechanical-receptor system of the lateral line is one of the most developed organs in fish (Montgomery et al., 1988; Coombs, 1999), its early development in predator post-larvae (Jones and Janssen, 1992; Valente, 1992) could favor the growth.

The cannibalistic behavior of *Brycon cephalus* (Günther, 1869) in the larval phase seemed to be highly efficient due to the presence of certain morphological attributes such well-developed nostrils that provided the ability of detecting the prey before fish visualized it (Cecarelli, 1997).

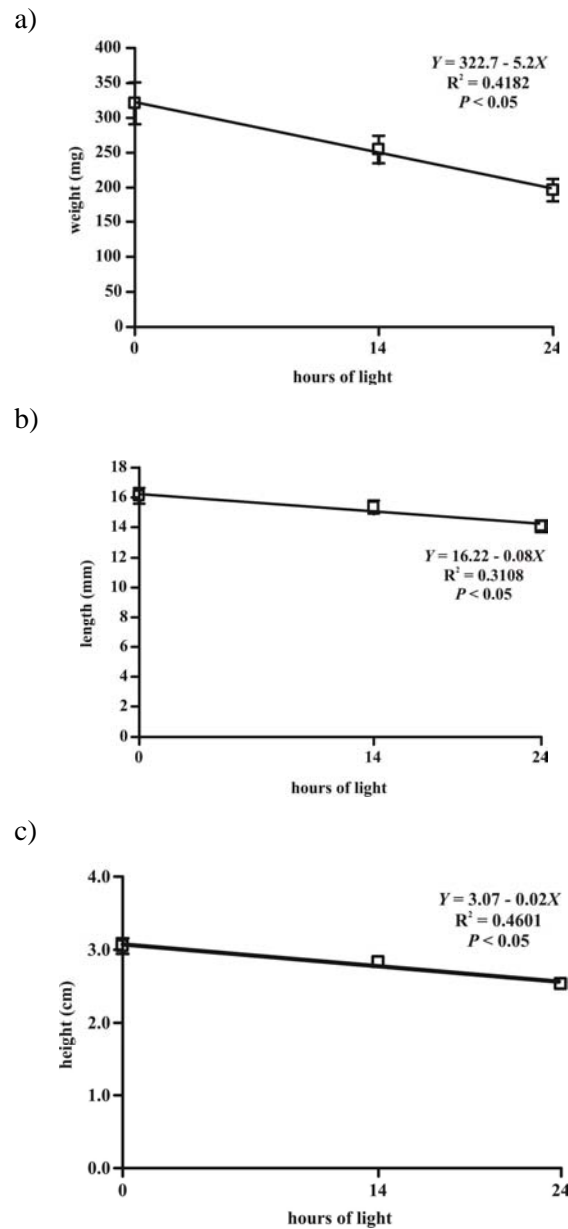
For *B. moorei* Steindachner 1878, an intense cannibalism was registered by Baras et al. (2000) that showed that cannibalistic post-larvae could efficiently consume preys without the presence of light. This characteristic, however, could be used not only to cannibalism but also to detect food other than sibling larvae in complete darkness, as the fish prey offered to dorado post-larvae in the present study.

Dorado post-larvae swam constantly in LD 24:0 and showed an inferior growth than the obtained in LD 0:24. Light favored the use of vision and swimming in search prey process leading to an energy consumption that was not used in the growth process. In intermediate photoperiod, post-larvae growth was more heterogeneous and as light:dark period varied, it seemed that dorado post-larvae did not define a unique strategy to capture preys, using alternately the static safe-energy and the swimming consuming energy. The strategies that occurred in both food regimes were easier noted in fish prey treatments.

The low growth effect obtained using *A. nauplii* could also be related to energy content variation which was higher in fish prey (Huuskonen et al., 1998). Even with the predation of sibling post-larvae which increased the availability of *A. nauplii*, the remaining post-larvae did not present a growth similar to any of the fish prey treatments. The higher survival found in all photoperiods when fish preys were used showed that light was not a limiting factor when the size of food was large. When a small size food like *A. nauplii* was used, the response to light increase was positive suggesting that preys could be found easier.



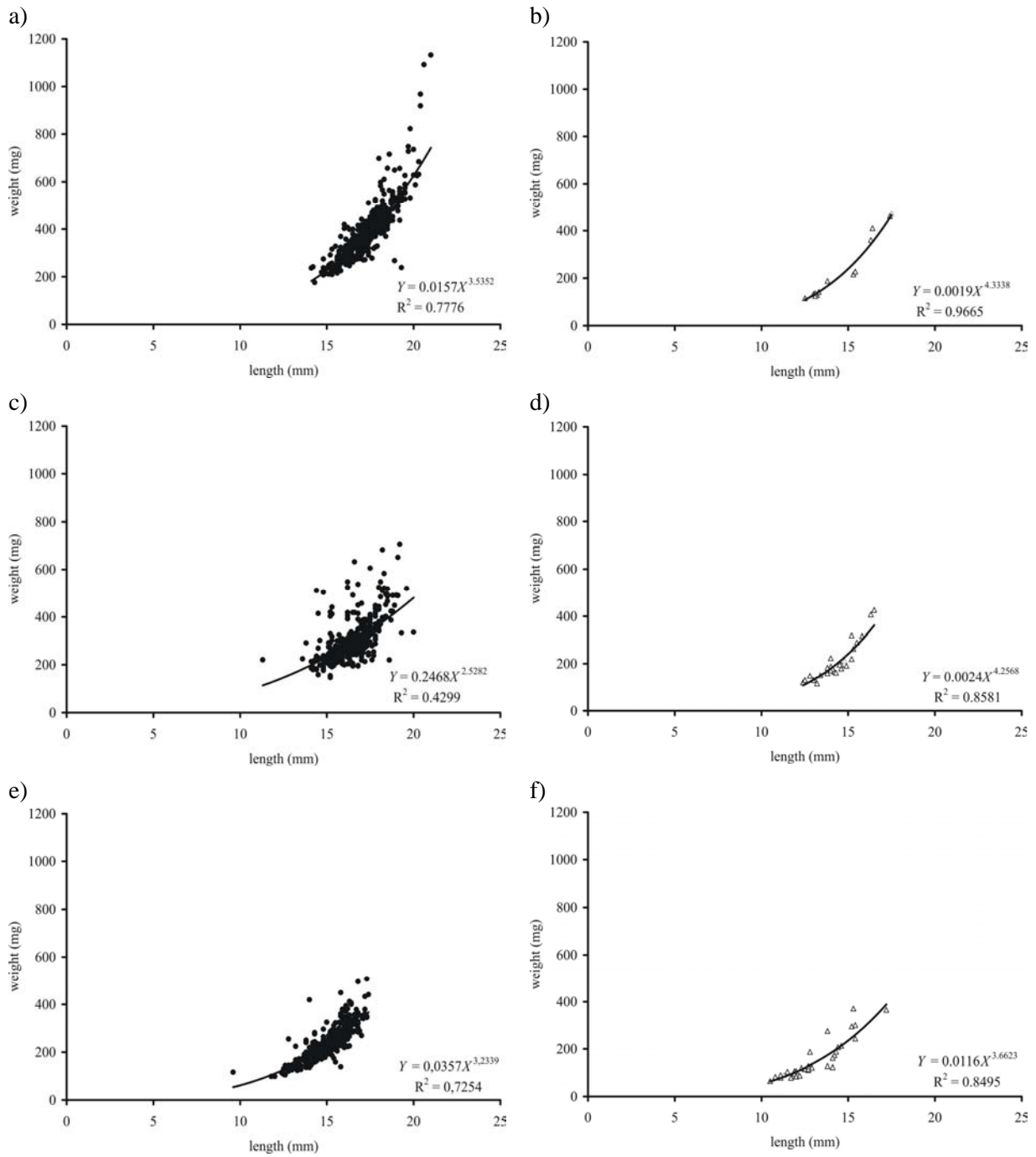
**Figure 2** - Mean ( $\pm$  standard error) cannibalism (arcsine transformed) of dorado (*Salminus brasiliensis*) post-larvae in different photoperiods with fish prey (F) or *Artemia* sp. (A) as food source after six days of cultivation. The slope in fish prey photoperiods was not different from zero ( $P > 0.05$ ).



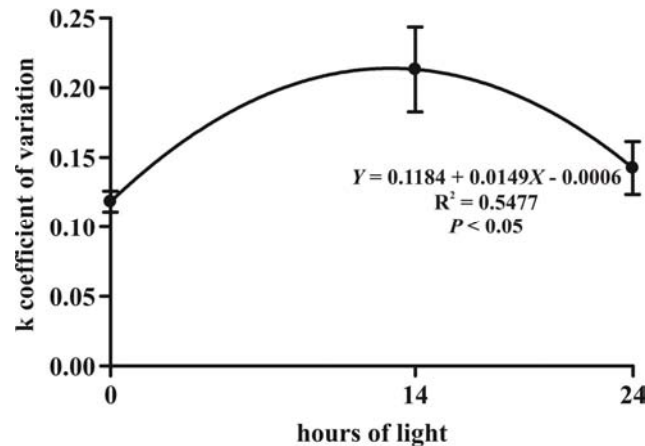
**Figure 3** - Growth of dorado (*Salminus brasiliensis*) post-larvae in different photoperiods with fish prey (F) or *Artemia* sp. (A) as food source after six day of cultivation. a) Mean ( $\pm$  standard error) total weight (mg). b) Mean ( $\pm$  standard error) total length (mm). c) Mean ( $\pm$  standard error) total height (mm).

**Table 2** - Mean ( $\pm$  standard error) length (mm), weight (mg) and height (mm) of dorado post-larvae after six days of cultivation with *Artemia* sp. nauplii or fish larvae. Different letters represent significant means by the use of Tukey's test ( $P < 0.05$ ).

Food type	Length (mm)	Weight (mg)	Height (mm)
<i>Artemia</i>	14.1 <sup>a</sup> $\pm$ 0.3	205.6 <sup>a</sup> $\pm$ 18.5	2.7 <sup>a</sup> $\pm$ 0.1
Fish larvae	16.3 <sup>b</sup> $\pm$ 0.4	309.0 <sup>b</sup> $\pm$ 24.8	2.9 <sup>b</sup> $\pm$ 0.1



**Figure 4** - Length-weight relationship among dorado (*Salminus brasiliensis*) post-larvae in different treatments after six days of cultivation. a) LD 0:24 + F; b) LD 0:24 + A; c) LD 14:10 + F; d) LD 14:10 + A; e) LD 24:0 + F; f) LD 24:0 + A. LD = light:dark; F = fish prey. A = *Artemia* sp. nauplii.



**Figure 5** - Mean ( $\pm$  standard error) condition factor (k) coefficient of variation of dorado (*Salminus brasiliensis*) post-larvae in different photoperiods after six days of cultivation with fish prey as food source.

Unlike dorado, *B. orbignyanus* (Valenciennes, 1850) presented high survival when *A. nauplii* or fish larvae were used as food in continuous darkness (Pereira and Nuñez, 2003), despite its similarity with dorado regarded to post-larvae cannibalistic behavior, which showed that some fresh water species could use *A. nauplii* as a good source of energy. The post-larvae of this species when submitted to four photoperiods (LD 0:24, LD 10:14, LD 14:10 and LD 24:0) and fed with *Artemia* nauplii presented a directly proportional relation between survival and photoperiod increase but no significant difference in length or weight (Tataje et al., 2002) showing that cannibalism in this species could be controlled with different strategies.

The very high intensity of cannibalism in all *Artemia* treatments showed that its use did not produce an adequate condition to dorado post-larvae cultivation. The nauplii density used, the frequency of feeding, the small size of the nauplii and their reduced survival time in fresh water might have been some of the factors that developed that state. The selection of preys carried out by fish could be influenced by the size of the organisms, and in some cases size could be more important than abundance. In addition, for any predator that utilizes vision in its search processes, there is a size limit to prey be located and when it is detected the predator will respond positively (Valente, 1992). This probably contributed to increase the cannibalism over small post-larvae by larger ones (Pienaar, 1990).

Fish prey produced the best effect on *S.*

*brasiliensis* post-larvae survival and photoperiod did not influence it, but post-larvae growth was inversely proportional to the photoperiod increase. The use of *Artemia* nauplii in the frequency and quantity offered did not induce a satisfactory growth or survival and very high cannibalism intensity was established at this condition.

The better growth in LD 0:24 was related to a safe-energy strategy that reduced energy consumption whereas in LD 24:0, as light favors the use of vision and swimming in searching preys, a higher energy consumption reduced the growth. In intermediate photoperiod, post-larvae did not define a strategy to capture preys, using alternatively the static safe-energy and the swimming consuming energy, which caused higher heterogeneity in post-larvae growth.

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## RESUMO

O efeito da alimentação e do fotoperíodo sobre o crescimento e a sobrevivência de pós-larvas de dourado (*Salminus brasiliensis*) foi investigado utilizando-se os seguintes tratamentos: LE (Luz: Escuro) 24:0 + náuplios de *Artemia* (A), LE 24:0 +



larva forrageira (L), LE 14:10 + A, LE 14:10 + L, LE 0:24 +A e LE 0:24 + L. Larvas de *Prochilodus lineatus* foram utilizadas como larva forrageira. Taxas de sobrevivência mais elevadas foram registradas nos tratamentos que utilizaram larvas forrageiras ( $P < 0,05$ ), que não foram influenciados pelo fotoperíodo, enquanto nos tratamentos com *Artemia* a sobrevivência foi muito reduzida, mas diretamente proporcional ao aumento da disponibilidade de iluminação ( $P < 0,05$ ). O melhor crescimento em LE 0:24 esteve relacionado ao uso de uma estratégia de baixo consumo energético enquanto em LE 24:0 o maior consumo de energia produziu menor crescimento. No fotoperíodo intermediário as pós-larvas não definiram uma estratégia única para capturar as presas, utilizando alternadamente a estratégia estática de baixo consumo de energia e a estratégia natatória, associada a um maior consumo energético, que causou maior heterogeneidade no crescimento.

## REFERENCES

- Baras, E.; Maxi, M. Y. J.; Ndao, M. and Mélard, C. (2000), Sibling cannibalism in dorada under experimental conditions. II. Effect of initial size heterogeneity, diet and light regime on early cannibalism. *J. Fish Biol.*, **57**, 1021-1036.
- Bleckmann, H. (1992.) Role of the lateral line in fish behavior. In *The Behavior of Teleost Fishes*, ed. T. J. Pitcher. Chapman-Hall, London, pp. 201-237.
- Boeuf, G. and Le Bail, P. Y. (1999), Does light have an influence on fish growth? *Aquaculture*, **177**, 129-152.
- Britski, H. A.; Silimon, K. D. de S. and Lopes, B. S. (1999), *Peixes do Pantanal*. EMBRAPA, Brasília.
- Bromage, N. R. and Roberts, R. J. (1995), *Broodstock Management and Egg and Larval Quality*. Blackwell Science, Oxford.
- Cecarelli, P. S. (1997), Canibalismo em larvas de matrinxã *Brycon cephalus* (Günther, 1869). Master Thesis, Universidade Estadual Paulista, Botucatu, Brazil.
- Coombs, S. (1999), Signal detection theory, lateral-line excitation patterns and prey capture behaviour of mottled sculpin. *Anim. Behav.*, **58**, 421-430.
- Dabrowski, K. R. and Jewson, D. H. (1984), The influence of light environment on depth of visual feeding by larvae and fry of *Coregonus pollan* (Thomson) in Lough Neagh. *J. Fish Biol.*, **25**, 173-181.
- El-Sayed, A. M. and Kawanna, M. (2004), Effects of photoperiod on the performance of farmed Nile tilapia *Oreochromis niloticus*: I. Growth, feed utilization efficiency and survival of fry and fingerlings. *Aquaculture*, **231**, 393-402.
- Esteves, K. E. and Pinto Lôbo, A. V. (2001), Feeding pattern of *Salminus maxillosus* (Pisces, Characidae) at Cachoeira das Emas, Mogi-Guaçu River (São Paulo State, Southeast Brazil). *Rev. Bras. Biol.*, **61**, 267-276.
- Gazzola, A. C. (2003), Efeito da amônia e do oxigênio dissolvido na sobrevivência de alevinos de dourado, *Salminus brasiliensis*. Master Thesis, Universidade Federal de Santa Catarina, Florianópolis, Brazil.
- Giri, S. S.; Sahoo, S. K.; Sahu, B. B.; Sahu, A. K.; Mohanty, S. N.; Mukhopadhyay, P. K. and Ayyappan, S. (2002), Larval survival and growth in *Wallago attu* (Bloch and Schneider): effects of light, photoperiod and feeding regimes. *Aquaculture*, **213**, 151-161.
- Godoy, M. P. (1987), *Peixes do Estado de Santa Catarina*. UFSC-ELETROSUL-FURB, Florianópolis.
- Gomez, K. A. and Gomez, A. A. (1984), *Statistical Procedures for Agricultural Research*. 2. ed. John Wiley, New York.
- Haine, O. S.; Ridd, P. V. and Rowland, S. (2001), Range of electro sensory detection of prey by *Carcharhinus melanopterus* and *Himantura granulata*. *Mar. Freshw. Res.*, **52**, 291-296.
- Hecht, T. and Pienaar, A. P. (1993), A review of cannibalism and its implications in fish larviculture. *J. World Aquac. Soc.*, **24**, 246-261.
- Huuskonen, H.; Karjalainen, J.; Medgyesy, N. and Wieser, W. (1998), Energy allocation in larval and juvenile *Coregonus lavaretus*: validation of a bioenergetics model. *J. Fish Biol.*, **52**, 962-972.
- Jones, W. R. and Janssen, J. (1992), Lateral line development and feeding behavior in the mottled sculpin, *Cottus bairdi* (Scorpaeniformes: Cottidae). *Copeia*, **2**, 485-492.
- Kamler, E. (1991), *Early Life History of Fish: an Energetic Approach*. Kluwer Academic Publishers, London.
- Kestemont, P.; Jourdan, S.; Houbart, M.; Mélard, C.; Paspatis, M.; Fontaine, P.; Cuvier, A.; Kentouri M. and Baras, E. (2003), Size heterogeneity, cannibalism and competition in cultured predatory fish larvae: biotic and abiotic influences. *Aquaculture*, **227**, 333-356.
- Lavens, P. and Sorgeloos, P. (1996), *Manual on the Production and Use of Live Food for Aquaculture*. FAO, Rome.
- Le Cren, E. D. (1951), The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Animal Ecol.*, **20**, 201-209.

- Montgomery, J. C. and Hamilton, A. R. (1997), Sensory contributions to nocturnal prey capture in the dwarf scorpion fish (*Scorpaena papillosus*). *Mar. Freshw. Behav. Physiol.*, **30**, 209-223.
- Montgomery, J. C.; MacDonald, J. A. and Housley, G. D. (1988), Lateral line function in an Antarctic fish related to the signals produced by planktonic prey. *J. Comp. Physiol., A*, **163**, 827-833.
- Morais Filho, M. B. and Schubart, O. (1955), Contribuição ao Estudo do Dourado (*Salminus maxillosus* Val.) do Rio Mogi Guaçu. Ministério da Agricultura, São Paulo.
- Paiva, M. P. (1983), Peixes e Pescas de Águas Interiores do Brasil. Editerra, Brasília.
- Pereira, A. S. and Nuñez, A. P. O. (2003), Larvicultura da piracanjuba *Brycon orbignyanus* Valenciennes, 1849 (Characiformes, Characidae) em diferentes densidades, dietas e formatos de tanque. *Acta Scientiarum*, **25**, 55-61.
- Pienaar, A. G. (1990), A study of coeval sibling cannibalism in larval and juvenile fishes and its control under culture conditions. Masters Thesis, Rhodes University, Grahamstown, South Africa.
- Popper, A. N. (1996), The teleost octavolateralis system: structure and function. *Mar. Freshw. Behav. Physiol.*, **27**, 95-110.
- Puvanendran, V. and Brown, J. A. (2002), Foraging, growth and survival of Atlantic cod larvae reared in different light intensities and photoperiods. *Aquaculture*, **214**, 131-151.
- Qin, J.; Fast, A. W.; DeAnda, D. and Weidenbach, R. P. (1997), Growth and survival of larval snakehead (*Channa striatus*) fed different diets. *Aquaculture*, **148**, 105-113.
- Serafini, R. L. (2005), Efeito do oxigênio dissolvido e da amônia na sobrevivência e crescimento de juvenis de dourado, *Salminus brasiliensis*. Master Thesis, Universidade Federal de Santa Catarina, Florianópolis, Brazil.
- Tataje, D. A. R.; Luz, R. K.; Meurer, S.; Zaniboni Filho, E. and Nuñez, A. P. O. (2002), Influência do fotoperíodo no crescimento e sobrevivência de pós-larvas de piracanjuba *Brycon orbignyanus* (Valenciennes, 1849) (Osteichthyes, Characidae). *Acta Scientiarum*, **24**, 439-443.
- Tesch, F.W. (1975), Orientation in space: animals, fishes. *Mar. Ecol.*, **2**, 657-707.
- Valente, A. C. N. (1992), *A Alimentação Natural dos Peixes: Metodos de Estudo*. Universidade do Porto, Porto.
- Zaniboni Filho, E. (2000). Larvicultura de peixes de água doce. *Inf. Agropec.*, **21**, 69-77.
- Zaniboni Filho, E.; Meurer, S.; Shibatta, O. A. and Nuñez, A. P. O. (2004), *Catálogo ilustrado de peixes do alto rio Uruguai*. Editora da Universidade Federal de Santa Catarina-Tractebel Energia, Florianópolis.
- Zar, J. H. (1996), *Biostatistical Analysis*. Prentice Hall, New Jersey.
- Zavala Camin, L. A.; Grassi, R. T. B.; Seckendorff, R. W. V. and Tiago, G. G. (1991), Ocorrência de recursos pesqueiros epipelágicos na posição 22°11'S-39°55'W, Brasil. *Bol. Inst. Pesca*, **18**, 13-21.

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