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Exploring the Length-weight Relationship, Relative Condition Factor and Sexual Dimorphism of Crimson Jobfish (*Pristipomoides filamentosus*) Landed along the Southern Coast of India

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ABSTRACT

Background: The study investigated the length-weight relationship (LWR), relative condition factor (Kn) and sexual dimorphism in *Pristipomoides filamentosus*, a deep-water snapper of economic importance in the tropical Indo-Pacific region.

Methods: A total of 891 fish (476 females and 415 males) were collected from the Vizhinjam fish landing centre at the southern tip of Kerala, India and analyzed from October 2022 to March 2023. The cube law and student's t-test were applied to calculate LWR and used to check if there was any significant deviation from the cubic relationship of both female and male *P. filamentosus*. Month-wise and length class-wise, mean Kn was calculated to check the health conditions of both female and male *P. filamentosus*. Body colouration, fin pigmentation and external characteristics of genital papillae and urogenital regions are used to explore the sexual dimorphic characteristics of *P. filamentosus*.

Result: Growth was negatively allometric and the coefficient of determination (R^2) for female, male and pooled sexes were 0.966, 0.976 and 0.970, respectively. The relative condition factor (Kn) was highest for females (1.20±0.02) in November and for males (1.17±0.02) in October. Additionally, fish with fork lengths (FL) between 49.5-54.5 cm exhibited the highest Kn values for females (1.31±0.04), while those with FL ranging from 54.5-59.5 cm showed peak Kn values for males (1.21±0.05). The average Kn value for *P. filamentosus* was approximately one, indicating that the fish were generally in good condition. Sexual dimorphism is more evident in mature *P. filamentosus* shows characteristic changes in females and males, including body and fin colouration (dichromatism) and external characteristics of the urogenital region and genital papillae. This study provides baseline information and reference points for effectively managing and conserving *P. filamentosus*.

Key words: Allometric growth, Genital papillae, Lutjanidae, Sexual dichromatism, Urogenital region.

INTRODUCTION

The family Lutjanidae comprises 17 genera and 105 species and is primarily found in tropical and subtropical seas, with only a few exceptions from estuaries (Allen, 1985; Anderson, 2003; Fricke *et al.,* 2024). Lutjanids form an important component in the commercial fishery of the Indian region. Wilson *et al.* (2019) reported the landing of 15 species of snapper along the Kerala coast and Nair *et al.* (2014) made a consolidated document containing reports of 49 species of snapper from Indian waters. The crimson jobfish (*Pristipomoides filamentosus*) formed one of the dominant species of snappers that landed along the Kerala coast (Wilson *et al.,* 2019). According to Grimes (1987), *P. filamentosus* is a long-living species (up to 44 years), a gonochoristic batch spawner and shows secondary sexual characteristics. *P. filamentosus* is generally reported from rocky bottoms up to a depth of 360 meters (McAllister *et al.,* 1992) and attain a maximum length of 100 cm (Anderson, 1986) and a weight of 9 kg (Manooch, 1987; Randall, 2007). *P. filamentosus* is a highly preferred fish because of its high-quality white meat (Martinez-andrade, 2003). It contributes significantly to the commercial catch on the southern coast of Kerala, where it is commonly referred to as "*Chey-meen*" in the vernacular language, Malayalam.

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Length-weight relationship (LWR) offers valuable insights into the environmental factors that may influence fish growth and development (Tagarao *et al.,* 2020). The study of LWR is essential in fish's biology, physiology and ecology (Blackwell *et al.,* 2000; Santos *et al.,* 2002; Shingadia, 2014; Baek *et al.,* 2015; Saygin *et al.,* 2016). Several studies on LWR from Indian coastal waters have focused on reef-associated commercially important fish species (Rangarajan, 1973; Oommen, 1976; Premalatha, 1989; Hamsa *et al.,* 1994; Abdurahiman *et al.,* 2004; Ramachandran *et al.,* 2013; Pradeep, 2018; Wilson *et al.,* 2019; Velamala *et al.,* 2020; Nair *et al.,* 2021). Few reports are available on relative condition factors (Kn) of lutjanids from various coastal waters (Masood and Farooq, 2010; Ramachandran *et al.,* 2013; Fakoya *et al.,* 2019; Rahman *et al.,* 2023; Rodriguez *et al.,* 2023). LWR and Kn are the key components of fisheries assessments because they provide information on fish growth, health and fitness in a habitat (Jisr *et al.,* 2018; Dinh *et al.,* 2022).

Sexual dimorphism, as described by Saurabh *et al.* (2013), refers to the systematic differences in form or colouration between males and females of the same species, aiding in sex determination. These differences can include features like brighter colours in males, larger body sizes in females, or the presence of specialized structures such as fin shapes or markings. Histological analysis of gonads is generally considered the most reliable method for sex determination and maturity phases of gonads (Longenecker *et al.,* 2022). Several studies were conducted on sexual dimorphic characters in lutjanid species (Grimes, 1987; Everson *et al.,* 1989; Martinez-andrade, 2003; Newman and Dunk, 2003; Luers *et al.,* 2017; Nichols *et al.*, 2022). Some fishes exhibit secondary sexual characteristics only during the spawning season, while others throughout their lives. It helps to identify the sex of the fish without any dissection, which is crucial for breeding programs, population studies and understanding reproductive behaviour. Fishes of both sexes generally differ externally in size, shape, colouration, genital papillae, fin texture and head shape (Saurabh *et al.,* 2013; Sharma and Singh, 2024). Determining sex using the urogenital region is more effective in *P. filamentosus* and further research is needed to determine whether genital papillae are sexually dimorphic (Luers *et al.,* 2017). The present study aims to provide information regarding the length-weight relationship, relative condition factor and sexual dimorphism of *P. filamentosus* collected from the southern coast of India.

MATERIALS AND METHODS

Locale of the study

Samples of *P. filamentosus* were collected monthly from hook and line landings of Vizhinjam fishing harbour (8°22″ 42.33″N and 76°59′27.9″E) located at the southern end of Kerala, India (Fig 1). The fish were mostly caught from off Vizhinjam coast (up to 30-40 nautical miles from the shore) and the study was conducted from October 2022 to March 2023. The specimens were then placed in insulated ice boxes and transported to the laboratory of the ICAR-Central Marine Fisheries Research Institute (CMFRI) at the Vizhinjam Regional Centre in Thiruvananthapuram, Kerala, for further analysis.

Length-weight relationship (LWR)

Fork length was measured to the nearest 0.1 cm using a metal scale and body weight was measured to the nearest 0.1 g using electronic weighing balance (ATLCasio, India). The cube law ($W = aL^b$), proposed by Le Cren (1951) and Pauly (1983), was applied to calculate the LWR for males, females and pooled sexes. The logarithmic equation was used:

$$\text{Log } W = \text{Log } a + b \text{ Log } L$$

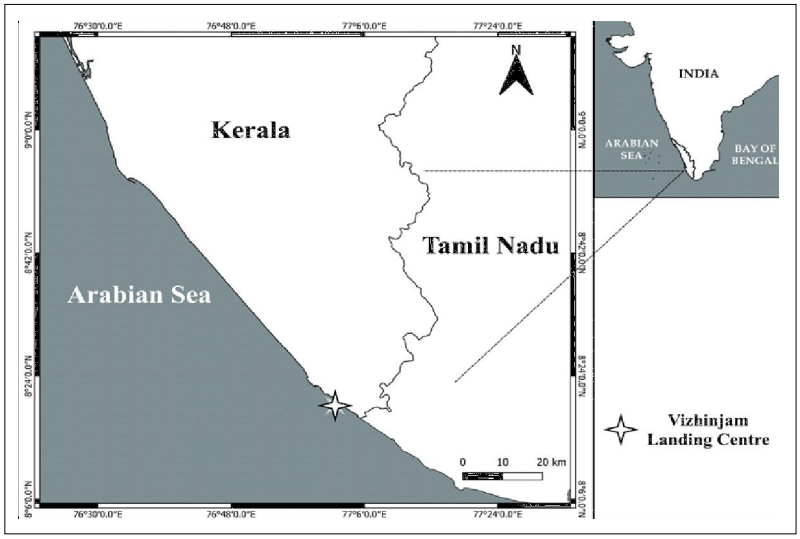

Fig 1: Sampling site of *P. filamentosus* along the southern coast of India.

L = Fork length.
a and b = Intercept and slope of the regression line, respectively.

The slope (b), intercept (a) and coefficient of determination (R^2) were calculated to determine the interdependence of these variables. A statistical test criterion of student's t-test was employed to check the isometric relationship of *P. filamentosus* (Zar, 1999).

Relative condition factor (Kn)

The month-wise and length class-wise mean relative condition factors for females and males of *P. filamentosus* were calculated following the equation proposed by Le Cren (1951);

$$Kn = \frac{W}{aL^n}$$

Where,
W = Actual weight of the fish in grams (g).
aL^n = Calculated weight obtained from the LWR.

Sexual dimorphism

Fishes were observed to identify the sexes before dissection based on variations in body colouration, fin pigmentation and external characteristics of the urogenital region and genital papillae (Nichols *et al.,* 2022). External sexing methods proposed by Smith *et al.* (2014) and Luers *et al.* (2017) were used here to examine the urogenital region and papillae and to determine the sex of each fish. After recording the morphological details, the sexes were confirmed by dissection and microscopical examination of the gonads.

RESULTS AND DISCUSSION

Length-weight relationship

A total of 891 fish (n = 476 (F) and 415 (M)) were examined for the Length-Weight Relationship (LWR). For females, the length ranged from 19.5 cm to 75.1 cm and weight ranged from 103.5 g to 4276.0 g. Similarly, the length of males ranged from 19.7 cm to 76.5 cm and weight from 130.1 g to 4346.1 g. Linearizing the two variables (Length and Weight) by taking their logarithmic values and then regressing them gave the linear expressions of LWR for males and females (Table 1). LWR parameters of *P. filamentosus* resulted in the intercept 'a' value for female, male and pooled sexes as 0.051, 0.057 and 0.053, respectively. The slope 'b' value is slightly higher in females (2.651) than males (2.638). The logarithmic relationship of length and weight for females, males and pooled sexes is represented in scatterplots (Fig 2 a, b and c). R^2 values

Table 1: Length-weight relationship of *P. filamentosus* from the southern coast of India.

Sex	Linear expression of LWR	Curvilinear relationship of LWR
Female	LnW = log -2.968 + 2.651 Log L (R2 =0.966)	$W = 0.051\ L^{2.651}$
Male	LnW = log -2.856 + 2.638 Log L (R2=0.976)	$W = 0.057\ L^{2.638}$
Pooled sex	LnW = log -2.940 + 2.651 Log L (R2 =0.970)	$W = 0.053\ L^{2.651}$

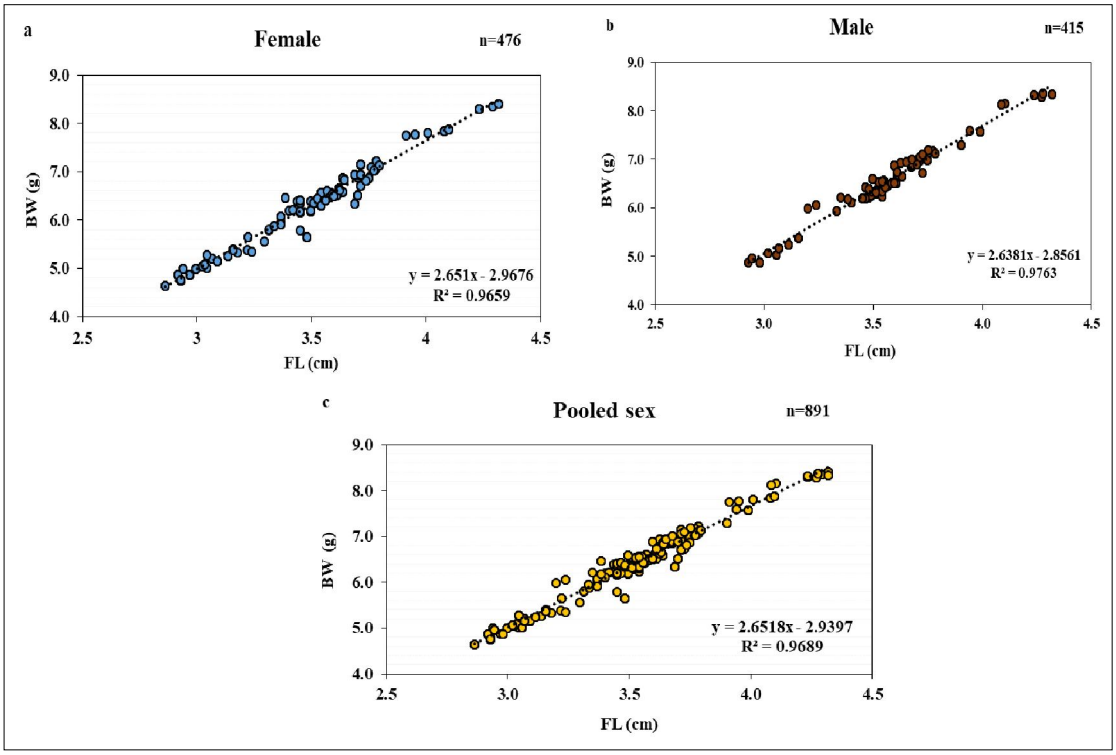

Fig 2: Scatter diagram showing LWR of (a) female (b) male and (c) pooled sexes samples of *P. filamentosus*.

of female, male and pooled sexes were observed as 0.966, 0.976 and 0.970, respectively. The regression coefficient 'b' is less than 3, indicating a negative allometric growth for males, females and pooled sexes of *P. filamentosus*. The allometric growth of *P. filamentosus* was statistically proved by a statistical test of hypothesis, with a null hypothesis H_0: b= 3 against the alternate hypothesis H_1: b≠3. The results showed that there was a significant de*via*tion from the cubic relationship of length and weight in both males and females (females, $t_{(476)}$ = (-15.25), p<0.05 and males, $t_{(415)}$ = (-17.90), p<0.05). Given that the p-value was less than the significance level, we reject the null hypothesis of the isometric relationship and accept the allometric growth of *P. filamentosus*.

LWR shows isometric, negative allometric or positive allometric growth pattern in fishes (Kop *et al.,* 2019). LWR is a major parameter that provides valuable information regarding the conditions of fish stock in a region (Rao *et al.* 2024). The coefficient of correlation (R^2) determines the strength and reliability of the length-weight relationship (LWR). A high R^2 value (close to 1) indicates a strong relationship between length and weight, suggesting accurate predictions, whereas a low R^2 value suggests variability due to environmental or biological factors (Froese, 2006). Kamikawa *et al.* (2015) reported the 'a' value for six *Pristipomoides* sp. ranged from 0.018 to 0.135, the 'b' values ranged from 2.91 to 3.11 and the coefficient of determination 'R^2' ranged from 0.96 to 0.99, which aligns with the findings of the present study. Similarly, Wilson *et al.* (2019) recorded 'b' values for *P. filamentosus* males (2.783), females (3.0134) and the pooled sexes (2.903), indicating an isometric growth pattern for females and a negative allometric growth pattern for males and the pooled sexes. Velamala *et al.* (2020), reported a negative allometric growth pattern in *P. typus* (2.993) and *P. multidens* (2.644). In a recent investigation by Nair *et al.* (2021), the 'b' values for *P. filamentosus* indicated isometric growth patterns (b=3) for all three categories (male, female and pooled sexes). LWR was not consistent throughout the year and can vary significantly due to different factors such as health, sex and food availability (Bagenal and Tesch, 1978; Froese, 2006).

Relative condition factor

The month-wise and length class-wise mean relative condition factors for females (n= 476) and males (n=415) of *P. filamentosus* were calculated. The Kn value for females varied during the study period from 0.96 to 1.20, with a mean value of 1.05. The peak value was observed in November (1.20±0.02), followed by October (1.13±0.01) and December (1.03±0.02), indicating healthy fish. Kn value was <1 in females during January (0.96±0.02), February (0.98±0.01) and March (0.97±0.02. The Kn value for males varied across the different months studied, ranging from 0.92 to 1.17, with an average of 1.02. The peak values were observed in October (1.17±0.02), followed by November (1.14±0.02) and December (1.04±0.01), indicating the healthy condition of the males during these months. The lowest Kn value for males was observed in February (0.92±0.01) (Fig 3a). Fakoya *et al.* (2019) reported that the Kn value of the Gorean snapper, *Lutjanus goreensis*, in the coastal zones of Lagos, southwest Nigeria, ranged from 0.80 to 1.07, with a mean value of 1.01 for males and from 0.96 to 1.11, with a mean value of 1.02 for females. In the current study, the Kn value for females ranged from 0.90 to 1.30, with a mean value of 1.03, while for males, it ranged from 0.85 to 1.21, with a mean value of 1.01. The length class-wise variation in Kn value for both females and males showed two peaks (0.90±0.02 and 0.85±0.04) within the length range of 74.5-79.5 cm, FL. The highest Kn value was observed in both sexes: 1.31±0.04 in 49.5-54.5 cm, FL for females and 1.21±0.05 in 54.5-59.5 cm, FL for males (Fig 3 b).

Masood and Farooq (2010) reported a Kn value close to one for four species of Lutjanids- *Lutjanus johnii, L. lutjanus, L. malabaricus* and *L. fulvus*-collected from the Karachi

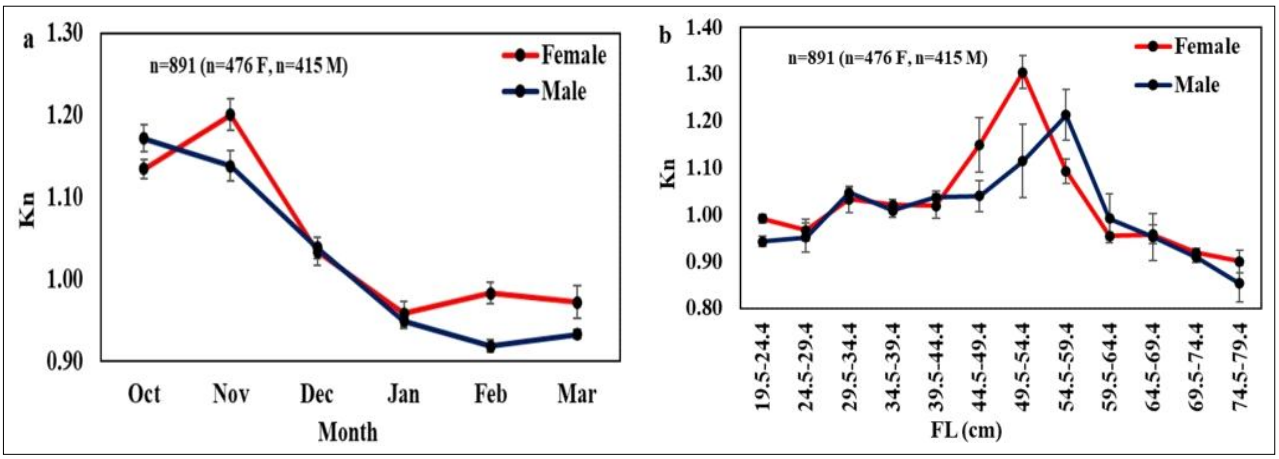

Fig 3: (a) Month-wise (b) Length class-wise variation in Kn values of *P. filamentosus.*

fishing harbour, Pakistan. Similarly, Rahman *et al.* (2023) observed a Kn value equal to or close to one for the length-wise relative condition factors of three coral-associated Lutjanids, including *L. johnii, L. quinquelineatus* and *L. xanthopinnis*, collected from the Terengganu waters of the South China Sea, Malaysia. Rodriguez *et al.* (2023) also reported a length class-wise mean Kn value of one for *L. synagris* from the Colombian Caribbean Sea. The results of the present study suggest that favorable conditions exist in the southern coast of Kerala, India, for *filamentosus*. In this study, relatively higher Kn values for both sexes from October to December indicate gonadal maturation during this period. Condition factors can be influenced by various biotic and abiotic factors, including food availability, water quality, age, size, sex and gonad development (Somy, 2014; Narasimhaiah *et al.,* 2021).

Sexual dimorphism

A total of 301 immature fish (Females- n = 167, Males- n = 134) and 293 mature fish (Females- n = 172, Males- n = 121) were selected for the analysis of sexual dimorphism and confirmation based on gonadal observation. Fish with a fork length (FL) ≥ 32.4 cm for females and FL ≥ 32.1 cm for males were classified as mature. *P. filamentosus* exhibited sexual dimorphic characteristics, including distinct changes in body colouration and variations in pigmentation on the pelvic, anal and pectoral fins and modifications of urogenital regions (Table 2). According to Smith *et al.* (2014) simplified methodologies for recognizing sexual dimorphism lacking in many marine fishes including deep-water snappers. In the present study, juveniles and subadults of *P. filamentosus* do not exhibit any sexual dimorphic characteristics. However, sexual dimorphic characteristics become evident in larger (≥ 30.0 cm, FL) and mature fish. Both sexes of juvenile *P. filamentosus* were pale lavender, which gradually became silvery towards the ventral side. Kami (1973) agreed with our observation that juveniles and subadults of *P. filamentosus* do not exhibit colour variations; these variations become evident only in large adults. Kami (1973) also confirmed the reliability of colour variations among males and females in sex determination in *P. filamentosus* and *P. auricilla* but did not report the details of these variations.

Both the genital septum and genital papillae were more pronounced at maturity. Gross visual observation of the urogenital region has been proposed as an accurate method to determine the sex of *P. filamentosus* (Luers *et al.,* 2017). The female *Etelis carbunculus* has an enlarged, crescent-shaped genital pore and the septum tissue,

Table 2: Sexual dimorphic characters observed in mature female and male *P. filamentous.*

Character	Female	Male
Body colouration	Pale lavender to brownish body colouration (Fig 4a).	Bright lavender to reddish-purple body colouration (Fig 4b).
Fin pigmentation a. Pelvic fin	Specifically, in immature or sub-adult females, pelvic fin membranes are usually white and translucent, with minimal black pigmentation. However, at maturity, the pelvic membrane between the first, second and third rays becomes dusky, lacking the orange-yellow tinges in larger females (Fig 4c).	Conversely, mature males usually have duskier pelvic fin membranes, with larger males having prominent orange-yellow tinges on the first, second and third pelvic rays and pale orange-yellow tinges on the last two rays (Fig 4d).
b. Anal fin	The anal fin membranes of large females exhibit slight duskiness but lack orange-yellow tinges (Fig 4e).	Larger mature males exhibit dusky anal fin membranes, often with an orange-yellow tinge along the anal spine rays except at their tip (Fig 4f).
c. Dorsal fin	Females have slightly dusky dorsal fins, with the fin membranes tinged yellow-orange at the top (Fig 5a).	In larger males, the membranes of the dorsal fins appear dusky, with a high concentration of black pigments and a pale orange-yellow tinge at the top (Fig 5b).
Urogenital region	At maturity, the females have a distinct genital septum between the urogenital and anal pores, with small, swollen, button-shaped genital papillae which face inward (Fig 5c).	In males, genital papillae are elongated, cylindrical, projecting outwards and more prominent than in females (Fig 5d) and the genital septum is not distinct.

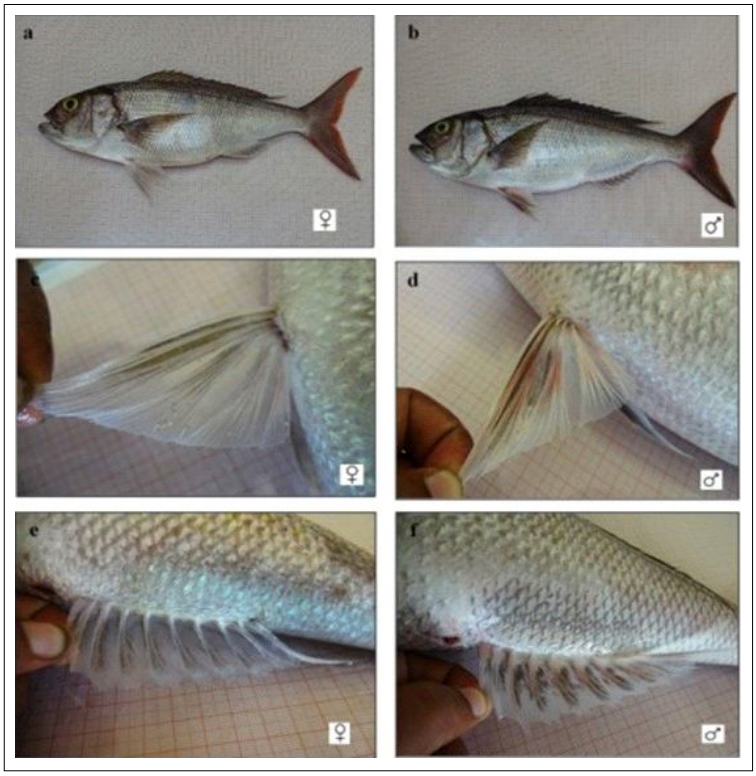

Fig 4: Photographs of texture of body colouration for (a) female and (b) male; texture of pelvic fin for (c) female and (d) male; texture of anal fin for (e) female and (f) male of *P. filamentosus*.

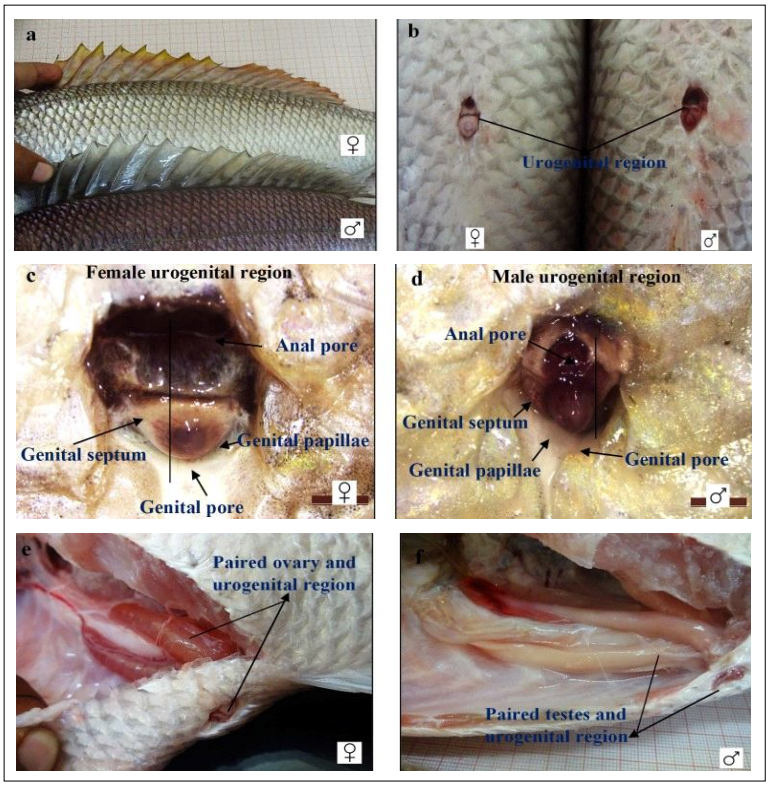

Fig 5: Photographs showing the texture of pectoral fin for (a) female and male; ventral view of urogenital region for (b) female and male; Stereoscopic view of urogenital region (c) female and (d) male of *P. filamentosus*; In situ observation of gonads with urogenital region for (e) female and (f) male.

which divides the two pore openings, resembles papillae. In contrast, the male fish lack a distinct papilla (Nichols *et al.,* 2022). The variations observed in body and fin colouration and characteristics of urogenital regions of both sexes were confirmed by dissecting the male and female gonads Fig 5 (e) and Fig 5 (f) and correlating the observed features. Kami (1973) reported traces of yellow colour in the ventral lobe of caudal fin in females and a distinct yellow blotch in the ventral lobe of the caudal fin of large males (>27.0 cm, FL) of *P. auricilla* from Guam. Sexual dimorphism is evident in urogenital modifications in deep water snappers (*P. zonatus*, *P. seboldii*, *Aphareus rutilans* and *E. coruscans*) from Hawaii (Nichols, 2019), similar to that reported in the present study in *P. filamentosus*. Sexual size dimorphism has reported in deep water red snapper (*E. carbunculus*), in which female is 20% longer than males (Williams *et al.,* 2017). Similarly, males are larger than females of same age group in humpback red snapper (*L. gibbus*) (Nanami, 2010; Taylor *et al.,* 2018; Moore, 2019) and Maori snapper (*L. rivulatus*) from north-eastern Australia (Wakefield *et al.,* 2020).

Along with characteristics such as body pigmentation, fin shape and genital papillae, sexual dimorphism constitutes a significant component of external morphological variation between the sexes (Andersson, 1994). Hedrick and Temeles (1989) identified three major adaptive mechanisms that encourage sexual dimorphism in fish: sexual selection, dimorphic niche and food competition. In a food fish breeding program, sexual dimorphic features of fish play a significant role in selecting good specimens of brood fish, which will yield good numbers of healthy eggs.

CONCLUSION

LWR, Kn and sexual dimorphism of *P. filamentosus* reported here is the first report from India. The estimated LWR showed a negative allometric growth pattern for females, males and pooled sexes in the present study. *P. filamentosus* exhibits lower Kn values from January to March and also in both the sexes' lower and higher length classes. Mature *P. filamentosus* displays sexual dimorphism, with differences in body colour patterns, fin texture, urogenital region and genital papillae between male and female fish. Sexual dimorphism is more evident in the breeding season and may have a role in sexual and natural selection. If sexual dimorphism is evident, it allows the market samplers to stratify their collection of length data by sex effectively and also to estimate the sex ratio in catches more effectively. In the food fish breeding program, the sexual dimorphic features of fish play a significant role in the selection of brood stocks for cannulation, induction and breeding. Since lutjanids are preferred for farming worldwide, this information will be helpful for broodstock development and breeding programmes.

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Author's contribution

Manoj Kumar Mohanan Pillai contributed to data collection, statistical analysis and writing of the original draft; B. Santhosh to research design, supervision, manuscript review and editing; S. Surya to statistical analysis, manuscript review and editing; F. Muhammed Anzeer and Shoji Joseph manuscript review and editing.

Conflict of interest

All authors declared that there is no conflict of interest.

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