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Feeding Aspects and Reproductive Biology of Smalltooth Emperor, *Lethrinus microdon* (Valenciennes, 1830) in the Gulf of Mannar along the Indian Southeast Coast

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ABSTRACT

Background: The Gulf of Mannar, situated on the southeast coast of India, is a unique distinctive productive marine ecosystem and is rich in biodiversity. Its significance stems from the presence of a string of 21 islands spanning 140 km between Rameswaram and Tuticorin, each adorned with a wealth of coral reefs and hosting a variety of ornamental and marine fish species despite their small and uninhabited nature. It is also first Marine Biosphere Reserve in South and South-East Asia, covers approximately an area of 19,000 sq. km.

Methods: Fish samples were collected monthly from three major fishing harbours situated in the Gulf of Mannar along the southeast Coast: Thoothukudi Fishing Harbour, Pamban Fishing Harbour and Chinnamuttom Fishing Harbour from December 2022 to November 2023. These species are caught using trawl net, gill net and hook and line and collected specimens were identified using FAO sheets and standard literature.

Result: In this study, a total of 405 specimens were collected. The length weight relationship was estimated for male: $W = 0.052^{2.57}$, $r^2 = 0.94$, female; $W = 0.057^{2.51}$, $r^2 = 0.94$; and pooled; $W = 0.063^{2.54}$, $r^2 = 0.90$, respectively. Fulton condition factor (K_F) value for male: 1.22, female: 1.33; and pooled: 1.19, respectively. Gonadosomatic index (GSI) of *L. microdon* was ranged between 1.21-2.21 for male and 1.85-2.31 for female and Gastrosomatic index (GaSI) varied from 1.45-2.37 for male whereas 1.89-4.43 was found for female. Hepatosomatic index (HSI) of *L. microdon* was ranged between 0.45-2.54 for male while for female was ranged between 1.11-3.21. The male and female (M:F) sex ratio was estimated 1:0.67. The peak spawning season was observed in June to August. The results provide the baseline biology information required to evaluate the fisheries and sustainable management of these underexploited fishes in the Gulf of Mannar ecosystem.

Key words: Food and feeding habits, Gulf of Mannar, Length-weight relationship, Lethrinidae, *Lethrinus microdon*, Reproduction.

INTRODUCTION

Lethrinids are one of the most commercially significant groups of fish along many tropical coasts and are regarded as an important source of animal protein for communities in the western Pacific and the Indian Ocean (Carpenter and Allen, 1989). *Lethrinus microdon*, are commercially important food fish and highly significant due to their abundance and high market value. It is widely distributed throughout the Indo-West Pacific, commonly found in sandy areas near coral reefs at depths of approximately 80 meters (Ebisawa, 2006). *L. microdon* is primarily caught using longline, gill nets, trawl nets and hook and line. Despite being a significant component of artisanal fisheries and widely distributed in the Gulf of Mannar (GoM), there is limited knowledge about the feeding and reproductive biology and stock status of lethrinid fishes on national and international levels.

The Gulf of Mannar was designated as the first Marine Biosphere Reserve in India as well as South East Asia. Covering an area of about 10,500 km^2, this region hosts approximately 3600 species of flora and fauna (Magesh and Krishnakumar, 2019). The Gulf of Mannar, located on the southeast coast of India, is referred to as a “Marine Biological Paradise” because of the remarkable richness and diversity of its fauna; hence its conservation is very

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important of this valuable flora and fauna thriving in this region (Retnamma *et al*., 2021).

While a comprehensive understanding of the principles of biology and stock is crucial for the development and execution of effective conservation programs (Mawa *et al*., 2021), there is a lack of comprehensive information regarding the feeding and reproductive characteristics of *L. microdon* despite the economic significance in the GoM. Hence, investigating feeding and reproductive biology facilitates understanding the basic feeding habits and resource utilization. The study of biology of emperor therefore becomes very important not only for using the data to develop improved exploitation strategies, but also to comprehend the substantial structural changes brought about in the ecosystem when they are removed by fishing. Therefore this study aimed to explore certain aspects of the feeding and reproductive biology of *L. microdon,* including gonadosomatic index, gastrosomatic index sex ratio, hepatosomatic index, sex ratio, length at first maturity stages and fecundity. Therefore, the current study aimed to gather information on the feeding and reproductive biology of the *Lethrinus microdon* in the Gulf of Mannar, India may potentially improve further stock status study of this species at GoM.

MATERIALS AND METHODS

Study area

Fish samples were collected fortnightly from three major fishing harbours situated in the GoM along the southeast Coast: Thoothukudi Fishing Harbour, TFH (8°43′26.7″N; 78°56′23.12″E), Pamban Fishing Harbour, PFH (9°27′84.82″N; 79°15′11.99 E) and Chinnamuttom Fishing Harbour, CMFH (8°23′92.65″N; 77°16’83.17″E) (Fig 1).

Sample collection and identification

A total of 405 specimens were collected during the present study from December 2022 to November 2023. These species were caught using longline, trawl nets, gill netsand hook and line. Upon collection, the specimens were identified using standard literature (Carpenter and Allen, 1989) and transported to the laboratory under refrigerated conditions for further examination. The total length and total weight were measured to the nearest 0.1 cm and 0.01 g, respectively.

Length-weight relationship and condition factor

The relationship between length (L) and weight (W) were estimated according to Le Cren (1951) using the following formula:

$$W = aL^b$$

Where:
W = Body weight (g).
L = Total body length (cm).
a = Intercept.
b = Slope value.

The parameters ‘a’ and ‘b’, along with their corresponding 95% confidence limits (CL) and coefficient of determination (r^2), were calculated using linear regression analysis in Microsoft Office Excel. When the coefficient of allometry (b) is equal to 3, the growth rates of length and weight are equal (Ricker 1975); hypo-allometry, or negative allometry growth, occurs when length increases more than predicted weight; hyper-allometry, or positive allometry growth, occurs when length increases less than predicted weight (Shingleton, 2010). The b value for each species was estimated using Student’s t-test (Sokal and Rohlf 1987) with a 95% confidence interval to determine if it significantly differed from the isometric value (H_0: b = 3).

The condition of fish species under study was determined using Fulton’s condition factor (K_F) (Fulton, 1904) by using the following formula:

$$K_F = 100*(\frac{W}{L^3})$$

Where:
W = Observed body weight (g).
L = Observed length of fish (cm) and the factor 100 is utilized to normalize K to unity.

The fish is said to be in good condition when K=1, while average or poor growth condition is indicated if K<1.

Biological characteristics

The collected specimens were dissected to extract all internal organs. The gut, intestine, liverand gonads were weighed using a digital balance, which were then used to assess biological parameters such as the Hepatosomatic index (HSI), Gastrosomatic index (GaSI) and Gonadosomatic index (GSI). The weights of the fish, gut, liverand ovaries were measured with a digital electronic balance to the nearest 0.01 g.

Gut content analysis

The analysis of the gut contents was conducted through close examination under a microscope. Visual estimation of gut content was performed for all specimens to identify the diet composition present in the fish gut. The GaSI (Desai, 1970) and HSI (Welcomme, 2001) were calculated using the standard protocol:

$$\text{GaSI (\%)} = \frac{\text{Weight of the gut}}{\text{Weight of the fish}} \times 100$$

$$\text{HSI (\%)} = \frac{\text{Weight of the liver}}{\text{Weight of the fish}} \times 100$$

Reproductive characteristics

Gonadosomatic Index

The female of ovaries was dissected using very fine forceps after that whole ovary was carefully removed and preserved in 5% formalin solution. The weight of the ovaries was measured in electronic weighing balance with accuracy 0.01 g. The Gonadosomatic index (GSI) was calculated by following formula (Bal and Rao, 1984):

$$GSI = \frac{GW}{TW} \times 100$$

Where:
GW = Gonad weight in (g).
TW = Total body weight in (g).

Sex ratio

The sex ratio was determined by considering the total number of male and female individuals collected during the sampling period. The significance differences in sex ratio were assessed using a Chi-square test (X^2) at a 1% level of significance ($P<0.05$) (Snedecor and Cochran, 1989) to test if the observed ratio between males and females differs from the expected 1:1 (male: female) ratio.

Length at first maturity

The mean length at sexual maturity (L_{50}) is the length at which 50% of individuals are matured (Stages III, IV and V). The length at first maturity was estimated by using the logistic curve formula (Udupay, 1986):

$$P = 1/[1+ e^{(-r(L-L_m))}]$$

Where:
P = Proportion of mature individuals by length (L).
r = Slope of the curve.
Lm = Length corresponding to a proportion of 50% of mature individuals (L_{50}).

Maturity stage

The maturity stages of female gonads were determined based on visualization of the morphometric characteristics of ovaries such as colour, shape, vascularization and size of the ova. The reproductive stages in female gonads were determined using the four-stage of the gonads maturity scale and categorized as Stage-I Immature; Stage II maturing; Stage III matured and Stage IV ripe (Brown-Peterson *et al*., 2011).

Fecundity

Fecundity, defined as the number of oocytes present in the ovary and weight, was estimated by using the gravimetric

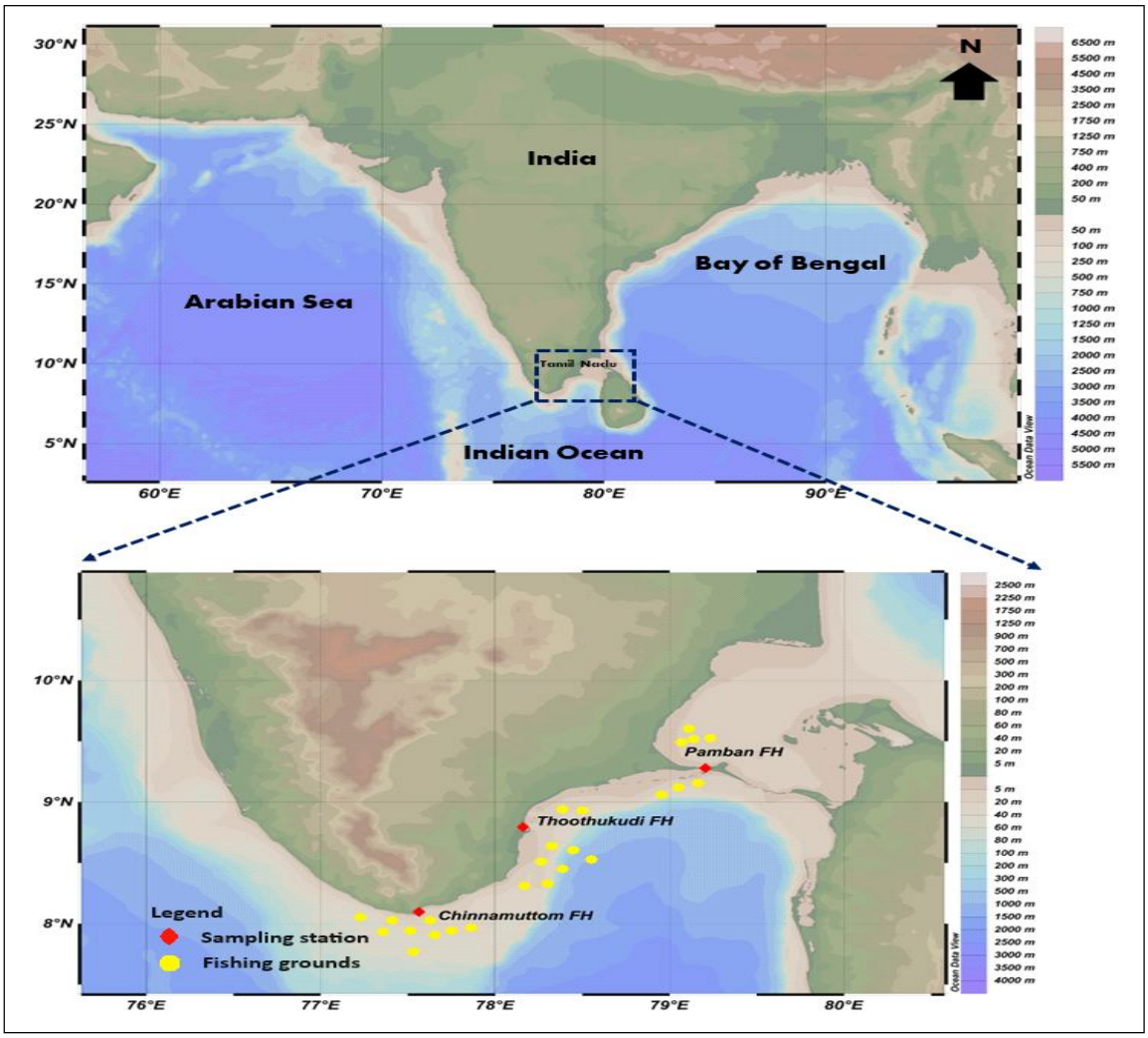

Fig 1: Sampling grounds of the gulf of mannar.

method. A subsample of 0.5 g eggs was taken from each portion of the ovary (anterior, middle and posterior) and preserved in Gilson fluid solution (Simpson, 1951) for easy release of the oocytes, which were then counted and measured with the help of a Sterozome microscope (20x) (Nikon DS-Fi1, Japan). Fecundity was calculated using the formula proposed by Garg *et al.* (2002):

$$F = F_S * \frac{GW}{GW_S}$$

Where:
F= Estimated fecundity of the individual.
Fs = Number of oocytes in a sample.
GW = Total weight of the ovary.
GWs = Weight of the subsample of the ovary.

RESULTS AND DISCUSSION

Length-weight relationship and condition factor

In the present study, the b value of *L. microdon* was estimated 2.57 (male), 2.51 (female)and 2.54 (pooled) whereas coefficient of determination (r^2) was 0.94 (male), 0.94 (female) and 0.90 (pooled) respectively (Table 1 and Fig 2). In the length-weight relationship of fishes, the b values were typically found between the estimated ranges of 2.5-3.5 (Froese, 2006). Ontomwa *et al.* (2018) and Matthews *et al*. (2019) have estimated growth co-efficient (b) estimates for *L. microdon* (2.6), which are in the same line of the present findings. Mehanna *et al.* (2017) and Al Kamel *et al*. (2020) observed b values as 2.9 and 3.1 for *L. microdon* which is higher than the recent findings, confirming the presence of a negative allometric pattern in this species, which is in line with the present study. Rajathy *et al*. (2021) estimated the slope value for *L. lentjan* (2.9) and *L. microdon* (2.8) which is higher than the current investigation. Grandcourt *et al*. (2010) and Daliri *et al*. (2012) registered a b value of 3 for *L. microdon* from the Southern Arabian Gulf and Northern Persian Gulf, which is higher than present observation. Thangaraj *et al.* (2022) reported b value for *L. microdon* (2.8) which is slightly higher than the present estimation. Vasantharajan *et al*. (2014) and Zaahkouk *et al*. (2017) estimated an almost identical b value of 3.0 for another species of lethrinid (*L. lentjan)* along the Indian coast and Red Sea, which are lower than the current findings. Currey *et al.* (2009) and Vasantharajan *et al*. (2014) reported a slope value of 2.9 for *L. nebulosus* from the Great Barrier Reef and Thoothukudi, Southeast coast, India, confirming the negative allometric as observed in the present study. Additionally, Daliri *et al*. (2012) reported a slope value of 2.6 for *L. nebulosus* from the Northern Persian Gulf, which is in conformity with the current observation. In comparison with the previous estimates, some variations in the b values were noted in the current study. These differences could be due to several factors, including fish physiology, growth phase, sex, sexual maturity, season, stomach fullness, length range and sample size, habitat, feeding rate, dietand health (Le Cren, 1951; Froese, 2006; Mondol *et al*., 2017). Additionally, sampling bias might also occur due to the use of different

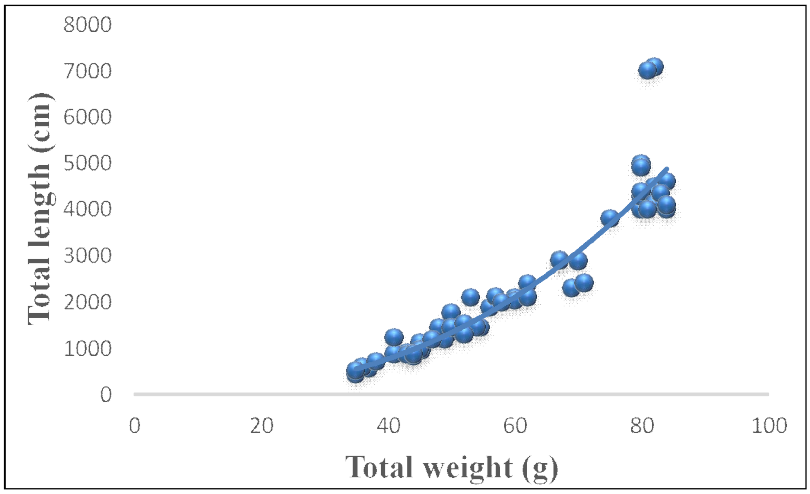

Fig 2: Length-weight relationship of *Lethrinus microdon.*

Table 1: Length-weight relationship of *Lethrinus microdon.*

Sex	N	a	95% CL of a	b	95% CL of b	r^2	K_F
Male	163	0.052	0.0039-0.0738	2.57	2.4109-2.7148	0.94	1.22
Female	242	0.057	0.0031-0.0821	2.51	2.4328-2.6917	0.94	1.33
Pooled	405	0.063	0.2276-0.4013	2.54	2.3838-2.7038	0.90	1.19

Note: N-Sample number; a - intercept; b - slope; CL - confidence limits; r^2 - coefficient of determination, K_F- Fulton condition factor.

gears, or absence of an independent and uniform sampling technique or relatively small sample size or narrow size range which may also affect the accuracy of b values as mentioned by Roul *et al*. (2017c).

The fulton condition factor (K_F) of *Lethrinus microdon* were estimated 1.22 for male, 1.33 for female and 1.19, for pooled, which reveals that these species are in good condition in the waters of the Gulf of Mannar (Table 1). Rajathy *et al*. (2021) recorded a K_F value of *L. nebulosus* as 1.44 from the Thoothukudi coast, India, which is in conformity with the present study. Ravikumar *et al*. (2023) reported the Fulton condition factor values from 1.3357 to 2.5846 for demersal reef fishes from the Gulf of Mannar, India, which is higher than the present findings. The results indicate that the ecological conditions in the waters of the Gulf of Mannar, located off the southeast coast of India, are favourable for the growth of *Lethrinus microdon* species. Additionally, the condition factor values nearing to one and more than 1 could be attributed to the well-being of the fish in the ecosystem besides the optimal environmental factors which are very conducive for the better growth and reproduction of the species. The health of fish varies slightly from habitat to habitat, possibly due to factors such as population size, food intake, reproductive development, sex, time of year and geographic location. When the condition factor e" 1, it indicates healthy growth condition of fish, whereas <1 signifies poor growth condition (Jisr *et al*., 2018). It can be influenced by both living and non-living factors, such as water quality and the food availability and predators (Blackwell *et al*., 2000).

Food and feeding habits

The analysis of gut contents indicated that fish constitutes the majority of the diet (50-60%), followed by crustaceans (40-50%) and mollusca (20-30%) and echinoderms (10%). The primary and most significant prey items were teleosts, crustaceans (including brachyurans and carideans)and molluscs (both gastropods and bivalves). In addition to the prey items, coral rubble and sand particles were also found in the gut. After analysed the gut samples, *L. microdon* can be regarded as a piscivorous species. These fish have a low-bodied form with conical teeth, enabling them to feed on fast-moving prey like nekton (Carpenter, 1996). The present observations also found similar results like studies by Randall (1995) and Carpenter and Allen (1989) which indicate that their primary prey consists of fish, followed by crustaceans, mollusksand polychaetes. This result is confirmed by Ali *et al*. (2016), but does not correspond to Fischer and Bianchi (1984) who stated that *L. microdon* feeds on crustaceans, mollusks and small fish. *L. microdon* typically feed primarily on fish, crustaceans, molluscan, with a smaller portion of their diet consisting of benthic prey. Clupeidae was the main prey, making up the largest percentage of *L. microdon* diets. Smaller specimens were found to consume an abundance of benthic invertebrates, while larger individuals showed a dietary shift. This change is attributed to their solitary behavior, wider home rangeand body morphology, which allows for faster swimming and the ability to target more mobile prey compared to subadults or juveniles. In younger specimens, mollusks, particularly bivalves, were found in notable amounts, whereas in adult fish, nekton became the primary dietary component due to their higher nutritional needs. The results also indicate ontogenetic changes in diet composition, which vary based on growth patterns, seasonal factorsand prey availability. The Gastrosomatic index (GaSI) value of *L. microdon* were ranged from 1.45-2.37 for male and 1.89-4.34 for female, respectively (Table 2 and Fig 3).The Hepatosomatic index (HSI) value were ranged from 0.45-2.54 for male and 1.11-3.21 for female, respectively (Table 2).

Reproductive characteristics

Sex ratio

The overall sex ratio of male and female was observed to be 1:0.67 (Table 3). The observed sex ratio was tested against 1:1 using the chi-square test for (n-1) degrees of freedom at 5% level of significance. The chi-square test indicated that there was no significance difference ($p>0.05$) in the average sex ratio and month-wise sex ratio (Fig 4). Grandcourt *et al*. (2010) observed the overall male: female ratio of *L. microdon* was 1:1.6, which is higher than present findings. In his study, male was more dominant than female in the present study. According to Al-Areeki *et al*. (2007) reported a overall sex ratio for *L. lentjan* were estimates to be 1:1.1 (Male:Female) in the Red Sea coast of Yemen which is higher than the present findings. Other similar study were reported by Damora (2018) 1:1.08 for *L. lenjan* in Indonesia waters; Degoon and Ali (2016) estimated the overall sex ratio was 1:1.7 for *L. mahsena* in the Sudanese Red Sea,. Kulmiye *et al*. (2002) estimated sex ratio was of *L. lentjan* were estimated to be 1.0:1.10 in Kenyan coastal waters, present findings. In the study males were more dominant than female. The sex ratio may fluctuate from the predicted 1:1 ratio from species to species, or even within the same population adaptability, reproductive behavior, food availability and environmental conditions (Asut *et al*., 2019).

Table 2: Gonadosomatic (GSI) index, Gastrosomatic (GaSI) and Hepatosomatic (HSI) of *Lethrinus microdon.*

Sex	Weight (gm)			GSI	GaSI	HSI
	Gonad	Gut	Liver			
Male (163)	0.30-4.51	1.51-8.34	0.21-2.13	1.21-2.21	1.45-2.37	0.45-2.54
Female (242)	1.20-8.42	1.71-12.32	0.39-3.14	1.85-2.31	1.89-4.34	1.11-3.21

The gonadosomatic index (GSI) value of *Lethrinus microdon* was ranged from 1.21-2.21 for male and 1.85-2.31 for female (Fig 5). Al-Areeki *et al*. (2007) reported a maximum GSI value of 2.43 (March) for another *Lethrinus* species, (*L. lentjan)* which is lower than the present study. Similar results recorded by Currey *et al*. (2009) and Ebisawa (1990) revealed high GSI value in July-August in Australia and Okinawan waters. The highest GSI value was recorded in *L. mahsena* (3.23) in June 2023 and the lowest value (0.26) was recorded in September 2023. Similar results were recorded by Soondron *et al*. (1999) in Mauritius water. Interestingly, their stomachs are fullest between September to November, but less full during the spawning season from June to August.

Length at first maturity

The length at which 50% of all fish of a particular size reach maturity is referred to as the length at first maturity (L_{50}). For both male and female *L. microdon,* the L_{50} attains maturity was 25.5 cm for male and 26.5 cm for female (Fig 6 and 7). Toor (1964) documented an L_{50} of *L. lentjan* was found 30 cm for male and 28.7 cm for female in the Indian Ocean, whereas Grandcourt *et al*. (2010) observed an L_{50} of *L. microdon* was estimated 24.6 cm for male and 27.7 cm in the Arabian Gulf, which is similar with the present findings. The present study differs from another species of *Lethrinus* (*L. lentjan),* attained length at first maturity of female at 26 cm in Red Sea Coast of Yemen by Al-Areeki *et al*. (2007), which is similar than the present investigation. Mrombo *et al*. (2019) observed that the L_{50} for male and female *L. lentjan* was 25.8 cm. and 26.2 cm, which are in agreement with the present findings. Toor (1964) reported an L_{50} of 30 cm for males and 28.7 cm for females (*L. lentjan*) in Indian Ocean waters, while Grandcourt *et al*. (2010) reported an L_{50} of 24.6 cm for males and 27.7 cm fork for females (*L. lentjan*) in the southern Arabian Gulf. Damora *et al*. (2018) reported L_{50} of *L. lentjan* as 25.1 cm for males and 25.3 cm for females, which is similar with the present findings. The gaps in first sexual maturity values could be changed due to variations in diet, water

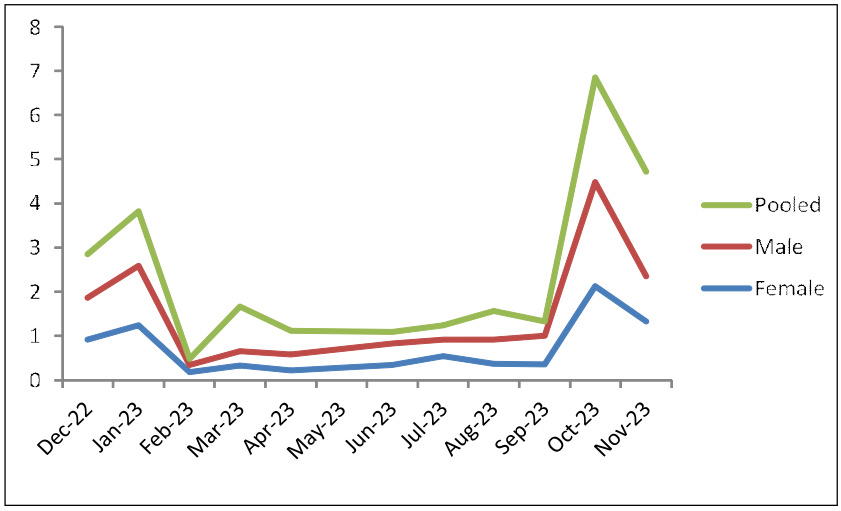

Fig 3: Gastrosomatic Index of *Lethrinus microdon.*

Table 3: Month-wise sex ratio of *Lethrinus microdon.*

Months	Male	Female	Sex ratio (M:F)	Chi-square	P-value
Dec-22	12	18	1:0.66	1.14	0.94
Jan-23	10	20	1:0.51	0.68	0.87
Feb-23	12	17	1:0.70	1.01	0.79
Mar-23	13	23	1:0.56	2.11	0.54
Apr-23	13	23	1:0.56	0.41	0.93
June-23	15	17	1:0.88	1.30	0.85
July-23	13	16	1:0.81	0.56	0.96
Aug-23	14	18	1:0.77	1.86	0.76
Sept-23	16	21	1:0.76	1.63	0.80
Oct-23	15	25	1:0.60	0.67	0.98
Nov-23	16	24	1:0.66	0.80	0.84
Dec-23	14	20	1:0.70	0.89	0.97
Total	163	242	1:0.67	1.08	0.85

temperature and stock population (Reznick, 1993). These differences may be also linked to varying levels of fishing pressure in different regions, as Lappalainen *et al*. (2016) suggested, noting that L_{50} can be a potential indicator of fishing pressure in fish stocks.

Maturity stages

The occurrence of various maturity of the gonad in different months showed that the peak spawning of *L. microdon* was in June to August. The simultaneous occurrence of immature, maturing, mature and ripe individuals in a number of months and evidence obtained from the hepatosomatic index and gonadosomatic index support above inferences. The observations of gonad maturity stages across different months revealed that peak spawning of *L. microdon* typically occurs in June to August in whole year. Motlagh *et al*. (2010) reported peak spawning of *L. nebulosus* in March in the Persian Gulf and Oman Sea. Al-Areeki *et al*. (2007) reported peak spawning of *L. lentjan* in April-May in the Yemen coastal water. Mrombo *et al*. (2019) reported peak spawning of *L. lentjan* in January in Kenya waters, there was no reported study on the maturity stages in *L. microdon*, although in the same genus of different species were reported. Toor (1964) also observed the peak spawning of *Lethrinus* species occurring June - August in Indian waters. The present study also indicated same peak spawning season. Spawning season can vary from region to region due to the environmental factors.

Fecundity

The total fecundity was ranged from 70,345 to 5,09,735 eggs. Al-Areek *et al.* (2007) reported 80295 to 837251 eggs of another *Lethrinus* species (*L. lentjan*) in Yemen coastal water, which is higher than the present findings. Mrombo

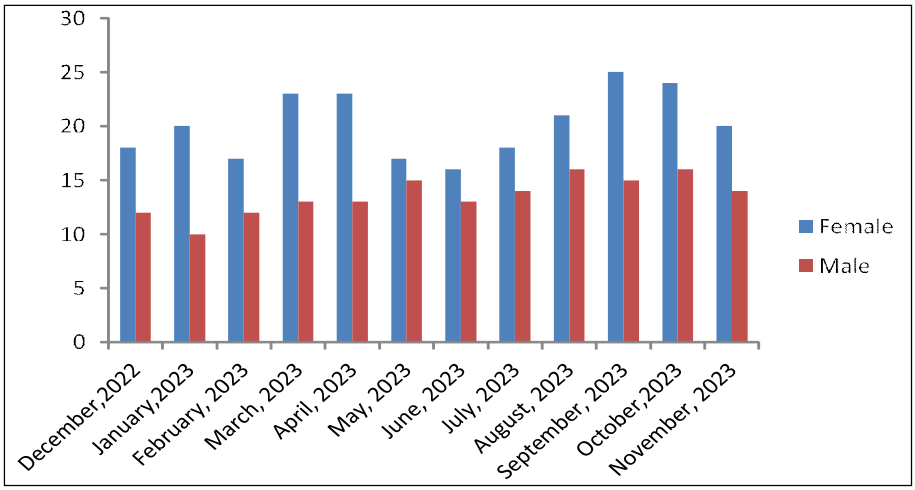

Fig 4: Month-wise percentage distribution of male and female of *Lethrinus microdon.*

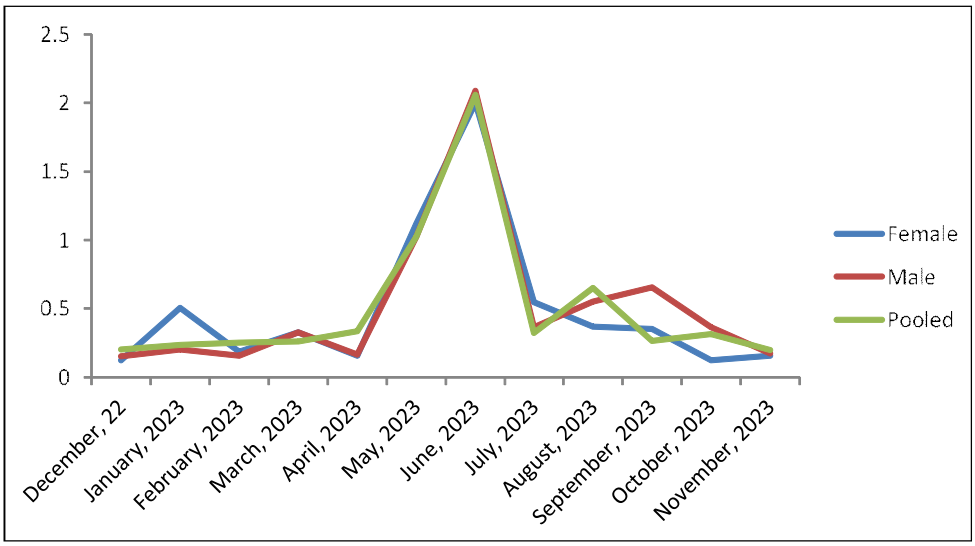

Fig 5: Gonadosomatic Index of *Lethrinus microdon.*

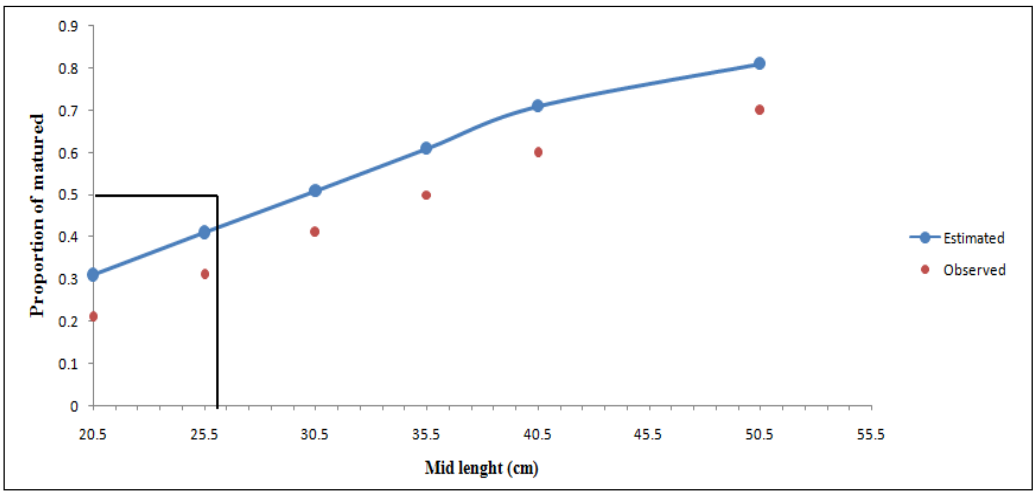

Fig 6: Length at first maturity of male *Lethrinus microdon.*

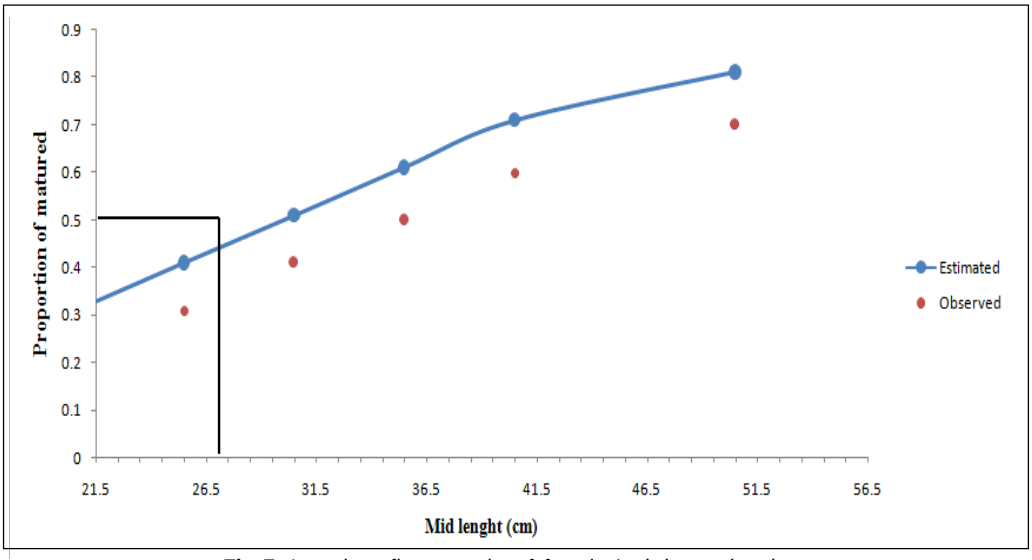

Fig 7: Length at first maturity of female *Lethrinus microdon.*

et al. (2019) reported 90 to 3,80,364 eggs of *L. lentjan* in Kenya waters, which is higher than the present investigations. Toor (1964) reported 12,146-77,922 eggs of *L. lentjan* in Indian water, which is lower than the current findings. Degoon and Ali (2016) estimated absolute fecundity of *L. mahsena* was 2,26,667-1,646,667 eggs per mature female, which is higher than the present investigation. According to Toor (1964) the fecundity of *L. mahsena* was 26,700-166200 eggs (Carpenter and Allen, 1989) which is lower than the present findings. The fluctuation may arise from various environmental factors like temperature, sunlightand weather conditions (Jonsson and Jonsson, 1999).

CONCLUSION

Our results provide partial information about the feeding habits and reproductive characteristics of *Lethrinus microdon*, of major prominence for fisheries management. The percentage occurrence of various food items in the gut content showed that the primary preferable food item was the fish. Thus, the present investigation revealed that *L. microdon* could be considered a piscivorous species, whose diet is mainly composed of teleostean fishes, crustaceans, molluscs and echinoderms. The information got by this study would be useful as a first step for the transition from single-species management to ecosystem-based management. Reproductive features provide baseline information for understanding the population dynamics which would help in formulating strategies for sustainable exploitation and conservation of this species in the region. The present investigation calls for further research in identifying the Smalltooth emperor fishing and spawning aggregation grounds and initiate measures for reducing fishing efforts with input and output controls to sustain the Smalltooth emperor fishery in the Gulf of Mannar coastal waters.

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Ethical statement

No live specimens here used in the present study.

Conflict of interest

All authors declared that they have no conflict of interest.

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