





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Full length article

## Spawning periodicity, sexual maturity, and reproductive potential of talang queenfish, *Scomberoides commersonianus* from the south-eastern Arabian Sea, India

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## ABSTRACT

Knowledge of reproductive biology forms the basis for assessing population dynamics and developing sustainable exploitation strategies. Although the talang queenfish (*Scomberoides commersonianus*) holds substantial commercial value, data from Indian waters are limited. This study analysed 723 specimens collected from Mangaluru and Malpe landing sites along the Karnataka coast during January 2020 to December 2024 to evaluate reproductive parameters. The sex ratio of 1:0.96 (male: female) indicated no significant difference between sexes. The length at which 50% of individuals reached sexual maturity (Lm50) was estimated at 48.3 cm for females and 45.8 cm for males. Fluctuations in GSI values, coupled with the occurrence of various maturity stages throughout the year, reveal that the species spawns year-round with two distinct spawning peaks, a major one during April–May and a minor peak in November–December. Individual females produced between 112,479 and 1,585,944 oocytes per spawning, corresponding to sizes of 56.1 cm and 92.6 cm, respectively, with a mean fecundity of  $657,720 \pm 115,884$ . Relative batch fecundity varied from 100 to 311 eggs  $g^{-1}$  (mean:  $218 \pm 15$  eggs  $g^{-1}$ ). As the first comprehensive report from Indian waters, the study delivers critical insights for guiding conservation and sustainable exploitation of this commercially significant species.

## Introduction

Queenfishes of the family Carangidae are tropical pelagic fishes belonging to the single genus *Scomberoides*. The genus traditionally comprised four recognized species: *Scomberoides commersonianus* (talang or giant queenfish), *Scomberoides tala* (barred queenfish), *Scomberoides tol* (needle-scaled queenfish), and *Scomberoides lysan* (lesser queenfish). More recently, an additional species, *Scomberoides pelagicus* (deep-bodied queenfish), was described from Indian waters (Abdussamad et al., 2022), thereby increasing the known diversity of the genus. Queenfishes are widely distributed throughout the Indo-Pacific region, ranging from eastern Africa and the Red Sea to Southeast Asia, northern Australia, and the western Pacific Ocean (Riede, 2004; Griffiths & Fry, 2005).

Queenfishes represent a valuable pelagic fishery in India, with an estimated annual production of 140,000 tonnes, constituting 4.1% of the nation's marine fish landings. Located on the southeastern Arabian Sea, Karnataka has a 320 km coastline and an extensive continental shelf of about 25,000 km<sup>2</sup>, making it the second-largest contributor to India's marine fish production with around 600,000 million tonnes (FRAEED, CMFRI, 2024). Queenfishes accounted for 1.03% of the state's marine landings and are mainly harvested using hook and lines operated from mechanized trawlers and drift gillnets.

This species is an important component of coastal and offshore fisheries, owing to its wide distribution, fast growth, and high market demand. Significant population decline of this species has neither been reported nor suspected (Smith-Vaniz & Williams, 2016). This pelagic species is a voracious predator that consumes a wide array of prey

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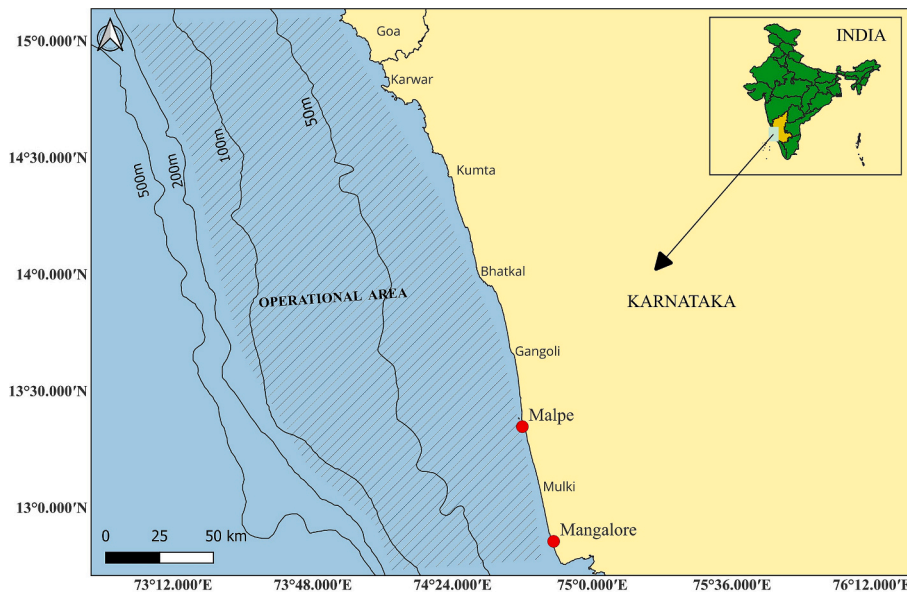


Fig. 1. Map showing the operational area of mechanized crafts and sampling locations for *Scombroides commersonianus*.

dominated largely by teleosts (Qamar et al., 2018).

Globally, studies have focused mainly on fishery, distribution (James, 1964; Pillai et al., 1987), length-weight relationships (Mbaru et al., 2010; Masoomizadeh et al., 2018; Azam & Naem, 2021), stock assessment (Taghavi Motlagh et al., 2005; Panhwar et al., 2014; Ali et al., 2024; Barua et al., 2024; Majeed, 2025), feeding ecology (Maasoumizadeh et al., 2014; Qamar et al., 2018), and proximate composition (Sutharshiny & Sivashanthini, 2011; Azam & Naem, 2021) with reproductive studies restricted to northern regions of Australia (Griffiths & Fry, 2005) and Pakistan (Qamar et al., 2020). Knowledge of reproductive characteristics, such as maturity size, spawning timing, and reproductive output, is crucial for assessing population trends and promoting sustainable fisheries and aquaculture practices (Shalloof & Salama, 2008; Gomez-Marquez et al., 2003). In this context, the present study aimed to investigate the reproductive biology of *S. commersonianus* along the southeastern Arabian Sea off Karnataka, India. Specifically, the study examined sex ratio, gonadosomatic index (GSI), maturity stages, length at first maturity, and spawning seasonality. By providing the first detailed account of the reproductive dynamics of this species from the region, the study establishes important baseline information that contributes to a better understanding of its population structure and supports the development of science-based management measures for the sustainable exploitation and conservation of the species.

## Materials and methods

### Data and sample collection

The quantities of *S. commersonianus* landed along the Karnataka coast by commercial fishing vessels operating in the Exclusive Economic Zone of the southwest coast of India during 2020–2024 were obtained from the databank of the National Marine Fishery Data Centre, ICAR–Central Marine Fisheries Research Institute, Kochi. A total of 723 specimens were collected between January 2020 and December 2024. Samples were collected fortnightly from the landings throughout the study period at two major fishing harbours of Karnataka—Mangaluru Fishing Harbour (12.853°N; 74.833°E) and Malpe Fishing Harbour (13.347°N; 74.701°E)—situated along the southwest coast of India (Fig. 1). These two landing centres together account for more than 85% of the total marine fish landings of the state. Specimens were collected periodically from the major fishing gears commonly operated in the

Table 1

Macroscopic characteristics of gonadal development stages used to classify the reproductive status of *Scombroides commersonianus*.

Stage	Ovary characteristics	Testis characteristics
Immature	Ovaries are very small, thin and transparent. They occupy only a small part of the body cavity and eggs cannot be seen with the naked eye.	Testes are small, thin and transparent. They occupy little space in the body cavity and no milt is present.
Developing	Ovaries increase in size and become slightly opaque. Early developing eggs start forming but are not fully developed.	Testes enlarge and become whitish. Sperm cells start developing but milt cannot be released.
Spawning capable	Ovaries are large and well developed, occupying a major part of the body cavity. Eggs are clearly visible and may be released with gentle pressure in some individuals.	Testes are large, firm and milky white. Milt is present and can usually be released with gentle pressure.
Regressing	Ovaries become loose and smaller after spawning. A few remaining eggs and post-spawning structures may still be present	Testes decrease in size and become softer. Some residual milt may remain but reproductive activity declines.
Regenerating	Ovaries are small to medium in size and contain mainly early-stage eggs as they recover for the next cycle.	Testes are small and pale. They remain inactive while preparing for the next reproductive cycle.

region, including hook and lines operated from the mechanized trawlers, and drift gillnets. No collections were made during the monsoon period, when a fishing ban on mechanized fishing vessels was imposed from 1 June to 31 July. The collected specimens were preserved in thermally insulated containers with ice and transported to the laboratory for further examination.

### Laboratory analysis

#### Length-weight relationship

In the laboratory, the fork length (FL) of each specimen was measured using a flexible measuring tape with an accuracy of 0.1 cm, and the body weight was determined using a digital balance with an accuracy of 0.1 g. The length-weight relationship was estimated following the method described by Le Cren (1951) using the equation  $W$

$= aFL^b$ , where W represents total body mass in g., FL is the fork length in cm, a is the coefficient associated with body mass and b is an exponent signifying allometric growth. Differences in length–weight relationships between males and females were tested using analysis of covariance (ANCOVA) following the procedure outlined by [Snedecor and Cochran \(1967\)](#).

#### Maturity stages and sex ratio

Each specimen was dissected through a ventral incision, and the gonads were carefully removed, blotted dry, and weighed to the nearest 0.01 g. The maturity stage of each specimen was determined through visual examination of the gonads based on their colour, size, weight, vascularization, and the extent of their occupation within the abdominal cavity. Based on these characteristics, the gonads were classified into five maturity stages—immature, developing, capable of spawning, regressing, and regenerating—as per the criteria described by [Brown-Peterson et al. \(2011\)](#), [Villegas-Hernandez et al., \(2014\)](#) and [Rajesh et al. \(2020\)](#). The key maturity characteristics used for the identification of various stages are described in [Table 1](#). Whenever the maturity stage was difficult to determine, the gonads were examined microscopically to accurately differentiate the stages.

The sex ratio (male:female) was tested against the expected 1:1 ratio using Peterson's Chi-square goodness-of-fit test with Yates' correction, and the level of significance was set at 5% ([Zar, 1996](#)).

#### Length at 50% maturity ( $L_m50$ )

The length at first maturity ( $L_{50}$ ) was estimated using the logistic model described by [King \(2007\)](#). The proportion of mature individuals in each length class was fitted to a logistic function:

$$P = 1 / (1 + \exp(-r \times (L) - Lm))$$

where P denotes the proportion of mature individuals in a given length class, L is the fork length, Lm represents the length at which 50% of the individuals are mature, and r is the slope parameter of the logistic curve. The parameters of the logistic model were estimated using a non-linear regression solver based on the ratio of mature to immature individuals in each length class, following the approach of [Huges and Stewart \(2006\)](#).

#### Gonadosomatic index

The GSI of each specimen was determined by dividing the weight of the gonads by the eviscerated body weight and multiplying by 100 to express it as a percentage. Spawning periodicity was inferred from peaks in mean GSI values and the predominance of individuals in the spawning-capable stage across maturity phases. Monthly variations in the GSI were assessed using Kruskal-Wallis's test, followed by Duncan's multiple range test when significant differences were detected.

#### Condition factor (K)

The condition factor (K) of *S. commersonnianus* was estimated to assess the relative well-being and physiological condition of the fish ([Froese, 2006](#)):

$$K = W/FL^3 \times 100$$

where, K is the condition factor, W is the total body weight of the fish (g), and FL is the fork length of the fish (cm).

The condition factor was calculated for each individual specimen and the monthly mean values were determined to examine seasonal variations in relation to reproductive activity and gonadal development.

#### Estimation of fecundity

Batch fecundity was determined for 17 ripe ovaries using a gravimetric method combined with image analysis as mentioned by [Murua](#)

**Table 2**

Monthly sex ratio of talang queenfish, *Scomberoides commersonnianus* in south-eastern Arabian Sea during 2020–2024.

Months	Sex ratio (Male: Female)	Chi square ( $\chi^2$ ) value
Jan	1.03	0.0001
Feb	0.85	0.0419
Mar	0.60	0.5625
Apr	1.09	0.0005
May	0.79	0.2215
Aug	1.35	0.4408
Sep	1.48	2.1346*
Oct	1.03	0.0002
Nov	0.77	0.6999
Dec	0.83	0.2143

\* Differ significantly at  $p < 0.05$ .

**Table 3**

Size based sex ratio of talang queenfish, *Scomberoides commersonnianus* in southeastern Arabian Sea during 2020–2024.

Length class (cm)	Sex ratio (Male: Female)	Chi square ( $\chi^2$ ) value
20–25	1.20	0.09
25–30	0.57	6.37*
30–35	1.19	1.10
35–40	1.27	2.24
40–45	0.98	0.01
45–50	1.44	2.91
50–55	0.73	0.95
55–60	0.72	0.81
60–65	0.78	0.25
65–70	2.0	0.33
70–75	2.0	0.67
75–80	1.00	0.01
80–85	1.00	0.33
85–90	1.00	0.67
90–95	3.00	1.00

\*\* Length classes 95–100 to 110–115 cm were excluded from the Chi-square analysis because individuals of one sex were absent in these classes.

\* Differ significantly at  $p < 0.05$ .

[et al. \(2003\)](#). Oocyte concentration was determined by weighing 3–5 subsamples from different regions of each ovarian lobe to the nearest 0.001 g, spreading them evenly, and counting and measuring the oocytes using a calibrated grid. Total fecundity was then estimated by scaling the egg count in each subsample according to its corresponding gonad subsample weight. The relationship between fecundity and fish length, body weight, and gonad weight was analyzed following the approach described by [Zupa et al. \(2013\)](#).

## Results

### Sex ratio and size composition

A total of 723 specimens of talang queenfish were examined, of which 369 (51.04%) were males and 354 (48.96%) females, resulting in an overall sex ratio of 1:0.96 (male: female). The annual sex ratio did not show a significant deviation from parity ( $p < 0.05$ ). Monthly analysis also indicated that the sex ratio remained close to unity during most months. However, in September, females were relatively more abundant, resulting in a male-to-female ratio of 1:1.48 ([Table 2](#)). Sex ratio across size classes showed that only the 25–30 cm FL class exhibited a significant deviation from the expected 1:1 ratio ( $p < 0.05$ ), with males dominating this size group. In all other length classes, the observed sex ratios did not differ significantly from parity ([Table 3](#)).

The FL of the specimens ranged from 22.6 to 113 cm. Male talang queenfish ranged in length from 22.6 to 110 cm (mean FL:  $39.4 \pm 0.68$  cm S.E.) and had body weights between 72.0 g and 8750 g (mean weight:  $586.9 \pm 46.88$  g S.E.). Females measured between 22.0 and 113 cm (mean FL:  $39.5 \pm 0.69$  cm S.E.) and had body weights ranging from

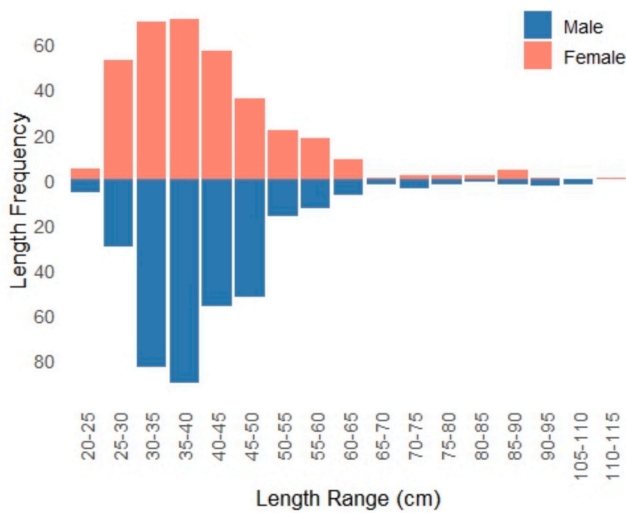


Fig. 2. Fork Length (FL) frequency histograms of *Scomberoides commersonianus* observed in the fishery during 2020–2024.

61.0 g to 8711 g (mean weight:  $578.7 \pm 44.12$  g S.E.). Independent *t*-test results indicated no significant difference ( $p > 0.01$ ) in the mean FL or body weight between males and females. Size-frequency analysis showed that individuals belonging to the 30–50 cm size class dominated the landings, with the 30–40 cm length group being the most abundant in both sexes (Fig. 2).

#### Length-weight relationship

The length–weight relationships of talang queenfish for males, females, and combined sexes are presented in Fig. 3.

Male:  $W = 0.0114 L^{2.87}$  ( $r^2 = 0.993$ ,  $n = 369$ ).

Female:  $W = 0.014 L^{2.81}$  ( $r^2 = 0.992$ ,  $n = 354$ ).

Sex combined:  $W = 0.0126 L^{2.84}$  ( $r^2 = 0.993$ ,  $n = 723$ ).

The estimated growth coefficient (*b*) values for males, females, and combined sexes were all less than 3, indicating a deviation from isometric growth.

#### Length at first maturity ( $L_{m50}$ )

The length at first maturity ( $L_{m50}$ ) of talang queenfish was estimated at 48.3 cm for females (Fig. 4a) and 45.8 cm for males (Fig. 4b), indicating that males attain maturity earlier than females.

#### Gonadosomatic index

The mean GSI of females ranged from 0.51 to 1.61 during the study period, with pronounced peaks in May ( $1.61 \pm 0.16$ ), April ( $1.12 \pm 0.18$ ), November ( $1.05 \pm 0.08$ ) and December ( $0.79 \pm 0.07$ ) (Fig. 5a). The average GSI levels during April–May and November were significantly higher ( $p \leq 0.05$ ) than during the rest of the year.

The average GSI of males ranged from 0.23 to 0.70, with maximum values recorded in April ( $0.70 \pm 0.04$ ) and May ( $0.69 \pm 0.05$ ). Moderate values were also observed in October ( $0.60 \pm 0.05$ ) and November ( $0.53 \pm 0.04$ ) (Fig. 5a).

#### Maturity stages

Higher proportion of spawning-capable females (49–58%) were recorded in the months of April–May and November–December (20.28%), indicating the occurrence of two distinct spawning peaks in a year (Fig. 6a). However, the continuous presence of individuals in spawning-capable, regressing, and regenerating phases noticed throughout the year that indicated the reproductive activity occurs year-round with varying intensity.

Macroscopic examination of testes revealed the occurrence of

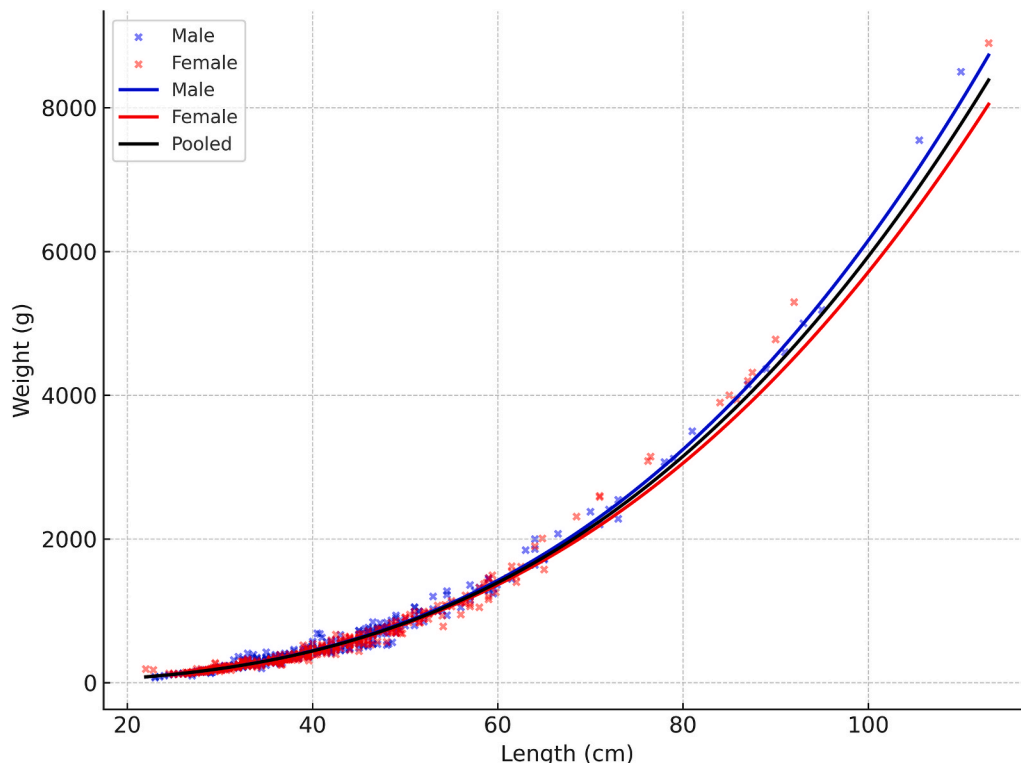


Fig. 3. Length-weight relationship in talang queenfish, *Scomberoides commersonianus* along the coastal waters of Karnataka during 2020–2024.

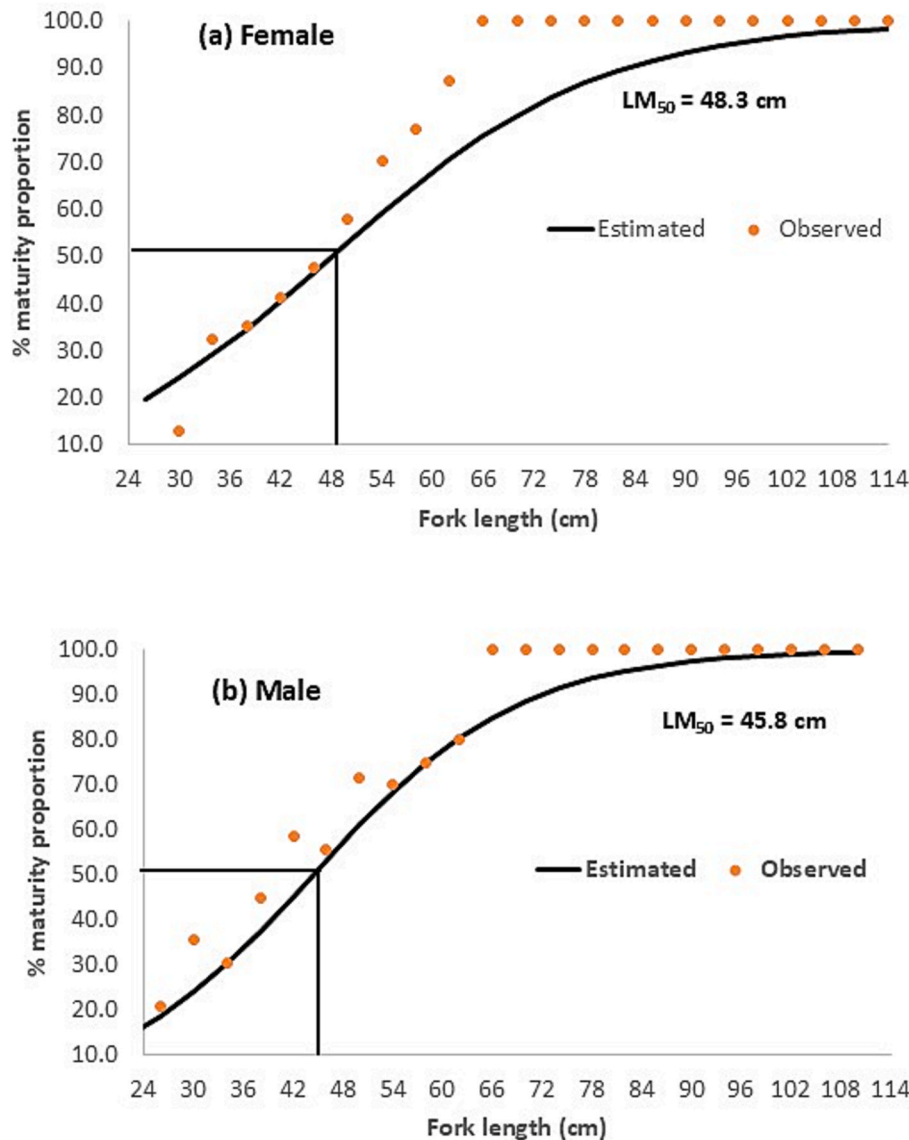


Fig. 4. Length at maturity (Lm<sub>50</sub>) of (a) female and (b) male talang queenfish, *Scomberoides commersonnianus*.

individuals with ripe testes throughout the year in varying proportions. The proportion of spawning-capable males was highest in April (51%) and May (49%), with secondary peaks in November (27%) and January (28%) (Fig. 6b).

#### Condition factor (K)

The mean condition factor ranged from 0.85 to 1.25, with maximum values recorded in April for females and from 0.7 to 1.05 with maximum values recorded in March for males. The seasonal variation in the condition factor (K) showed a pattern similar to that of the GSI (Fig. 5a and b).

#### Fecundity, and its correlation with fork length and body mass

Fecundity assessment is a key parameter for evaluating the reproductive potential of fish populations. Seventeen mature ovaries were selected for estimating batch fecundity. Oocyte counts ranged from 112,479 in a specimen measuring 56.1 cm to 1,585,944 in an individual of 92.6 cm. The average batch fecundity was estimated at  $657,720 \pm 115,884$  (mean  $\pm$  S.E.) eggs per female. Relative batch fecundity

(number of eggs per g of gutted body weight) varied between 100 and 311 eggs g<sup>-1</sup>, with an average of  $218 \pm 15$  eggs g<sup>-1</sup>. Fecundity showed a strong positive relationship with fish length ( $r^2 = 0.97$ ) and also increased with body mass ( $r^2 = 0.93$ ) (Fig. 7).

#### Discussion

The overall sex ratio of talang queenfish across months in the present study (1:0.96) indicates a nearly balanced distribution of males and females in the population. The analysis of sex ratio across length classes also indicated that males and females were present throughout most of the size range, with only minor variations among size classes. The overall sex ratio did not deviate significantly from the expected 1:1 proportion, suggesting a balanced representation of both sexes in the population. Such balanced sex ratios are generally considered advantageous for maintaining reproductive output and sustaining fish populations (King, 2007). A similar non-significant deviation from parity has been reported from northern Australian waters (Griffiths & Fry, 2005), whereas a strong male dominance was observed along the Pakistan coast (Qamar et al., 2020). Such regional differences in sex ratios may be influenced by variations in spatial distribution,

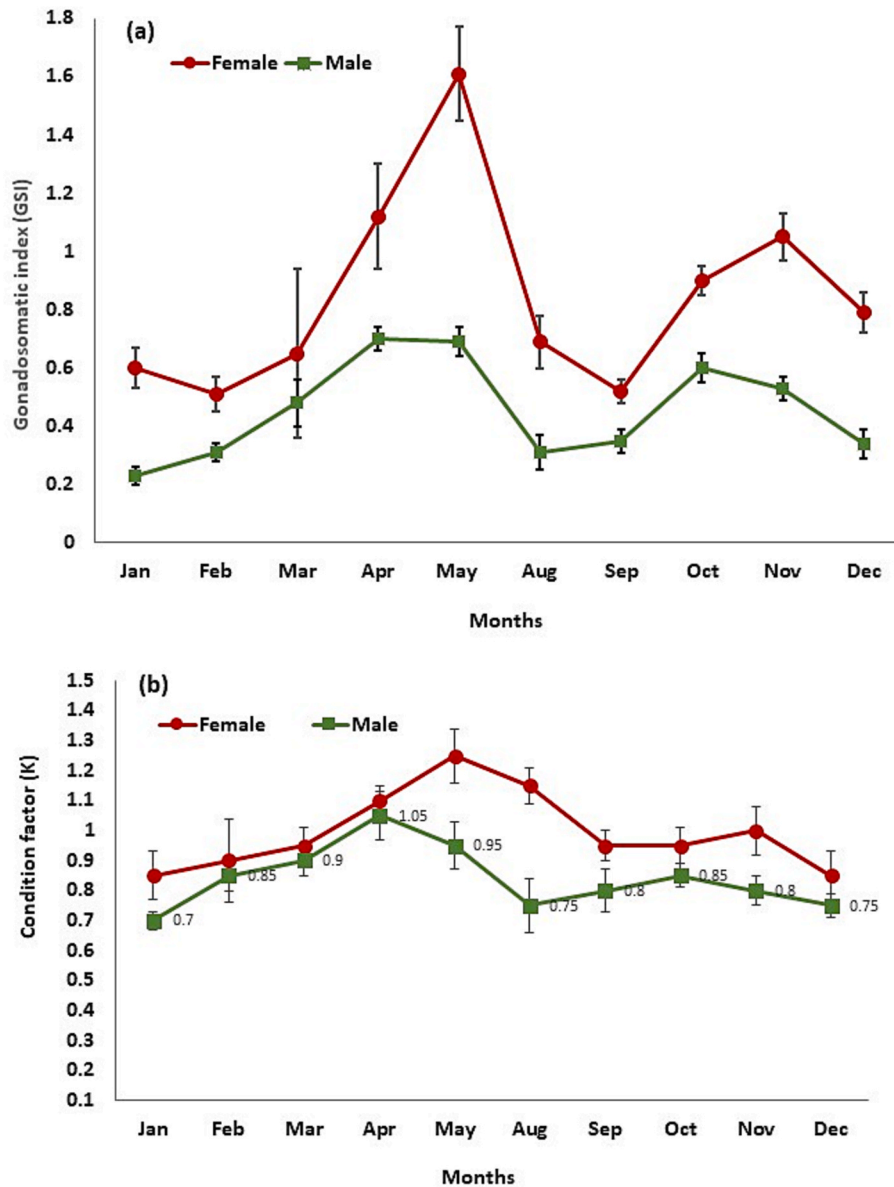


Fig. 5. (a) Gonado-somatic index (GSI) and (b) condition factor (K) of female and male *Scomberoides commersonnianus* in the coastal waters of Karnataka during 2020–2024.

behavioural patterns, environmental conditions, and seasonal reproductive migrations (De Sylva, 1973; Morato et al., 2003; Imam et al., 2012; Visconti et al., 2020; Palla & Sotto, 2021). The higher proportion of females observed in September could be related to seasonal aggregation associated with reproductive activity.

The size range recorded in the present study (22.6–113 cm FL) was slightly lower than the maximum sizes reported from the western Indian Ocean, Pakistan, and Bangladesh, but higher than those reported from several other regions (Table 4). Such variations may reflect differences in environmental conditions, productivity, and fishing pressure. The absence of significant differences in mean length and weight between males and females suggests similar growth patterns in both sexes. The dominance of the 30–50 cm size group, particularly the 30–40 cm class, indicates that the fishery mainly exploits intermediate-sized individuals, which may be influenced by gear selectivity and fishing practices.

Investigations on length–weight relationships are important in fisheries science as they provide information on growth characteristics, age estimation, stock dynamics, and the influence of environmental and climatic variations (Kolher et al., 1995; Froese, 2006). In the present

study, the length–weight relationship of *S. commersonnianus* showed negative allometric growth ( $b < 3$ ), indicating that length increases proportionately more than body weight. Similar growth trends have been reported from different geographical regions (Griffiths & Fry, 2005; Taghavi Motlagh et al., 2005; Panhwar et al., 2014; Masoomzadeh et al., 2018; Barua et al., 2024).

In contrast, studies from the Kenyan coast (Mbaru et al., 2010) and the Balochistan coast (Ali et al., 2024) reported positive allometric growth ( $b > 3$ ), indicating that body weight increases proportionately more than length (Table 4). Such regional discrepancies in growth patterns may be influenced by ecological conditions, food availability, fishing pressure, sampling period, sample size, length range of specimens, sex, gonadal maturity, health condition, and environmental factors that affect energy allocation strategies of the species (Le Cren, 1951; Froese, 2006; Froese et al., 2011; Roul et al., 2020; Jiang et al., 2024).

The length at first maturity ( $L_{m50}$ ) is an important parameter in fisheries management as it indicates the minimum size at which individuals contribute to reproduction and helps in formulating sustainable harvesting strategies. The estimated length at first maturity ( $L_{m50}$ )

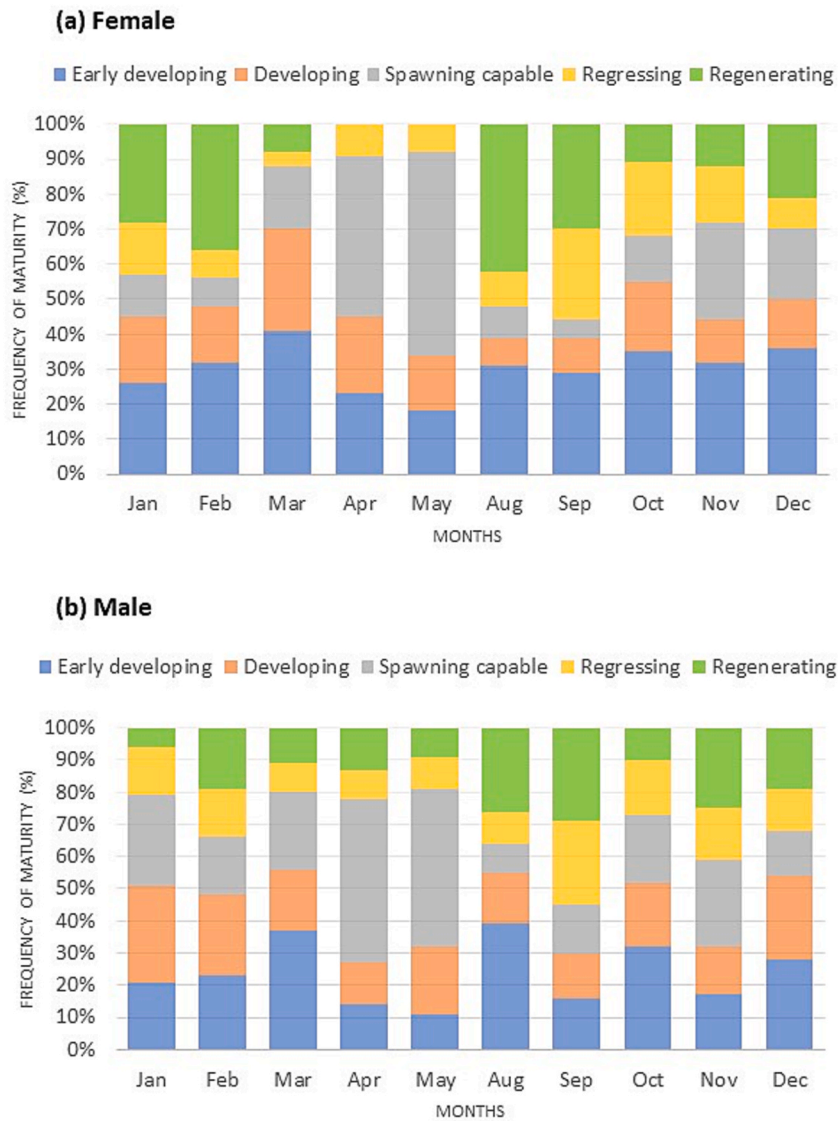


Fig. 6. Relative frequency of maturity stages of (a) female and (b) male *Scomberoides commersonnianus*.

in the present study is 48.3 cm FL for females and 45.8 cm FL for males, indicating that females attain maturity at a slightly larger size than males. The previous management recommendations proposed a minimum legal size of 31.5 cm FL, which was based on the minimum size at maturity (Rohit et al., 2016). However, this size is considerably lower than the Lm50 estimated in the present investigation. Setting the minimum legal size close to or above the length at first maturity is important for sustainable fisheries management, as it allows a substantial proportion of the population—particularly females—to spawn at least once before being subjected to fishing pressure. Therefore, the results of the present study suggest that the currently recommended minimum legal size may need reconsideration, and adopting a size limit closer to the estimated maturity length could contribute to improved spawning stock biomass and long-term sustainability of the fishery.

The earlier maturation observed in males compared to females in the present study is consistent with findings from northern Australian waters, where females matured at 47.6 cm FL and males at 38.5 cm (Griffiths & Fry, 2005). In contrast, studies from Pakistan reported smaller sizes at maturity (35 cm for males and 39 cm for females), although the trend of earlier maturation in males remained similar (Qamar et al., 2020).

Regional differences in Lm50, as observed between the southeastern

Arabian Sea, northern Australian waters, and the Pakistan coast, may be influenced by variations in environmental conditions, food availability, fishing pressure, and genetic factors (Sampson & Al-Jufaily, 1999; Rajesh et al., 2020). The longer time required for females to reach maturity may be associated with greater energy allocation towards gonadal development and egg production, which can delay maturation compared to males (Miller & Kendall, 2009).

The monthly distribution of gonadal maturity stages showed a close relationship with the variation in the GSI of *S. commersonnianus*. Early in the reproductive cycle, most individuals were in the immature and developing stages, corresponding with low GSI values. As the season progressed, the proportion of mature and spawning capable individuals, increased, accompanied by a rise in GSI, with peak values indicating the period of active spawning. The subsequent occurrence of spent individuals was associated with a sharp decline in GSI, reflecting gamete release after spawning. These patterns indicate that the spawning season coincides with the months when ripe individuals are most abundant and GSI values reach their maximum. The pronounced spawning peak observed during April–May coincides with the pre-monsoon summer period when water temperature, photoperiod, and salinity are relatively high in the region. Since fishes are heterothermic, reproductive activity and gonadal maturation are strongly influenced by environmental

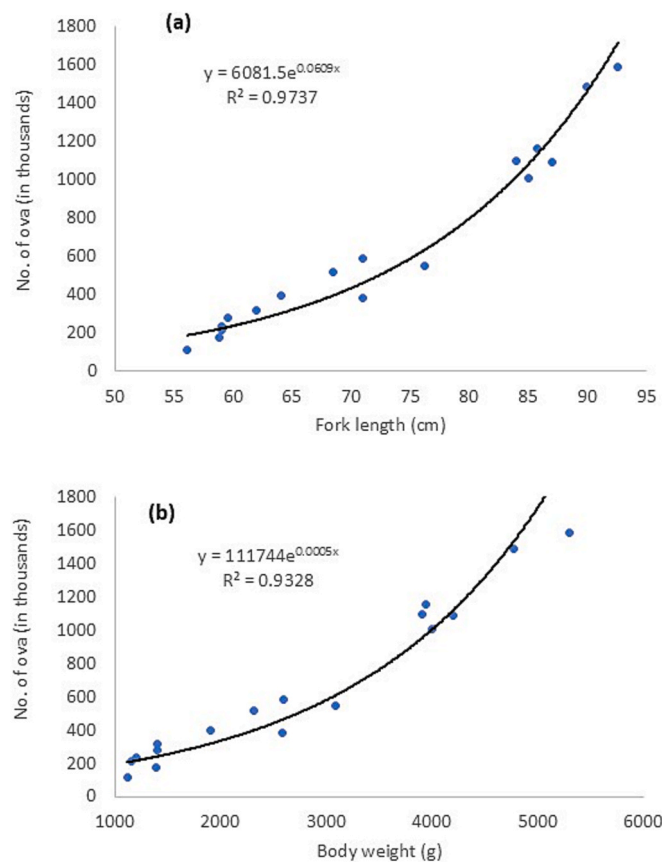


Fig. 7. Relationship between fecundity to – (a) fork length and (b) body weight of *Scomberoides commersonnianus*.

factors such as water temperature and day length (Zacharia & Jayabalan, 2007; Suyani et al., 2021). A secondary, less intense spawning phase observed during November–December corresponds to the cooler post-monsoon period characterized by moderate salinity.

The bimodal spawning pattern observed in the present study appears to be regulated by seasonal fluctuations in environmental conditions such as temperature, photoperiod, and salinity. Seasonal variability in the southeastern Arabian Sea is strongly influenced by the Southwest monsoon which regulate oceanographic conditions such as sea surface temperature, salinity, and nutrient availability. These monsoon-driven processes promote vertical mixing and nutrient enrichment, leading to enhanced phytoplankton and zooplankton production in coastal waters of the region (Vivekanandan et al., 2005; Krishnakumar et al., 2008).

The bimodal spawning pattern observed in *S. commersonnianus* appears to coincide with these productive periods associated with the pre–southwest monsoon and post-monsoon phases. Spawning during such periods may provide favourable conditions for larval growth by ensuring the availability of abundant planktonic prey during the early life stages. Similar relationships between seasonal productivity and larval fish survival have been reported in the Arabian Sea and other tropical marine ecosystems (Kumar et al., 2001; Rathnasuriya et al., 2021). Consequently, the timing of spawning in this species may represent an adaptive strategy that enhances larval survival and recruitment success in the highly dynamic monsoon-driven environment of the Arabian Sea.

At the same time, the continuous occurrence of reproductive stages throughout the year suggests prolonged reproductive activity, which is typical of many tropical marine fishes inhabiting relatively stable thermal environments. From an ecological perspective, such a bimodal spawning pattern with year-round reproductive activity may enhance recruitment opportunities, improve stock resilience, and support population persistence under variable fishing pressure and environmental conditions.

The findings of this study are consistent with reports from northern Australia, where talang queenfish exhibit a prolonged spawning period from September to March with two prominent peaks during November and February (Griffiths & Fry, 2005). Similarly, along the Pakistan coast, spawning activity occurs from March to July with a pronounced peak in June, followed by a secondary spawning phase between November and February with a smaller peak in December (Qamar et al., 2020). These regional variations in spawning phenology suggest that environmental factors such as water temperature and food availability may play a critical role in regulating reproductive periodicity in *S. commersonnianus*.

The identification of distinct spawning peaks has important implications for the management and conservation of *S. commersonnianus*. In tropical countries such as India, marine fisheries are typically characterized by multispecies exploitation using multiple types of fishing gears, which makes the implementation of species-specific seasonal closures operationally challenging. Nevertheless, the occurrence of peak spawning during April–May and October–November indicates critical reproductive periods when protection of spawning individuals could contribute to sustaining the stock. Therefore, reducing fishing pressure during these peak spawning months may help safeguard spawning aggregations and enhance recruitment. At the same time, further investigations are necessary to identify the precise spawning grounds and areas of high larval abundance. Mapping these critical habitats through targeted surveys and GIS-based spatial analyses would provide a stronger scientific basis for developing effective spatial or seasonal management measures for the conservation of the species.

Seasonal variation in the condition factor (K) of *S. commersonnianus*

Table 4

Length–weight relationships (LWRs) of *Scomberoides commersonnianus* recorded in the present study and accros other geographic areas.

Sex	Number	Length range (cm)	LWRs	r <sup>2</sup>	Growth (+/–)	Region	Reference
Female	148	–	W = 0.00003FL <sup>2.8130</sup>	0.990	Allometric (–)	Northern Australia	Griffiths and Fry (2005)
Male	158	–	W = 0.00005FL <sup>2.7629</sup>	0.998	Allometric (–)		
Pooled	306	23.3–92.1 (FL)	W = 0.00004FL <sup>2.7915</sup>	0.989	Allometric (–)		
Pooled	2530	18–111 (FL)	W = 0.0104FL <sup>2.93</sup>	0.979	Allometric (–)	Southeastern coastal waters of Iran	Taghavi Motlagh et al. (2005)
Pooled	504	21.5–96.0 (TL)	W = -6.722TL <sup>3.633</sup>	0.918	Allometric (+)	Kenyan coastal waters	Mbaru et al. (2010)
Pooled	1003	18–130 (TL)	W = 0.011TL <sup>2.88</sup>	0.952	Allometric (–)	Arabian Sea coast of Pakistan	Panhwar et al. (2014)
Female	247	12.6–96.9 (FL)	W = 1.7977FL <sup>2.8873</sup>	0.993	Allometric (–)	North-west Persian Gulf	Masoomizadeh et al. (2018)
Male	292	17.2–94.9 (FL)	W = 1.6855FL <sup>2.8141</sup>	0.987	Allometric (–)		
Pooled	563	8.6–96.9 (FL)	W = 1.8424FL <sup>2.9109</sup>	0.991	Allometric (–)		
Pooled	1635	21.0–105.0 (TL)	W = 0.0013TL <sup>3.377</sup>	0.90	Allometric (+)	Balochistan coast, Pakistan	Ali et al. (2024)
Pooled	1306	15–116.5 (TL)	W = 0.013TL <sup>2.84</sup>	0.980	Allometric (–)	Bay of Bengal, Bangladesh	Barua et al. (2024)
Female	354	22.0–113 (FL)	W = 0.0114FL <sup>2.81</sup>	0.993	Allometric (–)	Southeastern Arabian Sea	Present Study
Male	369	22.6–110 (FL)	W = 0.014FL <sup>2.87</sup>	0.992	Allometric (–)		
Pooled	723	22.0–113 (FL)	W = 0.0126FL <sup>2.84</sup>	0.993	Allometric (–)		

\* FL- Fork length, TL- Total length.

showed a pattern similar to that of the GSI. Both K and GSI increased progressively during the spawning season, indicating that individuals maintained good somatic condition while undergoing active gonadal development. The increase in K during this period suggests favourable feeding conditions and sufficient energy availability to support both body condition and reproductive processes. After the spawning period, both K and GSI declined, reflecting the release of gametes and the reduction in energy reserves following reproductive activity. Comparable observations with a similar pattern of GSI and condition factor have been reported earlier (Hasan et al., 2021; Nayak et al., 2021). This pattern indicates that the physiological condition of the species is closely linked with its reproductive cycle and spawning activity.

The fecundity values obtained in the present study differ from those reported in northern Australia, where fecundity ranged between 259,488 and 2,859,935 eggs, with an average of  $1,327,827 \pm 237,866$  eggs (mean  $\pm$  S.E.) (Griffiths & Fry, 2005). In contrast, studies from the Pakistan coast reported comparatively lower fecundity values ranging from 95,250 to 594,783 eggs in females measuring 57.5–112 cm, with an average of about 398,063 eggs per individual (Qamar et al., 2020).

The strong positive relationship observed between fecundity and fish length ( $r^2 = 0.97$ ), as well as body mass ( $r^2 = 0.93$ ), is consistent with earlier findings on talang queenfish (Griffiths & Fry, 2005; Qamar et al., 2020). These patterns highlight the disproportionate contribution of larger females to overall reproductive output compared to smaller individuals.

## Conclusion

The present study provides the first comprehensive assessment of the reproductive biology of *S. commersonnianus* from the southeastern Arabian Sea off the Indian coast. The findings generate important baseline information on key reproductive parameters of the species, including length at first maturity and spawning periodicity. These results provide a scientific basis for developing effective management measures such as the establishment of an appropriate minimum legal size and consideration of seasonal restrictions during peak spawning periods. Such measures would help protect spawning stocks, enhance recruitment, and support the sustainable exploitation and long-term conservation of this commercially important species in the region.

## Ethical approval

The authors did not conduct any experimental studies involving animals in this work.

## CRedit authorship contribution statement

**K.M. Rajesh:** Writing – review & editing, Formal analysis. **E.M. Abdussamad:** . **Mridula Rajesh:** Writing – review & editing, Formal analysis. **Sujitha Thomas:** Writing – review & editing. **Divya Viswambharan:** Writing – review & editing, Formal analysis. **Sunil Kumar S. Ail:** Writing – review & editing. **Somy Kuriakose:** Writing – review & editing, Resources.

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Declaration of generative AI in the manuscript preparation process

During the preparation of this manuscript, the author(s) utilized ChatGPT to enhance language and readability. The content was subsequently reviewed and edited by the author(s), who take full responsibility for the final published version.

## References

- Abdussamad, E. M., Gopalakrishnan, A., Mini, K. G., Sukumaran, S., Divya, P. R., Rethesh, T. B., Muhammed, A. A., Dipti, N. V., Akhil, A. R., Thomas, T., & Jacob, K. D. (2022). Description of a new species of queenfish, *Scomberoides pelagicus* from Indian Seas. *Journal of Environmental Biology*, 43(1), 105–114. <http://doi.org/10.22438/jeb/43/1/MRN-1975>.
- Ali, Z., Kalthoro, M. A., Ahmed, N., Shafi, M., Saeed, F., & Majeed, A. (2024). Population dynamics and stock appraisal of talang queenfish (*Scomberoides commersonnianus*) from Balochistan coast, Pakistan. *Pakistan Journal of Zoology*, 56(4), 1733–1742. <http://doi.org/10.17582/journal.pjz/20221218131229>.
- Azam, S. M., & Naeem, M. (2021). Proximate body composition of talang queenfish (*Scomberoides commersonnianus* Lacépède, 1801) from Pakistan. *Sarhad Journal of Agriculture*, 38(1), 204–209. <http://doi.org/10.17582/journal.sja/2022/38.1.204.209>.
- Barua, S., Liu, Q., & Azam, M. S. (2024). Population dynamics and stock assessment of Queenfish (*Scomberoides commersonnianus*) from the marine waters of Bangladesh. *Fisheries Management and Ecology*, 1–10. <https://doi.org/10.1111/fme.12707>
- De Sylva, D. P. (1973). Barracudas (Pisces: Sphyraenidae) of the Indian Ocean and adjacent seas – a preliminary review of their systematic and ecology. *Journal of the Marine Biological Association of India*, 15(1), 74–94.
- FRAEED, CMFRI (2024). Marine Fish Landings in India 2023. CMFRI Booklet Series No. 33/2024. ICAR-Central Marine Fisheries Research Institute, Kochi, India.
- Froese, R. (2006). Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *Journal of Applied Ichthyology*, 22, 241–253. <https://doi.org/10.1111/j.1439-0426.2006.00805.x>
- Froese, R., Tsikliras, A. C., & Stergiou, K. I. (2011). Editorial note on weight-length relations of fishes. *Acta Ichthyologica et Piscatoria*, 41, 261–263. <https://doi.org/10.3750/AIP2011.41.4.01>
- Gomez-Marquez, J. L., Peña-Mendoza, B., Salgado-Ugarte, I. H., & Guzman-Arroyo, M. (2003). Reproductive aspects of *Oreochromis niloticus* (Perciformes: Cichlidae) at Coateteleo lake, Morelos, Mexico. *Revista De Biología Tropical*, 51(1), 221–228. <https://www.researchgate.net/publication/8543129>.
- Griffiths, S. P., Fry, G. C., & van der Velde, T. D. (2005). Age growth and reproductive dynamics of the Talang queenfish *Scomberoides commersonnianus* in the northern Australia. Final report to the National Oceans Office, CSIRO, Cleveland, pp. 39.
- Hasan, M. R., Hossain, M. Y., Mawa, Z., & Hossain, M. A. R. (2021). Reproductive biology of *Heteropneustes fossilis* in a wetland ecosystem (Gajner Beel, Bangladesh) in relation to eco-climatic factors: Suggesting a sustainable policy for aquaculture, management and conservation. *Saudi Journal of Biological Sciences*. 29(2), 1160–1174. <https://doi.org/10.1016/j.sjbs.2021.09.050>.
- Huges, J. M., & Stewart, J. (2006). Reproductive biology of three commercially important Hemiramphid species in south-eastern Australia. *Environmental Biology of Fishes*, 75, 237–256. <https://doi.org/10.1007/s10641-006-0023-3>
- Imam, A. A., Mekkawy, S., & Hassan, A. A. (2012). Reproductive characteristics of the elephant-snout fish, *Mormyrus kannume* Forsskal, 1775 from the Nile, Egypt. *Journal of Biological Sciences*, 12, 15–24. <https://DOI:10.3923/jbs.2012.15.24>.
- James, P. S. B. R. (1964). Some observations on the fishery of *Chorinemus lysan* Forskal of the Rameshwaram Island with notes on its biology. *Indian Journal of Fisheries*, 11 A (1), 268–276. [https://eprints.cmfri.org.in/2144/1/Article\\_18.pdf](https://eprints.cmfri.org.in/2144/1/Article_18.pdf).
- Jiang, Y., Zhang, J., Cai, Y., Kong, X., Gong, Y., & Lin, Z. (2024). Length-weight relationships and condition factors of 24 mesopelagic fishes from the south China Sea. *Egyptian Journal of Aquatic Research*, 50, 528–537. <https://doi.org/10.1016/j.ejar.2024.09.002>
- King, M. (2007). *Fisheries Biology, Assessment and Management*. Oxford: Blackwell Publishing Ltd. <https://DOI:10.1002/9781118688038>.
- Kolher, N., Casey, J., & Turner, P. (1995). Length-weight relationships for 13 species of sharks from western north Atlantic. *Fishery Bulletin*, 93, 412–418.
- Krishnakumar, P. K., Mohamed, K. S., Asokan, P. K., Sathianandan, T. V., Zacharia, P. U., Abdurahiman, K. P., Veena, S., & Durgekar, N. R. (2008). How environmental parameters influenced fluctuations in oil sardine and mackerel fishery during 1926–2005 along the south-west coast of India? *Marine Fisheries Information Service*, 198, 1–5.
- Kumar, S. P., Ramaiah, N., Gauns, M., Sarma, V. V. S. S., Muraleedharan, P. M., Raghukumar, S., ... Madhupratap, M. (2001). Physical forcing of biological productivity in the Northern Arabian Sea during the Northeast Monsoon, Deep Sea Research Part II. *Topical Studies in Oceanography*, 48, 1115–1126. [https://doi.org/10.1016/S0967-0645\(00\)00133-8](https://doi.org/10.1016/S0967-0645(00)00133-8)

- Le Cren, E. D. (1951). The length–weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20, 201–219. <https://doi.org/10.2307/1540>
- Maasoumizadeh, S., Pazooki, J., & Valinasab, T. (2014). The investigation of food composition and the effects of season, sex, maturity and length on gastro-somatic index of queen fish in the northwest of Persian Gulf (Khuzestan waters). *Journal of Marine Biology*, 23, 69–80.
- Majeed, S. (2025). Length-based stock assessment of *Scomberoides commersonnianus* (Talang queenfish) from Gwadar Coast, Balochistan, Pakistan. *Thalassas: An International Journal of Marine Sciences*, 41(4), 257. <https://doi.org/10.1007/s41208-025-01021-z>
- Masoomizadeh, S. Z., Pazooki, J., & Valinassab, T. (2018). Changes in length weight relationship and condition factor of Talang queenfish (*Scomberoides commersonnianus*) in the north-west Persian Gulf. *Iranian Journal of Fisheries Science*, 17, 118–136. <https://doi.org/10.22092/IJFS.2018.115589>
- Mbaru, E. K., Mlewa, C. M., & Kimani, E. N. (2010). Length–weight relationship of 39 selected reef fishes in the Kenyan coastal artisanal fishery. *Fisheries Research*, 106, 567–569. <http://doi:10.1016/j.fishres.2010.09.012>.
- Miller, B., & Kendall, A. W. (2009). *Early life histories of marine fishes* (p. 396). University of California.
- Morato, T., Afonso, P., Lourindo, P., Nash, R. D. M., & Santos, R. S. (2003). Reproductive biology and recruitment of sea bream in the Azores. *Journal of Fish Biology*, 63, 59–72. <https://doi.org/10.1046/j.1095-8649.2003.00129.x>
- Murua, H., Kraus, G., Saborido-Roy, F., Withames, P. R., Thorsen, A., & Junquera, S. (2003). Procedures to estimate fecundity of wild collected marine fish species in relation to their reproductive strategy. *Journal of Northwest Atlantic Fishery Science*, 33, 33–54. <https://doi.org/10.2960/J.v33.a3>
- Nayak, N., Sonowal, J., Borah, R., & Biswas P. S. (2021). Synchronicity of Condition Factor with Reproductive Development in Rainbow Snakehead (*Channa bleheri* Vierke, 1991). *Agricultural Science Digest*. 41(4), 632-637. <https://doi: 10.18805/ag.D-5207>.
- Palla, H. P., & Sotto, F. P. (2021). Reproductive biology of brownstripe snapper *Lutjanus vitta* (Quoy and Gaimard, 1824) from West Sulu Sea, Philippines. *Egyptian Journal of Aquatic Research*, 47, 67–73. <https://doi.org/10.1016/j.ejar.2021.01.001>
- Panhwar, S. K., Qamar, N., & Jahangir, S. (2014). Fishery and stock estimates of talang queenfish, *Scomberoides commersonnianus* (Fam: Carangidae) from the Arabian sea coast of Pakistan. *Pakistan Journal of Agricultural Sciences*, 51(4), 1011–1016. <http://www.pakjas.com.pk>.
- Pillai, P. K. M., Pillai, M. A., & Jayaprakash, A. A. (1987). Some notes on queenfishes and their fishery along the Indian coasts. *Marine Fisheries Information Service*, 71, 21–23.
- Qamar, N., Panhwar, S. K., & Riede, R. (2018). Feeding patterns of two commercially important fish species *Scomberoides commersonnianus* and *S. tol* in the Northern Arabian Sea. *Pakistan Journal of Zoology*, 50, 941–949. <https://doi.org/10.17582/journal.pjz/2018.50.3.941.949>.
- Qamar, N., Panhwar, S. K., & Wang, P. (2020). Reproduction, sexual maturity, and spawning ecology of talang, *Scomberoides commersonnianus*, and needlescaled queenfish, *Scomberoides tol* in Pakistan. *Iranian Journal of Fisheries Sciences*, 19(5), 2705–2719. <https://doi:10.22092/ijfs.2020.122632>.
- Rajesh, K. M., Rohit, P., Abdussamad, E. M., & Viswambharan, D. (2020). Reproductive biology of the sawtooth barracuda, *Sphyræna putnamae* (Jordan and Seale, 1905) along the coastal waters of Karnataka, southeastern Arabian Sea. *Regional Studies in Marine Science*, 36, 1–7. <https://doi.org/10.1016/j.rsma.2020.101314>
- Rathnasuriya, M. I. G., Mateos-Rivera, A., Skern-Mauritzen, R., Wimalasiri, H. B. U., Jayasinghe, R. P. P. K., Krakstad, J. O., & Dalpadado, P. (2021). Composition and diversity of larval fish in the Indian Ocean using morphological and molecular methods. *Marine Biodiversity*, 51. <https://doi.org/10.1007/s12526-021-01169-w>
- Riede, K. (2004). *Global register of migratory species —from global to regional scales. Final Report of the R&D Project*. Bonn, Germany: Federal Agency for Nature Conservation.
- Rohit, P., Dineshbabu, A. P., Sasikumar, G., Swathi Lekshmi, Mini, K. G., ... Kini, S. (2016). *CMFRI Marine Fisheries Policy Series No.5; Management Plans for the Marine Fisheries of Karnataka* (pp. 1–110). Kochi: CMFRI Marine Fisheries Policy.
- Roul, S. K., Akhil, A. R., Retheesh, T. B., Rajesh, K. M., Ganga, U., Abdussamad, E. M., & Rohit, P. (2020). Length-weight relationships of fifty fish species from Indian waters. *Thalassas*, 36, 309–314. <https://doi.org/10.1007/s41208-020-00223-x>
- Sampson, D. B., & Al-Jufaily, S. M. (1999). Geographic variation in the maturity and growth schedules of English sole along the U.S. west coast. *Journal of Fish Biology*, 54, 1–17. <https://doi.org/10.1111/j.1095-8649.1999.tb00608.x>
- Shalloof, K. A. S., & Salama, H. M. M. (2008). Investigations on some aspects of reproductive biology in *Oreochromis niloticus* (Linnaeus, 1757) inhabited Abu-Zabal Lake, Egypt. *Global Veterinaria*, 2(6), 351–359.
- Smith-Vaniz, W. F., & Williams, I. (2016). *Scomberoides commersonnianus* (errata version published in 2017). *The IUCN Red List of Threatened Species* 2016: e.T20434679A115380988. <http://doi.org/10.2305/IUCN.UK.2016-3.RLTS.T20434679A46664114.en>. Accessed on 09 September 2025.
- Snedecor, G. W., & Cochran, W. G. (1967). *Statistical methods* (sixth ed.). New Delhi, India: Oxford and IBH Publishing Co.
- Sutharshiny, S., & Sivashanthini, K. (2011). Proximate composition of three species of *Scomberoides* fish from Sri Lankan waters. *Asian Journal of Clinical Nutrition*, 3(3), 103–111. <https://doi:10.3923/ajcn.2011.103.111>.
- Suyani, N. K., Rajesh, M., & Rajesh, K. M. (2021). First report on the diet and reproductive biology of red-toothed triggerfish *Odonus niger* (Ruppel, 1936) from the southeastern Arabian Sea. *Journal of the Marine Biological Association of the United Kingdom*, 101, 827–837. <https://doi.org/10.1017/S0025315421000771>
- Taghavi Motlagh, S. A., Seyfabadi, S. J., Hosseini, A., & Ahmadian Hosseini, S. H. (2005). Growth parameters and mortality rate of talang queenfish, *Scomberoides commersonnianus*, in southeastern coastal water of Iran. *Journal of Marine Science and Technology*, 3(4), 9–16.
- Visconti, V., Trip, E. D. L., Griffiths, M. H., & Clements, K. D. (2020). Geographic variation in life-history traits of the long-lived monacanthid *Meuschenia scaber* (Monacanthidae). *Marine Biology*, 167, 1–13. <https://doi.org/10.1007/s00227-019-3628-8>
- Vivekanandan, E., Srinath, M., & Kuriakose, S. (2005). Fishing the marine food web along the Indian coast. *Fisheries Research*, 72(2–3), 241–252. <https://doi.org/10.1016/j.fishres.2004.10.009>
- Zacharia, P. U., & Jayabalan, N. (2007). Maturation and spawning of the whitefish, *Lactarius lactarius* (Bloch and Schneider, 1801) (Family Lactariidae) along the Karnataka coast, India. *Journal of the Marine Biological Association of India*, 49(2), 166–176.
- Zar, J. H. (1996). *Biostatistical Analysis*. Prentice-Hall, Englewood Cliffs, N. J, pp. 663.
- Zupa, R., Santamaria, N., Bello, G., Deflorio, M., Basilone, G., Passantino, L., & Corriero, A. (2013). Female reproductive cycle and batch fecundity in the central-southern Adriatic population of *Engraulis encrasicolus* (Osteichthyes: Engraulidae). *Italian Journal of Zoology*, 80(4), 510–517. <https://doi.org/10.1080/11250003.2013.845260>