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Biology of the marine tucuxi dolphin (*Sotalia fluviatilis*) in south-eastern Brazil

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Age, growth and reproductive parameters related to the marine tucuxi are presented, as well as feeding habits and parasitism. The specimens' age ranged from zero (newborn) to 21 years for males and 0.5 to 30 years for females. In relation to the body dimension, length distributions were bell-shaped for both sexes with male marine tucuxi ranging from 86.0 to 200.0 cm in length and females from 117.5 to 198.0 cm. The body length of new-born and calves varied between 86.0 to 117.5 cm and the postnatal growth curve an asymptotic reached length of 191.0 cm. According to the relationship between age, body length and reproductive characteristics, male and female specimens were considered sexually mature when $\geqslant 6$ years and body length $\geqslant 180.0$ cm and $\geqslant 6$ years and body length $\geqslant 160.0$ cm, respectively. Males and females up to six years old represented around 80% of the captures, indicating a bias towards juveniles and individuals that have yet to reach sexual maturity. The youngest specimen with solid contents in the stomach was 119.0 cm in length and seven months old. The marine tucuxi feeds on neritic prey, preferentially on the teleost fishes *Trichiurus lepturus* and *Porichthys porossisimus*, and on the cephalopods *Loligo sanpaulensis* and *L. plei*. Back calculation of prey lengths indicated that fish ranged from 1.2 to 106.9 cm and cephalopods from 3.4 to 22.2 cm. The barnacle *Xenobalanus globicipitis* was recorded attaching to the caudal fin and the helminths *Braunina cordiformis*, *Anisakis typica*, *Halocercus brasiliensis* and *Nasitrema* sp. were found in the internal organs.

INTRODUCTION

Sotalia fluviatilis Gervais, 1853 (Cetacea: Delphinidae), known as tucuxi, occurs in Central and South America, including the basins of the Amazon and Orinoco Rivers (Borobia et al., 1991). Two different ecotypes are recognized based on skull and body dimensions: the marine and fluvial forms (Jefferson et al., 1993). The marine tucuxi inhabits coastal and estuarine waters and despite its continuous occurrence along the distributional range it is one of the less studied delphinids. This species of dolphin has been also affected by gill-net fisheries along its distribution (Siciliano, 1994).

The objective of this study is to present information about the biology of the marine tucuxi in south-eastern Brazil, based on specimens incidentally captured in fisheries along the northern Rio de Janeiro State ($\sim$21°S to 22°S).

MATERIALS AND METHODS

The Rio de Janeiro State is situated in south-eastern Brazil. The geographic limits to its northern coast are Barra do Itabapoana (21°18′S) and Macaé (22°25′S), and in Atafona harbour (21°35′S) gill-nets are largely used (Figure 1). The specimens of marine tucuxi analysed in the present study were collected after entanglement in gill-net fisheries, between 1987 and 2002. The number of specimens considered in each analysis is presented in Table 1.

Body length was measured along the longitudinal axis of the body from the tip of the upper jaw to the notch of the flukes. Age was estimated by counting the number of growth layers groups (GLGs) in the dentine. The GLG pattern described in Ramos et al. (2000) was adopted, i.e. one complete dentinal GLG comprising one narrow unstained layer and one stained broad layer; a fine darker layer demarcated the unstained layer of subsequent GLGs. Specimens with less than one complete layer were considered new-born (0 GLG) or calf (0.5 GLG). Foetal age was extrapolated through a combination of an assumed length at birth of 106 cm, a gestation period of 11.6 months and a prenatal growth rate of 9.4 cm/month, which were described in Ramos et al. (2000). Growth was determined by fitting a non-linear Gompertz model to length-at-age data (Zullinger et al., 1984) using Curve Expert 1.3 for Windows. Females with at least one corpus on the external surface of the ovary, pregnant or lactating were considered sexually mature. Males with sperm in the epididymis were considered sexually active (Perrin & Reilly, 1984).

The stomach contents were analysed in order to investigate feeding habits. Undigested prey were measured and weighed. Teleost otoliths and cephalopods beaks were used to identify, quantify and estimate the length and weight of the prey species. Only one shrimp was recovered from stomach contents and its rostrum was used to identify the species. The index of relative importance (IRI) (Pinkas et al., 1971) was calculated to determine the representative prey species and teleosts and cephalopods were considered as independent prey to reduce under- or over-estimation of their importance.

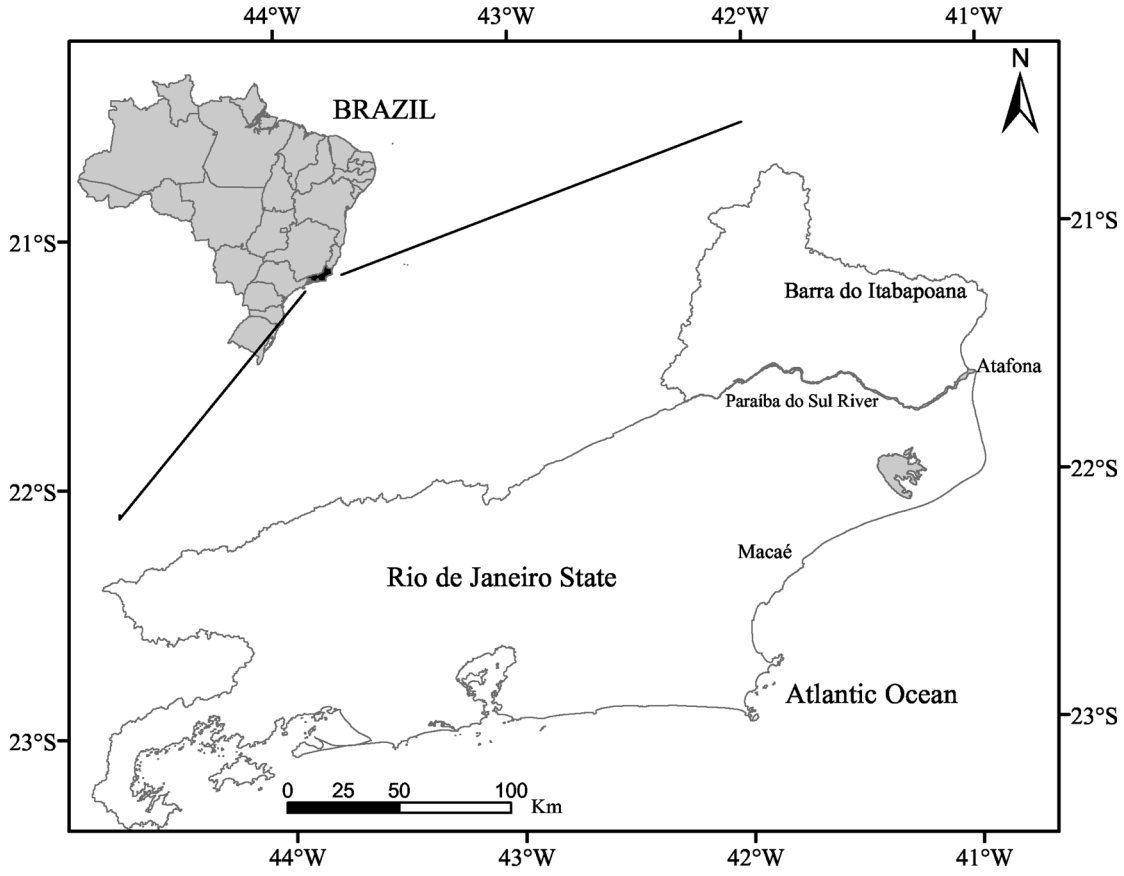

Figure 1. Rio de Janeiro State, south-eastern Brazil, indicating the limits of northern coast (Barra do Itabapoana and Macaé) and Atafona harbour.

Table 1. *Number of marine tucuxi specimens analysed in northern Rio de Janeiro State, south-eastern Brazil.*

Analysis	Number of specimens
Sex ratio	128
Body length	114
Age determination	116
Growth parameters	99
Feeding habits	77
Epizoics	116
Internal parasites (helminthes)	106

The external body surface and internal organs (stomach, heart, lungs, nasal cavity, kidneys and gonads) were examined in order to determine the presence of epizoics and internal parasites, respectively. The prevalence of infestation was calculated according to Bush et al. (1997).

RESULTS

Age, growth and reproductive parameters

No difference was observed in the ratio of males to females (1.3:1), suggesting that there is no sexual segregation with incidental captures along the study area. The age ranged from zero (newborn) to 21 years for males and 0.5 to 30 years for females, and males and females up to six years old represented around 80% of the captures. Body length of marine tucuxis ranged from 86.0 to 200.0 cm for males and from 117.5 to 198.0 cm for females. Length distributions were bell-shaped for both sexes (Figure 2). Growth curves fitted to length-at-age data by a Gompertz model are presented in Figure 3 and the estimated growth parameters are given in Table 2. The postnatal growth curve estimated an asymptotic length of 191.0 cm.

The lengths of the six foetuses ranged from 36.0 to 84.0 cm and the estimated elapsed gestation time was four to nine months. The body length of new-born (0 GLG) and calves (0.5 GLG) ranged between 86.0 and 117.5 cm (N=6).

According to the relationship between age and body length of the sexually mature individuals, 47 individuals could be classified as mature in this study: 23 females ($\geqslant$6 years and body length $\geqslant$160.0 cm) and 24 males ($\geqslant$6 years and body length $\geqslant$180.0 cm).

The youngest mature females were six years old and the length of mature females ranged from 161.0 cm to 196.0 cm. Among these females, six were pregnant and four lactating. We were able to observe macroscopically the sperm in the epididymis of six males ranging from 183.0 to 198.0 cm, confirming their testicular activity.

Feeding habits

The youngest specimen with solid contents in its stomach was 119 cm and seven months old. Teleosts were

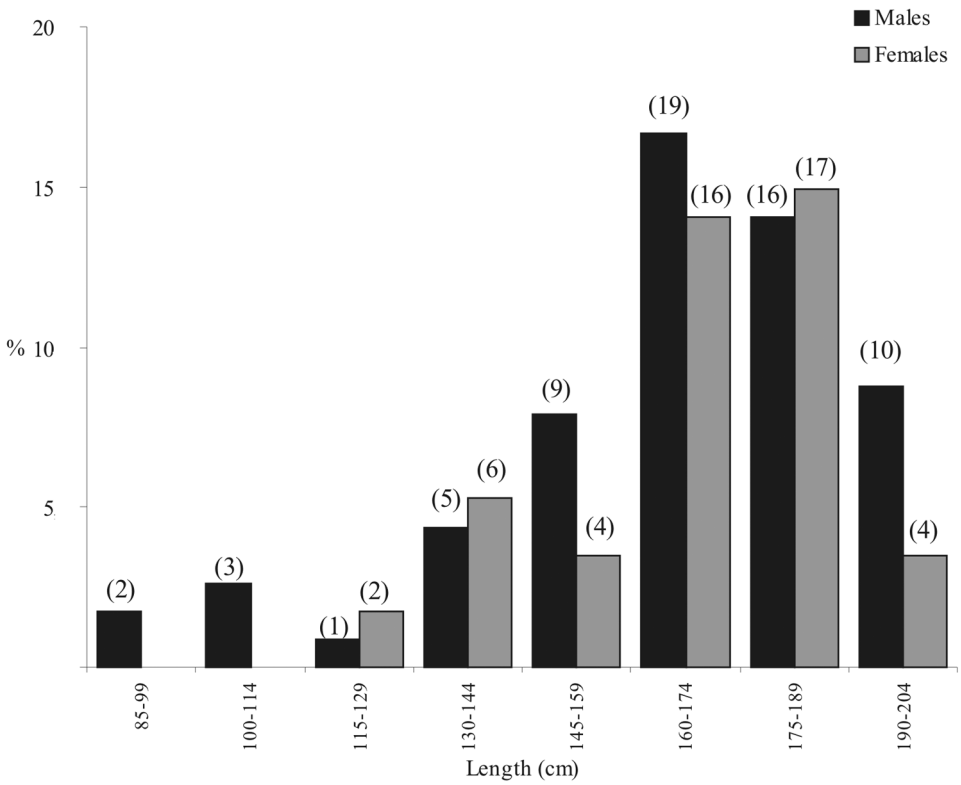

Figure 2. Length distribution of males (N=65) and females (N=49) of marine tucuxi incidentally captured in northern Rio de Janeiro, south-eastern Brazil.

recorded in 92% (N=71) of the stomachs with food remains. Thirty-two species of prey from 13 families were identified. The number of species in each stomach varied from one to ten (average=4.2, SD=2.2). The marine tucuxi feed preferentially on *Trichiurus lepturus* and *Porichthys porossisimus*, which constituted 5.6% of all identifiable prey items in the stomachs (Table 2). Back calculation of teleost lengths indicate that marine tucuxi feed on individuals ranging from 1.2 to 106.9 cm (Table 3).

Cephalopods were recorded in 63% (N=49) of the stomachs. Loliginidae species *Loligo sanpaulensis*, *Loligo plei* and *Lolliguncula brevis* were identified. The number of species in each stomach ranged from one to three (average=1.4, SD=0.6) and the mantle length from 3.4 to 22.2 cm. The species *Loligo sanpaulensis* and *L. plei* were primary prey items in the diet of the marine tucuxi. These two species accounted for 5.6% of all identifiable prey items in the stomachs (Table 3).

Only one stomach with food remains (1.4%) contained a single specimen of the custacean *Xyphopenaeus kroyeri*

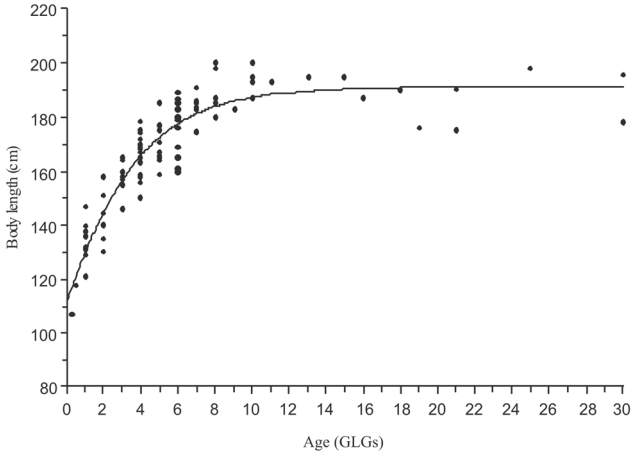

Figure 3. Length-at-age data of marine tucuxi incidentally captured in northern Rio de Janeiro State, south-eastern Brazil (N=99). The solid line represents the predicted growth trajectory from the Gompertz model.

Table 2. *Growth parameter values from the Gompertz growth model fitted to length-at-age data of marine tucuxi incidentally captured in northern Rio de Janeiro State, south-eastern Brazil (N=99).*

Age-range (years)	Body length-range (cm)	Asymptotic length (cm)	Correction factor	Growth rate constant	Correlation coefficient (r)
0 to 30	86.0 to 200.0	191.0	−0.627	0.332	0.92

Table 3. *Prey species of marine tucuxi in northern Rio de Janeiro State, south-eastern Brazil (N=77).*

		Density (N) (per stomach)		Size (cm)		Biomass (g) (per stomach)		
Species	FO (%)	Range	Average ±SD	Range	Average ±SD	Range	Average ±SD	IRI
Teleosts								
Trichiurus lepturus	70.0	1–22	5.4 ±4.6	31.5–106.9	66.1 ±21.9	10.1–4.231.5	1285.1 ±1255.6	5229.0
Porichthys porosissimus	35.0	1–52	15.7 ±15.8	10.7–19.2	15.0 ±2.5	11.8–3.679.1	888.6 ±1156.7	1533.0
Anchoa filifera	22.5	1–68	10.4 ±17.5	4.9–8.5	6.1 ±1.1	2.0–284.9	64.2 ±105.9	297.0
Paralonchurus brasiliensis	20.0	1–35	8.3 ±10.9	2.0–12.2	7.7 ±4.3	1.4–710.4	210.0 ±263.8	222.0
Ariosoma opisthophthalma	20.0	1–10	4.6 ±3.3	8.5–46.0	21.9 ±13.0	0.5–522.2	172.8 ±217.3	132.0
Isopisthus parvipinnis	22.5	1–44	6.7 ±10.7	3.3–10.7	7.8 ±2.7	4.0–68.4	29.8 ±19.1	90.0
Cynoscion guatucupa	10.0	1–89	13.6 ±26.7	15.5–27.1	19.5 ±5.2	35.8–920.4	523.4 ±435.7	50.0
Ctenosciaena gracilicirrhus	10.0	1–35	10.5 ±16.4	3.0–6.4	5.0 ±1.5	3.0–264.6	77.8 ±125.3	42.0
Cynoscion jamaicensis	15.0	1–9	3.7 ±3.2	6.3–9.2	7.6 ±1.1	4.3–71.5	31.1 ±27.7	33.0
Conodon nobilis	12.5	1–10	3.8 ±3.7	5.7–11.9	9.3 ±2.6	42.9–65.4	53.3 ±9.7	26.3
Macrodon ancylodon	10.0	2–26	6.6 ±7.5	9.2–12.8	10.8 ±1.5	32.8–185.4	93.7 ±80.8	20.0
Stellifer sp.	10.0	1–16	3.4 ±5.6	2.3–4.9	3.7 ±1.2	1.1–5.1	3.3 ±2.1	18.2
Sciadeichthys luniscutis	2.5	4–40	22.0 ±25.5	3.3–21.8	10.7 ±4.4	1006.8	—	13.0
Peprilus paru	7.5	1–2	1.5 ±0.6	6.8–14.9	10.5 ±4.1	19.6–166.9	71.8 ±82.5	6.0
Micropogonis furnieri	7.5	1–4	2.0 ±1.4	6.1–13.2	9.6 ±3.6	1.8–85.0	31.4 ±46.5	5.3
Bagre bagre	2.5	14	—	1.2–17.6	7.4 ±5.9	253.2	—	4.3
Nebris microps	5.0	1–4	2.0 ±1.2	9.5–12.4	11.0 ±2.1	20.2–76.1	48.2 ±39.5	2.5
Arius spixii	2.5	3	—	10.1–20.8	15.8 ±5.4	281.4	—	2.0
Mugil sp.	2.5	1–2	1.7 ±0.6	18.0–22.0	20.0 ±2.8	327.0	—	2.0
Stellifer brasiliensis	5.0	4	2.0 ±0.0	2.8–3.6	3.2 ±0.6	1.3–2.2	1.8 ±0.6	1.6
Sardinella brasiliensis	2.5	3	—	3.1–9.3	7.2 ±3.6	35.8	—	0.9
Cynoscion virescens	2.5	1	—	—	22.7	122.0	—	0.8
Pellona harroweri	2.5	1	—	—	7.5	7.1	—	0.3
Lujtanus sp.	2.5	1	—	—	—	—	—	—
Menticirrhus americanus	2.5	2	1.0 ±0.0	—	—	—	—	—
Odontognathus mucronatus	2.5	2	—	—	—	—	—	—
Orthopristis rubber	2.5	5	—	—	—	—	—	—
Pomatomus saltator	2.5	1	—	—	—	—	—	—
Pogonias cromis	2.5	1–3	2.0 ±1.4	—	—	—	—	—
Stellifer rastrifer	2.5	6	—	—	—	—	—	—
Umbrina conasai	2.5	2	1.0 ±0.0	—	—	—	—	—
Urophicys brasiliensis	2.5	1	—	—	—	—	—	—
Cephalopods								
Loligo sanpaulensis	51.1	1–56	11.1 ±14.1	3.4–13.5	4.8 ±2.0	3.3–320.0	57.6 ±73.8	4859.6
Loligo plei	48.9	1–15	2.9 ±4.0	5.1–22.2	13.1 ±4.4	4.6–1,350.5	172.2 ±307.6	4278.8
Lolliguncula brevis	22.2	1–6	2.2 ±1.8	3.8–5.3	4.5 ±0.5	3.6–41.7	15.4 ±15.4	197.6

FO, frequency of occurrence, i.e. percentage of stomachs with the prey; SD, standard deviation; IRI, index of relative importance (Pinkas et al., 1971).

(Penaeidae), which suggests that crustaceans are of lesser importance in the diet of the marine tucuxi.

Epizoics and parasites

The barnacle *Xenobalanus globicipitis* attached to the caudal fin was recorded on eight specimens (6.9%) with an average of six barnacles per dolphin (SD=4.8, range=1 to 16). Regarding internal parasitism, the prevalence was 43.4%, which corresponds to 46 specimens infested. Twenty-nine animals (63.0%) had the stomach trematode *Braunina cordiformis* (average=48, SD=76.1, range=1 to 327), 24 (52.2%) had the stomach nematode *Anisakis typica* (average=7, SD=11.9, range=1 to 49), five (10.9%) had the lungs nematode *Halocercus brasiliensis* (average=7, SD=6.0, range=1 to 15) and eight (17.4%) had the nasal cavity trematode *Nasitrema* sp. (average=7, SD=13.0, range=1 to 39).

DISCUSSION

Age, growth and reproductive parameters

In Paraná State (~25°S to 26°S), Rosas et al. (2003) found a maximum age of 30 years for the oldest female and 29 years for the oldest male. In São Paulo State (~24° to 25°S), Santos et al. (2003) also recorded a maximum age of 29 years to the marine tucuxi. As this species does not have sexual dimorphism (Jefferson et al., 1993), the maximum age seems to be about 30 years or less for both sexes. Age structures reported in the present study are similar to those observed for incidentally captured marine tucuxi in São Paulo and Paraná State waters,

which indicates a capture bias towards juveniles and individuals that are attaining sexual maturity.

In general, there are no significant differences in body length-range along the marine tucuxi distribution (Alves-Júnior et al., 1996; Rosas & Monteiro-Filho, 2002) and the largest recorded specimen was a 206.0 cm female (Barros, 1991). The asymptotic lengths estimated by Santos et al. (2003) (179.8 cm) and Rosas et al. (2003) (186.4 cm for males and 177.3 cm for females) were lower than our estimate. The difference could reflect differences in growth rate among marine tucuxi populations, but data from other regions are necessary to confirm it.

Ramos et al. (2000) examined the relationship between gonad length and body length of marine tucuxi in northern Rio de Janeiro State. They suggested that males and females attain sexual maturity at six years old, when they reached 180.0 and 160.0 cm, respectively. The present study corroborates their results. However, Rosas & Monteiro-Filho (2002) carried out histological analyses of 27 testis and 23 ovaries of marine tucuxi collected along the coast of Paraná State, which is around 800 km from the study area, and verifying that males were sexually mature at total lengths between 170.0 and 175.0 cm, at seven years, while females between 164.0 and 169.0 cm, at five and eight years. The differences could reflect the variation along marine tucuxi distribution and/or the methodology applied in those studies.

Rosas & Monteiro-Filho (2002) also found different values from Ramos et al. (2000) in relation to length at birth (92.2 vs 106.0 cm), prenatal growth rate (8.9 vs 9.4 cm/month) and lactation period (8.7 vs 9.4 months). They suggested that Ramos et al. (2000) over-estimated the body length at birth and the prenatal growth rate in northern Rio de Janeiro State because its sample could be biased by incidental capture selectivity. These studies suggest that differing life history patterns between marine tucuxi populations could occur along their distributional range.

Feeding habits

In northern Rio de Janeiro State, the main prey species of the marine tucuxi are abundant throughout the year in coastal areas, and some of them are related to estuarine areas. In general, they have low commercial value or are considered as by-catch in the local fisheries (Di Beneditto et al., 1998).

Epizoics and parasites

The barnacle *Xenobalanus globicipitis* has also been recorded on the body of marine tucuxi from Guanabara Bay (~23°S), Rio de Janeiro State, and from São Paulo State (Di Beneditto & Ramos, 2000). In the study area, these authors also reported its presence on the body of franciscana (*Pontoporia blainvillei*) and bottlenose dolphin (*Tursiops truncatus*).

Santos et al. (1996) analysed the internal organs of 23 marine tucuxis captured from 1989 to 1993 in northern Rio de Janeiro State and identified *Braunina cordiformis*, *Anisakis typica* and *Halocercus brasiliensis*. Our results confirm the occurrence of these helminth species and add the genus *Nasitrema* to the helminthofauna of the marine tucuxi in the study area. Due to their higher prevalence rates, the species *B. cordiformis* and *A. typica* could be considered potential biological tags of this cetacean population. Unfortunately, the knowledge about the marine tucuxi helminthofauna in other areas is restricted and do not allow comparisons.

Our results review, update and provide new information about the biology of *Sotalia fluviatilis* in south-eastern Brazil. This delphinid is one of the most vulnerable cetaceans in Brazilian waters due to its coastal habit and involvement in fisheries.

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