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Culture potentiality of long whiskers catfish, *Mystus gulio* (Hamilton, 1822) as an alternative climate change adaptation option

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Abstract. A 180-day long experiment was carried out to evaluate growth performances of *Mystus gulio* in salinity intrusion prone areas of central coast (Noakhali) of Bangladesh, as a coping measure to climate change adaptation. *M. gulio* fry (0.50 ± 0.008g) were stocked at the rate of 74130/ha in T_1 (mono culture of *M. gulio*), T_2 (*M. gulio* with *Oreochromis niloticus*) and T_3 (*M. gulio* with *Heteropneustes fossilis* and *Anabas testudineus*) and fed up to satiation. At the end, mean final weight (g) of *M. gulio* (29.50 ± 0.361, 21.20 ± 0.361 and 23.90 ± 0.356), % weight gain (5795.73 ± 39.296, 4053.11 ± 37.878 and 4681.48 ± 130.042), Specific growth rate (SGR %/day) were recorded (2.26 ± 0.004, 2.07 ± 0.005 and 2.14 ± 0.012) in T_1, T_2 and T_3 respectively where T_1 showed significantly ($p<0.05$) better growth performance. Significantly ($p<0.05$) better apparent food conversion ratio (AFCR) and apparent protein efficiency ratio (APER) were recorded in T_2 followed by T_3 and T_1 along with the highest gross production (kg/ha) in T_2 (2602.617 ± 86.996) followed by the T_3 (2014.45 ± 24.997) and T_1 (1586.68 ± 31.696). However, considering the survival, net profit and benefit cost ratio (BCR), T_3 was found to be significantly ($p<0.05$) more efficient and profitable. This culture technology may suggest as a way of coping measure for better utilization of vast salinity intruded areas of coastal Bangladesh.
Keywords: *Mystus gulio*, Salinity intrusion, Climate change adoption.

Introduction

Bangladesh is recognized as extremely vulnerable to the negative impact of climate change, most visibly in the form of cyclones and salinity intrusion, which poses threats to its fisheries resources and livelihoods of depending populations (Ali 1999; Allison *et al*. 2009; Karim and Nimura 2008; Barange *et al.* 2014). Particularly, increased water salinity can affect the survival of fish by diminishing feeding rate (Dendrinos and Thorpe 1985), thus fish farming is becoming more vulnerable to salinity intrusion in the coastal region of Bangladesh. Due to increasing trend of salinities *i.e.* salinity intrusion (Haque *et al.* 2008; Karim and Shah 2001) in the vast areas of Noakhali coastal belt, numbers of freshwater fish species are decreasing day by day.

Mystus gulio, a small indigenous catfish locally known as 'Nuna Tengra' is found in the coastal waters of Bangladesh (Hossain *et al*. 2015). It is delicious in taste, possesses high nutritional value and consumer preference; fetches high price and shows an increasing trend in demand, both in domestic and export markets (Haniffa 2009; Begum *et al.* 2010). However, due to indiscriminate exploitation and habitat destruction, its abundance and harvests in natural coastal waters have declined (Mijkherjee *et al.* 2002). Though culture practice of *M. gulio* in closed water has not been developed yet, and it has the potential to be cultured in fresh, brackish, and seawater because of its euryhaline and hardy nature (Rajkumar *et al.* 2013). The innovation of sustainable culture technology of this species may offer a potential adaptation option to cope with the climate change impacts in the coastal areas and simultaneously will contribute a lot to aquaculture production of Bangladesh. Considering the above-mentioned context, the culture of *M. gulio* with different species composition in the central coast (greater Noakhali region) could be a potential option to cope with the adverse climatic conditions while ensuring better utilization of these vast salinity intrusions prone areas. Therefore, the present study was undertaken to assess the culture potentiality of *M. gulio* with various species composition (i.e. mono and polyculture systems) in terms of growth performances, nutrient utilization, survival, production and profitability.

Materials and Methods

Study area and period: The experiment was conducted at the Noakhali Integrated Agro Industries Limited (NIAIL) located in between 22°38´and 22°59´ north latitudes and in between 90°54´ and 91°15´ east longitudes in the Sadar upzilla of Noakhali district, Bangladesh for a period of six months from May to November.

Species selection for mono and polyculture: Three fish species such as Nile tilapia, *Oreochromis niloticus*, Climbing perch, *Anabas testudineus*, Asian stinging catfish, *Heteropneustes fossils* were selected for polyculture with *M. gulio*.

Experimental design: Nine rectangular earthen ponds of 1.0 decimal, having an average depth of 1.5 m were used for the experiment. Three treatments (T_1, T_2 and T_3) each with 3 replications were designed according to completely randomized design (CRD) (Table I).

Table I. Experimental design with species composition and stocking densities

Treat-ments	Pond No.	Stocking Density	Species composition *M. gulio*	*O. niloticus*	*H. fossilis*	*A. testudineus*	Culture systems[1]
	1	300	300	0	0	0	Mono
T_1	5	300	300	0	0	0	Mono
	9	300	300	0	0	0	Mono
	2	300	250	50	0	0	Poly T
T_2	4	300	250	50	0	0	Poly T
	7	300	250	50	0	0	Poly T
	3	300	200	0	50	50	Poly SK
T_3	6	300	200	0	50	50	Poly SK
	8	300	200	0	50	50	Poly SK

[1]Mono: Monoculture of *M. gulio*, Poly T: polyculture of *M. gulio* with *O. niloticus*, Poly SK: polyculture of *M. gulio* with *H. fossilis* and *A. testudineus*.

Collection of fish, stocking and feeding management: Fry of *M. gulio* was collected from nursery ponds of NIAIL, Noakhali. Prior to release in experimental ponds, fry were acclimatized by a short 5 to 10 seconds bath and prophylactic treatment with (5% $KMnO_4$) solution. Fry of *M. gulio*, *O. niloticus*, *H. fossilis,* and *A. testudineus* were counted and stocked in triplicates ponds of different treatment (Table I). The fishes were hand-fed to apparent satiation four times per day (at 8.00, 11.00, 14.00 and 17.00 h) during the first month, thrice daily (at 9.00, 13.00 and 17.00 h) in second months and then twice a day (at 9.00 and 17.00 h) from third month to the end. During feeding time, a close observation was made and a record of supplied feed was kept for determining the apparent feed conversion ratio (AFCR) and apparent protein efficiency ratio (APER). The proximate composition of the feed (Table II), used in the current experiment was analyzed in triplicate according to standard procedures by AOAC (2000).

Table II. Proximate composition of feed use to fed fishes in the current experiment over 180 days

Feed component	Dry matter	Crude protein	Crude lipid	Ash	Crude fiber	NFE*
Amount (%)	89.96±0.48	30.32±0.12	9.95±0.16	18.28±0.58	9.35±0.46	32.1±0.20

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

Sampling of fish and monitoring water quality: A fortnightly sampling of fish was made by using a cast net and weight of fish measured by using a digital balance (OHAUS, CT 1200-S, USA) and length by a centimetre scale. Water quality parameters *viz*. temperature, dissolved oxygen (DO), water *p*H, soil *p*H, salinity, transparency, nitrate (NO_2), nitrite (NO_3), phosphate (PO_4), total ammonia (NH_3) and alkalinity were estimated and recorded on spot throughout the experimental period by using standard procedures and methods. The water temperature (°C) was measured by using a standard mercury thermometer, DO (mg/L) by DO meter (YSL, Model 58, USA), water pH by digital pH meter (Elico-Li-120), soil pH by soil pH and moisture tester (KS-05, TLEAD, China), salinity (ppt) by a refractometer (ATAGO, Japan), transparency (cm) by Secchi disc. Nitrate (mg/L), nitrite (mg/L), phosphate (mg/L), ammonia (mg/L) and total alkalinity were measured by using universal pocket meters. General conditions of the ponds were monitored regularly and the water quality parameters were measured between 10.00 to 13.00 h during the culture period.

Calculation of growth parameters

Mean final weight gain (g)= {Mean final fish weight (g) - Mean initial fish weight (g)}

% weight gain= [{(Mean final fish weight (g) - Mean initial fish weight (g)}/ Mean initial fish weight (g)] x100.

Specific growth rate (SGR %/day)= $[\{(\text{Log}_e W_2 - \text{Log}_e W_1)/(T_2-T_1)\} \times 100]$, 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/Total live weight gain .

Apparent protein efficiency ratio (APER)=Live weight gain/Dry weight of crude protein fed. Production (kg/ha) = [{Final number of fish harvested x individual weight of fish (g)}/1000] x 247.1.

Statistical analysis: One-way ANOVA (Duncan 1993) was applied by performing SPSS 17 for Windows (Chicago, USA). For all statistic tests, $\alpha=5\%$ was chosen as the significance criterion.

Results

Water quality parameters: The observed water quality parameters did not vary significantly ($p>0.05$) among the three treatments and they were found within the acceptable range for the fish culture. DO content significantly ($p<0.05$) differed between T_1 and T_2, T_1 and T_3 but there were no significant difference between T_2 and T_3. The water and soil pH in T_1 and T_2 showed marked variation over T_3 ($p<0.05$), and nitrate (NO_2) of T_1 showed significantly ($p<0.05$) higher value than T_2 and T_3 (Table III).

Growth performances and nutrient utilization: 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). Significantly ($p<0.05$) better nutrient utilizations i.e. AFCR and APER were recorded in T_2 (1.99 and 1.68) followed by T_3 (2.37 and 1.43) and T_1 (3.05 and 1.09) (AFCR and APER values respectively) (Table IV).

Table III. Summary of the variations in water quality parameters observed in different ponds of T_1, T_2 and T_3 during the 180 days culture period

Water quality parameters	T_1	T_2	T_3
Temperature (°C)	27.28 ± 1.846^a	27.25 ± 1.750^a	27.45 ± 1.790^a
DO (mg/l)	5.03 ± 0.165^a	5.16 ± 0.133^b	5.15 ± 0.224^b
pH (Water)	7.35 ± 0.083^a	7.33 ± 0.079^a	7.44 ± 0.156^b
pH (Soil)	6.37 ± 0.188^a	6.37 ± 0.094^a	6.55 ± 0.103^b
Salinity (ppt)	2.79 ± 1.090^a	2.72 ± 1.057^a	2.65 ± 1.018^a
Transparency (cm)	27.99 ± 1.619^a	28.84 ± 1.413^a	28.38 ± 1.571^a
Nitrate (NO_2) (mg/l)	0.217 ± 0.035^b	0.120 ± 0.086^a	0.166 ± 0.111^{ab}
Nitrite (NO_3) (mg/l)	0.045 ± 0.044^a	$0.050\pm0 .041^a$	0.043 ± 0.012^a
Ammonia (NH_3) (mg/l)	0.390 ± 0.043^a	0.420 ± 0.072^a	$0 .423\pm 0.073^a$
Phosphate (PO_4) (mg/l)	0.403 ± 0.070^a	0.387 ± 0.079^a	0.392 ± 0.064^a
Alkalinity (mg/l)	76.71 ± 7.065^a	80.95 ± 5.545^a	79.95 ± 7.331^a

Table IV. Growth performances and nutrient utilization observed in different treatments of the experiment over 180 days culture period

Morphometric parameters	**Fish Species**	**T_1**	**T_2**	**T_3**
Average initial weight (g)	*M. gulio*	0.50 ± 0.005^a	0.51 ± 0.006^a	0.50 ± 0.010^a
	O. niloticus	-	0.70 ± 0.009	-
	H. fossilis	-	-	0.500 ± 0.010
	A. testudineus	-	-	0.60 ± 0.009
	Combine	0.50 ± 0.005^a	0.55 ± 0.014^b	0.52 ± 0.008^a
Final weight of fish (g)	*M. gulio*	29.50 ± 0.361^c	21.20 ± 0.361^a	23.90 ± 0.356^b
	O. niloticus	-	180.17 ± 1.363	-
	H. fossilis	-	-	29.20 ± 0.721
	A. testudineus	-	-	86.40 ± 1.51
Mean final weight gain (g)	*M. gulio*	28.99 ± 0.357^c	20.69 ± 0.354^a	23.40 ± 0.358^b
	O. niloticus	-	179.26 ± 1.311	-
	H. fossilis	-	-	28.70 ± 0.711
	A. testudineus	-	-	85.79 ± 1.509
% weight gain	*M. gulio*	5795.73 ± 39.296^c	4053.11 ± 37.878^a	4681.48 ± 130.042^b
	O. niloticus	-	25641.74 ± 475.647	-
	H. fossilis	-	-	5745.80 ± 132.880
	A. testudineus	-	-	14301.45 ± 288.61
SGR (%/day)	*M. gulio*	2.26 ± 0.004^c	2.070 ± 0.005^a	2.14 ± 0.012^b
	O. niloticus	-	3.08 ± 0.010	-
	H. fossilis	-	-	2.26 ± 0.007
	A. testudineus	-	-	2.77 ± 0.011
	Combine	2.26 ± 0.004^a	2.24 ± 0.005^a	2.36 ± 0.164^a
AFCR	*Combine*	3.05 ± 0.084^c	1.99 ± 0.081^a	2.37 ± 0.080^b
APER	*Combine*	1.09 ± 0.027^a	1.68 ± 0.068^c	1.43 ± 0.007^b
Survival rate (%)[6]	*M. gulio*	72.55 ± 1.072^b	66.40 ± 1.20^a	75.67 ± 0.764^c
	O. niloticus	-	78.67 ± 3.055	-
	H. fossilis	-	-	74.00 ± 2.00

	A. testudineus	-	-	80.00±2.00
Survival (%)	Combine	72.55±1.072[b]	68.44±1.389[a]	76.55±1.268[c]
Production (kg/ha)	Combine	1586.68± 31.696[a]	2602.617±86.996[c]	2014.45±24.997[b]

Values are means of data obtained ± SD. Deviation (mean±SD) of fortnightly determinations. Values in the same row with same superscripts are not significantly different ($p > 0.05$).

Survival and production: After rearing for 180 days in pond conditions, survivals rates of fishes ranged between 67.33% and 77.66% among different treatments. Significantly ($p < 0.05$) higher survival rate (%) of the fishes were recorded in T_3 (76.55±1.268) compared to T_1 (72.55±1.072) and T_2 (68.44±1.389). Mean production of fishes ranged between 1555 to 2701 kg/ha among different treatments. Significantly ($p < 0.05$) higher gross production (kg/ha) were recorded in T_2 (2603±87) followed by T_3 (2014±25) and T_1 (1587±32) (Table IV).

Economic analysis (Benefit and cost analysis) of different culture systems: A simple cost-benefit analysis was performed to estimate the benefit cost ratio (BCR) and profitability that had been generated from these three types of culture systems. Though the expenditures in three different treatments did not vary significantly ($p > 0.05$) among themselves, however the lowest production costs (BDT/ha) was recorded in T_1 (363690±8565) followed by T_3 (369044±15067) and highest in T_2 (383005±7846) (Table V). Furthermore, consistently estimated higher net profit ($p < 0.05$) and higher BCR (BDT/ha) were recorded in T_3 over T_1 and T_2 respectively (Table V). BCR analysis revealed that T_3 (polyculture of *M. gulio* with *H. fossilis* and *A. testudineus*) was more profitable for the fish farmer over the monoculture of *M. gulio* and polyculture with *O. niloticus*.

Table V. Benefit and cost analysis (per hectare) of the experimental ponds in T_1, $T_2$and T_3

Items wise expenditures/ operational costs	**T_1**	**T_2**	**T_3**
Pond preparation	150	150	150
Seed cost[1]	900	900	1050
Lime (purchase rate BDT 12/kg)	135	135	135
Urea (@ BDT 16/kg)	24	24	24
TSP (@ BDT 24/kg)	36	36	36
Cow dung (@ BDT 2/kg)	60	60	60
Feed costs (@ BDT 45/kg)	2960.5	3195	2875.5
Others costs (BDT/treatment)	150	150	150
Total production costs (BDT/ treat)[2]	4415.5	4650	4480.5
Total production costs (BDT/ha)[2]	363690±8565[a]	383005±7846[a]	369044±15067[a]
Incomes and outputs			
Total production (kg/ha)	1586.68± 31.696[a]	2602.617±86.996[c]	2014.45±24.997[b]
Gross production value (BDT/ha)[3]	476006±9509[a]	479621±10284[a]	501858±6768[b]
Net profit (BDT/ha)[4]	112303±9508[a]	96714±10555[a]	132814±6768[b]
Benefit cost ratio (BCR)[5]	1.307±0.025[b]	1.253±0.025[a]	1.363±0.021[c]

Values are means of data obtained ± SD. Deviation (mean±SD) of fortnightly determinations. Values in the same row with different superscripts are significantly different ($p < 0.05$).
[1] Price of fry (BDT per pieces) *M. gulio* 1.0, *O. niloticus* 1.0, *H. fossilis* 2.0, *A. testudineus* 1.0.
[2]Physical labour cost involved was not considered because staffs of NIAIL themselves were in management works.
[3] Gross production values were estimated on the basis of sell values of produce crops. Market price of *M.* gulio 350, *O. niloticus* 125, *H. fossilis* 300, and *A. testudineus* 180 (BDT/kg).
[4] Net profit (BDT/treat[1])= Gross production value – Total production costs.
[5]BCR= Total production value/total production costs (BDT).

Discussion

Water quality parameters: In the present experiment, the highest water temperature and DO content were recorded as 30.50°C and 5.45 mg/l in the month of May and the lowest were 24.23 °C and 4.7 mg/l during the months of October and November. The changes in temperature and DO over the study period were may be related to the seasons of the year and with the time of the day. The highest salinity (4.92 ppt) was found in the month of May due to less rainfall and high temperature, but lowest salinity was found (1.01 ppt) in the month of August for excessive rainfall and these values did not show any significant variance between the treatments ($p > 0.005$). Although water and soil pH varied significantly ($p < 0.05$) under different treatment and values of nitrate (NO_2) in T_1 was significantly higher ($p < 0.05$) than the T_2. However, the ranges of water quality parameters in the present study more less aligned with the results of Rahman *et al.* (2009); Mamun *et al.* (2012); Hossain *et al.* (2014); Kader *et al.* (2018) and were within the acceptable limit for fish culture.

***Growth performances and nutrient utilization**:* At the end of experiment period, highest final weight, mean weight gain and percent weight gain of *M. gulio* were observed in T_1,. Whereas lowest individual final weight was observed in T_2. The reasons may be due to omnivorous nature of tilapia that utilize many types of natural food (as well as artificial feeds) in competition with *M. gulio* with same feeding habit that makes polyculture less efficient. Total weight gain was higher in case of T_3 because in this treatment *M. gulio* were cultured with *H. fossilis, A. testudineus* and they are less omnivorous fish and do not compete with of *M. gulio* feeding habit. Rajkumar *et al.* (2013) reported that effect of cholymbion growth, proximate composition and digestive enzyme activity of fingerlings of *M. gulio* and found final weight (g) 21.95± 0.66 and weight gain (g) 20.17±0.81 after 120 days of the experimental period. Chakraborty *et al.* (2004) reported for *O. niloticus* that fish fed to alternate day of feeding at maintenance and satiation ration showed maximum weight gain compared to the full fed fish in control treatment. In the present study, SGR values ranged from 2.07 to 2.27 in the three treatments and significantly higher SGR was found ($p < 0.05$) in T_1 compared to T_3 and T_2. Significantly ($p < 0.05$) higher AFCR and APER were recorded in T_2 followed by T_3 and T_1 respectively. The higher APER values indicated better utilization of protein while lower AFCR values indicated poor growth performance of fish. Kader *et al.* (2018) reported more or less similar range of FCR and PER for *A. testudineus*.

Survival and production: The significantly higher survival (%) of the fish ($p<0.05$) was recorded in T_3 followed by T_1 and lowest in T_2. Nevertheless, survival rate of various species in the present study was within the acceptable range of survivability (around 70-80%). The higher production was observed in T_2 than T_3 and T_1 respectively, although the mean weight gain (g) in T_1 was highest but total production was highest in T_2 (polyculture of *M. gulio* with tilapia). This due to individual growth of tilapia which was higher than others fishes in the experiment. The present result supports the findings of Begum (2009) who achieved the best production from higher stocking densities compared to that achieved with the lower ones.

Economic analysis: The economic analysis of the culture systems was carried out to assess the economic return under three culture systems Though the expenditures in different treatments did not vary significantly ($p>0.05$), however the lowest production costs (BDT/ha) was recorded in T_1 followed by T_3 and T_2 (Table V). However, significantly higher net profit (BDT) was found in T_3 followed by T_1 and T_2 due to the stocking of *M. gulio* with *H. fossilis* and *A. testudineus*. While this species has a great local and national market value, the bonuses were *H. fossilis* and *A. testudineus* which have a greater acceptance in the local market (Garcia-Perez *et al.* 2000). Nevertheless, significantly ($p<0.05$) higher BCR were also recorded in T_3 followed by the T_1 and lowest in T_2. The observation of higher net benefit is in agreement with those of Kader *et al.* (2018) and Usmani *et al.* (2003). The present results suggest that T_3 (polyculture of *M. gulio* with *H. fossilis* and *A. testudineus*) is more beneficial with higher profitability for the fish farmer over the T_1 (mono) and T_2 (polyculture with tilapia). Therefore, rural communities can use this culture technology as a way of coping measure (adapt) to climatic extremities, for better utilization of vast salinity intruded areas of coastal region of Bangladesh.

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Literature Cited

Ali, M.Y., 1999. Fish resources vulnerability and adaptation to climate change in Bangladesh. In *Vulnerability and Adaptation to Climate Change for Bangladesh*. Springer Netherlands.

Allison, E.H., A.L. Perry, M.C. Badjeck, W. Neil Adger, K. Brown, D. Conway, A.S. Halls, G.M. Pilling, J.D. Reynolds, N.L. Andrew and N. K. Dulvy, 2009. Vulnerability of national economies to the impacts of climate change on fisheries. *Fish Fish.,* 10(2): 73-196.

AOAC, 2000.Official methods of Analysis.17th edn.Association of Official Analytical Chemists, Washington DC.

Begum, M., H.K. Pal, M.A. Islam and M.J. Alam, 2009. Embryonic and larval development of *Mystus gulio* (Ham.). *Bangladesh J. Fish. Res.,* 13(2): 169-177.

Begum, M., H.K. Pal, M.A. Islam and M.J. Alam, 2010. Length–weight relationship and growth condition of *Mystus gulio* (Ham.) in different months and sexes. *Univ. J. Zool. Rajshahi Univ*., 28: 73–75.

Chakraborty, S.C., N.C. Bhattacharja, M.A. Mansur, 2004. Compensatory growth in tilapia (*Oreochromis niloticus*) fed on formulated diet at restricted and satiation ration. *Bangladesh J. Fish ,* 28(1-2): 1-8.

Dahanukar, N., R. Rautand, A. Bhat, 2004. Distribution, endemism and threat status of freshwater fishes in the Western Ghats of India. *J. Biogeogr.,* 31(1): 123-136.

Dendrinos, P. and J.P. Thorpe, 1985. Effects of reduced salinity on growth and body composition in the European bass *Dicentrarchus labrax*. *Aquaculture*, 49(3-4): 333-358.

FAO, 2014. The State of World Fisheries and Aquaculture, Opportunities and Challenges. Food and Agricultural Organization of the United Nations, Rome, Italy.

Garcia-Perez, A., D.E. Alston and R. Cortes-Maldonado, 2000.Growth, survival, yield and size distributions of prawn *Macrobrachium rosenbergii* and tilapia *Oreochromis niloticus* in polyculture and monoculture systems in Puerto Rico. *J. World Aquac. Soc*., 31: 446-451.

Haniffa, M.A., 2009. Native catfish culture a technology package for fish farmers. *Aqua. Asia Magaz.*,14 (3): 22–24.

Haque, S., G.D. Bhatta, N. Hoque, M.H. Rony and M. Rahman, 2008. Environmental impacts and their socioeconomic consequences of shrimp farming in Bangladesh. Presented in conference on *"Competition for Resources in a Changing World: New Drive for Rural Development"* Tropentag 2008, October 7-9, University of Hohenheim, Germany.

Hosain, M.T., G.U. Ahmed, M.M. Hassan, M.A. Kashem, M.M.M. Alam and M.M. Hossain, 2014. Health status of eels from open waters: a clinical and histopathological approach. *An. Vet. Anim. Sci.*1(1): 30-38.

Hossain, M.Y., R. Islam, M.A. Hossen, O. Rahman, M.A. Hossain, M.A. Islam and M.J. Alam, 2015. Threatened fishes of the world: *Mystus gulio* (Hamilton, 1822) (Siluriformes: Bagridae). *Croatian J. Fish.,* 7: 43-45.

Kader, M.A., M. Bulbul, M.M. Hossain, M.S. Hossain, G.U. Ahmed, S. Mian, M.A. Hossain and M.E. Ali, 2018. The use of fermented soybean meal and squid by-product blend as a substitute for fish meal in practical diets for climbing perch, *Anabas testudienus*, pond culture: Growth performance and economics analysis. *J. Appl. Aquac.,* 1-21.

Karim, M.F. and N. Mimura, 2008. Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. *Glob. Environ. Change*, 18(3): 490-500.

Karim, M.R. and M.S. Shah, 2001. Brackishwater shrimp cultivation restricts coastal agriculture. *Khulna Univ. Stud. Khulna, Bangladesh*, *2*(1): 123-134.

Khan, M.N., A.K.M.S. Islam and M.G. Hussain, 2003. Marginal analysis of culture of stinging catfish (*Heteropneustes fossilis*, Bloch) effect of different stocking densities in earthen ponds. *Pakistan J. Biol.Sci.,* 6: 666-670.

Mijkherjee, M., A. Paharaj and S. Das, 2002. Conservation of endangered fish stocks through artificial propagation and larval rearing technique in West Bengal, India. *Aquac. Asia*, 7(2): 8-11.

Rahman, M.O., H. Ali, M.M. Hossain, M. Anisuzzaman and M.J.U. Miah, 2009.Impacts of goat and sheep manures alone and in combination with urea on the polyculture of Indian and Chinese carps. *J. Environ. Sc. Nat. Resour.,* 2(1): 49-53.

Rajkumar, M., M.M. Rahman, A. R. Prabha, B. Phukan, 2013. Effect of cholymbi on growth, proximate composition, and digestive enzyme activity of fingerlings of long whiskered catfish, *Mystus gulio*. *ActaIchthyol. Piscat*., 43(1): 15–20.

Usmani, N., A.K. Jafrim and M.A. Khan, 2003. Nutrient digestibility studies in *Heteropneustes fossilis* (Bloch), *Clarias batrachus* (Linnaeus) and *C. gariepinus* (Burchell). *Aqua. Res.,* 34: 1365-2109.

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