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Full length Research Paper

Active Population of the edible clam *Meretrix casta* (Chemnitz) (International Union for Conservation of Nature status: weak) from two estuaries of North Kerala, south west coast of India

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The population parameters of the edible clam *Meretrix casta* (Chemnitz) from two estuaries along the coast of north Kerala, Southern India were estimated. *M. casta* has been cited as vulnerable as per al. (2006a). Growth of *M. casta* from the east coast has been reported by Abraham (1963), Durve (1970: 73) and Sreenivasan (1983). Jayawickrema and Wijeyratne (2009) have described the population dynamics of *M.* (IUCN) population status. The asymptotic length (L∞) for *M. casta* from Chaliyar estuary was 24.24 mm. The growth coefficient (K) was 1.8^{-}1. The growth performance index (ϕ') was found to be 1.92 and $_{t0}$ was calculated at -0.04283547 years. The length weight relationship is given by Log Y = -1.259635861 + 3.090977418Log X, r = 0.903010085. The total mortality (Z) estimate for *M. casta* from Chaliyar estuary was 3.92 year^{-1}; fishing mortality (F) 2.12 year^{-1}. Exploitation level (E) was 0.54. The asymptotic length (L∞) for *M. casta* from Kavvai estuary was 26.5 mm. The growth coefficient (K) was 2.0^{-1}. The growth performance index (ϕ') was found to be 2.03 and $_{t0}$ was calculated at -0.03441665 years. The length weight relationship is given by Log Y = -0.98701877 + 3.054878207 Log X, r = 0.613724895. The total mortality (Z) estimate for *M. casta* from Kavvai estuary was 2.98 year^{-1}; fishing mortality (F) 0.98 year^{-1}. Exploitation level (E) was 0.33. The *M. casta* is under exploited from both the estuaries. There is potential for increased exploitation of the edible clam from both estuaries since the present exploitation levels are far below the maximum sustainable yield (MSY).

Key words: *Meretrix casta*, population dynamics, Chaliyar, Kavvai estuaries, south west coast of India.

INTRODUCTION

Meretrix casta (Chemnitz) a venerid clam is edible and forms sustenance level fishery in the estuaries and backwaters of both east and west coast of India. Along west coast, it occurs in Goa, Aghnashini, Uppunda, Coondapur, Udyavara and Mulki estuaries in Karnataka and Ashtamudi, Chettuva, Beypore, Korapuzha, Moorad and Chaliyar estuaries in Kerala. This species contributes to livelihood of large number of fishers living along these estuaries (Laxmilatha et al., 2006a, b). Along the east coast, it forms a fishery in Vellar, Pulicat and Bhimunipatnam backwaters (Seshappa, 1971; Alagarswami and Meiyyapan, 1989b; Narasimham, 1991).

Biology and growth of the white clam has been studied by Abraham (1963), Durve (1964), Seshappa (1971), Krishnakumari et al. (1977), Sreenivasan (1983), Thangavelu and Sanjeevraj (1985), Thangavelu and Poovannan (1994), and Rao (1988). Age and growth of *M. casta* from west coast has been reported by Salih

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(1973), Parulekar et al. (1973) and Harkantra (1975). Fishery of *M. casta* has been described by Laxmilatha et al. (2006a). Growth of *M. casta* from the east coast has been reported by Abraham (1963), Durve (1970: 73) and Sreenivasan (1983). Jayawickrema and Wijeyratne (2009) have described the population dynamics of *M.casta* in the Dutch canal of Sri Lanka. Influence of environmental variables on the abundance of *M. casta* in Southern Thailand has been detailed by Tanyaros and Tongnunui (2011).

M. casta has been cited as vulnerable (A 1c, 1d) by the International Union for Conservation of Nature (IUCN) based on the population decline in several estuaries due to decline in extent of occurrence area (bed), quality of habitat and number of mature individuals (Ananda-Rao et al., 1998). The knowledge of the population characteristics is important for the implementation of appropriate management and conservation measures for the sustainable exploitation of the stock. The objective of this study is to understand the population dynamics of *M. casta* from two geographically separate estuaries along the west coast of India, which will enable the development of conservation and management measures for sustaining the fishery.

MATERIALS AND METHODS

Monthly samples of the edible backwater clam *M. casta* (Chemnitz) were collected from two estuaries Chaliyar (11°31'29°N - 76°3'26°E), in Kozhikode district, north Kerala and Kavvai estuary (11°21'-15°58'N - 75°47'-70°27'E) located in Kasargod district of north Kerala, south west coast of India during 2008 (Figure 1). A total of 1560 numbers.

M. casta and 1559 numbers were collected from Chaliyar and Kavvai respectively, for the study. The samples of *M. casta* were cleaned of all encrusting organisms. The total length was measured using digital vernier calipers to the nearest 0.1 mm along the anterior-posterior axis. The total weight was recorded in an electronic balance to the nearest 0.01 g. The monthly length frequency distribution data of *M. casta* were grouped into 3 mm intervals and used to estimate growth and population parameters using the FiSAT software (Gayanilo et al., 1995). Asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy growth function (VBGF) were estimated by means of ELEFAN –1 (Bertalanffy, 1934; Pauly, 1986). K-scan routine was conducted to assess a reliable estimate of the K value. The estimates of L_∞ and K were used to estimate the growth performance index (Φ') (Pauly and Munro, 1984) of *M. casta* using the equation $\Phi' = 2 \log_{10} L_\infty + \log_{10} K$.

The length – weight relationship ($W = a L^b$) was studied following Ricker (1975), where *W* is the weight (g), *L* the total length (mm), *a* the intercept (condition factor) and *b* is the slope (growth coefficient / relative growth rate). The parameters *a* and *b* were estimated by least squares linear regression on log-log transformed data: $\log_{10} W = \log_{10} a + b \log_{10} L$. The coefficient of determination (r^2) was used as an indicator of the quality of the linear regression. The inverse von Bertalanffy growth equation (Sparre and Venema, 1992) was used to find lengths of the *M. casta* at various ages. The VBGF was fitted to estimates of the length at curve using non-linear estimation procedure the VBGF is defined by the equation:

$$L_t = L_\infty [1-e^{-k(t-t_0)}]$$

Where L_t is the mean length at age L_∞ the asymptotic length, *K* the growth coefficient, *t* the age of the *M. casta* and t_0 is the hypothetical age at which the length is zero.

The total mortality (*Z*) was estimated by the length converted catch curve method (Pauly 1980, 1984). Natural mortality rate (*M*) for bivalves is considered approximately equal to the growth coefficient K (Gayanilo et al., 1997). The fishing mortality (*F*) was estimated using the relationship $F = Z - M$ where *Z* is the total mortality, *F* the fishing mortality and *M* is the natural mortality. The exploitation level *(E)* was obtained by the relationship: $E = F / Z$. Exploitation rate (*U*) was given by $U = F / Z * (1 - e^{-Z})$. The annual total stock and standing stock were estimated by Y / U and Y / F respectively, where "Y" is the annual average catch of the species

(Beverton and Holt, 1957; Ricker, 1975). Maximum sustainable yield (MSY) was calculated by the equation for exploited stocks, $MSY = Z*0.5*B$ (Gulland, 1979). The recruitment pattern of the stock was determined by the backward projection on the length axis of the set of available length frequency data as in FiSAT.

RESULTS

Fishery

M. casta is collected by hand picking, from shallow areas during low tides by women and children, particularly during peak season and is used for local / domestic consumption. The other method of fishing is by using a scoop or bag net attached to a pole. Two to three men operate from a canoe. The net is pushed into the mud to rake up the clams and lifted up. The bag net is vigorously shaken in the water to clear the mud in the bag net and the clams are transferred to the canoe. The depth of the fishing area is about 1.5 to 2 m at high tide.

*M. casta f*orms a sustenance level fishery in both the estuaries viz., Chaliyar and Kavvai. The annual production of *M. casta* in the Chaliyar estuary during 2008 was 1139 t, the total effort 6491 and the catch per unit effort of 175.5 Kg. The average monthly production was 94.9 t at an average monthly effort of 541. The maximum landings were during January to March (Table 1). The annual production of *M. casta* in the Kavvai estuary during 2008 was 2105 t, the total effort 12120 and the catch per unit effort of 173.7 Kg. The average monthly production was 175.4 t at an average monthly effort of 1010. The maximum landings were during March to May (Table 1).

Biology

Chaliyar estuary

The size range of *M. casta* contributing to the fishery in Chaliyar estuary was 15.8 to 33.4 mm. The modal classes were 20-22 (41.7%), 18-20 (24.2%), 22-24 (18.3%).The mean length was 21.5 ± 2.26 mm (n = 1560) and mean weight 3.17 ± 1.29 g. The sex ratio was 1:0.92. Over 50 % of the females were in mature condition. The mean condition index of *M. casta* during the year was 7.5%.

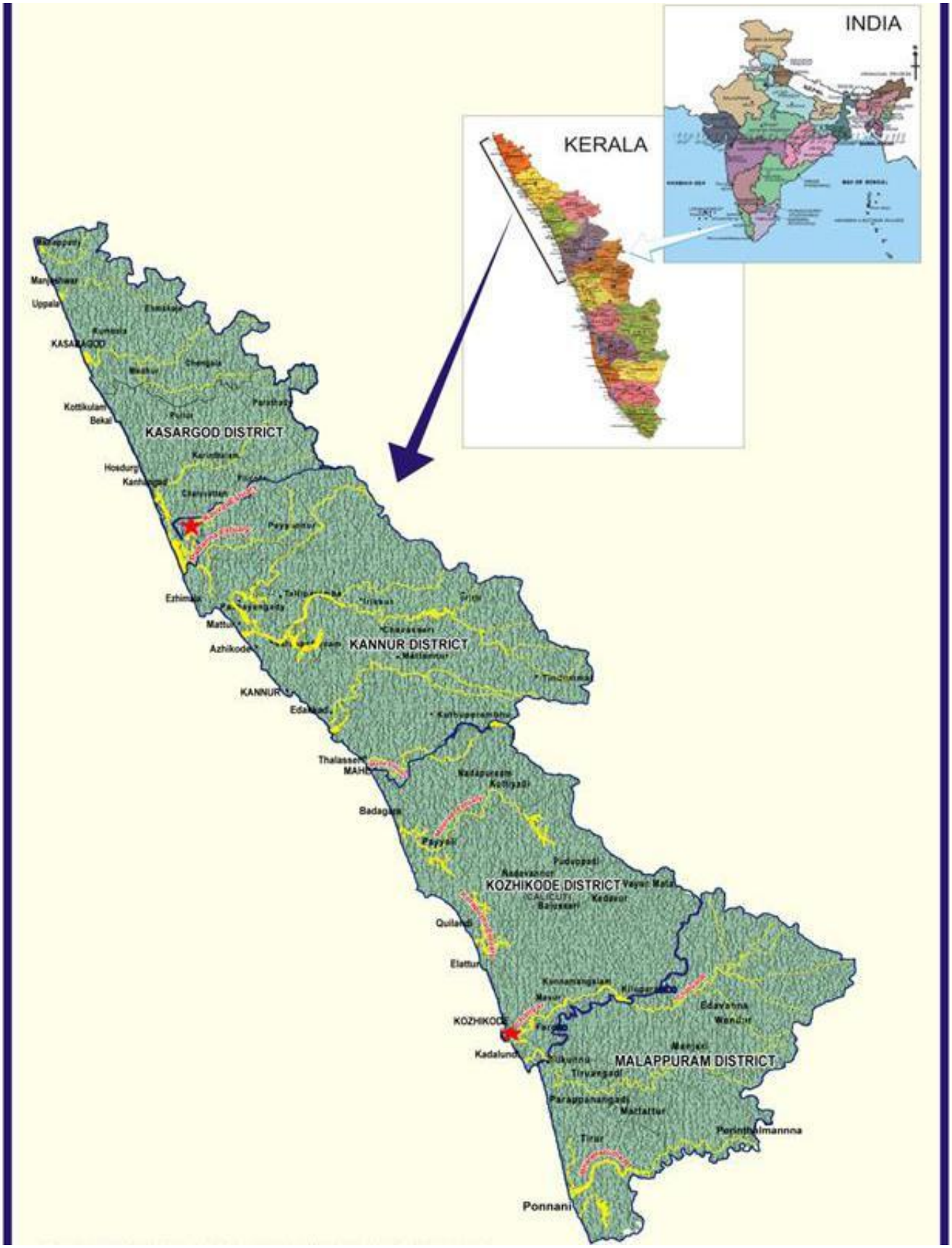

Figure 1 . Sampling sites of Meretrix casta in North Kerala.

Table 1. Fishery details of *M. casta* in two estuaries 2008.

Months	Chaliyar estuary			Kavvai estuary		
	Catch (T)	Effort	CPUE (Kg)	Catch (T)	Effort	CPUE (Kg)
J	322.4	1612.0	200.0	0.0	0.0	0.0
F	174.0	1392.0	125.0	0.0	0.0	0.0
M	262.3	1457.0	180.0	387.0	1480.0	261.5
A	173.4	990.0	175.2	273.6	1520.0	180.0
M	35.0	279.0	125.6	298.0	1560.0	191.0
J	30.0	150.0	200.0	198.8	1440.0	138.1
JU	0.0	0.0	0.0	173.8	1580.0	110.0
A	15.8	144.0	110.0	0.0	0.0	0.0
S	0.0	0.0	0.0	0.0	0.0	0.0
O	31.5	105.0	300.0	261.5	1480.0	176.7
N	67.2	252.0	266.7	251.0	1580.0	158.9
D	27.5	110.0	250.0	261.5	1480.0	176.7
Total	1139.1	6491.0	175.5	2105.2	12120.0	173.7
Mean	94.9	540.9	161.0	175.4	1010.0	116.1

Kavvai estuary

The size range of *M. casta* contributing to the fishery in Kavvai estuary was 11.2 to 37.8 mm. The modal classes were 18-20 (28%), 20-22 (25.4%) and 16-18 (14.6%). The mean length was 20.7 ± 3.14 mm (n = 1559) and mean weight was 4.67 ± 4.56. The sex ratio was 1:0.46. Over 34% of the females were in mature condition. The mean condition index of *M. casta* during the year was 7.0%.

Length weight relationship

Chaliyar estuary

The length of *M. casta* in the fishery ranged from 15.8 to 33.4 mm and the weight ranged from 1.17 to 14.75 g. The length weight relationship is given by Log Y = -1.259635861+ 3.090977418 Log X, r = 0.903010085. The computed growth coefficient (b) was 3.09 and the growth was isometric.

Kavvai estuary

The length of *M. casta* in the fishery ranged from 10.8 to 37.8 mm and the weight ranged from 0.26 to 32.85 g. The length weight relationship is given by Log Y = -0.98701877 + 3.054878207 Log X, r = 0.613724895. The computed growth coefficient (b) was 3.05.

Growth parameters

Chaliyar estuary

Asymptotic length (L_∞) of the VBGF was 24.24 mm and the growth coefficient (K) was 1.8^{-1} for *M. casta* from Chaliyar estuary. The growth performance index (ϕ') was found to be 1.91606 and t_0 was calculated at −0.04283547 years. The von Bertalanffy growth equation can be written as $L_t = 25.44 \{1-e^{-1.8(t-\_0.0428)}\}$. Accordingly, the clam attained a size of 21.2, 24.7 and 25.3 mm by the end of 1st, 2nd and 3rd year respectively. The longevity of *M. casta* from Chaliyar estuary was estimated as 2.5 to 3 years (Figures 2 and 3).

Kavvai estuary

Asymptotic length (L_∞) of the VBGF was 26.5 mm and the growth coefficient (K) was 2.0^{-1} for *M. casta* from Kavvai estuary. The growth performance index (ϕ') was found to be 2.025305865 and t_0 was calculated at −0.03441665 years. The von Bertalanffy growth equation can be written as $Lt = 26.5 \{1-e^{-2(t-\_0.0344)}\}$. Accordingly, the clam attained a size of 22.9, 26.0 and 26.4 mm by the end of 1st, 2nd and 3rd year respectively. The longevity of *M. casta* from Kavvai estuary was estimated at 3 years (Figures 2 and 3). The age and growth curve and the restructured length distribution using the growth parameters are shown in Figures 4 and 5.

Mortality, exploitation and virtual population analysis (VPA)

Chaliyar estuary

The total mortality (Z) estimates for *M. casta from* Chaliyar estuary was 3.92 year $^{-1}$. Natural mortality (M) was 2.78 year $^{-1}$ and fishing mortality (F) 2.12 year $^{-1}$ for

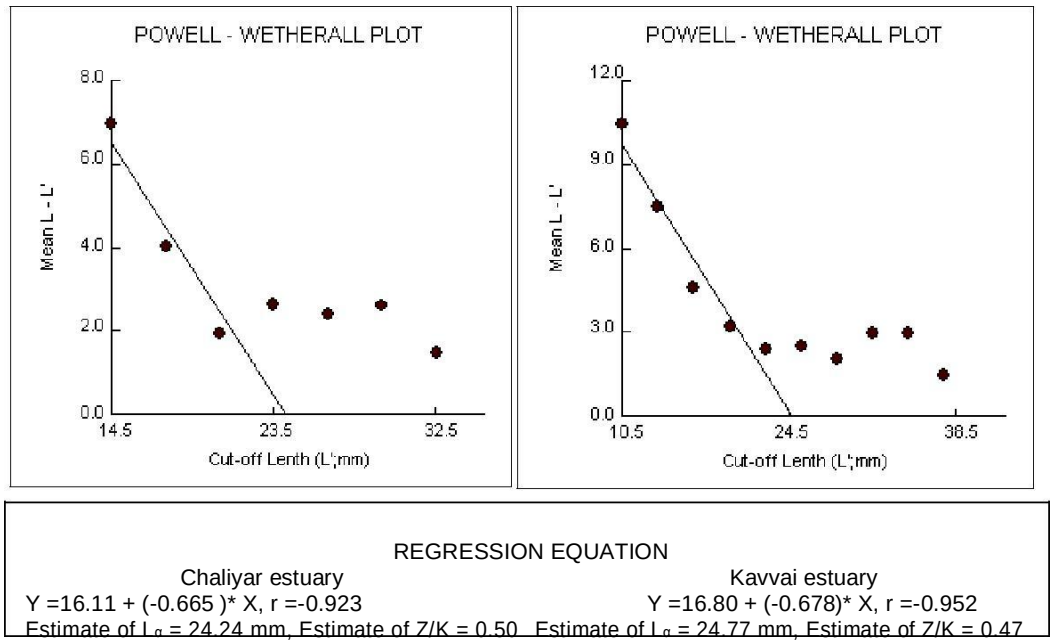

Figure 2. Estimation of L∞ and Z/K of *Meretrix casta* (Chaliyar and Kavvai estuary) using Powell-Wetherall plot.

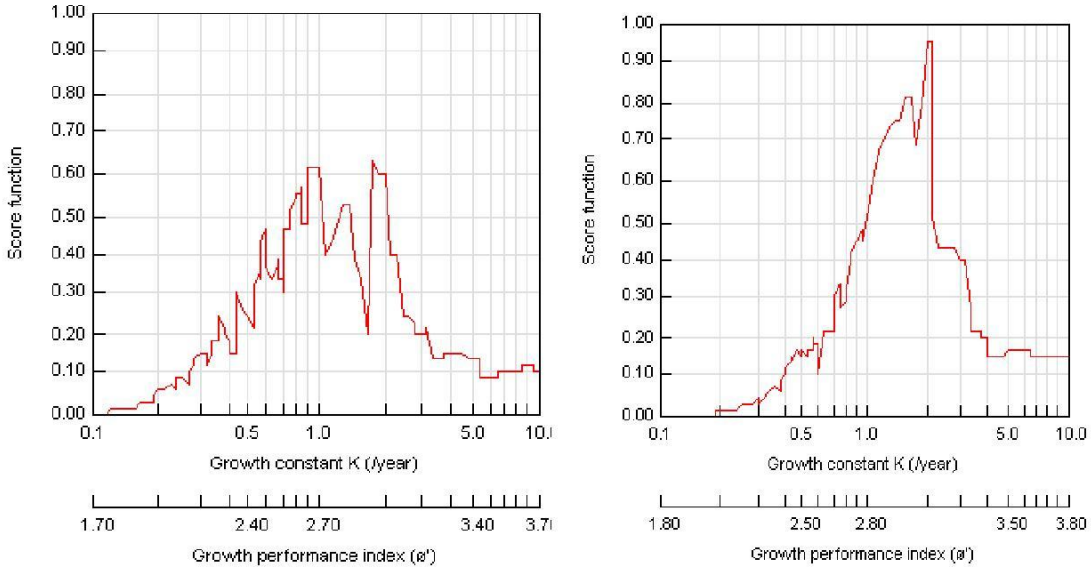

Figure 3. Estimation of K of *M. casta* and (Chaliyar estuary andKavvai estuary).

M. casta (Table 2). Exploitation level (*E)* of *M. casta* was 0.54 (Table 2).

Kavvai estuary

The total mortality (Z) estimates for *M. casta from* Kavvai estuary *was* 2.98 year $^{-1}$. Natural mortality (M) was 2.96 year $^{-1}$ and fishing mortality (F) 0.98 year $^{-1}$ for *M. casta* (Table 2). Exploitation level (*E)* of *M. casta* was 0.33 (Table 2).

Recruitment pattern

Chaliyar estuary

The recruitment pattern of *M. casta* was continuous throughout the year, however, two major peaks of recruitment was observed during April and June to August

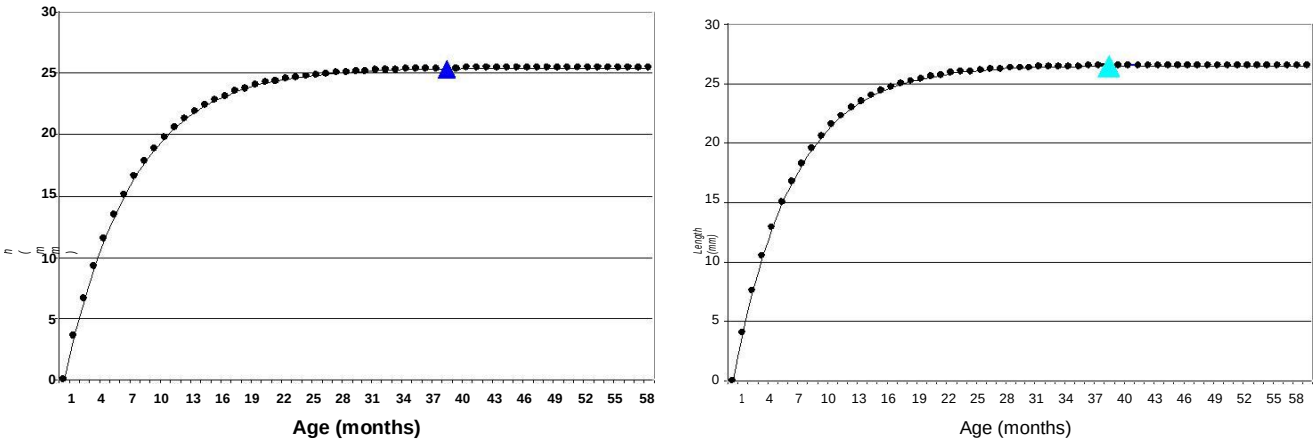

Figure 4. Plot of age and growth of *M. casta* (Chaliyar and Kavvai estuary) based on computed growth parameters.

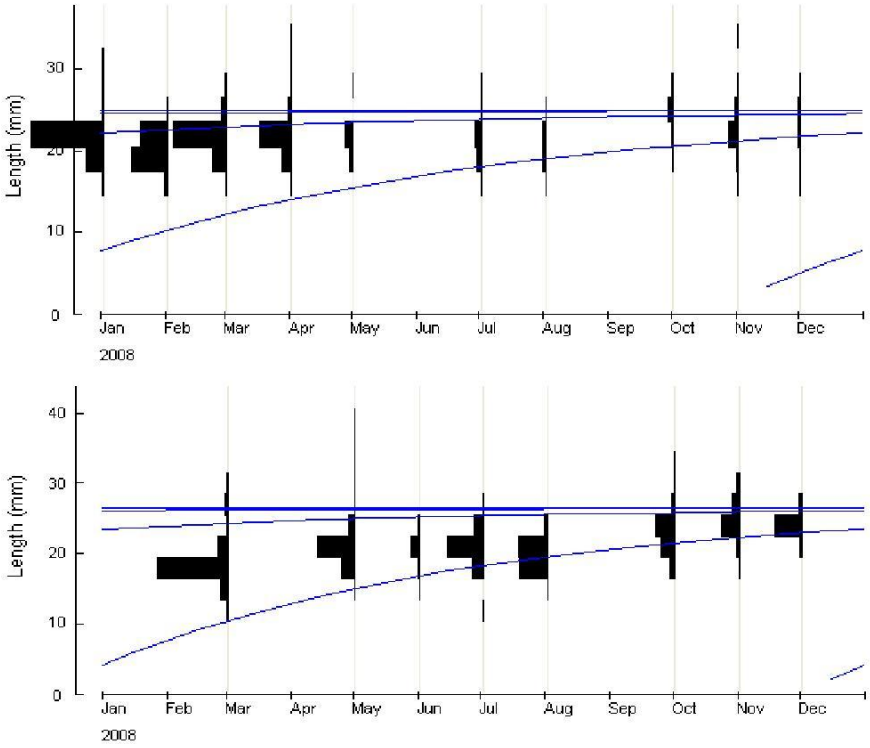

Figure 5. Restructured length frequency distribution with growth curves superimposed using ELEFAN I (L_α = 25.44 mm, K = 1.8 year $^{-1}$) *M. casta* (Chaliyari estuary) (L_α = 29.51 mm, K = 2 year $^{-1}$) *M. casta* (Kavvai estuary).

(Figure 6). The peak pulses produced over 70% of the observed recruitment during the year.

Kavvai estuary

The recruitment pattern of *M. casta* was continuous t hroughout the year, however, two major peaks of recruitment were observed during March-April and June to August (Figure 6). The peak pulses produced over 70% of the observed recruitment during the year.

Estimation of stock and MSY

Chaliyar estuary

The annual total stock (2008) of *M. casta* was estimated

Table 2. Population parameters of *Meretrix casta*, from two different estuaries, south west coast of India.

Population parameter	Chaliyar estuary	Kavvai estuary
a	0.055000184	0.10789001
b	3.0909	3.054878
Asymptotic length (L∞) in cm	2.544	2.65
Growth coefficient (K) year $^{-1}$	1.8	2.0
Natural mortality (M) year $^{-1}$	2.788	2.96
Fishing mortality (F) year $^{-1}$	2.12	0.98
Total mortality (Z) year $^{-1}$	3.92	2.98
Exploitation level (E)	0.54	0.328
Length range (cm)	1.58-3.34	1.08-3.78
Weight range (g)	1.17 – 14.75	0.26 – 32.85
Sample	1560	1559

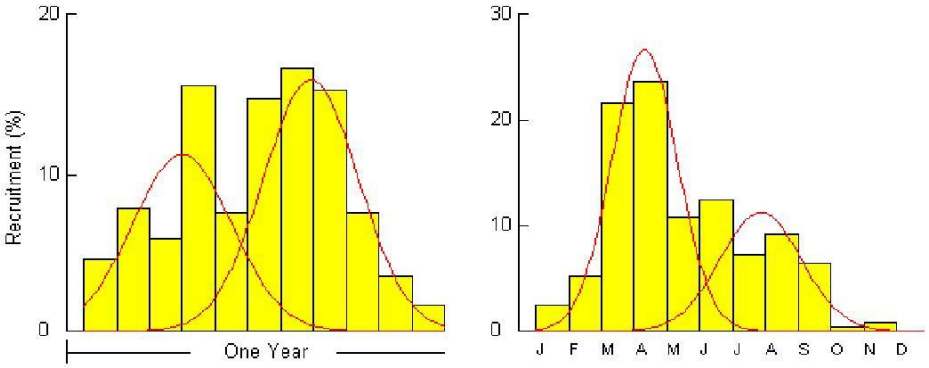

Figure 6. Recruitment pattern of *M. casta (Chaliyar* and Kavvai estuary).

at 0.0004654 t. The biomass (standing stock) was estimated at 537.3 t and maximum sustainable yield (MSY) of *M. casta* was estimated at 1053.13 t. The exploitation rate (U) was 0.53.

Kavvai estuary

The annual total stock of *M casta* (2008) was estimated at 0.0001483 t. The biomass (standing stock) was estimated at 2148.2 t and maximum sustainable yield (MSY) of *M. casta* was estimated at 3200.8 t. The exploitation rate (U) was 0.31.

DISCUSSION

M. casta forms a significant sustenance - level fishery in all major estuaries of India (Narasimham, 1991). *M. casta* is euryhaline, can tolerate low salinities and prefers high sand and silt habitat (Narasimham and Laxmilatha, 1991). The fishery of the edible clam is dependent on the spat fall and subsequent recruitment of the fishery. Salinity, temperature sediment texture and organic matter contribute to the abundance of bivalves (Lee, 1972). The spat fall is affected by the benthic state and pollution by increased pH due to coconut fibre retting and alteration of the sand bed due to sand mining. This has been reported for *M. casta* in Moorad estuary and Chettuva estuaries which has affected spat fall of *M. casta* from year to year (Laxmilatha et al., 2006a, b). The abundance of *M. casta* is also positively correlated to the organic matter content in the substrate (Fraga and Vives, 1960; Jayawardene and Wijayaratne, 2009). The salinity and total suspended solids (TSS) were critical factors influencing the abundance of estuarine clams. The pH and iron concentrations in bottom sediment water strongly related to clam densities (Jayawickrema and Wijeyaratne, 2009; Tanyaros and Tongnunui, 2011).

The mean size of *M. casta* contributing to the fishery was slightly higher from Chaliyar estuary at 21.5 mm although smaller sizes (11 mm) were being exploited from Kavvai estuary. *M. casta* attained 21.2 mm in Chaliyar and 23 mm in Kavvai estuary in 12 months. However, *M. casta* is reported to have attained 29.5 mm in 9 months in Adyar estuary (Abraham, 1963), 33.5 mm

in 9 months (Salih, 1973) and 35.4 mm in 11 months in Cochin barmouth, west coast (Salih, 1973). Durve (1970) reported slower growth rate of 0.79 mm per month in the fish farm in Mandapam due to high saline conditions. Sreenivasan (1983) reported growth of 34 in 13 months in *M. casta* transplanted to Vellar estuary. Balasubramaniam and Natarajan (1987) reported of 23 mm in the first year, 38.3 mm in the second year and 50.6 mm in the third year for *M. casta* in Vellar estuary. These variations in growth are due to the variations in hydrological conditions in the estuaries (Balasubramanian and Natarajan, 1987; Jayabal and Kalyani, 1986; Sreenivasan, 1983). The mean weight of clams fished from Kavvai estuary were higher (4.7 g) than those fished from Chaliyar estuary. This implies that the hydrographical conditions and productivity of the two estuaries have an important bearing on the growth of the clams (Abraham, 1963; Seshappa, 1971). The condition indexes of the clams from both the estuaries were almost same.

M. casta from Adyar backwater has been reported to attain a size of over 56.5 mm in a period of three years. However, since over 95% of the clams are fished before they reach a length of 30 mm (Abraham, 1963). In Korapuzha and Beypore estuaries on the west coast maximum size of 31 mm was obtained during 1950-1951) (Sheshappa, 1971). In Bhimunipatnam estuary on the east coast also, *M. casta* of over 20 mm formed only 5% of the fished clams clams over 40 mm were rarely rare (Ramamohana-Rao et al., 1977). Similar is the case in Chaliyar and Kavvai estuaries, clams of over 40 mm were rarely seen. The growth parameters reported for *M. casta* from five different sites in the Dutch canal of Sri Lanka ranges from 34 to 43.1 mm and growth coefficient ranged from 0.84^{-1} to 1.44^{-1} (Jayawickrema and Wijeyaratne, 2009). The growth attained by *M. casta* in both estuaries was also same and life span estimated was also 3 years in both cases. The computed growth co efficient (b) of *M. casta* from both water bodies are nearly same and growth was isometric. Isometric growth has been reported in *M. casta* (Narasimham et al., 1988).

Despite the large scale indiscriminate fishing of the clams of smaller size (<20 mm), the stock of *M. casta* has remained resilient in almost all the major estuaries including Chaliyar and Kavvai. The factors that have enabled this resilience are the high rate of growth, especially during early stages, the abbreviated larval stages, early attainment of sexual maturity, discontinuous breeding throughout the year with at least two peaks and euryhaline tolerance to salinity (Abraham, 1963; Balasubramanian and Natarajan, 1987; Jayawickrema and Wijeyaratne, 2009; Tanyaros and Tongnunui, 2011).

The total mortality (Z) estimate of *M. casta* from Chaliyar was higher compared to that of Kavvai estuary, fishing mortality was higher for *M. casta* from Chaliyar compared to Kavvai The exploitation level of *M. casta* in Chaliyar was 0.54 while it was very low in Kavvai at 0.33. The standing stock of *M. casta* in Chaliyar estuary is much lower compared to that in Kavvai estuary.

However, the clam fishery has sustained the livelihood of the local pickers for a long period of time and in recent years spat fall has become highly variable due to the changes in the bed due to environmental changes and climatic factors. It is reported that post Tsunami of 2004, there was very poor spatfall of *M. casta* in the Chaliyar estuary and consequently very poor recruitment in the following year. Heavy mortality due to heavy flooding in the west coast and poor yield of clam in the Mumbai coast due to excessive rainfall has been reported by Hornell (1916) and Rai (1932). In Kavvai estuary, several species of clams contribute to the fishery along with fishes. *Meretrix meretrix*, *Paphia malabarica* and *Villorita cyprinoides* are landed in significant quantities apart from *M. casta* and have higher market demand than *M. casta*. Therefore, a huge stock of *M. casta* is present which can still continue to sustain the fishery. The present level of exploitation of *M. casta* is far below the MSY and therefore production of *M. casta* can be significantly enhanced on a sustainable level. In Chaliyar, the present exploitation is only 50% of the MSY.

The population characteristics of *M. casta* from the two estuaries indicate that the two stocks can still be exploited on a sustainable level. However, the major issue of concern is the changes in the habitat / sand bed of the clams. Large scale sand mining also affects the spat settlement due to high levels of total suspended solids (Laxmilatha et al., 2006a, b). *M. casta* is fished for the meat (for local consumption) and shell in most estuaries. The undersized clams are exploited during the peak season, the meat is allowed to putrefy and shells are used by the lime industry (Laxmilatha et al., 2006a, b). Conservation measures such as relaying, ranching of seed for stock enhancement, regulations to restrict exploitation of seed clams, measures to regulate sand mining are imperative to manage the stocks of *M. casta*, which is gradually on its way to the endangered status (already cited as vulnerable by IUCN) due to loss of habitat. This in turn also affects the livelihood of the fishers dependent on this important fishery for their sustenance.

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REFERENCES

Abraham KC (1963). Observations on the biology of *Meretrix casta* (Chemnitz). J. Zool. Soc. India 5(2):163-190.

Alagarswami K, Meiyyappan MM (1989b). Prospects and problems of management and development of marine molluscan resources (other than cephalopods) in India. Bull. Cent. Mar. Fish. Res. Inst. 44(1):250-261.

Ananda Rao T, Molur S, Walker S (Eds.) (1998). Report of the workshop on 'Conservation assessment and Management plan for

mangroves of India' Zoo outreach organization, Coimbatore, India, P. 106.

Balasubramanian K, Natarajan R (1987). Age and growth of *Meretrix casta (chemnitz)* in Vellar estuary, Parangipettai *Bull. Cent.* Mar. Fish. Res. Inst. 42(1):145-147.

Bertalanffy L von (1934). Untersuchungen uber die Gesetzlichkeiten des Wachstums1. llgemeine Grundlagen der Theorie. Roux Arch. Entwicklungsmech. Org. 131:613-653.

Beverton RJH, Holt SJ (1957). On the dynamics of exploited fish populations. Fish. Invest. Ser. II London 19:533.

Durve VS (1964). Preliminary observations on the seasonal gonadal changes and spawning in the clam Meretrix casta (Chemmitz) from the marine fish farm. J. Mar. Biol. Assoc. India 6(2):241-248:

Durve VS (1970). On the growth of the clam *Meretrix casta* (Chemnitz) from the Marine Fish Farm. J. Mar. Biol. Assoc. India. 12:125-135

Fraga F, Vives F (1960). Retention of particulate matter, In: Marine mussels: Their Ecology, and Physiology (B. L. Bayne ed.). pp.13-65, Cambridge University Press, UK.

Gayanilo FC, Jr Sparre P, Pauly D (Eds.) (1995). The FAO- ICLARM Stock Assessment Tools (FiSAT) User's Manual. *FAO Computerized Information Series (Fisheries)* No. 8: Rome, FAO. P. 185.

Gayanilo FC, Jr Sparre P, Pauly D (1997). The FAO- ICLARM Stock Assessment Tools (FiSAT) User's Manual. Reference Manual, FAO, Rome, Italy, P. 126.

Harkantra SN (1975). Some observations on the clam beds of Kali estuary, Karwar. Mahasagar. 8:101-108.

Gulland JA (1979). *Report of the* FAO/UNDP workshop on the fishery resources of the Western Indian Ocean – South Equator. FAO, Rome, 10FC/DEV/79/ 45:1-37.

Hornell J (1916). The utilization of coral and shells for lime burning in the Madras Presidency. Madras Fish. Department Bull. 8:105-126.

Jayabal R, Kalyani M (1986). Age and growth of the estuarine clam *Meretrix meretrix* (L) inhabiting the Vellar stuary. Mahasagar 19(2):141-146.

Jayawickrema EM, Wijeyaratne MJS (2009). Distribution and population dynamics of the edible bivalve species *Meretrix casta* (Chemnitz) in the Dutch canal of Sri Lanka. Sri Lanka. J. Aquatic Sci. 14:29-44.

Krishnakumari L, Rajagopal MD, Sumitra V (1977). Some aspects of biology and biochemistry of the backwater clam *Meretrix casta* (Chemnitz). Mahasagar Bull. Nat. Inst. Oceangr. 10(3/4):157-163

Laxmilatha P, Velayudhan TS, Mohamed KS, Kripa V, Radhakrishnan P, Jenny Sharma C (*2006a).* The fishery and biology of *Meretrix casta* (Chemnitz) in the Moorad estuary, Kerala Indian J. Fish. 53(1):109-113

Laxmilatha P, Velayudhan TS, Mohamed KS, Kripa V, Radhakrishnan P, Jenny Sharma C (2006b). Bivalve resources of the Chettuva estuary. Kerala Indian J. Fish. 53(4):481-486,

Lee C (1972). An ecological study on some marine bivalve beds of Korean tide lands. In: proceedings of the Indo-pacific Fisheries Council 13th Sessions, Brisbane, Australia. pp.326– 331,

Narasimham K, Muthiah AP, Sundararajan D, Vaithinathan N (1988). Biology of the great clam *Meretrix meretrix* in the Korampallam creek, Tuticorin. Indian J. Fish. 35(4):288-293.

Narasimham KA (1991). Present status of clam fisheries of India. J. Mar. Biol. Assoc. India 33:(1.2):76-88.

Parulekar AH, Dwivedi SN, Dhargalkar VK (1973). Ecology of clam beds in Mandovi, Cumbarjua Canal and Zuari esuarine system of Goa. Indian J. Mar. Sci. 2:122-126.

Pauly D (1980). On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. ICES. J. Cons. 39:175-192.

Pauly D (1984). Length converted catch curves: A powerful tool for fisheries research in the tropics (Part II). Fishbyte 2(1):17-19.

Pauly D (1986). On improving operation and use of the ELEFAN programs. Part II. Improving the estimation of L. ICLARM Fishbyte, 4(1):18-20.

Pauly D, Munro JL (1984). Once more on growth comparisons in fish and invertebrates. Fishbyte 2(1):21.

Rai HS (1932). The shell fisheries of the Bombay Presidency. J. Bombay Nat. History Soc. 35:826-847.

Ramamohana-Rao V, Appa Rao T, Reuben S, Sampson, Manickam PE (1977). On the culture possibilities of *Meretrix casta* in Bhimunipatnam backwaters. Indian J. Fish. 24 (1,2):263-268.

Rao GS (1988). Biology of *Meretrix casta* (Chemnitz) and *Paphia malabarica* (Chemnitz) from Mulky estuary, Dakshina Karnataka. *In*: S. Mahadevan, KA, Narasimham, K. Satyanarayana Rao, KMS, Ameer Hamsa P Muthiah (Eds.), National seminar on shell fish resources and farming– Tuticorin. 19-21 January 1987. Bull. Cent. Mar. Fish. Res. Inst. 42(1):148-153

Ricker WE (1975). Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Canada 191:382

Seshappa G (1971). Some observations on the backwater clam *Meretrix casta (Chemnitz)* in the Beypore and Korapuzha estuaries. Indian J. Fish. 14 (1&2):298-305

Salih MKY (1973). On the growth of the backwater clam *Meretrix casta* (Chemnitz) in the clam beds off Cochin barmouth. J. Mar. Biol. Ass. India 15(1):345-353.

Sparre P, Venema SC (1992). Introduction to tropical fish stock assessment, Part I, *annual.* FAO Fish. Technical. 306:376.

Sreenivasan PV (1983), Growth of the clam *Meretrix casta* (Chemnitz) transplanted in the Vellar estuary. Proc. Symp. Coastal Aquac. 2**:**564-568

Tanyaros S, Tongnunui P (2011). Influence of environmental variables o the abundance of estuarine clam *Meretrix casta* (Chemnitz, 1782) in Trang Province, Southern Thailand. Songklanakarin J. Sci. Technol. 33(1):107-115.

Thangavelu R, Poovannan P (1994). Some aspects of biology of the clam Meretrix casta (Chemnitz) in Muttukadu backwaters. J. Mar. Biol. Assoc. India. 36(1&2):77-80.

Thangavelu R, Sanjeevraj PJ (1985). Fishery and biology of the clam *Meretrix casta* (Chemnitz) in Pulicat Lake. J. Mar. Biol. Assoc. India, 27(1,2):75- 83.