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Lesser spiny eel (*Macrognathus aculeatus*) feeding preferences in the Progo River, Yogyakarta, Indonesia

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Abstract. *Djumanto. 2023. Lesser spiny eel (*Macrognathus aculeatus*) feeding preferences in the Progo River, Yogyakarta, Indonesia. Intl J Bonorowo Wetlands 13: 36-42.* Lesser spiny eel (*Macrognathus aculeatus* Bloch, 1786) is a highly valued fish species in the Progo River, Yogyakarta, due to its delectable taste, high nutritional value, and attractive aquarium filler. Therefore, this study aims to identify the dietary preferences of *M. aculeatus* collected between September 2020 and March 2021. Each fish was measured for individual length and weight, followed by an abdomen examination and digestive tract extraction. The intestinal length was also measured, and the digestive tract contents were classified based on the type and volume. Other parameters examined included relative gut length, the proportion of each kind of feed, the index of the largest portion, and the trophic level. The results showed that the ratio of gut length to total length ranged between 0.51 and 0.67, indicating that *M. aculeatus* were carnivorous. Their diet's six categories of organisms included crustaceans, annelids, insects, phytoplankton, zooplankton, and detritus. Female *M. aculeatus* was found to primarily consume shrimp (77.88%), followed by additional detritus feed (19.53%) and complementary feed (3%). Meanwhile, the males consumed 99.04% shrimp as their primary diet, and the remaining 0.9% were complementary. The feed niche area for female and male *M. aculeatus* was 0.137 and 0.005, respectively, indicating a minimal diet selection. Based on the results, the larger the fish, the more limited the feed options available. That indicates domestication and reintroduction should be made to preserve genetic diversity through food formulation and spawning from natural stocks.

Keywords: Food, fresh water, leather fish, river

INTRODUCTION

Lesser spiny eel (*Macrognathus aculeatus* Bloch, 1786) is a tropical Southeast Asian freshwater fish found in Cambodia, Vietnam, Laos, Thailand, Malaysia, and Indonesia (Serajuddin et al. 1998; Pethiyagoda et al. 2008; Gupta 2016). Furthermore, these fish are mostly found in Indonesia's western regions, including Sumatra, Kalimantan, and Java islands. They also inhabit fresh-flowing waters like streams, rivers, ditches, and channels with muddy sand or gravel-sand bottoms. For example, in Yogyakarta, Indonesia, *M. aculeatus* have been observed at depths of over one meter in the Opak-Oya and Progo Rivers. These fish are typically captured in the morning or evening using nets and fishing rods. They can also be caught year-round, although the best results are obtained after rains stop a few days when the water is clear. *M. aculeatus* are highly valued in the market for their ornamental appeal and as a food source (Herawati et al. 2021). Consequently, catching these fish is increasing to meet the demand of ornamental fish traders and protein needs.

Macrognathus aculeatus is essential to meet the community's nutritional needs in the Yogyakarta. In the Bantul District, *M. aculeatus* is in high demand and fetches a higher market price (US 4-5 $ per kg) than walking catfish (US 2-3 $ per kg), primarily sold alive. *M. aculeatus* has a living habit on the bottom of the waters and is generally caught with fishing rods and cast nets (Nurdawati and Yuliani 2009). Local gear such as net rods were used exclusively to catch bottom-dwelling fish, including *M. aculeatus* from the Progo River. The natural population of this species tends to decline rapidly in the Special Region of Yogyakarta, as observed by the reduced supply in the ornamental fish market, reduced consumption due to habitat changes, and increased exploitation (Ohee et al. 2018). Recently, natural or river water collection catches meet all demands for *M. aculeatus*. Unregulated exploitation of *M. aculeatus* can harm the populations in their natural habitat. There is almost no information on fisheries and *M. aculeatus* resources for management and conservation. *M. aculeatus* is included in the Low Risk or Near Threatened category (Froese and Pauly 2023). However, it is not yet included in the list of protected fish by the government of the Republic of Indonesia.

In Yogyakarta, *M. aculeatus* are crucial in increasing the fishing community's income while simultaneously addressing their protein demands. Despite the razor-sharp fins, the meat of these fish is surprisingly tender, making it a popular choice among locals. However, capturing them is difficult due to the species' limited population, with catches accounting for less than 1% of the total individual yield or weight (Djumanto et al. 2013). That highlights the alarming scarcity of *M. aculeatus* in their natural habitat, further exacerbated by excessive fishing and dwindling broodstock. Moreover, several studies showed that attempts to breed *M. aculeatus* have been unsuccessful, indicating that fishermen should continue to rely on river capturing; this problem can cause a reduction in their population, thereby posing a threat of scarcity and even extinction. On the other hand, a previous study reported that the survival of this species should be maintained due to their important role in the river's ecosystem (Verma and Alim 2013). Therefore, several preservation methods have been developed, including domestication, spawning actions, and preventing juveniles from spawning.

Based on previous reports, there are only a few studies on *M. aculeatus*, particularly on the feeding habits of the fish in Yogyakarta's Progo River, which have a distinct ecosystem character. The feeding habits of *M. aculeatus* have been studied in the Musi River in South Sumatra Province, and the results showed that crustaceans, gastropods, pelecypods, pisces, insects, and litter were the main component of their diet (Nurdawati and Yuliani 2009). Furthermore, seasonal rainfall and drought have been reported to affect the number of prey species in the Progo River ecosystem. Therefore, this study aims to collect reliable data on feeding patterns and preferences as a first step in domesticating *M. aculeatus*.

MATERIALS AND METHODS

Study area

The Progo River originated from Temanggung District, Central Java, Indonesia and flowed approximately 140 km through the Magelang District and the western part of the Yogyakarta Special Region (DIY), Indonesia. Furthermore, it flowed across the Yogyakarta for roughly 56 km, with the Kaminjoro Dam positioned approximately 20 km from the estuary. The downstream river was 100 and 150 meters wide and one to four meters deep. The *M. aculeatus* fishing station was located 100 meters downstream of the Kaminjoro Dam in Yogyakarta (-7°52'43.7"S 110°15'58.4"E), as shown in Figure 1. During the six-month fishing season, sampling was conducted in the Progo River's lower regions between September 2020 and March 2021.

Procedures

The fishing spot was selected based on information from a local fisherman that a significant population of *M. aculeatus* inhabited the Kaminjoro Dam at a depth of 1-3 meters. Furthermore, the fishing location was around 100 meters downstream of the dam structure, with a little water flow, the substrate was muddy sand, and the riverbank was completely covered in plants. As a result, this station's water level rose during the rainy season, flooding the surrounding area.

The fishing rod with hook number 7 and commercial feed components ingredients was used to catch *M. aculeatus* in the morning. The samples were captured and preserved in plastic boxes with ice to keep them fresh. That method is done to inhibit the digestive process in the digestive system, followed by transportation to the laboratory for further examination.

Stomach contents analysis was performed on 99 specimens among the 120 collected samples. Each sampled specimen's total length (nearest 1 mm) and weight (nearest 0.1 g) were then measured. After mounting the fish on a wax plate, the abdomen was dissected, starting near the anus. The incision was continued vertically to the vertebrae bone using surgical scissors, then forward to the base of the pectoral fins and ended beneath the pectoral.

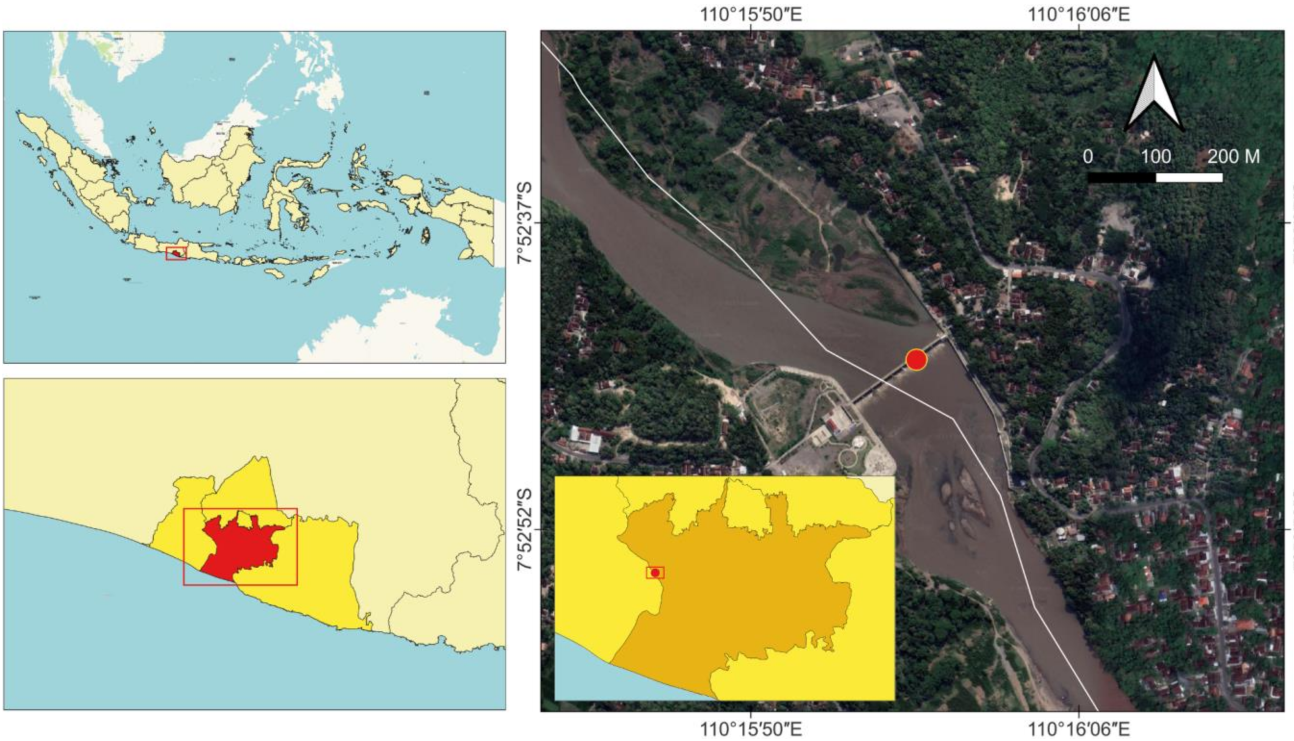

Figure 1. A map shows a *Macrognathus aculeatus* fishing ground in the lower reaches of the Progo River, about 100 meters from the Kaminjoro Dam, Yogyakarta, Indonesia

Next, the intestinal length was measured using a ruler from the base of the esophagus to the anus (nearest 0.1 cm). For further analysis, the contents of the digestive system were stored in plastic bottles and preserved in a 5% formaldehyde solution.

The digestive tract was dissected from the beginning of the stomach to the base of the anus. The contents were scraped off with a spatula and poured into a petri dish. On graph paper, food items in the petri dishes were positioned to determine their area, kind, and volume. Furthermore, standard light microscopes were used to identify small food items. Next, macro-sized food observations were carried out directly, followed by manual identification to make them more visible through a binocular microscope. Finally, a stereo microscope was used to determine the digestive sample kinds. Next, the digestive system's prey items were classified at the appropriate taxonomic level. Each prey item in the stomach was counted in quantity, volume, and frequency. In addition, the *M. aculeatus* sex was classified as male if the observed individual possessed testes and female with the observation of ovaries.

Data analysis

Macrognathus aculeatus can be classified as carnivores, herbivores, or omnivores using the morphological variable of gut length relative to the total length. In addition, the gut length ratio to total length can also be used to identify feed groups within each age group.

Relative Gut Length (RGL) was calculated with the formula (Biswas 1993):

$$RGL = \frac{\text{intestinal length}}{\text{total length}}$$

Where: RGL values < 1 denoted carnivores, 1-3 indicated omnivores, and > 3 referred to herbivores.

The preponderance index, also known as the significant proportion index, was a formula used to determine eating habits, namely the percentage of the most consumed feed types. Furthermore, the preponderance index was obtained by multiplying the frequency of occurrence by the volume of feed consumed by the prey with the following formula (Biswas 1993):

$$IP = \frac{V_i O_i}{\sum V_i O_i} \times 100$$

Where: IP denotes the preponderance index, while Vi and Oi indicate the volume and frequency of specific feeds (i) in the fish menu, respectively. Preferences for various types of feeding and species specialization were evaluated using the criteria, where IPs of > 40%, 4%-40%, and <4% were for the main, complementary, and supplementary feed, respectively.

The trophic level of a fish was determined based on the relationship between the trophic status of natural food and the eating patterns, which enabled classification within the ecosystem's food web. The following formula can determine the organism's trophic level (Biswas 1993).

$$TP = 1 + \sum \left(\frac{T_{tp} \times IP}{100}\right)$$

Where: TP denotes the trophic level of fish, Ttp denotes the trophic level of the p-th food group, and IP means the index preponderance. Values of <2.49, 2.5-2.99, and >3 indicated herbivores, omnivores, and carnivores, respectively. Fish species were classified into five trophic levels: (i) Herbivores (eat aquatic plants, algae, and other animals), (ii) Piscivores (eat fish), (iii) Carnivores (eat insects, arthropods, and other animals), (iv) Omnivores (eat a balanced diet of plants and animals), and (v) Detritivores (eaters of litter, detritus or sediment).

Feed niche breadth was used to determine the competition for food resources available to an organism within a species and across species or sizes. Furthermore, the food niche breadth value was standardized to be between 0 and 1, and it was calculated with the following formula (Biswas 1993):

$$Bi = \frac{1}{(n-1)}\left[\frac{1}{(\sum P_{ij}^2)} - 1\right]$$

Where: Bi denotes the standardized niche breadth index, pij denotes the proportion of predatory food i on prey j, and n means the total number of items (resources). Bi ranged from 0 (species consumes only one item) to 1 (species exploits available items in equal proportion). Values of < 0.4, 0.4-0.6, and > 0.6 were considered low, moderate, and high, respectively.

RESULTS AND DISCUSSION

The morphometry of the *M. aculeatus* is presented in Figure 2. The number of *M. aculeatus* caught in this study was 99, consisting of 45 females and 54 males. Among the females, the average length and weight were 33.4 cm (range 24.0-41.8 cm) and 132.0 g (range 16.0-239.0 g), respectively. Meanwhile, males' average length and weight were 30.8 cm (range 21.8-51.0 cm) and 98.3 g (range 33.0-372.0 g), respectively. The digestive system examination revealed that 31 female and 32 male individuals contained food, while the remaining were empty (36.36% emptiness). Based on sex, 14 females (31.11%) and 22 males (40.74%) had empty intestines. The results showed that the males had nearly three-fourth of the females' empty intestine contents.

The relative gut length of the *M. aculeatus* (Table 1) can be used to determine the type of food consumed by the fish. Furthermore, the intestinal length in each group varied, ranging from 21.8 to 51.0 cm. For example, in the <30, 30-40 cm, and >40 cm total length group, the gut length was 0.51-0.62, 0.62-0.67 cm, and 0.66-0.67 cm, respectively.

Macrognathus aculeatus were generally carnivorous based on the relative gut length ranging from 0.51 to 0.67. The results showed the value of the relative gut length increased along with the total length of the fish.

Table 1. Number of individual samples, size class, intestine length, relative gut length, and *Macrognathus aculeatus* food category

Length group (cm)	n (individual)	Gut length (cm)	Average gut length (cm)	Relative gut length	Average relative gut length	Eater category
30<	23	21.8-29.8	26.54	0.51-0.62	0.58	Carnivore
30-40	35	30.0-37.8	33.77	0.62-0.67	0.61	Carnivore
> 40	5	40.5-51.0	43.52	0.66-0.67	0.66	Carnivore

Table 2. Preponderance index (%) by sex and length group

Food category	Food item	Sex		Feed group	Length group (cm)			Feed category
		Female	Male		<30	30-40	>40	
Shrimp	*Macrobrachium* sp.	77.884	99.041	*	89.59	90.25	100	*
Worm	*Tubifex* sp.	0.010	0.226	***	1.81	0.00	0	***
Insects	Dragonfly nymph	0	0.007	***	0.06	0.01	0	***
Phytoplankton	*Synedra* sp.	2.365	0.098	***	0.90	1.11	0	***
Phytoplankton	*Volvox* sp.	0.020	0.007	***	0.01	0.02	0	***
Phytoplankton	*Navicula* sp.	0.107	0.002	***	0.10	0.01	0	***
Phytoplankton	*Merismopedia* sp.	0.004	0.001	***	0.01	0.00	0	***
Phytoplankton	*Rhizosolenia* sp.	0.004	0	***	0.01	0.00	0	***
Phytoplankton	*Melosira* sp.	0.033	0	***	0.00	0.02	0	***
Zooplankton	*Cyclops* sp.	0.045	0	***	0.00	0.02	0	***
Digested organic matter	Detritus	19.527	0.618	*** (M), ** (F)	7.52	8.57	0	** <30 cm, **30-40 cm, ***>40 cm

Note: * main feed, ** complementary feed, *** supplementary feed

Table 3. Feed niche breadth in each sex group and length group

Counting	Sex		Length group (cm)		
	Female	Male	<30	30-40	>40
$\sum P_i^2$	0.645	0.981	0.809	0.822	1.000
Niche breadth	1.550	1.019	1.237	1.217	1.000
Standardization	0.137	0.005	0.059	0.110	0

Figure 2. Specimen photography of *Macrognathus aculeatus* (Bloch, 1786) caught in the lower reaches of the Opak River, Yogyakarta, Indonesia. Female, 20.5 cm TL

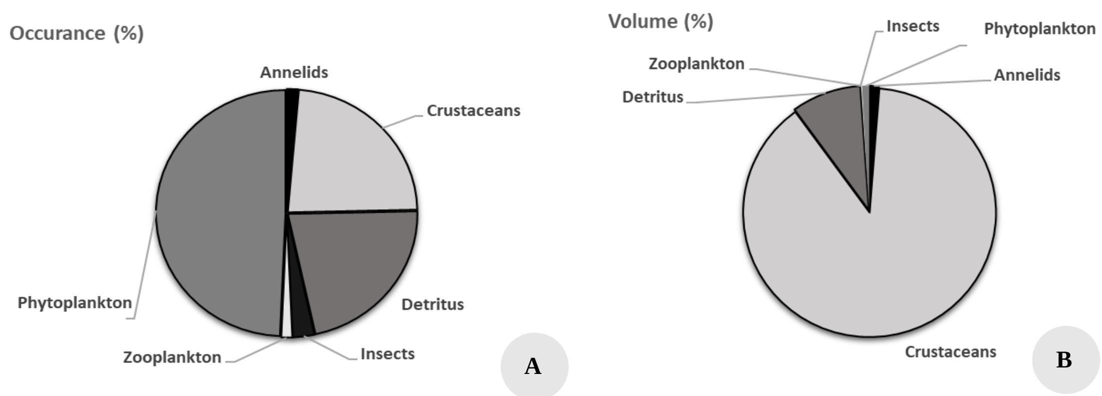

Figure 3. The composition of the feed types of *M. aculeatus* grouped based on the frequency of occurrence (A) and the volume of the feed (B)

The grouping of food composition, which includes annelids, crustaceans, detritus, insects, zooplankton, and phytoplankton, is presented in Figure 3. The frequency of occurrence shows that for each type of feed, phytoplankton has the highest frequency (49.32%), followed by crustaceans (23.29%) and detritus (21.92%), while annelids and zooplankton each are 1.37%. Based on the volume of feed in the fish stomach, the crustacean-type feed has the highest volume (88.76%), followed by detritus (8.92%) and annelids (1.23%). In contrast, insects, zooplankton, and phytoplankton have a total volume of 1.08%.

Based on the preponderance index, shrimp was the main feed for the male with an IP value of 99.04%, while other types of feed were complementary, as shown in Table 2. However, slightly different results were obtained among females with the same main feed with an IP value of 77.88%. Furthermore, detritus with an IP value of 19.53% and other types of feed were complementary.

The preponderance index value obtained for each size group showed that shrimp was the main feed with IP: 89.59%, 90.25%, and 100% for samples with sizes of <30 cm, 30-40 cm, and >40 cm, respectively. Furthermore, detritus served as supplementary feed for the <30 cm and 30-40 cm groups but as additional feed for the >40 cm. The results showed that the larger the length group, the higher the choice of shrimp. On the other hand, the worm was the highest additional feed for male fish and the <30 cm size group.

Niche breadth indicated whether an organism was a generalist or a specialist using available forage resources. The exclusive dependence of an organism on one of the available feed sources (specialist) indicates that it has a narrow niche. The analysis results (Table 3) showed that the male (Bi: 0.050) and female (Bi: 0.137) *M. aculeatus* had a very narrow feed niche. Similar results were also revealed in the length groups <30 cm, 30-40 cm, and >40 cm, with Bi of 0.059, 0.110, and 0, respectively. In the 30-40 cm long and the female groups, the range of the feed niche was more expansive compared to others.

Based on sex, female fish have a wider feed niche than males. According to the length, samples with a size <30 cm had the widest feed niche, which decreased along with increasing length. These results showed that female and young *M. aculeatus* could receive more diverse food types.

Discussion

The abundance of *M. aculeatus* in the Progo River was very low, causing a low catch in this study. That was due to the limited suitable habitats, which caused differences in the abundance of fish at each location (Nurdawati and Yuliani 2009). Furthermore, the feed was highly correlated with a particular water fish species. A previous study showed many factors influencing spatial distribution, including behavior in habitat selection and environmental factor interactions (Suresh et al. 2006). This election behavior was determined by fish activities, among others grouped in foraging and spawning activities (Craig and Crowder 2002). Fish tended to forage in areas rich in preferred food resources (Stenberg and Persson 2005), causing the *M. aculeatus* to occupy certain areas with a lot of feed (Abujam et al. 2013). *M. aculeatus* often remain in specific habitats throughout their lives and must adapt to prey on food available in these areas throughout the year (Gupta 2016). The same species occupying different habitats can eat different types of food (Nakazawa 2020), while the diet in several of the same regions still varies. Several studies showed that the feed consumed depended on age and level of growth. The timing and extent of diet and feeding habits changes varied between species, often followed by feeding style or habitat changes (Volkoff and Peter 2006).

Macrognathus aculeatus habitats included flowing waters, rivers, streams, or channels in the lowlands or adjacent to estuaries. Furthermore, the distribution of their habitats in Yogyakarta was relatively limited downstream of the river. This made the preferred fishing location very limited to the river flow, which was calm and fairly deep (Suresh et al. 2006; Djumanto et al. 2013); the low number of suitable habitats caused the *M. aculeatus* population density to be very low. The number of *M. aculeatus* caught in this study represented the population state in their habitat. In addition, catching fish was easier in the morning when the sun was shining with commercial pellet baits. Catches were also relatively high in the rainy season, especially after the rains in the upstream stop for a few days, so the water is fairly clear and calm, and the ratio of males to females was relatively balanced. The rainy season was believed to trigger the formation of spawning groups. During hunting for prey, fish mainly relied on the sight and smell of the bait. The study results were inconsistent with the fishing season for *M. aculeatus* in the Musi River, Sumatra, during the dry season (Nurdawati and Yuliani 2009). The maximum length of fish caught in this study was shorter than those from the Musi River. It was assumed that the limited availability of food and habitat caused *M. aculeatus* in the river to have difficulty finding suitable food to grow more freely and longer.

In this study, the total intestinal emptying rate was 30.25%, with higher values obtained in males. These findings are similar to a study on *Mastacembelus armatus* (Lacepède, 1800) in the Ganga River, India, where the rate at 39% (Alam et al. 2020). Furthermore, the rainy season preceding the breeding season was characterized by increased feeding activity for *M. armatus* (Uthayakumar et al. 2013). Furthermore, the percentage of empty stomachs was influenced by the amount of available prey and the relatively limited food choice (Khaing and Khaing 2020). The limited feed availability caused an empty stomach or minimized the feeding time in the morning when fish were collected, thereby leading to low intestinal content (Nurdawati and Yuliani 2009). Variations in empty or near-empty stomachs were related to the fish-to-prey ratio. However, *M. aculeatus* preferred to feed on shrimp, which is also the feed source for other species; hence, competition occurred. That limited prey availability condition, leading to several empty stomachs.

The relative gut length of *M. aculeatus* varied between 0.51 and 0.67 and increased compared to the total fish length or older fish size groups, which remained constant at <1. A low RGL value indicated that the *M. aculeatus* was a carnivorous fish. The parameter also had a high correlation with the feed nature. Predatory fish have intestines that are typically short and straight. The feeding habits determined the intestinal length, with the meat-eating group having short intestines for easier meat digestion. Meanwhile, the intestines of herbivorous fish were longer and more circular than predatory fish because plant feed has an extended digestion period. *M. aculeatus* have relatively short and straight intestines, qualifying them as carnivores besides predatory. These findings are consistent with the intestinal length of *Mastacembelus aral*, which ranged from 0.54 to 0.68 mm (Abujam et al. 2013). RGL varied between young, adult, and elderly groups, but no statistically significant difference existed. Furthermore, the same RGL across all age groups and sizes indicated *M. aculeatus*, as carnivores do not constantly change their eating habits during growth.

The *M. aculeatus*'s intestines contained food classified into six broad categories: crustaceans, worms, phytoplankton, zooplankton, insect larvae, and detritus. Females consumed significant debris, including animal body parts, mud, and sand. Furthermore, shrimp was the primary food source for both sex, detritus was an additional source for females, while others served as a complementary feed. Due to the lack of large canine teeth capable of tearing the prey, *M. aculeatus* often swallow shrimp. Although they consume the same primary feed types, the sexes, and sizes vary slightly. These findings are consistent with the food consumed by *Mastacembelus pancalus* (Hamilton, 1822) in the Ganga River (Serajuddin and Ali 2005). The diet of *M. pancalus* was classified into seven major categories; all large fish groups were particularly fond of crustaceans (shrimp), while the young group preferred annelids (earthworms). Various foods' availability varies by month due to changes in the production or supply in the environment. The presence of sand and mud confirmed that fish, particularly females, hunt for prey immersed in sandy mud at the bottom of the water (Blaber 2001). Although the river riparian zone was densely vegetated with aquatic plants, no vegetation was in their intestines, which indicated aquatic vegetation was not a type of feed consumed by these fish.

Shrimp was the most preferred feed, and the preponderance index indicated this. It was also the most abundant food item in males, along with worms, while debris was dominant among females. That indicated *M. aculeatus* were carnivorous and forage on the bottom of the water. Furthermore, fish diets and feeding habits varied based on food availability and environmental ecology. For example, insect larvae comprised 63.1% of the feed on *M. aral* in the upstream district of Assam, India, followed by zooplankton (20.02%), others (10.59%), as well as crustaceans, annelids, and mud (6%) (Abujam et al. 2013). Similar findings were reported for *M. armatus* species, which exhibited nearly identical essential feeding habits. Diverse food intakes indicated that their habitats have varying levels of food availability (Serajuddin and Ali 2005). Therefore, the proportion of various feed preferences can be correlated with their availability and the fish's habitat at a certain time. Furthermore, food availability determined fish diets influenced by biotic and abiotic environmental factors. Based on the feed type consumed, fish were classified as detritivores, herbivores, carnivores, or omnivores. They can also be classified as euryphagous, which consumes a wide variety of food, stenophagous with a limited variety of food, and monophagous with only one feed (Pavlov and Kasumyan 2002). *M. aculeatus* ate shrimp exclusively, classifying them as euryphagous carnivores with a limited prey selection. In addition, food consumption patterns were affected by changes in the rainy season and the quality and quantity of available food organisms.

In the Progo River, *M. aculeatus* have a limited food niche due to their reliance on several unbalanced feed groups. These findings are consistent with the species in the Musi River, which preferred crab and shrimp in large quantities, while other types of feed were scarce and unbalanced (Nurdawati and Yuliani 2009). Fish with a sufficiently large feed niche area can adapt to changes in available food resources. The greater the value of the niche area, the more generalist and non-selective the food pattern of the organisms consumed. Meanwhile, the smaller the area, the more selective the fish were in their food selection. Although *M. aculeatus* had a small food niche, they can grow significantly larger in the Musi River due to their vast feed habitat, with abundant crabs and shrimp. The abundance of prey in the extensive habitat can provide sufficient prey and reduce competition with other fish types. Small fish can also occupy a limited niche and become more selective in their food selection (Volkoff and Peter 2006). Only a small part of the available feed resources in waters are favored by fish, which depends on the food size, the food availability in nature, and the appetite.

In conclusion, *M. aculeatus* eat various food items, including crustaceans, annelids, insects, phytoplankton, zooplankton, and detritus. Furthermore, shrimp was reported to be the preferred food, followed by detritus, worms, and others. The *M. aculeatus* was a critical economic fish in inland fisheries, which served as a source of food and ornamental fish, with conservation and domestication potential. This study determined the gut length to the total length to be <1. *M. aculeatus* were classified as carnivores and bottom feeders due to consuming shrimp and worms with a primary diet similar to other meat feeder groups. The results showed that feeding habits were similar between sexes and size groups. Due to the breadth of their feed niche and the diversity and adaptability of their diets, these fish were less capable of broadening the food spectrum in response to feed availability and habitat degradation.

Moreover, commercial *M. aculeatus* feed was recommended to be formulated following the nutrient necessities in their natural diet to ensure successful aquaculture. Meanwhile, in-situ research is needed to ascertain the nutritional requirements of fish from wild seed and brood collections to assess the potential for domestication. Furthermore, spawning technique and seed reintroduction is expected to help manage and conserve this species in public waters.

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