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Polyculture of *Mystus gulio* (Hamilton 1822) in salinity intrusion prone areas of Bangladesh

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Abstract. A 120 days long culture experiment was conducted to evaluate the growth performance, nutrient utilization and profitability of *Mystus gulio* in salinity intrusion prone areas of Bangladesh. Nine uniform earthen ponds (1 decimal=40 m^2) with stocking density of 350 fish/decimal were randomly divided into three treatments in triplicate groups with different species composition explicitly T_1 (mono culture, 350 *M. gulio*), T_2 (polyculture, 250 *M. gulio* with 60 *Oreochromis niloticus* and 40 *Rhinomugil corsula*), and T_3 (polyculture of 250 *M. gulio*, with 40 *O. niloticus* and 60 *R. corsula*). Fishes were fed up to 20% of body weight at the start and 6% at the end. At the end, significantly ($p<0.05$) better growth performance of *M. gulio* were recorded in T_1 followed by T_3 and T_2. Significantly ($p<0.05$) better nutrient utilizations in terms of apparent food conversion ratio (AFCR) and apparent protein efficiency ratio (APER) were recorded in T_2 followed by T_3 and T_1. Survival (%) of fishes were significantly higher in T_3 (82.24) over T_1 (77.90) however, T_2 (80.56) did not have any significant ($p>0.05$) difference with T_1 and T_3. Significantly ($p<0.05$) higher production (kg ha^{-1}) were observed in T_2 (3,866.37±69.66) followed by the T_3 (3,489.968±62.22) and T_1 (1,682.50±21.93). Significantly higher net profit (BDT ha^{-1}) were observed in T_3 (158814.88) over T_1 (142599.76) and T_2 (129071.86). Based on the present findings, poly culture of *M. gulio* with *O. niloticus* and *R. corsula* may be suggested to the fish farmer as a potential climate change adaptation option to utilize the vast salinity intrusion prone areas of coastal Bangladesh.

Keywords: *Mystus gulio,* Species diversification, Climate change adaptation

Introduction

Climate change inducing salinity intrusion causing decline in availability of fishes in coastal Bangladesh that negatively affects food and income security of dependent community. A like many other resources, coastal fisheries is also vulnerable to climate change, tidal flood salinity intrusion and storm surges (Karim and Shah 2001, Haque *et al.* 2008, Ahmed and Diana 2015) due to that numbers of cultural fish species are decreasing day by day in coastal Bangladesh. Therefore, it is necessary to find out potentially suitable alternative adaptation option to climate change impacts and sustainable use of these vast coastal areas while securing livelihoods of the millions of peoples in coastal Bangladesh. Research and development of adaptation measures against climate change-related issues can help policy making decisions (Weber 2010, Chaudhary and Bawa 2011, Naess 2013). Development of culture techniques of salt tolerant euryhaline fish species may be the promising alternative adaptation strategy to compensate the loss of fish species and sustainability of fisheries production as well.

The *Mystus gulio* (Hamilton 1822), is a small indigenous oviparous euryhaline estuarine catfish and locally known as '*Nuna Tengra*' found in the coastal waters of Bangladesh (Hossain *et al.* 2015). In recent years, abundance and harvest of *M. gulio* in coastal waters have declined drastically mostly due to overexploitation and habitat destruction. *M. gulio* considered as near threatened in Bangladesh (IUCN Bangladesh 2015). *M. gulio* has the potential to be cultured in fresh, brackish and seawater because of it is euryhaline and hardy nature (Begum *et al.* 2008 & 2009, Hussain *et al.* 2008, Haniffa 2009). Though, having good potentiality of *M. gulio* culture with others salt tolerant fish species, however, culture techniques (mono and polyculture) of *M. gulio* has not been developed yet**.** Invention of *M.gulio* culture techniques concentrating on species diversification i.e. with other euryhaline salt tolerant species may be a promising possible solution to compensate the loss of fishery species due negative impact of climate change inducing salinity intrusion.

Species diversification and polyculture of *M. gulio* with salt tolerant *Rhinomugil corsula and Oreochromis niloticus* in different composition may be a potential adaptation option for better utilization of vast salinity intrusions prone coastal area and simultaneously will contribute to aquaculture production. *R. corsula* locally called as '*Khorul Bata'* is a surface-dwelling mullets (Akter *et al*. 2012) fetches high consumer preferences. Nile tilapia, *O. niloticus* considered as one of the most prominent aquaculture species in the world (FAO 2014) for its rapid growth rate, high tolerance to adverse environmental conditions, efficient feed conversion, ease of spawning, resistance to diseases and good consumer acceptance (Watanabe *et al.* 2002). Hossain *et al.* (2018) studied on polyculture of *M. gulio* with ***O.*** *niloticus*, Climbing perch, *Anabas testudineus*, and Asian stinging catfish, *Heteropneustes fossils* revealed encouraging results. Nevertheless, literature focusing culture of *M. gulio* is few or scant. Hence, the present research experiment was conducted to evaluate the growth performance, nutrient utilization and profitability of *M. gulio* culture with *R. corsula* and *O. niloticus* in salinity intrusion prone areas of Bangladesh.

Materials and Methods

Study area and study period: The experiment was conducted at the Noakhali Integrated Agro Industries Limited (NIAI), Noakhali located in between 22°38´and 22°59´ north latitudes and in between 90°54´ and 91°15´ east longitudes for a period of 120 days from 1 July to 30 October.

Pond preparation and stocking of fishes: A series of 9 earthen ponds with equal in size (40 m^2) and depth (1.5 m) were used in the experiment. Among them, three triplicates were randomly drawn and assigned for each of the three treatments (Table I). All experimental units were renovated after following FAO Good Aquaculture Practices (GAP) guidelines.

Table I. Species composition, stocking density under the study

Treat ments	Replic ation no.	Stocking density (decimal^{-1})	Species composition *M. gulio*	*O. niloticus*	*R. corsula*	Culture system	Remarks
	5	350	350	-	-	Mono	
T_1	1	350	350	-	-	Mono	Monoculture of *M. gulio*
	9	350	350	-	-	Mono	
	4	350	250	60	40	Poly 1	Polyculture of *M. gulio* (250) with *O. niloticus* (60) and *R.corsula* (40)
T_2	7	350	250	60	40	Poly 1	
	2	350	250	60	40	Poly 1	
	8	350	250	40	60	Poly 2	Polyculture of *M. gulio* (250) with *O. niloticus* (40) and *R. corsula* (60)
T_3	3	350	250	40	60	Poly 2	
	6	350	250	40	60	Poly 2	

Culture management: Fry of *M. gulio* and *O. niloticus* were collected from nursery ponds of NIAI. Ltd., Noakhali and fry of *R. corsula* were collected from Jessore with appropriate transportation methods. Initially fries were acclimatized by a short 5 to 10 seconds bath and prophylactic treatment with (5% $KMnO_4$) solution prior to stocking in experimental ponds. Experimental fishes were hand-fed four times per day (at 8.00, 11.00, 14.00 and 17.00 h) at the rate of 20% of body weight (BW) at the beginning (first month). Feeding rate were adjusted and gradually decreased to thrice daily (at 9.00. 13.00 and 17.00 h) in second months (@10% BW) and then twice a day (at 9.00 and 17.00 h) from third month (@6% BW) to the end with same feed. Proximate composition of commercial pelleted feed (Table II) was analyzed according to AOAC (2000).

Water quality monitoring: To monitor water quality, parameters were measured between 7.00-8.00 am during the culture period on monthly basis. The water temperature (°C), DO (mgl^{-1}) and water pH were measured by using YSI multiprove sensor (YSI, Model 556 MPS, USA, YSI incorporated). Soil pH was measured by soil pH and moisture tester (KS-05, TLEAD, China) and salinity (ppt) with automatic compensation salinity refratroctometer (ATAGO, ATC-S/Mill-E, Japan). Transparency (cm) were measured with manually prepared secchi disc (Wildlife supply company, USA, S/N 42114-138), nitrate (mgl^{-1}), nitrite (mgl^{-1}), phosphate (mgl^{-1}), ammonia (mgl^{-1}) and total alkalinity determined by using universal pocket meters.

Table II. Proximate composition of feed fed the experimental fishes

Feed component	Dry mater	Crude protein	Crude lipid	Ash	Crude fiber	NFE[1]
Amount (%)	89.89±0.040	30.10±0.031	8.28±0.015	18.69±0.06	10.74±0.046	32.18±0.095

Values are shown as mean ± Std. deviation (SD).
[1]Nitrogen free extract (NFE) calculated as [100 - % (protein + lipid+ ash + fiber)] (Wet wt. basis)

Sampling of experimental fish: Monthly sampling of experimental fishes were made by using a cast net to ascertain the growth of fish and to adjust the feeding rate. The length of sampled fishes were measured by using a centimetre scale and weight by a digital balance (OHAUS, Model CT 1200-S, USA). At the end on 120 days, complete harvesting was done dry out the earthen ponds and fishes were then counted weighed and measured individually.

Calculation of growth parameters, nutrient utilization, survivals, production and economics:
Mean weight gain (g) = Mean final body weight (g) - Mean initial body weight (g).
Weight gain (%) = [{(Mean final fish weight (g) - Mean initial fish weight (g)}/ Mean initial fish weight (g)] × 100.
Specific growth rate (SGR % day^{-1}) = [{(Log_e W_2 - Log_e W_1)/ (T_2-T_1)} × 100], Where, W_1 is the initial live body weight (g) at time T_1 and W_2 is the final live body weight (g) at time T_2 (day).
Apparent Feed Conversion Ratio (AFCR) = Total dry feed fed (g)/ Total live weight gain (g).
Apparent Protein Efficiency Ratio (APER) = Live weight gain (g)/ Dry weight of crude protein fed (g).
Survival rate (%) = (Final fish number / Initial fish number) × 100.
Production (kg ha^{-1}) = [{Final number of all harvested fish x individual weight of fish (g)} / 1000] x 247.1]
Net profit (BDT ha^{-1}) = Gross production value – Total production costs.
Benefit Cost Ratio (BCR) = Total production value / total production costs (BDT).

Statistical analysis: One-way analysis of variance ANOVA by SPSS 17 (IBM, USA) was used to detect the significance differences among the treatments. The values were given with means ± SD and differences were considered significant at subset for alpha = 0.05 ($p \leq 0.05$).

Results and Discussion

Water quality parameters: Over the study period, the values of observed water quality parameters i.e. temperature were ranged from (25.87-30.10°C), dissolved oxygen (4.46 - 5.50mg l^{-1}), salinity (1.23-3.47ppt), soil pH (6.34-7.72), transparency (25.50-33.50cm), NO_2 (0.01-0.03 mgl^{-1}), total NH_3 (0.24-0.49 mgl^{-1}) and PO_4 (0.34-0.49 mgl^{-1}), and were not significantly differs ($p > 0.05$) among the three different treatments (Table III). The recoded values of water pH and NO_3 were ranged from (7.03 to 7.73) and (0.03 to 0.087mg l^{-1}) respectively. The observed values of pH and nitrate in T_3 were significantly ($p < 0.05$) higher than the values of T_1 and T_2 (Table III). The values of alkalinity in different ponds were ranged from 65-93 mgl^{-1} and the values in T_2 and T_3 were significantly different ($p < 0.05$) over T_1 (Table III). Among the observed water quality parameters, pH, nitrate and alkalinity explicit significant difference ($p < 0.05$).

The variation of water pH may be associated with seasonal variation, rainfall and or soil water interactions related issue as average soil pH (6.91) of T_3 was higher compare to T_1 and T_2 (Table III). The variation in total alkalinity and nitrate (NO_3) over the study period in ponds may be associated with amount of fecal content excreted by the experimental fishes. The water quality parameters of the present research was closely related with results of Hossain *et al.* (2018) conducted a 180 days trail in the same experimental ponds of NIAI Ltd. during the month of

May to November and are more or less aligned with the findings of Kader *et al.* (2018); Kashem *et al.* (2014) and Rahman *et al.* (2009) in the earthen ponds of Mymensingh, Bangladesh. Nevertheless, all the recorded water quality parameters were within the range of acceptable limit suitable for the fish culture.

Table III. Water quality parameters observed in different treatments over 120 days

Water quality parameters	T_1	T_2	T_3
Temperature (°C)	27.76±1.205	27.63±1.446	27.8808±1.166
Dissolved oxygen (mgl^{-1})	5.09±0.217	5.15±0.219	5.1975±0.251
pH (Water)	7.34 ± 0.206^a	7.30 ± 0.134^a	7.4942 ± 0.1400^b
pH (Soil)	6.84±0.468	6.85±0.458	6.9150±0.416
Salinity (ppt)	2.35±0.620	2.32±0.797	2.3404±0.700
Transparency (cm)	29.52±2.541	30.97±3.010	29.4442±2.359
Nitrite (NO_2) (mgl^{-1})	0.02±0.004	0.02±0.005	0.0221±0.004
Nitrate (NO_3) (mgl^{-1})	0.05 ± 0.013^a	0.06 ± 0.014^a	0.087 ± 0.016^b
Ammonia(NH_3) (mgl^{-1})	0.34±0.059	0.37±0.066	0.36±0.071
Phosphate (PO_4) (mgl^{-1})	0.42±0.044	0.4200±0.0423	0.42330±.0470
Alkalinity (mgl^{-1})	70.33 ± 3.473^a	79.08 ± 9.337^b	78.92 ± 8.523^b

Values are means of data obtained ± Std. Deviation (mean ± SD) of monthly determinations. Values in the same row with different superscript indicate statistically significant difference ($p<0.05$). Absence of superscripts or values with same superscripts indicates no significant difference between treatments ($p>0.05$).

Growth performance, nutrient utilization and production: Significantly ($p<0.05$) higher final weight, weight gain, percent weight gain and specific growth rate of *M. gulio* were recorded in T_1 followed by T_3 and T_2 respectively (Table IV). The observed values of specific growth rate (SGR) of *M. gulio* were ranged between 2.22 and 2.62 (% day^{-1}) in different treatments, whereas SGR of *O. niloticus* and *R. corsula* were varied from 4.32 to 4.42 and 2.83 to 2.96 (% day^{-1}) respectively (Table IV). Though SGR (% day^{-1}) of *R. corsula and O. niloticus* did not vary significantly ($p>0.05$), significantly better final weight, weight gain, percent weight gain i.e. growth performance of *R. corsula and O. niloticus* were recorded in T_3 than T_2 (Table IV). Higher final weight gain, percent weight gain and SGR observed in *O. niloticus* compare to *M. gulio* and *R. corsula* related to the biological nature of the fish e.g. certain strain of *O. niloticus* can grow up to one kilogram in a year in pond culture in Bangladesh. Comparatively less production of *M. gulio* and *R. corsula* in T_2 than T_3 may be associated with omnivorous feeding habit of *O. niloticus* and may be due to unknown factors. Higher growth performance of *M. gulio* in T_1 over T_3 and T_2 may be due to less competition for food among the fishes in monoculture. Lowest individual final weight of *M. gulio* contrary to highest weight gain by *O. niloticus* in T_2 may be associated with the competition as both *O. niloticus* and *M. gulio* feed in same water layer with omnivorous feeding habit. Comparatively higher final weight gain and production of *M. gulio* in T_3 than T_2 may due to herbivorous feeding habit of bottom feeder *R. corsula,* which food mainly composed of fresh and decaying plant matter and *R. corsula* are not competitor of *M. gulio*. Final weight gain of *M. gulio* 20.17 (g) was recorded by Rajkumar *et al.* (2013) over 120 days study on effect of cholymbi on growth, proximate composition and digestive enzyme activity of *M. gulio* in Tamil Nadu, India.

Table IV. Growth performance and production of fishes observed in the experiment

Morphometric Parameters	Fish Species	T_1	T_2	T_3
Average initial weight (g)	*M. gulio*	1.12±0.01	1.12±0.02	1.13±0.01
	O. niloticus	-	1.21±0.01	1.19±0.02
	R. corsula	-	1.03±0.02	1.04±0.01
	Combine	1.12±0.01	1.12±0.09	1.12±0.07
Final weight of fish (g)	*M. gulio*	25.36±0.72^c	16.36±.07^a	20.57±0.03^b
	O. niloticus	-	216.08±0.92^a	236.18±0.19^b
	R. corsula	-	31.37±0.65^a	35.96±0.07^b
Mean final weight gain (g)[1]	*M. gulio*	24.2433±0.71^c	15.24±0.08^a	19.45±0.02^b
	O. niloticus	-	214.87±0.91^b	234.99±0.17^b
	R. corsula	-	30.34±0.64^a	34.9100±0.07937^b
% weight gain[2]	*M. gulio*	2158.69±51.32^c	1349.24±36.84^a	1720.73±13.91^b
	O. niloticus	-	17758.45±126.21^a	19806.67±330.56^b
	R. corsula	-	2945.78±42.91^a	3356.89±25.16^b
SGR (% day^{-1})[3]	*M. gulio*	2.60±0.02^c	2.23±0.01^a	2.42±0.01^b
	O. niloticus	-	4.35±0.06	4.41±0.01
	R. corsula	-	2.85±0.01193^a	2.95±0.01^b
AFCR[4]	*Combine*	2.95± 0.06^c	2.03±0.05^a	2.1333±0.03^b
APER[5]	*Combine*	1.13±0.02^a	1.6420±0.016^c	1.5753±0.031^b
Survival rate (%)[6]	*M. gulio*	77.90±1.00^c	72.5333±1.405^a	75.0667±1.007^b
	O. niloticus	-	89.9967±1.666	90.00±2.500
	R. corsula	-	79.17±5.204	81.67±1.665
Total Survival	Combine	77.90±1.00^a	80.56±2.14^{ab}	82.24±1.07^b
Production (kg $treatment^{-1}$)[7]	*M. gulio*	6.81± .089^c	2.9767±0.05^a	3.86±0.05^b
	O. niloticus	-	11.68±0.24^b	8.50±0.23^a
	R. corsula	-	1.01±0.03^a	1.76±0.04^b
Production (kg ha^{-1})[7]	*Combine*	1682.50±21.93^a	3866.37±69.65^c	3489.968±62.22^b

Values are means of data obtained ± Std. Deviation (mean ± SD) of monthly determinations. Values in the same row with different superscript indicate statistically significant difference ($p<0.05$). Absence of superscripts or values with same superscripts indicates no significant difference between treatments ($p>0.05$).

Significantly ($p<0.05$) better nutrient utilizations i.e. apparent feed conversion ratio (AFCR) and apparent protein efficiency ratio (APER) were recorded in T_2 (2.03 and 1.64) followed by T_3 (2.13 and 1.57) and T_1 (2.95 and 1.13) respectively (Table IV). Significantly ($p<0.05$) higher survival (%) of *M. gulio* were recorded in T_1 (77.90) followed by T_3 (75.06) and lowest in T_2 (72.53%). Survival of *O. niloticus* and *R. corsula* were not significantly varied ($p>$ 0.05) among the T_2 and T_3. However, combine survival rate (%) was significantly ($p<0.05$) higher in T_3 (82.24) and T_2 (80.56) over T_1 (77.90) (Table IV). The little variation of survivability was occurred due to environmental condition, initial size of the fish, high competition for food and space among the fishes. Significantly ($p<0.05$) higher gross production (kg $treatment^{-1}$) of *M. gulio* were recorded in T_1 (6.81) followed by the T_3 (3.86) and lowest (2.9767) in T_2 (Table IV). Mean production (kg $treatment^{-1}$) of *O. niloticus* were (11.88 and 8.50), and for *R. corsula* were (1.01 and 1.76) in T_2 and T_3 respectively. Significantly ($p<0.05$) higher total production (kg ha^{-1}) were observed in T_2 (3866.37) followed by the T_3 (3489.968) and lowest (1682.50) in T_1 (Table IV). Lower AFCR values indicated better growth performance of fish with lower amount of feed while higher APER values indicated better utilization of protein. The better feed utilization (AFCR & APER) and higher combine production (kg ha^{-1}) in T_2 compare to T_3 and T_1 also associated with higher individual growth of *O. niloticus* as higher number of *O. niloticus* stoked in T_2 (60) compare to T_3 (40). *O. niloticus* showed higher affinity to consume voraciously and utilize artificial feed as well as many types of natural food items. The findings were closely aligned with research trail by Hossain *et al.* (2018) in the experimental ponds of NIAI Ltd.

Economic analyses of different culture systems: A simple economic analysis was performed to estimate the profitability of mono culture and polyculture of *M. gulio* with *O. niloticus* and *R. corsula* (Table V). Significantly ($p < 0.05$) lowest production costs (BDT ha^{-1}) were recorded in T_1 (383,388.01) followed by T_3 (530,924.00±15066.51) and highest expense in T_2 (557,499.61). Likely significantly ($p < 0.05$) higher Benefit cost ratio (BCR) were also recorded in T_1 (1.38) followed by T_3 (1.30) and T_2 (1.23). Nevertheless, gross production value (BDT ha^{-1}) as well as significantly ($p < 0.05$) higher net profit (BDT ha^{-1}) were observed in T_3 (158,814.88) over T_1 (142,599.76) and lowest (129,071.86) in T_2 (Table V). The less amount of feed used in T_1 monoculture of *M. gulio* (feed adjustment according to % body weight) reduce the expenditure (feed cost) compare to T_2 and T_3. High market price and consumer demand of *M. gulio* results higher BCR in T_1. Nevertheless, considering the growth performance, nutrient utilization, survival, production, and economic profitability analysis, T_3 is found more beneficial with higher profitability over the T_1 and T_2. Higher profitability (BDT ha^{-1}) in T_3 may linked with the higher individual growth of *M. gulio* and *R. corsula* those have high market value and consumer preference than *O. niloticus*.

Table V. Benefit and cost analysis of the 120 days culture of *M. gulio*, *O. niloticus* and *R. corsula*

Items wise expenditures	T_1	T_2	T_3
Pond preparation	150	150	150
Seed cost (@BDT piece^{-1}, *M. gulio* 1, *O. niloticus* & *R. corsula* 2)	1050	1350	1350
Lime (purchase rate BDT 12 kg^{-1})	135	135	135
Urea (@ BDT 16 kg^{-1})	24	24	24
TSP (@ BDT 24 kg^{-1})	36	36	36
Cow dung (@ BDT 2 kg^{-1})	60	60	60
Feed costs (@ BDT 45 kg^{-1})	2993.09	4771.755	4521.33
Others costs (BDT treatment^{-1})	150	150	150
Total production costs (BDT)[1]	4598.09	6676.75	6426.33
Total production costs (BDT ha^{-1})	378729.35 ±4791.43^{a}	549941.64 ±7583.638^{c}	529315.38 ±2567.91^{b}
Incomes and outputs			
Total production (kg ha^{-1})	1682.50± 21.93^{a}	3866.37±69.66^{c}	3489.96±62.22^{b}
Gross production value (BDT ha^{-1})[2]	521329.11 ±7132.02^{a}	679013.50 ±11434.00^{b}	688130.26 ±10148.72^{b}
Net profit (BDT ha^{-1})	142599.76 ±11913.74^{a}	129071.86 ±5498.3^{a}	158814.88 ±7584.83^{b}
Benefit cost ratio (BCR)	1:1.38±0.04^{c}	1:1.23±0.01^{a}	1:1.30±0.01^{b}

Values (mean ± SD) in the same row with different superscript indicate statistically significant difference ($p < 0.05$). Absence of superscripts or values with same superscripts indicates no significant difference between treatments ($p > 0.05$).

[1]One USD equivalent to (80) eighty Bangladeshi Taka (BDT). The costs of pond leasing, rent, fuel, equipments, existing physical setup, opportunity cost of capital, and cost for physical labor involved were not included in cost benefit analysis. Here staffs of NIAI Ltd. themselves were in management works with the assumption that most marginal farmers involve themselves in most of the works in their own ponds. [2]Gross production values were estimated on the basis of sell values of produce crops. Sell price (@BDT kg^{-1}) of *M. gulio*: 310, *O. niloticus*: 135, & *R. corsula*: 250.

The present results revealed that polyculture of *M. gulio* in T_3 i.e. (250 *M. gulio* with 40 *O. niloticus* and 60 *R. corsula*) is more beneficial with higher profitability over the T_1 and T_2 and may be suggested to the fish farmer as a potential climate change adaption option. This technique may bring opportunity to culture euryhaline fish species in climate risk environment for local fishers, marginal or even rural poor fish farmers. As increased salinity profoundly changing freshwater ecosystem which creates a major problem in the coastal zone of Bangladesh in the aspect of fish biodiversity and socio-economic scenarios. Rural communities can compensate their loss by use this technology as a way of adaptation to climate extremities and for better utilization of vast unused salinity intruded areas of central coast, Bangladesh.

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