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Some Aspects of Population Biology of *Oreochromis niloticus* (Linnaeus, 1758) from Lakes Alau and Bako, North-East Nigeria

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Abstract: Population biology is key to identifying the stock status of individual fish species within an environment. This study assessed morphological characteristics and condition factors of *Oreochromis niloticus* under different environmental conditions of Lakes Alau and Bako. Fish samples were collected, identified, weighed and sixteen morphological traits were measured using standard methods. Length-weight relationships (LWR) and condition factors (K) were estimated using standard formula. Total length (16.84±1.93 cm), standard length (13.42±1.68 cm), body depth (5.50±1.14 cm), head length (4.55±0.57 cm), caudal peduncle length (4.97±0.67 cm) and pectoral fin length (5.16±0.63 cm) of *O. niloticus* populations from Lake Bako were higher than those in Lake Alau. *Oreochromis niloticus* from Lakes Alau (3.508) and Bako (3.535) exhibited positive allometric, while K varied from 1.85±0.14 (Lake Alau) to 1.87±0.13 (Lake Bako) respectively. It is evident from this study that *Oreochromis niloticus* thrive in both Lakes, and they display morphological plasticity.

Keywords: *Oreochromis niloticus; Morphological characteristics; Length-weight relationships; Condition factor; Lakes Alau and Bako*

1. Introduction

Fish generally demonstrate greater variances in morphological traits both within and between populations than other vertebrates and are equally more susceptible to environmentally induced morphological changes (Onkar and Saima, 2015). Morphological variation has been affirmed as a necessity for taxonomic identity, population differentiation, and genetic diversity assessment for effective management of fisheries resources (Asmamaw and Tessema, 2021). Fish species with wide geographical range such as *Otrochromis niloticus* exhibit measurable variations in characters in different habitats (Ayoade, 2008). Such variations have genetic and environmental components which cause population differentiation within a species. Morphometric studies, offer opportunities to identify fish species in relation to their habitat as well as ecological conditions of the water body (Olanrewaju *et al*., 2021).

The knowledge of length-weight relationship parameters also has numerous practical applications in fishery research and management (Olanrewaju *et al*., 2017). Length and weight data are valuable for understanding fish conditions, growth pattern, and population dynamics, providing crucial insights for conservation, management and aquaculture. Changes in both length and weight are key indicators of

fish's growth rate, which often described by their relationship. Factors like food availability, temperature, water quality and habitat structure can influence this relationship and thus affect growth (Xu *et al*., 2022). Any variations in these factors will directly affects fish metabolism, reproduction, and overall productivity, thereby hindering fish ability to thrive and reach their full potential. However, inland fisheries especially *O. niloticus* population face significant negative impacts from various environmental factors, including climate change, habitat degradation, and water pollution. These factors can disrupt their populations, reduce yields, and threaten the livelihoods of communities that depend on inland fisheries.

Nile tilapia, an indigenous fish to Nigeria is the most common species caught by artisanal fishers at Lakes Alau and Bako, Northeastern Nigeria. The fishing pressure on this species results in various forms of adaptations leading to changes in its morphology, physiology and ecology. This therefore implies that biological and ecological characteristics of fish populations from different aquatic habitat cannot be the same. Many studies have been conducted on length-weight relationship and condition factor of *O. niloticus* in Northeast Nigeria: Adedeji *et al*. (2016) in Lake Geriyo, Abdulhakim *et al*., (2015) in Lake Alau, Utete and Chikova (2013) in Lake Alau. However, there is scanty literature on morphometry, growth pattern and condition factors of *O. niloticus* in Lakes Alau and Bako. This study was therefore designed to examine morphometry, growth patterns and well-being of *O. niloticus* populations in Lakes Alau and Bako, Northeast Nigeria. This study will provide biological information on *O. niloticus* population parameters from different habitats, contributing to database on the population biology of this fish species in Nigeria.

2. Methodology

2.1 Description of study areas

Lake Alau lies between Latitude 11°39'84" – 11°40'02"N and Longitude 13°39'92" – 13°40'12"E at the highest altitude of about 354m above sea level (Gwari *et al*., 2014). The lake is the largest man-made lake in Borno State, Northeast Nigeria with a mean depth of 9.5 m and surface area of 56 km^2, with annual inflow calculated of 329,000 m^3 (Olanrewaju *et al*., 2017). The Lake is characterized by loamy soil and a mean temperature of 28.6 ºC, pH of 7.28, total and alkalinity of 38.4 mg/l. The lake region is characterized by a high evaporation rate that exceeds the mean annual rainfall of 600 mm. Climate of the Lake Alau region is mainly characterized by alternating wet and dry seasons following the annual movements of the Intertropical Convergence Zone (ITCZ), the dry seasons from March to June and rainy seasons from July to October. The dry season is preceded by a period of dry Harmattan with very low temperature and dry harmattan wind between November and February (Bankole *et al*., 1994). In contrast, Lake Bako in Mambila Plateau, Taraba State, Nigeria is a large concrete dam situated nearby to the locality Jimeta, as well as near the village Bokki. It is located at Longitude 6°42'52" – 6°43'10"N and Latitude 11°21'8" – 11°21'20"N and has an elevation of 145 metres. The lake region has the climatic characteristics of a typical temperate region (Bako *et al*., 2016). The rain starts in February to November with an annual mean value of 1850mm.

2.2 Collection of fish specimen and identification

A total of 100 adult specimens of *O. niloticus* each were obtained from Lakes Alau (69.76±18.65g) and Bako (90.84±31.23g), which were used for the study. The specimens were collected from the lakes with a cast net and preserved with iced block in an ice chest to retain its freshness while in transit to the wet laboratory of Department of Fisheries, University of Maiduguri,

Borno State, Nigeria for further analysis. Fish samples upon collection were identified using identification guide provided by Olaosebikan and Raji (2013).

2.3 Morphometric analysis

At the laboratory, specimens were weighed to nearest 0.01 g using a digital analytical balance (Camry model EK5350). Sixteen linear measurements of different body parts were measured to the nearest 0.1 mm in a fresh condition. The morphological indices measured were total length (TL), standard length (SL), body depth (BD), snout length (SL), head length (HL), eye diameter (ED), caudal peduncle length (CPL), caudal peduncle depth (CPD), pre-pelvic fin length (PPvL), pre-pectoral fin length (PPcL), pre-anal fin length (PAL), pre-dorsal fin length (PDL), caudal fin length (CFL), dorsal fin length (DFL), anal fin length (AFL), and pectoral fin length (PFL) following the method of Olanrewaju *et al*. (2024). There were repeated measures of all individuals by multiple observers to ensure consistency in measurements.

2.4 Length-weight relationships

The length-weight relationship of the fish samples was established using the equation $W = a\ L^b$ (LeCren, 1951), W = body weight of the fish specimens (g), L = total length (cm), a = intercept, b = slope of the regression line. After logarithmic transformation of this relation (log W = log a + b log L), parameters (a) and (b) were estimated by least squares linear regression (Zar, 1999).

2.5 Condition factor

The condition factor (K) was also calculated to estimate the state of well-being (i.e., the health or fattening) of the fishes in the two study habitats using Fulton index, $K = \frac{100\ W}{L3}$. Here, K is the condition factor, W is the total body weight of individual fish in grams, and L is the corresponding total length of specimens in centimeters.

2.6 Statistical analysis

Data analysis was conducted using IBM SPSS (version 20.0) software. Linear regressions were performed to establish morphological variations between the different populations of *Oreochromis niloticus*. The coefficient of variation (CV) was calculated as: $CV\% = \frac{100\ x\ SD}{X}$, where SD refers to the standard deviation, and X refers to the mean of the measurements of morphometric characters in each specimen. Also, the relationship between length and weight of the fish was examined by simple linear regression analysis. Bailey's t-test was employed to find out whether 'b' value significantly deviated from the expected cube value of 3(t=(b-3)/Sb, where b is the regression coefficient, Sb is the standard error of 'b'. The Pearson correlation 'r' between morphometric measures was calculated to reveal whether significant correlation exists between them.

3. Results

3.1 Morphological characteristics

The mean lengths of selected body and head-related morphometric characters in the study were higher in *O. niloticus* from Lake Bako **(Table 1)**. It was, however, significantly higher ($P<0.05$) in total length (16.84±1.93 cm), standard length (13.42±1.68 cm), body depth (5.50±1.14 cm), head length (4.55±0.57 cm) and caudal peduncle length (4.97±0.67 cm). Similarly, the result showed that the population from Lake Bako had higher coefficients of variation (CV) values compared to the one from

Lake Alau in all examined body and head-related measurements. The least CV value (8.65%) was recorded in total length while the highest were obtained in snout length (18.59%) for strain in Lake Alau. However, the CV values for the selected variables in Lake Bako strain were found between 11.46% (TL) and 88.24% (ED).

Table 1. Analysis of variance of Body and Head related morphometrics (cm) for *O. niloticus* from Lakes Alau and Bako, Borno States, Nigeria

	Lake Alau			Lake Bako			
MC	Range (cm)	Mean±SD	CV (%)	Range (cm)	Mean±SD	CV (%)	Sig. value
TL	12.00 – 17.10	15.37±1.33	8.65	14.00 – 20.80	16.84±1.93	11.46	0.003*
SL	9.50 – 14.20	12.54±1.17	9.33	11.00 – 16.70	13.42±1.68	12.52	0.036*
BD	3.20 – 5.90	4.89±0.59	12.07	1.20 – 6.90	5.50±1.14	20.73	0.022*
SNL	1.00 – 2.00	1.56±0.29	18.59	1.00 – 4.40	1.59±0.79	49.69	0.868
HL	3.20 – 4.70	4.22±0.38	9.01	3.50 – 5.90	4.55±0.57	12.53	0.020*
ED	0.50 – 1.00	0.96±0.12	12.50	0.80 – 5.70	1.36±1.20	88.24	0.096
CPL	2.80 – 5.20	4.41±0.50	11.34	3.50 – 6.80	4.97±0.67	13.48	0.001*
CPD	1.00 – 2.00	1.71±0.26	15.21	0.90 – 9.70	2.32±1.59	68.53	0.063

MC morphometric characters, *TL* total length, *SL* standard length, *BD* body depth, *SNL* snout length, *HL* head length, *ED* eye diameter, *CPL* caudal peduncle length, *CPD* caudal peduncle depth, *SD* standard deviation, *CV* coefficient of variation, *Sig. value* $p<0.05$

Analysis of the eight fin-related morphometrics indicated no significant differences ($p>0.05$) between *O. niloticus* strains from Lakes Alau and Bako, except pectoral fin length **(Table 2)**. The pectoral fin length was significantly higher ($p<0.05$) in the strain from Lake Bako (5.16±0.63 cm) than those from Lake Alau (4.78±0.58 cm). The CV of *O. niloticus* strains from Lake Bako reveal higher variability in all the measured variables than those from Lake Alau. In Lake Alau, the CV value was highest in Anal fin length (13.04%) but least in Dorsal fin length (10.29%) and ranged from 12.21% (Pectoral fin length) to 36.46% (Caudal fin length) in Lake Bako.

3.2 Length-weight relationships and condition factor

The results of length-weight relationship (LWR) and condition factor (K) of *O. niloticus* are as presented in **Table 3**. The weight range obtained for *O. niloticus* from Lakes Alau and Bako were 27.00 to 97.00g and, 48.00 to 155.00g, respectively while, the mean weight was 69.76±18.65 g and 90.84±31.23 g, respectively. The calculated growth coefficient '*b*' values for the LWR were 3.508 in population from Lake Alau and 3.535 from Lake Bako. However, the '*b*' values for *O. niloticus* from both lakes were significantly different from 3 (t-test; $p<0.05$), indicating positive allometric growth. In both populations, there is a high degree of correlation (r^2) with those from Lake Alau showing 0.962 and Lake Bako have 0.960. The K values were similar in samples of *O. niloticus* taken from Lakes Alau (1.85±0.14) and Bako (1.87±0.13).

Table 2. Analysis of variance of fin related morphometric characters (cm) of *O. niloticus* from Lakes Alau and Bako, Borno States, Nigeria

MC	Lake Alau			Lake Bako			
	Range	Mean±SD	CV (%)	Range	Mean±SD	CV (%)	Sig. value
PPVL	3.60 – 6.20	5.09±0.62	12.18	3.60 – 7.00	5.25±0.82	15.62	0.452
PPCL	3.00 – 5.30	4.18±0.52	12.44	3.30 – 10.00	4.65±1.29	27.74	0.099
PAL	6.50 – 11.00	9.16±1.01	11.03	3.60 – 12.60	9.38±2.20	23.45	0.652
PDL	3.50 – 5.60	4.63±0.49	10.58	3.10 – 6.30	4.71±0.77	16.35	0.646
CFL	2.50 – 4.20	3.06±0.37	12.09	2.50 – 10.10	3.84±1.40	36.46	0.010
DFL	5.60 – 8.40	7.48±0.77	10.29	1.00 – 10.20	7.69±1.79	23.28	0.602
AFL	1.50 – 2.80	2.30±0.30	13.04	1.80 – 3.30	2.46±0.34	13.82	0.099
PFL	3.50 – 5.50	4.78±0.58	12.13	4.20 – 6.70	5.16±0.63	12.21	0.032*

MC morphometric characters, *PPvL* pre-pelvic fin length, *PPcL* pre-pectoral fin length, *PAL* pre-anal fin length, *PDL* pre-dorsal fin length, *CFL* caudal fin length, *DFL* dorsal fin length, *AFL* anal fin length, *PFL* pectoral fin length, *SD* standard deviation, *CV* coefficient of variation, *Sig. value* $p<0.05$

Table 3. Length-weight relationship and condition factor of *O. niloticus* from Lakes Alau and Bako, Borno States, Nigeria

Parameters	Populations	
	Lake Alau	Lake Bako
Body weight ranges (g)	27.00 – 97.00	48.00 – 155.00
Mean body weight (g)	69.76±18.65	90.84±31.23
a (intercept)	–0.2334	–0.2365
b (slope)	3.508	3.535
MSE(b) (mean standard error of slope)	0.149	0.147
R (regression coefficient)	0.980	0.981
R^2 (coefficient of determination)	0.960	0.962
Sig. value	0.000	0.000
Allometry	Positive (+)	Positive (+)
K (condition factor)	1.85±0.14	1.87±0.13

3.3 Correlation coefficient between various morphological parameters

Correlation coefficient matrixes between the various morphological parameters of *O. niloticus* population from Lake Alau are as presented in **Table 4**. The pairwise comparisons revealed significant positive as well as negative correlations between the morphometric variables ($p<0.01$). Caudal fin length with pre-anal fin length ($r = 0.45$, $p<0.05$) were moderately and positively correlated, as well as caudal peduncle depth with caudal peduncle length ($r = 0.42$, $p<0.05$). However, the caudal fin length shows no significant correlation ($p>0.05$) with body depth ($r = 0.23$), eye diameter ($r = 0.21$), caudal peduncle length ($r = -0.02$), pre-pelvic fin length ($r = 0.38$), pre-pectoral fin length ($r = 0.23$) and pre-dorsal fin length (0.32). For the population from Lake Bako, the pre-anal fin length was negatively correlated to the snout length ($r = -0.57$, $p<0.05$) but positively correlated to the head length ($r = 0.48$, $p<0.05$) and caudal peduncle length ($r = 0.47$, $p<0.05$) **(Table 5)**. The anal fin length was positive and moderately ($p<0.05$) correlated to the pre-pelvic length ($r = 0.42$) and caudal peduncle depth ($r = 0.45$). In addition, there is a negative correlation between eye diameter and body depth ($r = -0.43$); pre-pelvic length and eye diameter ($r = -0.43$). However, positive correlation was found between pre-pectoral fin length and caudal peduncle length ($r = 0.43$); caudal fin length and head length ($r = 0.40$), dorsal fin length and pre-anal fin length ($r = 0.49$); pectoral fin length and caudal peduncle depth ($r = 0.46$).

4. Discussion

4.1 Morphological characteristics

In fish biology, the sizes of fish are generally considered to be more important than their age because several physiological and ecological factors affect sizes (Ajibare and Loto, 2022). However, fishing significantly impacts fish sizes leading to reduction in the proportion of larger fish in populations, favouring smaller, faster-growing species. In the present study, the size of fish sample (12.0 – 20.8 cm TL) is in concordance with 7.0 – 15.5 cm (Wudil River, Nigeria) and 6.0 – 22.0 cm (Wase dam, Nigeria) reported by Getso *et al*. (2017) and Yem *et al*. (2020) respectively. This indicated high productivity of the two lakes supporting good growth and development of Nile tilapia population. However, Palomares and Pauly (1998) reported that Tilapia can reach sizes between 10 and 63 cm under the right environmental conditions. The variability in fish size and shape of body traits within a species is usually quantified by fish morphometries in fish biology.

Fryer and Iles, (1972) noted that the measurements of morphometric characters are dependable tools to characterize fish species because they are sensitive to environmental changes. A scan of the univariate analysis of morphometric parameters of *O. niloticus* from the two Lakes shows variation in favour of stock from Lake Bako. It became apparent from this finding that some of the morphometric characters, especially among body and head related parameters (TL, SL, BD, HL, CPL and PFL) were significantly high in *O. niloticus* population from Lake Bako. This result confirmed morphological plasticity due to environmental variability of *O. niloticus* as documented by several authors including Adedeji *et al*. (204), Asmamaw and Tessema, Amoussou *et al.* (2017) and Lalèyè *et al*. (2017). Similar trend was also reported by Oyewumi *et al*. (2019) in *Sarotherodon galileaus*, Fagbuaro (2015) in *Tilapia zillii*. This may be due to differences in ecological conditions of the two lakes which consequently have great bearing on the growth and development of the body as predicated by Ayoade (2011). Yemi *et al*., (2007) and Wimberger (1992) asserted that fish morphological plasticity is primarily influenced by habitat variables such as temperature, turbidity, food supply, water depth, and velocity. These ecological conditions reflect the growth pattern and wellbeing of fish in their habitat.

Table 4. Pearson correlation table for morphometric parameters of *O. niloticus* population from Lake Alau, Nigeria

	TL	SL	BD	SNL	HL	ED	CPL	PPVL	PPCL	PAL	DPL	CFL	DCP	DFL	AFL	PL
TL	1															
SL	0.98**	1														
BD	0.92**	0.92**	1													
SnL	0.69**	0.69**	0.52**	1												
HL	0.86**	0.88**	0.78**	0.68**	1											
ED	0.65**	0.65**	0.75**	0.38	0.56**	1										
CPL	0.62**	0.59**	0.70**	0.34	0.48**	0.32	1									
PPvL	0.94**	0.92**	0.86**	0.73**	0.80**	0.64**	0.57**	1								
PPcL	0.80**	0.80**	0.80**	0.65**	0.69**	0.61**	0.58**	0.92**	1							
PAL	0.95**	0.97**	0.86**	0.69**	0.85**	0.68**	0.52**	0.93**	0.83**	1						
DPL	0.88**	0.89**	0.83**	0.66**	0.71**	0.54**	0.66**	0.84**	0.73**	0.88**	1					
CFL	0.42**	0.47**	0.23	0.67**	0.60**	0.21	-0.02	0.38	0.23	0.45*	0.32	1				
CPD	0.72**	0.70**	0.57**	0.55**	0.68**	0.33	0.42*	0.70**	0.58**	0.68**	0.53**	0.42	1			
DFL	0.94**	0.93**	0.88**	0.70**	0.75**	0.68**	0.52**	0.94**	0.84**	0.93**	0.86**	0.38	0.65**	1		
AFL	0.74**	0.74**	0.81**	0.52**	0.60**	0.70**	0.57**	0.75**	0.66**	0.67**	0.66**	0.21	0.59**	0.74	1	
PL	0.89**	0.87**	0.80**	0.74**	0.70**	0.59**	0.66**	0.87**	0.78**	0.88**	0.88**	0.39	0.66**	0.89**	0.64**	1

** Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed)

Table 5. Pearson correlation table for morphometric parameters of *O. niloticus* population from Lake Bako, Nigeria

	TL	SL	BD	SNL	HL	ED	CPL	PPVL	PPCL	PAL	PDL	CFL	CPD	DFL	AFL	PFL
TL	1															
SL	0.99**	1														
BD	0.74**	0.76**	1													
SnL	0.05	0.04	-0.39	1												
HL	0.92**	0.91**	0.66**	0.08	1											
ED	0.02	-0.05	-0.43*	0.96**	-0.01	1										
CPL	0.83**	0.85**	0.63**	0.05	0.71**	0.03	1									
PPvL	0.79**	0.77**	0.77**	-0.34	0.79**	-0.43*	0.58**	1								
PPcL	0.53**	0.51**	0.29	0.71**	0.52**	0.68**	0.43*	0.19	1							
PAL	0.56**	0.59**	0.78**	-0.57*	0.48*	-0.66**	0.47*	0.72**	-0.16	1						
PDL	0.62**	0.62**	0.50**	-0.23	0.74**	-0.34	0.35	0.76**	0.38	0.59**	1					
CFL	0.28	0.24	0.09	-0.05	0.40*	-0.01	0.12	0.35	0.21	-0.25	0.27	1				
CPD	0.52**	0.49*	0.44	-0.20	0.34	-0.13	0.68**	0.39	0.18	0.36	-0.02	0.06	1			
DFL	0.30	0.35	0.28	0.20	0.30	0.06	0.15	0.14	0.15	0.49*	0.39	-0.58**	-0.29	1		
AFL	0.72**	0.71**	0.38	0.22	0.75**	0.19	0.60**	0.48*	0.55**	0.16	0.28	0.42*	0.45*	0.01	1	
PFL	0.90**	0.91**	0.66**	0.06	0.88**	0.02	0.72**	0.76**	0.51**	0.55**	0.64**	0.23	0.46*	0.33	0.64**	1

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed

4.2 Length-weight relationships and condition

Length-weight relationship is considered a crucial tool for determining possible differences between separate unit stocks of the same species (King, 2007). Analysis of the length and weight relationships showed positive allometric growth pattern with strong coefficient of determination in both Lakes. This is an indication that both Lakes provide optimal growth conditions leading to an increase in body mass at a faster rate than length. The higher *b* values observed for *O. niloticus* in this study differs from the negative allometric growth that was previously recorded for this fish in Wase dam (1.52) (Yem *et al.*, 2020), Upper River Benue (1.43) (Edward, 2018) and Wudil River (0.80) (Getso *et al*., 2017), all in Northern Nigeria. However, positive allometric growth has been reported for *O. niloticus* in several water bodies including Shala Lake (3.19) (Wagaw *et al*., 2022), Golinga Reservoir (3.37) (Naangmenyele *et al*., 2021) and Koka Reservoir (3.17) (Asmamaw *et al*., 2019). The variation in this regard is related to environmental factors in different habitats, which affect growth and general wellbeing of the fish.

The high exponent '*b*' values found in this study explain the optimal physiological condition (K) experienced by the fish in both Lakes. This is supported by Asmamaw and Tessema (2021) in Lakes Koka (1.48) and Ziway (1.2), Tessema *et al*. (2019) in Lake Hayq, (1.81). This result is also consistent with the previous study by Olanrewaju *et al*. (2024) who reported condition factor of 1.71±0.20 – 2.32±0.63 for three Cichlid species in Alau Lake. By implication, the high condition factor index is evidence of good environmental condition that usually leads to better wellbeing of fish. Mortuza and Al-Misned (2013) confirmed that the condition factor is an important quantitative parameter for determining the relative degree of nourishment and habitat condition of fish. It is also stated that beyond environmental factor, age and maturity stage of fish can significantly affect the K value (Sadiq *et al*., 2025).

Conclusion

The study revealed that *Oreochromis niloticus* in Lakes Alau and Bako show morphological plasticity in total length, standard length, body depth, head length, caudal peduncle length and pectoral fin length. The regression analysis of the body weight against the standard length of *O. niloticus* shows a positive allometric growth pattern in both Lakes. Condition factor index of *O. niloticus* in both Lakes is optimal, indicating favourable habitats for growth, survival and reproduction. In essence, the study has provided baseline data on the population biology of *O. niloticus* in Alau and Bako Lakes, Nigeria.

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Disclosure statement:

Conflict of Interest: The authors declare that there are no conflicts of interest.

Compliance with Ethical Standards: All handling of vertebrates was approved under the US National Research Council's guidelines for the Care and Use of Laboratory Animals.

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