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Food spectrum dynamics of anadromous Hilsa, *Tenualosa ilisha* (Hamilton, 1822) inhabiting River Brahmaputra, India curtailing apprehension of food selectivity: An insight into its domestication

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Food and feeding habits of *Tenualosa ilisha* collected from two sampling locations in Brahmaputra River, Assam, India for a period of 12 months from May 2018 to April 2019 were studied. Index of preponderance revealed semi-digested animal matter (25.92 %) as the most dominant food item followed by Bacillariophyta (23.32 %). 31 genera of phytoplankton and 15 genera of zooplankton were observed in the gut of the species. Major groups of zooplankton include cladocerans, copepods, followed by rotifers, while diatoms, green algae and blue green algae were dominant phytoplankton groups. The anadromous tropical shad is planktivorous by nature and has a preference for zooplankton in smaller size groups (< 250 mm) and phytoplankton in larger size groups (> 250 mm). GaSI values (mean±SE) ranged from 1.50±0.14 to 6.93±0.89 and HSI values from 0.58±0.06 to 1.54±0.15. Index of fullness was found to range from 7.08±0.42 to 1.81±0.40. Feeding intensity, GaSI, HSI values showed seasonal variation, found to be low during October to December and high during February to June. Size group-wise analysis of feeding intensity showed high feeding intensity in lower size groups (< 250 mm) and comparatively low feeding intensity and high percentage of empty stomachs in higher size groups (> 250 mm). RLG values ranged from 1.181±0.028 to 1.450±0.052. Monthly average RLG values were found to be highest during November and in the size group of 351 – 400 mm. Changes in food composition were noticed in both months and as well as size groups.

[**Keywords**: Brahmaputra River, Food and feeding habits, Planktivorous, *Tenualosa ilisha*]

Introduction

Feeding ecology was widely investigated in different marine and freshwater fish species globally in order to determine the divergence and overlaps exhibited by groups that coexisted in a habitat or a single fish species occupying different ecosystems[1]. Relevant information on feeding ecology of fishes can be useful in understanding prey-predator relationships, trophic status of fishes and their role in the ecosystem[2] as well as understanding their distribution pattern influenced by availability of preferred food items[3].

Food stuff observed in the gut may vary with fish species, individual size, abundance and type of food present in the ecosystem, environmental factors, season and time of the day[4]. Studies on food and feeding habits is an obligatory aspect in fishes, which exhibits a disparate feeding mode and occupies diverse ecosystems[5] besides being of importance in understanding their biology[6]. Changes in food and feeding habits may also have a significant impact on general health of fishes. Thus, a sound understanding of relationship existing between fishes and their preferred food items is an essential criterion towards proper fisheries management[7].

Feeding intensity in fishes vary according to stage of maturity, season and abundance of food in the environment[4]. Gastro-Somatic Index (GaSI) is an indicator of feeding intensity in fishes on a temporal scale and its values vary seasonally and with maturity stage. It is usually found to be low during the spawning season due to cessation of feeding and is high during post-spawning period[8]. Hepato-Somatic Index (HSI) is also an important tool which indicates energy storage in fish and along with index of fullness of gut acts as reliable indicators of feeding activity and feeding intensity of any fish species[9,10].

Length of gut in relation to total length of the fish in consideration has been widely used to group fishes into different feeding categories such as herbivores, omnivores, and carnivores[11]. In general, relative gut length is higher in herbivores as compared to omnivores followed by carnivores[12].

The migratory shad Hilsa, *Tenualosa ilisha* is reported to have a wide geographical distribution range right from waters of Persian Gulf to Laos. The species is anadromous by nature and migrates from sea to rivers for breeding. Economic value of Hilsa fishery is over US $ 2 billion. It forms a major fishery in Ganga-Brahmaputra-Meghna river basin and is of significant cultural and economic importance for the people of India, Bangladesh and Myanmar[13-15]. Globally, highest catches of Hilsa is reported from Ganga-Brahmaputra-Meghna deltaic region of India and Bangladesh. Total catch of Hilsa stands at about 0.72 million tonnes per annum in recent times with Bangladesh contributing 50 – 60 % of the total global catch followed by Myanmar (20 – 25 %) and India (15 – 20 %) with other nations like Iraq, Kuwait, Malaysia, Pakistan and Thailand contributing around 5 – 10 %[(ref. 16)]. This high valued fish species formed a lucrative fishery in coastal belt, estuarine zones and in major river systems of India, like Ganga, Brahmaputra, Narmada, Tapti and Godavari in the past as reported by Hora & Nair[17]. Hooghly, Brahmaputra and Ganga rivers along with their tributaries contribute a significant portion to the tune of around 70 % of Hilsa catch in India[13,14].

Brahmaputra is one of the major rivers draining north-eastern region of India[18,19]. Hilsa formed a major commercial fishery in lower stretches of the River Brahmaputra in Assam[20]. However, a series of factors like pollution, over exploitation etc., has resulted in drastic decline in catch of this highly prized species from the Indian part of River Brahmaputra. Average catch of Hilsa from Brahmaputra River, Assam during 1973 – 1979 was 22.1 kg day^{-1} which declined to 2.9 kg day^{-1} during 1996 – 1998. This period witnessed an overall decline of fish catch from the river by 81 %, with the percentage contribution of Hilsa shad to total catch fell from 11.2 % to 2.1 %[(ref. 21)].

Planktonic feeding behaviour of Hilsa was confirmed by various authors[22-23]. A possible deviation in feeding habit of this shad species was also evident at different size groups as facilitated by change in habitat[24]. Being a long-distance migratory species, the species come from different habitats during the course of its lifetime, which may result in variation in its food and feeding habits[23].

Food and feeding biology of Hilsa is an extensively studied topic from a wide range of ecosystems in India and abroad[23,25]. A few selected studies on length-weight relationship, otolith, reproductive biology and morphological variations in Hilsa are reported from the Brahmaputra river system[13,14,26,27]. However, no reports on the food and feeding habits of this highly prized migratory fish species are available from the Indian part of River Brahmaputra. Due emphasis are also being laid in Indian sub-continent for culturing this highly prized species in captive conditions. Understanding its food spectrum dynamics across time and life stages as provided in the present study can be crucial in formulating feeding strategies for successful rearing. Thus the present study was carried out to meet this research gap.

Materials and Methods

A total of 275 fresh (dead) individuals (male = 147; female = 128) of *T. ilisha* were randomly collected from Sri Ram Ghat landing centre, Dhubri and Uzanbazar landing centre, Guwahati of River Brahmaputra in Assam during May, 2018 to April, 2019 (Fig. 1). The size of the specimen varied from 146 to 403 mm in total length and 26.75 to 762.00 g in total weight. Sampling was done at regular monthly intervals. The mesh size of drift gill nets used by fishers to catch Hilsa was measured to range from 20 to 80 mm.

Fresh fishes preserved in ice were brought to the laboratory, washed, cleaned and wiped properly before further analysis. Total length and total weight of the collected specimens were measured using a measuring scale and analytical balance with an accuracy of 0.1 cm and 0.01 g, respectively. During dissection, ventral side of belly region of the specimens were split open to determine the sex and maturity stages. Subsequently, alimentary canal right from oesophagus to anus was taken out. The body of the fish was then preserved in 10 % neutral buffered

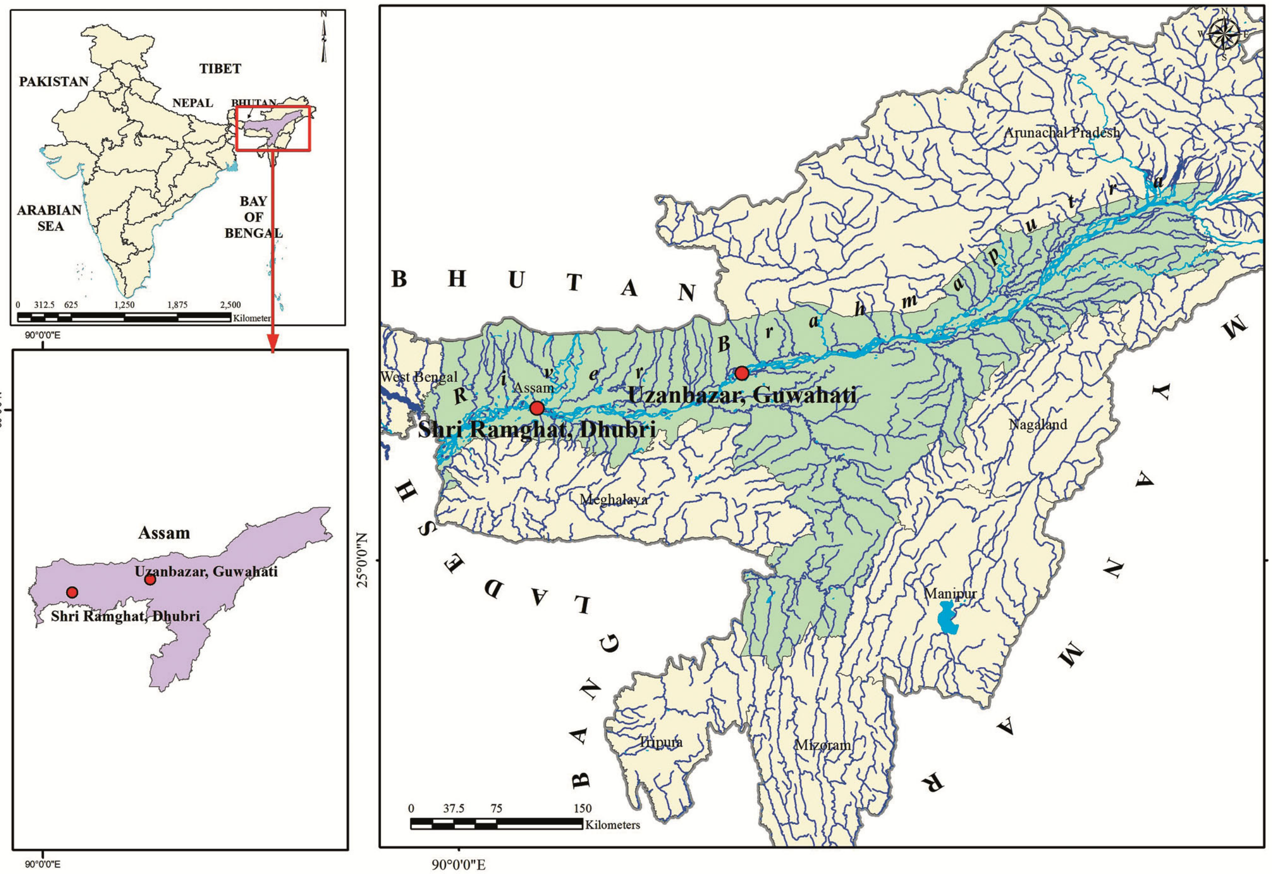

Fig. 1 — Sampling stations in River Brahmaputra, Assam (ArcGIS Desktop: Release 9.3.)

formalin. After measuring the gut length and weight, gut contents were taken out from alimentary canal, dissolved in water and observed under a trinocular microscope (Axioster Plus, Carl-Zeiss) with the help of a Sedgwick-rafter counting cell for both qualitative and quantitative analysis. Plankton present in gut was identified till genus level following standard literature[28]. Other items like semi-digested matter, sand particles, etc., present in gut were identified by visual inspection.

Gastro-Somatic Index (GaSI) was calculated following Desai[30]:

$$Gastro - somatic\ index\ (GaSI) = \frac{Weight\ of\ the\ stomach}{Total\ weight\ of\ the\ fish} \times 100$$

Index of fullness or the degree of satiation was measured on a scale of 1 – 10. For stomach containing traces of food a score of 0.5 is given and for stomach fully filled with food a score of 10 is given. The results were then averaged month-wise and length group-wise to determine the mean index of fullness following Robotham[31].

Index of preponderance (IP) is a combination of occurrence and volume of food items. It was estimated following Natarajan & Jhingran[32]:

$$IP = \left(\frac{Vi * Oi}{\sum Vi * Oi}\right) \times 100$$

Where, Vi and Oi are percentage volume and percentage occurrence of a particular food item 'i' respectively.

Index of Relative Importance (IRI) helps in determining the most important food item found in gut of fish[33]. It was calculated using the following formula:

$$IRI = (\%Ni + \%Vi) \times \%Oi$$

Where, Vi is the volume of food item 'i', Oi is the frequency of occurrence of food item 'i' and Ni is the total number of food items.

Data generated duirng the study was tabulated and food items were ranked based on the scores obtained.

Length of gut was measured with a scale of 0.1 cm accuracy. Relative Gut length (RLG) was calculated by taking the ratio of gut length against total body length of the fish following Al-Hussainy[34]:

$$Relative\ gut\ length = \frac{Length\ of\ the\ gut}{Total\ length\ of\ the\ fish}$$

Weight of liver was measured using an analytical balance with an accuracy of 0.01 g and Hepato-Somatic Index (HSI) was estimated following Sulistyo *et al.*[35]:

$$HSI = \frac{Weight\ of\ liver\ (g)}{Weight\ of\ the\ fish\ (g)} \times 100$$

Results

Diet composition

Month-wise percentage composition of different food items observed in gut of *T. ilisha* (Fig. 2) shows that semi-digested animal matter was the most dominant food item observed in gut of *T. ilisha* during majority of the months *viz.* July (48.49 %), May (47.55 %), March (45.52 %), August (43.64 %) and June (37.71 %), while semi-digested plant matter was dominant during November (42.55 %), October (35.96 %), and December (31.17 %). Analysis showed that phytoplankton dominated during January (60 %), September (52.51 %), February (48.14 %) and October (35.96 %), while zooplankton dominated during April (58.44 %). Sand particles were the least dominant item observed in gut across all the months.

Length-group wise analysis of food composition in gut of *T. ilisha* showed that zooplankton is the preferred food item in lower size groups from 101 – 250 mm, while in size groups > 250 mm phytoplankton is the dominant food item. Highest share of zooplankton was observed in 101 – 150 mm (44.23 %) and lowest was observed in 301 – 350 mm (7.57 %) size group. Percentage contribution of phytoplankton was highest in 301 – 350 mm (49.36 %) and lowest in 101 – 150 mm (11.56 %) size group (Fig. 2).

Among different groups of phytoplankton, Bacillariophyta was the most dominant group with maximum share during January (91.02 %). Highest share of Chlorophytes and Cyanophytes were observed during September with contribution of 59.58 and 40.42 %, respectively (Fig. 3). Among zooplankton, Cladocera was the most dominant group and showed highest abundance in April (77.43 %) followed by January (48.77 %), November (38.46 %) and December (35.05 %). Copepods were dominant in May (58.12 %), March (41.48 %), August (40.55 %) and September (36.33 %), Rotifers during October (42.88 %) and February (39.14 %); while Crustacean nauplius was dominant during the months of June

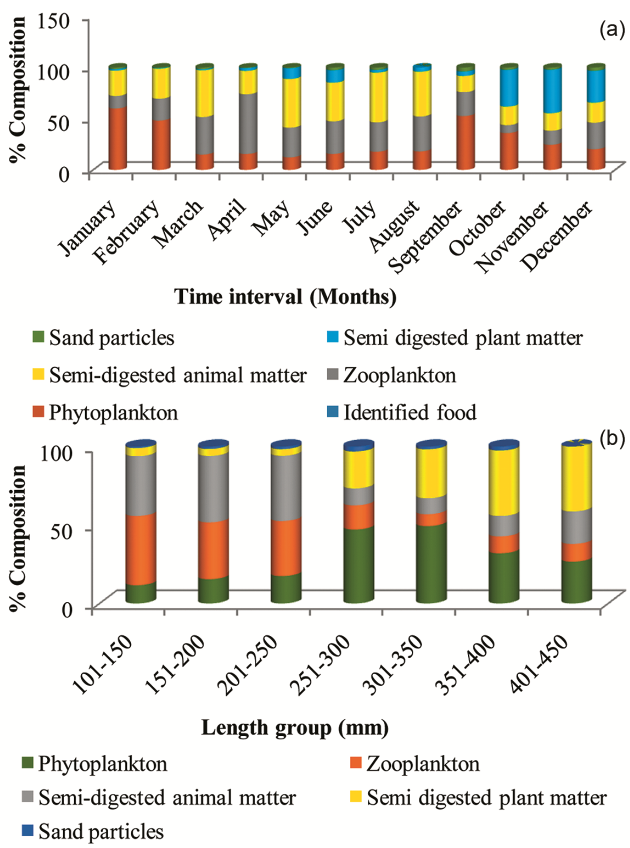

Fig. 2 — Percentage composition of different groups of food items observed in gut of *Tenualosa ilisha*: a) Monthly variation and b) Length-wise variation

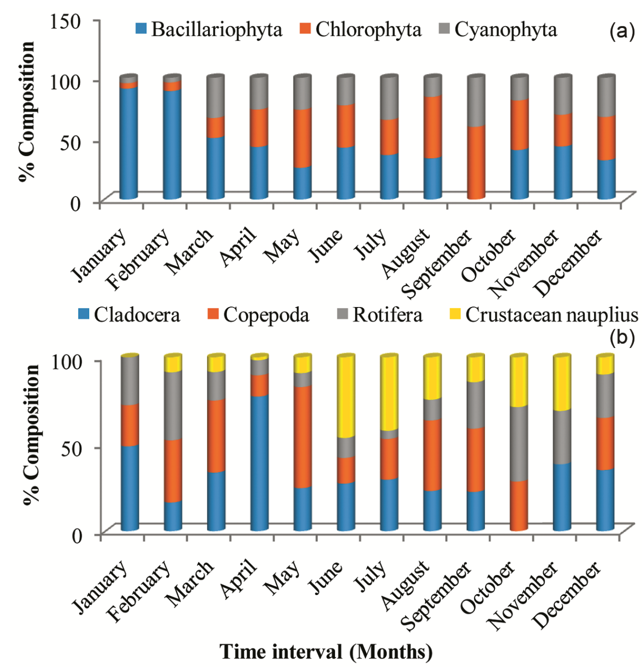

Fig. 3 — Percentage composition of different food items/ groups observed in gut of *Tenualosa ilisha*: a) Phytoplankton and b) Zooplankton

(46.32 %) and July (42.23 %), details of which are given in Figure 3.

With regard to diversity of food items in gut, a total of 31 genera of phytoplankton, which includes 13 genera under Class Bacillariophyta; 11 genera under Chlorophyta; and 7 genera under Cyanophyta were recorded in gut of *T. ilisha*. 15 genera of zooplankton, which includes 6 genera under Sub-class Copepoda; 5 genera under Cladocera; and 4 genera under Rotifera were observed in gut of the species (Table 1). Among planktonic groups Cladophora (4.01 %), Bosmina (3.25 %), Pseudodiaptomus (3.11 %), Melosira (2.39 %), Daphnia (2.35 %), and Oscillatoria (2.11 %) were dominant in gut of the species.

Index of preponderance

Month-wise index of preponderance (Fig. 4) revealed that semi-digested animal matter were dominant in the gut of *T. ilisha* during March and from May to August. Semi-digested plant matter was dominant during November to December. Cladocera was dominant during April (52.39 %); Bacillariophyta was dominant during January (67.90 %), February (59.96 %) and October (32.38 %); and Cyanophyta was dominant during September (34.66 %).

Overall values of index of preponderance revealed dominance of semi-digested animal matter (25.92 %) in gut of *T. ilisha* followed by Bacillariophyta (23.32 %) and Cladocera (12.30 %). Crustacean nauplius (2.65 %) and sand particles (0.48 %) were the least dominant food items observed in gut of the species. Details of index of preponderance of different groups of food items observed in gut of *T. ilisha* are given in Table 2.

Index of Relative Importance (IRI)

Month-wise %IRI of different groups of food items observed in gut of *T. ilisha* (Fig. 4) revealed that Bacillariophyta was the most prevalent food item round the year except during the months of April, May and September. Cladocera (34.38 %) was the most dominant food item in the month of April, Copepoda (27.90 %) during May and Chlorophyta (45.07 %) during the month of September (Fig. 4). Comparatively, low percentage of Rotifera, Crustacean nauplius and sand particles was observed in gut of *T. ilisha* almost throughout the year.

Overall %IRI of different groups of food items observed in gut of *T. ilisha* is given in Table 3. It is seen that Bacillariophyta (26.62 %) followed by semi-digested animal matter (18.34 %), Chlorophyta (13.22 %), Cyanophyta (11.74 %), Cladocera (9.76 %), and Copepoda (6.27 %) were the most prevalent food items in gut of the species, while Rotifera, Crustacean nauplius and sand particles were the least prevalent items.

Gastro-Somatic Index (GaSI)

GaSI values (mean±SE) ranged from 1.50±0.14 to 6.93±0.89 for both the sexes together. In case of male and female, maximum GaSI value (mean±SE) was recorded in April (7.25±1.16 and 6.12±1.54, respectively). Minimum GaSI value was observed in September for male (1.51±0.20) and for female in October (1.25±0.13; Fig. 4).

Hepato-Somatic Index (HSI)

Monthly mean±SE values of HSI of *T. ilisha* are shown in Figure 4. Low mean HSI values of 0.58±0.06 (both sexes), 0.76±0.05 (male), and 0.35±0.07 (female) was observed during November. High HSI values in both sexes combined (1.54±0.15) and in males (1.69±0.17) was observed during June, while in females high HSI value of 1.53±0.18 was observed in May. Overall, higher HSI values were observed in the species from April to July.

Index of fullness

Monthly average index of fullness value was found highest during March (7.08±0.42) and lowest during December (1.81±0.40) and October (1.89±0.28) for both the sexes combined. In case of males mean index of fullness values were found to range from 0.79±0.28 (December) to 7.50±0.16 (April), while in females it ranged from 2.45±0.56 (December) to

Table 1 — Planktonic groups observed in the gut of *Tenualosa ilisha*

Phytoplankton	Genera	Zooplankton	Genera
Bacillariophyta	*Melosira*, *Odontella*, *Navicula*, *Synedra*, *Fragillaria*, *Stenopterobia*, *Gyrosigma*, *Nitzschia*, *Gomphonema*, *Surirella*, *Pinnularia*, *Cyclotella*, *Ditylum*	Copepoda	*Pseudodiaptomus*, *Paracalanous*, *Acartia*, *Mesocyclops*, *Eucyclops*, *Oithona*
Chlorophyta	*Spirogyra*, *Mougeotia*, *Pediastrum*, *Eudorina*, *Gloeocystis*, *Chlorella*, *Monoraphidium*, *Scenedesmus*, *Cladophora*, *Closterium*, *Oocystis*	Cladocera	*Daphnia*, *Ceriodaphnia*, *Bosmina*, *Chydorus*, *Alonella*
Cyanophyta	*Anabaena*, *Oscillatoria*, *Lyngbya*, *Microchaete*, *Chrococcus*, *Aphanocapsa*, *Coelosphaerium*	Rotifera	*Brachionus*, *Lecane*, *Keratella*, *Polyathra*

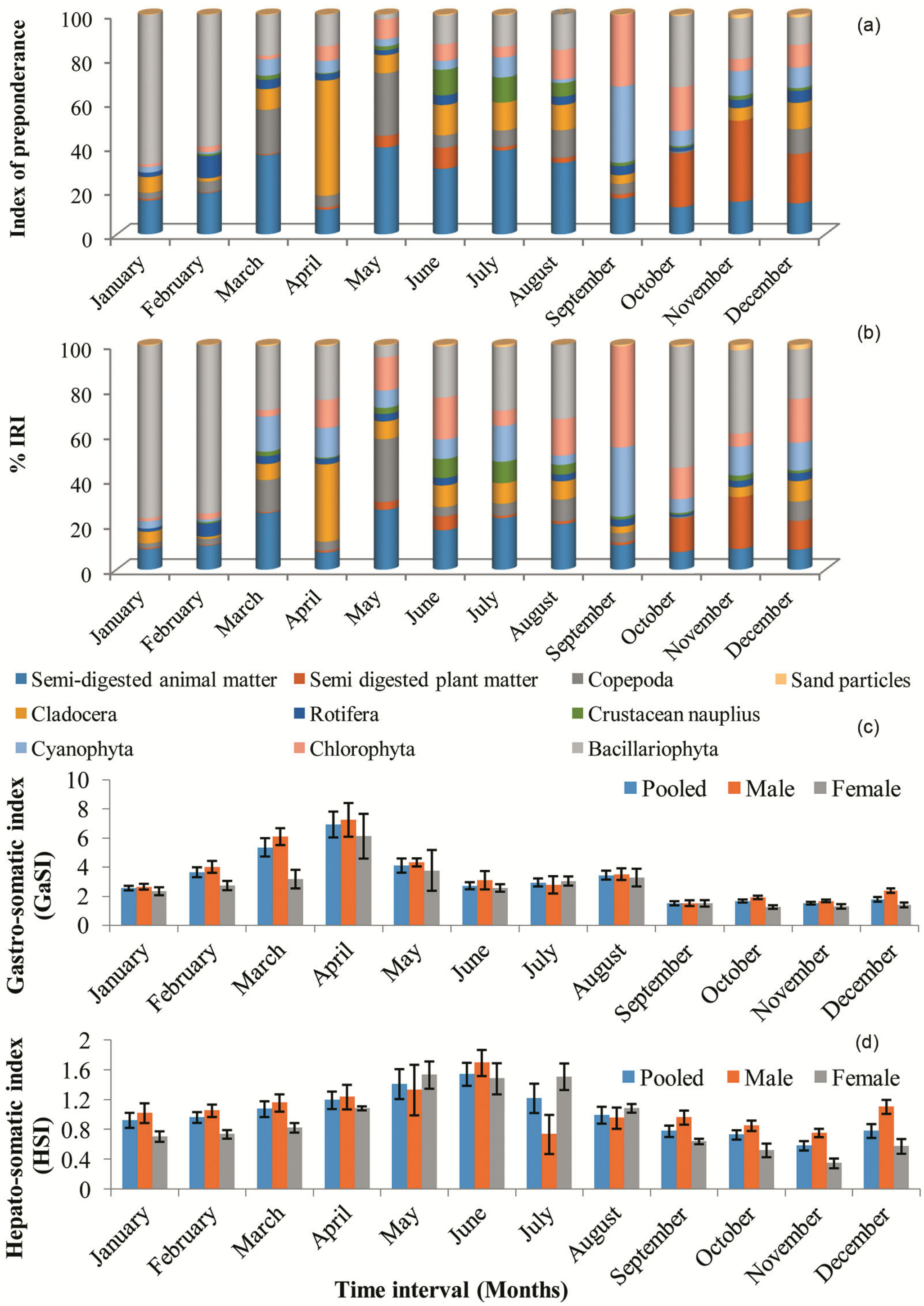

Fig. 4 — Monthly variation in a) GaSI; b) Index of preponderance; c) IRI and d) HSI of *Tenualosa ilisha*

7.50±0.29 (March; Fig. 5). In case of size groups, mean±SE values of index of fullness was found to range from 1.75±0.34 (251 – 300 mm) to 6.06±0.40 (201 – 250 mm) for both the sexes. In case of males lower values were observed in the higher length groups of 251 – 300 mm (1.44±0.53) and 301 – 350 mm (1.44±0.32), while higher values were observed in 201 – 250 mm (6.88±0.45) and 101 – 150 mm (5.75±1.75) size groups indicating low and high feeding intensity, respectively. Mean values of index of fullness in females was found to range from 1.96±0.46 (251 – 300 mm) to 5.25±0.59 (201 – 250 mm; Fig. 5).

Relative Length of Gut (RLG)

Month-wise and size group-wise monthly mean±SE values of relative RLG are depicted in Figure 6. Lowest RLG values of 1.181±0.028 (both sexes), 1.180±0.050 (male), and 1.183±0.005 (female) was observed during May, while highest mean RLG values of 1.450±0.052 (both sexes), 1.449±0.054 (male) and 1.452±0.105 (female) was observed during November. Size group analysis revealed that high mean values of RLG was observed in the size group 351 – 400 mm with values of 1.609±0.154 (both sexes), 1.456±0.263 (male), and 1.712±0.208 (female). Highest RLG value of 1.849 was observed in the size group 401 – 450 mm for which a single female specimen was reported. Low mean RLG values of 1.219±0.048 was observed in males in 101 – 150 mm size group, while in females low mean RLG values (1.271±0.022; 1.273±0.022) was observed in 201 – 250 mm and 151 – 200 mm size groups, respectively. It is to be noted that females were not recorded in 101 – 150 mm size group.

Table 2 — Index of preponderance of different groups food items observed in gut of *Tenualosa ilisha*

Food items	% of Volume (V_i)	% of Occurrence (O_i)	*Vi* * *Oi*	% IP
Phytoplankton				
Bacillariophyta	13.80	17.96	247.84	23.32
Chlorophyta	8.09	12.19	98.61	9.28
Cyanophyta	5.87	12.82	75.19	7.08
Semi-digested plant matter	12.48	6.84	85.42	8.04
Total	40.24	49.81	507.06	47.71
Zooplankton				
Cladocera	10.98	11.91	130.69	12.30
Copepoda	7.92	9.97	78.97	7.43
Rotifera	4.27	8.72	37.23	3.50
Crustacean nauplius	4.68	6.01	28.16	2.65
Semi-digested animal matter	30.81	8.94	275.47	25.92
Total	58.66	45.55	550.52	51.80
Others				
Sand particles	1.10	4.65	5.13	0.48

Discussion

Gut content analysis of *T. ilisha* from Brahmaputra River system revealed planktivorous nature of feeding[36]. Zooplankton (copepods and cladocerans), diatoms, blue green algae, mud and sand particles are dominant food items found in gut of Hilsa[23]. De & Datta[11] and De[37] reported that zooplankton (copepods) formed the most important food item during different life stages (fry, juvenile and adult) of the species throughout the year.

Dominance of semi-digested animal matter which is basically semi-digested zooplankton was observed in gut of the species during the present study. Among zooplankton, cladocerans was found more dominant in gut of the species as compared to copepods, while most of the earlier studies observed dominance of copepods in gut of the species. Availability of specific food items and their abundance for fish in a particular habitat is reflected in gut of fishes dwelling in that region[38]. Thus, observed variation in dominance of food types in gut of species can be correlated with their abundance in environment, where the fish species lived at a certain period of life. Comparatively, higher percentage of sand particles were observed in gut of the species during September to December as compared to remaining part of the year. Bacillariophyta was dominant food item in gut of the species during January and February. Dutta *et al.*[39] stated that occurence of relatively higher percentage of sand particles in gut of Hilsa is due to

Table 3 — Index of relative importance of different food items observed in gut of *Tenualosa ilisha*

Food items	% of Volume (V_i)	% of Number (*Ni*)	% of Occurrence (O_i)	IRI	%IRI
Phytoplankton					
Bacillariophyta	13.80	18.88	17.96	586.96	26.62
Chlorophyta	8.09	15.82	12.19	291.38	13.22
Cyanophyta	5.87	14.33	12.82	258.84	11.74
Semi-digested plant matter	12.48	7.42	6.84	136.19	6.18
Total	40.24	56.45	49.81	1163.6	54.92
Zooplankton					
Cladocera	10.98	7.09	11.91	215.11	9.76
Copepoda	7.92	5.95	9.97	138.29	6.27
Rotifera	4.27	4.84	8.72	79.42	3.60
Crustacean nauplius	4.68	6.36	6.01	66.41	3.01
Semi-digested animal matter	30.81	14.41	8.94	404.32	18.34
Total	58.66	38.65	45.55	932.32	44.02
Others					
Sand particles	1.10	4.91	4.65	27.98	1.27

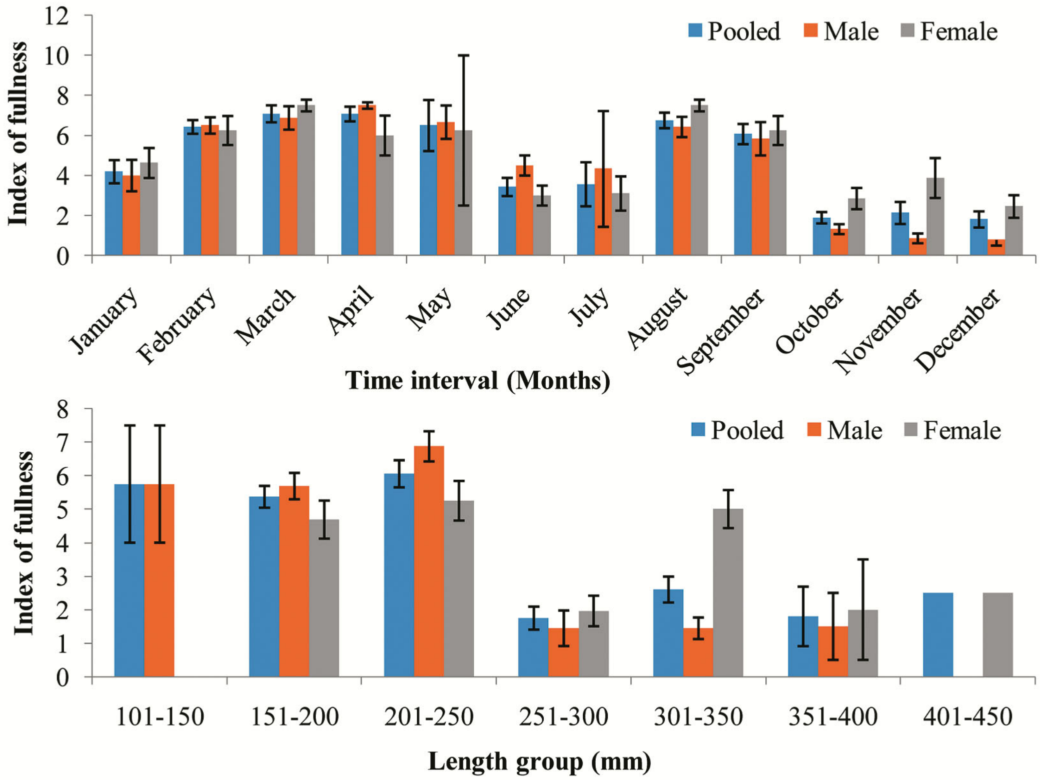

Fig. 5 — Index of fullness of *Tenualosa ilisha*: a) Monthly variation and b) Length group-wise variation

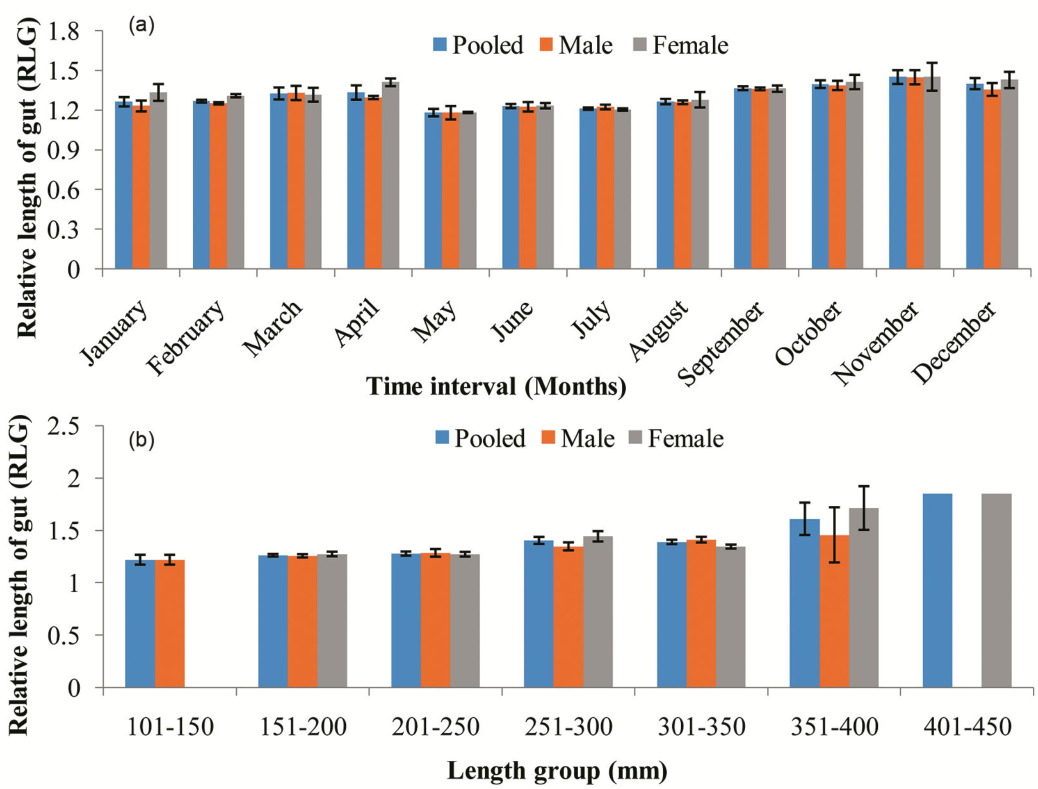

Fig. 6 — Estimated relative length of gut (RLG) of *Tenualosa ilisha*: a) Monthly variation and b) Length group-wise variation

bottom feeding behaviour of the species during spawning season. They further reported the dominance of diatoms (Bacillariophyta) in the gut of the species post spawning[39]. Occurrence of sand particles in gut of the species has also been reported by Rahman *et al.*[36].

Size group-wise analysis of food composition revealed zooplankton as more dominant in lower size groups compared to phytoplankton and vice-versa. Halder[40] reported size group-wise variation in food preference of Hilsa, with zooplankton dominating the gut in juveniles and diatoms in higher size groups. De[37] reported dominance of zooplankton in lower size groups and increase in percentage composition of phytoplankton with increase in size of the species. This may be attributed to presence of more developed gill rakers and better filtering efficiency in adult Hilsa.

Index of preponderance confirmed the dominance of semi-digested animal matter followed by Bacillariophytes in gut of the species. However, index of relative importance revealed dominance of Bacillariophyta (26.62 %) followed by semi-digested animal matter (18.34 %), Chlorophyta (13.22 %) and Cyanophyta (11.74 %) in gut of the species. It is due to the fact that IRI considers the number besides volume and occurence of food items[33].

GaSI is an indication of stomach fullness and is an indirect way of measuring the feeding intensity in fishes[4]. GaSI values vary across seasons and across maturity stages of fishes and is found to be low during spawning season due to cessation of feeding and high during post-spawning period[8]. Cessation of feeding during breeding season occurs mainly to avoid stress in spawning activity[41], which generally results in low GaSI value in fishes during this period. De[37] reported that GaSI value in Hilsa from Hooghly River showed a marked decline from July with its minimum in October, which corresponds with the breeding season of the species in the river and it showed an increasing trend post spawning from the month of January onwards with peak in April. During the present study, higher GaSI values in both the sexes combined and in males and females individually were observed during March to May and lower values were observed during September to December. The variation observed in GaSI curve during present study with earlier observations may be attributed to the difference in breeding season of the species across ecosystems.

Index of fullness is an indirect way of measuring the feeding intensity. In present study, high percentage of empty stomachs and low index of fullness or feeding intensity was reported during October to December and high feeding intensity during February to May, which may be attributed to cessation of feeding during the breeding season and high feeding activity post spawning, respectively[4]. Dutta *et al.*[39] reported that feeding intensity in Hilsa showed seasonal oscillation with low feeding intensity during June – September (spawning season) and maximum feeding intensity during February – March (post-spawning). Hilsa ceases to feed during spawning migration as the species remains busy in upstream migration and spawning activities[39]. Temporal variation in feeding intensity of fishes is also influenced by the availability of food in environment and maturity stage[42]. Shafi *et al.*[43] reported that feeding intensity is high in juvenile stage of Hilsa as compared to adults which is in line with the present findings.

In general, gut length of herbivores is longer than omnivores followed by carnivores[12]. During the current study, mean relative gut length of *T. ilisha* was found to be 1.336±0.013. Mean relative gut length of the species increased with increase in length groups. Longer length of gut in fishes as observed in the present study is a manifestation of its planktivorous feeding habit. De[37] reported that relative gut length in Hilsa ranged from 0.86 to 1.87, with a mean value of 1.39 and stated that relative gut length increased with increasing length groups which corroborates with present findings. Fishes feeding on plant matter have long digestive tracts, which is an evolutionary anatomical modification that increases passage time of food through the gut, thereby increasing digestive efficiency of plant food matter[44].

HSI is an indicator of energy stored in fish and acts a reliable indicator of feeding activity and feeding intensity[10]. During the present study, HSI value in *T. ilisha* was found to be low during October to December, increased from March and peaked in June. This may be attributed to the seasonal fluctuation in feeding intensity of the species in Brahmaputra River system. As stated earlier cessation of feeding in fishes during spawning season and marked increase in feeding intensity post spawning is well-documented[4,8]. Low HSI values observed in the species during October to December may be attributed to initiation of spawning activity and subsequent low feeding rate during this period. Liver plays a significant role in egg development as it produces vitellogenin, the yolk precursor and is the site of reserve energy in fishes. Utilization of energy reserves stored in liver towards maturation of gonads during spawning season might also be one of the possible causes for decline in liver weight, which has resulted in low HSI values during October to December[45].

Conclusion

The present study on food and feeding habits of the anadromous and highly prized Hilsa fish from the Brahmaputra river, India revealed that semi-digested animal matter, Bacillariophyta, Cladocera, Chlorophyta, Copepoda and Cyanophyta were the dominant food items present in gut. Size group variation in food preferences of the species was evident from the study with share of zooplankton being highest in 101 – 150 mm length group and phytoplankton in 301 – 350 mm. Variation in diet composition was also observed across the months. High RLG values confirm the planktivorous nature of this species. Temporal variation in feeding dynamics was observed with low feeding intensity during October to December as evident from lower GaSI, HSI and Index of fullness values, which might be due to the onset of breeding migration. The results of present study will help researchers in comparing its food preference and feeding habits across the ecosystems (marine to freshwater) and across life stages and seasons. Further, being a long distant migratory fish, the present study will assist fish biologists in understanding the feeding biology of the species during the course of its migration to freshwater systems and will help in identifying possible habitat preferences based on food availability, which will assist in sustainable management of this important resource.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

SB: Major contributor in writing the manuscript, data collection and conception of idea and design; VG: Substantively revised the manuscript, helped in interpretation of the data; AKJ: Have substantial contribution in design the study, critically revised the manuscript; BKB: Assisted in sampling and laboratory analysis of samples; GD: Assisted in drafting and revising the manuscript; AKS: Significantly helped in designing and revising the manuscript; PG: Helped in laboratory analysis of the samples; DKM: Assisted in data analysis and manuscript preparation; DM: Prepared GIS maps and assisted in data analysis; BKD: Helped in the conception of idea, designing the manuscript and final critical revision of the manuscript.

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