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Feeding Ecology and Bio-indices of *Pomadasys maculatus* (Bloch, 1793) from Hooghly-Matlah Estuary, West Bengal, India

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The present study investigated the seasonal variation in bio-indices, feeding intensity, and diet composition of *Pomadasys maculatus* (Bloch, 1793) from the Hooghly-Matlah estuary, West Bengal, India. A total of 492 specimens, ranging from 97-190 mm in total length and 14.07-123.31 g in body weight, were analysed over a one-year period (February 2022 to January 2023). Indices *viz.*, Relative length of gut (RLG), Gastro-somatic index (GaSI), Hepato-somatic index (HSI), Gonado-somatic index (GnSI), Stomach fullness index (SFI), and Vacuity index (VI), were evaluated to understand feeding ecology and reproductive condition. The RLG ranged from 0.70 to 0.77 with no significant seasonal variation, confirming the carnivorous feeding habit of the species. Significant seasonal variations ($p < 0.05$) were observed in GaSI, HSI, GnSI, SFI, and VI, indicating marked changes in feeding activity, energy allocation, and reproductive status. GnSI attained its highest values during the post-monsoon season, suggesting peak gonadal maturation and spawning, whereas GaSI and SFI were lowest during the monsoon, reflecting reduced feeding activity during reproduction. Of the stomachs examined, 59.15% contained food, while 40.85% were empty, with an overall mean vacuity index of 40.87%. Gut content analysis revealed that crustaceans constituted the dominant prey, with semi-digested shrimp, *Acetes* spp., shrimp remains, fish remains, and semi-digested fish being the principal dietary components. Seasonal variations in prey composition indicated shifts in prey availability and feeding preference, while cluster analysis demonstrated high dietary similarity (70-75%) between the pre-monsoon and post-monsoon seasons. The study demonstrates that feeding activity and energy allocation in *P. maculatus* are closely linked with seasonal reproductive cycles and confirms its role as a carnivorous predator in the Hooghly-Matlah estuary. These findings provide important baseline information for understanding the trophic ecology of the species and support ecosystem-based fisheries management and conservation of estuarine fish resources.

(***Key words:*** *Diet composition, Feeding indices, Hooghly-Matlah estuary, Pomadasys maculatus*)

Marine fisheries constitute a vital component of the Indian fisheries sector by contributing significantly to food and nutritional security, employment generation, livelihood support, and foreign exchange earnings. According to the latest estimates of the ICAR-Central Marine Fisheries Research Institute (CMFRI, 2024), India's marine fish landings were approximately 3.45 million tonnes during 2024, representing a marginal decline from the 3.53 million tonnes recorded in 2023. The eastern coast of India supports diverse marine and estuarine ecosystems that sustain numerous commercially important finfish and shellfish resources. Among the maritime states, West Bengal occupies a unique position because of its extensive estuarine network, productive coastal waters and the ecologically significant Sundarbans mangrove ecosystem. The state possesses a coastline of about 158 km encompassing the districts of North 24 Parganas, South 24 Parganas, and Purba Medinipur, and recorded an estimated marine fish production of 233,148 tonnes during 2024. Among these regions, the Hooghly-Matlah estuarine system in South 24 Parganas serves as one of the most productive fishing grounds, supporting rich biodiversity and providing livelihood to thousands of artisanal fishers.

Estuaries are among the most productive aquatic ecosystems, functioning as important nursery, feeding, breeding and migration grounds for numerous marine and estuarine fishes. Their high nutrient availability, dynamic salinity gradients and abundant food resources

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support diverse fish assemblages and play a crucial role in maintaining coastal fisheries. Understanding the biology and ecology of estuarine fishes is therefore essential for sustainable fisheries management, particularly under increasing anthropogenic pressures and climate-driven environmental changes.

The family Haemulidae (grunts) comprises more than 130 species distributed among approximately 17 genera worldwide and is widely distributed throughout tropical and subtropical marine waters of the Atlantic, Indian, and Pacific Oceans. Members of this family generally inhabit shallow coastal waters, estuaries, lagoons, coral reefs, and soft-bottom habitats, although some species occur at depths exceeding 100 m (Konchina, 1977; Randall, 1995). Haemulids are predominantly carnivorous, feeding mainly on benthic invertebrates and small fishes, thereby serving as important intermediates in coastal food webs by transferring energy from lower to higher trophic levels. Several species support valuable commercial and artisanal fisheries because of their high market demand and nutritional value.

Among the haemulids, the genus Pomadasys represents the largest and one of the most economically important genera within the family. The saddle grunt, *Pomadasys maculatus* (Bloch, 1793), is a demersal species distributed throughout the Indo-West Pacific region, including the coastal waters of India, Sri Lanka, Bangladesh, Southeast Asia, and northern Australia. It commonly inhabits sandy and muddy bottoms of coastal waters and estuaries at depths ranging from approximately 20 to 110 m (Amtyazv *et al.,* 2014). Like other grunts, *P. maculatus* is capable of producing characteristic grunting sounds by grinding its pharyngeal teeth (Parenti, 2019). The species is commercially exploited by trawl nets, gill nets, and other artisanal fishing gears and contributes substantially to the coastal fishery landings of several Indo-Pacific countries.

Knowledge of biological parameters, feeding ecology, and trophic relationships is fundamental for understanding the ecological role of fish populations and for developing science-based fisheries management strategies. Bio-indices such as gonadosomatic index, hepatosomatic index, stomach fullness etc. provide valuable information on growth pattern, physiological condition, reproductive status, energy allocation, and overall health of fish populations. These parameters are widely used as indicators of habitat quality, environmental variability, and population dynamics.

Diet composition and feeding ecology are equally important aspects of fisheries biology because food availability directly influences growth, survival, reproduction, and population productivity. Stomach content analysis remains one of the most reliable approaches for investigating trophic ecology and resource utilization in fishes (Hyslop, 1980). Information on diet composition helps elucidate trophic position, feeding strategy, niche breadth, prey selectivity, and ecological interactions within aquatic communities (Wootton, 1992; Winemiller, 1989; Krebs, 1998; Nagelkerken *et al.,* 2006; Layman *et al.,* 2007; Hammerschlag *et al.,* 2010). Such information is indispensable for ecosystem-based fisheries management, particularly in estuarine ecosystems where environmental conditions and food availability fluctuate seasonally.

Despite the commercial importance of *P. maculatus*, biological and trophic ecological information on the species from the Hooghly-Matlah estuary and the eastern coast of India remains scarce. Existing studies have primarily focused on taxonomy, distribution, diversity, while comprehensive information on bio-indices, feeding intensity, and diet composition is largely lacking. Considering the ecological significance of the Hooghly-Matlah estuary and the increasing fishing pressure on its resources, detailed investigations into the biology and feeding ecology of *P. maculatus* are necessary.

Therefore, the present study was undertaken to evaluate the bio-indices and diet composition of *Pomadasys maculatus* from the Hooghly-Matlah estuary, West Bengal, India. The findings are expected to provide baseline information on the species' biological condition, feeding ecology, and trophic role, thereby contributing to sustainable fisheries management and conservation of this commercially important estuarine resource.

MATERIALS AND METHODS

Study area and sample collection

A total of 492 specimens of *Pomadasys maculatus* (Bloch, 1793) were collected monthly from Nagendra Bazar Fish Market, Diamond Harbour, South 24 Parganas, during February 2022 to January 2023. No samples were collected during May 2022 owing to the annual marine fishing ban imposed along the West Bengal coast. The fish landed at the market were captured from the Hooghly - Matlah estuarine system by commercial fishing vessels operating in the region. Fresh specimens were transported to the laboratory in insulated ice boxes and processed immediately upon arrival. Each specimen was identified following standard taxonomic keys, and total length (cm) and body weight (g) were recorded prior to dissection. The specimens were subsequently examined for bio-indices, feeding intensity, and diet composition.

Fig.1. *General view of Pomadasys maculatus*

Dissection and gut content analysis

The abdominal cavity of each specimen was opened through a ventral incision, and the sex was determined based on the morphology of the gonads (testes or ovaries). The digestive tract, liver, and gonads were carefully removed for further analyses. The stomachs were examined immediately whenever possible. In cases where immediate examination was not feasible, stomachs were preserved in 5% buffered formalin until analysis. Each stomach was opened longitudinally, and the contents were transferred to Petri dishes for qualitative and quantitative examination.

Food items were identified to the lowest possible taxonomic level using standard identification keys and grouped into major prey categories for dietary analysis.

Feeding intensity

Feeding intensity was assessed visually based on the degree of stomach fullness following the method of Zacharia (2004) and Zacharia and Abdurahiman (2004). The stomachs were classified into seven categories: Gorged, Full, Three-fourths (3/4) full, Half (1/2) full, One-fourth (1/4) full, Trace and Empty.

Feeding indices

Vacuity index (VI)

The vacuity index (VI), representing the percentage of empty stomachs, was calculated according to Vagh *et al.* (2021):

$$\textit{Vacuity index} = \frac{\textit{Number of empty specimens}}{\textit{Total number of specimens examined}} \times 100$$

Stomach fullness index (SFI)

The stomach fullness index (SFI) was estimated following Soares and Vazzoler (2001) as cited by Vagh *et al.* (2021):

$$\textit{Stomach fullness index} = \frac{\textit{Weight of the stomach contents (g)}}{\textit{Total weight of the fish - Weight of the stomach contents (g)}} \times 100$$

Bio-indices

Relative length of gut (RLG)

The relative length of the gut (RLG) was calculated according to Al-Hussaini (1949):

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

Gastro-somatic index (GaSI)

The gastro-somatic index was estimated following Bhatnagar and Karamchandani (1970) and Desai (1970):

$$Gastro\text{ - }somatic\ index = \frac{Weight\ of\ the\ stomach}{Weight\ of\ the\ body} \times 100$$

Hepato-somatic index (HSI)

The hepato-somatic index was calculated following Busacker *et al.* (1990):

$$Hepato\text{ - }somatic\ index = \frac{Weight\ of\ the\ liver}{Weight\ of\ the\ body} \times 100$$

Gonado-somatic index (GnSI)

Gonado-somatic index was calculated following by King (1995):

$$Gonado\text{ - }somatic\ index = \frac{Weight\ of\ the\ gonad}{Weight\ of\ the\ body} \times 100$$

Statistical analysis

The mean values of organic indices such as an RLG, GaSI, HSI, GnSI were tested for significant following ANOVA technique. Cluster analysis was carried out by using Bray-Curtis similarity index (Bray and Curtis, 1957) and dendrogram was generated to understand the similarity in feeding pattern among different seasons by using PAST ver 4.0 software.

RESULTS AND DISCUSSION

A total of 492 specimens of *Pomadasys maculatus* were analysed during the study. The sampled fish ranged from 97 to 190 mm in total length and from 14.07 to 123.31 g in body weight, representing a wide size range of the population inhabiting the Hooghly-Matlah estuary.

Diet composition

The seasonal diet composition indicated that the most frequent food item was semi-digested shrimp with highest during monsoon season by number (43.93 %) (Fig. 2a) and in post-monsoon season by occurrence (29.30 %) (Fig. 2b), while it was lowest during pre-monsoon season for both by number (17.54%) and by occurrence (8.83%) (Fig. 2a and 2b). *Acetes* sp. was found higher during post- monsoon season for both by number (31.10 %) and by occurrence (21.60 %) and lower during monsoon season. Shrimp remains and fish remains were higher during pre-monsoon season. Ribbon fish was found higher during post-monsoon season (0.53 % by number) and (1.59 % by occurrence) and nil during pre-monsoon and monsoon season. Pony fish was recorded in post-monsoon season (0.82 % by number and 2.24 % by occurrence). *Bregmaceros* sp. was found relatively more during pre-monsoon season for percentage of number (5.80 %) and percentage of occurrence (6.67 %) compared to post-monsoon season (2.75 % by number, 0.57 % by occurrence) and was nil during monsoon season. *Sepia*

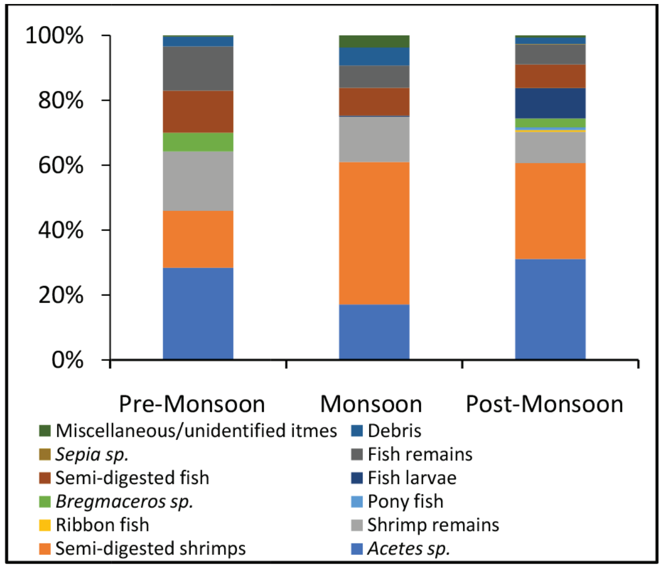

Fig. 2a. *Season wise percentage composition of food items in gut contents of P. maculatus (Percentage of numbers)*

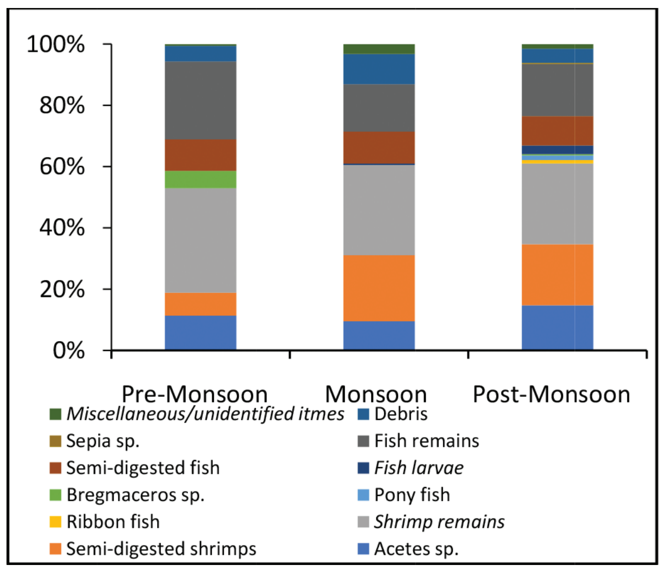

Fig.2b. *Season wise percentage composition of food items in gut contents of P. maculatus (Percentage of occurrence)*

sp. was found during only post-monsoon season, (0.09 % by number, 0.53 % by occurrence), and was nil during pre-monsoon and monsoon seasons. Fish larva was found only during monsoon (0.33 % by number, 0.57 % by occurrence) and post-monsoon season for (9.40 % by number, 4.21 % by occurrence). Semi-digested fishes were higher during pre-monsoon season (12.97 % by number) and in post-monsoon (14.01% by occurrence). Debris and miscellaneous items were found higher during monsoon season. So, the major preferred food item was semi-digested shrimps, *Acetes* sp., shrimp remains, semi-digested fishes and fish remains. Among varied food items semi-digested shrimp, occupied the first place in the diet constituting about 31.51 % and 22.36 % by number and occurrence respectively (Fig. 3).

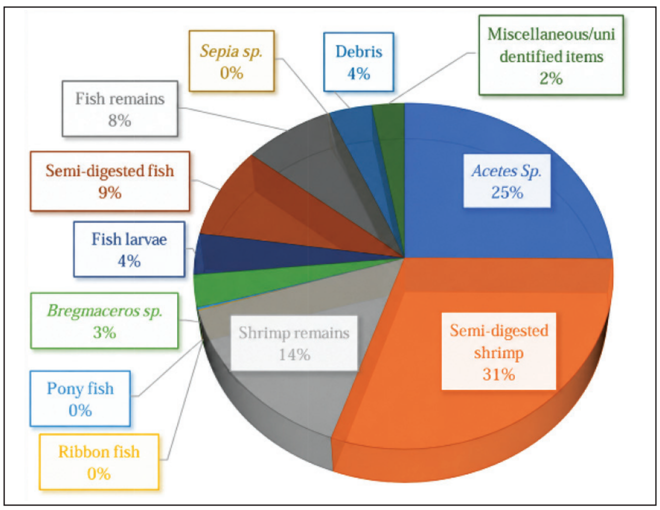

Fig. 3. *Annual average diet composition (Numerically) of P. maculatus*

Cluster analysis on the season-wise numerical percentage values of the prey groups revealed that, the similarity of food items between post-monsoon and pre-monsoon varied from 70 % - 75 % (Fig 4).

Fish feeding practices and diet composition place a strong emphasis on the way fish consume their food (Kume *et al.,* 1999). According to Hajisamaea *et al.* (2003), understanding a fish community's feeding ecology requires knowledge of its feeding habits. Fish feeding data could be used to determine the trophic interactions in the aquatic ecosystem (Abdel-Aziz and Gharib, 2007).

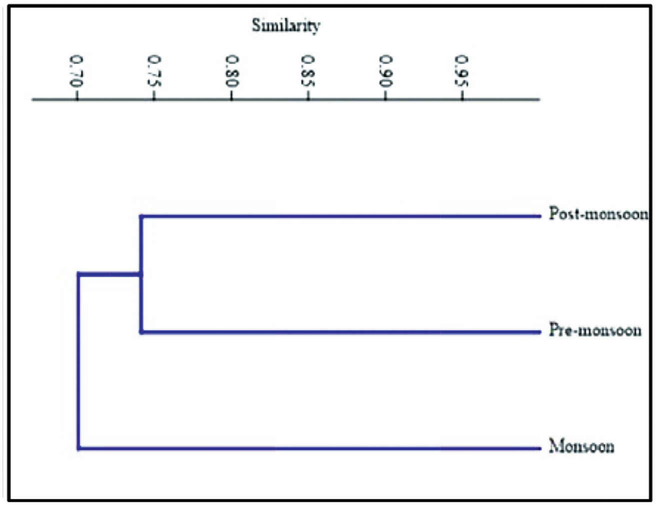

Fig. 4. *Dendrogram showing seasonal similarities of stomach contents (Numerically)for P. maculatus based on Bray-Curtis index*

Amtyaz *et al.* (2013) studied food and feeding habits of *P. stridens* and it was found that the fish was a carnivore which mostly consumed crustaceans (14.53 %), mollusks (11.57 %), small teleost fish (11.1 %), and polychaetas (1.99 %).

In most *Pomadasys* species, it has been noted that crustacean form the common food item (Venkataraman, 1960; Deshmukh, 1973; Hussain and Abdullah, 1980; Van Der Westhuizen and Marais, 1977; Blaber, 1980; Joubert and Hanekom, 1980). According to Shalloof and Khalifa (2009) food and feeding is directly correlated to the food availability in the surrounding which is affected by the seasonal variation and other factors. In the present study, the food analysis indicates that *P. maculatus* as carnivorous fish. In numerical method it was found that the major food items were semi - digested shrimp (31.51 %), *Acetes* sp. (25.27 %), shrimp remains (13.56 %), semi - digested fish (9.28 %), fish remains (8.49 %). The diet composition reported for other species mainly consumed crustaceans and teleost (Table 1).

Feeding intensity

Feeding intensity were classified into 3 categories: actively fed fish (full and gorged), moderately fed fish (1/2 full and ¾ full), and poorly fed fish (1/4, empty). For pooled data, the gorged was nil in March, April, June and

Table 1. *Comparative analysis of food and feeding habits of fresh water and estuarine cat fishes*

Species	Author	Diet composition	Location
P. jubelini	(Adebiyi, 2011)	Molluscs, crustaceans, fish, annelids and algae	Nigeria
P. stridens	(Karimi *et al.*, 2019)	Crustacean, mollusca, foraminifera, nematodes, echinodermata, annelida and miscellaneous	Persian Gulf
Brachydeuterus auratus	(Adebiyi and Akoka, 2012)	Crustaceans, fish, annelids, nematods, blue green algae, diatoms, detritus, unidentified material	Nigeria
Pomadasys maculates	(Salman *et al.*, 2003)	Crustacea, mollusca, worms, algae, sandy clay, detritus	Yemen
Pomadasys kaakan	(Vahabnezhad *et al.,* 2021)	Fishes, decapod, bivalve, gastropod, mentis shrimp, echinoderms, cephalopods	Oman sea
Pomadasys maculatus	Present study	Fish, semi-digested shrimp, *Acetes* sp., ribbon fish, pony fish, *Bregmaceros* sp., *Sepia* sp.	Hooghly-Matlah estuary

July. In case of male, the gorged was nil during March, April, June, July and October of 2022 and in January 2023, whereas in case of female, the percentage of fullness (gorged) was nil during March, April, June and July of 2022. Percentage of gorged stomachs were higher during post-monsoon (11.38 ± 5.11) season, followed by monsoon (3.37 ± 3.89) and pre-monsoon (2.5 ± 4.33) season, respectively (Fig. 5).

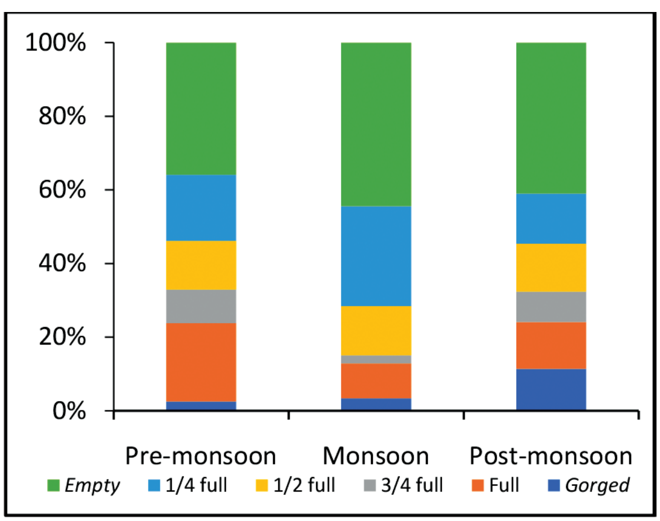

Fig. 5. *Season wise variation in feeding intensity of P. maculatus*

Based on the amount of food items contained and the degree of stomach distension caused on by feeding, the intensity of feeding was calculated (Mohammed *et al.,* 2018). Fish feeding intensity reflects the intensity and amplitude change of action and behaviour during fish feeding, which can directly reflect fish appetite (Zhou *et al.,* 2019).

Amtyaz *et al.* (2013) observed that out of 391 P. Stridenss tomachs examined, 4.84% were gorged, 9.76% were full, 2.85% were 3/4 full, 10.07% were 1/2 full, 14.39% were 1⁄4 full, 23.04% were little, and 35.04% were empty. The intensity of feeding was high during cold seasons than warm seasons. Such observation is in agreement with the present study, where out of 492 stomachs, 291 (59.15%) were with food and 201 (40.85%) were without food (empty). Among these 6.05 % stomachs were gorged, 13.88% were full, 6.32% were 3/4 full, 13.18% were 1/2 full, 19.71% were 1/4 full and 40.87 % were empty for pooled data.

Safi and Khan (2005) studied the feeding intensity of *P. maculatus* and observed that the percentage of feeding intensity was higher during January 2001 (28.57%) and it was decreased after January 2001 and became nil in March, April, May, July, August and September 2001and after that gorged samples gradually increased up to January 2002 (20%). It resembles with the present study, where, higher percentage of intensity of feeding in 6 categories of fullness of stomach occurred in December 2022 for pooled data and for male 17.02% and 22.22% respectively, whereas for female it was in January 2023 (17.86%). For pooled data, the gorged samples were nil in March, April, June and July. Incase of male, gorged samples were nil during March, April, June, July and October of 2022 and in January 2023, whereas incase of female, gorged samples were nil during March, April, June and July of 2022.

Feeding indices

Stomach fullness index (SFI)

Seasonal variations in the stomach fullness index (SFI) of *Pomadasys maculatus* are presented in Fig. 6. In males, the mean SFI values during pre-monsoon,

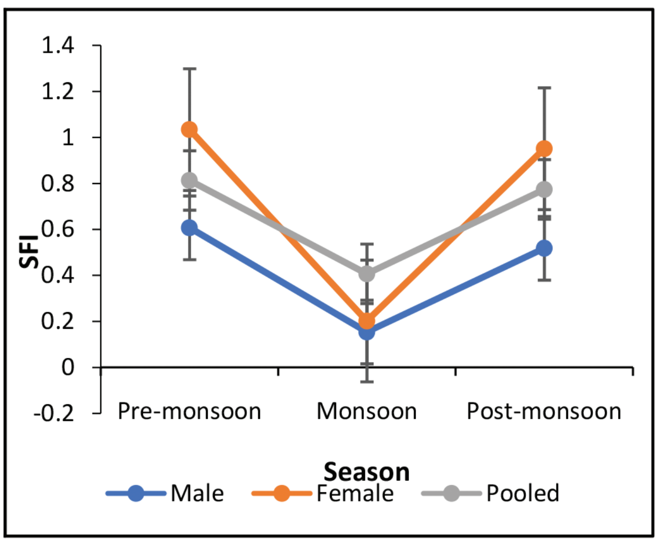

Fig. 6. *Seasonal variation in stomach fullness index (SFI) of P. maculatus*

monsoon, and post-monsoon were 0.61 ± 0.48, 0.15 ± 0.10, and 0.52 ± 0.33, respectively, whereas corresponding values in females were 1.03 ± 0.74, 0.20 ± 0.11, and 0.95 ± 0.58. In both sexes, SFI values were highest during the pre-monsoon and post-monsoon seasons and lowest during the monsoon season (Fig 6). Significant seasonal variations in SFI were observed ($F = 1996.25$, $p< 0.05$). Females exhibited higher mean SFI values (0.70) than males (0.41), indicating comparatively greater feeding intensity.

The seasonal pattern of SFI suggests that feeding activity in *P. maculatus* is closely associated with its reproductive cycle. The marked decline in SFI during the monsoon season coincided with the onset of gonadal maturation and spawning activity. Elevated GnSI values observed from September to January indicate that the spawning period extends over these months in both sexes. Reduced stomach fullness during the reproductive period may be attributed to the expansion of mature gonads within the abdominal cavity, leaving less space for stomach contents and causing a decline in feeding activity. Furthermore, a substantial amount of energy is diverted towards gonadal development and spawning, resulting in lower feeding intensity during this period.

Similar observations have been reported in haemulid fishes. Salman *et al.* (2003) found higher feeding intensity in female *P. maculatus* than in males and reported significant seasonal differences in stomach fullness, with maximum feeding activity occurring during autumn. Likewise, Robillard *et al.* (2008) demonstrated an inverse relationship between feeding intensity and reproductive activity, whereas Dadzie *et al.* (2000) suggested that increased feeding following spawning helps replenish energy reserves required for somatic growth and subsequent reproductive cycles. Safi *et al.* (2013) also reported enhanced feeding activity during cooler months, which is consistent with the higher SFI values observed during the pre- and post-monsoon seasons in the present study.

The recovery of SFI values during the post-monsoon season indicates a resumption of active feeding following spawning. Moreover, the observed seasonal fluctuations in SFI, together with the corresponding changes in GaSI, HSI, and GnSI, suggest a shift in energy allocation in *P. maculatus.* Feeding intensity decreases during gonadal maturation and spawning, while energy reserves accumulated in the liver are mobilized to support reproductive processes. Following spawning, feeding activity increases to replenish depleted energy stores and prepare for the next reproductive cycle. The significant seasonal variation in SFI thus reflects the combined influence of reproductive physiology and environmental factors on the feeding ecology of *P. maculatus*.

Variation in stomach fullness may also be influenced by ontogenetic shifts in feeding habits and prey size. Salman et al. (2003) and Nikolsky (1963) reported that the food spectrum and feeding intensity change with increasing body size, leading to considerable variation in stomach fullness among individuals. Such ontogenetic dietary shifts may partly explain the variability observed in SFI values in the present study.

Vacuity index (VI)

Seasonal variations in the vacuity index (VI) of *Pomadasys maculatus* are presented in Fig. 7. In males, mean VI values during pre-monsoon, monsoon, and post-monsoon were 39.97 ± 13.63, 50.12 ± 5.25, and 50.31 ± 24.63, respectively, whereas corresponding values in females were 29.06 ± 5.50, 40.71 ± 12.84, and 32.37 ± 27.04. In males, higher VI values were recorded during the monsoon and post-monsoon seasons, while females exhibited the highest mean VI during the monsoon season (Fig 7).

Overall, the vacuity index was higher in males (47.42%) than in females (34.15%), indicating a greater proportion of empty stomachs and comparatively lower

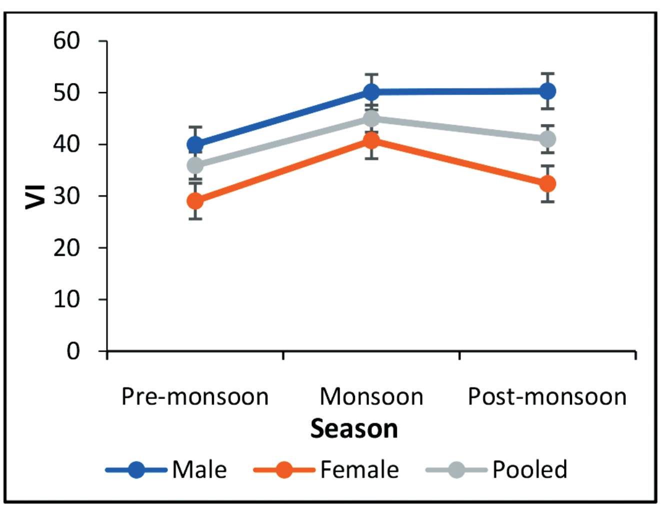

Fig. 7. *Seasonal variation in vacuity index (VI) of P. maculatus*

feeding intensity in males. Monthly analysis revealed maximum VI values in January (75%) for males and October (70.83%) for females, whereas minimum values were observed in November (22.72%) and December (10%) for males and females, respectively.

The seasonal variation in VI reflects changes in feeding activity associated with reproductive processes and environmental conditions. Higher VI values during the monsoon season corresponded with reduced stomach fullness and gastro-somatic indices, suggesting decreased feeding intensity during periods of gonadal maturation and spawning. Such reductions in feeding activity are commonly associated with increased allocation of energy towards reproductive processes and seasonal fluctuations in food availability and environmental parameters.

The lower overall vacuity observed in females compared to males indicates relatively greater feeding activity in females, which is consistent with the higher stomach fullness index (SFI) values recorded in females. The inverse relationship between VI and feeding-related indices (SFI and GaSI) further supports the notion that feeding intensity decreases during the reproductive period and recovers following spawning. Lower VI values recorded during November and December suggest enhanced feeding activity after spawning, possibly to replenish depleted energy reserves and support subsequent growth and reproductive cycles.

Overall, seasonal fluctuations in VI, together with variations in SFI, GaSI, HSI, and GnSI, indicate that feeding activity in *P. maculatus* is strongly influenced by reproductive physiology and seasonal environmental changes. The increased proportion of empty stomachs during the monsoon and early post-monsoon periods reflects reduced feeding associated with gonadal development, whereas lower vacuity during the cooler months indicates recovery of feeding activity and replenishment of energy reserves.

Bio indices

Biological indices are widely used in fisheries science to assess the physiological condition, growth, reproductive status, feeding intensity, and overall health of fish populations. These indices provide valuable information on the life-history characteristics of fish and their responses to environmental variations. Commonly used biological indices include the Gonado-Somatic Index (GSI), Hepato-Somatic Index (HSI), Relative Gut Length (RGL), Condition Factor (K), and Gastro-Somatic Index (GaSI).

Relative gut length (RLG)

The relative length of gut (RLG) ranged from 0.70 to 0.77 and exhibited only minor seasonal variations (Fig. 8). Similar values were observed during pre-monsoon and monsoon seasons, whereas females showed a slightly higher RLG and males a lower RLG during the post-monsoon period. The consistently low RLG values (<1) indicate that *Pomadasys maculatus* is predominantly carnivorous, and the limited seasonal fluctuations suggest that its feeding strategy remains largely unchanged throughout the year

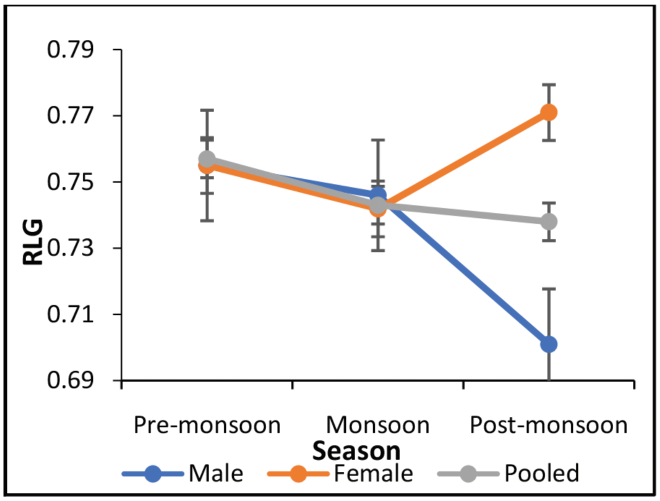

Fig. 8. *Seasonal values of relative length of gut (RLG) of P. maculatus*

Salman *et al.* (2003) reported RLG values ranging from 0.8 to 1.2 for *Pomadasys maculatus* and characterized the species as carnivorous. Similarly, Karimi *et al.* (2019) observed an RLG value of 0.98 ± 0.03 in *Pomadasys stridens* from the northern Persian Gulf, suggesting carnivorous to omnivorous feeding habits. According to Kramer and Bryant (1995), RLG values of 0.6-0.8 are typical of carnivorous fishes, whereas omnivorous and herbivorous species generally exhibit higher values. Variations in RLG among species and size groups may arise from differences in growth rates and dietary composition, as fish with faster growth tend to possess relatively longer intestines (Kramer and Bryant, 1995b). Moreover, the digestibility of plant, detrital, and animal-based diets can influence gut length (Pogoreutz and Ahnelt, 2014).

In the present study, the relative length of gut ranged from 0.70 to 0.77 and showed only minor seasonal fluctuations. Similar values were observed during the pre-monsoon and monsoon seasons, while females exhibited slightly higher RLG values and males slightly lower values during the post-monsoon period. However, these differences were not statistically significant. The consistently low RLG values (<1) indicate that *P. maculatus* is predominantly carnivorous, corroborating the findings of Salman *et al.* (2003). The limited seasonal variation in RLG further suggests that the species maintains a relatively stable feeding strategy throughout the year, without any marked shift in trophic habit.

Gastro-somatic index (GaSI)

The gastro-somatic index (GaSI) of *Pomadasys maculatus* exhibited distinct seasonal variations (Fig. 9). In males, GaSI values were 1.46 ± 0.70, 0.68 ± 0.10 and 0.99 ± 0.36 during pre-monsoon, monsoon and post-

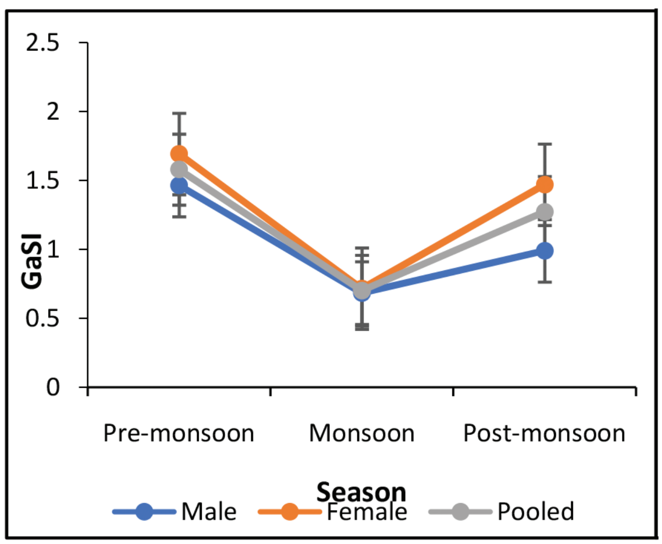

Fig. 9. *Seasonal variation in gastro-somatic index (GaSI) of P. maculatus*

monsoon seasons, respectively. Corresponding values in females were 1.69 ± 0.98, 0.72 ± 0.14 and 1.47 ± 0.66. For both sexes, the mean GaSI was highest during the pre-monsoon season and lowest during the monsoon season. One-way ANOVA revealed significant seasonal differences in GaSI ($F = 21.17$, $p < 0.05$), indicating seasonal variation in feeding intensity.

The gastro-somatic index, which represents the ratio of gut weight to body weight, is widely used as an indicator of feeding activity and nutritional condition in fishes (Desai, 1970; Ahmed *et al.,* 2022). Seasonal fluctuations in GaSI reflect changes in feeding intensity associated with physiological processes and environmental conditions. The significantly lower GaSI observed during the monsoon season may be attributed to reduced feeding activity associated with the onset of spawning and concurrent changes in environmental factors, particularly water temperature (Sakamoto and McCormick, 2006). Increased energy allocation towards gonadal development during reproduction is often accompanied by a decline in feeding intensity, resulting in reduced stomach fullness.

Similar seasonal trends have been reported in other members of the family Haemulidae. Vahabnezhad *et al.* (2021) reported lower GaSI values in Pomadasyskaakan during spring and higher values during autumn, with significant monthly variations ($p < 0.05$). Likewise, Kamali *et al.* (2004) observed minimum GaSI values in P. kaakan during the post-monsoon period, coinciding with peak spawning activity. Safi *et al.* (2013) reported higher feeding intensity in Pomadasysstridens during cooler months and lower values during warmer periods. In the present study, GaSI values were also relatively higher during the cooler months (November - February), ranging from 1.26 to 2.27 in males and 1.27 to 2.83 in females, suggesting enhanced feeding activity during these periods.

The observed seasonal differences in GaSI indicate that feeding activity in *P. maculatus* is strongly influenced by reproductive cycles and environmental conditions. Variations in prey availability and seasonal changes in habitat conditions may further contribute to fluctuations in stomach fullness and feeding intensity. These findings suggest that *P. maculatus* exhibits adaptive feeding responses to seasonal changes in resource availability and physiological demands.

Hepato-somatic index (HSI)

Seasonal variations in the hepato-somatic index (HSI) of *Pomadasys maculatus* are presented in Fig. 10. The mean HSI showed a gradual increase from pre-monsoon to post-monsoon in both sexes. In males, the mean HSI values were 0.62 ± 0.06, 0.83 ± 0.35 and 0.91 ± 0.34 during pre-monsoon, monsoon and post-monsoon

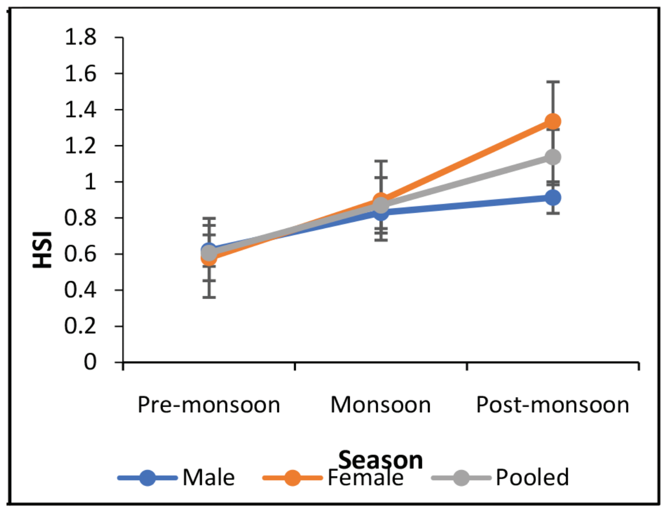

Fig. 10. *Seasonal variation of hepato-somatic index (HSI) in P. maculatus*

seasons, respectively. Corresponding values for females were 0.58 ± 0.16, 0.90 ± 0.23 and 1.34 ± 0.36. Significant seasonal differences in HSI were observed ($F = 34.769$, $p < 0.05$), indicating marked temporal changes in energy reserves and metabolic activity.

The hepatosomatic index is commonly used as an indicator of metabolic activity and hepatic energy storage in fishes (Verma and Prakash, 2019; Prakash, 2022). In the present study, HSI values increased progressively from pre-monsoon to post-monsoon, with relatively higher values recorded during the spawning season. Monthly observations revealed an increase in HSI during August in both males (1.28) and females (1.11), preceding the rise in gonado-somatic index, suggesting the accumulation of energy reserves in the liver prior to reproductive activity. The liver plays an important role in vitellogenesis and supplies nutrients required for gonadal maturation; therefore, elevated HSI values before and during spawning may reflect increased physiological activity associated with reproduction.

Similar findings have been reported in other haemulid fishes. Fehri-Bedoui and Gharbi (2008) observed that HSI values in *Pomadasys incisus* peaked approximately one month before spawning, indicating the involvement of hepatic reserves in reproductive processes. Likewise, Palazón-Fernández (2007) reported significant monthly variations ($p<0.01$) in HSI of *Haemulon plumieri*, with elevated values during reproductive periods. Batool and Siddiqui (2020) also recorded maximum HSI values during August in females and December in males, while Olapade and Tarawallie (2014) found that the pattern of HSI variation closely paralleled that of the gonado-somatic index in *Pseudotolithus senegalensis*.

In the present study, peak monthly HSI values were recorded during October in both males (1.38) and females (1.75), coinciding with the spawning period. The close correspondence between HSI and reproductive activity suggests that liver energy reserves are mobilized to support gonadal development and spawning. Thus, seasonal fluctuations in HSI of *P. maculatus* reflect changes in metabolic status and reproductive physiology, with increased hepatic activity occurring during periods of gonadal maturation.

Gonado-somatic index (GnSI)

Seasonal variations in the gonado-somatic index (GnSI) of *Pomadasys maculatus* are presented in Fig. 11. In males, mean GnSI values were 0.81 ± 0.23, 0.92 ± 1.09 and 3.09 ± 0.62 during pre-monsoon, monsoon and post-monsoon seasons, respectively. Corresponding values in females were 1.02 ± 0.58, 1.14 ± 1.43 and 5.12 ± 0.91. In both sexes, GnSI was lowest during the pre-monsoon season and reached its maximum during the post-monsoon season. Seasonal differences in GnSI were highly significant ($F = 12460.21$, $p<0.01$), whereas

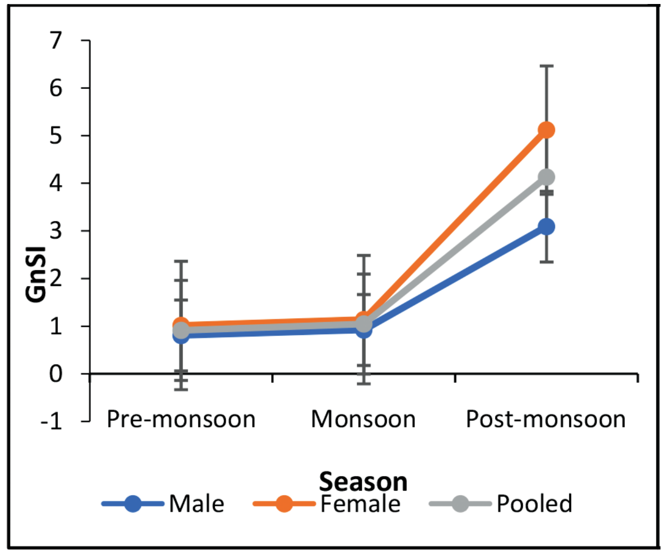

Fig. 11. Seasonal variation in gonado-somatic index (GnSI) of P. maculatus

no significant differences were observed between sexes, indicating synchronous reproductive activity.

The gonado-somatic index is widely used to assess reproductive condition and to determine the timing of gonadal maturation and spawning in fishes (King, 1996; Dadzie and Wangila, 1980). In the present study, elevated GnSI values during the post-monsoon season indicate that gonadal maturation and spawning activity predominantly occur during this period. Monthly observations revealed higher GnSI values from September to January in both sexes, with values ranging from 2.56 to 3.19 in males and from 3.26 to 4.41 in females. The lower GnSI values observed during June and July suggest spent and resting phases of the reproductive cycle.

Similar reproductive patterns have been reported for other haemulid species. Amtyaz *et al.* (2014) reported high GnSI values in *P. maculatus* from August to November along the Karachi coast, with peak values occurring during October and lower values during July. Likewise, Fehri-Bedoui and Gharbi (2008) observed GnSI values ranging from 0.16 to 7.88 in *Pomadasys incisus*, with declining values corresponding to spent and resting periods. Al-Nahdi *et al.* (2010) reported GnSI values between 0.4 and 5.5 in *Pomadasys commersonnii*, while Adebiyi (2013) and Agbugui (2013) recorded maximum GnSI values during September and October in *Pomadasys jubelini*, indicating peak spawning activity.

In the present study, females consistently exhibited higher GnSI values than males, reflecting greater investment in gonadal development and oocyte production. The occurrence of elevated GnSI values from September to January suggests that *P. maculatus* spawns primarily during this period in the Hooghly-Matlah estuarine system. Furthermore, GnSI showed a significant positive correlation with hepato-somatic index (HSI) in females ($r = 0.6782$, $p < 0.05$), indicating that hepatic energy reserves contribute to gonadal maturation and reproductive activity. The close association between HSI and GnSI suggests that energy accumulated in the liver is subsequently mobilized to support vitellogenesis and spawning.

Overall, the seasonal pattern of GnSI indicates a well-defined reproductive cycle in *P. maculatus*, with post-monsoon months representing the peak spawning season and pre-monsoon months corresponding to the resting phase.

CONCLUSION

The present study provides comprehensive information on the seasonal dynamics of bio-indices and feeding ecology of *Pomadasys maculatus* in the Hooghly-Matlah estuarine system, West Bengal. Gut content analysis revealed that the species predominantly feeds on crustaceans followed by fishes and molluscs, indicating a carnivorous feeding habit. The relative length of gut (RLG) values (<1) further confirmed the carnivorous nature of the species. Seasonal fluctuations in GaSI, SFI, HSI, GnSI, and VI demonstrated marked changes in feeding intensity and reproductive physiology. Feeding-related indices (GaSI and SFI) were highest during the pre- and post-monsoon periods and declined during the monsoon season, whereas HSI and GnSI increased during the post-monsoon period, indicating enhanced gonadal development and reproductive activity. Elevated GnSI values from September to January suggest that this period constitutes the principal spawning season of *P. maculatus* in the Hooghly-Matlah estuary. The significant positive relationship between HSI and GnSI, together with the inverse association of VI with GaSI and SFI, indicates a shift in energy allocation from feeding activity towards gonadal maturation during the reproductive period. Overall, *P. maculatus* exhibits pronounced seasonal changes in feeding and reproductive indices, reflecting adaptive responses to physiological demands and environmental conditions. The findings provide baseline information on the feeding ecology and reproductive dynamics of this commercially important haemulid species and contribute to a better understanding of its ecological role and resource management in the Hooghly-Matlah estuarine ecosystem.

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CONFLICTS OF INTEREST

The authors do not report any conflicting interests.

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