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Population Structure, Condition Factor and Reproductive Period of *Astyanax paranae* (Eigenmann, 1914) (Osteichthyes: Characidae) in a Small and Old Brazilian Reservoir

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ABSTRACT

The population structure, condition and reproductive period of Astyanax paranae *adult individuals inhabiting a small reservoir were investigated. The fishes were quarterly captured from the riverine and lacustrine zones of the Alagados Reservoir, Paraná, Brazil, during 1996/1997 and 1998/1999. The sex ratio differed from 1:1 with the predominance of the females in all standard length classes and total population sample. The females showed higher condition than the males. Both the sexes presented lower mean condition values in April and higher mean condition values in July. The estimated values of the regression coefficient indicated isometric growth for the females and males. The gonadosomatic relationship reached a maximum value of 14.80% for the females and 8.43% for the males. The reproductive period possibly occurred from October to April.*

Key words: Brazil, condition factor, freshwater fish, gonadosomatic relationship, sexual proportion

INTRODUCTION

Recent taxonomic proposal of Lima et al. (2003) included the subspecies *Astyanax scabripinnis paranae* (Eigenmann, 1914) in the species category *Astyanax paranae*. This fish is a small characin, popularly known as lambari-do-rabo-vermelho. It is commonly found in the Upper Paraná River basin (Garutti and Britski, 2000), where the Alagados Reservoir is located (Luiz et al., 2005). A peculiar characteristic of *A. paranae* is its restricted distribution to low order rivers (Godoy, 1975; Castro and Casatti, 1997; Garutti and Britski, 2000; Vilella et al., 2002; Pavanelli and Caramaschi, 2003; Benedito-Cecilio et al., 2004) where it forages predominantly on the insects and plant matter (Castro and Casatti, 1997; Vilella et al., 2002; Ferreira, 2004; Bennemann et al., 2005). *A. paranae* has also been described as a short life cycle species (Barbieri, 1992a). Previous studies have shown *A. paranae* as the most abundant fish species in the Alagados Reservoir (Luiz, 2000) and also characterized the species feeding habit as detritivorous (Abelha, 2001). Ichthyofaunistic surveys registered the occurrence of *A. paranae* in other small reservoirs located in the Piquiri River Basin (Paraná State) (Luiz et al., 2005), specifically, in the Melissa and Santa Maria

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Reservoirs (Elaine Luiz, pers. comm.). Impoundments are environments high susceptible to the management actions addressed to the fishes populations (Agostinho et al., 2003). The efficiency of such actions, especially for the survival of the resident ichthyofauna, depends fundamentally on the knowledge of the fishes biology. In the specific case of *A. paranae*, there is a lack of information about the biology of the populations inhabiting the reservoirs.

Some quantitative aspects of the population structure such as sexual ratio, the weight-length relationship, condition and reproduction are useful tools in the fishes studies. They reveal either the biological attributes (weight, length, gonadal maturity and others) or the species relationship to the environmental conditions (Wootton, 1999).

The sex ratio varies considerably among the fishes species and examples of such variation in the tropical species can be found in Giamas et al. (1984), Goulart and Verani (1992), (higher frequency of the males); Rodrigues et al. (1989b), Andrian et al. (1992) (sex ratio of 1:1); Rodrigues et al. (1989a) (higher frequency of the females).

The weight-length relationship is frequently used in the fishery assessment to predict the weight from the length, to estimate the fishes condition and to infer the fishes growth pattern (Bagenal and Tesch, 1978; Ney, 1993; Morey et al., 2003). The study of condition assumes that heavier fishes of a given length are in better condition, hence, condition indices are frequently used as indicators of the general 'well-being' of fish populations (Jones et al., 1999).

The gonadosomatic relationship (RGS) and the relative frequency of the gonadal maturity stages are the methods commonly used in the studies of the fishes reproductive period (Barbieri and Verani, 1987; Garutti, 1989; Goulart, 1994; Vazzoler, 1996). The former quantifies the gonadal development degree (Wootton, 1999) and the latter qualifies the intensity of gonadal maturity (Vazzoler, 1996).

The aim of this work was to study the aspects of the weight-length relationship, condition factor and reproductive period of *A. paranae* in Alagados Reservoir, Paraná State, to fill a gap in the current knowledge of *A. paranae* populations inhabiting the reservoirs.

MATERIALS AND METHODS

Study site

The Alagados Reservoir is located in the second plateau of the Paraná State (Maack, 2002) (S25º01'50.0"; W50º03'41.9"), close to the Ponta Grossa and Castro cities. The latter was the type locality of *A. paranae* (Garutti and Britski, 2000). Alagados is a small (area of 7.1 Km^2), old (closed in 1945), narrow and elongated (Fig. 1) reservoir located near the Pitangui River mouth (a low order river), which was dammed for hydropower generation and water supply purposes (Copel, 1999).

The Alagados Reservoir drainage basin area has been intensively used for agriculture and cattle-breeding. Consequently, the original forest covering, named by Maack (2002) as Campos Gerais (physionomic structure corresponding to native grassy vegetation and woods of *Araucaria*), was broadly replaced by the agriculture cultivation and exotic forage pasture. The grass associated to scattered arboreal vegetation, including small groupings of *Araucaria* and the exotic *Pinus*, predominantly, compose the riparian vegetation along the reservoir bank.

Sampling.

The fishes were quarterly collected from April 1996 to January 1997 and from April 1998 to January 1999 with the gill nets (2.4; to 16.0 cm diagonally stretched) and trammel nets (6.0; 7.0; 8.0 cm stretched mesh) left for 24 h in the reservoir riverine and lacustrine zones (*sensu* Thornton, 1990). These were removed in the morning (8:00 a.m.), afternoon (4:00 p.m.) and night (10:00 p.m.). The captured fishes were fixed in the field in 10% formalin solution and brought to the laboratories of the Núcleo de Pesquisas em Limnologia, Ictiologia e Aqüicultura (Nupélia), Universidade Estadual de Maringá. All the fishes were identified, enumerated, weighed (g), measured (total and standard length; cm), dissected, gonads were weighed (g) and the gonadal maturity stages were obtained. The gonadal maturity classification was adopted from Vazzoler (1996) scheme and macroscopically assigned at four stages: stage I (initial gonadal development), stage II (maturing or mature gonads), stage III (partially or totally spent gonads) and stage IV (resting or recovering gonads). The voucher specimens were deposited in the Ichthyological Collection of Nupélia: NUP

657. It was not possible to simultaneously obtain all the biometric data for total sampled fishes, hence, results regarding the condition factors and reproduction were related to 500 specimens.

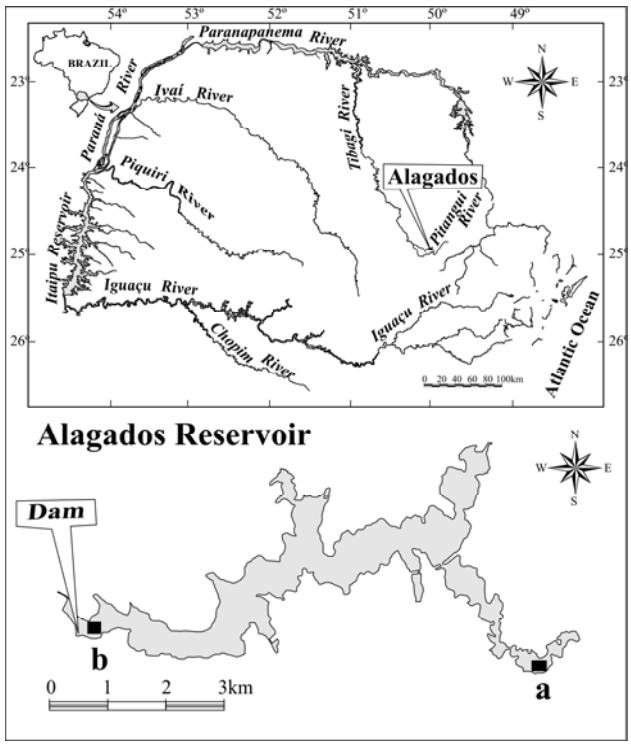

Figure 1 - Location and morphometry of the Alagados Reservoir, Brazil, depicting sample sites in the (a) riverine and (b) lacustrine zones

Data analysis.

In the analysis of the population structure, the sex ratio was established per standard length class (of 1.0 cm) and for the total specimens in the sample. The differences in the sex ratio were tested by the chi square test (χ^2). Significance level implied α=0.05.

The condition of each specimen was evaluated by the allometric condition factor (Ka), described by the equation $Ka=Wt/Ls^b*100$ (Bagenal and Tesch, 1978) where Wt was the total weight in grams, Ls was the standard length in centimeters and *b* was a constant related to fish growth. It was obtained by the weight-length relationship linearization: $Wt=aLs^b$ (Bagenal and Tesch, 1978) using the logarithmic transformation: lnWt=lna+blnLs, where *a* was the intercept and *b* the regression coefficient. The parameter *b* used to calculate the condition factors was that obtained for each sex over the entire sampling period. All the linear regressions were computed by the program Statistica™ (StatSoft, 1996) using the minimum square method.

For comparative analysis of the fishes condition, the mean value of Ka was calculated for each sampling month (April, June, October and January) for both the sexes. The influence of the gonadal weight in the allometric condition factor was graphically inferred by plotting the sampling months mean values of both Ka and the somatic condition factor (K') (Vazzoler, 1996). K' was calculated by the equation $K'=Wc/Ls^b$, where Wc=Wt-Wg , Wt was the total weight, Wg was the gonadal weight and Ls and *b* were the same parameters already described for Ka.

In the inference of the fishes growth pattern, a t test was used for the females and males *b* in order to evaluate H_0: *b*=3 using the equation (|3.0-*b*|/standard error of *b*) at the 0.05 level of significance and (n-1) degrees of freedom (Norman and Streiner, 1994). The cases where *b*<3.0 represented the fish that became less round

as length increased, whereas, when *b*>3.0 the fish became more rotund as the length increased, characterizing the allometric growth; when *b*=3.0 the fish grew without changes in the corporal proportions, indicating the isometric growth (Jones et al., 1999).

The sexes were grouped in the evaluation of *A. paranae* reproductive period and the relative frequency of the gonadal maturity stages was established considering the total number of the collected specimens in the month as 100%. These results were compared to the mean values of the gonadosomatic relationship (RGS), calculated for each individual using the expression RGS=Wg/Wt*100, where Wg was the gonadal weight and Wt was the total weight (Vazzoler, 1996).

RESULTS

Weight-length relationship

Among 699 specimens evaluated, 244 were captured in the riverine zone and 455 in the lacustrine one. The results comprised the adult population stratum, since the minor examined individual (standard length=5.0 cm) presented resting gonads. The females occurred in significantly higher frequency than the males either in the length classes as in the total sample (Table 1).

Table 1 - Distribution of the females and males per standard length class and results of the chi square test (X^2) applied to the sex ratio of *Astyanax paranae* in the Alagados Reservoir, Brazil. n=specimens number; %=percentage of frequency; * =significant at 5% level.

Length class	Standard length				Total	X^2
	Female		Male			
	n	%	n	%		
5 — 6	64	90.14	7	9.86	71	64.45*
6 — 7	226	63.31	131	36.69	357	7.08*
7 — 8	100	68.49	46	31.51	146	13.68*
8 — 9	90	94.74	5	5.26	95	80.06*
9 — 10	7	100.00	-	0.00	7	100.00*
10 — 11	21	100.00	-	0.00	21	100.00*
11 — 12	2	100.00	-	0.00	2	100.00*
Total	510	72.96	189	27.04	699	21.09*

Results of weight-length relationships for the females and males are displayed in Table 2. The parameter *b* was not statistically different from 3.0, indicating isometric growth for both the sexes. The allometric condition factor (Ka) varied from 4.71 to 2.17 for the females and from 3.25 to 1.51 for the males. The females presented higher mean values for Ka and K' than the males (Fig. 2a and 3a). For both the sexes, Ka and K' showed similar fluctuation along the sampled months with a sharp fall in April and a subsequent rise in July when the maximum mean values were reached (Fig. 2a and 3a).

The females presented higher difference between the mean values of Ka and K' than the males, with minimum difference in April and maximum difference in October and January (Fig. 2b). For the males, a slight fall and rise in the differences between the condition factors was observed in April and October, respectively (Fig. 3b).

Table 2. Weight-length relationship of *Astyanax paranae* females and males in the Alagados Reservoir, Brazil. n=number of specimens, *a*=intercept, *b*= regression coefficient, R^2=correlation coefficient, SE=standard error of b, t=summary of t test.

Group/Parameter	n	*a*	*b*	R^2	SE	t
Female	358	-3.49	2.93	0.94	0.04	$t_{(357)}$=1.75, p>0.05
Male	142	-3.90	3.10	0.85	0.11	$t_{(141)}$=0.91, p>0.05

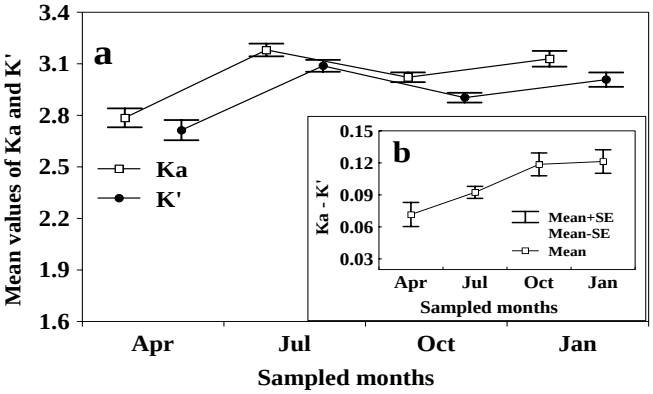

Figure 2 - Mean (± standard error) values of the allometric (Ka) and somatic (K') condition factors (a) and the difference between the mean values of Ka and K' (Ka – K') (b) for the females of *Astyanax paranae* (n=358) in the Alagados Reservoir, Brazil, during sampled months

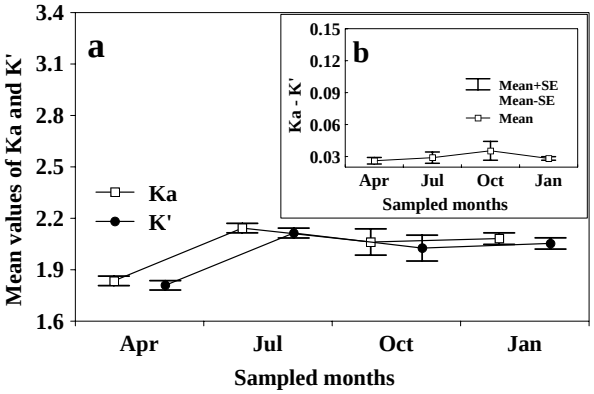

Figure 3 - Mean (± standard error) values of the allometric (Ka) and somatic (K') condition factors (a) and the difference between the mean values of Ka and K' (Ka – K') (b) for the males of *Astyanax paranae* (n=142) in the Alagados Reservoir, Brazil, during sampled months

Reproduction

The examination of the relative frequency of the gonadal maturity stages indicated that the four stages occurred simultaneously along the sampling period (Fig. 4). Stage II (maturing or mature gonads), the most advanced maturity stage, was more frequent in July and October. Stage III (partially or totally spent gonads) was relatively constant in October, January and April and included approximately 50% of the specimens. Stages I (initial gonadal development) and IV (resting or recovering gonads) were the less representative in the sampled months and showed frequencies less altered, excepting a slight reduction in stage IV in October.

Individual maximum values of the gonadosomatic relationship (RGS) corresponded to 14.80% for the females and 8.43% for the males. The mean values showed a rise from July to October, coinciding with the interval of higher frequency of the specimens showing mature or maturing gonads (Fig. 5).

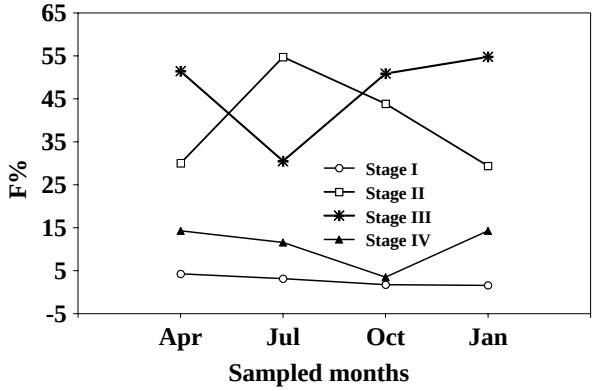

Figure 4 - Percentage frequency distribution (F%) of gonadal maturity stages for grouped sexes of *Astyanax paranae* in the Alagados Reservoir, Brazil, during sampled months. Stage I=initial; Stage II=maturing/mature; Stage III=partially/totally spent; Stage IV=recovering/rest

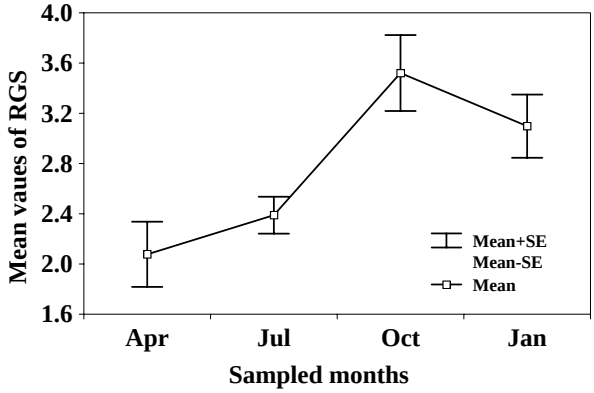

Figure 5 - Mean (± standard error) values o f the gonadosomatic relationship (RGS) for grouped sexes of *Astyanax paranae* in the Alagados Reservoir, Brazil, during sampled months

DISCUSSION

The relatively higher capture of the fishes in the lacustrine zone of the Alagados Reservoir highlighted the species adaptability to the lentic environments. This is a common attribute among *Astyanax* species and was correlated to their success in reservoirs colonization (Agostinho et al., 1999). The prevalence of females seemed to be a tendency in *A. paranae* adult population since similar result was reported by Barbieri (1992b) for *A. paranae* population inhabiting a low order river, the Ribeirão do Fazzari (São Paulo State). However, the evidence was not sufficient to be conclusive, considering the lack of information about *A. paranae* in other environments. Oscillations in the environmental conditions, especially food supply, may affect the sex ratio among different populations of the same species (Nikolsky, 1978).

The observed distinct values of *b* between the females and males, were coherent with the reports of variations in this parameter for the same fish species related to the age, sex, season and environmental conditions (Le Cren, 1951; Bagenal and Tesch, 1978; Bolger and Connolly, 1989; Goulart, 1994; Godinho, 1997; Morey, et al., 2003; Peck et al., 2005). Usually, *b* varied from 2.0 to 4.0 (Bagenal and Tesch, 1978). Although, extreme values could be found, i.e., Peck et al.

(2005) reported *b* equal to 5.0 for young of the clupeid *Sprattus sprattus*. For many fish populations *b* was close to 3.0 (Ney, 1993) as it was observed for *A. paranae* in Alagados. Similarly, Barbieri (1992a) reported isometric growth for *A. paranae* in the stream population.

The highest mean values of Ka and K' for the females indicated the higher condition of this sex in the Alagados. On the other hand, the similar fluctuation of Ka and K' for both the sexes characterized the lower condition of the adult population in April and its higher condition in July. Thus, this result suggested that during the interval of time between April and July the specimens invested in the tissue accumulation ('fattening period') to support the gonadal cycle, since the maturation occurred mainly in July.

Seasonal variations in condition factors have frequently been related to the fishes gonadal cycle development (Le Cren, 1951; Hoyt, 1971; Barbieri and Verani, 1987; Goulart, 1994; Ikomi, 1996; Lizama and Ambrósio, 2002). It was suggested that the difference between Ka and K' would be positively related to the amount of stores allocated from the viscera and muscles to the gonads (Vazzoler, 1996). Therefore, higher differences between Ka and K' could be expected in the reproductive period, especially for the females (Barbieri and Verani, 1987; Vazzoler, 1996) considering that each egg represented a massive cytoplasmic investment (Wootton, 1999).

The observed rise and fall in the differences between the condition factors suggested higher reproductive activity in October and January and the inverse in April. This inference was only partially coherent with the frequency of the gonadal maturity that indicated higher frequency of the fishes showing partially or totally spent gonads also in April. These results could be explained in the context of multiple spawning. This reproductive strategy was previously observed for *A. paranae* population in the Ribeirão do Fazzari (São Paulo State) (Barbieri, 1992b) and for other *Astyanax* species populations inhabiting the reservoirs (Agostinho et al., 1999; Suzuki et al., 2005). In this study, the gonads of *A. paranae* were not observed microscopically, therefore, it was not possible to draw a reliable inference about the species spawning strategy; however, the lowest mean value of the RGS in April indicated that the gonads were lighter this month. Thus, the relatively smaller amount of the gametes in the gonads of the specimens still spawning in April would express the final stage of successive gametes productions.

Another point to consider in this context, was the relationship between the RGS values and the fishes reproductive strategy suggested by Wootton (1999). The author observed that higher values of the RGS predominated in the species that were total spawners, whereas, the smaller and intermediate values were more frequent in the fishes that were multiple spawners. In the High Paraná River, the female fishes presented maximum individual values of the RGS ranging from 3.34% (*Plagioscion squamosissimus*) to 28.39% (*Steindachnerina insculpta*) (Vazzoler, 1996). Comparatively, *Astyanax* species showed intermediate values, i.e., 17.60% for *A. altiparanae* (Bailly et al., 2005) and 18.43% for *A. fasciatus* (Vazzoler, 1996). The higher RGS value for *A. paranae* females in Alagados Reservoir was similar to its congeners and quite close to the value previously observed (≈14.00) for the species (Barbieri, 1992b).

The seasonal timing of the fishes reproduction is related to the suitability of the environment for the vulnerable larval fish (Wootton, 1999). Essential requirements are appropriate food, protection of the predators and benign abiotic conditions (Vazzoler, 1996; Wootton, 1999). For the fish species inhabiting the reservoirs, the lentic conditions and unpredictable changes in the water level were the most frequent limiting factors for the reproduction (Agostinho et al., 1999). In the specific case of *Astyanax* species that proliferated in the reservoirs, the reproductive strategy included long reproductive period, rapid maturation, multiple spawning, small eggs, high fecundity and absence of parental care (Suzuki et al., 2005). In spite of the inexistence of monthly samples to establish the picture frequently adopted to describe the fishes reproductive period (Garutti, 1989; Goulart, 1994; Vazzoler, 1996), the higher frequency of the specimens showing partially or totally spent gonads in October, January and April was an evidence for intensive spawning activities in these months. Therefore, it could be suggested that *A. paranae* reproductive period in the Alagados Reservoir possibly occurred from October to April. Similarly, the reproductive period for *A. paranae* in the stream population was characterized as long, with spawning extending from July to March in the Ribeirão das Marrecas (Veregue and Orsi, 2003) and from November to

January in the Ribeirão do Fazzari (Barbieri, 1992b).

Finally, for *A. paranae* population in the Alagados Reservoir, it could be concluded that: (i) the sex ratio for the sampled population stratum differed significantly from 1:1 and showed the prevalence of the females either in the length classes as in the total sample; (ii) the estimated values for the parameter *b* indicated isometric growth for both the sexes; (iii) the females were in better condition than the males; (iv) both the sexes were in lower condition in April when the reproductive period possibly finished; (v) both the sexes showed recovered condition in July when the gonadal maturation was more intense; (vi) the reproductive period possibly occurred from October to April.

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RESUMO

Foram investigados a estrutura populacional, condição e período reprodutivo de indivíduos adultos de *Astyanax paranae* habitantes de um pequeno reservatório. Os peixes foram capturados trimestralmente nas zonas fluvial e lacustre do reservatório de Alagados, Paraná, Brasil, durante 1996/1997 e 1998/1999. A proporção sexual diferiu de 1:1, com predomínio de fêmeas em todas as classes de tamanho padrão e na amostragem total da população. As fêmeas apresentaram melhor condição que os machos. Menores valores médios de condição ocorreram em abril e os maiores em julho, tanto para fêmeas quanto para machos. Os valores estimados do coeficiente de regressão linear indicaram crescimento isométrico para ambos os sexos. A relação gonadossomática alcançou o valor máximo de 14,80% para fêmeas e 8,43% para machos. O período reprodutivo da espécie possivelmente, se estendeu de outubro a abril.

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