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Original Article

Seasonal analysis of food items and feeding habits of endangered riverine catfish *Rita rita* (Hamilton, 1822)

Análise sazonal de itens e hábitos alimentares de bagres ribeirinhos *Rita rita* (Hamilton, 1822) ameaçados de extinção

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Abstract

This investigation presents the food and feeding activity of and endangered riverine catfish *Rita rita,* during February 2017-January 2018. A total of 225 fish individuals was analyzed for stomach contents by characterizing the dominant food items and morphometric features. The results divulged ten major food items consumed, preferably fish scales and eggs, teleost fishes, copepods, cladocerans, rotifers, and mollusks. Total length and body weight of fish varied between 9-34 cm (20.53 ± 6.90 cm) and 10-400 g (9125.94 ± 102.07 g), respectively. The index of relative importance (IRI%) showed the importance of rotifers over the other food items. Morisita's index of diet overlap indicated seasonal variations in catfish diets with summer and monsoon displaying the least overlap, while maximum overlap during monsoon and winter seasons. The non-metric multidimensional scaling (nMDS) indicated the close association between the food items available during summer and winter seasons with a significant difference among the seasons (ANOSIM, *R = 0.638, P = 0.013*). Levin's niche breadth index arranged in the order of 0.88>0.81>0.78>0.63>0.43 for the size classes of V, IV, III, II and I, respectively. The PCA explained 95.39% of the total variance among the food items and fish size groups. Small-sized fish individuals displayed a greater correlation with food items suitable for their mouth size. In conclusion, the variety and frequency of food items recorded indicated considerable feeding plasticity and opportunistic feeding behavior with a shift from carnivorous to omnivorous feeding nature. This study could render useful information on the food and feeding habits of *R. rita* and provide background for preparing its diet for future aquaculture practices.

Keywords: *Rita rita*, feeding habits, stomach contents, plasticity, multivariate analysis, morphometric.

Resumo

Esta investigação apresenta a alimentação e a atividade alimentar de bagres ribeirinhos Rita rita ameaçados de extinção, no período de fevereiro de 2017 a janeiro de 2018. Um total de 225 peixes foi analisado quanto ao conteúdo do estômago, caracterizando os itens alimentares dominantes e as características morfométricas. Os resultados apresentaram dez principais itens alimentares consumidos, preferencialmente escamas e ovos de peixes, teleósteos, copépodes, cladóceros, rotíferos e moluscos. O comprimento total e o peso corporal dos peixes variaram entre 9-34 cm (20,53 ± 6,90 cm) e 10-400 g (9125,94 ± 102,07 g), respectivamente. O índice de importância relativa (IRI%) mostrou a importância dos rotíferos sobre os demais itens alimentares. O índice de sobreposição de dieta de Morisita indicou variações sazonais nas dietas de bagres no verão e nas monções, exibindo a menor sobreposição, enquanto a sobreposição máxima ocorreu durante as estações das monções e do inverno. A escala multidimensional não métrica (nMDS) indicou a estreita associação entre os itens alimentares disponíveis durante o verão e o inverno, com uma diferença significativa entre as estações (ANOSIM, R = 0,638, P = 0,013). O índice de amplitude de nicho de Levin foi organizado na ordem de 0,88 > 0,81 > 0,78 > 0,63 > 0,43 para as classes de tamanho de V, IV, III, II e I, respectivamente. O PCA explicou 95,39% da variação total entre os itens alimentares e os grupos de tamanho de peixes. Peixes de pequeno porte apresentaram maior correlação com itens alimentares adequados ao tamanho da boca. Em conclusão, a variedade e a frequência dos itens alimentares registrados indicaram plasticidade alimentar considerável e comportamento alimentar oportunista, com uma mudança da natureza carnívora para onívora. Este estudo pode fornecer informações úteis sobre os hábitos alimentares e de alimentação de R. rita e apresentar subsídios para a preparação de sua dieta em futuras práticas de aquicultura.

Palavras-chave: *Rita rita*, hábitos alimentares, conteúdo estomacal, plasticidade, análise multivariada, morfométrico.

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1. Introduction

Investigations on feeding habits and preferences provide essential data on the trophic interactions and nutrient flow in the aquatic ecosystems (Fatema et al., 2013; Campos et al., 2015; Atique and An, 2018, Atique et al., 2019; Saeed et al., 2020; Rahman et al., 2020) as the success of a fish species in its typical habitat is associated with its diet because it provides crucial insights into its natural history (Braga et al., 2012; Batool et al., 2018; Kim et al., 2019; Iqbal et al., 2017a, 2020; Khanom et al., 2020). The management decisions on the management of fish populations include numerous aspects of fish biology, feeding preferences, and water quality management (Atique and An, 2020; Atique et al., 2020a, b; Hara et al., 2020; Jewel et al., 2020; Momi et al., 2021). Therefore, investigations on the trophic ecology, mainly targeting the food and feeding preferences of valuable fish species, are incredibly vital for the conservation and restoration of endangered fish species and their stocks (Blaber, 1997; Fagbenro et al., 2000; Bae et al., 2020; Moon et al., 2020). Changes in dietary preferences of a fish species largely depend on the availability of preferred prey items in the associated environment. An abundance of favorite prey items in the environment regulates their predominance of food items in the fish stomach (Palmeira and Monteiro-Neto, 2010; Gondal et al., 2020; Kim et al., 2021). Moreover, energy requirements by fish in a specific phase of life sometimes induce ontogenetic shifts in dietary mode and selectivity (Cruz Escalona and Abitia Cárdenas, 2004). Thus, analysis of stomach contents based on the seasonal and morphological traits could help in establishing standard practices in fishery science and could provide relevant scientific advice on sustainable fisheries management (Hyslop, 1980; Zacharia, 2004).

Rita rita is a commercially exploited fish species in Bangladesh and is appreciated for its high nutritious value (Mohanty et al., 2015). The natural distribution of this fish species is described from shallow and muddy to clear waters in rivers and wetlands of Bangladesh (Islam et al., 2015; Galib et al., 2016; Sultana et al., 2017; Jewel et al., 2018; Parvez et al., 2019) and in the closer countries (Gupta, 2015; Iqbal et al., 2017b; Muhammad et al., 2019). Nowadays, the populations of *R. rita* in the riverine ecosystem of Bangladesh are facing the critical threat of extinction due to over-exploitation and loss of breeding grounds (Molla et al., 2008). Consequently, it has been categorized as endangered fish species in Bangladeshi waters (IUCN, 2010). Therefore, captive breeding could offer a suitable option to conserve this fish species. Several successful experiments of the induced breeding in *R. rita* have been performed in Bangladesh (Molla et al., 2008; Taslima and Mollah, 2012), and now the task at hand for the fisheries scientists is to improve the captive culture system of this species. However, the successful domestication of this endangered fish species could only be achieved by suitable rearing in an aquaculture system. Therefore, precise knowledge of the feeding biology and food preferences is essential to the development of viable and appropriate artificial feed for this species. To date, comprehensive research on the feeding habits of *R. rita* lacks in the Padma River, Bangladesh. Considering the grander importance and imminent threats of extinction, this study was planned to investigate the in-depth food and feeding habits of *R. rita*. We also performed the quantitative stomach content analysis with potential variations based on seasons and fish body size that are linked with feeding variations in *R. rita*.

2. Materials and Methods

2.1. Study area

The present study covers approximately 50 km upstream stretch of Padma River from Godagari (24°27’34.79” N and 88°20’09.54” E) to Charghat (24°16’43.25” N and 88°45’06.75” E) points (Figure 1). This river characterized by the discharge of effluent from vegetable markets and slaughter discharges and from household septic tanks. Inundation of this river due to monsoon flood causes the recruitment of several food items from adjacent wetlands. Therefore, the presence of diversified food items in water makes this ideal river habitat for experimenting on food and feeding habit of *Rita rita*.

2.2. Sample collection

The fish samples were collected from the commercial catch of fishers during summer (February to April 2017), monsoon (July to September 2017), and winter (November 2017 to January 2018) seasons. A total of 225 pieces of *R. rita* were collected during the sampling period, with a sample size of 75 fish individuals in each sampling season. After procurement, the fish samples were stored in a 10% solution of alcohol and transported to the laboratory for further analyses. In the laboratory, morphometric records such as total length (TL), body weight (BW), stomach weight with food and without food contents, horizontal mouth gape (HG), and vertical mouth gape (VG) was measured to the nearest 0.01 unit (cm and g, respectively). Measurement of HG and VG were further used to analyze the mouth area (MA) dimension according to the ellipse model of Erzini et al. (1997). The formula of the MA is as follows (Equation 1).

$$\left(\mathrm{MA} = 0.25\pi\left(\mathrm{VG} \times \mathrm{HG}\right)\right) \tag{1}$$

where: MA is the ellipse area measured in cm^2. Size related variations of food items were analyzed after grouping the collected samples into 5 size categories such as I = 9-14, II = >14-19, III = >19-24, IV = >24-29 and V = >29-34 cm.

After dissecting the stomach, the food contents of each fish were identified by visual and microscopic observations to the lowest possible taxonomic level. The identified food items were then counted and weighed in grams to the nearest 0.001 precision using a digital weighing machine.

2.3. Estimation of food contents

The importance of each food item in the stomach of *R. rita* was assessed by employing the index of relative

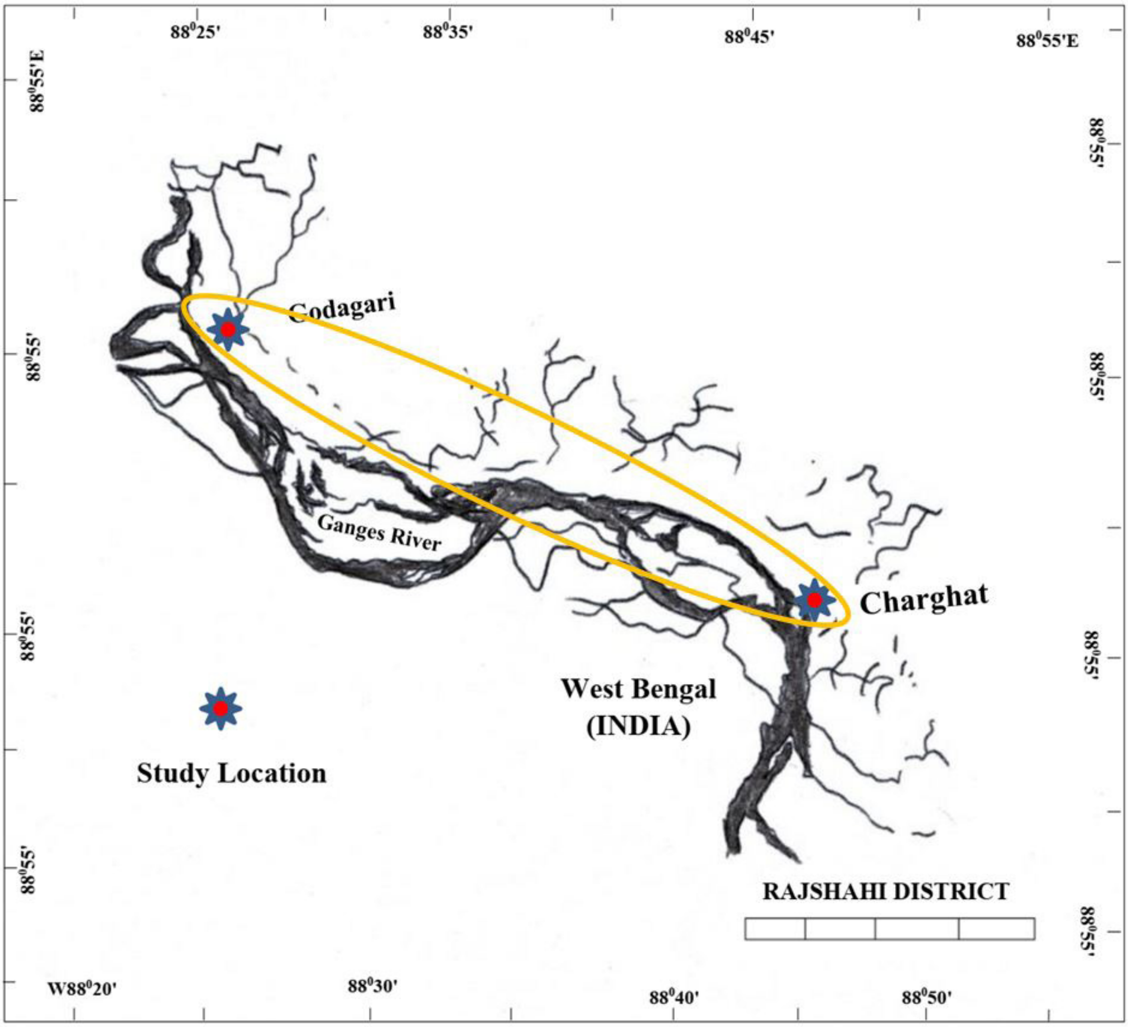

Figure 1. Study area map showing the stretch of Padma River covered during the sampling of *R. rita*.

importance (IRI), which was calculated according to the Formula 2 given by Ugwumba and Ugwumba (2007).

$$IRI\% = (\%N + \%W) * \%FO \tag{2}$$

where: %FO, %N and %W are the frequency of occurrence, numerical composition, and the weight composition of each food item. The feeding activity of each fish individuals was measured by the degree of stomach fullness.

The stomachs were classified as full (100%), three-quarters filled (75%), half-filled (50%), one-quarter filled (25%), and empty (0%) according to Zahorcsak et al. (2000). Season and size-related dietary overlap and niche breadth of *R. rita* were analyzed by Morisita's index of similarity and Levin's standardized niche breadth index (Krebs, 1999a, b) using %FO data of all food items. Morisita's index ranges from 0 (no overlap) to slightly greater than 1 (high overlap), and Levin's index is measured on a scale from 0 (minimum niche breadth) to 1 (maximum niche breadth).

2.4. Seasonal variations and statistical analyses

Seasonal variation in the food items of *R. rita* was assessed by non-metric multidimensional scaling (nMDS). To test significant difference in food items between the seasons, analysis of similarity (ANOSIM) was also performed using the Bray-Curtis similarity matrix. Furthermore, a similarity percentage analysis (SIMPER) was done with the objective of identifying the food items mostly responsible for the formation of seasonal groups. Principal component analysis (PCA) was applied to inspect the primary sources of diet variation among the size groups. The difference in the diet composition of *R. rita* was also compared by cluster analysis (CA) using the Bray-Curtis similarity index.

The length-weight relationship of *R. rita* was estimated using the following Equation 3.

$$BW = aTL^{b} \tag{3}$$

where: BW is the body weight (g), TL is the total length (cm), *a* is the intercept and *b* the slope. The relation between mouth size dimensions and total length was estimated using the following Equations 4, 5 and 6, respectively.

$$(HG,\ VG,\ MA) = a + b(TL) \quad (4)$$

$$HG = a + b(VG) \quad (5)$$

$$(HG,\ VG) = a + b(MA) \quad (6)$$

The coefficient of determination (*r^2*) was used to analyze the interaction between the variables and the significance level of each estimation by one-way analysis of the variance (ANOVA). Finally, the relationship between the food items and the morphometric measures was investigated by canonical correspondence analysis (CCA). All the multivariate analyses were performed by using % FO data after the transformation into corresponding square root data. All the multivariate analyses (nMDS, ANOSIM, SIMPER, PCA, CA and CCA) were done using PAST (v. 3) (Hammert et al., 2001) and univariate (ANOVA) using SPSS (v. 20).

3. Results

3.1. Diet composition and feeding intensity

The examination of stomach contents of 225 individuals of *R. rita* resulted in the identification of 10 major food items, including fish scales, fish eggs, teleost fishes, copepods, cladocerans, rotifers, insects, mollusks, plant materials, and mud and sand particles (Table 1). The index of relative importance (IRI%) based analysis showed a variation among the seasons and size groups of fish. IRI% value of fish scales and teleosts were found higher during the summer season as well as in the fish size group >29-34 cm. However, insects and mollusks displayed the higher IRI% values during summer, and in the size group >24-29 cm. Fish eggs, plant materials, and mud and sand particles were the most contributory food item in fish stomach contents during monsoon season based on the IRI% index. These food items were mostly preferred by the fish size group >29-34 cm, except for mud and sand particles, for which the index value was higher in fish size group >24-29 cm. During the winter season, the IRI% values of copepods, cladocerans, and rotifers were higher compared to other seasons, and these were the primary food items for the fish size groups of 9-14 and >14-19 cm. Overall, rotifers were the essential food item in the diet of *R. rita* in Padma River. The seasonal and size-related variations in the % fullness of fish stomachs were also recorded during the study period and shown in Figure 2. A higher number of fish stomachs were witnessed to be empty (44%) during the monsoon season, while the full bellies showed only 28% during the summer season. Fish with a larger size group (>29-34 cm) was found with the highest percentage of empty (80%) stomach, whereas >19-24 cm size group fish individuals were found with the highest rate of full bellies.

3.2. Seasonal variation in food items

Morisita's index of diet overlap indicated variations in diets among the seasons, with summer and monsoon seasons showing the least food overlap (Morisita's index = 0.66). However, the maximum diet overlap was displayed between monsoon and winter (Moisita's index = 0.74) seasons, while moderate overlap was noticed between summer and winter (Morisita's index = 0.73). The summer season was found to occupy the diverse niche breadth (Levin's index = 0.76) followed by the winter season (Levin's index = 0.60) with the narrowest during monsoon season (Levin's index = 0.58). The analysis using non-metric multidimensional scaling (nMDS) indicated the close association between the food items available during summer and winter seasons. In contrast, the distinction of monsoon samples was evident from the past two sampling seasons (Figure 3). However, there was an overlap between the dietary food items during winter and monsoon seasons.

Table 1. Index of relative importance (IRI%) calculations based on stomach contents (food items) in different seasons and size groups in *R. rita* sampled from Padma River.

Stomach contents	Seasons			Fish size groups					
	Summer	Monsoon	Winter	9-14	>14-19	>19-24	>24-29	>29-34	Overall
Fish scale	2.58	0.00	0.49	0.00	0.81	0.70	1.85	4.27	1.02
Fish eggs	0.00	6.15	0.00	0.10	0.12	0.29	0.77	2.73	2.05
Teleost	6.69	0.01	0.10	0.00	0.18	4.66	4.40	7.56	2.27
Copepods	17.45	23.11	23.82	24.67	23.41	23.59	17.10	20.52	21.46
Cladocerans	22.61	24.57	25.59	25.26	25.46	24.32	24.12	21.85	24.25
Rotifers	25.32	26.86	33.09	30.78	32.63	26.63	26.44	23.18	28.42
Insects	10.86	2.79	4.54	3.82	4.72	6.46	10.13	7.30	6.06
Mollusks	3.37	0.00	0.02	0.00	0.05	1.03	2.76	2.07	1.13
Plant materials	0.00	0.46	0.01	0.00	0.03	0.09	0.03	0.53	0.15
Mud and sand particles	11.16	16.05	12.35	15.36	12.58	12.23	12.39	9.99	13.19

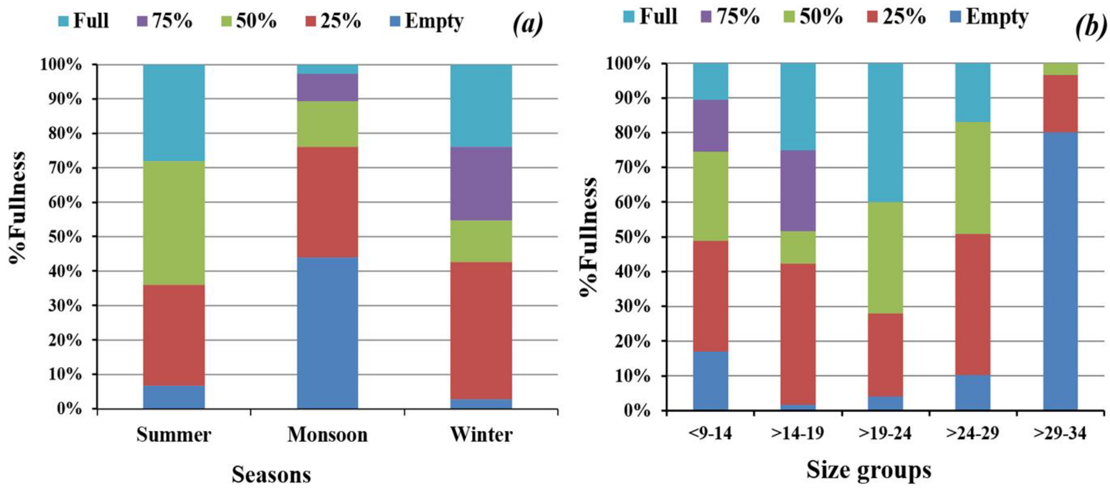

Figure 2. Fullness index of fish stomach in different seasons (a) and size groups (b) of *R. rita* sampled from Padma River.

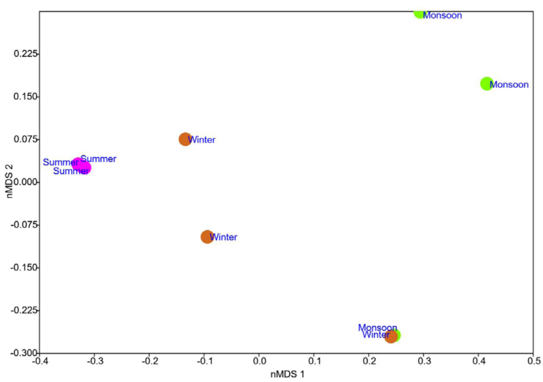

Figure 3. Seasonal variation in frequency of food items assessed by non-metric multidimensional scaling (nMDS) analysis in *R. rita* sampled from Padma River.

A significant difference was also observed among the seasons (ANOSIM, *R = 0.638, P = 0.013*) in terms of food items identified in the stomach of *R. rita*. Furthermore, the SIMPER analysis revealed 80.57% contribution of teleost (18.13%), fish scale (18.06%), mollusks (17.66%), fish eggs (14.80%) and plant materials (11.93%) informing the seasonal variation of the food items in *R. rita* studied in Padma River. The dissimilarity between summer and monsoon season was 30.02%, with fish scales (19.71%) being the most prevalent food item making this difference. With the highest contribution of 27.84%, mollusks created the dissimilarity of 17.08% between summer and winter food groups. Fish eggs, which were most abundant during the monsoon season, were noted to contribute (26.07%) most in the dissimilarity (19.33%) between monsoon and winter season's food items.

3.3. Variations in the diet with fish size groups

The broad-spectrum diet overlap was observed between the size class IV and V (Morisita's index = 1.20), and the narrowest between I and IV (Morisita's index = 0.15). The size group III also showed higher dietary overlap between size groups IV and V (Morisita's index = 1.16 and 1.00 for III-IV and III-V, respectively). Fish with larger size groups preferred to have nearly similar food items that increased their diet overlap value. On the contrary, smaller body size, together with little mouth gaps, made the smaller size groups compatible with the only food items that were easy to capture, such as zooplankton and insects, which decreased dietary overlap between size classes I and IV. This overlap in food items between the more substantial size fish groups increased the niche breadth of these size groups. Therefore, Levin's niche breadth index was arranged in the order of 0.88>0.81>0.78>0.63>0.43 for the size classes V, IV, III, II and I, respectively. Principle component analysis (PCA) explained 95.39% of the total variance among the stomach contents and fish size groups with principal component (PC) 1 variance equal to 87.84%, while PC 2 variance as 7.55%. The PCA manifested a close association among the more substantial size group of fish (III, IV, and V), which was mostly influenced by the abundance of food items such as fish scales, fish eggs, teleost, mollusks, and plant materials. On the other hand, smaller size groups (I and II) were found to show a higher correlation with the food items that were suitable for their ease of capturing such as Rotifera, Cladocera, and Copepoda (Figure 4). The hierarchical clustering of size groups based on the percentage frequency of each food item created three distinct clusters at the similarity level of 90%. Clusters A and C individually represented the size groups I and II, respectively. In contrast, cluster B was a cumulative group of size classes III, IV, and V (Figure 5) that justified the output of PCA analysis.

3.4. Morphometric relation with food items

Measurements of different morphometric characters of *R. rita* collected from the Padma River are shown in Table 2. Total length (TL) and body weight (BW) of the investigated fish varied between 9-34 cm and 10-400 g with mean values of 20.53 ± 6.90 cm and 125.94 ± 102.07 g, respectively. *R. rita*

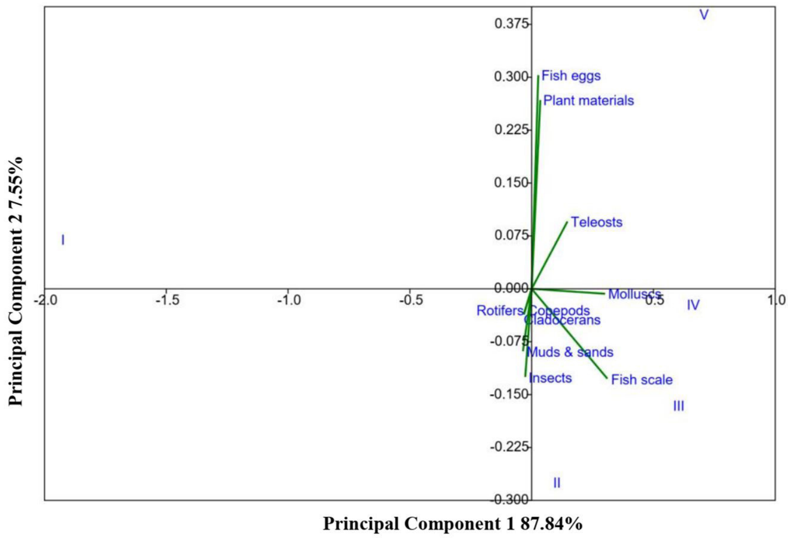

Figure 4. Principle component analysis (PCA) on fish size groups and food items in *R. rita* sampled from Padma River (Roman numbers indicated the different size group of fish, such as I = 9-14 cm, II = >14-19 cm, III = >19-24 cm, IV = >24-29 cm and V = >29-34 cm).

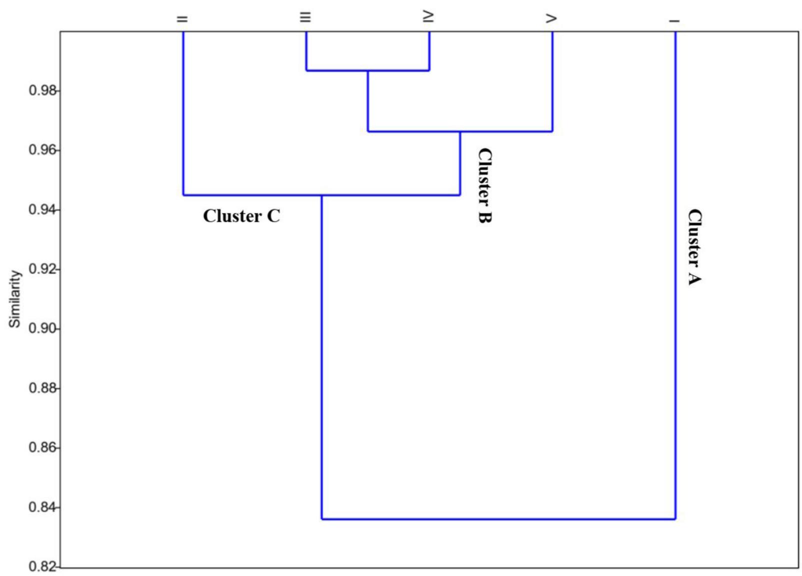

Figure 5. Links between the fish size groups based on cluster analysis in *R. rita* sampled from Padma River (Roman numbers indicated the different size group of fish, such as I = 9-14 cm, II = >14-19 cm, III = >19-24 cm, IV = >24-29 cm and V = >29-34 cm).

Table 2. Descriptive statistics of body morphometric and mouth dimensions in *Rita rita* from Padma river.

Variables	Minimum	Maximum	Mean ± SD
TL	9.00	34.00	20.53 ± 6.90
BW	10.00	400.00	125.94 ± 102.07
HG	1.00	1.60	1.21 ± 0.11
VG	1.00	4.00	2.67 ± 0.76
MA	1.00	4.46	2.59 ± 0.90

SD = Standard deviation; TL = Total length; BW = Body weight; HG = horizontal mouth gape; VG = vertical mouth gape; MA = mouth area.

displayed a horizontal mouth gape (HG) of 1.21 ± 0.11 cm and vertical mouth gape (VG) of 2.67 ± 0.76 cm. Mouth area (MA), which was calculated from HG and VG, varied from 1.00 - 4.46 cm and the mean value was 2.59 ± 0.90 cm. Table 3 shows the relation between body morphometric and mouth dimensions of *R. rita*. All the relationships were highly significant (ANOVA, P<0.01) with r^2 value higher than 0.80 except for the relations of HG vs. TL, HG vs. VG, and HG vs. MA. Canonical correspondence analysis (CCA) demonstrated the relationship between the morphometric measurements and food items (Figure 6). In contrast, the first two axes of CCA explained 99.10% total data variability

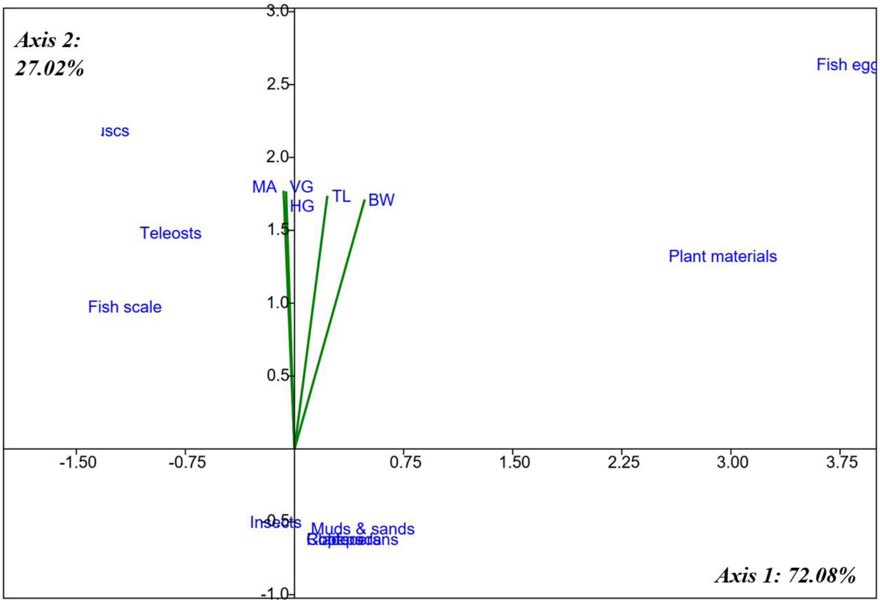

Figure 6. Canonical correspondence analysis of food items and morphometric measures of *R. rita* sampled from Padma river (TL = Total length; BW = Body weight; HG = horizontal mouth gape; VG = vertical mouth gape; MA = mouth area)

Table 3. Relationship between body morphometric and mouth dimensions of *R. rita* from Padma river.

Equations	Regression parameters						
	a	95% CL of a	SE (a)	b	95% CL of b	SE (b)	r^2
BW = a×^{b}	0.047	0.038-0.058	0.015	2.540	2.470-2.609	0.035	0.959
HG = a+L	0.391	0.326-0.456	0.033	0.196	0.174-0.218	0.011	0.585
VG = a+L	1.438	1.291-1.585	0.075	0.801	0.752-0.851	0.025	0.822
MA = a+L	-070	–(226) –-(114)	0.079	0.997	0.945-1.050	0.027	0.864
HG = a+G	0.007	0.609- –(021)	0.014	0.195	0.017-0.223	0.014	0.452
HG = a+A	0.022	0.004-0.041	0.009	0.189	0.170-0.208	0.010	0.628
VG = a+A	0.219	0.201-0.238	0.009	0.811	0.792-0.830	0.010	0.969

BW = Body weight; HG = horizontal mouth gape; VG = vertical mouth gape; MA = mouth area; *a* is the intercept the slope; SE the standard error of mean; and CL is the confidence interval.

with the eigenvalues of 72.08 and 27.02% for axis 1 and 2, respectively. However, the permutation test was significant for axis 2 (P = 0.016). According to CCA analysis, the relation of food items such as fish scales, fish eggs, teleost, mollusks, and plant materials with the morphometric characters was highly positive, whereas copepods, cladocerans, rotifers, and insects were negatively influenced by the increased morphometric measures of *R. rita*.

4. Discussion

During the study period, the importance of food items of *R. rita* in Padma River was expressed with IRI%. As IRI% depends on the percentage of numerical, weighted, and the frequency of occurrence value, it is more trustworthy and applicable for revealing trends of data related to food items in the diet (Behzadi et al., 2018). We identified ten types of food items in the stomach of *R. rita,* and the present findings are similar to the results of Alam et al. (2016) in Ganges River and Mushahida-Al-Noor et al. (2013) in Padma River. Iqbal and Waseem (2008) also studied that the gut content of *R. rita,* which constituted of four food items identified as crustaceans, mollusks, shells, fish scales, and rotten vegetation/debris. Overall, the present study demonstrated that crustaceans (Copepods, Cladocerans, Rotifers, and insects) were the essential food items for *R. rita* in Padma River. Among the crustaceans, rotifers constituted a significant proportion according to the value of IRI% index. Similar observations were made by Mushahida-Al-Noor et al. (2013), where they reported the dominance of crustaceans in the food items of *R. rita* from the same river. Apart from crustaceans, teleost, fish scales, and mollusks were the abundant food items of *R. rita* during the study period. Although quantitative variation in the IRI% index of food items was observed, qualitative similarities among them justified the opportunistic feeding activity by *R. rita* in the Padma River. However, seasonal and size-related variations in food item's importance were observed during the study period, which was due to the environmental conditions and maturity stage of fish (Oribhabor and Ogbeibu, 2012; Yazicioglu et al., 2018).

IRI% index values of teleost, fish scales and mollusks were higher during the summer season compared to monsoon and winter seasons. Moreover, the higher percentage of the full stomach was recorded during the summer season that indicated the higher abundance of food items available in the environment. Similar observations were also made by Jewel et al. (2019), where they reported the richness of food items during the summer season in Padma River. During monsoon season, the number of food items in the water became scarce due to the higher volume of water that diluted the concentrations of available food items (Atique and An, 2019; Atique et al., 2020b; Haque et al., 2020). Monsoon season was also the breading season of *R. rita* (Rahman and Mollah, 2014) in Padma river. Therefore, the number of fish with an empty stomach increased in this season. The effect of gonadal maturation in stomach fullness was also reported by Abbas (2010) in freshwater catfish *Eutropiichthys vacha*. However, the stomach content of fish during monsoon season was mostly occupied by fish eggs, and again the more abundant fish contributed most to consume this food item due to their higher abundance in the river. Monsoon also caused the flooding of the dried area of the river, where the farmers generally grow their crops during the dry season. Therefore, intentional or unintentional intake of plant materials made a significant contribution to the food items in *R. rita* during the monsoon season. Flooding also caused an increased amount of mud and sand particles in the stomach of fish during the study period (Abera, 2007; Worie and Getahun, 2015; Admassu et al., 2015). Winter was the season with moderate food items in the fish stomach; the contribution of crustaceans was higher than the other two seasons. Abundant food items in water reduced the number of fish with an empty stomach and increased different fullness index categories of fish. Abundant and poor food items in the environment of Padma River during summer and monsoon seasons respectively caused the least dietary overlap (Morisita's index = 0.66) between these seasons. Moreover, diverse niche breadth (Levin's index = 0.76) was also observed during the summer season and the narrowest during monsoon season (Levin's index = 0.58). During the study period, the variation of food items in the stomach was significant among the seasons, and teleost (18.13%), fish scale (18.06%), mollusks (17.66%), fish eggs (14.80%) and plant materials (11.93%) were the most contributory food items causing this variation.

The tendency to consume the crustaceans in all size groups of *R. rita* was higher. However, IRI% was found to decrease with an increasing body size of fish. Preference of crustaceans by smaller fish groups was also reported by Tesfahun (2018) in African catfish (*Clarias gariepinus*), and by Haubrock et al. (2018) in channel catfish (*Ictalurus punctatus*). Moreover, the IRI% index values of food items such as fish scales, teleost, and mollusks were found to increase with an increasing fish size that might be due to their stronger and bigger jaws helping them to crush the larger food items. On the other hand, absence or little amount of these food items in the smaller fish groups proved their inability to include them in their diet (Mushahida-Al-Noor et al., 2013) that could be linked with smaller mouth size. Therefore, dietary differences are indeed potentially linked to gape-limited predation (Johnson et al., 2008). In general, the contribution of only animal origin food items was significant in smaller size group fish. In contrast, the contribution of all sorts of food items, including plant materials, increased with the size of fish. This proved an ontogenetic dietary shift from narrow to a broader range of food items and also shifts in the feeding habit from carnivorous to omnivorous feeding nature (Alam et al., 2016). As evident from the present study, diet overlap was the narrowest between I and IV (Morisita's index = 0.15) size groups of fish due to their dissimilarity in the preference for food items. On the other hand, fish with larger size groups preferred to have nearly similar food items that increased their diet overlap value and niche breadth diversity (0.88). Principle component analysis (PCA) and cluster analysis (CA) also showed a close association among the larger size group of fish (III, IV, and V), whereas PCA provided distribution of food items with their importance indicated by variables length and CA demonstrated the grouping of food items in different size groups of fish. During the study period, the percentage of fish with an empty stomach was higher (80%) in the larger size group (>29-34 cm) of fish indicated reduced feeding intensity during the peak spawning period. This phenomenon was also described by Usman et al. (2018) in *Plotosus canius* and Khan et al. (2011) in *Mysteus nemurus*.

During the study period, BW of *R. rita* sampled was within the range of 10-400 g that was quite diverse than the findings reported by Alam et al. (2016). Therefore, the inclusion of quite smaller and larger sized fish provided more precision in the present study. The growth rate of VG was higher compared to HG of *R. rita* that indicated its adaptation for different food and feeding guilds (Koundal et al., 2016). Greater VG compared with HG was also indicative of the column-omnivore/carnivore feeding habit of *R. rita* that is similar to the findings of Koundal et al. (2016) in *Mastacembelus armatus*. Analysis of regression between total length and body weight implied a high allometric coefficient, which demonstrated a faster weight gain than length. Changes in body structure could also have an impact on the feeding habit of fish. Mouth morphometric dimensions (HG, VG and MA) were found to have a significant correlation with explained variances higher than 50%, except for the regression between HG *vs* VG. As there are no previous studies on the relation between the different mouth size dimensions for the studied species, sufficient comparison could not be made. However, studies conducted by Nilsson and Brönmark (2000) and Magnhagen and Heibo (2001) showed that the relation between mouth dimensions and body length was linear and increased with the total BW in pike *(Esox lucius)* fish samples. Moreover, CCA analysis in the present study described a profoundly positive influence of mouth dimensions on fish scales, fish eggs, teleost, mollusks, and plant materials, while negative with the food items such as copepods, cladocerans, rotifer, and insects.

5. Conclusion

This study presented the food and feeding preferences of *R. rita* during various seasons and fish size groups in Padma River, Bangladesh. The *R. rita* showed variations in feeding intensity both at seasonal and ontogenetic scales. Environmental food abundance was found to shape the feeding habit of this fish species in Padma River. The fish also showed a typical carnivore nature during the early stages of life, and that was shifted to an omnivorous feeding type with increasing body size. Crustaceans constituted the major food items in the smaller size groups and were accompanied by fish scales, teleost, mollusks, and plant materials in the larger size group of fish. The present findings on the feeding activity pattern of *R. rita* could contribute to the existing knowledge on sustainable management of this potentially exploited endangered fish species. Additionally, the results of this study could contribute to the development of appropriate feed formulation techniques in aquaculture of this species.

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