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FOOD AND FEEDING HABITS OF *MUGIL CEPHALUS* (LINNAEUS, 1758) FROM THE GODAVARI ESTUARY, ANDHRA PRADESH, INDIA

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Abstract

The present study investigated the food and feeding habits of Mugil cephalus collected from the Godavari estuary, Andhra Pradesh, India, during 2021 to evaluate gut content composition, feeding intensity and gastro-somatic index (GSI). A total of 320 specimens were examined to assess monthly variation in food composition and feeding activity. Gut content analysis revealed that algae, diatoms, and vegetative material formed the major dietary components throughout the study period. Algal contribution ranged from 16.14% in January to 82.36% in August, while diatoms showed maximum occurrence in April (42.51%). Vegetative material was highest in January (30.28%) and lower values were observed during subsequent months. Animal origin food items, including fish body parts, fish larvae, crustaceans, and polychaetes, occurred in comparatively lower proportions. Feeding intensity analysis indicated that 1/2 full and 1/4 full stomach conditions constituted the major proportion during most months, with the highest 1/2 full stomach occurrence recorded in December (36.86%) and 1/4 full stomachs in September (46.74%). Pearson's correlation analysis of gut content composition showed the strongest positive relationship between crustaceans and sand/mud ($r = 0.761$), whereas algae and vegetative material exhibited the highest negative correlation ($r = -0.768$). Feeding intensity categories showed the highest positive correlation between 1/4 full stomachs and traces ($r = 0.765$). Male and female GSI values exhibited a weak positive relationship ($r = 0.200$). Overall, algae, diatoms and vegetative material constituted the major portion of stomach contents throughout the study period.

Keywords: *Mugil cephalus, gut content, feeding intensity, gastro-somatic index, Pearson correlation, Godavari estuary*.

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INTRODUCTION

Grey mullet, *Mugil cephalus* (Linnaeus, 1758), is one of the most commercially important estuarine and coastal fish species widely distributed in tropical and subtropical waters. The species belongs to the family Mugilidae and is recognized for its broad environmental tolerance, adaptability to fluctuating salinity conditions, and high commercial demand in capture fisheries and aquaculture systems [1, 2]. *Mugil cephalus* inhabits estuaries, lagoons, coastal waters, and river mouths where nutrient-rich habitats provide suitable feeding grounds for growth and survival [3, 4]. Due to its omnivorous feeding behaviour and ability to utilize a wide range of food resources, the species plays an important role in energy transfer within estuarine food webs [2, 5]. In India, mullets are considered economically valuable fish resources, particularly along the east coast where estuarine fisheries support the livelihoods of coastal communities [6, 7].

Studies on food and feeding studies are essential for understanding trophic ecology, feeding preference, habitat utilization, and nutritional requirements of fish species. Knowledge of dietary composition provides useful information on prey selection, food availability, and ecological interactions within aquatic ecosystems [8, 9]. Gut content analysis is widely used to assess feeding behaviour and seasonal dietary shifts in fishes because it reflects actual dietary utilization under natural environmental conditions [10, 11]. Variations in food composition may occur due to differences in environmental conditions, prey abundance, seasonal productivity, and habitat characteristics [12, 13]. Understanding feeding habits is therefore important for fisheries management, stock assessment, and sustainable utilization of commercially important fish species such as *Mugil cephalus*.

Food and feeding behaviour of fish species often changes according to environmental conditions, food availability, and habitat productivity. In estuarine ecosystems, mullets are generally regarded as opportunistic feeders that consume algae, diatoms, detritus, phytoplankton, benthic organisms, crustaceans, and organic matter available in bottom sediments [14, 15]. Previous studies on *Mugil cephalus* have reported that algae and diatoms constitute major components of the diet, while crustaceans, polychaetes, fish larvae, and detrital materials occur in variable proportions depending on locality and season [16-18]. Similarly, studies conducted in estuarine waters of Ghana, Nigeria, Bangladesh, and Egypt have demonstrated that feeding patterns of mullets are influenced by seasonal fluctuations and habitat-specific food availability [4, 19, 20]. The observed dietary variability of *Mugil cephalus* reflects its capacity to utilize diverse food resources under varying estuarine conditions.

Assessment of feeding intensity through stomach fullness analysis provides important information on feeding activity and temporal changes in food consumption. Assessment of stomach fullness categories such as gorged, full, partially full, traces, and empty stomachs has been widely applied to determine feeding intensity and periodicity in fishes [9, 10]. Variations in feeding intensity are often associated with seasonal changes, reproductive activity, food abundance, and environmental conditions [21, 22]. Several studies on mullet species have reported fluctuations in stomach fullness conditions, reflecting temporal shifts in feeding activity and food utilization [7, 23]. Therefore, assessment of feeding intensity provides additional insight into the feeding ecology and physiological condition of fish populations inhabiting estuarine ecosystems.

The gastro-somatic index (GSI) is another useful biological indicator to evaluate feeding condition and digestive activity in fishes. GSI provides information regarding the relative contribution of gut weight to total body weight and may vary according to feeding condition, seasonal changes, and reproductive status [24, 25]. Previous investigations on mullet species have shown that monthly variations in GSI are often associated with changes in feeding activity and food intake [13, 26]. Studies on mullet feeding ecology have emphasized that combined assessment of gut content composition, feeding intensity, and GSI provides useful information regarding feeding periodicity and food utilization patterns under estuarine conditions [27, 28].

Although several studies have reported food and feeding habits of *Mugil cephalus* from different estuarine systems in India and other countries, information on feeding ecology, feeding intensity, and gastro-somatic index (GSI) of *Mugil cephalus* from the Godavari estuary, Andhra Pradesh, is limited [6, 7, 18].

Estuarine conditions, food availability, and environmental variability may influence feeding behaviour and dietary composition of fish species, highlighting the need for region-specific investigations to better understand local feeding ecology. Therefore, the present study was undertaken to investigate the food and feeding habits of *Mugil cephalus* from the Godavari estuary by analyzing gut content composition, feeding intensity, and gastro-somatic index (GSI) during different months of the year.

MATERIALS AND METHODS

Study area

The present study was conducted in the Godavari estuary, Andhra Pradesh, India, one of the major estuarine systems along the east coast of India. Fish samples were collected from the Balusutippa fish landing centre located in the Gautami Godavari estuary (16°38'13.51"N and 82°15'19.35"E). The estuary supports diverse fish fauna and serves as an important fishing ground for commercially valuable fish species, including *Mugil cephalus*. Balusutippa is one of the major fish landing centres where mullets are regularly landed by local fishermen, making it suitable for consistent sample collection throughout the study period.

Sample collection

Fresh specimens of *Mugil cephalus* were collected monthly from Balusutippa landing centre during the year 2021, except during periods of fishing restrictions. Fish specimens were obtained directly from local fishermen immediately after landing to ensure freshness and avoid post-capture deterioration of stomach contents. A total of 320 specimens were examined during the study period.

The collected specimens were transported to the laboratory in insulated ice boxes to preserve freshness and minimize decomposition before analysis. In the laboratory, each specimen was identified following standard taxonomic keys and external morphological characteristics.

Morphometric measurements and dissection

In the laboratory, the total length (cm) and body weight (g) of each specimen were measured using a measuring board and electronic balance, respectively. The abdominal cavity was carefully opened through a mid-ventral incision, and the alimentary canal was dissected out. Stomachs were removed carefully and preserved in 5% formalin solution for further analysis.

The degree of stomach fullness was examined visually and categorized into seven feeding intensity classes, namely gorged, full, 3/4 full, 1/2 full, 1/4 full, traces, and empty stomachs, following standard stomach fullness methods commonly used in fish feeding studies [8, 10].

Gut content analysis

The stomach contents were carefully removed and examined under a compound microscope and stereomicroscope for identification of food items. Food components present in the stomach were sorted and identified carefully to the lowest possible taxonomic level using standard identification manuals and relevant literature.

The food items identified in the gut contents were classified into major categories, including algae, diatoms, vegetative material, fish body parts, fish larvae, crustaceans, polychaetes, dinoflagellates, and sand/mud particles.

The percentage composition of gut contents was determined by estimating the relative contribution of each food item in the stomach contents and expressed as percentages for monthly comparison. Gut content analysis was carried out following standard occurrence and volumetric methods commonly used in fish feeding studies [8, 9].

Feeding intensity

Feeding intensity was assessed based on the degree of stomach fullness. The stomachs were classified into gorged, full, 3/4 full, 1/2 full, 1/4 full, traces, and empty categories. The percentage occurrence of each feeding category was calculated monthly to understand feeding activity and temporal variation in feeding intensity [10].

Gastro-somatic index (GSI)

The gastro-somatic index (GSI) was estimated to assess feeding condition during different months. After dissection, stomach weight and total body weight of individual fish were recorded. GSI was calculated using the following formula:

GSI = (Weight of gut / Total body weight) × 100

Male and female specimens were analyzed separately to determine monthly variation in feeding condition [24].

Statistical analysis

The monthly variation in gut content composition, feeding intensity, and gastro-somatic index (GSI) of *Mugil cephalus* was assessed using percentage based observations and descriptive statistics. Pearson's correlation analysis was carried out to examine the relationships among gut content components, feeding intensity categories, and GSI values of males and females. Correlation coefficients (*r*) were calculated using Microsoft Excel 2021.

RESULTS

Percentage composition of gut content

Table 1. Monthly percentage composition of gut content in *Mugil cephalus* during the year 2021.

Months	Algae	Diatoms	Vegetative material	Fish body parts	Fish larvae	Crustacean	Polychaete	Dinoflagellates	Sand/mud
January	16.14	18.31	30.28	2.57	1.08	6.9	-	23.48	1.24
February	21.23	16.12	28.01	-	-	18.22	-	7.3	9.12
March	23.41	27.6	21.61	-	-	9.84	0.71	13.11	3.72
April	18.83	42.51	15.73	-	1.52	6.32	2.28	10.75	2.06
May	32.26	26.23	8.56	5.25	2.13	11.61	1.21	6.54	6.21
Jun	46.21	11.36	10.43	-	-	15.39	3.35	8.65	4.61
July	60.14	22.13	12.21	-	-		-	3.29	2.23
August	82.36	-	6.16	-		8.51	1.83		1.14
September	57.14	13.1		7.36			3.75	18.02	0.63
October	49.28	18.22	15.3	1.29	-		1.5	11.26	3.15
November	62.13	24.19			-	4.36	2.07	6.13	1.12
December	47.86	15.17	10.34	-	3.07	8.17	0.94	10.91	3.54

The gut content analysis of *Mugil cephalus* revealed considerable monthly variation in food composition throughout the study period. The stomach contents mainly comprised algae, diatoms, vegetative material, fish body parts, fish larvae, crustaceans, polychaetes, dinoflagellates, and sand/mud, with considerable variation in their proportions among months.

Algae constituted the major portion of the stomach contents in most months. The lowest contribution was recorded in January (16.14%) and February (21.23%), followed by an increase during subsequent months. The highest percentage of algae was observed in August (82.36%), followed by November (62.13%), July (60.14%), and September (57.14%).

Diatoms also formed an important component of the stomach contents and exhibited monthly fluctuations. Their contribution ranged from 11.36% in June to a maximum of 42.51% in April. Comparatively higher values were recorded in March (27.60%), May (26.23%), November (24.19%), and July (22.13%).

Vegetative material contributed substantially to the stomach contents, particularly during the early months of the year. The highest proportion was recorded in January (30.28%), followed by February (28.01%) and March (21.61%). Lower values were observed in May (8.56%) and August (6.16%).

Animal-origin food items such as fish body parts, fish larvae, crustaceans, and polychaetes occurred in relatively lower proportions. Fish body parts were absent in several months but appeared intermittently, with the highest contribution recorded in September (7.36%), followed by May (5.25%) and January (2.57%).

Fish larvae were observed in small quantities, with the highest percentage recorded in December (3.07%), followed by May (2.13%) and April (1.52%).

Crustaceans formed a moderate component of the stomach contents and showed monthly variation. The highest contribution was observed in February (18.22%), followed by June (15.39%) and May (11.61%).

Lower values were recorded during the remaining months.

Polychaetes contributed minimally to the stomach contents and were absent in several months. However, their occurrence was observed in June (3.35%), April (2.28%), November (2.07%), August (1.83%), October (1.50%), May (1.21%), December (0.94%), and March (0.71%).

Dinoflagellates formed an appreciable component of the stomach contents, particularly during January (23.48%) and September (18.02%). Moderate contributions were also observed in March (13.11%), October (11.26%), and December (10.91%).

Sand/mud occurred in relatively low proportions throughout the study period. The highest percentage was recorded in February (9.12%), followed by May (6.21%) and June (4.61%), whereas comparatively lower values were observed during the remaining months. Overall, algae, diatoms, and vegetative material constituted the major portion of the stomach contents throughout the study period, whereas animal-origin food items occurred in comparatively lower proportions.

Correlation matrix for gut content

Table 2. Pearson correlation matrix for gut content composition of *Mugil cephalus.*

Variables	Algae	Diatoms	Vegetative material	Fish body parts	Fish larvae	Crustacean	Polychaete	Dinoflagellates	Sand/mud
Algae	1.000	-0.613	-0.768	-0.026	-0.306	-0.410	0.369	-0.557	-0.456
Diatoms	-0.613	1.000	0.194	-0.063	0.281	-0.118	-0.127	0.174	0.042
Vegetative material	-0.768	0.194	1.000	-0.286	0.031	0.395	-0.695	0.387	0.430
Fish body parts	-0.026	-0.063	-0.286	1.000	0.113	-0.274	0.342	0.453	-0.129
Fish larvae	-0.306	0.281	0.031	0.113	1.000	0.128	-0.174	0.156	0.116
Crustacean	-0.410	-0.118	0.395	-0.274	0.128	1.000	-0.148	-0.176	0.761
Polychaete	0.369	-0.127	-0.695	0.342	-0.174	-0.148	1.000	0.029	-0.347
Dinoflagellates	-0.557	0.174	0.387	0.453	0.156	-0.176	0.029	1.000	-0.227
Sand/mud	-0.456	0.042	0.430	-0.129	0.116	0.761	-0.347	-0.227	1.000

The Pearson's correlation analysis of gut content composition of *Mugil cephalus* showed both positive and negative relationships among the dietary components. Algae exhibited negative correlations with diatoms ($r = -0.613$), vegetative material ($r = -0.768$), crustaceans ($r = -0.410$), dinoflagellates ($r = -0.557$), and sand/mud ($r = -0.456$), whereas a positive correlation was observed with polychaetes ($r = 0.369$).

Diatoms showed positive correlations with vegetative material ($r = 0.194$), fish larvae ($r = 0.281$), and dinoflagellates ($r = 0.174$), while negative correlations were observed with crustaceans ($r = -0.118$) and polychaetes ($r = -0.127$).

Vegetative material exhibited positive correlations with crustaceans ($r = 0.395$), dinoflagellates ($r = 0.387$), and sand/mud ($r = 0.430$), whereas a strong negative correlation was observed with polychaetes ($r = -0.695$).

Fish body parts showed positive correlations with fish larvae ($r = 0.113$), polychaetes ($r = 0.342$), and dinoflagellates ($r = 0.453$), whereas negative correlations were observed with crustaceans ($r = -0.274$) and sand/mud ($r = -0.129$).

Crustaceans exhibited the highest positive correlation with sand/mud ($r = 0.761$), while negative correlations were observed with polychaetes ($r = -0.148$) and dinoflagellates ($r = -0.176$).

Overall, algae and vegetative material exhibited the highest negative correlation ($r = -0.768$), whereas crustaceans and sand/mud showed the strongest positive correlation ($r = 0.761$).

Feeding Intensity

The feeding intensity of *Mugil cephalus* showed monthly variation throughout the study period, as indicated by stomach fullness categories. The stomachs examined were categorized into gorged, full, 3/4 full, 1/2 full, 1/4 full, traces, and empty categories, with variation observed in their monthly proportions. The occurrence of gorged stomachs was generally low during most months. Gorged stomachs were absent in February, March, May, June, August, September, and November, whereas comparatively higher percentages were observed in December (8.95%), July (5.48%), April (3.58%), and October (3.33%). January also recorded a low occurrence of gorged stomachs (2.96%).

Full stomachs exhibited monthly variation, with the highest proportion recorded in October (19.42%), followed by January (18.74%), November (15.63%), December (14.25%), and May (13.81%). Lower values were observed in June (5.15%), February (5.31%), and July (5.83%).

The proportion of 3/4 full stomachs varied considerably among months. The highest percentage was observed in November (45.38%), followed by May

(25.42%), October (18.16%), July (16.61%), and February (14.26%). Comparatively lower values were recorded in April (2.58%) and September (4.85%).

The occurrence of 1/2 full stomachs remained comparatively higher in several months. The highest proportion was recorded in December (36.86%), followed by February (35.05%), January (33.45%), June (27.17%), July (24.14%), May (23.12%), and October (23.01%). Lower values were observed in November (17.86%) and March (18.46%).

The proportion of 1/4 full stomachs showed noticeable monthly variation, with the highest percentage observed in September (46.74%), followed by March (43.11%), April (40.25%), August (38.08%), and June (33.42%). Lower values were recorded in November (10.86%) and January (16.53%).

Stomachs containing traces of food were recorded in all months, with comparatively lower values observed in December (7.23%), February (8.73%), and January (9.92%). Higher proportions of trace feeding were observed in March (24.25%), June (23.02%), April (21.17%), and August (18.13%). The proportion of empty stomachs also varied among months. Empty stomachs were absent in June and November, while the highest percentage was recorded in February (13.21%), followed by September (11.38%), January (8.14%), August (7.65%), and October (7.24%). Lower values were observed in March (2.19%), May (2.21%), and December (3.21%). Overall, stomachs categorized as 1/2 full and 1/4 full constituted a relatively larger proportion during most months, whereas gorged stomachs occurred in comparatively lower proportions throughout the study period.

Table 3. Monthly percentage of feeding intensity in *Mugil cephalus* during the year 2021.

Months	No. of stomachs examined	High feeding		Moderate feeding		Low feeding	Empty	
		Gorged	Full	3/4th Full	1/2 Full	1/4 Full	Traces	
January	32	2.96	18.74	10.26	33.45	16.53	9.92	8.14
February	30	–	5.31	14.26	35.05	23.44	8.73	13.21
March	26	–	6.28	5.71	18.46	43.11	24.25	2.19
April	22	3.58	7.17	2.58	20.31	40.25	21.17	4.94
May	12	–	13.81	25.42	23.12	21.02	14.42	2.21
June	28	–	5.15	11.24	27.17	33.42	23.02	–
July	29	5.48	5.83	16.61	24.14	29.53	13.07	5.34
August	25	–	7.57	6.72	21.85	38.08	18.13	7.65
September	28	–	2.63	4.85	19.56	46.74	14.84	11.38
October	27	3.33	19.42	18.16	23.01	17.82	11.02	7.24
November	29	–	15.63	45.38	17.86	10.86	10.27	–
December	32	8.95	14.25	11.93	36.86	17.57	7.23	3.21

Correlation matrix for feeding intensity

Table 4. Pearson correlation matrix for feeding intensity of *Mugil cephalus*.

Variables	Gorged	Full	3/4 Full	1/2 Full	1/4 Full	Traces	Empty
Gorged	1.000	0.314	-0.141	0.477	-0.297	-0.424	-0.065
Full	0.314	1.000	0.490	0.210	-0.820	-0.550	-0.211
3/4 Full	-0.141	0.490	1.000	-0.159	-0.729	-0.449	-0.418
1/2 Full	0.477	0.210	-0.159	1.000	-0.449	-0.560	0.287
1/4 Full	-0.297	-0.820	-0.729	-0.449	1.000	0.765	0.185
Traces	-0.424	-0.550	-0.449	-0.560	0.765	1.000	-0.356
Empty	-0.065	-0.211	-0.418	0.287	0.185	-0.356	1.000

The Pearson's correlation analysis of feeding intensity categories of *Mugil cephalus* showed both positive and negative correlations among stomach fullness conditions. Gorged stomachs exhibited positive correlations with full stomachs ($r = 0.314$) and 1/2 full stomachs ($r = 0.477$), whereas negative correlations were observed with 3/4 full ($r = -0.141$), 1/4 full ($r = -0.297$), traces ($r = -0.424$), and empty stomachs ($r = -0.065$).

Full stomachs showed positive correlations with 3/4 full ($r = 0.490$) and 1/2 full stomachs ($r = 0.210$), while negative correlations were observed with 1/4 full ($r = -0.820$), traces ($r = -0.550$), and empty stomachs ($r = -0.211$).

The 3/4 full stomach category exhibited negative correlations with 1/2 full ($r = -0.159$), 1/4 full ($r = -0.729$), traces ($r = -0.449$), and empty stomachs ($r = -0.418$).

The 1/2 full stomach category showed a positive correlation with empty stomachs ($r = 0.287$), whereas negative correlations were recorded with 1/4 full ($r = -0.449$) and traces ($r = -0.560$).

The 1/4 full stomach category exhibited a strong positive correlation with traces ($r = 0.765$), while negative correlations were observed with gorged (r = −0.297), full (r = −0.820), and 3/4 full stomachs (r = −0.729). Traces showed a negative correlation with empty stomachs (r = −0.356).

Among the feeding intensity categories, the highest positive correlation was observed between 1/4 full stomachs and traces (r = 0.765), whereas the strongest negative correlation was recorded between full and 1/4 full stomachs (r = −0.820).

Gastro-somatic index

Table 5. Gastro-somatic index of *Mugil cephalus* in different months during the year 2021.

Months	No. of males	No. of females	GSI (Male)	GSI (Female)
January	18	14	3.40	1.89
February	9	21	1.30	1.28
March	15	11	2.68	1.79
April	14	8	4.37	2.34
May	8	4	2.82	3.56
June	19	9	1.75	1.54
July	19	10	2.69	1.98
August	18	7	1.53	1.69
September	19	9	2.49	1.21
October	15	12	2.04	3.98
November	12	17	2.37	2.51
December	17	15	2.30	2.06

The gastro-somatic index (GSI) of *Mugil cephalus* exhibited monthly variation in both males and females throughout the study period. Monthly fluctuations were observed in GSI values, with differences observed between sexes across months.

In males, GSI values ranged from 1.30 in February to 4.37 in April. The highest GSI value was recorded in April (4.37), followed by January (3.40), May (2.82), July (2.69), and March (2.68). Comparatively lower values were observed in February (1.30), August (1.53), and June (1.75). Intermediate values were recorded during September (2.49), November (2.37), December (2.30), and October (2.04).

In females, GSI values varied from 1.21 in September to 3.98 in October. The highest GSI value was observed in October (3.98), followed by May (3.56), November (2.51), April (2.34), and December (2.06). Comparatively lower values were recorded in September (1.21), February (1.28), June (1.54), and August (1.69). Intermediate GSI values were observed in January (1.89), July (1.98), and March (1.79).

The number of males and females examined also varied among months. The highest number of males was recorded during June, July, and September (19 each), whereas the lowest number was recorded in May (8). In females, the highest number was recorded in February (21), followed by November (17), while the lowest number was observed in May (4). Overall, monthly variation in GSI was observed in both sexes, with comparatively higher GSI values recorded during specific months in males and females.

Pearson correlation of GSI

Table 6. Pearson correlation matrix of gastro-somatic index (GSI) in *Mugil cephalus.*

Variables	GSI (Male)	GSI (Female)
GSI (Male)	1.000	0.200
GSI (Female)	0.200	1.000

The Pearson's correlation analysis of gastro-somatic index (GSI) values of *Mugil cephalus* showed a weak positive relationship between male and female GSI values (r = 0.200) during the study period.

DISCUSSION

The present study demonstrated that *Mugil cephalus* in the Godavari estuary predominantly consumed algae, diatoms, and vegetative material throughout the study period, indicating that plant origin food items constituted a major proportion of the diet. Algae formed the major dietary component in most months, reaching the highest proportion during August (82.36%), whereas diatoms showed maximum occurrence in April (42.51%). Similar observations have been reported in previous studies where algae, diatoms, and detrital materials formed the dominant food items in *Mugil cephalus* inhabiting estuarine and coastal waters [1, 2, 6]. Studies from Bangladesh, Nigeria, and Andhra Pradesh also reported that mullets largely depend on phytoplanktonic and detrital food sources, particularly in estuarine habitats characterized by high organic productivity [7, 16, 17]. The predominance of plant-origin food materials observed in the present study is comparable with earlier findings reported for mullet species inhabiting estuarine ecosystems.

Monthly variation in food composition observed during the present investigation reflects seasonal shifts in dietary utilization by *Mugil cephalus*. Although algae and diatoms dominated the stomach contents, food items of animal origin such as crustaceans, fish larvae, fish body parts, and polychaetes were also observed in lower proportions, indicating omnivorous feeding behaviour. Comparable feeding patterns have been documented in mullet species from estuaries of Ghana, Egypt, and Nigeria where dietary composition changed according to seasonal productivity and habitat conditions [4, 15, 19]. Mondal et al. [18] and Kumary

[23] similarly reported that algae and diatoms represented major dietary items in *Mugil cephalus*, while crustaceans and benthic organisms contributed comparatively smaller proportions. The occurrence of diverse food items in the stomach contents reflects variability in food utilization by *Mugil cephalus* under estuarine conditions.

The correlation analysis of gut content composition further provided information regarding dietary associations among food components. In the present study, crustaceans exhibited the strongest positive correlation with sand/mud (r = 0.761), suggesting the possible ingestion of benthic food materials during bottom feeding activity. Similarly, positive associations among benthic food components have been reported in mullet feeding studies where sediment-associated organisms constituted an important dietary source [3]. A strong negative correlation was observed between algae and vegetative material (r = −0.768), which may reflect variation in food availability among months. Previous investigations have shown that mullets alter their feeding composition depending on habitat productivity, plankton abundance, and seasonal changes in estuarine food resources [12, 13]. The presence of both positive and negative dietary relationships in the present study indicates variability in food utilization patterns across different months.

Feeding intensity analysis revealed noticeable monthly variation in stomach fullness conditions, with 1/2 full and 1/4 full stomachs constituting a major proportion during most months. The highest occurrence of 1/2 full stomachs was recorded in December (36.86%), whereas 1/4 full stomachs reached the highest proportion in September (46.74%). Similar fluctuations in feeding intensity have been reported in mullet species from estuarine ecosystems where feeding activity varied according to food availability and seasonal conditions [21, 22]. Lavanya et al. [7] and Kumary [23] also observed temporal variation in stomach fullness conditions in *Mugil cephalus*, suggesting differences in feeding periodicity during different months. The comparatively lower occurrence of gorged stomachs in the present study suggests variation in feeding activity during different months of observation.

The correlation analysis of feeding intensity categories showed both positive and negative relationships among stomach fullness conditions. The strongest positive relationship was observed between 1/4 full stomachs and traces (r = 0.765), indicating similarity between partially fed conditions and trace feeding patterns. Conversely, a strong negative correlation was recorded between full and 1/4 full stomachs (r = −0.820), reflecting differences in feeding intensity across months. Comparable variability in feeding periodicity has been documented in previous feeding ecology studies of mullets and estuarine fishes, where stomach fullness conditions fluctuated in response to prey availability and environmental changes [5, 26]. The observed feeding relationships in the present study suggest temporal shifts in food consumption intensity by *Mugil cephalus* within the study area.

The gastro-somatic index (GSI) of *Mugil cephalus* exhibited monthly variation in both sexes, with higher male GSI values recorded during April (4.37) and higher female GSI values observed during October (3.98). Variations in GSI are often associated with feeding condition, digestive activity, and seasonal biological processes in fishes [24, 25]. Similar fluctuations in GSI values have been reported in mullet species inhabiting estuarine systems, where feeding intensity and gut condition varied according to seasonal changes [27, 28]. In the present study, Pearson's correlation analysis showed a weak positive relationship between male and female GSI values (r = 0.200), indicating a slight monthly similarity between sexes in feeding condition. The observed variation reflects monthly changes in GSI values of *Mugil cephalus* in the Godavari estuary.

CONCLUSION

The present study demonstrated that *Mugil cephalus* in the Godavari estuary primarily consumed algae, diatoms, and vegetative material, indicating an omnivorous feeding habit with a clear dependence on plant-origin food resources. Monthly variation in gut composition and stomach fullness reflected changes in feeding activity across seasons. The predominance of half-full and quarter-full stomachs suggested consistent but moderate feeding intensity, whereas fluctuations in GSI values indicated temporal differences in feeding condition between males and females. Overall, the present study improves understanding of the feeding ecology of *Mugil cephalus* and emphasizes the importance of estuarine food resources in supporting its growth and survival.

RECOMMENDATIONS

Regular monitoring of food resources and environmental conditions in the Godavari estuary is recommended to understand seasonal changes in feeding behaviour of *Mugil cephalus*. Protection of estuarine habitats supporting algal and detrital productivity should be considered to maintain healthy mullet populations. Future studies incorporating water quality, plankton dynamics, and reproductive biology may provide deeper insights into feeding ecology and resource utilization. Comparative studies from other estuarine systems of Andhra Pradesh may also strengthen regional fisheries management and conservation planning.

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The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

ETHICAL STATEMENT
The present study was conducted using fish samples obtained from the fish landing centre and did not involve experimental procedures on live animals. Therefore, formal ethical approval was not required for this study.

ARTIFICIAL INTELLIGENCE (AI) USE STATEMENT
The authors declare that no artificial intelligence (AI) tools or AI-assisted technologies were used in the preparation, writing, analysis, or interpretation of this manuscript.

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