Reproductive Characteristics of *Nemipterus japonicus* (Bloch, 1791) along the Malabar Coast, India

V. Mahesh [a]*, P.K. Asokan[a], T.M. Najmudeen[b], K. Vinod[a], N.R. Kalavathi[c], P.U. Zacharia[b], M.Vijisha[a], P.V. Gopalan[a]

[a]Calicut Regional Station, ICAR-Central Marine Fisheries Research Institute, Kerala, [b]Finfish Fisheries Division, ICAR-Central Marine Fisheries Research Institute, Kochi, [c]Department of Fisheries Resource Management, College of Fisheries, Mangalore, India
*Corresponding author Email: mahesh.fishco@gmail.com, mahesh.v@icar.org.in

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Abstract

In fisheries management, a comprehensive comprehension of the reproductive biology of fish species is imperative, with specific emphasis on factors such as sexual maturation, the dynamics of the reproductive cycle, and the quantitative assessment of fecundity. To elucidate the reproductive dynamics of *Nemipterus japonicus* captured along the Malabar coast, encompassing parameters such as the sex ratio, sexual maturation, fecundity, and reproductive periodicity, a rigorous investigation was conducted spanning the period from 2017 to 2021. Sampled individuals of *N. japonicus* exhibited total lengths ranging from 5.5 to 35.2 cm. The exponent value (b = 2.991) observed in this current study exhibited a high degree of proximity to 3, indicative of an isometric growth pattern. The collective sex ratio stood at 1:1.3, signifying a higher prevalence of females than males. Attainment of 50% sexual maturation (L_{m50}) occurred at a total length of 15 cm for males and 15.5 cm for females which is earlier than the reported length. Monthly changes in the gonadosomatic index exhibited elevated values from September to December, reaching their zenith in October. The study ascertained *N. japonicus* matured significantly earlier than in the last decade and the spawning season shifted to lower temperature months for better reproductive output along the south-west coast of India. Based on these findings, a minimum legal capture size of 15 cm is recommended to reduce recruitment overfishing and support the long-term sustainability of *N. japonicus* populations.

Keywords: *Nemipterus japonicus*; Length-weight; Early maturity; Spawning cycle; Minimum legal size

Introduction

Fishery, both marine and inland has witnessed very high growth rate in Indian subcontinent (Hridoy et al., 2024). *Nemipterus japonicus*, often called Japanese threadfin bream belongs to the Nemipteridae family and constitutes a vital component of the demersal fish catches caught primarily by bottom trawl fishing. Most *Nemipterus* species usually inhabit areas close to sandy or muddy sea beds, at depths ranging from 5 to 80 m (Kerdgari et al., 2009). A total of ten species from the *Nemipterus* genus have been documented in the waters of India. (Barman and Mishra,2009; Mahesh et al., 2022), of which *N. randalli* and *N. japonicus* are the predominant species along the Kerala coast. The average catch of *Nemipterus* spp. in Kerala is 40,000tonnes which contributed 37% to the demersal fish landings and 7% to the total fish landings of the state (NMFDC, 2017-2022). Due to its affordable price and meat quality, Japanese threadfin seabream ranks among the highly favoured and economically significant edible fish species, especially for surimi production.

Regulations are based on the reproductive characteristics of species subject to the greatest fishing pressure. Knowledge of reproductive parameters encompassing the length-weight correlation, sex ratio dynamics, reproductive periodicity patterns, and the peak spawning season is essential for determining the closure of the fishing season and minimum harvest sizes. Owing to their significant implications within the realm of fisheries, a plethora of investigations have been undertaken concerning the length-weight relationship, as evidenced by scholarly contributions such as those by Zacharia (1998), Rajkumar et al., (2003), Manojkumar (2004) and comprehensive investigations into diverse facets of nemipterid biology, with specific emphasis on *Nemipterus japonicus*, have been pursued. This scholarly exploration is evident in works by Gopal and Vivekanandan (1991), Rajkumar et al., (2003), Manojkumar (2004), Kizhakudan et al., (2008) along the Indian coast. A dearth of investigations on the length-weight relationship and reproductive biology of *Nemipterus japonicus* was observed along the Malabar coast. The current research endeavours to fill this gap by undertaking an evaluation of the length-weight relationship and reproductive biology of *Nemipterus japonicus* along the Malabar Coast by regularly sampling from the commercial fish landings for five years and examining the biological traits *viz.,* population maturity, reproductive biology and breeding seasonality, thereby facilitating an in-depth comprehension of the species' reproductive cycle.

Materials and methods

Between 2017 and 2022, a total of 5,970*Nemipterus japonicus* encompassing a spectrum of total lengths varying from 5.5 to 35 cm were meticulously acquired from the five prominent fishing harbours of Kasaragod, Kannur, Calicut, and Malappuram districts situated along the south-eastern periphery of the Arabian Sea (Fig. 1). The specimens were collected every 10 days, landed from trawl boats, except in July, when mechanised fishing vessels are prohibited from operating. The specimens obtained were expeditiously preserved within insulated ice containers and transferred to the laboratory located at the Calicut Regional Station of the Central Marine Fisheries Research Institute, facilitating their subsequent in-depth examination and scholarly analysis.

Length-weight allometry

The total length (TL) and body weight of all individual fish were meticulously measured with a precision of 1 mm and 0.1 g, respectively. The association between length and weight was quantified through the application of the formula denoted as $W = a(L)^b$, where W signifies the total body weight in grams, L represents the total length in centimeters, 'a' embodies the coefficient of body weight, and 'b' denotes the exponent signifying allometric growth, as stipulated by Le Cren (1951). To compare the correlation between the length and weight of both male and female specimens, an analysis of covariance (ANCOVA) methodology was employed, as detailed by Snedecor and Cochran (1967).

Reproductive biology

Sex ratios were derived from monthly estimates of male and female numbers within the sample. The categorization of fish maturity phases hinged upon evaluating the spatial occupancy of the testes or ovaries and their macroscopic attributes. Employing the delineations outlined by the International Council for the Exploration of the Sea (ICES) in Lovern and Wood's seminal work from 1937, the gonadal stages were delineated as immature, virgin developing/spent recovering, early maturing, late maturing, mature, running, and spent. Stage III (early maturing) onwards is considered as mature fish. The weight of gonads was measured to the nearest 0.01 g.

To ascertain fecundity, the ovaries were conserved in customised Gilson's fluid (Bagenal and Braum, 1978). The fraction of mature fish in each length class was logistically fitted to calculate the length at first maturity (L_{m50}) (King, 2007). The calculation of the gonadosomatic index (GSI) was conducted by factoring in both the weight of the gonads and the total weight of the fish, employing the subsequent formula: GSI = (GW/SW) * 100, wherein GW and SW correspond to the gonadal and somatic weights, respectively.

Excess moisture was removed from preserved ovaries and segments extracted from the anterior, middle, and posterior portions of ovaries exhibiting mature and running characteristics were employed as subsamples. Fecundity (F) was quantified through the application of the subsequent formula: $F = [(Nss \times Wo) / Wss]$, wherein Nss symbolizes the oocyte count within the subsample, Wo denotes the overall weight of the ovary, and Wss represents the cumulative weight of the subsample.

Results

Length-weight allometric relationship

In order to establish the length-weight allometric relationship, a dataset encompassing 5,970 fish specimens was employed, characterized by a range of total lengths (TL) spanning from 5.5 to 35.2 cm, and corresponding total weights (W) spanning from 2.2 to 498 g. All data were pooled and a common relationship was obtained for all sampled fishes including the undetermined sex specimens. Within this comprehensive dataset (illustrated in Fig. 2), the length-weight relationships were deduced as follows:

$$\text{Log W} = -4.35246+2.99158 \text{ Log L } (r=0.98799)$$

Sex distribution proportion

On a monthly basis, the sex ratios of male and female individuals were calculated from a dataset of 5,675 fish with a total length (TL) exceeding 10 cm (individuals differentiated as male and female). The collective sex ratio was determined to be 1:1.3, implying a higher occurrence of females within the population. Throughout the duration of the study, female specimens consistently outweighed their male counterparts in the sample, except for the months of February and June, as depicted in Figure 3.

Attainment of sexual maturity

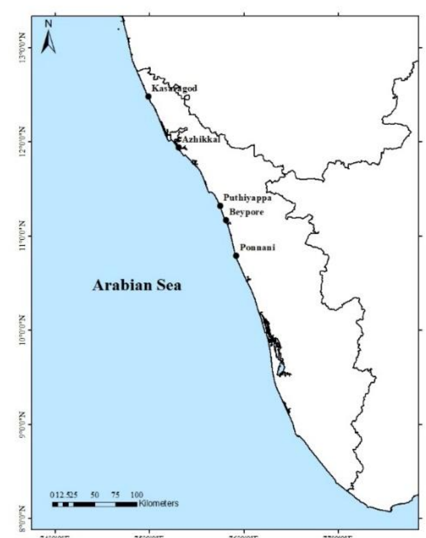
Within every length category, the point of sexual maturity was ascertained for both males and females. The estimated length at first sexual maturity (L_{m50}) was 15.0 cm TL for males and 15.5 cm TL for females. The smallest mature male and female recorded in the study measured 11.4 cm TL and 11.7 cm TL, respectively. (Fig. 4).

Spawning Season and Gonado-Somatic Index (GSI)

Mature fish with maturity stages V& VI were documented between September and December, with their highest concentration observed in October. Monthly fluctuations in the gonadosomatic index (GSI) by sex are illustrated in Figure 5. In both male and female specimens, the GSI exhibited a rising trend from May, maintaining elevated levels until October, followed by a gradual decline starting in November. Consequently, the period from September to December, with a zenith in October, was identified as the spawning season, indicating heightened spawning activity within this interval.

Fecundity

Fecundity exhibited a positive correlation with increasing length and weight. The absolute fecundity spanned from 15,870 to 1,72,968 individuals. The average fecundity was determined to be 76,592 eggs. Mature to running phases ova ranging in size from 230 to 455 µm with a mode of 280-320 µm were observed.



Malabar coast Districts

- Kasaragod
- Kannur
- Calicut
- Malappuram

Major Fishing Harbours (FH)

- Kasaragod FH
- Azhikkal FH
- Puthiyappa FH
- Beypore FH
- Ponnani FH

Fig. 1. Major fishing harbours along the Malabar coast.

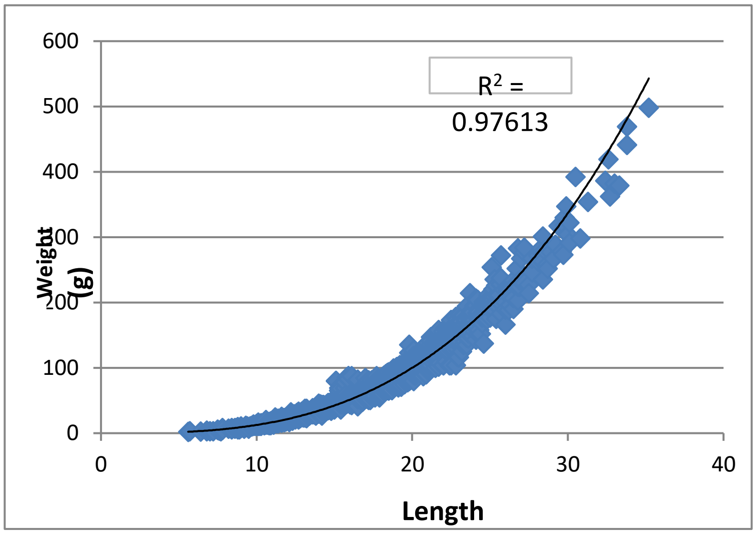


Fig. 2. Relationship between length and weight of *N. japonicus* (sexes combined)

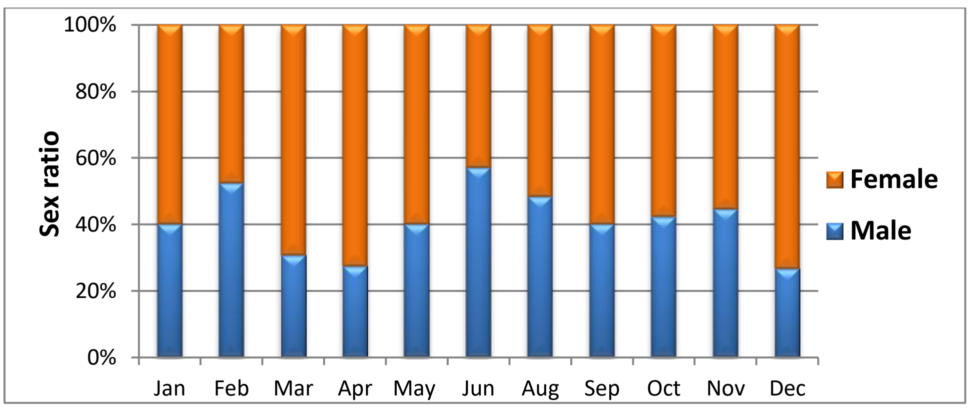


Fig. 3. Fluctuations in the monthly sex ratio of *N. japonicus*

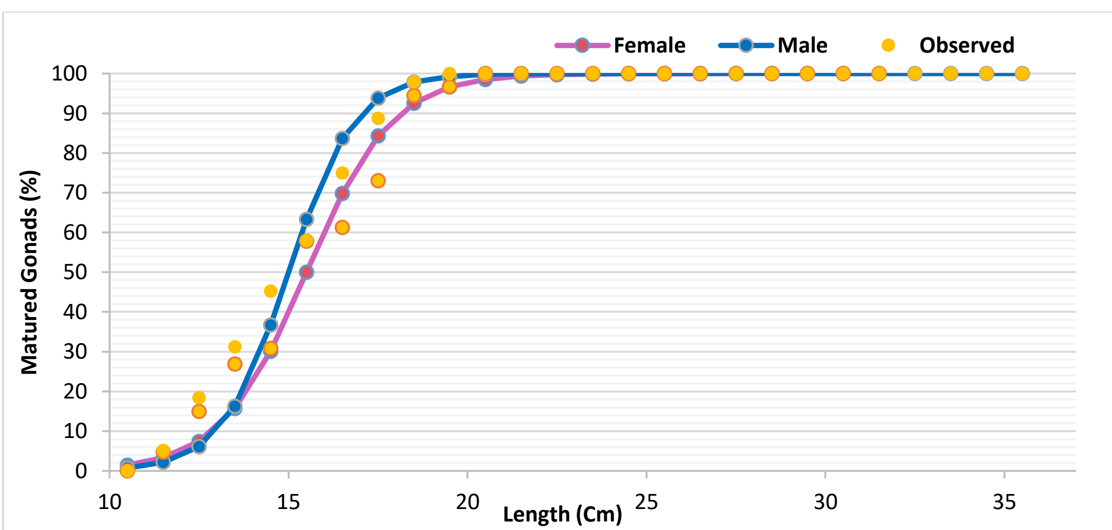


Fig. 4. Attainment of Maturity Length for *N. japonicus* along the northern Kerala coast

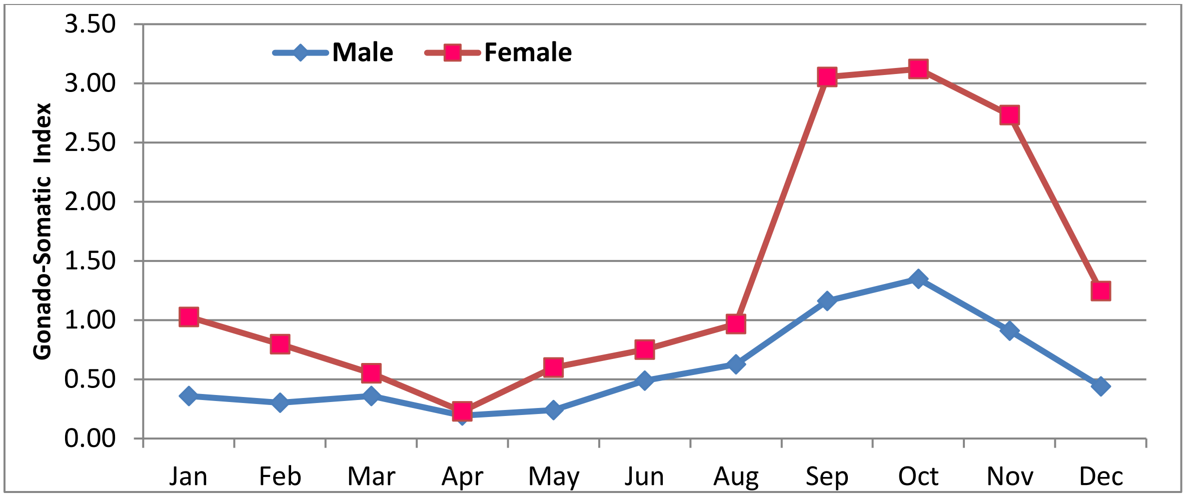


Fig. 5. Temporal Changes in the Gonado-Somatic Index of *N. japonicus*

Discussion

The b value's mean (2.991) in the present investigation is closely approximated 3, signifying the species' isometric growth. Along the Kerala coast, an allometric coefficient (2.84) was documented for *N. japonicus* encompassing both sexes. The species has manifested both isometric and allometric growth dynamics during distinct temporal phases. Isometric growth patterns for *N. japonicus* were obtained from Madras (Vivekanandan and James, 1986), Mumbai, Ratnagiri, Panaji (Pawar et al., 2011) and Veraval coast (Raje, 2002; Manojkumar, 2004). Allometric growth patterns have been reported from Veraval (Gopal and Vivekanandan, 1991) and Mangaluru coast (Rajesh et al., 2011). Body shape exhibits a direct correlation with mass, a trait governed by ecological determinants including temperature, food accessibility, and reproductive circumstances, alongside additional variables like gender, age, fishing season, and fishing locale.

In the current investigation, the sex ratio exhibited a marginal deviation from the anticipated 1:1 ratio, implying the prevalence of female specimens within commercial harvests. The comparable predominance of female individuals within trawl catches of *N. japonicus* has been documented by Acharya (1990) in the vicinity of the Bombay coast, Manojkumar (2004) off the Veraval coast, Rao et al., (2017) along the northeastern Indian coast, and Sarman et al., (2018) off the Saurashtra coastline.

The findings of the present investigation revealed a male-biased precocity in sexual maturation. Approximately 50% of the male fish attained maturity at a length of 15 cm, while the corresponding length for females was slightly greater, at 15.5 cm. Krishnamoorthi (1971) documented the initial spawning length of *N. japonicus* off the Andhra-Orissa coast as 16-17 cm, with the second spawning occurring at around 22 cm. Notably, reports from the Veraval coast by Gopal and Vivekanandan (1991) as well as Manojkumar (2004) indicated sexual maturity lengths for *N. japonicus* ranging from 18 to 18.3 cm. Furthermore, Rajesh et al., (2013) reported the first sexual maturity length for males and females as 16.5 cm and 17.5 cm, respectively, in the context of the Mangaluru coast. According to CMFRI 2015, a study conducted between 2011 and 2013 found that the species matures at 14-14.5 cm off the coast of Chennai, Tamil Nadu. Rao et al., (2017) recorded the length at which females attained maturity as 15.1 cm along the northeastern coast of India. Conversely, Sarman et al., (2018) ascertained the length at initial sexual maturity for *N. japonicus* off the Saurashtra coast as 24 cm. Disparities in maturity length observed across distinct geographical areas are likely attributed to environmental factors. Consequently, it can be inferred that the biological traits of species within an ecosystem are subject to spatial and temporal variations.

In the current investigation, the period of spawning activity encompassed the months from September to December, with the acme of Gonado-Somatic Index (GSI) values observed in October, signifying the zenith of the spawning season. Previous studies showed that the peak spawning period was between September and November off Visakhapatnam (Rajkumar et al., 2003). Manojkumar (2004) noted a spawning period spanning from October to February along the west coast of India. Kizhakudan et al., (2008) identified a spawning season spanning September to December off the Saurashtra coast and Rao et al., (2017) delineated a spawning season from August to February in the northern regions (Digha and Paradeep) and September to March in the southern regions (Visakhapatnam and Kakinada) of the northwestern coast. Sarman et al., (2018) documented the continuous year-round spawning of *N.*

japonicus, with the apex of spawning activity occurring in December and January along the Saurashtra coast. Bakhsh (1994) deduced that the spawning behaviour of the threadfin bream exhibits regional divergence over extended timeframes, with influences such as wind patterns and ocean currents exerting a more direct effect on this behaviour as opposed to temperature.

The investigation at hand revealed that *N. japonicus* had a fecundity range of 15,870 to 1,72,968 eggs, exhibiting an average of 76,592 eggs with ova diameters spanning from 230 to 455 µm. In diverse regions of India, studies examining *N. japonicus* fecundity have reported ranges of 10,260 to 1,84,946 eggs (Raje, 2002), and 14,212 to 46,387 eggs (Manojkumar, 2004) along the Veraval coast, as well as 10,472 to 65,225 eggs with a mean of 33,752 eggs off the Mangaluru coast (Rajesh et al., 2013), 13,176 to 1,30,798 eggs along the north-eastern coast (Rao et al., 2017), and a fecundity range of 14,806 to 1,65,032 eggs along the Saurashtra coast (Sarman et al., 2018). Notably, the fish size has been identified as the underlying determinant for the fecundity variation observed across distinct regions.

Conclusion

The conducted investigation provided comprehensive insights into the reproductive biology of *N. japonicus* along the Northern Kerala coast (also known as the Malabar coast), marking the initial instance of such elucidation. Biological information is imperative to frame management measures in multispecies fisheries. The study signposted that *N. japonicus* matured significantly earlier (15-15.5 cm TL) compared to the last decade on the southwest coast. Shift in the spawning season to a lower temperature (Oct-Dec) months for better reproductive output is also evident for the climate change impact on tropical fishes. A similar observation was recorded along the east coast on the shift in the spawning peak of *N. japonicus* to cooler months in the recent decade. The outcome of the study aid to plan better management and conservation strategies for fishery resources. The study advocate the trawl fishing ban or effort reduction in such areas at peak spawning season and/or strongly recommends increasing the minimum legal size (MLS) to 15 cm for *N. japonicus* landings along the southwestern coast of India can benefit the sustainable harvest of the resource by decreasing the recruitment overfishing.

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Declaration of competing interest: The authors declare no conflicts of financial interest or personal affiliations that could be perceived to have influenced the research presented in this manuscript.

Ethical Approval (applicable for both human and/ or animal studies):
This declaration is “not applicable” to the study conducted since the sampling was done from commercial landings and the species do not belong to endangered and protected in the wild under the Indian Wildlife Protection Act.

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