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Evaluation of Feeding Aspects of the Bagrid Catfish *Mystus gulio* (Order: Siluriformes)

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ABSTRACT
Detailed knowledge of food and feeding habits is essential for the thriving culture of a fish species. The present study analyses the food and feeding habits of an indigenous bagrid catfish, *Mystus gulio,* from Vembanad Lake, southern Kerala's most extensive wetland system. The main objective is to check the feasibility of utilizing *Mystus gulio* as a bioremediation agent for kitchen waste recycling. From the Vembanad Lake, 779 specimens were sampled from fishery catches during July 2015 to June 2017. The gut contents of 318 specimens were analyzed to summarize the species' diet components and food preferences. Gastro somatic index, relative length and fullness of gut, feeding intensity, food components, and index of preponderance for various food items were calculated. The results showed that the fish is an omnivorous bottom feeder, feeding mainly on fish offal, plant matter, filamentous algae, prawns, and polychaetes. The results points to the possibility of considering this species a bioremediation agent for recycling kitchen waste.

Key words: Bagridae, Vembanad Lake, Indigenous, Feeding Index, Relative Length of Gut, Gut content

INTRODUCTION

The "long whiskered catfish" *Mystus gulio* (Ham 1822) of family Bagridae is widely distributed in fresh and brackish waters of India. Several studies on the food and feeding habits of different species of *Mystus* have been reported (Bhatt 1971, Khan et al. 1988, Rao 2007, Gupta 2014, Chattopadhyay et al.2014, Gupta and Banerjee 2014a, Rao 2017). Feeding habits of *M. gulio* were reported earlier by Pantulu (1961), Pandian (1971), Ritakumari et al. (2006), and Beegum et al. (2008), but no such work has been reported from the Vembanad backwaters of Kerala. This fish species has emerged as a major aquaculture species in some Asian countries (Siddiqui 2007) and is exported as an indigenous ornamental fish from India (Ng 2010, Gupta and Banerjee 2014b). It is of high nutritional value due to rich protein, micronutrients, vitamins, and mineral content (Kumar et al. 2019). This species comes under the "least concern" category of IUCN (Ng 2010).

Disposal of household waste is a significant problem, mounting high with the consumerism of society. Food wastes include any food substance, raw or cooked, which is discarded or intended or required to be discarded (Anonymous 2012). The considerable amount of unutilized food waste points to the depletion of nutritive resources and causes severe environmental degradation. The only suggestion is to reduce waste or *implement in situ* treatment that will ensure community hygiene on a sustainable basis. Using food waste for fish culture would be a sustainable strategy as it also ensures the production of fish utilizing wastes at no extra cost. Since food and feeding studies form the basis for successful fisheries management programs, we explored the food preferences and feeding habits of *M. gulio* in the Vembanad Lake, Kerala. The present study also aims to disclose the feasibility of utilizing this indigenous catfish for kitchen waste recycling.

MATERIAL AND METHODS

Study area

The Vembanad Lake (9°30"- 10°12'' N and 76°10"-76°30'' E), a part of the Vembanad-Kol Wetland system, is the largest Ramsar site on the southwest

coast of India. The saltwater regulator constructed across the lake at Thanneermukkom in 1976 prevents saline water intrusion, thereby dividing the water body into a saltwater lagoon in the north and a freshwater lake in the south. The unscientific operation of the Thanneermukkom barrage results in the complete absence of flushing in the upper reaches, causing severe ecological degradation in the southern zone of the Vembanad estuary (Asha et al. 2016).

Sampling and analysis

Using cast net and gill net**,** 779 specimens of *M. gulio* were collected monthly from the Vembanad Lake during July 2015 to June 2017. Fishes of different size groups were preserved in 10% formalin in the collection site itself to prevent further digestion of food materials. The total length (TL) of individual fish has been measured to the nearest 0.1 cm using a measuring scale from the tip of the snout to the tip of the caudal fin, and the total weight (TW) to the nearest of 0.01 g using an electronic balance (Shimadzu Corporation, Type BL-220H). In the laboratory, fish were dissected for the qualitative and quantitative analysis of the gut and gut contents. The fullness of the guts was identified as empty (I), poor (II), moderate (III), full (IV), and gorged (V) based on the contents. The percentage occurrence of these categories was calculated to assess the fish's feeding activity. Feeding intensity (FI) was assessed on the degree of distension of the stomach and the quantity of food contained. Monthly as well as size-based Variation in Gastro Somatic Index (GaSI) and Relative Length of Gut (RLG) (Al-Hussaini 1949) were calculated by applying the formulas:

$$GaSI = \frac{\text{Weight of gut}}{\text{Weight of fish}} \times 100$$

RLG = (length of gut/length of fish)

Each gut was emptied into a Petri dish and examined both macroscopically and microscopically. The gut contents were analyzed using the percentage of occurrence method (Hynes 1950). Seasonal and size-based diet composition was also assessed. The food preferences of the fish were assessed by the 'Index of Preponderance' method of Natarajan and Jhingran (1961), which accounts for both the frequency of occurrence of food items as well as their quantity into consideration.

$$IP = \frac{Vi \times Oi}{\sum ViOi} \times 100$$

where, IP = index of preponderance, Vi = volume index of the food item, Oi = occurrence index of the food item

Data analysis

All values are given as ranges, mean, and standard deviation. Seasonal variations in the GaSI and food preference were assessed by analysis of variance (ANOVA) at 95% confidence level. Whereas, the t-test was used to compute the variations in the diet in different size groups. The dominance curve of different food items was plotted using the statistical software Primer 6.

RESULTS AND DISCUSSION

The present investigation addresses the feeding intensity and food preferences of *M. gulio* from Vembanad Lake. Fishes ranging from 6.6 to 22.3 cm length (mean 14.68±3.83 cm) and 3.2 to 162.6 g in weight (mean 47.64±30.95 g) were utilized. The GaSI of *M. gulio* varied from 2.69±1.18 to 9.2±4.03 (Table 1). The values showed no significant variations in different seasons ($P>0.05$). It is an efficient way of comparing the feeding scale. It has a close relation to its reproduction. RLG varied from 0.8±0.04 to 0.95±0.15, unfolding their omnivorous feeding mode with an affinity towards carnivory. RLG is a commonly accepted correlate of fish diet. Generally, gut length reflects diet - predators have short and simple guts, while in omnivores and herbivores, it is long and complex, reflecting the digestibility and nutrient content of the species' preferred food item (Pogoreutz and Ahnelt 2014). RLG was lower (0.85±0.11) in smaller size group (<10.0 cm) compared to larger ones (0.94±0.08) (Fig.1). RLG was reported to increase with the proportion of vegetable matter in the gut of the fish (Basudha and Vishwanath 1999, Dasgupta 2004).

Feeding intensity showed moderate feeding activity throughout the year, and even in the breeding season, there was no cessation of feeding. The

Table 1. Monthly variations in GaSI and RLG in *Mystus gulio* collected from Vembanad Lake

Month	n	GaSI.			RLG.		
		Min.	Max.	Mean ± SD	Min.	Max.	Mean ± SD
July	76	0.87	9.6	5.8 ± 1.8	0.53	0.98	0.80±0.09
August	98	2.1	8.79	5.6 ± 1.9	0.64	1.08	0.89 ± 0.14
September	64	1.54	13.54	3.37 ± 1.99	0.72	1.27	0.93±0.10
October	47	1.31	15.19	9.2 ± 4.03	0.8	1.16	0.92±0.06
November	60	0.16	18.1	4.28 ± 3.7	0.64	1.02	0.85± 0.07
December	50	1.28	14.25	7.67 ± 3.02	0.68	0.97	0.89 ± 0.05
January	100	0.82	6.01	2.69 ± 1.18	0.64	1.28	0.87±0.08
February	60	1.16	15.54	5.8 ± 3.08	0.68	1.2	0.92±0.09
March	75	1.6	14.4	4.96 ± 2.57	0.79	1.51	0.95±0.15
April	45	1.36	10.5	5.6 ± 2.6	0.72	1.06	0.90±0.07
May	59	2.2	8.44	5.12 ± 1.15	0.55	0.91	0.81± 0.08

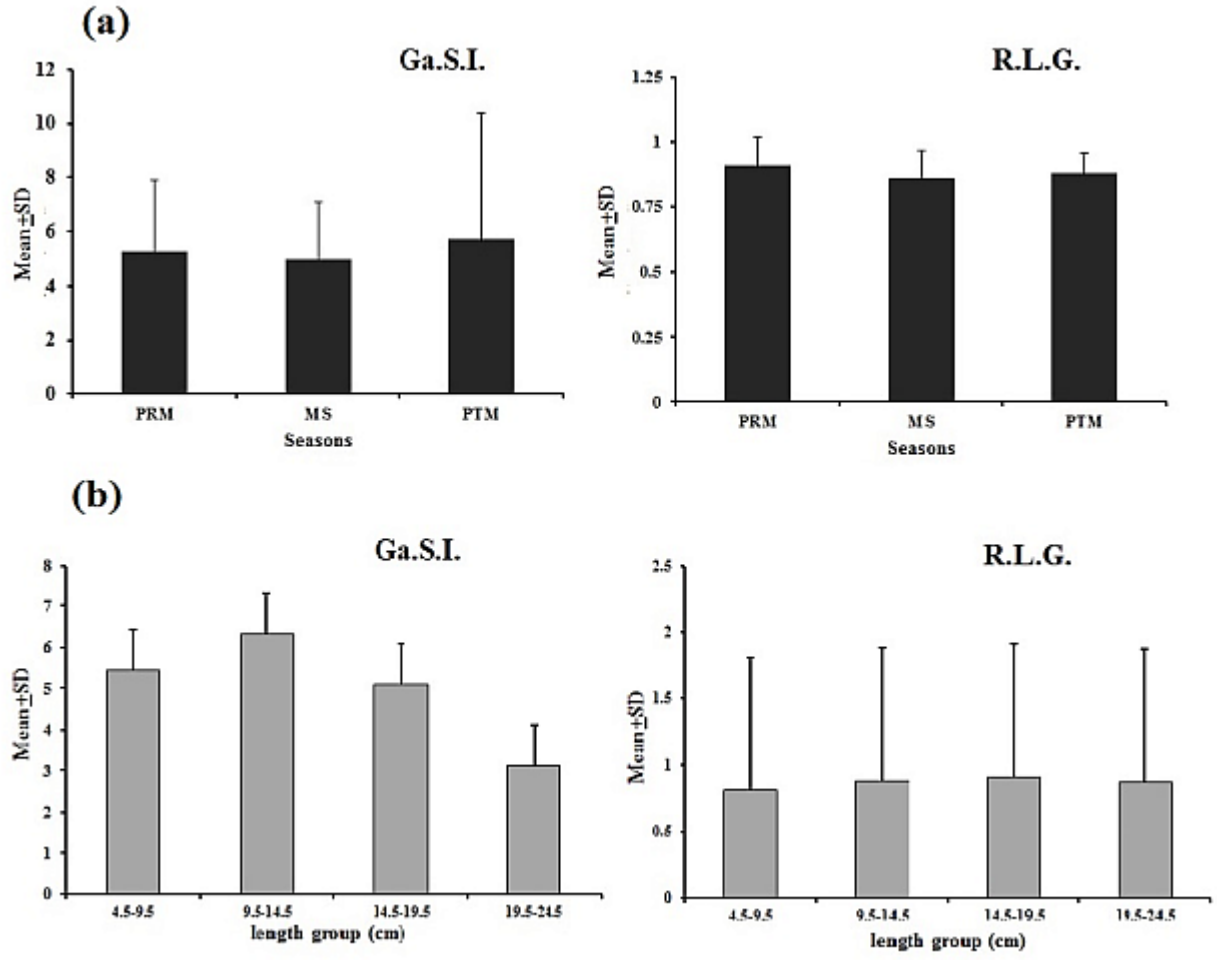

Figure 1.GaSI and RLG in *M.gulio* (a) seasonal; (b) size wise

maximum proportion of empty guts was encountered in May (52%), whereas full guts were higher in October and July (28%). Maximum feeding was observed from October to January (Table 2). Intense feeding was rarely encountered in pre-monsoon and monsoon seasons, representing the breeding period of *M. gulio*.

Table 2. Index of fullness of gut (%) in *Mystus gulio* collected from Vembanad Lake during 2015-2017 (N: number of fishes collected in monthly sampling)

Months		Index of fullness				
	N	I	II	III	IV	V
July	16	22	26	28	8	76
August	20	44	32	4	0	98
September	28	56	16	0	0	64
October	16	28	16	28	12	47
November	20	24	24	16	16	60
December	20	32	36	4	8	50
January	24	38	34	0	4	100
February	0	44	40	16	0	60
March	32	32	32	4	0	75
April	32	36	24	8	0	45
May	52	36	12	0	0	59
June	0	33	42	25	0	45

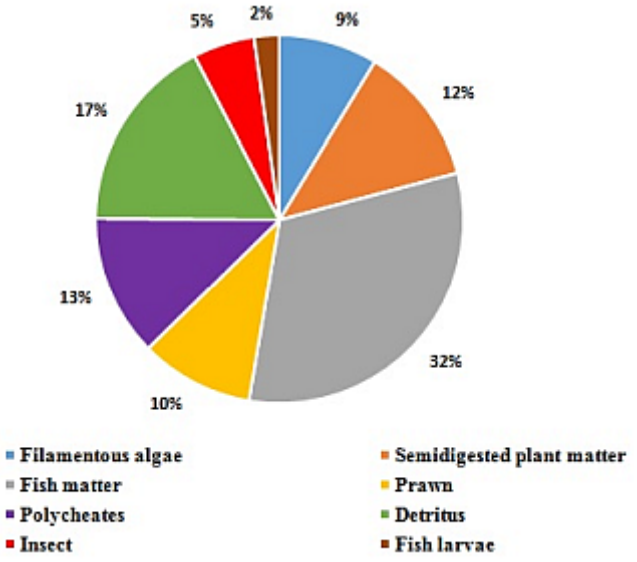

Figure 2. Contribution (%) of different items present in the gut of *M. gulio*

Since the investigation was carried out to assess the potentiality of *M. gulio* in kitchen waste utilization, comparatively large-sized food items represented in the gut content were subjected to analysis rather than microscopic items. Dominant food items present in the gut of *M. gulio* were fish matter (31.75%) followed by detritus (17.31%), polychaetes (12.48%), semi-digested plant matter (12.22%), prawn (9.96%), filamentous algae (8.65%), body parts of insects (5.41%) and fish larvae (2.22%) (Figs. 2, 3). Fish species belonging to the family Ambassidae, Engraulidae, and Lutjanidae occurred in varying proportions in the gut, and most of them were partly digested, which made the identification difficult. Fishes collected from human-inhabited areas contained high fish waste levels in their gut. Remains of food waste, including boiled rice, chicken bones, and vegetable parts, were also encountered occasionally. A notable amount of polychaetes, detritus, decayed leaves, and roots in the gut indicates its bottom-feeding nature.

Earlier studies reported *M.gulio* as an omnivorous fish (Pandian 1971), feeding mainly on diatoms, copepods, cladocerans, rotifers, fish eggs, fish larvae, and other benthic organisms (Yusuf and Majumdar 1993). Ritakumari et al. (2006) examined the diet of *M. gulio* from the canals of Vypin Island, which join the Vembanad lake at Kochi and observed the dominance of plant matter followed by filamentous algae. Siddique (2007) suggested that this species can be used to control water pollution as it consumes aquatic detritus. Beegum et al. (2008) give a better understanding of the diet composition and omnivorous nature of *M. gulio*. The present study also suggests the omnivorous nature of *M. gulio*, which is more geared towards a carnivorous diet.

The diet composition of *M. gulio* exhibited remarkable variations similar to that of *M. vittatus* (Reddy and Rao 1987, Chaklader et al. 2014). The fish matter was present in comparatively high proportion in all seasons, with the highest in post-monsoon. Among the different components of the diet, only plant matter and fish showed significant variation in the consumption in different seasons ($P<0.05$). Notably, fish larvae (1.52 ± 0.23 cm) of the family Engraulidae appeared (12.62%) exclusively in the pre-monsoon season. Seasonal and size wise variability in the contribution of different food items is given in Table 3. Size based variation in the diet composition revealed that the composition of food items showed no significant variation in different size groups (t-test, $P>0.05$). Comparatively large-sized

Figure 3. Most preferred food items present in the gut of *M. gulio* (a. fish larva, b,c,d: different types of fishes, e,f: fish waste, g: bone piece, h: prawn, i:polychaetes, j: fish scale and crustacean body part)

Table 3. Seasonal and size-based variations in percentage composition of different food items in the gut content of *Mystus gulio* (PRM: pre-monsoon, MS: monsoon, PTM: post-monsoon; N: total number of fishes)

Food items	Seasons			Size wise	
	PRM (N=72)	MS (N=118)	PTM (N=128)	<10.0 cm (N=72)	>10.0 cm (N=246)
Filamentous algae	23.73	0.12	6.12	0	9.98
Plant matter	17.60	7.29	11.56	4.81	14.01
Fish	11.49	28.32	37.07	61.9	35.04
Prawn	0.19	28.71	9.91	2.72	11.76
Polycheates	1.17	0.70	16.72	0	14.37
Detritus	24.52	24.67	14.62	23.24	6.14
Insect	8.69	10.18	4.01	7.33	6.09
Fish Larvae	12.62	0.00	0.00	0	2.61

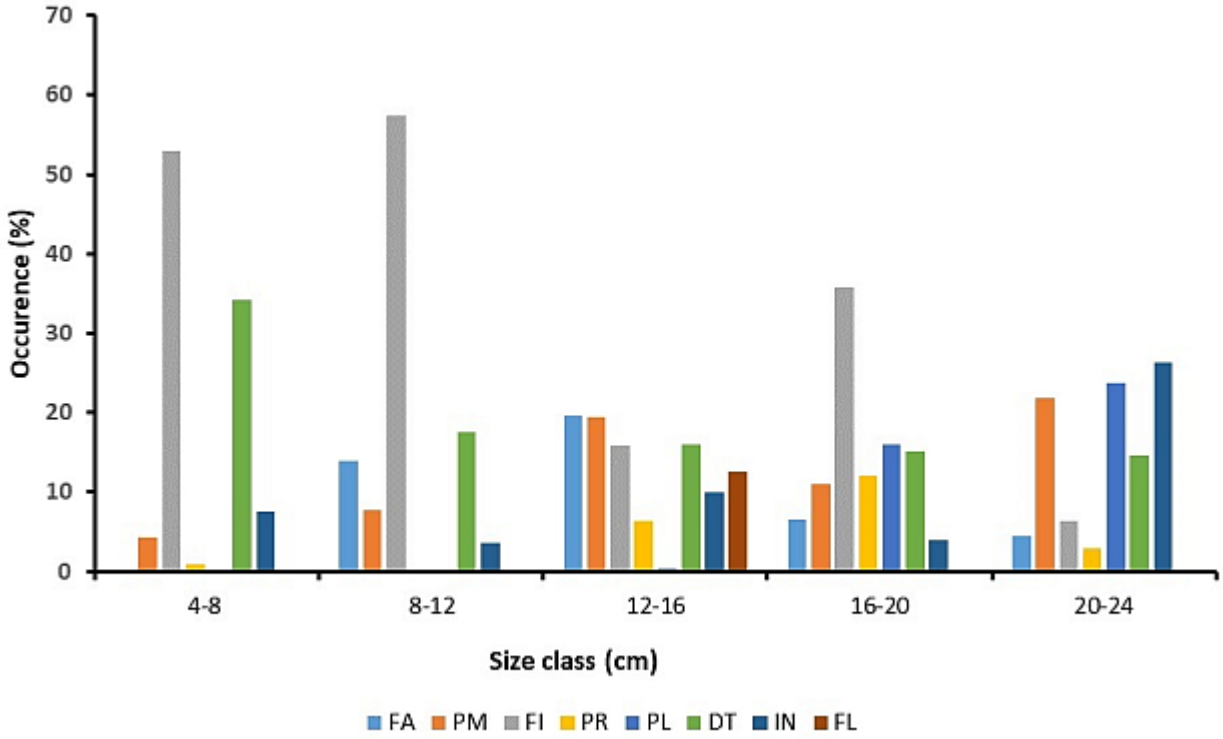

Figure 4. Food preference in different size groups of *M. gulio* (FA: filamentous algae, PM: semi digested plant matter, FI: Fish matter, PR: prawn, DT: detritus, PL: polychaetes, IN: insect body parts, FL: fish larvae)

fishes consumed a considerable amount of plant and animal matter (Fig. 4). The presence of both plant and animal matter in the diet of larger groups indicates their omnivorous feeding nature. Higher animal food consumption by fishes in the growing stages may be an adaptation to compensate for their high protein requirement during the period. Prasad and Ali (2008) reported a shift from an animal to a plant-based diet during the growth phase of *H. brachysoma* in the Periyar River of Kerala.

The index of preponderance was calculated to determine the feeding range and preference of various food items by species (Table 4). Fish matter forms the most preferred group with an Index of preponderance value of 59.29. Plant matter was the next favoured food item (12.66), followed by filamentous algae (6.87), prawn (6.83), detritus (5.89), polychaetes (4.55), and insect body parts (3.35). Similar type of feeding nature was observed in other catfishes like *M. seenghala, M. vittatus, H. brachysoma, Arius arius, Clarias gariepinus, Hemibagrus punctatus* (Das and Moitra 1963, Padmakumar 2018, Padmakumar et al. 2009, Karodt and Radhakrishnan 2010, Chaklader et al.2014, Rabelo and Soares 2014, Bhutekar et al.2016, Rao 2017). *M. gulio* is considered a generalist feeder (Fig. 5) and a mid-level carnivore, and their co-existence with other catfishes leads to resource competition (Maitra et al. 2020). This study reveals that *M. gulio* is an omnivorous fish that prefers carnivory and has a broad food spectrum.

CONCLUSIONS

Exotic catfishes like *Pangasius sutchi* and *Clarias gariepinus* were commonly used for recycling kitchen waste. Considering the negative impacts of these exotic catfishes on aquatic biodiversity, identification of an indigenous species to substitute them assumes significance. Hardy nature, generalist feeding and higher proportion of food waste in the gut content of *M. gulio points to the possibility of utilizing this species for recycling kitchen waste.* Finally, it is vital to do further research regarding this species' waste utilization ability and growth performance to include it in the backyard culture

Table 4. Index of Preponderance (IP) of food items in the gut of *Mystus gulio* (N= 318)

Food classes	Vol. Index (V), %	Occurrence (O), %	V*O	IP	Grade
Filamentous algae	9.89	16.82	166.35	6.87	III
Plant material	13.8	22.22	306.64	12.66	II
Fish	40.24	35.67	1435.36	59.29	I
Prawn	11.24	14.71	165.34	6.83	IV
Polychaete worms	14.10	7.81	110.12	4.55	VI
Detritus	6.50	21.92	142.48	5.89	V
Insect	6.27	12.91	80.95	3.35	VII
Fish larvae	2.53	5.41	13.69	0.56	VIII

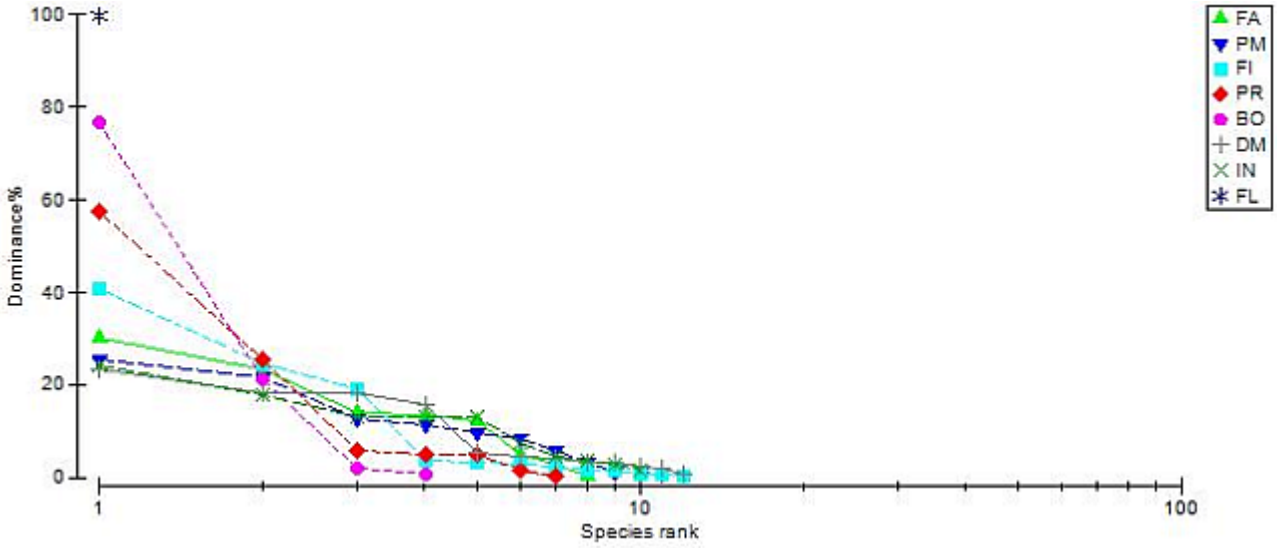

Figure 5. Dominance of different food items present in the gut of *M. gulio* (FA: filamentous algae, PM: semi digested plant matter, FI: Fish matter, PR: prawn, DT: detritus, PL: polychaetes, IN: insect body parts, FL: fish larvae)

systems.

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Authors' contributions: MPH and KGP conceived and performed the experiment; analyzed and interpreted the data; wrote the paper. BL analyzed and interpreted the data; wrote the paper

Conflict of interest: All authors declare no conflict of interest

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