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Note

Biometric growth parameters and diet composition of *Mugil cephalus* Linnaeus, 1758 in Negombo Lagoon, Sri Lanka

N. T. P. Nimasha, H. A. C. C. Perera* and A. M. P. M. Abeysinghe

Department of Zoology and Environmental Management, Faculty of Science, University of Kelaniya, GQ 11600, Dalugama, Sri Lanka

Abstract

The Length-weight relationship, condition factor, and diet composition of the flathead grey mullet *Mugil cephalus* were studied in the Negombo Lagoon, Sri Lanka, from August 2022 to March 2023. The sampled specimens ranged between 16.9 and 32.0 cm in total length (TL) and 55.50 -and 291.70 g in weight. A negative allometric growth pattern was observed (b<3, t-test, p<0.05) with a significant positive correlation between length and weight expressed by the equation: $W=0.0266TL^{2.690}$, ($R^2=0.951$, n=100). Fulton's condition factor (K) of males and females were 1.0501 ± 0.0359 and 1.0048 ± 0.0123, respectively. The relative gut length (RGL) ranged from 1.52 to 3.18, and the gastrosomatic index (GaSI) ranged from 2.012 to 3.874. The average RGL (2.442 ± 0.146) indicated that the species was an omnivore. Stomach content analysis revealed that algae (30.86%), sand particles (25.71%), and detritus (23.43%) were the main food items. The occurrence of synthetic debris such as nylon fibres were also observed in the stomachs of flathead mullets during the study.

*Correspondence e-mail:
chinthap@kln.ac.lk

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The Negombo lagoon in Sri Lanka is considered one of the most productive estuaries, extending 12 km in length from south to north, and is closely associated with the fishing industry. There are 15 species of mullets known to exist in Sri Lankan estuaries (Gammanpila *et al*., 2016). They are considered a reliable candidate species in brackishwater aquaculture due to their euryhaline nature (Whitfield *et al.,* 2012). They can be classified into six groups based on their feeding habits: plankton feeders, herbivores, omnivores, slime feeders, foul feeders, and detritus feeders (Gammanpila *et al*., 2016). The juveniles and adults are hardy, eurythermal, and euryhaline and do not compete for food (Jamabo and Maduako, 2015). In general, mullets are benthic feeders (Rao and Babu, 2013). They consume detritus, diatoms, and microscopic algae (McDonough and Wenner, 2003). The flathead mullet *Mugil cephalus* (Family: Mugilidae) is one of the important food fish supporting the fishery resources of the lagoon (Islam *et al*., 2009; Mendis *et al.*, 2020). Catch structure analyses by different gear types, in some countries, have shown that the length of most of the speciments of the species caught is below the length at first maturity, which may severely affect the sustainability of this species (Mendis *et al*., 2015). The Negombo Lagoon faces adverse environmental issues due to changes in the catchment and rising external demand on the estuary and wetland for other purposes related to urban and industrial expansion (Mendis *et al*., 2015). This study aimed to analyse the length-weight relationship, condition factor, and diet composition of *M. cephalus* in the Negombo Lagoon, to provide baseline information for establishing the trophic and ecological status of the speciesin the lagoon.

The fish samples (n=100) were collected from fishermen's catch during August 2022 to March 2023, once a month from the Negombo fish landing centre, in Lellama on the west coast of Sri Lanka. Biological as well as fisheries data were also collected during the period. Collected samples were transported to the laboratory in the Department of Zoology and Environmental Management, University of Kelaniya, in ice box, and kept at -20^{0}C until analysed. The samples were thawed and blotted before dissection. Standard and total lengths (cm) were measured using a measuring board, while the weights (g) were taken to the nearest 0.1g using a sensitive electronic balance. The fish was dissected, and the stomach content was removed. The food and feeding habits of *M. cephalus* were studied by examining stomach contents preserved in 10% formalin solution. Based on visual observation, stomach fullness was classified into 5 categories namely, Empty, Half (1/2) full, One-fourth (1/4) full, Three-fourths (3/4) full, and Full (Das, 1977). The stomach contents were transferred into a petri dish and identified to the lowest taxonomic level. Larger food items were sorted out and subsequently the stomach contents were dropped on glass slides using a dropping pipette and examined under a light microscope (with magnifications up to ×100). The gut content evaluation was done using the frequency of occurrence method (Fatema *et al*., 2013 ; Asuquo *et al.,* 2015; Jambo and Maduako, 2015).

The relationship between total length and weight of the sampled fish was evaluated using the following equation (Khayyami *et al*., 2014)**:**
$W=aL^b$
where, W=Body weight in g, L=Total length in cm, a=Regression intercept, b=Regression coefficient

Fulton's condition factor (K) was estimated using the following relationship (Guisse *et al*., 2021):

$$K = \frac{100W}{L^3}$$

where, K = Condition factor, W = Body weight in g, L = Total length in cm

The deviation of the sex ratio from the hypothetical value of 1:1 was tested with the Chi-square (χ2) test: χ2=∑(p-p')2/p', where p is empirical, and p' is theoretical (expected) frequency (in the case of 50%). The gonads were observed to determine the sex of each fish. The maturity scale followed for this analysis is given in Table 1.

To evaluate the feeding intensity of *M. cephalus*, Gastrosomatic index (GaSI) was used (Lavanya, *et al.*, 2018).

$$\text{GaSI} = \frac{\text{Stomach weight}}{\text{Body weight}} \times 100\%$$

The fish samples were dissected, and the length of the guts was measured to the nearest 0.1 cm and weighted to the nearest 0.1 g. Relative gut length (RGL) was calculated using the equation (Lavanya *et al*., 2018):

$$\text{R.G.L.} = \frac{\text{LG}}{\text{TL}}$$

where, LG = Length of gut in cm, T = Total length of fish in cm

Each food group's dominance was evaluated using the following equation (Fatema *et al*., 2013 ; Asuquo *et al.,* 2015; Jambo and Maduako, 2015).

$$\text{Percentage frequency of occurrence} = \frac{\text{No. of stomachs were each food items is present}}{\text{Total no. of stomachs analysed}}$$

The minimum, maximum, and mean length and weight of *M. cephalus* from Negombo Lagoon are presented in Table 2.

The weight ranged from 55.50 - 291.70 g, and the recorded mean weight was 134.74±4.78 g. In the present study, the total length varied from 16.9 to 32.0 cm, and the estimated mean total length was 23.4±0.287 cm. The length frequency distribution of *M. cephalus* collected from Negombo Lagoon (Fig. 1) showed that the length size class 23-24 cm had the highest percentage frequency.

The length at first maturity of the species is reported as 30 cm in lagoons (Fishbase, 2003), which is lower than the maximum length observed in the present study. However, 97% of the fish were smaller than 30 cm. A previous study conducted in the Negombo Lagoon

Table 1. Maturity scale used in the classification of gonads of *M. cephalus* (Espino-Barr *et al*., 2016)

	Females	Males
Immature	Sexually immature, in which sex cannot be distinguished, the gonads appear as very fine filaments.	
Developing	Oocytes cannot be observed, ovaries are pale pink	Testis start to develop and are light-coloured
Maturing	Oocytes are beginning to develop, with an opaque appearance, and the colour of the ovaries starts to turn dark pink	Testis also shows a darker and opaque colour.
Mature	Ovaries are rose-orange, oocytes are big and transparent	Testes are whitish
Ripe	Gonads show an intense blood supply; ovaries and testes show brighter colours.	
Spent	Both ovaries and testes are empty, gonads' colour tend towards a dark pink.	

Table 2. Ranges and mean values of total length (TL) (cm), weight (g), and calculated K values of *M. cephalus*

	TL (cm)		Weight (g)		K
	Min - Max	Mean ± SD	Min – Max	Mean ± SD	Mean ± SD
Pooled	16.9 – 32.0	23.486 ± 2.865	55.50 - 291.70	134.74 ± 47.79	1.0079 ± 0.00864
Male	16.90 -32.00	23.49 ± 4.29	55.5 - 276.0	141.1 ± 62.5	1.0501 ± 0.0359
Female	21.0 - 31.5	25.081 ± 2.538	98.42 - 291.70	163.15 - 51.88	1.0048 ± 0.0123
Immature	17.50 –27.40	22.53 ± 2.19	59.00 - 206.00	116.06 ± 30.89	0.9960 ± 0.0724
Mature	21.50 - 31.5	26.18 ± 2.355	100.5 - 283.5	189.3 ± 47.0	1.0373 ± 0.0735

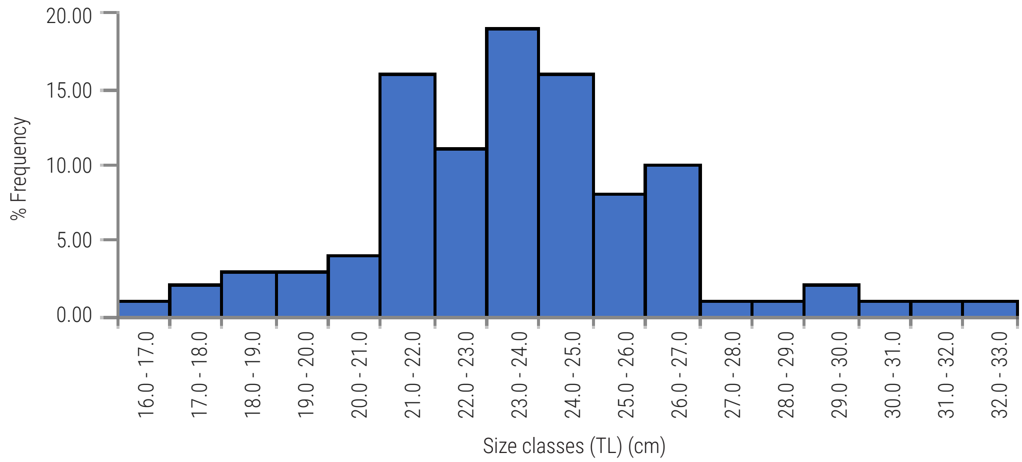

Fig. 1. Length frequency distribution of *M. cephalus* from Negombo Lagoon

showed that the length ranged from 5 to 25 cm (Wijeyaratne and Costa, 1986). According to a study conducted in the Cross River estuary in Nigeria, the length of the species ranged from 12 to 20 cm (Asuquo *et al.,* 2015). A study conducted in the special Wildlife Reserve of Gueumbeul in Senegal has shown that the length and the weight of species ranged between 11.125 cm and 15.9–145. 26 g, respectively (Guisse *et al*., 2021).

Length-weight relationship provides reliable data on a fish's relative well-being and growth patterns. Table 3 represents the Length-weight relationship (LWR), b values, and growth type of *M. cephalus* in Negombo Lagoon.

present study, the 'b' values for mature and immature fish were 2.812 and 2.653, also indicating negative allometric growth.

Fulton's condition factor (K) is used to evaluate the physiological state of the fish. In this study, the mean condition factor for females, males, and pooled samples were 1.005±0.012, 1.050±0.036, and 1.008±0.0086, respectively. K values of males (1.050±0.036) was found to be greater than that of females (1.005±0.012). This indicates that the male fish has a healthier condition compared to female fish. The overall Fulton's condition factor was 1.008±0.009, which was greater than the K-value of males. Mean condition factor for immature and mature fish were 0.996±0.072 and 1.037±0.074,

Table 3. Length-weight relationship (LWR) of *M. cephalus* in Negombo Lagoon

Sex	N	LWR	Parameters of LWR		r^2	Growth type
			a	b		
Pooled	100	$W = 0.0266TL^{2.690}$	0.0266	2.690	0.951	Negative allometric
Male	14	$W = 0.0664TL^{2.411}$	0.0664	2.411	0.983	Negative allometric
Female	32	$W = 0.0109TL^{2.974}$	0.0109	2.974	0.948	Negative allometric
Immature	49	$W = 0.0266TL^{2.653}$	0.029	2.653	0.9459	Negative allometric
Mature	15	$W = 0.0664TL^{2.812}$	0.0191	2.812	0.9295	Negative allometric

Of the 100 specimens examined, sex could be determined in only 46 specimens, as internal damage in the remaining specimens hindered accurate sex identification. The 'b' values obtained in the present study for female, male, and pooled samples were 2.974, 2.411 and 2.690, respectively. The one-sample t-test showed that the obtained 'b' values were significantly different from 3 for males, females, and pooled samples ($p<0.05$), and indicated negative allometric growth. A study conducted in the Special Wildlife Reserve of Gueumbeul in Senegal also reported negative allometric growth in males (b=2.899) and females (b=2.60) of *M. cephalus* (Guisse *et al*., 2021). This recorded negative allometry may be due to the lack of food resources (Guisse *et al*., 2021). Earlier studies have confirmed that the allometry coefficient is related to the quality of the aquatic environment and the availability of natural foods (Guisse *et al*., 2021). Variations in the growth parameters observed in fish species may be attributed to developmental stage, sex, maturity, season, and harsh environmental conditions (Sahoo *et al*., 2012). In the

respectively. The slight differences in K values could be due to differences in habitats, food availability, gonad development, and sex (Dienye *et al*., 2019).

The sex ratio was calculated to obtain knowledge about relative abundance in the spawning season during the study period. The number of females and males of *M. cephalus* sampled from August 2022 to March 2023 is represented in Table 4. The observed sex ratio in the sampled population was 1:2 (χ^2=7.04, df=1, p = 0.008; $p<0.05$).

Fish in the spawning and spent stages were not observed in the present study, primarily because they do not spawn in brackishwaters. According to a study conducted in Palaiopotamos Lagoon (western Greek coast, eastern Mediterranean Sea), females' daily migration patterns were more persistent than those of males. It indicates a possible leadership of females during the spawning migration (Khayyami *et al.,* 2014). The male-to-female sex ratio

Table 4. Sex ratio of *M. cephalus* sampled from August 2022 to March 2023

Month	No. of males	No. of females
August	1	5
September	5	2
October	0	6
November	1	5
December	3	4
January	1	5
February	0	1
March	3	4
Total	14	32

reported by Silva and De Silva (1981) and Bekova and Raikova-petrova (2017) are 1:1. During the spawning season, it has been observed in *M. cephalus* that one female is surrounded by several males. Therefore, the total number of males exceeds that of females (Wijeyaratne and Costa, 1986). A study conducted in Lagos lagoon, Nigeria reported female dominance, with the female:male sex ratio of *M. cephalus* being 1.09:1 (Lawson and Jimoh, 2010). In the present study, the male:female sex ratio estimated was 1:2. This could be the result of the differential environmental conditions (Offem *et al.,* 2009) or due to smaller number of samples caught. The observed sex ratio may also have been biased, as internal damage to many of the sampled fish hindered accurate sex identification. The number of individuals recorded in different maturity stages, were: Immature–49; Developing-19; Maturing–17; and Mature-15.

Gastrosomatic index (GaSI) represents the feeding intensity of the fish. In the present study, the GaSI ranged from 2.012 to 3.874, with an average value of 2.760±0.156. The plot of average GaSI against size classes in standard length showed that the highest peak varied from 20 to 21 cm, and the lowest peak was observed with the size class 24-25 cm. Under normal conditions, mullets appear to feed almost continuously throughout the day, though at differing intensities (Silva and Wijerathne, 1977).

RGL was calculated to determine the feeding habit of *M. cephalus* and GaSI was calculated in order to determine the feeding intensity of fish. The plotted graphs of RHGL and GaSI values against SL are shown in Figs. 2 and 3 respectively.

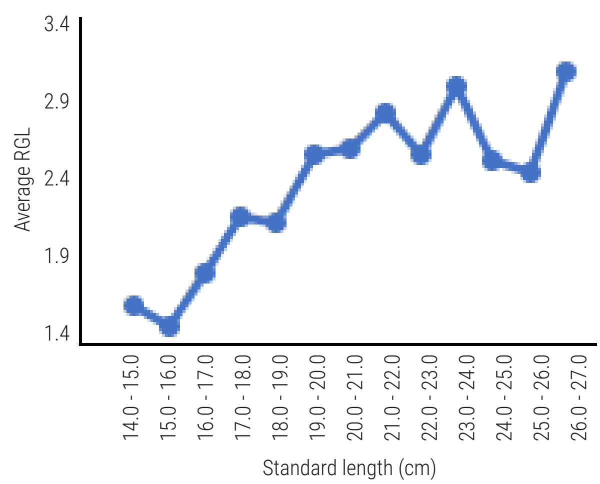

Fig. 2. Average relative gut length (RGL) against size classes of standard length (SL) (cm) of *M. cephalus*

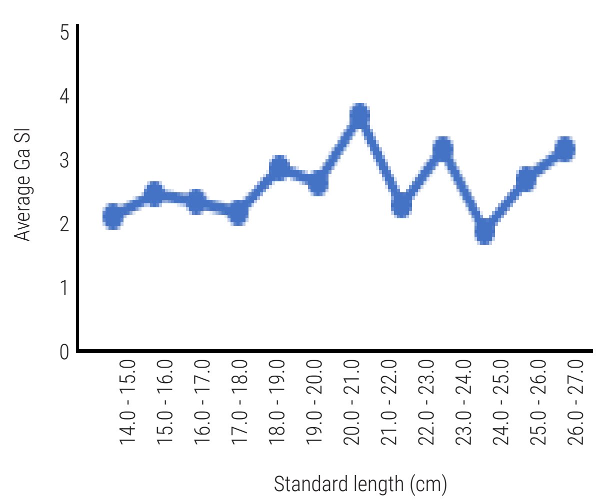

Fig. 3. Average gastrosomatic index (GaSI) against size classes of standard length (SL) (cm) of *M. cephalus*

RGL values estimated for *M. cephalus* in the present study ranged from 1.52 to 3.18 cm. Wijeyaratne and Costa (1986) observed that RGL ranged from 3.52 to 5.14 cm. The highest value of RGL was observed in the 26-27 cm size class, and the lowest, in the 15-16 cm size class. RGL value smaller than 1 indicates a carnivorous diet, values between 1 and 3 shows an omnivorous diet, and values higher than 3 indicate herbivorous or detritus feeding (Karachle and Stergiou, 2010). The mean RGL estimated in the present study was 2.442±0.146, indicating that the *M. cephalus* in Negombo Lagoon is an omnivore.

The overall percentage of stomach fullness in *M. cephalus* is presented in Table 5. Most of the sampled fish had stomachs that were approximately one-fourth (1/4) full. Percentage frequency of occurrence of each food item in the stomach of *M. cephalus* is shown in Table 6.

Table 5. No. of fish and percentages of stomach fullness of *M. cephalus* from Negombo Lagoon

Fullness	No. of fish	Percentage (%)
Full	5	5
Three-fourths (3/4) full	6	6
Half (1/2) full	11	11
One-fourths (1/4) full	57	57
Empty	21	21
Total	100	

Table 6. Frequency of occurrence (%) of each food item consumed by *M. cephalus* from Negombo Lagoon

Food item	No. of stomachs with the food item	Percentage %
Algae	54	30.86
Plant material	8	4.57
Crustaceans	1	0.57
Insect parts	1	0.57
Annelids	5	2.86
Sand	45	25.71
Detritus	41	23.43
Synthetic fibers	20	11.43

Juvenile mullets up to 35 mm in total length are primary carnivorous (Wijeyaratne and Costa, 1986). Juveniles feed on plankton and obtain their food from the water column during diurnal migrations. As they grow, their feeding habit gradually shifts to benthic grazing (Wijeyaratne and Costa, 1986; Jamabo and Maduako, 2015). In Negombo Lagoon, the transition occurs when they are between 20–50 mm (Wijeyaratne and Costa, 1986). At this size, they feed mainly on detritus and bottom-living serpulid polychaetes (Wijeyaratne and Costa, 1986). In the present study, in fish ranging from 16.9-26 cm TL, the animal material (crustaceans, annelids, and insect parts) consisted of only a very minor proportion of the food. Earlier studies found that the diets of young mullet were dominated by diatoms (Bacillariophyceae), followed by green algae and blue-green algae (De Silva and Wijeyaratne, 1977). According to Wijeyaratne and Costa (1986), serpulid polychaetes and detritus were the most abundant food items in the length groups from 15 to 25 cm. In the present study, the major food of *M. cephalus* in Negombo Lagoon observed was algae (30.86%), detritus (23.43%), sand (25.71%), plant materials (4.57%), annelids (2.86%), insect parts (0.57%), and crustaceans (0.57%). The presence of plant material and invertebrates indicated that it was omnivorous. The presence of organic matter and sand in high proportions indicated the benthic feeding habit of the species (Jamabo and Maduako, 2015). The high dietary importance of sand and detritus may be attributed to the marginal mangrove vegetation growing on water-logged deposits of soft mud and clay-silt sediment. The decomposing leaves and other biogenic materials in the marsh provide a constantly enhanced nutrition pool for algae, which can be seen blooming abundantly on the exposed mud surface (Jamabo and Maduako, 2015). Present results (Table 5) confirmed that algae were dominant and formed 30.86%. While sand particles have no nutritional value (Wijeyaratne and Costa, 1986; Jamabo and Maduako, 2015), the ingested sand particles are helpful in the digestive process, possibly assisting in the grinding of food particles in the gizzard-like thick-walled pyrolic stomach; and these particles are filtered through the pharyngeal apparatus. The sand particles, are covered with organic material, bacteria, and protozoa, and so, considered as good sources of vitamin B_{12} for *M. cephalus* (Jamabo and Maduako, 2015). The presence of synthetic nylon fibres (11.43%) among the stomach contents indicates contamination of the lagoon ecosystem by discarded fishing gear and plastic debris. A study conducted on the eastern coast of Hong Kong reported that 60% of 60 flathead grey mullets contained microplastics in their stomachs (Cheung *et al*., 2018). Another study conducted in Lake Cernek located in Kizilirmak Delta, Turkiye has shown that 90% of 30 fishes analysed had microplasticts in their digestive tracts (Terzi, 2023). The results of the present study are possibly early alerts of future concerns in the food web and the health of the lagoon. The present study also recorded the presence of shed gill epithelia in the stomach contents, although these were not considered a food item (Gammanpila *et al*., 2016). While several studies have investigated the food and feeding habits of mullet species in Sri Lanka, shed the occurrence of shed gill epithelia has not been previously documented, possibly because they are not recognised as dietary components. Nevertheless, documenting their presence is important, as it helps prevent their misidentification as periphyton or polychaete moults during stomach content analysis (Gammanpila *et al*., 2016).

While the present study provides baseline information on growth and feeding biology of the flathead grey mullet in Negombo Lagoon, long term monitoring is recommended to assess population abundance, size structure, and overall stock health. In addition, the adoption of selective fishing gears and sustainable fishing practices is essential to minimise the capture of juveniles and non-target species, thereby contributing to the sustainable management and conservation of flathead grey mullet fisheries.

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