Breeding success of *Cacicus haemorrhous* (Linnaeus) (Aves: Icteridae) in different environments in an Atlantic Forest reserve in Southeast Brazil

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ABSTRACT. Several factors, including the site where the colony was established and number of active nests can influence directly or indirectly the breeding success of colonial birds. The red-rumped cacique, *Cacicus haemorrhous* (Linnaeus, 1766), is a passerine (Icteridae) that breeds in colonies in different environments. The objective of this study was to evaluate the breeding success of red-rumped cacique in relation to three environments (lake edge, forest and swamp) in which colonies were established in an Atlantic Forest reserve in southeast Brazil. Seven colonies from the three environments were monitored during the breeding season of 2001. Overall probability of nest survival was 40.5%. We found that colonies established in the swamp presented higher nest survival than the others and the ones in the lake edge had lower survival. Nest predation was the most important cause of nest failure, representing 46.5% of all nest losses. Other failure causes were abandonment and fall of nests, representing 6.6% and 6.1% of the losses, respectively. Red-rumped cacique had higher success breeding in colonies located in the swamp.
KEY WORDS. Nest predation; red-rumped cacique; reproduction.

RESUMO. Sucesso reprodutivo de *Cacicus haemorrhous* (Linnaeus) (Aves: Icteridae) em diferentes ambientes de uma reserva de Mata Atlântica no sudeste do Brasil. Diversos fatores, incluindo os locais onde as colônias são estabelecidas e o número de ninhos ativos, podem exercer uma influência direta ou indireta no sucesso reprodutivo de aves que reproduzem em colônias. O Guaxe é uma espécie de Passeriformes (Icteridae) que se reproduz em colônias situadas em diferentes ambientes. O objetivo deste estudo foi avaliar o sucesso reprodutivo de *Cacicus haemorrhous* (Linnaeus, 1766) em relação a três ambientes (margem de lago, floresta e brejo) onde são estabelecidas colônias em uma reserva de Mata Atlântica no sudeste do Brasil. Sete colônias foram monitoradas durante a estação reprodutiva de 2001 apresentando uma probabilidade de sobrevivência dos ninhos de 40,5%. As colônias estabelecidas em brejos apresentaram sucesso reprodutivo significativamente maior do que colônias estabelecidas nos outros ambientes (margem de lago e floresta). A predação foi o fator mais importante de perdas de ninhadas, com 46,5% dos ninhos predados. Outras causas de perdas de ninhadas foram o abandono e a queda de ninhos, representando 6,6% e 6,1% das perdas, respectivamente. *Cacicus haemorrhous* obtém maior sucesso reprodutivo em colônias localizadas em área de brejo.
PALAVRAS CHAVE. Guaxe; predação de ninhos; reprodução.

Most studies about avian breeding success shows that predation is the main factor of brood loss (MARTIN 1993, AGUILAR *et al*. 2000, PICMAN *et al*. 2002). The quality of the breeding habitat has been considered as another important factor in breeding success. Some breeding habitats provide better food resources (WITTENBERGER 1980), while others are safer against predators (LENINGTON 1980) or better protected against variations from climatic extremes (PLESZCZYNSKA 1978).

For several species of colonial birds, variables such as sites of colony establishment, number of active nests, and degree of nest grouping have been considered factors that influence directly or indirectly the breeding success (TENAZA 1971, ROBINSON 1985, MASSONI & REBOREDA 2001). These factors influence in predator vulnerability and are related to the probability of nest desertion (MASSONI & REBOREDA 2001). According to HORN (1968), while one strategy can be efficient for some predators, this strategy can result in a greater vulnerability to other types of predators. Therefore, colonial species that are attacked by several kinds of predators have to deal with a variety of selective pressures that favors different sites of colonies establishment and different spatial distributions of nests within colonies (ROBINSON 1985).

The red-rumped cacique, *Cacicus haemorrhous* (Linnaeus, 1766), is an exclusively Neotropical Icteridae that occurs throughout the Amazon region; southeast and central-west of Brazil; east of Andes; Colombia; Paraguay and northeast of Argentina (PARKES 1970, SICK 1997). It inhabits humid tropical forests, including gallery forests. It is common in canopies and forest edges, river banks and clearing (FEEKES 1981, RIDGELY & TUDOR 1989). It is a species that breeds in colonies, weaving nests in a bag form, suspended from the extremity of branches from tall and smooth trunk trees in the middle of the forest and forest edges or on branches over water (FEEKES 1981, SICK 1997). It can occur in mixed colonies, associated with Crested oropendola (*Psarocolius decumanus*, Pallas 1769) (Icteridae) or yellow-rumped cacique (*Cacicus cela*, Linnaeus 1758) (Icteridae) (SICK 1997). In the study area, red-rumped cacique breeding sites can be separated in at least three environmental types, with variable vulnerability to nest predators. The three environments considered in this study were lake edge, forest clearing and swamp.

Thus, breeding aspects were studied in order to evaluate the role of colony sites and predation in the breeding success of red-rumped cacique in the study area. Our specific objective was to evaluate difference in the breeding success related to three environments (lake edge, forest clearing and swamp) in the study area.

MATERIAL AND METHODS

Study area

The study was conducted in Parque Estadual do Rio Doce (PERD), located between 19º48'-19º29'S and 42º38'-48º28'W, in the Rio Doce Valley, southeast Brazil. The park has 35,974 ha, with altitudes varying from 230 to 515 m above the sea level (CETEC 1981 *apud* TUNDISI & SAIJO 1997). The natural limits of the park are the Doce River to the east and Piracicaba River to the north. The presence of 38 lakes occupying 6% of the park's total area characterizes the landscape. The climemate is humid tropical, with rainy season from October to March and dry season from April to September.

The PERD is covered by vegetation that receives several denominations in the literature. According to VELOSO *et al.* (1991), the park vegetation is named "Sub-mountainous Semideciduous Forest". Outside the park's limits, there is a predominance of *Eucalyptus* spp., pasture lands, agriculture and forest fragments (SIF 1990).

Nest colony classification

It was considered as a colony a group of two or more nests established in bushes or trees, and simultaneously active during the breeding period, with movement of the individuals between nests or nest cluster. Groups of two or more active nests built on branches pending over water and the tree trunk in dry soil (without mud or water) were considered as lake edge colonies. Nests established on a tree in forest clearings or near human buildings and not associated to aquatic environments were considered as

forest colonies. Nests established on trees or shrubs existent in flooded and muddy sites were considered as swamp colonies.

Data collection

Seven colonies were monitored at three-day intervals during the breeding season of 2001. A map of the colonies was elaborated and each nest was plotted and received an identification number. During visits, nests' contents were inspected. Most nests were located on a position in the colony tree where we were able to access them and see their contents directly. To inspect the nests located in a difficult location to be accessed by the observers, we used two strategies: 1) we used a stick with a small mirror fixed at the end and looked at the contents reflected in the mirror with aid of binoculars or; 2) we observed the nests with binoculars and assumed their contents based on the behavior of their owners. During nest observations, when the female stayed inside the nest for a long time (at least 20 min.) and when it was not carrying food items during the observation, we assumed that the contents of the nest were eggs. When we observed the female bringing food items and feeding the nestlings, we assumed that the contents of the nest were nestlings. To avoid disturbances in the colony, many times we used the second strategy even to re-inspect accessible nests that had their contents observed directly during the previous inspection. For each nest, the following data was recorded: initial and final nest building dates, laying and hatching dates, and dates when the nestlings left the nest, or when the nest was either abandoned or predated. This monitoring had the objective to evaluate breeding success and also to know in which nest phase nest loss was highest. Seven colonies were monitored, two of lake edge, two of forest, and three of swamps. Colonies were considered active from the date that the first female laid eggs to the date that the last nest in the colony became inactive.

Nests were considered successful when at least one nestling left the nest. Nests that were found empty, without any sign of damage in their structure caused by predation and those with nestling aged over 21 days, were considered successful. When found empty before the nestling's age of 21 days, usually presenting traces of predatory actions, such as damage to its structure, blood traces and/or feathers, the nest was considered predated. Nest containing dead nestling with signs of aggression, such as injuries and beak marks, were also considered predated. Nests were considered abandoned when eggs remained (intact) in the nest for more than 25 days. Nest found with dead nestling without any signs of aggression were considered abandoned. Other causes of nests losses were nest falling to the ground and destruction due to rainfall or other unknown factors. Nests abandoned before eggs were laid were not considered in the breeding success analysis.

Data analyses

For each colony, the percentage of successful nests was calculated, generating the percentage of successful nests for each environment (lake edge, forest and swamp). The nest sur-

vival was also calculated according to Mayfield's protocol (MAYFIELD 1961, 1975). For each colony, the following was calculated: nest survival during incubation (%NsI); nest survival during nestling period (%NsN) and nest survival from start incubation to fledgling (%Ns).

Statistical analyses

Kruskal-Wallis was applied to verify the difference in breeding success (% of nest success) among the three environments. This test was also applied to assess if predation rate was different among the three environments (lake edge, forest and swamp). Qui-square Mantel-Haenszel test was applied to confirm the difference in breeding success among the three environments. To evaluate if nest survival probability (%Ns) calculated by Mayfield's method and the nest success percentage (% of nest success) supply the same information, a Wilcoxon test was applied. Non-parametric statistic was used due to the strong differences found within environments, especially between the two colonies of the lake edge (Tabs I and II). Linear regressions were used to evaluate the relationship between: a) number of nests and nest survival probability (%Ns); b) number of nests with predation rate and; c) number of nests with overall nest failure. All tests were applied according to OTT (1988) and TRIOLA (1999) and conducted in a Statistica statistical package (STATSOFT 1995). In result, the standard error (SE) was used and a significance level of 5% was applied.

RESULTS

Considering all nests (n = 296), including the ones that were lost or abandoned before eggs were laid, the colonies varied from 9 to 85 nests, with mean of 42.3 ± 30.7 nests. In those colonies, the number of nests that had eggs varies from 7 to 74 nests, with mean of 32.6 ± 24.6 and a total of 228 nests (Tab. I). Thus, the analyses presented here refer to these 228 nests that had eggs during the study period.

Nests predation

Predation was the main factor of nest loss, with 46.5% of total losses caused by predator action. Lake edge colonies pre-

sented higher predation rate, with 76.5% of their nests predated. The smallest predation rate was found in forest colonies, with 38.1% of their nests predated. The swamp colonies had 46.6% of their nests predated (Tab. I). However, the difference in predation rate among the three environments was not significant (H = 1,489, d.f. = 2, p = 0.475).

Overall predation rate during the incubation period was 21.9%, with swamp colonies presenting the highest proportion (25.7%) of the nests predated in this period. Predation during nestling period was 24.6%, with lake edge colonies presenting the highest nestling predation rate (58.8%) (Tab. I). We did not find difference in the nest predation rates between the incubation and nestling periods (Z = 1,577, p = 0.115) when nest from all colonies were considered together.

Nest abandonment and fall

Nests were abandoned during several building phases. Out of 296 nests registered, 23% were abandoned before eggs were laid. Some females practically finished nest building and later abandoned them without laying eggs. The smallest abandonment rate, before eggs were laid, occurred in swamp colonies (18.2%), and the highest was in forest colonies (31%). Lake edge colonies had 19% of their nests abandoned before eggs were laid.

Considering only nests that had eggs (228 nests), three (1.3%) were abandoned during incubation and 12 (5.3%) during the nestling period. Therefore, the abandonment of nests after eggs were laid represented 6.6% of brood losses in the study area (Tab. I). Other cause of brood loss was nest unfastening, causing its fall. The nest fall represented 6.1% of brood loss (Tab. I).

Breeding success

The breeding success of the red-rumped cacique in the study area calculated by the number of successful nests was 40.8% (Tab. I). Nest survival from start of incubation to fledgling (%Ns) calculated through Mayfield's protocol presented similar result to the simple percentage (Tab. II).

There was no significant difference between nest survival probability (%Ns) and the simple percentage of nest success (% of nests that at least a nestling left the nest) (Z = -0.676,

Table I. Total number of nests, number of nests that have eggs and fate of red-rumped cacique in Parque Estadual do Rio Doce.

Environment	Colony	Total of nests	Nests with eggs	Nests fate (%)					
				Abandoned	Died nestling	Fallen nests	Predated eggs	Predated nestling	Nests successful
Lake edge	1	9	7	1 (14.3)	1 (14.3)	0	1 (14.3)	3 (42.8)	1 (14.3)
	2	12	10	0	1 (10.0)	0	2 (20.0)	7 (70.0)	0
Forest	3	46	31	2 (6.4)	3 (9.7)	5 (16.1)	3 (9.7)	6 (19.3)	12 (38.7)
	4	48	32	0	3 (9.4)	7 (21.9)	6 (18.7)	9 (28.1)	7 (21.9)
Swamp	5	19	18	0	0	0	2 (11.1)	2 (11.1)	14 (77.8)
	6	85	74	0	1 (1.3)	0	21 (28.4)	17 (23.0)	35 (47.3)
	7	77	56	0	3 (5.3)	2 (3.6)	15 (26.8)	12 (21.4)	24 (42.8)
Total		296	228	3 (1.3)	12 (5.3)	14 (6.1)	50 (21.9)	56 (24.6)	93 (40.8)

p = 0.499). Since the two percentages denoted the same information, we considered as measure of breeding success the nest survival probabilities calculated through Mayfields' protocol.

Breeding success was significantly different among the three environments (H = 5.756, d.f. = 2, p = 0.050 and χ^2 = 18.958, d.f. = 1, p < 0.001) (Tabs I and II). Lake edge colonies presented the smallest breeding success and swamp colonies presented the highest breeding success.

The number of nests in the colony was not significantly related to nest survival (%Ns) (r^2 = 0.371, d.f. = 6, p = 0.412), predation rate (r^2 = 0.038, d.f. = 6, p = 0.676) and nest failure (all cause of nest loss combined) (r^2 = 0.137, d.f. = 6, p = 0.414).

Lake edge colonies had mean activity duration (9.4 ± 1.0 weeks) relatively smaller than forest (13.0 ± 1.8 weeks) and swamp (13.3 ± 4.8 weeks) colonies, but this difference was not statistically significant (H = 1.357, d.f. = 2, p = 0.507). The analysis above was repeated considering only the time interval (9.4 weeks) in which colonies of the three environments were active. In this analysis it was observed a significant positive relationship between number of nests and nest survival (%Ns) (r^2 = 0.824, d.f. = 6, p = 0.023) (Fig. 1) and a significant negative relationship between number of nests and nest failure (all causes of nest loss combined) (r^2 = 0.609, d.f. = 6, p = 0.038). The relationship between number of nests and predation rate remained not significant (r^2 = 0.433, d.f. = 6, p = 0.108).

Nest survival during incubation (%NsI) was significantly higher than nest survival during nestling period (%NsN) (H = 5.589, d.f. = 1, p = 0.018) (Tab. II).
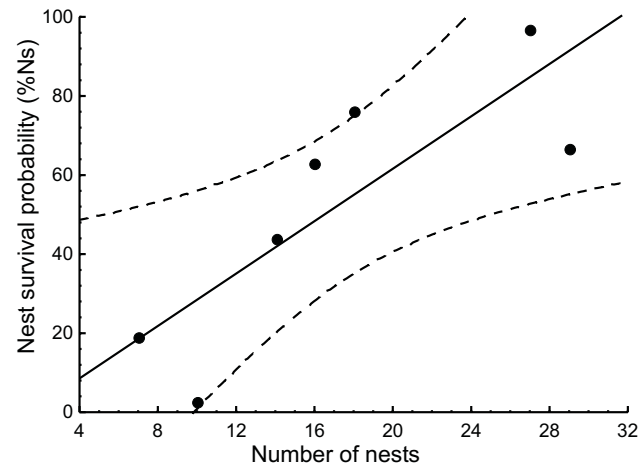

Figure 1. Correlation between number of nests and nest survival probability (%Ns) of red-rumped cacique in Parque Estadual do Rio Doce. Dashed lines represent confident interval.

Table II. Nest survival parameters of red-rumped cacique in three environments in Parque Estadual do Rio Doce. [1] Nest survival during incubation; [2] nest survival probability during nestling period; [3] nest survival from start of incubation to fledgling.

Environment	Colony	%NsI [1]	%NsN [2]	%Ns [3]
Lake edge	1	72.0	26.3	19.0
	2	79.1	3.3	2.6
Forest	3	80.8	44.4	35.9
	4	84.0	26.2	22.0
Swamp	5	89.0	85.9	76.3
	6	72.4	67.3	48.7
	7	71.7	60.9	43.7
Total		76.3	53.1	40.5

DISCUSSION

The number of red-rumped cacique nests varied considerably in colonies from each environment. The swamp was the environment where colonies presented the largest number of nests and also the highest breeding success. In the lake edge colonies it was observed the contrary, being also the environment with the highest predation rate in relation to the other two environments (forest and swamp). SICK (1997) stated that caciques

colonies sizes vary significantly and ROBINSON (1985) has observed yellow-rumped cacique colonies varying from 2 to 250 nests, of which as many as 100 may be active at the same time.

Nest predation

Predation was the main factor of nests loss in the study area. Higher predation rate in colonies established in lakes and river edges was also observed for red-rumped cacique population in Suriname (FEEKES 1981) and yellow-rumped cacique population in Peru (ROBINSON 1985), where the predation rate in this environment was 100% in five years of study. These authors attributed larger vulnerability in this environment to terrestrial and arboreal predators. It was observed that forest clearing and swamp sites were chosen by a larger number of females. Swamp colonies, which presented predation rates relatively smaller, had more than twice as many nests as lake edge colonies. Several studies have established an inverse relationship between colony size and nest predation rate (WESTNEAT 1992, WIKLUND & ANDERSSON 1994, PICMAN et al. 2002). Therefore, the small number of nests in the lake edge colonies should be considered in the assessment of nests predation rate.

Several mechanisms can reduce predation in larger colonies. The frequency and efficiency of attack to predators can increase in larger colonies (HOOGLAND & SHERMAN 1976, ROBINSON 1985), and predators can satiate themselves where preys are abundant and the probability of attack per nest is reduced (FOSTER & TREHERNE 1981, NISBET & WELTON 1984). However, many females breeding together can be harmful if predators are attracted to nest concentrations or by females movement, increasing the predation risk in very crowded areas. WEATHERHEAD & ROBERTSON (1977) related that predation risk increase with female density in a red-winged blackbird (*Agelaius phoeniceus*, Linnaeus 1766) (Icteridae) population, but this relation was not observed in another population of the same species (CACCAMISE 1976).

Nestling predation rate (24.6%) was slightly larger than eggs predation rate (21.9%), however this difference was not statistically significant. AGUILAR *et al*. (1999) did not find significant difference in the predation rate between the two nest phases of Euler's flycatcher (*Lathrotriccus euleri*, Cabanis 1868) (Tyrannidae). However, RODRIGUES & CRICK (1997) found larger nest loss in the nestling phase for Chiffchaff (*Phylloscopus collybita*, Vieillot 1817) (Sylviidae) in the temperate region. SLAGSVOLD (1982) suggested that predation rates are frequently larger during nestling phase because nests become more exposed to visualization by predators which are conducted by adult movement for nestlings feeding.

Predation is one of the factors most considered by theories that try to explain the evolution of bird colonial breeding (BROWN 1975, PLEASANTS 1979, WITTENBERGER & HUNT 1985, WIKLUND & ANDERSSON 1994, PICMAN *et al*. 2002). Therefore, it is not surprising that the main cause of red-rumped cacique nests loss is predation as suggested in the present study. Besides, predation has also been considered as the largest factor of brood loss for several non-colonial bird species (ONIKI 1979, MARTIN 1993, LOPES & MARINI 2005, AGUILAR *et al*. 1999, 2000), reflecting the importance of knowing the factors associated with predation to define conservation strategies of bird species.

Nest abandonment and fall

Nest abandonment rate (23%) before females laid eggs was possibly related with aggressive interactions between females. ROBINSON (1988) studying Yelllow-rumped cacique in Peru related that many young females began building nests and abandoned them later. This author considered that these females were the focus of intense aggression from adult females, which often expelled young and took over nest sites in which young females had begun to build. Besides, adult females of red-rumped cacique often remove material used by young females to build their own nests (DUCA & MARINI 2004), possibly causing nest abandonment. Only 11.6% out of 251 nests began by young females of yellow-rumped cacique were completed (ROBINSON 1988). It is possible that nest abandonment before eggs were laid and long period (about 60 days) of nest building by some females (DUCA & MARINI 2004) are explained by similar reasons related above for yellow-rumped cacique in Peru. CURIO (1983) and PROCTER-GRAY & HOLMES (1981) discussed that the attempt of reproducing by young females is a way of obtaining experience and the energy cost is compensated with larger breeding success when they get older.

Nest abandonment after eggs were laid (6.6%) and nest fall (6.1%) were important causes of nest losses. ONIKI (1979), in studies conducted in Amazon, found similar nest abandonment rates (about 5.3%). FEEKES (1981) reported that disturbance, predation and bad weather often caused all birds to desert colonies leaving their offspring behind. Although GÖTMARK (1992) considers that the main disturbance caused by researchers in bird nests is abandonment of eggs and nestlings, it did not seem to be an important cause of red-rumped cacique nests abandonment in this study.

FEEKES (1981) relates fall and tear of red-rumped cacique nests in Suriname only to strong wind gusts and rain, and ROBINSON (1985) relates fall of yellow-rumped cacique nests only to accidental action of predators. In spite of other hypotheses, we believe that female behavior removing material from other nests (DUCA & MARINI 2004) and fight between them are the main causes of red-rumped cacique nests fall in the study area. These agonistic interactions frequently happened on the nests, damaging their structure and leaving them more susceptible to unfasten later or provoking their immediate fall. One of the reasons to happen these aggressive interactions is the frequent behavior of females that steal material of other nests to use in the building of their own nest. Several times it was observed nests with eggs or nestlings having their structure damaged due to theft of material by other females (DUCA & MARINI 2004).

Breeding success

The red-rumped cacique nest survival probability was 40.5%. Smaller values were reported for Kirtland's warbler (*Dendroica kirtlandii*, Baird 1852) (Parulidae) (MAYFIELD 1961) and red-winged blackbird (WESTNEAT 1992), both with a nest survival probability of 32%, and larger value was found for Kentucky warbler (*Oporornis formosus*, Wilson 1811) (Fringillidae) (SARGENT *et al*. 1997). The three studies mentioned above, however, were accomplished in the temperate region. MASON (1985), working in subtropical region, found nest survival probability varying from 6.8% to 71% for passerine species. Therefore, it was observed that the nest survival probability of bird species is highly variable and that the value found for red-rumped cacique is compatible with values from the literature mentioned above and with other tropical passerine (RICKLEFS & BLOOM 1977).

The existence of a gradient in breeding success among the three environments considered here can be explained by an association of factors, which most likely were unchained by predation pressure. A similar gradient in the breeding success was also observed in colonies of red-rumped cacique and yellow-rumped cacique in Suriname (FEEKES 1981) and yellow-rumped cacique colonies in Peru (ROBINSON 1985). These authors consider that the gradient in breeding success observed is a result of differentiated vulnerability of those environments to terrestrial and arboreal predators. According to ROBINSON (1985), most cacique females that lose nests to a predator tend to select safer sites against that kind of predator. For this mechanism, the safest sites against predators accumulate the largest number of nests, promoting other benefits related to a larger number of nests and individuals (ROBINSON 1985, WIKLUND & ANDERSSON 1994, PICMAN *et al*. 2002). In this study, we found a significant relationship between the number of nests with nests survival probability and failure percentage when we analyzed only the active nests on the period of time that the colonies from three environments were active. It suggests that the presence of larger number of nests increases nest survival probability of red-rumped cacique.

BURGER (1985) considers predation the factor that influences the most selection of breeding sites. MARTIN (1995) also

found consistent results with the prediction that birds select breeding sites in agreement with the predation risk. This author found a large variation in life history characteristics in the breeding sites of 123 bird species from North America, with 50-60% of these characteristics being explained by a correlation between nest predation rate and the different breeding sites.

Even though in this study we did not detect a significant difference between predation rates during incubation and nestling periods, it was observed a larger nest survival probability during incubation period. KELLY (1993) also found a larger survival rate during incubation period for Dusky flycatcher (*Empidonax oberholseri*, Phillips 1939) (Tyrannidae), but this difference was not statistically significant. BEST & STAUFFER (1980) found higher nest success during nestling than during incubation period for 10 out of 13 studied species.

The results presented here indicate that red-rumped cacique obtain higher breeding success in colonies established in swamp environments than the ones established in forest or lake edge. However, the difference in predation rate among the three environments was not significant, predation was the main cause of nests loss and it should be considered as an important factor supporting a higher breeding success and number of nests in the swamp environment.

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