Feeding behavior and growth performance of tade mullet, *Liza tade* (Forsskail, 1775) in brackish water gher farming system

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***Abstract*—**The study was conducted to appraise the growth performances, and feeding behavior of tade mullet (*Liza tade*) in an extensive polyculture gher-farming system. The ghers were occupied with unfiltered estuarine water (15.5 ppt), containing various types of crustacean and fish species. The water was replaced (25-30%) every cosmological cycle through bamboo screens. Tade mullet (4.35±0.80 g) stocked at 2500 fingerlings/ha were attained a mean final weight of 277.42±12.65 g. The result showed an undesirable algometric growth because of the scarcity of food resources in the extensive gher farming system. Feeding concentration in terms of stomach richness increased with increasing fish weight. The study showed that tade mullet is an herbivorous fish, grazing mainly on phytoplankton and organic matter from the bottom sediment in regards of ecological view. Although tade mullet fed on a wide variety of phytoplankton groups including Bacillariophyceae, Myxophyceae and Chlorophyceae according to the order of supremacy, they vigorously select Chlorophyceae followed by Myxophyceae and Bacillariophyceae according to order of preference indicating their ability to select favorite food items.

Keywords*—Liza tade*, polyculture, extensive system, feeding ecology, growth performance.

I. Introduction

THE mullets belonging to the family Mugilidae, comprises mainly of coastal marine species and are widely distributed in all tropical, subtropical and temperate seas. Mullets are generally considered to be ecologically important and forms major food resource for human populations in certain parts of the world [1]. Tade mullet (*Liza tade* Forsskål 1775) is one of the most important mullet species widely cultured in both brackish and freshwater mono and poly-culture fish ponds [2]. Due to its good consumer preference and market price, non-carnivorous food habit and abundant availability of seeds, tade mullet is a good candidate for polyculture with other species including shrimps [3]. It has a high quality flesh, superior growth, large maximum size and wide salinity and temperature tolerances [4].

In any aquaculture practice, growth potential of a fish species is considered to be one of the most important criteria for selecting as a candidate species. Available reports regarding growth of tade mullet is highly variable from farming trials. Tade mullet fingerlings (5 g) were grown to 215-265 g in 18 months with *Liza parsia* at ratios of 1: 2 and 1: 4 at overall stocking density of 25,000/ha in West Bengal coast [5]. Growth of tade mullet fingerlings (6.16±0.49 g) up to 203.24 g at stocking density of 3,300/ha in 148 days culture with *Penaeus monodon* at stocking density of 50,000/ha was reported [6]. Much lower growth was also reported where tade mullet fingerlings (7.60±0.24 g) attained 80.40±4.02 g at stocking density of 1,500/ha in 180 days polyculture with *Mugil cephalus* (4,500/ ha), *L. parsia* (2,000/ha) and *P. monodon* (20,000/ha) [3]. For efficient culture and management of fish resource, knowledge on food and feeding habits of fishes is of immense importance [7]. Food and feeding habits of a species of fish is intimately associated with the ecological niche that they occupy in the natural environment [8] and knowledge on this aspect is advantageous in their proper management and exploitation [9]. Mullets are generally considered as herbivorous, omnivorous, plankton feeders, or even micro crustacean predators [10].

The tropic behavior of mullets has been reported by different authors using extensive terminology which categorized feeding patterns of these species [9]. Some examples include algae feeders [11], micro and meio-benthos feeders [12], interface-feeders [13], deposit feeders [14], benthic microphagous omnivores [15] and limno-benthofagous [16]. Food and feeding habits of the fish vary with time of the day, season of the year, size of the fish, environmental condition and with different food substances present in the water body. Changes in feeding habits of a fish species are a function of the interactions among several environmental factors that influence the selection of food item [17]. Stomach content analysis and features of the alimentary system provide information on food, feeding behavior and selective feeding if any [18]. Feeding behavior at the level of prey selection can have implications at the individual [19], population [20] and community levels [21].

In India, *L. tade* occurs in marine, shallow coastal waters, coastal lakes and estuarine environments and is cultured in brackish water farms [22], freshwater tanks [23] and experimentally in salt water ponds [24]. In West Bengal, the low-lying lands near estuaries and deltaic areas enclosed by embankments called "Bheries" are used for traditional finfish

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cultivation, mostly for mullets, especially during rains [25] where tade mullet is considered as most preferred fish due to its superior taste and market value. In spite of being widely cultured as an important component in traditionally practiced extensive polyculture, information on tade mullet growth performances and feeding ecology in such systems are scarce. Therefore, the present study was designed to assess growth performances and feeding ecology with special emphasis on prey preferences of tade mullet in extensive polyculture system to strengthen the ecosystem approach for brackish water polyculture management.

II. MATERIALS AND METHODS

The trial was carried out during February to December, 2015 at Vathshala, Debhata, Satkhira, Bangladesh. Three tide-fed brackish water gher (0.75 to 1.0 ha) located at the bank of a creek of Isamoti river were selected. The ghers were dewatered and sundried at the beginning. Lime stone powder was applied to the dried pond bottom at 500 kg/ha during first week of January. During the tidal period, the unfiltered saline water (15.5 ppt) from the adjacent stream of the river was allowed to let into the gher during at the second week of January through bamboo screen fitted inlet system and each was filled up to a depth of 115 cm. Traditional bamboo screen used in 'Bhery' allows entry of small fry of different species but restricts the exit of bigger fishes. Entry of tade mullet fry along with other species was not projected as seeds of *L. tade* remain available in south-east and south-west coasts during November–April and north-east coast during July–October [27]. Tade mullet fry was collected during October. They were reared in a different nursery pond before stocking in the gher. Other fish fry entered into the gher along with tidal water were allowed to grow for one month and pre-nursed fingerlings of tade mullet. The weight and size of fingerlings were 4.35 ± 0.80 g and 9.75±0.65 cm, respectively. The stocking density was 2500 fingerlings/ha during February. About 25-30% water was replaced in every cosmological cycle depending on the plenty of tidal waters throughout the rearing period. It was followed by a common practice during the culture period. The samples of water and fish were collected from three ghers to reject any possible biasness. Then the both samples of fish and water were placed with ice in an insulated box before transporting to the field-based laboratory for subsequent analysis.

In total, 15 individual fishes were collected randomly during the middle of each month from each of the three ghers (i.e., 45 individuals per sampling) of fishes in each month and the resulting total numbers of 450 of fishes were collected and analyzed throughout the study period. Gravimetric data of fishes were collected monthly throughout the experimental period. The total length (TL) in centimeter (cm) was recorded with a slide caliper, while body weight (W) in gram was measured by using a digital electronic balance.

Daily weight gain (DWG) is a function of weight and time and was estimated for each replicate pond with the formula:

$$DWG = (Wf - Wi)/t$$

Where, Wf and Wi are the average final and initial weight in time t.

Specific growth rate (SGR) was calculated by using the conventional equation:

$$SGR = (\ln Wf - \ln Wi)100/t$$

Where, Wf and Wi are the average final and initial weight in time t.

The mathematical relationship between length and weight was calculated by using the conventional formula [28]:

$$W = a.TL^b$$

Where, W is fish weight (g), TL is total length (cm), a is the proportionality constant and b is the isometric exponent. The parameters a and b estimated by non-linear regression analysis.

Fulton's condition equation was used to find out the condition factor [29]:

$$K = \bar{w}\ X\ 10^2/(\overline{TL})^3$$

Where K = the condition factor, $\bar{w}$ = the average weight (g) and $\overline{TL}$ = the average total length (cm).

After gravimetric measurements, the whole gut were detached by cutting above the cardiac and below the pyloric sphincters and then preserved in a vial with 4% formalin. The stomach fullness degree was assessed by visual estimation and classified as S1, S2, S3, S4, S5, S6 and E, ,which were further expressed by satisfied, full, 3/4 full, 1/2 full, 1/4 full, little and empty, respectively [30]. The gut contents were placed into 4% formalin. From each vial, one ml gut contents were then transferred to Sedgwick-Rafter counting cell and phytoplankton constituents were identified and counted accordingly [31-32]. Planktonic constituents of stomachs were categorized as Bacillariophyceae (diatoms), Chlorophyceae (green algae), Myxophyceae (blue-green algae), copepods, and dinoflagellates and fish parts. Then, it was considered as numeric percentages of each category. The major constituents as organic matter and sand particles in the gut were also assessed. Water samples were collected from surface of the gher between 09:00 and 10:00 h bi-monthly. Water quality parameters such as water temperature, pH, dissolved oxygen (DO), alkalinity, nitrite-nitrogen (NO_2-N), nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N) and phosphate-phosphorus (PO_4-P) were measured and studied by following the standard methods [33]. Salinity was evaluated by using a refractometer (ATAGO, Japan). Monthly plankton samples were collected by filtering 100 L of water through bolting silk plankton net (mesh size 64 μm). Plankton densities were immediately preserved in 4% buffered formalin for further qualitative and quantitative analysis.

The percentages of food composition in the stomach contents under different groups were compared among the fish ghers to evaluate quarry preferences. Differences in final length, final weight, daily weight gain (DWG), specific growth rate (SGR), survival and exponential value of length-weight relationship (LWR) were determined by analysis of variance with the General Linear Model procedure using SPSS for Windows version 17.0 (SPSS Inc. Chicago IL USA). Duncan's Multiple Range Test [35] was used for comparison of treatments. All data were expressed as mean ±

standard error (SE).

III. RESULTS

Growth in terms of final length (cm) and weight (g) of the fish are presented in Figure 1. Fishes were grown from 4.35±0.80 g to 277.42±12.65 g in weight and (9.75±0.65 cm) to (35.56±2.65 cm) after 300 days of rearing. Mean daily weight gain (DWG) was 0.925±0.125 g/day, which were ranged between 1.45 g in July and 0.36 g in February. Specific growth rate (SGR) varied between 4.35%/day (February) and 0.44 %/day (September) with a mean value of 1.53±0.42%/day.

Fig. 1. Growth performances of tade mullet (*Liza tade*) reared in extensive gher-farming system.

Fulton's condition factor (K) of fish was 1.25±0.07, considering the whole rearing period. Length-weight relationship (LWR) showed curvilinear growth pattern and exponential value (b) of LWR was recorded to be 13.39, indicating negative allometric growth (Fig. 2).

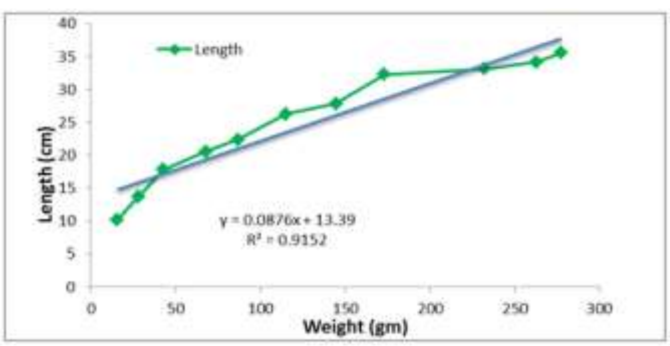

Fig. 2. Length-weight relationship of tade mullet (*Liza tade*) reared in extensive gher-farming system.

Feeding intensity of tade mullet indicated by the extent of stomach fullness is depicted in Figure 3. Lower feeding intensity was observed during the initial months of rearing, characterized with higher number of empty stomachs. Feeding intensity was observed to increase gradually indicated by increasing number of satisfied and full stomachs as rearing proceeded. Highest feeding intensity was observed during the final month of December. Percentage occurrences of food materials observed in the tade mullet stomachs are presented in Figure 4.

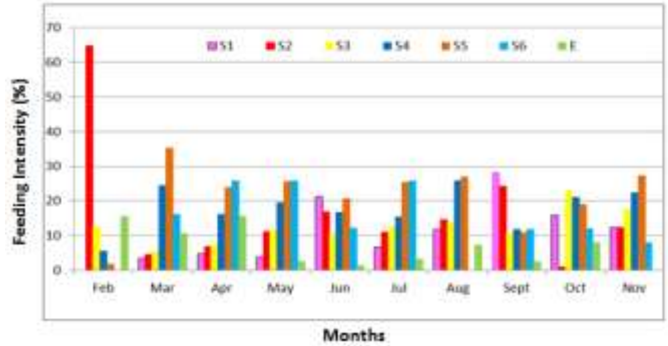

Fig. 3. Feeding intensity of tade mullet (*Liza tade*) in extensive brackish water gher farming during the rearing period; n = 45 for every month. In total 15 fishes were collected monthly from three ghers during the study; S1= Gorged, S2=Full, S3= ¾ Full, S4= 1/2 Full, S5=1/4Full, S6= Little, E= Empty.

According to the order of dominance, the most abundant phytoplankton groups in the three rearing ghers were Bacillariophyceae (22.14–41.12%), Chlorophyceae (8.45-21.27%) and Myxophyceae (4.55-13.44%). The dominant zooplankton groups in the stomach was dinoflagellates (1.64-5.65%) followed by copepods (0.18-3.05%). Fish and shrimp parts (0.12-9.98%) as non-planktonic suspended material were also present. Percentage occurrence of decayed organic matter such as rotted parts of macrophytes, unidentified organic particles, cladoceran appendages and foraminifera shell was ranged between 8% and 14%. Sand particles and mud constituted 20.66-45.35% of the total stomach content.

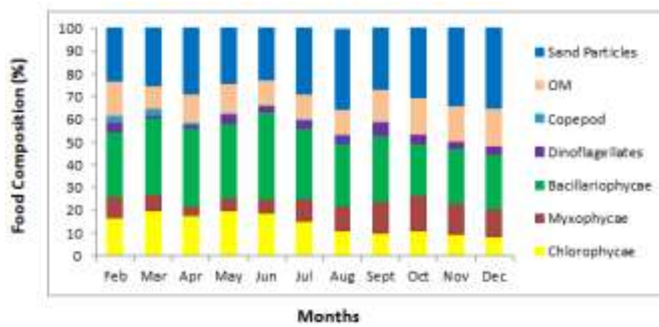

Fig. 4. Preference of food material occurrences in the stomach of tade mullet (*Liza tade*) in extensive gher farming system.

The overall average water quality parameters of the experimental ghers are shown in Table 1. Among the water quality parameters of experimental ghers, water temperature showed wide range and fluctuated between 19.8 and 34.4°C (Table 1). Maximum temperature was recorded during April (34.4°C) and minimum during November (19.8°C). Dissolved oxygen (DO) and pH value were almost similar all over the culture period and ranged between 5.80 to 9.01 mg/L and 7.82 to 8.82, respectively (Table 1). Salinity showed wide variations in three experimental ghers all through the study and the maximum salinity was recorded to be 18.5 ppt during summer (May) and the minimum salinity was 3.3 ppt during rainy (August) (Table 1). This is the usual seasonal salinity variations of the tidal water in the Sundarban region. Nitrogenous metabolites such as nitrite-nitrogen (NO_2-N) and total ammonia nitrogen (NH_3-N) varied between 9.30-24.48 and 21.81-44.09 μg/L, respectively in three ghers (Table 1). Concentration of total ammonia nitrogen was significantly ($P < 0.05$) higher in gher 3 than other two ghers. Nitrate-nitrogen (NO_3-N) and phosphate-phosphorous (PO4-P) concentrations ranged between 68.63 and 112.20, and 20.62 and 432.75 µg/L (Table 1), respectively while there were no significant ($P > 0.05$) difference surrounded by three experimental ghers. Significantly ($P < 0.05$) rich planktonic concentration was observed in gher T_1 and poor in Gher T_3.

TABLE1. DIFFERENT WATER QUALITY PARAMETERS IN THE EXPERIMENTAL GHERS.

Water quality parameters	**T_1**	**T_2**	**T_3**
pH	8.04 ± 0.23^a	7.96 ± 0.25^a	7.78 ± 0.31^b
Temperature (°C)	29.95±1.35	29.95±1.35	29.7±1.9
Salinity (‰)	12.87±5.34	12.74±5.32	12.89±5.19
DO (mg/L)	6.06 ± 0.42^a	5.99 ± 0.52^a	5.69 ± 0.52^b
NO_2 – N (µm/L)	16.35±5.83	15.91±5.62	16.11±6.63
NO_3 – N (µm/L)	93.12±15.41	92.66±11.14	92.97±8.94
NH_4 – N (µm/L)	30.96 ± 5.61^b	31.19 ± 7.91^b	34.89 ± 6.27^a
PO_4 – P (µm/L)	32.07±13.43	31.91±11.98	31.89±12.74
Phytoplankton (Nos/L x 10^3)	15.38 ± 1.62^a	15.12 ± 1.94^b	14.95 ± 1.73^c
Zooplankton (Nos/Lx 10^3)	3.05 ± 0.25^a	2.91 ± 0.023^b	2.83 ± 0.17^c

Means bearing different superscripts indicate statically significant differences in a row ($P < 0.05$); Values are expressed as mean ± SE (n=10 for each ghers in every month).

The occurrence of planktonic percentage and other suspended food particles of the composition components in gher water are accessible in Figure 5. According to order of supremacy, the most abundant phytoplankton groups in three ponds were Bacillariophyceae, Chlorophyceae, and Myxophyceae. The dominant zooplankton group in three ghers was dinoflagellates followed by copepods; however fish and shrimp parts were also present. The most plentiful genera were observed under Bacillariophyceae according to the order of supremacy, such as *Nitzschia*, *Gyrosigma*, *Navicula*, *Cyclotella*, and *Melosira. Coscinodiscus*, *Cymbella*, *Synedra*, *and Pleurosigma* were among the other less abundant genera under Bacillariophyceae. Other plentiful genera under Chlorophyceae according to the order of dominance were observed such as *Pediastrum*, *Chlorella*, *Scenedesmus* and *Tetraedron.* Furthermore, *Ankistrodesmus*, *Coelastrum*, *Crucigenia*, *Scenedesmus* and *Pandorina* were also faced as less abundant genera.

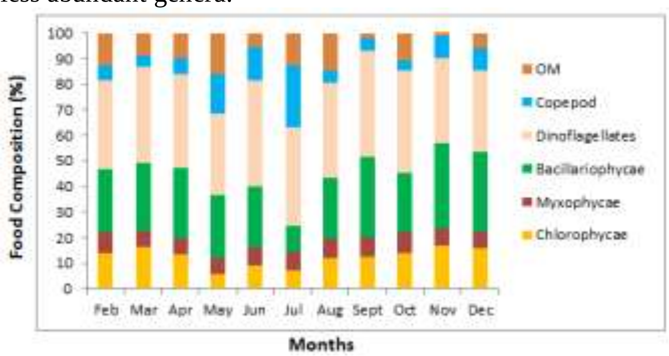

Fig. 5. Percentages of suspended food particles available in water column of extensive tade mullet (*Liza tade*) culture gher.

Anabaena and *Oscillatoria* were the most dominant genera under Myxophyceae, while other genera such as *Chroococcus*, *Gloeocapsa*, and *Merismopedia* were moderately less abundant. Myxophyceae comprised of 4.55-8.92% among planktonic forms. Common Dinoflagellates, such as *Ceratium* and Peridinium, and Copepods like *Calanus* spp. were most abundant genera surrounded by the zooplankton groups. Rotifers and Cladocera existed as less abundant zooplankton groups. Highest percentage occurrence of dinoflagellates and copepods were observed during April (47.56%) and July (24.88%), while lowest percentage occurrence were found during May (31.06%) and August (2.04%), respectively.

IV. DISCUSSION

The growth and metabolism of euryhaline species are generally affected by the salinity due to use of the energy for osmoregulation is not available for their growth [36]. Tade mullet required a minimum energy for osmoregulation at 15 ppt and isosmotic salinity for this species is 10 ppt [37]. Existing ambient salinity are nearly close to the isosmotic salinity in the studied ghers that will have to be helped tade mullet to grow up without the salinity stress. Some other factors like availability of food and stocking density might have hampered the growth in the study. Compared to polyculture of shrimp-tade mullet in fed ponds, much higher growth rate was found in the present study. There has been reported that the 6.16±0.49 g tade mullet fingerlings attained 203.24 g in which ADG 1.33 g/day was also found for 148 days with stocking density of tade mullet at 0.33 individual/m^2 and tiger shrimp 5 individuals/m^2 [6]. The lower growth rate of tade mullet was reported from Sundarbans [5], where tade mullet fingerlings of 5 g were grown to 265 g with an ADG of 0.48 g/day for 18 months with *Liza parsia* at the ratio of 1: 4. These observations indicate the viability of tade mullet-tiger shrimp polyculture. However, tade mullet fingerlings attained from 7.60±0.24 g to 80.40±4.02 g in weight whereas the ADG rate was 0.40 g/day at a stocking density of 1,500 individual/ha for 180 days polyculture with *Mugil cephalus* (4,500/ha), *L. parsia* (2,000/ha) and *P. monodon* (20,000/ha) [3]. The higher growth rate of tade mullet was found in -tiger shrimp-tade mullet polyculture. It may be attributed that there was no feeding competition among organisms at different trophic levels, whereas the lower growth rate of that in polyculture with parsia and tiger shrimp, may be accredited in the feeding competitions with other mullets belonging to the same trophic level.

On the other hand, it was observed that the mullets which were entered naturally with a lower stocking density in the present study might be a reason behind improved growth of tade mullet in spite of being non-fed mullets-shrimp polyculture system. The isometric exponent (b=2.951) of length weight relationship in the present study indicated negative allometric growth of tade mullet. When the b parameter is equal to 3, growth is isometric and when it is less than or greater than 3, it is allometric [38]. More specifically, growth is positive allometric when organism's weight increases more than length (b > 3), and negative allometric when length increases more than weight (b < 3) [39]. Negative allometric growth and low condition factor (K= 0.64±0.02) of tade mullet in the present study indicates shortage of food materials in the farming system as competition for space is not likely in such low density and low production systems. Exponent value of LWR in the present study corroborated with those reported from tropical lagoon of Sri Lanka [40].

Higher feeding frequency in bigger fishes than smaller ones may be attributed to the fear of potential predators by the smaller fishes while feeding as they are more vulnerable and would rather feed more cautiously than their bigger counterpart [41]. In tide-fed extensive farming systems, tade mullets coexist with other herbivorous and some carnivorous fishes such as *Lates calcarifer*, *Megalops cyprinoides*, *Eleutheronema tetradactylum*, *Therapon jarbua*, *Glossogobius giuris* etc., which gains entry during the process of tidal water exchange and lowers production [3]. Larger fish may require more food to obtain the necessary energy for reproductive activity than smaller ones require for growth. Moreover, a wider mouth opening in larger fish helps to ingest relatively larger quantity food items at a time [42].

Reports on tade mullet feeding ecology is rare, however, food and feeding habits of other mullets have been studied by many authors [10, 15, 40, 43-47]. Mullets are well suited for farming since they feed on algae, diatoms, small crustaceans, decayed organic matter and mud; hence there is a little need to feed [48]. Mullets have been reported that they are chiefly plankton feeders [49, 50]. Bacillariophyceae followed by myxophyceae and Chlorophyceae as most dominant food constituents of *M. cephalus* in brackishwater environments have been reported from various parts of Indian subcontinent [7, 51, 52] and other parts of the world [53-56]. Planktonic algae were reported to be the dominant food item of gold spot mullet, *L. parsia* and planktonic groups according to the order of dominance were Chlorophyceae, Bacillariophyceae and Myxophyceae [57]. Phytoplankton groups in stomach content of tade mullet according to the order of dominance in the present study are Bacillariophyceae, Chlorophyceae, and Myxophyceae. Differences in the order of dominance of different planktonic groups in the stomach content of mostly available mullet species such as *M. cephalus*, *L. parsia* and *L. tade* indicate some shorts of sharing strategy of the trophic level which they belong.

Maintenance of good water quality is essential for optimum growth and survival of aquatic organisms under culture. Recorded water quality parameters in the present study were within optimum ranges for brackish water aquaculture [58]. Concentrations of toxic gases like nitrite-nitrogen (NO_2-N) and ammonia-nitrogen (NH_4-N) remained lower than the critical level and concentrations of nutrients like nitrate-nitrogen (NO_3-N) and phosphate-phosphorous (PO_4-P) was much lower than fertilized ponds from Sundarban [3, 59]. Lower nutrient concentrations in the studied system may be attributed to complete dependence on natural productivity without any additional input. Order of dominance of the planktonic groups in the ambient water in the present study was corroborated with that reported from the Hooghly estuary [60].

V.CONCLUSION

The findings obtained from the present experiment suggest that tade mullet has good growth performance and can be well-thought-out for increased farming, however, the protocols for intensified mono and polyculture has to be uniformly standard. For feeding behavior, the study indicates that tade mullet is mainly an herbivorous fish, which browses on phytoplanktonic cells in the water column and consumes the organic matter from the lower sediments. Although tade mullet fed on Bacillariophyceae, Myxophyceae and Chlorophyceae according to the order of dominance, they showed preference towards Chlorophyceae followed by Myxophyceae and Bacillariophyceae. Additional research will be desired to unveil feeding strategies of other co-existing species in the studied environment having more importance in aquaculture. This will enable establishment of optimum species combination for improved brackish water polyculture based on optimum food sharing and resource utilization as a step forward towards sustainable aquaculture production.

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