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# Population dynamics of *Meretrix casta* (Gmelin, 1791) along Thoothukudi, Gulf of Mannar, India

S Takar*[,a], P Jawahar[a], U R Gurjar[b,c], S D Kingston[a], N Neethiselvan[a], J J Pereira[a] & I Jagadis[d]

[a]TNJFU-Fisheries College and Research Institute, Thoothukudi, Tamil Nadu – 628 008, India

[b]ICAR-Central Institute of Fisheries Education, Mumbai, Maharashtra – 400 061, India

[c]Krishi Vigyan Kendra, Parsauni, DRPCAU, Pusa, Samastipur, Bihar – 845 458, India

[d]ICAR-CMFRI, Regional Centre, Thoothukudi, Tamil Nadu – 628 008, India

*[E-mail: takarsuman42@gmail.com]

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The present study was performed to understand the population dynamics and current status of *Meretrix casta* stock along the southern coast of Tamil Nadu, India. The estimated value for asymptotic length, growth coefficient and growth performance index was 5.41 cm, 0.77 year$^{-1}$ and 1.35, respectively. The value of $t_0$ was recorded to be -0.07529 years. The instantaneous rate of total mortality (Z), fishing mortality (F) and natural mortality (M) was estimated at 2.58 yr$^{-1}$, 0.98 yr$^{-1}$ and 1.60 yr$^{-1}$, respectively. Virtual population analysis showed that fishing mortality was higher in the largest group (41 – 50 mm). The current exploitation rate (U) and exploitation ratio (E) were recorded as 0.35 and 0.38, respectively, which was lower than the $E_{opt}$ = 0.5 criterion. The present study indicated that the exploitation of *M. casta* is near to optimum level and suggests further scope to increase the fishing effort for the optimum harvest of *M. casta* from the studied region. However, regular monitoring programs should be implemented to sustain these resources.

[**Keywords**: Exploitation, Growth & mortality parameters, *Meretrix casta*, Population, Thoothukudi]

## Introduction

Bivalves such as oysters, clams and mussels are the most diverse group of class Mollusca, which is exploited along the Indian coast for food and shells. A total of 1,100 species of bivalves have been reported from Indian waters[1]. The bivalve fishery is dominated by the most diverse family Veneridae, which inhabits intertidal areas and comprises over 800 species with approximately 170 genera; out of these, 82 species with 25 living genera were reported from India[2-4]. Bivalve production has been steadily increasing over the past several decades[3]. As a result, their demand has increased, and prices are rising quite fast. In 2018, India produced about 1,32,531 tonnes of bivalves, with clams (76.3 %), mussels (15.3 %), and oysters (8.4 %) making a significant contribution[5].

The *Meretrix* genus of the family Veneridae is broadly dispersed throughout the globe and fetches a good economic value[6]. *M. casta* is a commercially important edible bivalve species abundant in backwaters, bays and estuaries[7-9]. *M. casta* is widely distributed along the Indian coastal waters of Kerala, Karnataka, Goa, Maharashtra, Andhra Pradesh, Tamil Nadu, Orissa and Andaman[10]. *M. casta* is the most common species that supports a fishery in the Pulicat Lake[11] and luxuriantly occurs in all the estuaries of Tamil Nadu[2]. The meat of *M. casta* has high demand in the markets of Goa[12]. Thus, *M. casta* forms a substantial level of fishery in the major estuaries of the country[13]. International Union for Conservation of Nature (IUCN) has cited *M. casta* under the vulnerable category in several estuaries based on the decline in the number of mature individuals, the extent of occurrence area and habitat quality[14].

The basics of fisheries management and conservation outcomes usually depend upon estimates of the fishery and population dynamics[15,16]. *M. casta* is a source of food and income generation for the fishers along the Thoothukudi, Gulf of Mannar, India. However, the population characteristics and stock status of *M. casta* are not known in the region. Therefore, the present study was carried out to generate baseline data on the population dynamics for the sustainable utilization and conservation of *M. casta* along the region.

## Materials and Methods

The monthly samples of *M. casta* (Fig. 1) were randomly collected from September 2019 to April 2021 during low tides from the Palaykkayal estuary (8°41'08.16" N; 78° 07'35.34" E) along the Thoothukudi, Gulf of Mannar, India (Fig. 2). The collected samples were brought to the laboratory for further analysis. Specimens were identified following standard keys[2,17]. The size of samples as total length (anterior-posterior axis) was measured with the help of a digital Vernier caliper to the nearest 0.1 cm.

A total of 3500 samples were used to estimate the length-frequency distribution. The length data were categorised into class intervals of 3 mm, which were used to calculate the population characteristics using the FAO-ICLARM Stock Assessment Tools – II (FiSAT-II) software[18]. The growth parameters such as $L_\infty$ and K were estimated using the Electronic Length Frequency Analysis – I (ELEFAN-I) module of FiSAT-II software package[18]. Length at age data was generated by employing the inverse von Bertalanffy growth function (VBGF) as $t = t_0 - (1/K) * \ln (1 - Lt/L_\infty)$. The value of growth performance index phi prime ($\Phi'$) was calculated as per given equation, $\Phi' = 2 \log10 (L\infty) + \log10 (K)$[19].

The total instantaneous mortality rate (Z) was estimated as per the cumulative catch curve method[20] by using the FiSAT-II[18]. The natural mortality rate (M) was calculated as per the method given by Cushing[21] and the fishing mortality (F) was estimated

Fig. 1 — *Meretrix casta* caught from Thoothukudi coast, Gulf of Mannar, India

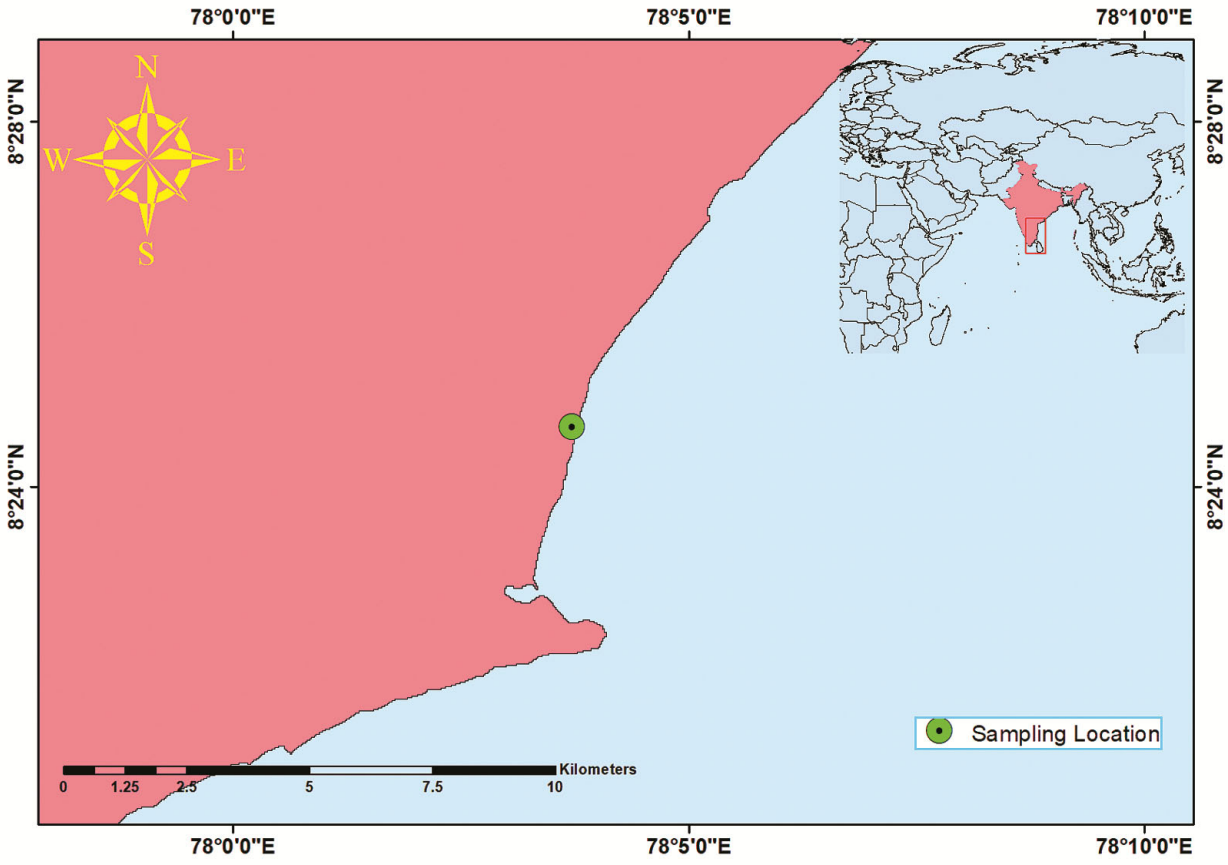


Fig. 2 — Map of sampling location at Thoothukudi, Gulf of Mannar, India

by the following equation, F = Z-M. The exploitation ratio (E) was noted by the given formula[22]: E = F / Z and the exploitation rate (U) was estimated using the given equation: U = F / Z * (1 - $e^{-Z}$)[23]. The relative yield-per-recruit (Y'/R) and biomass-per-recruit (B'/R) were estimated using the knife-edge selection curve[24].

## Results

In the present study, a total of 3500 samples of *M. casta* were collected with the length ranging from 0.861 to 5.21 cm (8.61 – 52.11 mm).

### Age and growth parameters

The observed extreme size and the predicted maximum length were 5.21 cm and 5.45 cm (Fig. 3). The range of 95 % confidence interval of maximum length was 5.23 – 5.67 cm. Based on length-frequency data, ELEFAN-I estimated growth parameters such as annual growth coefficient (K) and asymptotic length ($L_\infty$) of the VBGF for *M. casta* were 0.77 $yr^{-1}$ and 5.41 cm, respectively. The value of hypothetical age at length zero ($t_0$) was estimated to be -0.07529 yr and the growth performance index or phi prime value (φ′) for *M. casta* recorded from Thoothukudi waters was 1.35 (Table 1). In the present study, it was estimated that *M. casta* attains a length of 12.31 mm, 26.83 mm, 41.37 mm, and 55.89 mm at the nd of 0.5, 1.0, 1.5, and 2 years of its lifespan, respectively.

### Mortality parameters and exploitation pattern

The estimated value of total mortality coefficient (Z) was found as 2.58 $yr^{-1}$ using the cumulative catch curve method (Fig. 4). The value of natural mortality and annual fishing mortality (F) was recorded as 1.60 $yr^{-1}$ and 0.98 $yr^{-1}$, respectively (Table 1). The length structured population analysis indicated the maximum and minimum fishing mortality were recorded at the mid-length of 45.5 mm and 11.5 mm, respectively. The fishing mortality was relatively higher over the mid-length size of 44.5 mm (Fig. 5). The M/K and Z/K values were recorded as 2.08 and 3.35, respectively, for *M. casta*. The value recorded of the exploitation rate (U) was 0.35, and the exploitation ratio (E) was 0.38 (Table 1).

### Relative yield-per-recruit (*Y'/R*) and biomass-per-recruit (B'/R)

The relative yield-per-recruit (*Y'/R*) and biomass-per-recruit (B'/R) model displayed that the exploitation rates were $E_{0.5}$ (optimum sustainable yield) = 0.324, $E_{0.1}$ (maximum economic yield) = 0.515, $E_{max}$ (maximum sustainable yield) = 0.661 and

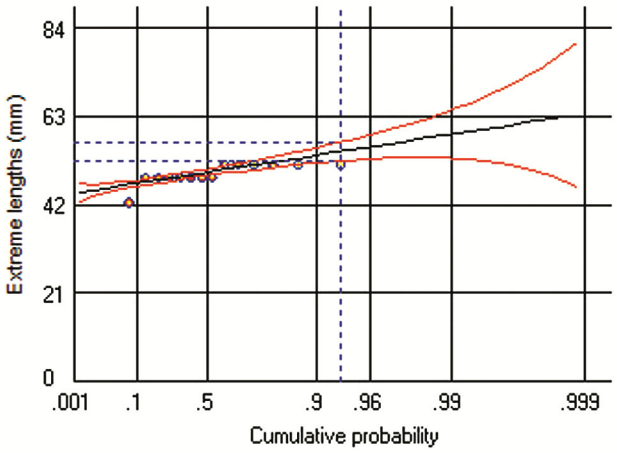


Fig. 3 — Predicted extreme length of *Meretrix casta* based on extreme value theory

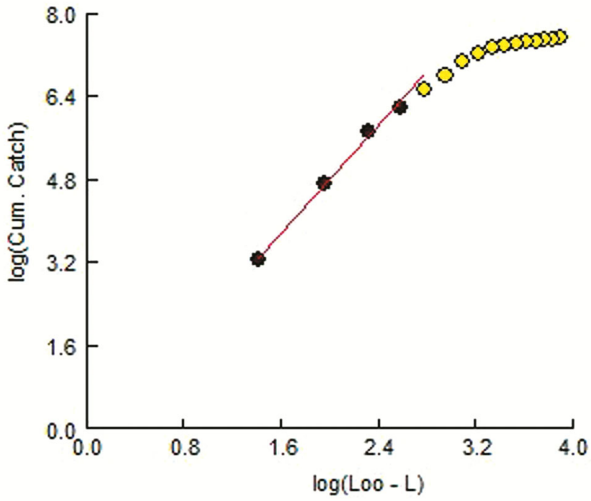


Fig. 4 — Jones and van Zalinge's cumulative catch curve for *Meretrix casta*

Table 1 — Comparison of growth, and mortality parameters of *Meretrix casta* from the different localities

| Locality | $L_\infty$ (mm) | K ($yr^{-1}$) | Z ($yr^{-1}$) | M ($yr^{-1}$) | F ($yr^{-1}$) | E | φ′ | Authors |
|---|---|---|---|---|---|---|---|---|
| Chaliyar estuary | 25.44 | 1.8 | 3.92 | 2.78 | 2.12 | 0.54 | 1.92 | Laxmilatha (2013) |
| Kavvai estuary | 26.50 | 2.0 | 2.98 | 2.96 | 0.98 | 0.32 | 2.03 | |
| Sri Lanka | 34.0–43.1 | 0.84–1.40 | 2.34–3.08 | 0.8–1.44 | 1.16–2.24 | 0.5–0.7 | 1.23 | Jayawickrema & Wijeyaratne (2009) |
| Gulf of Mannar | 54.08 | 0.77 | 2.58 | 1.60 | 0.98 | 0.38 | 1.35 | Present study |

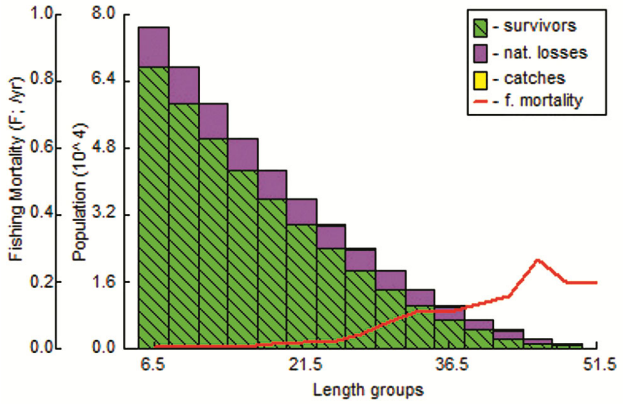


Fig. 5 — Length-structured virtual population analysis of *Meretrix casta*

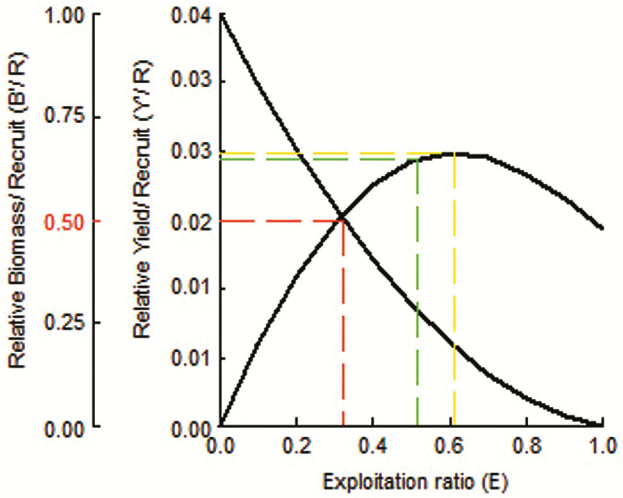


Fig. 6 — Relative Y'/R and B'/R value of *Meretrix casta* from the Gulf of Mannar

current exploitation ratio was (0.38), which is 57 % of the estimated $E_{max}$ obtained from the selection curve (Fig. 6).

## Discussion

The present investigation was carried out on the population dynamics of *M. casta*, which is a commercially important species along the Gulf of Mannar, Tamil Nadu. Bivalve fishery is dominated by the family Veneridae, but bivalve resources are least managed along the Indian coast[25].

### Length-frequency distribution

The observed length (8.6 to 52.11 mm) of *M. casta* during the present study was higher than earlier few records[7-9,26] might be due to less exploitation. The length of *M. casta* ranges from 8 to 42 mm recorded from Moorad estuary along the Kerala coast[8] and 11.2 to 37.8 mm from the estuaries of the north Kerala[26]. The maximum size of *M. casta* recorded from the Uppanar, Pennaiyar, and Vellar estuaries along the Tamil Nadu coast was 39.5 mm[7]. The length range of *M. casta* was recorded as 34.0 to 43.1 mm from the Sri Lankan waters[9]. Few areas recorded higher lengths of *M. casta*, such as Palar estuary (28 to 55 mm)[27]; Kandleru estuary (39 to 55 mm)[28]; and Sonmiani Bay Baluchistan-Pakistan (77 mm)[6]. The difference in the size range of *M. casta* might be due to variations in biotic-abiotic factors, geographical distribution, availability of food, climate change, water pollution and fishing efforts[9,29].

### Growth parameters and growth performance index

The estimated asymptotic length ($L_\infty$) of 54.08 mm recorded in the present study was higher than Chaliyar (25.26 mm) and Kavvai (26.50 mm) estuaries along the Kerala coast[26]. Jayawickrema & Wijeyaratne[9] observed $L_\infty$ as 34.0 – 43.1 mm from the Sri Lanka waters. Asymptotic length depicted the maximum size that could be attained by an individual[30] and length depends on adaptation to environmental conditions[31]. The varied asymptotic length might be due to variations in their geographic distributions, fishing pressure, and local environmental situations[32]. The environmental factors are significant in changing the population size of any organisms[9].

The value of growth coefficient (K) has been connected to longevity or life span of species[33], which is associated with mortality[34]. In the present study, the K value was obtained as 0.77 $yr^{-1}$, which is lower than earlier reported from the Dutch canal of Sri Lanka (K: 0.84 – 1.40 $yr^{-1}$)[9] and from the southwest coast of Kerala (K: 1.8 – 2.0 $yr^{-1}$)[26] (Table 1). The variation in growth might be due to the fluctuations in water quality parameters and geographical distribution of particular species[35].

In the present study, the hypothetical age at zero-length ($t_0$) was recorded as -0.07529 year using von Bertalanffy's plot. The value of $t_0$ as the hypothetical age when the length of the species is zero[36]. Usually, the value of $t_0$ has a small positive or, more commonly a small negative[37]. Laxmilatha[26] recorded $t_0$ for *M. casta* as -0.0428 years, and -0.0344 years from Chaliyar and Kavvai estuaries, respectively.

The phi prime ($\varphi'$) value is a reliable index for assessing the growth parameters as the value of this

index is almost similar for the same generic species. In the present study, the phi prime (φ′) value recorded for *M. casta* was 1.35. The observed growth performance index value is lower than the earlier estimated from Kerala waters[26], while higher than Srilanka waters[9] (Table 1). The variation in growth performance value depends on different factors such as the genome, hydrological characteristics, nutrient levels, food, habitat suitability and methods used to analyze the data[9,29,38]. Generally, growth and mortality have inter-relationships, which are affected by fishing pressure, predation susceptibility, and food requirements of the individuals[39]. Mortality parameters and the death rate of species are crucial parameters for framing the regulations for sustainable fishing[40].

**Estimation of length at age**

The present study shows growth attained by *M. casta* of 12.31 mm, 26.83 mm, 41.37 mm, and 55.89 mm at the end of 0.5, 1.0, 1.5 and 2 years, respectively. *M. casta* grew 29.5 mm in 9 months with a monthly growth of 3.3 mm in Adyar estuary along the east coast of India[41]; Durve[42] recorded an average monthly growth of *M. casta* as 0.79 mm along the Mandapam coast. *M. casta* grew 34.0 mm in 13 months in the Vellar estuary[43], while *M. casta* grew 23.0 mm in one year and 38.3 mm at the end of the second year in the same estuary[35]. *M. casta* grew 33.5 mm in 9 months and 35.4 mm in 11 months, with a monthly growth rate of 3.2 to 3.7 mm[44]. The per month growth rate of clams was recorded as 2.7 mm[45] and 2.9 mm[46] along the west coast of India. From Chaliyar estuary *M. casta* attained the length of 21.2, 24.7 and 25.3 mm at the end of one, two and three years, respectively[26] and from Kavvai estuary, this species reached a length of 22.9, 26.0 and 26.4 mm at the end of one, two and three years, respectively[26]. The results of the present study are more similar to studies conducted on the east coast of India than on the west coast of India, which might be attributed to the study area.

**Estimation of mortality parameters and exploitation ratio**

In the present study, fishing mortality (0.98 $yr^{-1}$) was observed to be lower than the natural mortality rate (1.60 $yr^{-1}$), which might be due to more predation and anthropogenic pressures, such as high industrial discharge and waste disposal into the aquatic environment. The polluted local environmental conditions lead to diseases[47]. Laxmilatha[26] found the total mortality (Z), natural mortality (M), and fishing mortality (F) as 2.98 – 3.92 $yr^{-1}$, 2.78 – 2.96 $yr^{-1}$, and 0.98 – 2.12 $yr^{-1}$, respectively, for *M. casta* (Table 1). The same species may have a different natural mortality rate in different geographical areas, mainly depending on prey and predation density influenced by the fishing pressures[38]. Several factors in the aquatic environment lead to high natural mortality of the bivalve population, such as unacceptable conditions, lack of food, predation, diseases, competition, low dissolved oxygen and high temperature in the water bodies[37]. The value of the natural mortality coefficient is directly associated with the growth coefficient and inversely linked to the value of asymptotic length[33].

In the present investigation, M/K and Z/K values were recorded as 2.08 and 3.35, respectively. The M/K value should be in the range of 1.0 – 2.5[(ref. 23)]. A stock is generally considered growth-dominated if the Z/K value is equal to one and mortality-dominated if the Z/K value is ≥ 2.0. Based on this, the standing stock of *M. casta* was noted to be mortality-dominated along the studied region.

For the overall fisheries management, the suggested optimum exploitation value is 0.5[(ref. 48)]. In the present study, the observed exploitation ratio (E) was 0.38, which is lower than the recorded value of $E_{max}$ (0.66), indicating that the current exploitation of *M. casta* is lower than the optimum exploitation level. The exploitation ratio was reported as 0.32 – 0.54 along the Kerala coast[26] and 0.5 – 0.7 from the Sri Lankan waters[9]. Along the Kerala coast, the under-sized clam was exploited during the peak season for local consumption and sold to various industries for lime, cement and ornaments purpose[8,49]. The strict implementation of the existing regulations is needed for effective utilization and conservation of sedentary marine resources along the Indian waters[50,51].

## Conclusions

The present exploitation rate was lower than the maximum sustainable yield ($E_{max}$); hence there is further scope to increase the fishing efforts along the studied region to get a maximum sustainable yield of *M. casta*. The natural mortality rate is relatively high due to industrial and waste discharge into the local environment. The present baseline information on population dynamics of *M. casta* may help in the decision-making process for developing conservation plans and sustainable utilization of the

bivalve resource along the Thoothukudi, Gulf of Mannar, India.

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**Conflict of Interest**

The authors declare no conflict of interest.

**Ethical Statement**

This manuscript does not contain any experimental studies performed with live animals.

**Author Contributions**

ST: Data investigation, data analysis and initial draft preparation; PJ: Conceptualization and supervision; URG: Data analysis and editing; SDK: Sample analysis and laboratory supervision; NN & JJP: Writing- review and editing; and IJ: Sample analysis.

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